PROCEDURES FOR MODELING BUILDINGS TO MNECB AND CBIP
- PART 1 -

Version 3.0

March 2005

Prepared for:

Natural Resources Canada
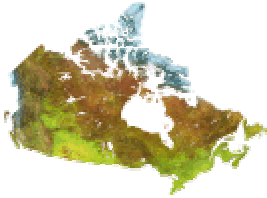
Ottawa, Ontario

Natural Resources Canada would like to thank the following organizations for allowing details and plans of their buildings to be included in this manual:

- Breton Banville et Associés
- École Élémentaire Catholique de Barrhaven
- Bryden Martel Architects
- Clemann, Large, Patterson and Associates Ltd

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1. INTRODUCTION

1.1 Background

In 1997, the National Research Council of Canada published the Model National Energy Code for Buildings (MNECB). This code contains a set of "prescriptive" energy-efficiency measures that should be included in new commercial buildings. The code also allows for the substitution or trading-off of prescriptive energy-efficiency measures provided that the substitution does not increase building energy consumption. Because the code is voluntary, these measures only apply if the code is adopted by the provincial government or local authority having jurisdiction.

Because the MNECB is a code, it represents a minimum level of energy efficiency. The Commercial Building Incentive Program (CBIP) is a Natural Resources Canada program intended to encourage the design and construction of energy-efficient commercial buildings. CBIP provides an incentive to building owners if their "proposed" building design is expected to consume 25% less energy than a standard or "reference" building. The reference building is defined as a building designed to the prescriptive requirements of the Model National Energy Code for Buildings (MNECB), and following CBIP rules where a conflict exists with the MNECB or the MNECB does not address the design issue.

The EE4 computer program developed by Natural Resources Canada was specifically designed as a compliance-checking tool for both the MNECB and CBIP. Under the CBIP rules, building energy efficiency must be calculated using EE4 software. In special circumstances, DOE2 is required to simulate features that are not readily simulated in EE4. This is allowed with prior written permission from Natural Resources Canada provided the basic building architectural and mechanical systems are entered in EE4 to determine the corresponding reference case.

The reference building is architecturally identical to your proposed design, thus having the same wall orientations, areas, windows, level of air-tightness, number of occupants, indoor set-point temperatures (space heating, cooling, hot water), fan operation, appliance and electrical usage and process equipment. The reference building will be insulated to the MNECB prescriptive levels as outlined in Appendix A of MNECB and applicable to the climatic region and space heating fuel for your location. The reference building will have a defined heating and cooling plant (if applicable), a representative air handling system (single zone direct expansion cooling, variable air volume or self contained heating/cooling unit). The type of air handling system selected for the reference building is dependent upon the building's function, and the type of air handling system contemplated in the proposed design. The reference air handling system will use calculated fan energy based upon good duct design practices and shall include free cooling where applicable. The circulation pumps for heating and cooling shall be sized based upon the proposed design's allowable temperature difference and the proposed design's pump head. The reference building will be constructed with a certain mass level and not incorporate any window shading devices. For a complete understanding of how the reference building is created and how the equipment is sized and operated, see "Performance Compliance for Buildings: Specifications for Calculation Procedures for

Demonstrating Compliance to the Model National Energy Code for Buildings Using Whole Building Performance" (MNECB/CS) (http://nrc.ca/irc/catalogue/energy2.html).

The EE4 software predicts the energy use of the proposed building design and the reference building design. (The software can also predict the energy use of buildings that do not comply with the MNECB or that use non-standard operating schedules and inputs such as occupant heat gain and receptacle loads. These building simulations are referred to as "non-compliant".) The non-compliant feature removes all of the CBIP and MNECB rules and schedules and allows the user to enter a building for energy simulation purposes only. The user however should be aware that EE4 even in non-compliant operation has a series assumptions that are not alterable in non-compliant mode. These include features such as hot water delivery temperature, piping losses, internal heat gain allocations, standby losses for equipment, boiler and chiller load/part load factors, ventilation air reheating temperatures, secondary heating and cooling loop operation, humidity control and fan performance curves.

It is important that EE4 simulations for CBIP and MNECB buildings be performed accurately and consistently, so as not to undermine the credibility of the programs. Buildings and building systems are, however, extremely complex. Simulators can achieve different results on the same building because of assumptions made about the performance of the various building components. This manual provides guidance on how to model buildings in accordance with MNECB and CBIP requirements, so as to minimize these differences.

The purpose of these simulations is NOT to accurately predict the expected energy use of the building. Rather it is to provide a uniform and consistent means of verifying compliance to MNECB and CBIP and comparing the energy efficiency of building designs. MNECB and CBIP simulations assume typical building use patterns and standards of construction (as identified in the MNECB/CS). Because use patterns and standards of construction vary from building to building, simulations based on these assumptions may or may not be indicative of the actual building energy consumption.

Also EE4 was not intended to simulate all energy uses in a building (exterior lights, elevator usage, steam humidifiers, dehumidification, gas appliances, solid fuel heating, special process equipment, refrigeration), therefore energy usage as predicted by EE4 is limited only to the features modeled within the program and the inherent program assumptions. EE4 and DOE2 simulations submitted under the CBIP program are not intended to predict the actual energy usage of the design due to underlying assumptions in the software such as occupancy patterns, schedule of equipment operation, interior temperatures, etc. The simulations are intended to provide a comparison between the proposed design and the generated reference building using the assumptions of MNECB, CBIP and the EE4 software.

1.2 Scope of the Manual

This manual gives recommended simulation procedures in three keys areas:

1. Rules for dividing buildings into thermal zones and spaces
2. Sources of information for performance values of envelope components and building equipment

3.   Guidance on modeling simple and complex HVAC systems

This manual also includes some modeling examples for showing compliance to the MNECB and CBIP.

This manual should be used in conjunction with the MNECB, the EE4 user's guide and help system, and Natural Resources Canada (NRCan) training courses. These documents provide detailed information on use of the software and compliance rules. These documents can be obtained from the web sites of CBIP (http://cbip.nrcan.gc.ca), EE4 (http://www.ee4.com) and NRC (http://nrc.ca/irc/catalogue/energy2.html).

The procedures within this document will be used to assess compliance with the MNECB and CBIP rules; therefore the user should consult this document in preparation of the data for entry into the simulation program.

This manual must be used as the basis for all simulations. The modeling rules within this manual supercede previous manuals, EE4 help files, and CBIP guidelines. The EE4.com website provides additional modeling methods and workarounds that have not been included in the manual or have been derived after this manual issuance. The EE4.com website also provides access to other simulation tools, such as Wizards that have been developed for specialty buildings and allows the user to enter general design characteristics in an on-line screening tool to predict energy usage and greenhouse gas emissions. The screening tool should be ideally used at the early design process to assess the energy impact of various design considerations. The energy impact can then be used with economic and costing data to assess the cost effectiveness of incorporating energy conserving features within your design. See www.ee4.com for more details.

NRCan requires that EE4 be used as the base for all simulations. In some cases, EE4 may not be sufficient to model certain energy efficiency measures. An excerpt from NRCan's official policy appears below.

BASE APPROACH

EE4 is used exclusively to prepare a performance path submission. To perform an assessment in the context of the whole building performance, NRCan is establishing the principle that EE4 should be used as a basis.

VARIATION 1

EE4 must be used first, in accordance to the base approach, to create the reference building. Adjustments of the EE4 outputs are allowed and must be all documented. Modifying EE4-generated building files is not acceptable as a standard procedure, however NRCan recognizes that this may be the most appropriate solution in some particular cases. The EE4 outputs can be either supplemented with engineering data or edited through changes to the DOE files. Instructions for performing modifications of EE4 outputs for which special CBIP rules have been developed are available from NRCan. If the proposed modifications do not have established CBIP rules then the proponent shall notify NRCan prior to application submission. The engineering data used to directly modify the EE4 results can be generated by manual calculations or software

outputs such as RETScreen. Changes made to the DOE files generated by EE4 are allowed with the use of a DOE-2 version 2.1E software version authorized by NRCan.

VARIATION 2

The building take-off is performed directly with DOE including the development of the reference building. This is acceptable only when it is demonstrated that the other options were exhausted, and requires prior permission from NRCan to proceed with this approach. This approach will require the extensive checking of compliance to MNECB and CBIP requirements for both reference & proposed buildings. As a result, full documentation of the process and assumptions made is required. Files must be submitted in a version of the DOE-2 version 2.1E software authorized by NRCan.

ARENA & RETAIL FOOD STORE WIZARDS

Arenas and retail food stores are to be simulated using the on-line EEWizards which are available at http://cbip.nrcan.gc.ca. This manual does not apply to these EEWizards. Modeling guidance on the EEWizards can be found on the on-line EEWizard manual.

SCREENING TOOL

The on-line Screening Tool can be used to help designers determine if their new building design may qualify for an incentive under the Commercial Building Incentive Program (CBIP). The screening tool does not use as precise information as EE4 and therefore is to be used for screening purposes only, it does not ensure that you will qualify for an incentive. Modeling guidance for the Screening tool can be found in the program itself (by clicking on the blue text near the inputs).

1.3   Manual Organization

This manual has two parts. Part 1 describes procedures required for consistent simulation of buildings. These procedures should be considered mandatory for those wishing to simulate buildings "in accordance with good engineering practice". Part 2 provides an example of a building simulated in accordance with the CBIP/MNECB rules using the zoning and data input procedures defined in this manual.

Each chapter deals with a specific aspect of building simulation. The chapters are as follows:

Chapter 1: Introduction

Provides background information on the MNECB and CBIP and the differences between them. Tables compare how energy-efficiency measures are handled in MNECB and CBIP.

Chapter 2: Building Zoning Principles

Describes the rules for dividing a building into thermal zones and spaces.

Chapter 3: Building Function and Operation

Introduces EE4 and discusses modeling procedures that relate to defining building function and operating parameters, including utility rates.

Chapter 4: Central Plant Equipment

Describes modeling techniques for equipment entered primarily as central plant equipment, including boilers, chillers, service water heaters, cooling towers, pump, and heat pump loop information.

Chapter 5: HVAC Equipment

Describes modeling techniques for equipment entered at the "system" and "zone" levels, including coils, fans, heat recovery systems, economizers, baseboard units, and air-source heat pumps.

Chapter 6: Modeling of HVAC Systems

Provides an overview of the 15 system types that can be modeled in EE4, and procedures and examples on choosing the best system as a model.

Chapter 7: Building Envelope Modeling

Describes the modeling procedures for walls, roofs, floors, windows, and doors. This section also discusses specialty products such as curtainwalls, balconies, and wall/floor junctions.

Chapter 8: Electrical System Modeling

Presents the techniques for modeling lighting and other electrical systems and equipment.

Chapter 9: CBIP Submission Guidelines

Presents information to be considered before final CBIP submission is made to NRCan.

Chapter 10: Troubleshooting

This section lists some of the common errors encountered during the EE4 modeling process and how to overcome them.

Part 2: EE4 Simulation Example

Contains a complete EE4 simulation of a typical office building. This section includes a description of the building, its HVAC and lighting systems. A set of building drawings is included in the appendix. The EE4 simulation file for this exercise can be downloaded from the EE4 web site (http://www.ee4.com).

1.4 Overview of MNECB and CBIP

1.4.1 Eligible Buildings

MNECB (Appendix E, section E-1.1.2.1.(2)) states "...MNECB would not apply to any single-family house no matter its size, but would apply to the following:

1.   buildings more than three storeys in building height,
2.   buildings of three storeys or less in building height having a *building area* (footprint) of more than 600m²,
3.   buildings of three storeys or less in building height that contain occupancies other than dwelling units.

Agricultural buildings whose primary function is not based upon human occupancy conditions (ventilation, space conditioning) are not eligible.

Non-mechanically ventilated buildings may also be eligible for CBIP depending on their occupancy, however the corresponding CBIP reference building will also be non-mechanically ventilated (contact CBIP Account Manager if you are uncertain). See section 9.5 for modeling procedures.

"Building area" is a defined term under the MNECB. The definition (MNECB 1.1.3.2.(1)) is as follows:

"*Building area* means the greatest horizontal area of a *building* above *grade* within the outside surface of the exterior walls or within the outside surface of exterior walls and the center line of *firewalls*."

1.4.2 MURBs

For multi-use buildings containing residential occupancy, the residential proportion of the building must meet criteria of a MURB mentioned below to be eligible for CBIP. If the residential proportion of a building does not meet the criteria of a MURB, that area must be excluded from the building model.

For a MURB project to be eligible for CBIP it must meet the following:

1.   be greater than 3 storeys in building height (ie. 4 storeys or more including fully occupied residential stories partially below grade) or be greater than 600 m² in building area (footprint), as defined in the MNECB above.
2.   have a common entrance,
3.   have building permit issued on or after April 1, 1999.

NOTE:

Basements (full or semi) will count as a storey if 75% of the total basement floor area is liveable space (dwelling units). Total floor area include spaces such as garage, storage and laundry whether these spaces are conditioned or not.

Garage is not accepted as sole common entrance.

For more detailed information on modeling MURB credits refer to Appendix D.

1.4.3 Renovations

A renovation project must conform to all of the following criteria:

  A) The owner/proponent must have complete existing "As Built" documentation of the building (drawings and specifications). The completeness of this information is judged on the ability to answer questions regarding the building construction[1].
  B) The owner/proponent must intend to modify architectural, ventilation, space conditioning and lighting systems in combination. All systems must be affected.

All submissions must be made under the CBIP Performance Path. See Appendix G for details.

1.4.4 Additions

Additions to existing buildings are eligible under CBIP, however only the addition heated area is eligible for the CBIP incentive. The addition is treated as a separate building for compliance purposes. Only enter the envelope areas for walls, roofs, floors that separate the addition space from the outside (i.e., exclude common walls).

If existing building services (heating, cooling, ventilation, service water heating) are extended into the new addition, only new mechanical/electrical items specific to the addition must meet the MNECB mandatory requirements. If a new boiler and/or chiller is added to the existing building and provides heating and/or cooling to the addition, this boiler/chiller is to be entered into the model. The drawings and specifications for the new heating/cooling equipment must be provided in order to claim any equipment credits in EE4. If the air handling system is extended to the new addition, the existing system must be simulated as the system for the addition. The heating and cooling capacities for these units are to be pro-rated to the design heating/cooling load as determined by the EE4 sizing program. The fan power is to be pro-rate by the ratio of total fan power to supply air provided. The heating efficiency and cooling COP must match the existing building systems, which are providing the supply air to the addition. The supply air must match the drawings and the outdoor air requirements for the spaces within the addition. All calculations must be documented.

1.4.5 Industrial Type Buildings

Industrial buildings are eligible for CBIP. Any building that can save greater than 10% building energy from recovery of process energy are eligible for the Industrial Building Incentive Program (IBIP). More information on the IBIP program can be found at http://oee.nrcan.gc.ca/newbuildings/ibip/ibip.cfm.

1.4.6 Arenas and Recreation Centres

Arena and recreation centres are eligible for CBIP and must be modeled using the On-line EEwizard. If more that 50% of the energy use in a combination buildings (i.e. arenas with office tower) is attributable to the other building type, two separate simulations are required. The EEWizard will be used to model the arena and associated areas and EE4 will be used to model the other building type.

The on-line Wizards should be used to determine the energy use of the proposed and reference buildings for the arena and recreational areas. The total energy and cost for this area is to then be added to the total energy and cost generated by EE4 for the rest of the building.

If there exists shared services (heating, cooling, DHW and ventilation) between the arena (modeled in the Wizard) and the remainder of the building (modeled in EE4), then pro-rate the services according to the loads provided and separate the equipment between the arena Wizard areas and the EE4 areas. If the arena EEWizard provides waste heat to the recreation component of the building and this space is not modelled within the 'Multi-purpose space', then manually determine how much hourly heat is available and utilized. Then manually remove this hourly heat from the EE4 generated output. Thoroughly document your calculations and methodology.

Use of waste heat from the arena to heat pool water is currently not a CBIP eligible item.

1.4.7 Retail Food Stores

The On-line EEWizard provides detailed refrigeration calculation for food cooling and operation of display cases and coolers. If refrigeration is a large component of the buildings energy load, then you should use the On-line Wizard. If you are modeling a shopping center or a strip mall and the food store is only a small component (less than 50% energy), then you are not required to use the On-line Wizard and can use EE4 for simulation purposes. If using EE4, the refrigeration heat recovery portion would be excluded from the EE4 simulation.

1.5   Energy Efficiency Measures

This section contains a list of common energy efficiency measures that can be implemented and modeled in EE4 for credit in reaching the CBIP target. Note that some of these parameters may also be penalties if the default reference building system has a better performance (as described in the MNECB and Compliance Supplement). If viewing this manual on-line, click the item in the list to view more information on that particular measure (reader will be taken elsewhere in this manual). Information is subdivided into building operation, building envelope, and HVAC systems.

BUILDING OPERATION AND CONSTRUCTION

Building Automation System: No credit is offered, since for most functions, the reference building is assumed to shut off lights and fans etc when not required. Exceptions are daylighting, occupancy control of lighting, and demand controlled ventilation.

Nighttime Temperature Setback: No credit is offered as both reference and proposed buildings must follow the same temperature schedule. Most default MNECB temperature schedules already assume nighttime temperature setback.

Automatic Lighting Controls: Credits are offered for occupancy sensors or automatic daylight dimming. Controls must be automated (no credit for user-controlled dimmers).

Demand Controlled Ventilation: Credits are offered for demand controlled ventilation using CO_2 sensors. The sensors must be located in each thermal zone. Limits for the effect of demand control ventilation have been developed for certain building types where this control strategy is accepted (schools, offices, warehouses, assembly buildings. Details on how to apply the demand control ventilation strategy are given in section 5.13.

BUILDING ENVELOPE

Wall/Roof R-values: Credit is offered if a proposed building value is better than a reference building value. A penalty is experienced if a proposed building value is worse than a reference building value. Reference building R-value is based on MNECB Appendix A.

Below Grade and Slab Insulation: The proposed building must meet the MNECB mandatory insulation requirements, however no credit is provided if the insulation exceeds the mandatory requirements.

Window U-values: Credit is offered if a proposed building value is better than a reference building value. A penalty is experienced if worse than reference building value. Reference building U-value is based on MNECB Appendix A.

Window to wall ratio: If the window to wall ratio is greater than 40% in each space a penalty may be experienced if the proposed window thermal values are not improved over those of the reference building. If the proposed window to wall ratio (WWR) is less than 40%, both buildings have the same WWR. If the proposed building WWR is greater than 40%, the reference building's window area for the specific space is fixed at 40% and the resultant increased reference wall area will be insulated to MNECB R-values.

Window solar heat gain coefficient: Simulator has the option of choosing to give proposed building and reference building the same (entered) SHGC, or fixing the reference at a value of 0.65. A credit is offered if the proposed building glazing has a SHGC less than 0.65 and the comparison check-box is checked.

Skylight to roof ratio: Simulators may experience a penalty if the skylight to roof ratio is greater than 2% for a given space and the window to wall ratio is greater than 40%.
If the proposed skylight to roof ratio (SRR) is less than 2%, both buildings have the same SRR. If the proposed space SRR is greater than 2% and the window to wall ratio is greater than 40% for the same space, the reference building is fixed at 2% and the resultant increased reference roof area will be insulated to MNECB R-values for that roof type.

Door U-value: No credit for improved door U-values. Reference building doors are equal in size and performance to the proposed building.

Infiltration/Air Tightness: No credit for improved air tightness of walls or windows. For modeling purposes, the infiltration rate in both proposed and reference buildings is fixed at 0.25 L/s per m^2 of gross above grade envelope area.

Overhangs and Sidefins: Credit may be offered for overhangs and sidefins on windows. Where overhangs or side fins block needed solar gains a penalty may be produced. The reference building windows do not have any overhangs or sidefins.

Wall/Roof Absorptivity and Roughness: No credit available for these wall parameters. They are modeled identically in proposed and reference buildings.

HVAC SYSTEMS

HVAC System Type: There are potential credits or penalties for certain HVAC system types. Reference building systems are established by the MNECB/CS (Tables 5.4.1.A, B and C), and are: constant volume single-zone systems if the proposed building uses single-zone systems; variable air volume systems if the proposed building is a multi-zone system, or a distributed zonal system (fan coils, distributed heat pumps). Some exceptions apply depending on space classification. For example, dwelling units are equipped with a packaged terminal air conditioning unit, known as an accommodation unit. The MNECB/CS provides details regarding fan power limits, static pressures, and heating / cooling sources for varied conditions in the proposed building. The following are the reference fan characteristics, which may could be a credit or penalty in comparison with the proposed fan/duct design.

System Type	Cooling Type	Supply Fan		Return Fan	
		Static Press.	Eff.	Static Press.	Eff.
Single Zone	DX	325 pa	40%	-	-
	Hydronic	500 pa	50%	150 pa	25%
Multi-zone	DX	750 pa	45%	150 pa	25%
	Hydronic	1000 pa	55%	250 pa	30%
Accom Unit	all types	125 pa	25%	-	-

Supply Fan Controls: in VAV and dual duct systems, credits are available for the type of supply fan.

Equipment Efficiency: Credit is available for HVAC equipment with higher efficiency than stipulated in the MNECB. This is applicable to boilers, chillers, fans, pumps, heat pumps, and burners (unit heaters, roof-top furnaces, furnaces, domestic water heaters).

Chillers: Chiller efficiencies and types are calculated based upon the cooling capacities in the reference case. Credits or penalties may exist depending upon the proposed design chiller and the cooling load and compared to the following:

Requ'd Cooling Capacity	Reference Chiller Type	Reference Chiller COP
Less than 700 kW	Reciprocating	3.8
700 – 2100 kW	Centrifugal	5.2
greater than 2100 kW	Centrifugal (2 chillers)	5.2

Boilers, Heaters and Burners: will have reference thermal efficiency of 80%.

Pump Characteristics: The following are the reference pump characteristics, which may also result in a credit or penalty compared to the proposed design:

Pump Function	Pump Type	Pump Efficiency
Boiler	constant speed	calculated as a function of capacity
Cooling Tower	constant speed	70%
Chiller	constant speed	calculated as a function of capacity

Equipment Sizing: In general the reference building boiler(s) and chiller(s) are sized directly to the reference building load, however if the proposed building design oversizes boilers and chillers, the reference will match the oversizing to a limit of 130% of the calculated reference building load. Simulators will experience a penalty if boilers or chillers are greater than 30% oversized based on EE4 load calculations. Heating equipment cannot be undersized.

Ventilation equipment air handling capacities are allowed to be oversized by 20% overall for the heated air space recognizing air transfers between ventilation equipment. The oversizing is determined by the ventilation standard you are adopting the make-up air. The reference building will be limited to a 20% oversizing factor which you are required to provide on a building/heated space basis.

Condensing (High-Efficiency) Burners: Credit is available for condensing technology in boilers and furnaces.

Ventilation Air Heat Recovery: Credit is available for sensible heat recovery systems, including plate heat exchangers, energy wheels, heat pipes and glycol/hot water run-around heat recovery loops. The latent heat recovery portion of heat wheels or energy recovery generators is not available as a credit.

Economizers: All reference building systems use enthalpy controlled economizers. Therefore, there may be a potential penalty if the proposed building does not have "free cooling" economizers on air handling equipment.

Boiler Return Water Temperature and Outdoor Air Reset: Credit for reset of supply water temperature based on outdoor air temperature. The modeled boiler efficiency is to be increased to receive this credit. Credit for operating boiler at a lower return water temperature. This credit involves increasing the boiler efficiency when the return water temperature is less than 160°F.

Supply Air Temperature Reset: In VAV systems, credit for resetting supply air temperature based on demand of zones.

Modulating/Multi-stage Burners: Credit for multi-stage firing of boilers only. The credit involves the break-up of the boiler capacity into up to smaller boilers of equal capacity and sequence them at a 90% sequencing ratio, but leave the entered thermal efficiency unchanged from manufacturers data. The number of boiler is determined by the number of stages of firing. Modulating boilers are modelled via return water temperature.

Multi-Staging Roof-top Units: A credit is available for efficiency improvements of multi-staging roof-top units. The credit is limited to a 1.5% thermal efficiency increase for areas of less than 5000 heating degree days and 2% thermal efficiency increase for locations of 5000 and greater annual heating degree days.

Modulating/Multi-stage Chillers: Credit for modulating chillers (no credit for multi-stage cooling on air handling equipment). The credit involves the break-up of the chiller capacity into smaller chillers to match the modulation (maximum of 10 smaller chillers) and sequence them at a 90% sequencing ratio, but leave the entered COP or EER unchanged from manufacturers data.

Variable Speed Drives: Credit for variable speed drives on pumps, supply fans (VAV systems only) and cooling tower fans as reference systems have constant speed pumps and fans. No credit is available for multi-speed pumps/fans. Multi-speed pumps/fans should be entered as a single speed pump/fan using the average efficiency.

Outdoor Air Rates: No credit for reduced outdoor air rates – ventilation rate is equal in both proposed and reference buildings with certain exceptions. See Outdoor Air Section for more information.

Garage Demand Ventilation: CO/NOx ventilation control of a heated or unheated parking garage (interlocked supply and exhaust) is not an eligible CBIP credit, as CO/NOx ventilation control in parking garages is considered common practice.

Humidification: No credit is given to the use of heat wheels and dessicant wheels to reduce humidification requirements.

LIGHTING/ELECTRICAL SYSTEMS

Reduced Lighting Power Density: Credit is available for total connected lighting power density that is lower than MNECB levels.

Exterior Lighting: Exterior lighting is not considered in CBIP; it is not modeled in EE4 and is not eligible for credit.

Vertical Transportation: Elevators/escalators are not considered in CBIP and not eligible for credit. The exception to this rule is elevator use in MURBS. Elevators are available for a credit installed in MURBS (refer to Appendix D modeling rules).

Appliances: Credit for energy-efficient appliances installed in MURBs. Refer to Appendix D modeling rules.

MISCELLANEOUS

Cogeneration Systems: No credit is normally available for cogeneration systems (use of electric generator waste heat for building heating or cooling needs) If the building is served by waste heat from a central cogeneration plant (i.e. at a university or hospital), the heating plant should be modeled as district heating and select the "purchased heating" option for your central heating plant. However, NRCan may provide a credit for certain systems. For more information regarding credits for cogeneration contact NRCan directly.

Process Heat Recovery: Using heat generated from an industrial, manufacturing, service or electrical generation process to directly heat ventilation air, service water heating, and hydronic loop heating is an available IBIP credit. More information on obtaining credit for using the waste heat can be found at http://oee.nrcan.gc.ca/newbuildings/ibip/ibip.cfm. Laboratory fume hood heat recovery for any purpose is a CBIP and IBIP eligible item. More information on this can be found in Appendix E.

Fuel-Switching: Fuel switching from a fossil fuel to another type of fossil fuel or electricity is not an available CBIP credit even if the switching decision results in a potential reduction of greenhouse gas emissions. The reference building will use the principal heating source for the thermal zones that you have described for your building and following the rules on selecting the principal heat source. The only fuel switching that is considered as a credit is the use of renewables.

Low-Flow Faucets and Showers: Credit is available for fixtures that limit hot water flow to below code-mandated maximum flowrates.

Domestic Hot Water Heat Recovery: Credit is available for drainwater heat recovery systems. See Appendix F for calculation on drainwater heat recovery credits.

Renewable Energy: Credit is available for use of renewable energy systems, including photovoltaic panels, solar thermal air heating, solar domestic hot water systems, and wind turbines. These technologies require calculations to be performed outside EE4 with software such as RETScreen. Ground source heat pumps (geothermal energy) can be modeled directly as an HVAC system in EE4.

There are some energy-saving technologies that are not considered in the MNECB and as such are not currently modeled in EE4. These technologies may be recognized by CBIP. These items require special treatment outside of EE4 using DOE 2.1 software or other software to predict energy savings. Building simulators should review Chapters 5 and 6 in this manual and contact the CBIP Technical Manager for the approved techniques to handle technologies not considered in this manual, which you feel may warrant a credit.

2.   BUILDING ZONING PRINCIPLES

One of the first steps in the CBIP modeling process is to examine the plans and specifications thoroughly and come up with strategy to subdivide the building into "zones". The process to make this decision is described in this section.

2.1   Dividing Buildings into Zones

Buildings are made up of thermal *zones*. A zone is a portion of a building served by a common HVAC system that has similar heating loads, cooling loads and operating schedules. For example, a typical small light-industrial building has a minimum of two zones: a front office zone served by a rooftop unit and a back storage zone heated by unit heaters. Zones in turn are made up of 1 or more *space*s. A space is a room or series of rooms with similar heat gains and losses and is used for the same *function*. For example, the office zone could have 3 spaces: photocopy room, general office spaces and corridors. These three spaces are served by the same HVAC system and have identical hours of operation, but the method of lighting, occupant density, and ventilation rates are different.

One of the most difficult aspects in modeling buildings is dividing the building into zones and spaces. There is no one right answer and different simulators will develop their own zoning strategies. Nevertheless, there are a series of rules that can be applied to minimize differences between simulators and thus provide a more representative simulation.

A zone includes those areas in the building that meet three criteria:

- Served by the same HVAC system
- Similar operation and function
- Similar heating/cooling loads

The following sections discuss each of these criteria.

Same HVAC System

The first step in defining zones is to divide the building up into areas served by the same HVAC system. In EE4, "system" usually refers to the centralized air handling equipment serving an area of the building. Buildings can have several systems or only one system, depending on the building size and system type.

For example, a small retail building in a plaza may be served by 2 rooftop units. In this case, each rooftop unit is a "system". The first step in zoning this building would be to divide the building into 2 general areas, according to the location served by each rooftop unit.

On the other hand, a high-rise apartment building may have one central make-up air unit providing ventilation air to the corridors, and individual heat pumps distributed throughout the building heat and cool individual apartments. In this case, there is only 1

system. To subdivide the building further, it is necessary to look at the secondary zoning criteria (similar loads and/or operation).

The zone boundaries should match the area of influence of each HVAC system. If there are variations within this zone, the zone can be divided into spaces (see Dividing Zones into Spaces section). (See exception under Grouping Similar Zones section). An important aspect of modeling buildings is determining the amount of over-sizing of the HVAC equipment. If the zone boundaries do not correspond with the HVAC system, the amount of over-sizing will not be calculated correctly. This does not preclude a zone being heated by one system and cooled by another. Zone boundaries do not have to be physical separations and can simply be an air boundary to be a valid zone. For example, an open office concept design may have heating on the perimeter of the building but offices farther inward from the perimeter may not have any heating at all. The perimeter zone would be separated from the interior zone even if it were an open concept office.

Multi-zone systems (multi-zone, dual-duct, VAV) will normally serve several zones and should be modeled as such. As a guide to zoning for these systems, use a zone for each set of areas controlled by a single thermostat. This may result in a large number of zones, which significantly increases the level of effort to model a building. In many cases zones can be grouped together without loss of accuracy. For example, rooms that are similar but have individual thermostats to handle random occupancy patterns can be grouped together. Consider a multi-zone system serving a group of meeting rooms. The meeting rooms will be used sporadically and the HVAC must be able to take that into account. But from a modeling point of view, all the rooms are the same and can be grouped into a single zone. Another example is hotel/motel rooms. Each room has its own thermostat to handle variations in room use, but each room is just as likely to be full or empty. In this case, all rooms can be treated as one zone (provided they have the same heating and cooling loads under normal operation – see next section). Other rules for grouping zones are discussed later.

Similar Operation and Function

The next step is to examine the function of each of these zones. Those parts of a building that have significantly different hours of operation should be separated into different zones. For example, part of an office may operate during normal business hours whereas another part of the office may operate as a 24-hour telephone support department. In most cases, these parts would be handled by different HVAC systems and therefore would be divided into separate zones because of the first criteria. Areas that have different space function (e.g., offices, corridors and washrooms) can be modeled as one zone provided they have the same operating schedules.

Refer to Section 2.2 for further information and criteria on defining zones by operation and function, and on subdividing zones into spaces.

Similar Heating/Cooling Loads

The third step is to divide building areas into rooms or groups of rooms that have similar heating and cooling loads. Applying this criteria means that exterior rooms facing in each direction should be modeled as separate zones (different solar gains). Interior floor

areas are modeled separately from perimeter areas. High-internal-heat-gain computer rooms are modeled separately from general office areas. To a large extent, this is the same as dividing the building into areas served by the same HVAC system and thermostat. It is likely that the building designer took variations in heating and cooling loads into consideration when laying out the HVAC systems.

This is not always the case, however. In the previous section, it was stated that similar hotel/motel rooms could be grouped together as a single zone. The north-facing rooms will have significantly different loads than the south-facing rooms. These two sets of rooms should be modeled as separate zones.

Perimeter areas should be modeled separately from interior areas. In some buildings, particularly in open office plans, it is difficult to tell where this transition occurs. The dividing line between perimeter and interior areas should be set according to the following rules (in the order listed):

- Position of full-height walls separating perimeter areas from interior areas
- Area of influence of perimeter HVAC systems. Separate HVAC systems are often used for perimeter areas and interior areas. The area conditioned by the perimeter HVAC system defines the perimeter zone.
- Any space or partition no more than five meters from exterior walls. Note that the CBIP definition of a lighting control zone for daylighting purposes is a space with a depth from the perimeter wall of no more than 1.5x the window head height. It may be more convenient to make the perimeter thermal zone the same as the daylighting zone.

Grouping Similar Zones

Applying the three criteria given above may result in a large number of zones, which although accurate requires significant data input time. The rules given below can be used to group similar zones:

1. Similar rooms with individual thermostats. These rooms can be grouped together provided they have similar heating and cooling loads. See example of multiple meeting rooms and hotel/motel rooms described in "Same HVAC System and Thermostat".

2. Same area on different floors. In many office buildings and apartments, the same floor plan is repeated on each storey. The same areas on each floor can be grouped into a zone. Top and bottom floors are modeled separately because of the extra heat transfer out of the roof and floor. In Figure 2-1, the second and third storeys can be grouped together.
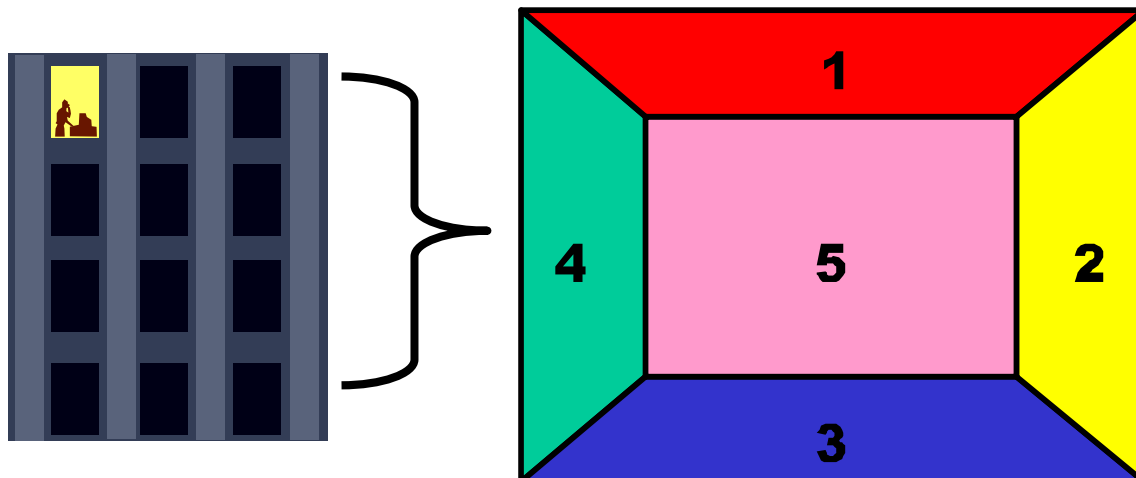
Figure 2-1 – Typical Zoning for Offices and Apartments

3.   Areas with similar heating/cooling loads. Areas with similar heating and cooling loads can be grouped together into one zone. For example, all the west-facing offices in a building could be grouped together provided they have similar space function and envelope characteristics. Areas need not be adjacent or contiguous to be treated as one zone. Consider Figure 2-2 where the end offices have much larger windows than the other offices. The offices with similar window-to-wall ratios could be grouped together as one zone. If these areas were conditioned by separate HVAC systems, the heating and cooling characteristics would have to be added together to properly calculate the amount of over-sizing of the HVAC equipment.

4.   Service areas and functions: washrooms, corridors and mechanical/electrical rooms, stairways, and locker rooms. These room types cannot be defined as a stand-alone zone; they must be included with areas that have similar operating schedules. For example, corridors and washrooms will likely be used the same hours as the office areas they serve and therefore should be included with the office zone.
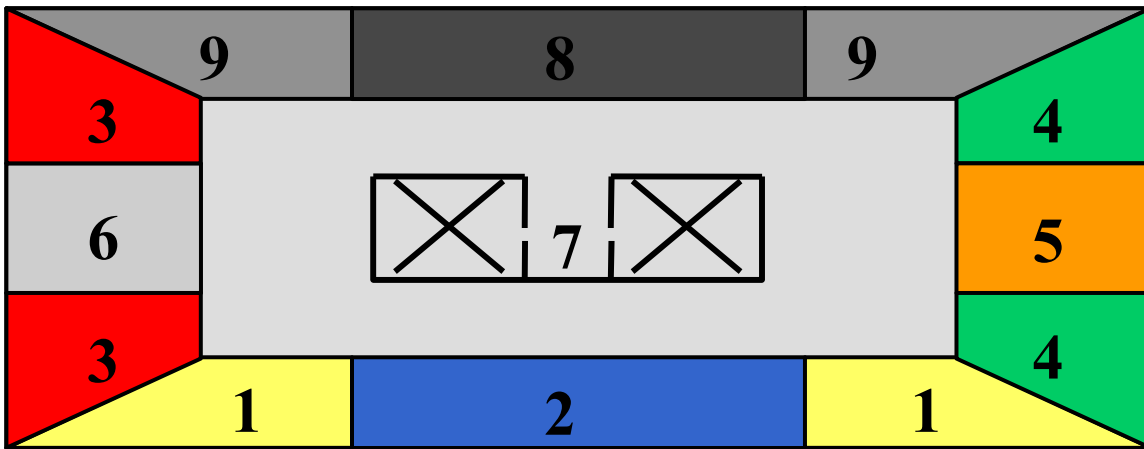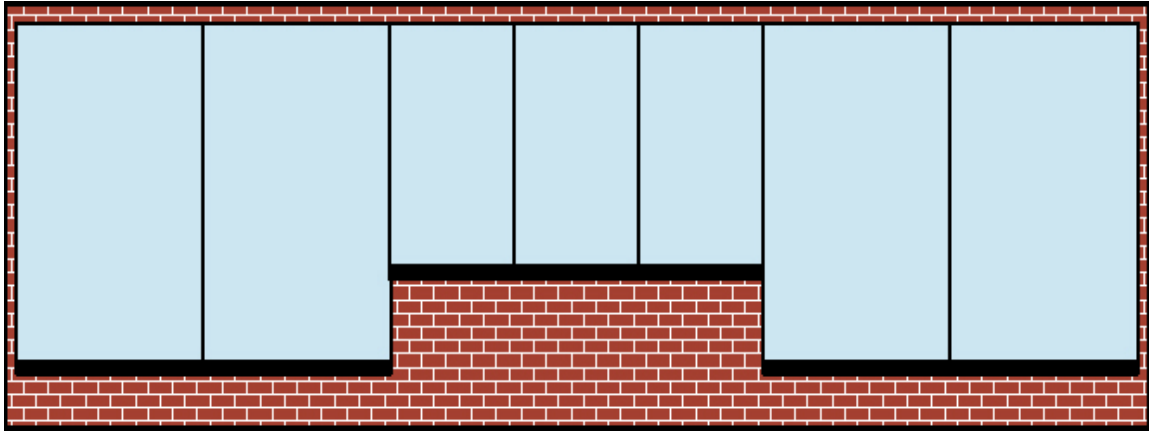
Figure 2-2 – Grouping Zones According to Heating and Cooling Loads

2.2 Dividing Zones into Spaces

It is important to understand how the EE4 software models spaces in order to properly zone a building. EE4 adds up the hourly heating and cooling loads of all the spaces in a zone to determine the net load on the zone. If one space required cooling and another heating, these loads would cancel each other and incorrectly indicate no or little need for space conditioning. For this reason, spaces within the same zone must have similar heating and cooling loads.

Defining spaces is a simple way of specifying variations within a zone. For example, a zone in an office building may contain drafting areas, a photocopy room and general office areas. The function in each of these spaces is different, that is, they each have their own lighting, ventilation and occupancy requirements. These areas can be modeled as individual spaces assuming they are served by the same HVAC system and would all be either heated or cooled as a group according to the same schedule. In EE4, corridors, mechanical rooms, washrooms, stairwells and locker rooms do not have a

valid operating schedule, i.e. the schedule in Table 4.3.2.B is marked with a *. These rooms must be combined with an adjacent space that has a valid operating schedule.

It is important to note that all spaces within a zone must have the same default operating schedules, according to table 4.3.2.B found in Appendix B of this document. For instance, a zone could be subdivided into an "Exhibit/Auditorium" space and "Lobby" because both have default schedules "C". However, a zone cannot contain a lobby and an "Office Category 1" because the office has default-operating schedule "A". The simulator would have to select the type of schedule that would apply to all spaces in the zone or would have to create a representative average schedule. If the schedules of operation are significantly different; the two spaces should be defined as separate zones. The spaces marked with a schedule "*" (as noted in the paragraph above) can be combined with any type of space. Often, zones will only contain 1 or 2 spaces, but can never contain more than 4.

When selecting the space function, it is important to be concerned more with the operating schedule of the spaces than with matching the name with that given in the Space Function List. This is significant in buildings where there are small rooms that have different operating schedules from the more dominant spaces that the building. Small rooms tend to be rooms like janitor closets, housekeeping rooms, or small storage rooms (i.e., paper storage, gym equipment storage, recycling storage, etc.). Rather than defining these smaller spaces as their own zone, they should either be lumped in with the rooms around them OR a space function should be selected that has no operating schedule (e.g. corridor or mechanical room). A typical example of a school building is given below:
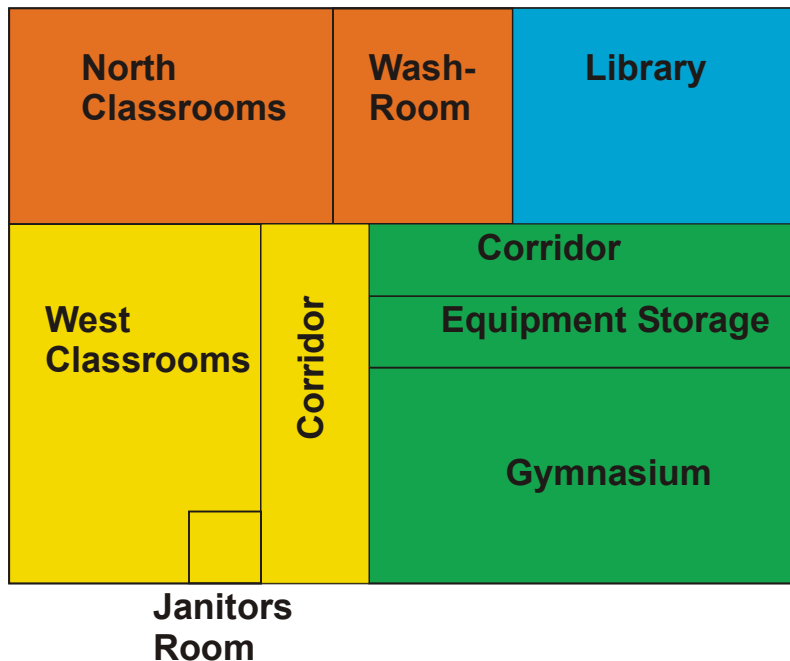
Figure 2-3–Defining Spaces

West Classrooms Zone:

West Classrooms: Space Function = Education - Classroom

> Janitors Room: Group with Corridor
> Corridor: Space Function = Service -
> Corridors

North Classrooms Zone:

> North Classrooms: Space Function =
> Education - Classroom

Washroom:

> Space Function = Service -Toilet & Washrooms

Library Zone:

> Library: Space Function = Library: Reading

Gymnasium Zone:

> Gymnasium: Space Function = Assembly –
> Recreational Sports Area

Equipment Storage:

> Group with Corridor
> Corridor: Space Function = Service -
> Corridors

If the building is defined using "building type" rather than "space function" (see Section 3.2), there is never any need to have more than one space per zone.

2.3 Defining Unconditioned/Partially Conditioned Zones

Portions of the building containing unconditioned spaces that have no or little impact on building energy use can be ignored. Unconditioned spaces do not have thermostat control to maintain a desired temperature nor have a system designed to deliver heating or cooling to the space. Examples include vented attics, fully vented crawlspaces, elevator penthouses, unheated parking garages, unheated vestibules and unheated mechanical rooms outside the insulated building envelope (e.g., penthouses). The RSI value of the envelope component protected by the unconditioned space may be increased by 0.16 m^2-$^{\circ}$C/W (MNECB Clause 3.3.1.4-1). Mechanical, elevator shafts and electrical rooms that are heated OR are within the insulated building envelope should be included in the building model. The procedure to model unconditioned zones is given in Section 3.4.

Small heated vestibules can be included with the zone they service. Small vestibules have a heater capacity of less than 5 kW. Large vestibules heated by an independent HVAC system should be modeled as a separate zone.

Dummy Zones

Because a vestibule space is a service type space and does not have a valid schedule (the schedule in Table 4.3.2.B is marked with a *), this zone must contain a space that

has a valid operating schedule. In this case the simulator would create a small space of 0.5 m2 area of a valid space representing the building with a single light and then define the vestibule space as a service space. The schedule and temperatures in the vestibule will follow the 0.5 m2 space unless custom schedules are created. This is referred to as a dummy zone to allow the service space to be simulated as a separate zone. This is only accepted if there is a clear need to adopt this method such as a corridor having its own heating, separate air handling system or the space function method already contains four defined spaces. An alternative method of entering a vestibule with its own system is to model using "building type" rather than "space function" as the input designation type.

Parking Garages and Crawl Spaces

Indoor heated or minimally heated parking garages should be treated as a separate zone in order to account for lighting and heating energy. Crawlspaces that are heated or that serve as a supply air or exhaust air plenum should be modeled as a separate zone. The procedure to model unconditioned or partially conditioned zones is given in Section 7.8.

Heating a garage or a crawl space with exhaust air is not considered using a heating source (except for multi-unit residential buildings – see Appendix D). For non-MURB buildings, consider the garage or crawl space as unheated and model as an exposed floor with an RSI increase of 0.16 m2-C/W (MNECB Clause 3.3.1.4-1).

If a garage or a crawl space has a dedicated heating source, then it must be modeled as a separate zone.

2.4 Zoning Example

A zoning strategy for a "big-box" retail store appears in Figure 2-4 – Zoning Strategy for Big-Box Retailer below.
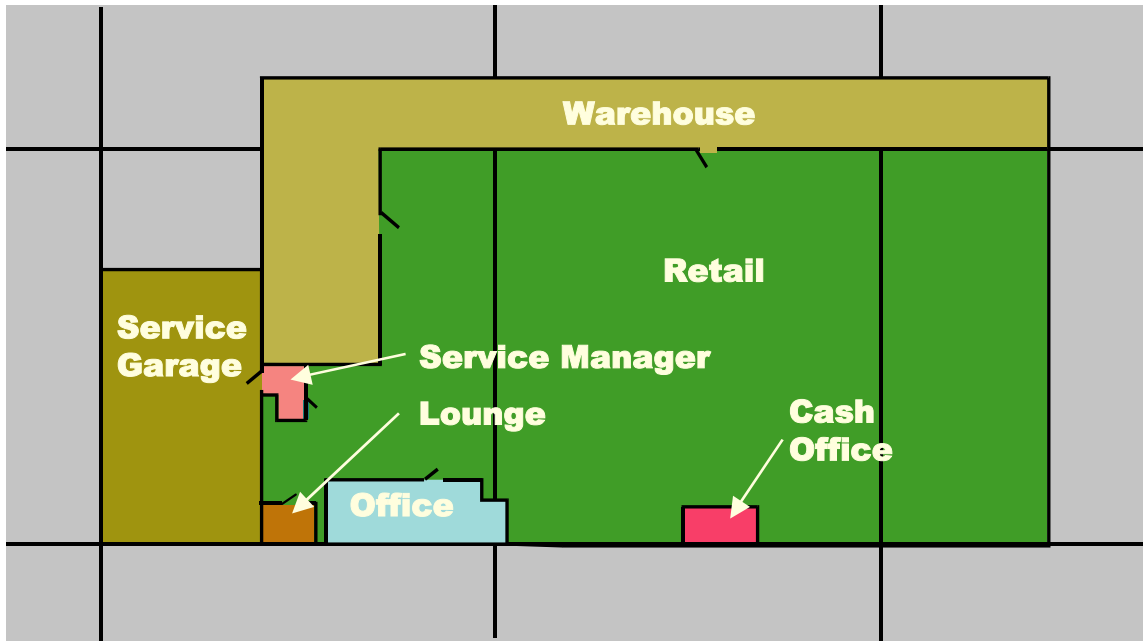
Figure 2-4 – Zoning Strategy for Big-Box Retailer

The store is primarily retail space, with two small office areas and an adjacent service garage. 6 rooftop units serve the retail and warehouse areas; separate ducted HVAC systems serve each office area, and the service garage is served by a number of exhaust fans and make-up air units. There are few windows in the building.

The retail area was modeled as one large zone, because of constant occupancy, scheduling and lighting characteristics throughout. Furthermore, the lack of windows in the building would indicate that the perimeter areas would not have significantly different load characteristics than the interior spaces.

Although the same rooftop units serve the warehouse area as the retail space, it is modeled as a separate zone because it would have a significantly lower occupant density and lighting density.

The office areas and lounge are each served by smaller ducted HVAC systems with perimeter baseboards. Furthermore, these areas are only occupied until 5pm but the retail space remains open until 9pm. For these reasons the office areas should be modeled as separate zones.

The service garage has significantly different space use characteristics than the rest of the building. Outdoor air ventilation rates for service areas are very high, and these areas are generally not air-conditioned. For these reasons the service garage should be modeled as a separate zone.

3. BUILDING FUNCTION AND OPERATION

This section provides an overview of EE4 and describes how to calculate or obtain input parameters relating to building operation and function. The topics included in this section include building type vs. space function, utility rates, principal heating source, and various building operation parameters (schedules, indoor temperatures, process loads, domestic hot water loads). Inputs specific to central plant equipment, HVAC systems, building envelope, and lighting are covered in subsequent chapters.

3.1 Overview of EE4

The EE4 program uses a "Building Tree" graphical interface (See Figure 3.1). The Building Tree is presented in a hierarchical manner, using icons to represent the various elements of the building. A building element cannot be defined until its predecessor in the tree hierarchy is defined. The Building Tree elements and their important input parameters are listed below in the order of entry.

Figure 3-1 – EE4 Building Tree Hierarchy
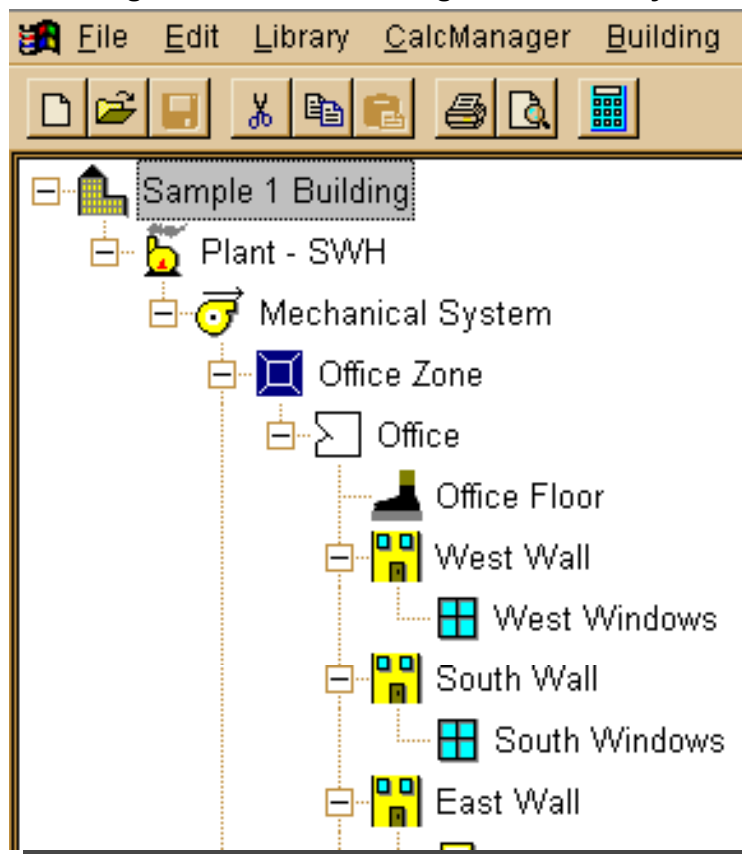
Building:
- Project and designer name and general information
- Location selection
- Utility rate information

- Selection of "Building Type" or "Space Function"

Plant:
- Description of central boilers, service water heaters, chillers, and cooling tower
- Central/Ground Source heat pump loop characteristics
- Heating / cooling changeover dates (2-pipe systems)

System:
- Definition of 1 of 15 HVAC system types
- Characteristics of central supply fan, return fan, heat recovery ventilator, economizer, humidifier
- Characteristics of make-up air units (zonal systems only)

Zone:
- Zonal heating, cooling, and airflow characteristics
- Definition of principal heating source
- General lighting characteristics
- Entry of HVAC, lighting, and occupancy schedules

Space:
- Floor area, occupant density, and outdoor air flow rates
- Process and receptacle loads
- Service hot water loads
- Exhaust fan characteristics

Envelope Components:
- Wall, floor, roof, below grade and interior partition areas and construction types
- Specific light fixture characteristics

Windows, Doors, and Skylights:
- Entered as elements within walls and roofs

When all building elements are entered, the simulation can be performed. EE4 uses the information entered in the Building Tree and incorporates CBIP and MNECB rules to construct two input files: one for the proposed building and one for the MNECB reference building. Each input file is then analyzed by the building energy analysis program DOE-2.1. The results of the DOE-2.1 calculation are then passed back to EE4 for display of the simulation results.

A third simulation, known as a "Non-Compliance" run, may also be performed. Non-Compliance mode allows you to modify certain inputs normally fixed or restricted for the code compliance calculation. You may run EE4 with user-defined schedules and occupant densities. The Non-Compliance run is purely optional and is for information purposes only.

3.2   Building Type vs. Space Function

A key decision in modeling buildings is whether to model by *building type* or by *space function*. This decision defines many of the simulation inputs, including occupant density, outdoor ventilation air requirements, receptacle loads, reference building lighting loads and operating schedules for occupants, fans, lights and receptacle loads. If building type is chosen, then a single set of these inputs is defined for each building (or part of the building). Mixed-use buildings (e.g., an office building with retail space or a cafeteria) can be defined using building type provided each zone or group of zones clearly falls into one of the building types. Nine building types are defined in the MNECB:

- Office
- Restaurant
- Retail
- Mall/Concourse/Atria
- School (including colleges and universities)
- Service Establishment (includes all institutional buildings)
- Warehouse (includes light manufacturing)
- Hotel/Motel
- Multifamily Residential

Modeling the building using the space function approach allows lighting, receptacle loads, ventilation air rate, low flow showers and operating schedules to be defined for each space with the zone. For example, the office building type can consist of washrooms, corridors, offices, lobbies and any of over one hundred different functions. The space function approach allows for specification of different operating characteristics for each of these spaces. With the building type approach a single set of operating parameters is defined for the entire building area.

The space function approach is recommended in most cases because of its flexibility in describing the various building functions. There are two exceptions to this rule:

1.   Speculative commercial buildings where the tenant leaseholds are not known

2.   Single-purpose buildings that are clearly typical of one of the nine building type categories (e.g., fast-food restaurant)

Whenever there is doubt, the space function approach should be used.

The principle advantage of the building type approach is that it reduces the level of effort in describing the building in the EE4 software. Provided that the building is typical of one of the nine building types, the building type approach should provide results similar to the space function approach (see example given below). The building type also allows the modeling of service functions (corridors, vestibules, washrooms, mechanical rooms) as separate zones because of the definition of the building type. The average lighting, ventilation rate, occupancy includes the effects service functions. If the selection of

building type contains a very high proportion of a non-representative space function (eg. Office space with a very large atria), then space function selection should be used.

Not all space functions are represented in EE4, although the list is extensive. If the space function is not explicit then select the closest type using occupant density and minimum outdoor air requirements as the governing factor and change the schedules to match the specific space function. For example, if the space function is a car wash space, with a high process water load, few occupants, open 24-hours per day and minimal lighting; selecting the "Non-Industrial Shop " space function will require considerably more outdoor air for ventilation purposes than likely designed (2.5 L/sec/m^2). A storage/warehouse space function will contain a minimum outdoor air rate that may match the car wash design conditions more closely (0.25 L/sec/m^2 to 0.4 L/sec/m^2) and the simulator can alter the process loads, hours of operation, temperatures and electrical loads in the zone schedule to match the car wash design conditions. These schedules will also be transferred to the reference design, whereas the EE4 calculation will not proceed unless the minimum outdoor air requirements of the space function selected are met.

However you decide the space function best represents your design, the key component is to document your decision-making process. If you feel the selection of the building type or space function is questionable and subject to varying opinions, contact your OEE Account Manager to obtain a written ruling.

3.3 Energy Savings Versus Cost Savings

To qualify for the CBIP program; following the meeting of all the mandatory MNECB requirements, the energy consumption of the proposed building must be 25% lower than that of the reference building. The CBIP incentive, however, is two times the annual energy cost difference between the proposed and reference buildings (to a maximum of $60,000). Because of the different costs of energy, it is possible (but not likely) that a building design could meet the 25% energy savings but achieve no cost savings and therefore not receive any incentive.

To meet the CBIP program requirements and maximize the financial incentive, the proposed design should save energy in all end uses. In most parts of Canada, fossil fuels (natural gas and oil) are less expensive than electricity. Because space heating is typically the largest energy requirement in buildings, it will be necessary to increase insulation, add ventilation heat recovery and improve heating system efficiency to meet the 25% energy savings target. On the other hand, because electricity use for lights and motors is typically the largest operating cost in buildings, energy efficient lighting and motors will be required to achieve a large incentive.

3.4   Utility Rates

The utility rate structures are entered in the Building Element, Energy Cost tab. Most rate structures used in Canada can be entered. The natural gas price structure should include the cost of gas, transportation to the utility, and delivery to the customer. These are often listed as separate items on the utility bill, but need to be totaled for entry into EE4. The electricity structure should include both consumption and demand charges. All rates should include any provincial taxes but should NOT include GST. For provinces with harmonized provincial/federal sales taxes, deduct the full GST (7%) to determine the provincial tax to add to that utility. In the submission package, details on how the utility rate and additional changes were calculated.

Many utility companies have a variable rate structure in which the price of energy decreases (or increases) depending on the amount used per month. These rate structures are handled by EE4 as multi-tier systems. For each block or "limit", both the energy cost and the maximum number of units sold at that rate are entered. For instance, if natural gas costs one rate for the first 100 m^3, another rate for the next 1000 m^3, and anything greater than 1100 m^3 is charged at a third rate, enter "100" and "1000" into the first and second "Limit" boxes in EE4.

For electricity bills, the rate structure for consumption (i.e. kWh) and peak monthly demand (kW) are entered. Electric utilities use two approaches to define the block sizes (or limits), either a fixed block size of kWh and kW or a variable kWh block size depending on the peak monthly kW consumed. The later rate structure is entered in the Tab labeled "Energy/Demand Rate (kWh/kW)".

There are four areas in which fixed monthly charges may be entered:

1.   Meter charge – Enter a fixed monthly charge for service, if applicable. This is a base amount charged every month, regardless of the amount of energy used.

2.   Minimum monthly charge – Enter the minimum monthly charge the customer must pay in the event there is no energy use during the billing period.

3.   Demand charge – Enter the monthly maximum demand charge, per unit.

4.   Minimum demand charge – Enter the monthly minimum demand charge, per unit.

The last two "demand" charges should not be confused with the demand charges entered in the rate structure. These two values should only be used if there is a fixed charge each month as opposed to a charge that varies with peak demand. If there are other monthly charges such as transformer charges or sentinel light charges, add these to the meter charge.

All block utility rates must start with January 1 as the first block and end with December 31 as the final block.

If your natural gas rate varies seasonally (summer charge from May 1 to September 30 and winter charge from October 1 to April 30) then you must enter periods instead of just

the summer and winter period. The first period would be the winter period from January 1 to April 30, the second period from May 1 to September 30 and the third period from October 1 to December 31.

When entering block rates, set the ending hour to 24 otherwise time of use pricing will be activated.

Time of Use Rates: Data Entry

If you wish to enter time of use rates complete the following:

- Only 3 hourly time steps are allowed per season as defined by the periods
- Time steps must end with 24 hours
- Block rates are allowed in the time steps

Electrical Example:

Season	Time of Use	Rate
Winter (dec 1 – mar 31)	7 am to 10 am	$0.12 /kWh
	10 am to 5 pm	$0.08 /kWh
	5 pm to 8:30 pm	$0.12 /kWh
	8:30 pm to 7 am	$0.04 /kWh
	Weekends/holiday	$0.06 /kWh
Spring (apr 1 – june15)	7 am to 8:30 pm	$0.08 /kWh
	8:30 pm to 7 am	$0.04 /kWh
Summer (june 16 – sep 15)	7 am to 8:30 pm	$0.16 /kWh
	8:30 pm to 7 am	$0.06 /kWh
	Weekends/holidays	$0.08 /kWh
Autumn (sep 16 – nov 30)	7 am to 8:30 pm	$0.08/kWh
	8:30 pm to 7 am	$0.04 /kWh

In this example, there are four seasons with either 4 rate periods or 2 rate periods. The example is simplified to avoid block rates per time of use rate.

EE4 can accommodate 3 seasons with 3 periods per season, therefore some averaging must be applied to prepare the data for EE4:

The first season must commence in January, therefore the winter season is actually 2 winter seasons in EE4. Jan to Mar. 31 season and the Dec 1 – 31 season if the winter season is critical. The user will have to decide how to group the months depending on whether cooling or heating costs are critical. If the building is natural gas heated and electrically cooled then, the winter season would be grouped with the spring and autumn seasons as follows:

> Season 1: Jan 1 – June 15
>
> Season 2: June 16 – Sep 15
>
> Season 3: Sep 16 – Dec 31

If electric heating exists and the building has a high heating load, then the winter seasons should remain intact and the spring, summer and autumn seasons grouped:

> Season 1: Jan 1 – Mar 31
>
> Season 2: Apr 1 – Nov 30
>
> Season 3: Dec 1 – Dec 31

Weekend and holiday rates cannot be entered separately in EE4 (available in DOE2), therefore their pricing should be averaged over the week to determine a weekly corrected price. For simplicity sake, holiday rates will be ignored and an average weekly rate will be determined.

In this example the summer rates are going to be kept separate from the balance of the year therefore the 3 seasons are:

> Season 1: Jan 1 to June 15
>
> Season 2: June 16 to Sep 15
>
> Season 3: Sep 15 to Dec 31

Season 1 will require average over different time steps and a selection of 3 representative periods with period 1 starting with 1 and period 3 ending in 24:

> Period 1: 1 am to 7 am
>
> Period 2 7 am to 8:30 pm (hour 21 assuming a rounding to the nearest hour)
>
> Period 3: 8:30 pm to 24:

From 1 am to 7 am and from 8:30 pm to midnight, the rate is a constant $ 0.04 /kWh thorough the week, therefore averaging is required to include the weekend to determine an averaging daily rate.

Assume that January 1 begins on a Monday and calculate the weekdays and weekends throughout the January 1 to June 15 Season 1 and multiply by the daily rate:

Jan weekdays: 23 days	23 days * 0.04 /kWh = 0.92
Jan weekends: 8 days	8 days * 0.06 /kWh = 0.48
Feb weekdays: 21 days	21 days * 0.04 /kWh = 0.84
Feb weekends: 8 days	8 days * 0.06 / kWh = 0.48
Mar weekdays: 21 days	21 days * 0.04 /kWh = 0.84
Mar weekends: 10 days	10 days * 0.06 /kWh = 0.6

Average price 1 am - 7 am = (0.92 + 0.48 + 0.84 + 0.48 + 0.84 + 0.6) /
      (23 +8+21+8+21+10)
= 0.0457 cents/kWh

This is the value for period 1 and for period 3 (same rates from 9 pm to midnight) for the winter season.

From 7 am to 8:30 pm (period 2), various time of use rates are available for different months, therefore a time averaging is required as follows:

1.   Determine a winter average daily rate from 7 am to 8:30 pm
      Ave = (3 hrs * 0.12 + 7 hrs * 0.08 + 4 hrs * 0.12) / (3 hrs + 7 hrs + 4 hrs)
      = $0.10 /kWh

The average daily rate for the winter time of 7 am to 9 pm is $0.10 /kWh for all days within the week.

2.   Weekend rates for winter time period are constant throughout the weekend at $ 0.06 /kWh, therefore no averaging is required

3.   Assume that January 1 begins on a Monday and calculate the weekdays and weekend throughout the January 1 to June 15 Season 1 and multiply by the daily rate:

Jan weekdays: 23 days	23 days * 0.1 /kWh	= 2.3
Jan weekends: 8 days	8 days * 0.06 /kWh	= 0.48
Feb weekdays: 21 days	21 days * 0.1 /kWh	= 2.1
Feb weekends: 8 days	8 days * 0.06 / kWh	= 0.48
Mar weekdays: 21 days	21 days * 0.1 /kWh	= 2.1
Mar weekends: 10 days	10 days * 0.06 /kWh	= 0.6

Average price 7 am to 9 pm =
2.3 + 0.48 + 2.1 + 0.48 + 2.1 + 0.6) / (23 +8+21+8+21+10)
= 0.08637 cents/kWh

Therefore season 1 (jan 1 to june 15) will have the following periods and rates

      Period 1:   ending hour: 7,   rate: $0.0457 /kWh

      Period 2:   ending hour: 21   rate: $0.08637 /kWh

      Period 3:   ending hour: 24   rate: $0.0457 /kWh

Season 3 will have the exact same periods but the average price will change even though the rates are identical because of a differing number of weekdays and weekend days (will affect the average).

Season 2: Calculation: (June 16 to September 15):

The rates are: weekdays: 7 am to 8:30 pm: $ 0.16 /kWh
                            8:30 pm to 7 am: $ 0.06 /kWh
            weekends: all day: $0.08 /kWh

There will be 3 periods: 1 am - 7 am, 7 am – 9 pm, 9 pm - midnight

Averaging is required as the rates differ on the weekday and weekend and EE4 uses the same rate for each day of the period.

1. Period 1: Average rate: 1 am to 7 am period

Determine the number of weekdays and weekend days assuming January 1 is on a Monday

       June 16 – June 30 weekdays : 10   10 * 0.06 = 0.6

       June 16 – June 30 weekend days: 5   5 * 0.08 = 0.4

       July: weekdays: 23   23 * 0.06 = 1.38

       July weekend days: 8   8 * 0.08 = 0.64

       August weekdays: 22   22 * 0.06 = 1.32

       August weekend days: 9   9 * 0.08 = 0.72

       Sept 1 – 15 weekdays: 10   10 * 0.06 = 0.6

       Sept 1 – 15 weekend days: 5   5 * 0.08 = 0.40

Average rate =
(0.6 + 0.4 +1.38 + 0.64 + 1.32 + 0.72 + 0.6 + 0.4) / (10+5+23+8+22+9+10+5)
 = 0.0659 /kWh (rate for 1 am to 7 am)

2. Period 2: Average rate: 7 am to 9 pm period

Determine the number of weekdays and weekend days assuming January 1 is on a Monday.

       June 16 – June 30 weekdays : 10   10 * 0.16 = 1.6

       June 16 – June 30 weekend days: 5   5 * 0.08 = 0.4

       July: weekdays: 23   23 * 0.16 = 3.68

       July weekend days: 8   8 * 0.08 = 0.64

       August weekdays: 22   22 * 0.16 = 3.52

       August weekend days: 9   9 * 0.08 = 0.72

       Sept 1 – 15 weekdays: 10   10 * 0.16 = 1.6

       Sept 1 – 15 weekend days: 5   5 * 0.08 = 0.40

Average rate = (1.6 + 0.4 + 3.68 + 0.64 + 3.52 + 0.72 + 1.6 + 0.4) / (10+5+23+8+22+9+10+5)
 = 0.1365 /kWh (rate for 7 am to 9 pm)

3. Period 3: Average rate: 9 pm to midnight period

Determine the number of weekdays and weekend days assuming January 1 is on a Monday

June 16 – June 30 weekdays : 10	10 * 0.06 = 0.6
June 16 – June 30 weekend days: 5	5 * 0.08 = 0.4
July: weekdays: 23	23 * 0.06 = 1.38
July weekend days: 8	8 * 0.08 = 0.64
August weekdays: 22	22 * 0.06 = 1.32
August weekend days: 9	9 * 0.08 = 0.72
Sept 1 – 15 weekdays: 10	10 * 0.06 = 0.6
Sept 1 – 15 weekend days: 5	5 * 0.08 = 0.40

Average rate = (0.6 + 0.4 +1.38 + 0.64 + 1.32 + 0.72 + 0.6 + 0.4) / (10+5+23+8+22+9+10+5)
 = 0.0659 /kWh (rate for 9 pm to midnight)

Season 3: Calculation: (September 16 to December 31):

The rates are:

Sept 16 – Nov 30: weekdays and weekends: 7 am to 8:30 pm: $ 0.08 /kWh
Sept 16 – Nov 30: weekdays and weekends: 8:30 pm to 7 am: $ 0.04 /kWh
Dec 1 - Dec 31:   weekdays   7 am to 8:30 pm: $0.1 /kWh ave)
Dec 1 – Dec 31:   weekdays   8:30 pm to 7 am: $ 0.04 /kWh
Dec 1 – Dec 31:   weekends: 7 am to 8:30 pm: $ 0.06 / kWh
Dec 1 – Dec 31:   weekends: 8:30 pm to 7 am: $0.06 /kWh

There will be 3 periods: 1 am - 7 am, 7 am – 9 pm, 9 pm - midnight

Averaging is required as the rates differ on the weekday and weekend and EE4 uses the same rate for each day of the period.

1. Period 1: Average rate: 1 am to 7 am period

Determine the number of weekdays and weekend days assuming January 1 is on a Monday.

Sept 16 – Sept 30 days: 16   16 * 0.04 = 0.64

October : days: 31   31 * 0.04 = 1.24

November: days: 30   30 * 0.04 = 1.2

December weekdays: 22   22 * 0.04 = 0.88

December weekend days: 9   9 * 0.06 = 0.54

Average = (0.64 + 1.24 +1.2 + 0.88 + 0.54) / (16+31+30+8+22+9)
 = 0.0412 /kWh (rate for 1 am to 7 am)

2. Period 2: Average rate: 7 am to 9 pm period

Determine the number of weekdays and weekend days assuming January 1 is on a Monday.

Sept 16 – Sept 30 days: 16   16 * 0.08 = 1.28

October: days: 31   31 * 0.08 = 2.48

November: days: 30   30 * 0.08 = 2.4

December weekdays: 22   22 * 0.1 = 2.2

December weekend days: 9   9 * 0.06 = 0.54

Average = (1.28 + 2.48 + 2.4 + 2.2 + 0.54) / (16+31+30+8+22+9)
= 0.0824 /kWh (rate for 7 am to 9 pm)

3. Period 3: Average rate: 9 pm to midnight period

Determine the number of weekdays and weekend days assuming January 1 is on a Monday.

Sept 16 – Sept 30 days: 16   16 * 0.04 = 0.64

October : days: 31   31 * 0.04 = 1.24

November: days: 30   30 * 0.04 = 1.2

December weekdays: 22   22 * 0.04 = 0.88

December weekend days: 9   9 * 0.06 = 0.54

Average = (0.64 + 1.24 +1.2 + 0.88 + 0.54) / (16+31+30+8+22+9)
= 0.0412 /kWh (rate for 9 pm to midnight)

EE4 Input for Time of Use Rates:

Season 1:   Ending Month: 06   Ending Day: 15

Period 1:   Ending Hour: 7, Blocks: 1   Rate: $0.0457 /kWh

Period 2:   Ending Hour: 21, Blocks 1:   Rate: $0.0864 /kWh

Period 3:   Ending Hour: 24, Blocks 1:   rate: $0.0457 /kWh

Season 2:	Ending Month: 09	Ending Day: 15
Period 1:	Ending Hour: 7, Blocks: 1	Rate: $0.0659 /kWh
Period 2:	Ending Hour: 21, Blocks 1:	Rate: $0.1365 /kWh
Period 3:	Ending Hour: 24, Blocks: 1	rate: $0.0659 /kWh
Season 3	Ending Month: 12	Ending Day: 31
Period 1:	Ending Hour: 7, Blocks: 1	Rate: $0.0412 /kWh
Period 2:	Ending Hour: 21, Blocks: 1	Rate: $0.0824 /kWh
Period 3:	Ending Hour: 24, Blocks: 1	rate: $0.0412 /kWh

Renewable Pricing

If your building is heated with renewables (wood) or heated with purchased hot water or steam you must still enter the utility rates corresponding to the heating source fuel that was used to generate the hot water or steam. In the case of renewables, you must enter the utilities for the fuel that would have been the fuel of choice if renewables were not considered (required to generate a fuel bill for the reference case).

Example: remote lodge off-grid heated with wood and electricity provided by a combination micro-hydro and diesel generator

Solution:

Determine the fuel that would be used in the remote area to heat the building as wood is not an MNECB reference fuel: trucked in fuel: propane or oil.

Simulate the building using propane or oil as the principal heating source and entered purchased heating as the fuel and enter the oil or propane pricing.

Electricity is generated by burning diesel or via micro-hydro. Enter the cost of diesel converted to an average consumption cost for electricity as the electrical pricing ($/ekWh). Do not enter demand pricing. If diesel costs 50 cents/litre, the ekWh cost is $0.05/ekWh (154862 BTU/Can gallon for diesel or 35.92 MJ/litre).

This will represent the pricing for the reference case electricity. The simulator would use another analysis (RETScreen for example) to determine the contribution of micro-hydro and diesel for the proposed case electrical cost. The proposed case wood cost would be the cost of propane or oil, but converted to the energy equivalent for wood heating (MJ per cord or cubic foot or wood purchase units).

The renewable pricing (wood and micro-hydro equivalents would be subtracted from the proposed case to determine the fossil fuel (diesel in this case) purchased energy.

CBIP does not recognize the purchase of green power as an eligible credit, and the utility prices for the proposed and reference case must match.

Utility Pricing from Internal Operations

In some instances the pricing for utilities may reflect other administrative and operational items that need to be removed from the pricing. For example, at a university campus, a central plant may provide energy services to the buildings. The price of these services may include energy management system costs, internal administration costs and possibly other costs. These non-energy costs need to be removed from the utility costs. If this is difficult to compute, then use the utility cost from the local utility supplier as if the building were not connected to the campus grid.

Deregulated Pricing

CBIP requires a referenced price to determine the incentive. Under a deregulated regime; the contract with the energy supplier is required as part of the submission. Barring this, electrical/gas rates shall be based upon the long-term contract printed from the supplier's web site. If this is not available for electricity go to the independent energy market operator (IMO) web site (www.theimo.com). They list the average electricity price since May 1, 2002 (when the market opened). To this add the retailer charges for consumption and demand (which can be obtained from the local municipal utility), transportations charges, debt retirement charges, transmission charges and provincial sales tax. These are all available from the utility web site.

3.5 Determination of Principal Heating Source

A key factor in modeling buildings is the selection of the "principal heating source"; the primary fuel used to heat a zone. The principal heating source defines the insulation levels of the reference building envelope (as listed in the MNECB Appendix A). The higher the cost of the heating fuel is, the higher the insulation requirement (heating fuel cost applicable at the time the MNECB was developed in 1997). The principal heating source is defined at the zone level and thus there may be a different principal heating source and prescriptive insulation level for each zone.

In many buildings, there may be more than one source of heat for a zone. There are three important rules that must be applied in determining the "principal" heating source.

First, consider all heating sources that provide 10% or more of the zone heating capacity. This includes (i) heat supplied through radiators, convectors, and fan coils from a central boiler, (ii) heat supplied in a central air handler including outdoor air preheating, duct heaters and (iii) zone heaters (including all vestibule heaters) if greater than 5 kW output).

Second, determine the fuel supplied for each heating source. In the case of zone heating from a central plant, the heating source is the fuel for the central plant. For district heating systems, the heating source is the fuel used at the district heating plant. Special attention is needed for air-source heat pump systems. Although heat pumps are defined as a heating source, many heat pump systems require back-up heaters to meet the peak-heating load. Both the back-up fuel and heat pumps must be included in determining the principal heating source.

Third, select the heating source that accounts for a minimum of 10% of the zone heating capacity with the highest "Energy Source Adjustment Factor" (ESAF) from among all the heating sources for the zone. The ESAFs vary from region to region and are given in Table 3-1 (which is taken from the MNECB Appendix D).

The ESAF is roughly the ratio of the cost of the heating source relative to electric resistance heating. When using the performance path to show compliance to the MNECB, energy usage must be multiplied by the ESAF to show that the <u>cost</u> of energy for the proposed building is less than the cost of energy for the reference building. For the CBIP program, energy use is NOT multiplied by the ESAF. For CBIP, the goal is to show that energy "consumption" is 25% less than that for the reference building.

Table 3-1 – Energy Source Adjustment Factors (taken from MNECB Appendix D)

Province or Territory	Region	Energy Source					
		Electricity	Propane	Oil	Natural Gas	Heat Pump, Electric	Other
Newfoundland	A	1	0.70	0.22	—	0.33	1
	B	1	0.70	0.17	—	0.33	1
	C	1	0.70	0.57	—	0.33	1
	D	1	0.70	0.79	—	0.33	1
P.E.I.	A	1	0.49	0.30	—	0.33	1
Nova Scotia	A	1	0.45	0.23	—	0.33	1
New Brunswick	A	1	0.87	0.34	—	0.33	1
Quebec	A	1	0.54	0.54	0.53	0.33	1
	B	1	0.54	0.54	0.53	0.33	1
	C	1	0.54	0.54	—	0.33	1
Ontario	A	1	0.28	0.28	0.20	0.33	1
	B	1	0.28	0.28	0.20	0.33	1
Manitoba	A	1	0.48	0.48	0.31	0.33	1
	B	1	0.48	0.48	0.31	0.33	1
Saskatchewan	A	1	1	1	0.16	0.33	1
Alberta	A	1	0.53	0.53	0.15	0.33	1
	B	1	0.53	0.53	0.15	0.33	1
	C	1	0.53	0.53	0.15	0.33	1
British Columbia	A	1	0.43	0.43	0.36	0.33	1
	B	1	0.48	0.48	BCG 0.35 PNG 0.37	0.33	1
	C	1	0.45	0.45	0.40	0.33	1
	D	1	0.48	0.48	0.35	0.33	1
	E	1	0.58	0.58	0.41	0.33	1
Yukon	A	1	0.26	0.29	—	0.33	1
	B	1	0.17	0.17	—	0.33	1
	C	1	—	0.18	—	0.33	1
Northwest Territories	A	1	0.19	0.19	—	0.33	1
	B	1	0.27	0.24	—	0.33	1
	C	1	0.17	0.17	0.05	0.33	1
	D	1	0.11	0.11	—	0.33	1
	E	1	0.10	0.10	—	0.33	1
	F	1	0.10	0.10	—	0.33	1
	G	1	0.09	0.09	—	0.33	1
	H	1	0.10	0.10	—	0.33	1

Entering "other" as the principal heating source always assumes an electrical heating source. If the heating source is steam, enter the fuel used to generate the steam as the principal heating source. If the principal heating source is biomass, renewables, diesel or coal, contact NRCan for assistance.

3.6 Building Schedules and Equipment Operation

When the building type or space function is selected for each zone or space, default or standard values of building operation are assigned. The same values are assigned to both the proposed building and the reference building. The operating parameters include occupant density, process loads, receptacle loads, ventilation rates, heating and cooling thermostat setpoints, and hourly schedules for occupancy, lighting, receptacles, process loads and HVAC operation. The default schedules are listed in the MNECB Help System and the fan operation is summarized in Table 3.2. The fan operation is also indicative of the hours of occupancy, cooling system operation and temperature setup.

For the most part, changes to any of these operating parameters will have little impact on the energy savings of the proposed design. For example, increasing the thermostat setpoint will increase the heating energy consumption. However, the percentage increase will be about the same in the proposed and reference buildings. Thus, the percentage savings or difference between the two designs will likely be the same.

There are, however, two important exceptions to this rule. First, if a zone has exceptionally high internal heat gains from process loads, receptacle loads or occupancy, there could be a significant shift in the building heating and cooling loads. If the heating load is significantly reduced, the effectiveness of additional insulation is very low. Second, some buildings may have much longer operating hours than the default schedules provide. Examples include retailers or offices that operate 24 hours a day. In these situations, the longer operating hours will greatly increase the energy savings from ventilation air recovery.

For the above reasons, it is recommended that the default values be used unless there is a significant difference between the proposed operation and default values. A "significant" difference is considered to be greater than a 25% difference in any of building operation parameters (e.g. 25% more or less operating hours per week).

If the expected thermostat setpoint differs from the default values (21°C for heating and 23°C for cooling) by more than 3C^{o}, the default values should be changed. The temperatures need to be entered in two places: in the heating and cooling temperature schedules (Zone Element/Schedules Tab) and in the Room Element (used for sizing purposes only).

Table 3-2 – Fan Operating Schedules

Schedule	Typical Functions	Operating Hrs / Week	Mon-Fri On-time	Saturday On-time	Sunday On-time
A	Office	75	6am to 9pm	None	None
B	Restaurant	122	8am to 2am	8am to 2am	9am to 11pm
C	Retail	94	7am to 9pm	7am to 9pm	9am to 7pm
D	School	80	7am to 11pm	None	None
E	Warehouse	69	7am to 7pm	8am to 5pm	None
F	Hotel/Motel	168	Always On	Always On	Always On
G	Residential	168	Always On	Always On	Always On
H	Health Care	168	Always On	Always On	Always On
I	Theatre/Church	77	2pm to 1am	10am to 1am	7am to 2pm

Note: the same schedule is used for supply, return and exhaust fans in EE4

Changing Schedules in EE4

In EE4, building operation schedules are changed in the Zone element, "Schedules" tab. There are 8 schedules that can be changed: lighting, occupancy, receptacle loads, process loads, service water heating, fans, heating, and cooling. When changing schedules, a yearly schedule is first defined. The yearly schedule is composed of various weekly schedules each defined by the ending date of which that schedule is in effect. For example, if a different schedule is in effect from May 1 until September 30, three separate schedules must be entered: one schedule ending April 30, (for the January 1 to April 30 period), another schedule ending September 30, and a third schedule ending December 31. Schedules must be entered in chronological order.

Once an ending date is specified, the weekly schedule can be edited. For each day of the week, an hourly schedule can be edited. For fractional schedules, enter the percentage (0 to 100) for each hour. For temperature schedules (heating and cooling) enter the actual temperature setpoint (Celsius or Fahrenheit depending on the units in which the user is working). Schedules cannot be changed if you are applying a demand ventilation strategy. You must use the MNECB default schedules and then apply the scheduling change on this schedule as per the methods outlined in section 5-12.

Process Loads

Very high process loads have a high impact on heating and cooling loads and should be modeled in EE4. Examples of process loads include centralized computer servers, commercial cooking and refrigeration equipment and industrial processes. However, in determining whether the building meets the 25% energy reduction target, the energy use for these non-regulated process loads must be removed from the proposed and reference buildings. This must be done by performing a hand calculation and using the following procedure:

Observe the process load schedule to determine how many hours per year the process load is present. If the process load is fractional at some hours, determine an equivalent number of annual hours.

Multiply the size of the load (in kW) by the number of annual hours to determine the energy use (in kWh) per year.

Convert kWh to MJ (or BTU) and subtract from the final energy figure reported by EE4 for both proposed and reference buildings running the simulation.

Calculate the annual process electrical cost using the average cost (DOE2 ES-D report will provide the "virtual electricity rate") and the calculated process energy and subtract this value from both the proposed and reference cases. The electrical demand is not easily determined using this method and will be omitted from the comparison.

Alternatively, the annual energy attributed to the process load can be taken from the DOE2.1 detailed simulation report (BEPS report). The "MISC EQUIPMT" row includes the energy for the process loads and receptacle loads. The process loads can be removed, but the receptacle loads must be included in the calculation of the percent savings. Two EE4 runs can give you the process load contribution in the DOE2.1 BEPS report (one with process energy and one without).

The energy cost for the process load is to be calculated based on the "virtual" energy rate for the building. This "virtual rate" can be found in the ES-D report in the generated .SIM file for the proposed building.

Any process heating or cooling equipment required to deal with the process loads can be also be excluded in the calculation of percentage energy savings (e.g. pumping power for pumping the chilled water to cool equipment).

Grocery stores and ice arenas have very high process loads that contribute a substantial portion of the total building energy use. . An on-line retail food store and arena Wizard is available for use with CBIP compliance at http://cbip.nrcan.gc.ca.

Natural gas process loads (steam humidifier, health care laundry, gas-fired pool) cannot be modeled as a gas process load in EE4. These will have to be modeled as electric process loads and removed from the proposed and reference case simulation. The annual electrical costs will be higher due to the assumed electrical process load, however the increase occurs equally in the proposed and reference case and CBIP is concerned with the savings, therefore no adjustment is required for the costs for CBIP purposes.

To simplify the simulation process, it is acceptable to ignore non-regulated process loads and associated equipment if their energy consumption is isolated from the rest of the building, for example a dedicated computer room. The make-up outdoor air for kitchen exhaust hoods, and the energy required to condition this air, can also be excluded from the simulation.

Service Water Loads

Service water refers to hot water used for cooking, bathing, dish and clothes washing. In a restaurant, the service water-heating load includes dishwashing hot water needs. In the majority of cases the hot water that is consumed and then disposed via a drain is included in service water heating. Exceptions are process specific hot water such as car wash hot water or pool hot water.

The default service water-heading load is determined from the building type or space function. Appendix B of this manual displays the default loads (in units Watts per occupant) used in the analysis.

Although the MNECB does not give credit for any measures to reduce hot water consumption, for CBIP this requirement has been relaxed and there are potential energy savings from using low-flow showerheads and faucets.

Credits for low-flow showerheads and faucets only apply if the building is defined by space function. The procedure to get a credit for low-flow showerheads and faucets is as follows:

- Select the SWH tab in the Room Element. Note that washrooms themselves will not have the water load. Rather the occupancy of the associated rooms around them will be used to calculate the service water load.
- Enter the anticipated hot water load in Watts per person (prior permission from NRCan is required to alter the default), or enter the MNECB default hot water consumption.
- Enter the percentages of the peak water consumption for that space attributable to shower heads and faucets
- Enter the maximum flow rate for the showerheads and faucets in L/s. The maximum flow rates permitted by the MNECB for showerheads and faucets are 9.5 and 8.3 L/min respectively. (Warning: fixtures are often rated in L/min; be sure to divide these values by 60 for EE4 input.

Potential energy savings are also obtained from a **wastewater heat recovery system.** Since these systems recovery some of the heat that would normally go down the drain, the load on the hot water plant is reduced. Wastewater heat recovery systems are then modeled as low-flow showerheads or faucets as described above. The procedure to account for drainwater heat recovery is provided in Appendix F.

3.7   Weather File Selection

MNECB has divided Canada into 34 climatic regions based on input from the provinces and territories. These regions are used to establish the thermal requirements for the MNECB or CBIP reference building used to establish the minimum acceptable level of performance for comparison with the proposed building.

The thermal performance of building envelope assemblies including windows is roughly based on heating degree days, the principal heating fuel, and a life cycle calculation

using energy and material costs circa 1995 as explained in Appendix F of the MNECB. The MNECB climate zones provide a shortcut to an assessment of the climatic and economic conditions upon which the code values are based.

The selection of a weather file is a relatively straightforward exercise: select from the list nearest your actual site location within the MNECB administrative region.

In some specific cases a different weather file should be selected depending on climatic differences between the nearest site and the location of the proposed building. This is due to differences in altitude (mountainous regions) and differences between coastal sites and inland sites.

The weather file selection should be based upon the closest representative weather file for the administrative region or province. In some circumstances, the MNECB conditions do not properly describe the climate, or available fuels for a specific location. This is particularly pronounced in regions where there are large changes in geographic conditions within a single jurisdiction, such as British Columbia Region A, which includes high altitude mountainous areas surrounding Vancouver, plus the delta areas of the lower Fraser Valley. Other discrepancies exist where heating fuels that were not available in specific regions when the MNECB was published, are now available for building projects. This is the case for the use of natural gas in Nova Scotia and New Brunswick. In these cases there may be a benefit to the simulator using the weather file for a different, but compatible jurisdiction.

It is acceptable for a simulator to change the location of the project (changing both the weather file used for the simulation, and the reference building envelope thermal performance values), if a different location can provide a significantly better description of the operating conditions under which the project will function. Changes of this nature must be reviewed and accepted by the CBIP technical committee prior to the submission being received. The reasons for the change must be described in the simulators notes submitted with the CBIP application, and be accepted by the reviewer for the change to be allowed.

The decision to accept the change will depend on a balance of weather file, fuel availability, and reference thermal values. In some cases the changed location also may change the modelled principal heating fuel.

In the case of a condominium project in Whistler BC, the project was in BC region A with the closest weather station being Vancouver. Due to the difference in altitude and design temperature, the weather file was changed to Castlegar, another mountain town, but one in BC Region E. Under this change the reference building walls became much more effective (moving from U=0.810 to U=0.450) for Propane, Oil, and Heat Pump principal heating source fuels, but otherwise the reference building stayed the same as it was for the original region. The increase in reference RSI values (to RSI 2.22, or R 12.6) for walls was thought reasonable for the actual climate.

In a second case, a warehouse project was proposed for a site in New Brunswick, using natural gas as the principal heating fuel. As the MNECB region for New Brunswick did not include natural gas, a change in heating fuel was requested for the simulation. The choices were between propane and heating oil. Initially propane seemed to be the most appropriate substitution based on the energy content of the fuel and its form. However,

the reference building envelope values for propane were much more strict than those for natural gas in areas where gas was available, reflecting the market for fuel delivery more than the energy value. In most jurisdictions where there is a differentiation of principal heating fuels, natural gas allows the least restrictive envelope values. Accordingly, it was decided that heating oil could be used as the principal heating fuel for the simulation.

4.   CENTRAL PLANT EQUIPMENT

This section explains "central plant" equipment, that is, centralized equipment that generally serves the entire building. This equipment includes service water heaters, boilers, chillers, cooling towers, and central heat pump loops. This equipment is primarily defined in the "Plant" element in EE4. Some commercial buildings are served by simple systems that do not require boilers, chillers, or cooling towers, such as packaged rooftop units. In these cases, some elements in the central plant may be left undefined.

4.1   Service Water Heaters

The water-heating load (or demand) of a building is dependent on the space function or building type selected (see Section 3.6). The "Service Water" tab in the Plant element in EE4 is used to describe the water heating method used to meet this load. Process water heating (laundry, car washes) ideally should not be included in the modeling of the service water heating. However, there is a method to include it provided the energy source for the process and the service are identical (see procedure at end of this section).

There are two main methods of heating water. For buildings with large water heating loads, water is heated by a boiler and stored in a large insulated tank. For these systems, the boiler thermal efficiency should be entered in the Service Water Heating tab in the Plant Element. In other cases, storage tank water heaters are used (similar to conventional residential water heaters). The energy efficiency of these heaters is most often expressed in terms of Energy Factor. Energy Factor accounts for combustion efficiency as well as tank heat losses. The Energy Factor should not be used in EE4; instead the combustion or thermal efficiency should be used. Sometimes, this needs to be calculated by dividing the water heater output by the fuel input.

If the box "not included in the analysis" on the plant tab is checked, EE4 will assume an electric water heater auto-sized to meet the hot water load in both proposed and reference buildings. Checking this box is not recommended.

EE4 does not model heat losses from water storage tanks or the supply and recirculation piping. Thus, no credit or penalty is available for changes in tank or piping insulation (assuming the MNECB mandatory requirements for thickness of tank and pipe insulation have been met).

In some cases, service hot water needs are met by small electric storage or instantaneous heaters that serve only a small load in one area of the building. These water heaters must be grouped into the central water heater.

EE4 assumes an inlet water temperature of 12.8°C and a supply temperature of 60° C throughout the year.

Multiple Water Heating Systems

EE4 allows one heating system per plant, therefore multiple water heaters must be combined based on their use of operation.

Multiple Fuel Water Heaters:

If the water heating is provided by different fuels (electricity and natural gas), select the fuel with the higher heating capacity (not the volume capacity) or the circuit that is considered the main hot water circuit and assume that the entire needs are met by that fuel.

Example:

Tank 1: capacity = 225 litres, input rate = 10kW, fuel = electricity, efficiency = 100%
Tank 2: capacity = 200 litres, input rate = 17.5 kW, fuel = gas, efficiency = 80%
Tank 3: capacity = 100 litres, input rate = 12.5 kW, fuel = propane, efficiency = 82%

Solution:

Entered EE4 fuel = gas
Entered EE4 volume = 225 + 200 + 100 = 525 litres
Entered EE4 input rate = 10 + 17.5 + 12.5 = 40 kW
Entered EE4 efficiency = (10*1.0 + 17.5*0.8 + 12.5*0.82) / 40 = 0.856 (85.6%)

Multiple Single-Use Water Heaters:

If a building contains a number of water heaters that are not controlled to start up in sequence, then these are referred to as single use water heaters.

In this case simply sum the volumes and the input rates and enter a capacity weighted efficiency. This will create a single water heater which will follow the load/part load curve of the boiler and its operating schedule. This is reasonable since all water heaters are assumed (via the schedule of operation) to perform at the higher end of the load/part load curve during high water usage and at the lower end of the curve during standby operation. Single use water heaters will perform in this manner individually or in a grouping. It is still permissible to alter the schedule of hot water usage, as EE4 will average them for the simulation.

Example: an apartment building with 340 water heaters

100 water heaters are electric: 100 litres volume, 7.5 kW input capacity, efficiency = 100% each
100 water heaters are natural gas: 100 litres volume, 12 kW input capacity, efficiency = 82% each
100 water heaters are natural gas: 250 litres volume, 20 kW input capacity, efficiency = 83.5% each
40 water heaters are natural gas: 0 litres volume, 10 kW input capacity, efficiency 88% each (tankless)

Solution:

Entered EE4 volume = (100*100) + (100*100) + (100*250) + (40*0) = 45000 litres
Entered EE4 input = (100*7.5) + (100*12) + (100*20) + (40*10) = 4350 kW
Entered EE4 efficiency = [(100*7.5*1.0) + (100*12*0.82) + (100*20*0.835) + (40*10*0.88)] / 4350 = 0.86 (86%)

Multiple Sequenced Water Heaters:

In some instances water heaters are sequenced in operation similar to lead/lag boilers. Grouping sequenced heaters into a single heater is permissible, but it will result in a larger heater than necessary to meet the non-peak load. In this instance, the heater will be performing on the poor part of the load/part load efficiency curve for a combustion heater. This will be underestimating the performance of the heater. Similarly, entering the input capacity of only the lead heater will overestimate the performance of the heater. Therefore an averaging of input capacities is required to approximate a more realistic annual performance.

An operation or sequencing factor is to be applied to the total heating capacity of the water heaters. This factor is based on the amount of time each water heater is to operate. The following procedure is to be used to determine the sequencing factor:

Assume water heaters are sequenced as follows:

Water heater #1 is to operate 100% of the time.
Last water heater is to operate 20% of the time

All water heaters in between the first and last heater are to operate at even increments between 20% and 100%

Sequencing Factor = (sum of above %) / (# of boilers * 100)

This sequencing factor is to then be multiplied by the total heating capacity to determine a heating capacity that is related to the operation of the water heaters in the design. If the user has an operation of sequenced water heaters then these would be acceptable provided that documentation and a calculation method is provided.

Example:

5 water heaters, each 135 litres volume with a
heating capacity of 5 kW
Current EE4 indicates: entered volume = 5 x 135
= 675 litres
entered capacity = 5 x 5 = 25 kW
Assume water heaters are sequenced as follows:
Heater 1 operates 100% of the time
Heater 2 operates 80% of the time
Heater 3 operates 60% of the time
Heater 4 operates 40% of the time
Heater 5 operates 20% of the time

> Average operation of all heaters = (100 + 80 + 60 + 40 + 20) / 500
> = 0.6

This would be applied to the total heating capacity = 25 * 0.6 = 15 kW average heating capacity.

Indirect Water Heating

If the service hot water is provided via a common space heating/water heating boiler feeding a coil in a tank or hot water circuit, then the entered volume is the storage tank size (If any, zero volume assumes a boiler coil or instantaneous water heater) , the efficiency is the same as that of the boiler, and the input rate is the size of the boiler coil necessary to provide hot water. The boiler system will have a hot water input or output capacity for the service water needs. This should be available from the literature or the mechanical designer. Remember to remove this input capacity from the boiler total capacity entered in the heating plant.

Seasonal Boilers

If the design includes seasonal boilers, such as a school with a dedicated natural gas boiler for the school year and a small electric tank boiler for the summer months (cleaning crew use) enter the natural gas school year boiler as the representative boiler for the entire year. If you wish to model a seasonal heater, then you have the option of scheduling 0 hot water use with the hot water usage schedule.

Renewable Water Heating

If renewable energy is used for hot water heating, enter specs corresponding to the fuel that would be used in the event that renewable energy was not used. A dummy water heater must be defined with the following information:

capacity = capacity of the renewable system plus the backup
input rate = input rate of the renewable system plus the back up
efficiency = efficiency of backup, or 100% if no backup and electric would have been the fuel without renewables, or 80% if no backup and fossil fuel would have been the fuel without renewables

The renewable energy component is calculated outside of EE4 using RETScreen or other renewable energy analysis software. The renewable energy delivered is manually removed from final EE4 output to calculate the building energy use.

Process Water Heating

Process water heating; while supported in DOE2.1, is not available in EE4. Therefore the simulator has the option of including or excluding this process from the CBIP compliance calculation.

If the process energy is to be excluded and the equipment heating the process water also provides the domestic hot water and/or hot water for space heating, this entered

equipment is to be derated. Documentation and calculations need to be provided showing the derating of this equipment.

The process energy can be included to model how the internal heat gains from the processes affect the heating/cooling loads and equipment sizing. Modeling this will give a better representation of the building energy uses and costs.

Follow these steps to include process water heating into the service water heating calculation. This requires 2 separate EE4 simulations and assumes that the fuel for process water heating and service water heating are identical.

Run #1 (With Process Water)

1. Convert the process to a W/occ value and add to occupant value to determine a tal water heating for the building. Add the process in the zones and spaces where the process occurs.
2. Add process volume to service DHW volume.
3. Add process heating input rate to service DHW input rate.
4. Calculate a volume or capacity rate efficiency as the total efficiency:
   Eff = (200 kW * 0.75 + 50 kW * 0.84) / (200 + 50) = 0.768
   Where: 200 kW = capacity of process boiler, 75% = thermal eff of process boiler
   50 kW = capacity of Service DHW, 84% = thermal eff of service DHW.
5. Run the calculations (with process).
6. Create a duplicate EE4 file and remove the process inputs leaving the service DHW .
7. Run the calculations (without process).
8. Subtract the MJ and energy costs to determine the process water heating contribution.

The steps to include process water heating assumes that the process water heating and the domestic water heating fuel sources are the same. If the process and domestic water heating fuels are different, use the domestic water heating fuel as the representative fuel.

4.2 Boilers

Boiler characteristics are entered in the Plant element, Central Heating tab. The boiler is simply defined by entering the fuel type, output capacity and efficiency (AFUE or thermal efficiency; choose whichever rating is stated on manufacturer's literature).

Altitude Adjustments

DOE2.1e provides an adjustment to the efficiency or heating output of gas/propane boilers from sea level rating conditions to altitude. However this adjustment has not been implemented in EE4. Therefore, simply enter the sea level efficiency and heating input of gas/propane boilers.

Multiple Boilers

Multiple central boilers are often installed to provide better part load performance or back-up capacity in case of equipment failure or maintenance. Boilers that are strictly for back-up, that is kept off and must be manually switched to the operating boiler, should be ignored. In all other cases (lead/lag boilers, load/peaking boilers) enter all boilers. In EE4, it is assumed that the multiple boilers have the same capacity and performance characteristics. (It is not possible to define boilers of different sizes or efficiencies within the same heating loop).

Different boilers can be accommodated only by defining separate heating plants which serve distinct parts of the building. EE4 allows a total of 10 heating plants.

On the Plant Element, Central Heating Tab, the boiler multiplier is the number of boilers and the sequencing capacity is the increase in load required to start the next boiler. If the sequencing capacity is unknown, assume that it is 90% of the output capacity of the first boiler.

Multiple Boilers of Different Efficiency

At present, EE4 cannot model multiple boilers of different operating efficiency. If the boilers are operated to provide uniform runhours, determine the capacity-weighted average efficiency.

Example: 2 boilers:
> boiler 1: output capacity = 450 kW, efficiency = 88%
> boiler 2: output capacity = 150 kW, efficiency = 72%

Solution:

boilers 1 and 2 would be combined as follows:
> capacity = (450 + 150) / 2 boilers = 300 kW each
> efficiency = (450 * 0.88 + 150 * 0.72) / (450 + 150) = 0.84
> (84%)

Entered plant boiler multiplier = 2, each boiler: output = 300, efficiency = 0.84, sequencing = 270 kW

For lead/lag and peaking boilers cases, the following procedure is to be followed:

Note: This prodedure involves 2 EE4 simulations. The first is used to determine the average boiler efficiency. The second is used for determining compliance to CBIP.

1. Complete Steps 1a) to b) to create a table such as that shown below.

Step 1a) List the boilers in order of their firing sequence, with the thermal efficiency and output capacity of each. The example below uses three boilers: B-1 is an 500 MBH condensing boiler with rated thermal efficiency = 95%; B-2 and B-3 are 800 MBH non-condensing boilers with rated thermal efficiencies = 80%. (B-1 is the lead boiler. B-2 will fire second, and B-3 third.)

Step 1b) Determine the cumulative plant capacity at each stage of the firing sequence. In the example below, only B-1 fires during Sequence 1, so the cumulative plant capacity is 500 MBH. During Sequence 2, both B-1 and B-2 fire, so the capacity is 1,300 MBH. During Sequence 3, all three boilers fires, so the capacity is 2,100 MBH.

Step 1c) Determine the percent of the total plant capacity that can be met by each stage of the sequence. In the example below, the total plant capacity is 2,100 MBH. So Sequence 1 can provide 500/2100 = 24%, Sequence 2 can provide 62%, and Sequence 3 can provide 2100/2100 = 100%.

Step 1d) Determine the Plant Thermal Efficiency of each stage of the sequence. This is done be calculating the capacity weighted average thermal efficiency of all the boilers that fire during a sequence. In the example below, in Sequence 1, only B-1 fires, so the Plant Thermal Efficiency for that stage is 95.0%. In Sequence 2, both B-1 and B-2 fire, so the Plant Thermal Efficiency is (95x500 + 80x800) / (500 + 800) = 85.8%.

Step 1a)				Step 1b)	Step 1c)	Step 1d)
Sequence	Boiler Designation	Boiler Thermal Efficiency	Boiler Output MBH	Cumulative Plant Capacity MBH	Percent of Total Plant Capacity	Plant Thermal Efficiency
1	B-1	95%	500	500	24%	95.0%
2	B-2	80%	800	1,300	62%	85.8%
3	B-3	80%	800	2,100	100%	83.6%

2. In EE4, set the boiler thermal efficiency to 80%, and make sure the total boiler plant output capacity is equal to the total plant capacity calculated above. (For the example above, this would be 2,100 MBH.)

3. Set the EE4 options so that the Plant PV-A and PS-C reports are created and the DOE-2 output files are not deleted when the simulation is run.

4. Run the simulation for the proposed building.

5. Open the DOE-2 ".sim" file for the proposed building and locate the PV-A report. Check that the total installed boiler capacity matches the Total Plant Capacity from the table above. If it is not, then return to Step 2 and correct the boiler capacity entered into EE4.

6. Complete Steps 6a) to 6e) to create a table such as that shown below.

6a) In the DOE-2 ".sim" file, locate the PS-C report. Use the LOWER line of data for the boiler to create a table of part-load hours as shown below.

6b) For each part load range, enter the Plant Efficiency in the table below based on the calculations in the above table. (Use the column "Percent of Total Plant Capacity" in the above table to determine which efficiency corresponds to each part-load range. If the "Percent of Total Plant Capacity" falls within a Part Load Range, switch to the next higher Sequence.)

6c) In the table below, multiply the Hours column by the Efficiency column.

	Step 6a)		Step 6b)	Step 6c)
Part Load Range	Hours		Plant Efficiency for Part-Load Range	Hours x Efficiency
0 – 10	3000		95.0	285000
10 – 20	1500		95.0	142500
20 – 30	800		85.8	68640
30 – 40	300		85.8	25740
40 – 50	50		85.8	4290
50 – 60	10		85.8	858
60 – 70	0		83.6	0
70 – 80	0		83.6	0
80 – 90	0		83.6	0
90 – 100	0		83.6	0
100 – 110+	0		83.6	0
Total	5650		-	527028

6d) Sum the Hours column and the "Hours x Efficiency" column.

6e) Divide the sum of "Hours x Efficiency" by the sum of "Hours" to determine the average plant thermal efficiency. (For the above example, it is 93.3%.)

7. In EE4, enter the boiler efficiency determined in step 6e).

8. Run the simulation for the proposed and reference buildings to determine CBIP compliance

Multi-stage / Modulating Boilers

Boilers with multi-stage or full modulating firing capability allow improved part-load efficiency performance and are credited in EE4. If a boiler is multi-stage, simply divide the boiler into smaller boilers according to the number of stages of firing, and model as multiple boilers as described above. For instance, a 100 kW, 84% efficient, 2-stage boiler should be modeled as two 50 kW boilers, each with 84% efficiency. The sequencing capacity should be 45 kW (90% of 50 kW).

Modulating boilers should be modeled using the boiler return water temperature and outdoor air reset approach (see below).

Condensing Boilers

Boilers with rated thermal efficiencies over 88% are considered condensing or "high efficiency" boilers. However, these high operating efficiencies can only be achieved when the return water temperature is sufficiently low for condensation of flue gas to occur (typically less than 130ºF). In some heating systems, these low temperatures only

occur at part load periods in the shoulder seasons, or if the boiler is used for domestic hot water heating. Low temperature heating systems such as radiant in-floor heating or boilers used to maintain a heat pump loop temperature may achieve the highest operating efficiencies at all times.

To model a condensing boiler, select the condensing boiler check-box.

Boiler Return Water Temperature and Outdoor Air Reset

Lowering the boiler return water temperature increases the boiler efficiency as more heat can be recovered from the flue gases. The efficiency of the boiler is based on the average return water temperature to the boiler over the heating season. For outdoor air reset of boiler water temperature, use the average of the upper and lower settings (i.e. for a return water loop that has a range of 70°C to 60°C depending on the outdoor air temperature, the midpoint is 65°C).

If the boiler has an average inlet water temperature less than 70°C, use the following equation to calculate the boilers' efficiency:

Modeled Efficiency = (70 – Average Boiler Inlet Water Temp) * 0.1 + Rated Efficiency

For example, if the boiler specification states that the boiler has an efficiency of 80% and the design specifies a return water temperature of 60 °C, then the modeled boiler efficiency is 0.81 = (70-60)*.1 + 80 or 81%.

When using the above equation, the efficiency cannot exceed 87% unless it is a condensing boiler. If this is the case, refer to the section on condensing boilers.

A heating plant is eligible for both multi-staging and return water temperature/outdoor air resets, as the reset improves boiler efficiency by extracting more heat from the exhaust and multi-staging simply minimizes short cycling thereby improving part load performance.

Flue Gas Heat Recovery

Flue gas heat recovery can be approximated as a potential credit depending on the intended use of the recovered heat: service water heating supplementing, hot water loop heating.

Service Water Heating: Flue Gas Heat Recovery

If it is used to preheat domestic hot water, you will need to determine the heat recovery available from flue gas heat recovery and them complete 2 EE4 runs:

First EE4 run: as is file without any flue gas heat recovery component.

Second EE4 run: volume = 0 litres, input rate = recovered energy, efficiency = 1.0, fuel must be the same as your as is file.

Subtract the results to obtain the annual flue gas recovery (energy in MJ and cost savings) credit to be manually subtracted from the EE4 run without any flue gas heat recovery.

Use the First EE4 run (without flue gas heat recovery) reference file's energy usage and cost as the base for CBIP compliance.

Boiler Loop Water Heating: Flue Gas Heat Recovery

Increase the design temperature drop by a percentage rated:

(flue gas temperature * flow rate) / (hot water temperature * total water flow rate)

Example: if the flue gas temperature was 93.3 C and the flow rate via a recovery coil was 10 Litres/minute and the water loop was maintaining 60 C water and the flow rate was 200 Litres/minute the design.

Temperature drop increase would be:

Temp drop increase = (93.3 * 10)/ (60 * 200) = 0.07775 increase in design temperature drop. Therefore the temperature drop would be increased by 7.78%.

4.3   Chillers

Define the central chiller characteristics in the Plant element, "central cooling" tab. If the building contains only packaged systems that use direct expansion of a refrigerant, leave the chiller undefined.

Electric Chillers

Three types of chillers can be specified in the EE4 program: reciprocating, centrifugal and absorption. For screw-type chillers, define a reciprocating chiller and enter the performance characteristics of the screw chiller. The COP and output of the chiller should be at ARI 550/590 test conditions as shown below.

Table 4-1 – Rating Conditions for Chillers

	Water-Cooled	Evaporative-Cooled	Air-Cooled
Condenser Entering Water Temperature	29.4°C (85°F)	-	-
Entering Air Temperature	-	23.9°C (75°F) Wet Bulb	(35°C) 95°F Dry Bulb
Evaporator Leaving Water Temperature	(6.7°C) 44°F		

All electric chillers must be cooled (condenser) by either a fan (air-cooled) or cooling tower (water cooled), which is selected in the chiller information. If water-cooled is selected, a cooling tower must be defined.

If the design incorporates seasonal cooling (ie: chillers only activated during summer months and the building relies on economizer cooling during other parts of the cooling season), this can only be accommodated via changes in the cooling schedules for the zones under the chiller plant.

Gas-Fired/Absorption Chillers

Typical gas-fired and steam absorption chillers have COPs of under 1.0, well below the MNECB requirement for electric chillers of 2.7. When showing compliance to the MNECB, the cooling energy consumption is multiplied by the ESAF of the fuel powering the absorption chiller. The low ESAF for fuels generally more than makes up the differences in COP, and absorption chillers can be an energy-efficiency measure. In the CBIP program, ESAFs are not used and a special procedure must be used to evaluate gas-fired chillers. Two simulations must be performed. First, select gas-fired absorption chiller but enter the COP of the reference building electric chiller (not the COP of the gas-fired chiller). This simulation is done to see if the 25% energy target has been met. Second, if the energy target has been met, enter the actual COP of the gas-fired chiller (typically less than 1.0) to determine the annual cost savings for incentive calculation purposes.

Absorption and direct-fired chillers do not require a condenser to be defined in EE4. Direct-fired chillers require the fuel source to be specified (often natural gas or propane).

Modulating Chillers

Modulating chillers are handled identically as with modulating boilers. Take your total chiller capacity and divide by the number of steps of modulation control to derive an average capacity of each modulating stage. Create a chiller with this capacity and the overall COP. Enter the number of modulation stages as the chiller multiplier and enter the sequencing capacity.

Example: Reciprocating chiller of a total 800 kW with 4 stages of modulation and a COP of 4.0

Enter a chiller of 200 kW capacity and a COP of 4

Enter chiller multiplier of 4 and a sequencing capacity of 180 kW (90% of total capcity brings on the second stage).

Double-Bundled Chillers and Chiller Heat Recovery

If a double bundle chiller is used to cool the building with its waste heat being used for heating (ventilation air, space heating or service water heating), then you must enter the following modeling procedure in the DOE file.

Under Plant tab, change the chiller type by DBUN-CHLR. For example:

        CH-1 = PLANT-EQUIPMENT   TYPE = DBUN-CHLR
                SIZE = 1.2010 I-N = 1 ..
        PART-LOAD-RATIO   TYPE = DBUN-CHLR   E-I-R = 0.2632 ..
Under $ NECB Plant curves$,enter the following : DB-CAP-FT   CURVE-FIT   TYPE =
BI-QUADRATIC
COEF=(1.000000,0.000000,0.000000,0.000000,0.000000,0.000000) ..
DB-CAP-FTRISE   CURVE-FIT TYPE = QUADRATIC
COEF=(1.000000,0.000000,0.000000) ..
DB-EIR-FPLR CURVE-FIT TYPE = QUADRATIC
COEF=(0.349032,0.263871,0.387097) ..
DB-EIR-FT   CURVE-FIT TYPE = BI-QUADRATIC
COEF=(-0.714258,0.000000,0.000000,0.025103,-0.000058,0.000000) ..
DB-EIR-FTRISE   CURVE-FIT TYPE = QUADRATIC
COEF=(1.000000,0.000800,0.000360) ..
Under EQUIPMENT-QUAD, enter the following: ????
DBUN-CAP-FT   DB-CAP-FT
DBUN-CAP-FTRISE   DB-CAP-FTRISE
DBUN-EIR-FPLR   DB-EIR-FPLR
DBUN-EIR-FT   DB-EIR-FT
DBUN-EIR-FTRISE   DB-EIR-FTRISE

EE4 will not recognize manually changes in the DOE file. The modifications entered in
the DOE file must be the last modifications to enter.

4.4 Cooling Towers

If a water-cooled chiller is defined in the "Central Cooling" tab, or if the building uses a
cooling tower to reject heat from a central heat pump loop, a cooling tower must be
defined. In EE4, no distinction is made between open cooling towers and closed-circuit
fluid coolers.

Enter cooling tower characteristics in the "cell" field on the "Cooling Tower" tab in the
Plant element. "Cell" refers to a single section of the cooling tower containing a fan, and
inlet and outlet water lines. A cooling tower may be composed of one or more cells. In
EE4, only a single cooling tower may be defined, although there may be up to 25
different cells, defined in a method similar to multiple boilers or chillers (but for this case
it is not necessary to define sequencing capacity). EE4 does not permit cells to have
different fan characteristics, or different entering and leaving water conditions. If this is
the case, use a capacity-weighted average method similar to that described for boilers.

4.5 District Heating and Cooling

Buildings in dense urban areas, or buildings on university or hospital campuses are often
heated and/or cooled by a district heating/cooling system. In these cases the primary
source of heating or cooling is a large plants that serve several buildings in addition to

the one being considered. One form of district heating is cogeneration plants, where hot water/steam is a product of electrical generation. For CBIP purposes, district heating/cooling and cogeneration systems are to be modeled as purchased heating or cooling.

Purchased heating / cooling is also to be selected for any form of heating or cooling that is delivered to the building by a third party who charges for that commodity like a utility. For example, a building on a deep lake cooling system would be considered to use purchased cooling, because the client is purchasing chilled water. However a client who installs his own lake/pond water cooling system, such as a water source heat pump, would be considered to use high efficiency cooling.

Similarly on the heating side, if a client purchases waste steam from a hydro, industrial or cogeneration plant it would be considered purchased heating unless the client owned the hydro, industrial or cogeneration plant. If the client owns his own cogeneration plant and it is installed on-site, then it would no longer be considered purchased heating, but a boiler plant (see cogeneration plants section 4.8.2).

In the university and hospital campus case, the client and the heating/cooling source provider may be same. In this case the simulator has the choice of entering purchased heating/cooling or entering the central plant specifications (see sections 4.5.1 and 4.5.2).

4.5.1 District / Purchased Heating

If purchased heating is selected, EE4 defaults to an initial 80% boiler fueled by the purchased heating fuel selected.

If steam is the fuel, the fuel used to generate the steam is to be selected. If steam is the by-product from a nuclear plant, electricity is to be entered as the purchased heating fuel. If the steam is the by-product of an industrial process, the fuel used to generate the process is to be entered. If the fuel used to generate the process is not available in EE4, such as coal, enter the fuel corresponding to the lowest Energy Source Adjustment Factor for the region.

EE4 sizes the 80% boiler by adding the zonal heating capacities entered in the each of the zones and any air handler heating capacities using hot water heating. Therefore if the zonal and air handing heating capacities are oversized, the resulting seasonal performance of the initial 80% boiler will degrade according to the load/part load curve (regardless of controls). The reference 80% initial boiler will size according to the design heat loss calculation for the site and will also follow the load/part load curve for an 80% boiler to determine seasonal performance.

In a purchased heating scenario, a boiler can be defined directly if the following conditions are met:

1.   A new boiler(s) is being installed in the district heating plant to serve the proposed building only.

or

2.   The entire district heating plant overall boiler efficiency is tested to an NRCan agreeable method (or standard) by an agreed testing agency.

In these cases create a boiler with the fuel of the district heating plant. Enter the boiler efficiency and the zone & air handler heating (if applicable) capacities as the boiler capacity.

Heating from Both Building Boiler and Central Heating Plant

A third case exists where purchased heating cannot be selected: a combination boiler plant with a district heating system serving the same zones and air handlers.
If a combination boiler/district heating plant exists, a capacity weighting factor method is to be used to create a representative boiler in EE4. The steps in the subsequent example are to be followed:

Example: A high efficiency boiler (88%, 200 kW capacity) to provide the base heating. Peak heating is provided by a district heating plant loop (unlimited capacity, efficiency unknown so use 80%)

Solution:

1.   Enter the 88% boiler with 200 kW capacity in EE4 assuming the district heating plant does not exist and save the file.

2.   Run the sizing calculation in EE4 to determine the total heating required by the boiler/district combo. Total the heating sizes required. If there are areas of the building that are heated without the boiler and district heating plant combo, such as an electric baseboard in a vestibule, exclude these areas from the calculation. For this example, assume the sizing calculation determined a total heating capacity required of 285 kW. This is the size of the boiler/district heating combo plant.

3.   The difference between the installed capacity and the required capacity is the size of the district heating plant; 85 kW in this example.

4.   Calculate a capacity weighted efficiency using the following equation:

Effcap = [boiler cap * boiler eff + plant cap * plant eff] / total cap
= [200 * 0.88 + 85 * 0.80] / 285 = 0.8561403

5.   Define a representative boiler in EE4 with a capacity of 285 kW and a thermal efficiency of 85.6%.

This method does not provide for an adjustment for usage (base versus peak).

If the boiler/district heating plant combination uses 2 different fuels and they each provide at least 10% of the heating capacity of the building, define the representative boiler using the fuel with the highest Energy Source Adjustment Factor. EE4 allows only 1 boiler to be defined to serve a zone, therefore the representative boiler will not reflect the reality of the design (energy use and fuel costs). If the boiler or district heating plant accounts for less than 10% of the heating, select the dominant fuel to represent your

boiler/district heating plant combination. In both scenarios, complete a capacity weighted efficiency calculation as described above.

4.5.2 District/Purchased Cooling

If the cooling is purchased from a central cooling plant (including deep lake water), then this is considered purchased cooling. For these cases, check the "Purchased Cooling" box on the Plant Element/Central Cooling Tab. The program assumes that the purchased cooling was produced at the same COP as used in the reference building.

EE4 will sum the entered zones and air handler cooling capacities (except for DX cooling) to size the chiller for the proposed case and use the design cooling calculation for the reference case.

If the cooling plant is within the building (including lake water to water heat pump or flow through water system), then define an air-cooled chiller using a COP of 10 and the entered capacity.

If the design incorporates district cooling in addition to a chiller plant create a load weighted representative chiller.

Example: base cooling is provided by district cooling, peak cooling is provided by a 4.2 COP scroll chiller of 200 kW capacity.

Solution:

1.   Enter the building with purchased cooling selected and run EE4.

2.   From the BEPS DOE2 report read the cooling load in MBTU (1 BTU = 0.000293 kW)

3.   If the cooling load is:
               less than 700 kW: purchased cooling COP = 3.8 (reciprocating type)
               greater than 700 kW: purchased cooling COP = 5.2 (centrifugal)

4.   Assume DOE BEPS report cooling load = 1,750,000 BTUH (512.87 kW)

5.   Weighted chiller capacity = 513 kW

6.   COP = [200 * 4.2 + (513-200) * 3.8] / 513 = 3.96

7.   Type = highest load provided = centrifugal Central Heating

If the building is served by hot water or steam from a district plant, "Purchased Heating" is chosen. The program assumes that the purchased heat was produced with an 80% efficient boiler – the same value used in the reference building.

Utility Rate Considerations

In purchased heating/cooling situations, the actual utility rate charge is sometimes not available or not directly applicable. For instance, utilities may be charged to the building in units $/m^3 chilled water or $/GJ steam. The effective rate may be difficult to convert to utility units for entry into EE4 because seasonal average COPs and heating efficiencies must be taken into account. In these cases, enter the utility rate paid by the district heating/cooling company for utilities, if available. If not, it is acceptable to use the local rate from the utility that would have served the building.

4.6   Heat Pumps

Three entirely different heat pump types can be modeled in EE4: ground-source (includes well/lake water), boiler/cooling tower source, and air-source. These systems are briefly discussed below; see Chapter 5 and Chapter 6 for more information on heat pumps and modeling heat pump systems.

Air source heat pumps condition ventilation air and are modeled as systems rather than heating and cooling plants. Ground and boiler/tower source heat pumps receive hot or chilled water from a central source (boiler, chiller, cooling tower, ground loop, well/lake water loop). The central source is defined in the EE4 heating plant under the Heat Pump tab, whereas the air tempering at the specific zones is defined at system and zone level by the size and airflow of the air source heat pumps.

The ground source and boiler/cooling tower source are the only types of heating plants available to central heat and cool circulating loop water.

Ground Source (or Geothermal) Heat Pumps

A ground source heat pump plant consists of single or multiple (distributed) heat pumps, which reject heat to, or accept heat from the ground via a "ground loop" or a "water loop" (from well/lake). Both loops can be defined as using ground water directly (open-loop) or consisting of in-ground heat exchangers (closed-loop).

To define the ground source information, select "Ground source" for the source of the heat pump loop on the Heat Pump tab, in the Plant element. EE4 requires that monthly "ground temperatures" be entered in the appropriate boxes. However, the actual ground water / well water temperatures are entered only if the heat pump plant is open-loop. For closed-loop water plants, the monthly entering water temperature must be entered in the monthly "ground temperature" fields.

The recommended source of information is "Soil Temperature Averages" from Atmospheric Environment Service in Downsview, Ontario. Table 4-2 provides some representative values from the AES document. When modeling in EE4 version 1.50, a minimum ground temperature of –2. °C (28°F) is required to avoid underheated hours being calculated.

Table 4-2 – Open Loop Temperatures (Depth 1.5 metres)

Source: "Soil Temperature Averages" from Atmospheric Environment Service

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vancouver	8.2	7.5	7.7	8.7	10.4	12.4	14.1	15.1	15.3	14.3	12.2	9.9
Edmonton	1.0	0.3	0.0	0.3	2.9	6.7	9.9	12.4	11.5	8.6	5.7	2.9
Regina	1.3	0.2	-0.2	-0.1	0.9	4.9	8.9	11.0	11.2	9.1	6.4	3.3
Winnipeg	2.9	1.6	0.9	0.8	1.8	5.4	9.5	12.1	12.5	10.9	8.1	5.1
Toronto	6.6	5.4	4.5	4.9	8.1	11.8	14.6	16.5	16.3	14.3	11.9	9.2
Montreal	3.3	2.3	1.4	1.4	4.2	8.2	11.3	12.9	13.2	11.2	8.4	5.4
Fredericton	4.4	3.3	2.8	2.6	5.1	9.1	12.1	13.7	13.8	12.0	8.7	6.0
St John's	4.2	3.2	2.7	2.5	3.9	6.8	9.7	11.6	11.7	10.3	8.2	6.1
Fort Smith	0.6	0.2	0.0	-0.2	-0.1	3.5	8.7	10.9	10.4	7.2	4.0	1.9

Source: "Soil Temperature Averages" from Atmospheric Environment Service

Closed loop heat pumps are designed in two primary arrangements: horizontal-loop (pipes run horizontally a metre or two below ground surface) and vertical-loop (pipes run vertically many metres below ground). For horizontal loop systems, the soil temperatures corresponding to the loop depth should be entered into EE4. Although the design monthly entering water temperatures should be entered, Table 4-3 some suggested average data for several Canadian cities based on the AES data above.

Table 4-3 – Monthly Entering Water Temperatures for Horizontal Closed-Loop Heat Pumps (ºC)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vancouver	5.0	3.8	6.0	10.0	14.0	18.0	21.0	22.0	22.7	20.0	14.0	10.0
Edmonton	3.1	0.2	2.4	6.4	10.4	14.4	17.4	18.4	20.8	18.1	12.1	8.1
Regina	2.9	0.1	2.3	6.3	10.3	14.3	17.3	18.3	20.6	17.9	11.9	7.9
Winnipeg	3.6	0.8	3.0	7.0	11.0	15.0	18.0	19.0	21.3	18.6	12.6	8.6
Toronto	5.5	2.7	4.9	8.9	12.9	16.9	19.9	20.9	23.2	20.5	14.5	10.5
Montreal	3.9	1.2	3.4	7.4	11.4	15.4	18.4	19.4	21.6	18.9	12.9	8.9
Fredericton	4.2	1.7	3.9	7.9	11.9	15.9	18.9	19.9	21.9	19.2	13.2	9.2
St John's	3.2	1.6	3.8	7.8	11.8	15.8	18.8	19.8	20.9	18.2	12.2	8.2
Fort Smith	2.5	0.1	2.3	6.3	10.3	14.3	17.3	18.3	20.2	17.5	11.5	7.5

For vertical loop systems, annual temperature swings are generally less extreme; enter the value from Table 4-4 for each month of the year. However, always use calculated monthly design entering water temperatures instead of the following tables if the information is available, especially for well/lake water loops.

Table 4-4 – Monthly Entering Water Temperatures for Vertical Closed Loop Heat Pumps (ºC)

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vancouver	8.2	7.6	8.7	10.7	12.7	14.7	16.2	16.7	17.0	15.7	12.7	10.7
Edmonton	4.2	2.7	3.8	5.8	7.8	9.8	11.3	11.8	13.0	11.7	8.7	6.7
Regina	3.8	2.4	3.5	5.5	7.5	9.5	11.0	11.5	12.7	11.3	8.3	6.3
Winnipeg	4.4	3.0	4.1	6.1	8.1	10.1	11.6	12.1	13.3	11.9	8.9	6.9
Toronto	7.9	6.5	7.6	9.6	11.6	13.6	15.1	15.6	16.8	15.4	12.4	10.4
Montreal	5.4	4.1	5.2	7.2	9.2	11.2	12.7	13.2	14.3	12.9	9.9	7.9
Fredericton	6.0	4.8	5.9	7.9	9.9	11.9	13.4	13.9	14.9	13.5	10.5	8.5
St John's	5.0	4.2	5.3	7.3	9.3	11.3	12.8	13.3	13.8	12.5	9.5	7.5
Fort Smith	3.2	2.0	3.1	5.1	7.1	9.1	10.6	11.1	12.1	10.7	7.7	5.7

In addition to ground temperatures, the pump flow rate and head information must be entered. The flow rate to be entered is the net flow through the ground heat exchanger or open-loop. See section 4.7 on calculating pump head and efficiency information.

Ground source heat pumps are typically configured in one of two ways. The first, which is the model in EE4, uses heat pumps distributed throughout the building and a central make-up air system for ventilation only. The heat pumps are water to air. To model this type of system, a hydronic heat pump must be selected as the system type.

The EE4 model does not allow the make-up air unit to be connected to the heat pump loop. If heat pump is selected as being the heating source for the make-up air unit, EE4 will create an air-to-air heat pump using outside air rather than a water-to-air heat pump that represents the ground source. The air-to-air heat pump performance will degrade as the air temperature drops.

The second ground source heat pump configuration has the heat pumps located centrally and heated and chilled water produced by the heat pumps is circulated throughout the building. EE4 does not specifically model this system type. To model this system configuration, the heating/cooling capacities of the central ground source heat pump system are allocated to the zones that they serves (similar to a distributed heat pump system) based on the heating/cooling requirements of each zone. The COP entered at the zone level with match the central ground source plant. The heating/cooling capacities and fan power of the fan coils are to be entered as the capacities and fan power of the heat pump units.

If the ground source heat pump is connected to a complex air handling system (e.g., VAV, Dual-Duct), contact NRCan for technical assistance. Similarly, if the ground source heat pump operates in combination with a boiler plant, contact NRCan for modeling details. Additional information must be entered in the System and Zone elements to completely model a ground source heat pump system; refer to Chapters 5 and 6.

Boiler/Cooling Tower Source Heat Pumps

This heat pump system may also be referred to as simply a "water-loop heat pump" or "distributed heat pump" system. In these systems, a low-temperature water loop runs throughout the building. Heat pumps located in individual building zones reject heat to or extract heat from the central loop as required. When the central loop drops below a

specified temperature (i.e. most zones are extracting heat from the loop), a boiler fires to add heat to the loop. When the central loop becomes too hot, (i.e. most zones are rejecting heat to the loop) water is diverted to a central cooling tower (or closed circuit fluid cooler) to reduce the loop temperature.

This system requires the user to select "Boiler/Cooling Tower Loop" on the Heat Pump tab, Plant element. Boiler and cooling tower information also must be entered as described in Sections 4.2 and 4.3. Pump information must also be entered in 3 different locations: heat pump tab, boiler tab, and cooling tower tab. The pump head entered on the heat pump tab will be pumps that operate continuously to circulate water around the loop. Boiler pumps are those dedicated to the boiler side-stream, and usually operate only when the boiler is firing. Similarly, the cooling tower pump information is that on the cooling tower stream, which operate only when heat must be rejected. See Section 4.7 for more information on entering pumps.

Note: When defining a hydronic heat pump to represent the ground source heat pump, if the air handler has heating / cooling coils fed from the ground source heat pump loop, and heat pump is selected as the air handler heating source, EE4 creates an air-to-air heat pump using outside air rather than a water-to-air heat pump to represent the ground source. The air-to-air heat pump performance will degrade as the air temperature drops. Additional information must be entered in the System and Zone elements to completely model a water source heat pump system; refer to Chapters 5 and 6.

Air Source Heat Pumps

Although similarities exist between water-source and ground-source heat pumps, air source heat pumps are an entirely different concept and are handled differently in EE4. Air source heat pumps, which extract heat from outside air, are considered "System equipment" rather than "Plant equipment" and no specific heat pump information is entered in the Plant element. See Section 5.2 for detailed information on air-source heat pumps.

Combination Ground Source Heat Pump/Boiler Plants

EE4 models the heating plant as either a ground source heat pump supplying hot and chilled water to the building circulating loop or boiler/cooling tower supplying hot and chilled water to a central heat pump circulating system.

The ground source heat pump plant is automatically sized to meet the heating load of the building therefore the capacity and the COP of the central heat pump plant is not required.

Combination plants which use a ground source loop for cooling and a boiler plant for heating are not supported. In this case simulate a chiller to represent the ground source heat pump plant (cooling plant) and the boiler to simulate the heating plant.

Seasonal plants are equally not supported. In this case, enter the heating plant expected to operate for the majority of the heating season.

4.7 Pumps

Pumps often represent a significant portion of building energy use and should be modeled correctly. Pumps are entered in 4 different locations in the Plant element: "Central Heating" tab, "Central Cooling" tab, "Cooling Tower" tab, and "Heat Pump" tab.

Pump head information and efficiency need only be entered in the areas where a plant element is defined. That is, if the building has a boiler serving baseboard radiators but there is no chiller (air conditioning is provided via direct expansion of a refrigerant), it is only necessary to define pumps on the "Central Heating" tab. However, if the building is served by a boiler, water-cooled chiller, and cooling tower, it is necessary to enter corresponding pump information on all three tabs of "Central Heating", "Central Cooling" and "Cooling Tower".

EE4 does not support primary and secondary loop pumps, but only one heating circulation circuit, one cooling circulating circuit and one cooling tower circuit. If secondary loop pumps exist, these need to be combined with the primary loop pump for a single circuit entry only if the secondary circuit pumps operate continuously as distribution pumps and not as zone flow control pumps. If the secondary loop pumps are simply flow control measures, enter only the boiler and chiller distribution pumps are the plant pumps using the method for effective pump head described later in this section.

Two-pipe fan coil and two-pipe induction unit systems may use the same pumps for both heating water and chilled water. For these systems, pump information should be defined on the "Central Cooling" tab only (and Cooling Tower, if applicable). EE4 realizes the same pumps are used for heating and cooling and applies cooling pump information for both heating and cooling modes.

The pump information required for EE4 includes only the distribution pumps for heating and cooling that are responsible for delivery of hot and cold water throughout the plant circuit. Any additional pumps such as zone flow control pumps (secondary loop type pump), water treatment pumps and condensate collection and return pumps should be excluded from the pump EE4 input.

Pump and Motor Efficiency

Motor efficiency is the ratio of shaft mechanical power to electric input power and is generally available in electrical specifications. If electrical efficiency information is not available, 85% is a good default value to use.

Pump efficiency is the ratio of fluid power to applied mechanical shaft power and can be determined by locating the operating point of the pump on manufacturer's curves. If pump curves are not available or if operating point cannot be obtained, 65% should be the default value used (NOT 77% as is default in the EE4 software).

Calculating Pump Head

EE4 requires the "effective" pump head to be entered. If the pipe design is as simple as one pump, then the pump head should be entered (pump head and flow rates are

generally listed in mechanical specifications and/or drawings). However, most piping schemes consist of several pumps in series, some in parallel, boiler and chiller circulation pumps, glycol pumps, etc. In these cases, follow this procedure to determine effective pump head:

Locate all pumps in either a heating, cooling, cooling tower, or heat pump circulation system. Boiler circulation pumps (primary and secondary loop circuits) and any glycol pumps should be included with the heating system. Do not include standby or back-up pumps (pumps that are on-line only for emergency backup) or any secondary loop pumps that are strictly operational for zone flow heating/cooling control purposes.

Determine flow rate and pump head from the drawings and/or specifications.

For each pump, multiply the pump head by the flow rate.

Sum all of these values together and divide by the net system flow rate. The net system flow rate is that through the "main" distribution system. For example, in a primary/secondary-heating scheme, this would be the flow through the distribution or secondary piping (not the boiler piping loop). This value is the effective pump head. If the value is greater than 448 kPa (150 ft), simply enter 448 kPa. An effective means to complete this calculation is by a simple spreadsheet as shown in Table 4-5.

Table 4-5 – Pump Effective Head Calculation Example

Pump No.	Head (kPa)	Flow (L/s)	Head x Flow
P-1: Distribution Pump 1	75	20	1500
P-2: Distribution Pump 2	75	20	1500
P-7: Boiler #1 Circulation Pump	40	8	320
P-8: Boiler #2 Circulation Pump	40	8	320
P-14: Glycol preheat pump	20	10	200
Sum of Head x Flow			3840
Net System Flow			40 L/s
Effective Head			96 kPa

In the example above, pumps P-1 and P-2 are in parallel, both operate continuously, and are the primary distribution pumps serving the building. Thus, the net system flow is the sum of the flows of these two pumps.

The EE4 entry would be a flow weighted average pump and motor efficiency. In the above example if pump 1 had a motor efficiency of 85% and a pump efficiency of 70% and pump 2 had a motor efficiency of 82% and a pump efficiency of 66% , the entered EE4 values would be:

Motor eff = (20 * 0.85 + 20 * 0.82) / (20 + 20) = 0.835
Pump eff = (20 * 0.70 + 20 * 0.66) / (20 + 20) = 0.68

Design Temperature Drop

Design temperature drop is the design temperature differential around a single loop of the piping system. For chilled water systems, this is better named "design temperature rise". A typical heating system may deliver hot water at 160ºF and return to the boiler at 140ºF. In this case, the design temperature drop is 20ºF. Similarly, a chiller may supply water at 40ºF and it returns to the chiller at 50ºF. In this case, the design temperature drop is 10ºF. Regardless of whether the piping loop increases in temperature (cooling water) or decreases in temperature (heating water), the design temperature drop is always a positive number.

Pump Type

EE4 support single speed and variable speed pumps. If the distribution loop for the heating or cooling circuit includes 2-speed pumps, these should be entered as single speed pumps. If the distribution circuit contains a combination of pump types, enter the type which provides the majority of the flow.

Pump Operation and Control

EE4 supports single speed and variable speed pumps. All multi-speed pumps are considered single speed, unless it is specifically a variable speed pump. Minimum operating speeds are not simulated, but EE4 defaults to 50% capacity for single speed pumps and 75% capacity for variable speed pumps. Also pumps are assumed to be running continuously throughout the year.

Pumps default to a heated supply water temperature of 60 C and a chilled supply water temperature of 7.3°C.

4.8 Special Central Plant Cases

Some special cases not handled directly by EE4 are described below.

Natural Cooling

 Some designers incorporate natural cooling concepts into the building design and do not install a mechanical cooling system. Under the MNECB and CBIP rules, the reference building is assumed to have a cooling system only if the proposed building has a cooling system. If there is no mechanical cooling (chiller, heat pump. DX coil) in the proposed design, there is none in the reference building. Thus, there is no credit given for reduced cooling energy use for naturally cooled buildings.

Undercooled Hours

Detailed explanations must be provided in the case of a warning messages indicating 1000 or more undercooled hours for one zone. Detailed explanation of the warning must

be provided. In particular, details must be given on the zone strategy for the zone and use of any the presence of free--cooling systems must be indicated.

Combined Heat and Power Plants

Combined heat and power (CHP) plants include fuel cells, cogeneration systems, and engine systems which burn a fossil or biomass fuel to generate electricity and produce usable heat. If the CHP plant is located within the property line of the proposed building, then it is considered as a potential credit for CBIP. If electricity or waste heat is purchased or delivered from a CHP plant located outside of the property line of the proposed building, then it is considered purchased heating/electricity and zero heating or electrical generation credits are available.

If the CHP is located within the proposed building property line, then model as follows:

1.   Define a boiler with the thermal efficiency of the CHP plant from specifications
2.   Define the fuel for the CHP plant. If the fuel is biomass or diesel, select the fuel for the region with the lowest Energy Source Adjustment Factor
3.   Run the file and save the results
4.   Enter the CHP into Retscreen to determine the annual electricity generated
5.   Manually remove the Retscreen annual electricity generated from the Proposed Case electrical consumption and recalculate the Total Annual Energy Use in MJ
6.   Use the average electrical rate from the DOE2 ES-D report to calculate the annual electrical cost savings and subtract from the EE4 proposed case electrical cost.

Condensate Heat Recovery

This is not a CBIP eligible item unless the design incorporates a heat exchanger to transfer condensate heat to ventilation air or service water heating. Running condensate lines through a supply or return duct or plenum, into a partially conditioned space (crawl space, mechanical room, parking garage) can technically save energy, but is not considered a design improvement and therefore not considered as a CBIP credit. If the design incorporates a heat exchanger to transfer heat from the condensate lines to ventilation air, circulation air or service water heating, then document the procedures, design options, available recovery potential and submit to the CBIP Account Manager for consideration.

Thermal Storage

EE4 cannot model the active thermal storage (i.e., hot or chilled water storage tanks to allow for load shifting and smoothing out of peak heating and cooling demands). At present, the only means to partially account for this effect in EE4 is to increase the floor weight to heavy (in the Zone Element/General Tab). The DOE 2.1 calculation engine of EE4 has the capability to model thermal storage. Modeling of thermal storage in DOE 2.1 is extremely complicated and should only be undertaken by experienced DOE 2.1 users. Alternatively, hand or spreadsheet calculations could be used to estimate the benefit of thermal storage. You must receive approval from Natural Resources Canada

CBIP Technical Manager if you wish to use hand calculations or DOE 2.1 instead of EE4.

5. HVAC EQUIPMENT

This chapter details HVAC equipment that is entered in the System and Zone elements. Included in this chapter is detailed information on how to model: fans, ventilation heat recovery, heat pumps, humidifiers, heating and cooling coils, economizers, baseboard radiators, and radiant heating/cooling panels. This chapter should be used in conjunction with chapter 6, which explains HVAC system modeling as a whole.

5.1 Central Heating and Cooling Coils

Central heating and cooling coils refer to those coils that are usually located within a central air-handling unit, often in a rooftop unit or mechanical penthouse. Central coils should not be confused with zonal coils (such as reheat coils, fan coil units, or baseboards).

Heating Coils

Central heating coil characteristics are entered in the System element, General tab, in the box labeled "Heating characteristics". The options for "heating type" include electricity, various fossil fuels, hot water, heat pump, none or "other".

If electricity is selected, there is a central electric heating coil in the rooftop unit or central air handler. If the unit is fired with natural gas, oil, or propane, then the appropriate fossil fuel should be selected.

If the air-handling unit contains a hot water coil from a boiler OR if the primary coil is filled with glycol, which is heated by a hot water to glycol heat exchanger, "hot water" should be selected. If "hot water" is selected, it is necessary that a boiler be defined in the central plant.

If the central system contains an air-source heat pump, then "heat pump" should be selected as the heating type. This should not be confused with ground-source or water-source heat pump. If the plant in the building is a ground/water source heat pump, and the air handling system contains a coil fed from this plant, either select electricity, none or heat pump as the heating fuel for the air handler. EE4 does not model a ground/water source heat pump for ventilation air heating, only an air-to-air heat pump. The air-to-air heat pump performance will drop as the outside air temperature falls. If 'electricity' is selected to represent the ground/water source heat pump, then electric coils with a COP of 1 will be modeled. If 'none' is selected, then all of the heating of the ventilation air will have to be provided by the heat pump terminal units in the zone.

If heating type "other" is selected, EE4 will model the system as if it were electric resistance heating. It is not recommended that "other" ever be selected as the heating type.

In some instances, no heating will be done at a central air handler, or a central air handler does not exist, or central air heating is done with ground or water-source heat pumps. In these cases, choose "none" as the heating type.

Depending on the system type selected, "coil control" and "supply temperature" may be defined. Options for "coil control" are: constant temp (air is delivered to all zones at the specified temperature), zone reset (temperature is reduced depending on the heating needs of the coldest zone at that time) or OA reset (temperature reduces with increasing outdoor air temperature). The specifics of these reset schemes (factor by which the supply temperature changes in response to zone or outdoor air temperature change) are fixed in EE4. If the air handling system type contains an outdoor air reset strategy, and this coil control option is not available, then the entered thermal efficiency of the heating device can be increased by 1.5%..for locations of less than 5000 heating degree days and 2.0% for locations of 5000 and greater annual heating degree days.

Several systems require "supply temperature" to be entered. Always enter the warmest design supply temperatures (generally 43ºC for air-based systems). For fan coil and hydronic heat pump systems (water-source or ground-source), the heating supply temperature always must be less than the cooling supply temperature. A good default temperature to use for these systems is 18ºC. Fan coil and heat pump systems rely on the zone system to provide the majority of the space conditioning, therefore the ventilation air needs to be only minimally conditioned (cooling supply of 21 C and a heating supply of 15 C). The greater the conditioning of the ventilation air for a central and distributed system (fan coil, heat pump) the reduced need to specific zone conditioning. Enter in the heating capacity of the heating device. If multi-stage heating exists, enter the total heating capacity.

Finally, efficiency might be entered, depending on the heating type selected. For electric and hot water systems, efficiency is not applicable and this entry is greyed out. For fossil fuels, enter the efficiency as a number between 0 and 1 (usually 0.80 to 0.82). If the heating type is air-source heat pump, enter the EER or COP. Do not enter an EER/COP for ground or water-source heat pumps in this location unless you are accepting the fact that an air-to-air heat pump will be modeled with poorer performance than the ground/water source.

Cooling Coils

Cooling coils are similar to heating coils, as discussed above. Again, only enter the cooling coil information attributable to a central rooftop unit or air-handling system. Depending on system type chosen, coil control may be an option. Coil control types are identical to those for heating as discussed above.

The ratio of sensible cooling to total cooling may also be entered. Coil or air-handling unit manufacturers usually provide this information. Use 75% if information is not available.

For supply temperature, enter the lowest cooling design temperature. For fan coil or hydronic heat pump systems, the supply temperature must be greater than the heating supply temperature. A good default value to use is 20ºC.

If a "packaged" system has been selected, cooling efficiency information is entered. For built-up systems this value is greyed out because built-up systems imply that chilled water from a central chiller is used in the coil.

Finally, for fan coil and hydronic heat pump systems, "Cooling type for make-up air systems" must be specified. If the central unit cools by direct expansion of a refrigerant, select "DX". If the unit will be served by the central chiller, choose "hydronic". If the unit is served by a ground/water source heat pump, select DX cooling as the cooling source and enter the COP of the ground/water source plant.

If ventilation air staged cooling is installed, enter the total cooling capacity and the average supply temperature.

5.2   Air Source Heat Pumps

Air source heat pumps are common in moderate climates and provide heating or cooling via a vapour compression cycle where heat is accepted from or rejected to outdoor air. The air source heat pump is therefore only conditioning the ventilation air when selected as the heating or cooling source for the air handling system.

An air-source heat pump is defined by selecting "heat pump" in the "Heating Type" field in the System element, General tab, as described in Section 5.1. An air-source heat pump can be defined for any of the 15 EE4 system types. In cooling mode, an air-source heat pump operates exactly like a standard direct-expansion air conditioning unit. See Section 5.1 (cooling coils) for information on modeling cooling characteristics.

As outside temperature decreases, the efficiency and capacity of an air source heat pump decreases significantly, and the operating time for defrost cycles increases. Generally, at a specified outdoor temperature, the heat delivered by unit is negligible and is turned off. When the heating load exceeds the capacity of the heat pump, a back-up heater is used to deliver the necessary heat. In EE4, the back-up heater type is limited to an electric resistance heater. Furthermore, below an outside temperature of 23ºF (-5º C), the air-source heat pump is turned off and the entire heating load must be met with the back-up electric resistance heater. The capacity of this heater is defined in the "back-up heating" field on the System element, General tab. Note that the back-up heating capacity will generally exceed the heat pump heating capacity, because the back-up heater is used in times of greatest heating loads. Back-up heating sources other than electricity cannot be defined in EE4 at the present time.

In addition to heat pump and back-up heating capacity, the efficiency of the heat pump must be entered at the bottom of the General tab. Select whether efficiency is to be entered in COP or EER (generally, heat pump heating capacities are stated in COP). Always enter the ARI-rated COP, not operating COP. Use ARI 210/240 rated conditions. For cooling mode, the COP and output of these heat pumps should be at 35ºC (95ºF). For heating mode, the COP and output should be at 47ºF. EE4 will de-rate the efficiency automatically depending on the outside air temperature predicted in the simulation, using an MNECB standard part-load curve. COP should not account for energy use due to the fan or blower.

5.3   Zone-Level Heating Devices

In contrast to central heating and cooling coils, baseboard radiators, reheat coils, radiant heating/cooling panels, and zone-level fan coils and heat pumps are modeled in the Zone element, Mechanical tab.

Baseboard Radiators, Reheat Coils, Heating Panels

Hot water or electric baseboards, reheat coils, and heating panels are treated identically in EE4. No distinction is made between these devices because all deliver heat to a single zone.

To model these systems, "hot water" or "electric" must be selected in the System element, Zone tab. It is not possible to define hot water or electric reheat panels in zones in the same system. If there are mixed hot water and electric heating devices in a zone, the simulator must choose the predominant type and assume all devices are of that predominant type.

Where mixed hot water and electric heating devices are present in a zone, simulators and designers need to be aware of the fact that the reference building will set the envelope requirements to the levels required for an all electrically heated zone if the proportion of heating input using electricity is greater than 10%. In the Zone element, mechanical tab, the baseboard/reheat coil/heating panel capacity must be entered. It should be noted that in EE4, these devices are activated first upon a call for heat in the zone, up to their maximum capacity, before any call for heat is made from the central system. For example, in a zone in an apartment building, a natural gas-fired furnace is supplemented by 5 kW of electric heat. When EE4 predicts that heat is required in the zone, electric heat will be delivered first. When the hourly heating load exceeds 5 kW, only then will the furnace begin to supply natural-gas source heated air to the zone. If this is not the operational design of the system, and ventilation air is conditioned first to the zone with the zone heating providing supplementary heating, then manually reallocate the zone heating capacity to more in ventilation air heating (system heating description). Document your methodology and remember that zone heating schedules and fan operational schedules differ. If you have reallocated zone heating to the system and the fans are turned off (night unoccupied space), then none of the system heating will be distributed to the zone and the zone may be underheated.

Some buildings have combined heating and cooling panels, or "recool" panels located in the zone. These systems must be modeled as fan coil systems as described in section 6.4.

Fan Coils and Hydronic Heat Pumps

Fan coil and heat pump systems are similar to baseboard radiators in that heating output is defined on the Zone element, Mechanical tab. However, fan coil and hydronic heat pump systems do not require that electric or hot water reheat be specified in the System element, Zone tab. For further information on how to enter the information in the System element for a heat pump/fan coil system, refer to Chapter 6, section "System Types".

However, in addition to heating capacity, fan coil and hydronic heat pump systems also require zone cooling capacity, fan flow rates, and fan power to be defined. Always use the nameplate-rated fan power. See more on fans in Section 5.4. If a heat pump / fan coil serves more than one zone, allocate the heating/cooling capacity between the different zones so the total is the same as the heat pump /fan coil unit. These capacities are to be found in the specifications or on the drawings.

Heat pumps also require the COP to be entered at this point. For ground source or water loop heat pumps, use ARI 325/330 rated conditions: For cooling COP and output at 26.7 C air dry bulb (80 F) 19.4 C air wet bulb (67 F) liquid full load at 21 C (70 F). For heating COP and output at 21 C air-dry bulb (70 F), 15.6 C air wet bulb (60F) liquid full load at 21 C (70 F). Do not use manufacturer-published operating COP/EER ratings. EE4 will adjust the efficiency automatically depending on the calculated loop or entering water temperature. Note that common convention in the heat pump industry reports heating efficiency in COP and cooling efficiency in EER, but EE4 requires both to be entered as COP. Simply divide EER by 3.41 to convert to COP. If the heat pump is serving more than one zone, the COP will be the same for each of these zones, unless an adjustment has been made due to electric space heating also being provided in the zone.

COP/EER values should not take into account fan/blower power. However, if it is known that COP does take include fan power, enter a value of zero in the fan power field.

Heat pumps in the zone are only available if the air handling system selected is a hydronic heat pump system. Zonal heat pumps are not supported in EE4 for VAV, constant volume or other air handling systems.

Similarly if the building contains zonal air-to-air heat pumps, such as window units, these cannot be modeled as zone heating/cooling devices. In this case the are to be modeled as separate air handling systems; either packaged single zones or multi-zones (if grouped) and an adjustment made to the current air handling unit serving these zones.

5.4   System Air Flow Rates and Fans

Supply and Exhaust Fan Overview

EE4 assumes balanced air flows in each zone and for each system, that is, the total system supply airflow equals system return airflow plus zone exhaust air flows. Referring to Figure 5-1,

Supply Flow = Return Flow + Zone Exhaust Flow

also,
Supply Flow = Outside Air Flow + Recirculated Air Flow

Supply fans are usually located in centralized air handlers, and are often the largest fans (in terms of electrical draw) in the building. In EE4, supply fans are defined in the System element, Supply Fan tab.

Return fans are also located in central locations, drawing air back to the central air handler for recirculation or exhaust to outdoors. Return fan characteristics are entered in the System element, Return Fan tab.

There are two ways to exhaust air from buildings: zone exhaust fans (e.g. washroom and kitchen exhausters) and central exhaust. Central exhaust systems are not entered; EE4 assumes that air not exhausted by a zone-level fan is exhausted by the central exhaust. In other words,

Central Exhaust Flow = Outdoor Air Flow – Zone Exhaust Flow

The total exhaust fan flow rate cannot be greater than the total outdoor airflow rate to the building. The determination of the outdoor airflow rate is described in the next section.

Heat recovery can only occur on central exhaust air, not on zone exhaust air (see discussion on heat recovery later this chapter). Thus, zone exhaust fans reduce the benefit of heat recovery.

Zone exhaust fans are those that exhaust directly to outdoors, such as a bathroom exhaust fan, a kitchen range hood, fume hoods, or a thermostat-controlled fan in an equipment room. Generally, zone exhaust fans are relatively small, distributed throughout the building and often do not operate continuously. Do not confuse zone exhaust fans and central exhaust fans. If an exhaust fan is located in centralized air handling equipment (including relief fans in rooftop units), do not enter it as a zonal exhaust fan. It should be considered to be a return fan, or in some cases, taken into account as a supply fan (distributed heat pump and fan coil systems).
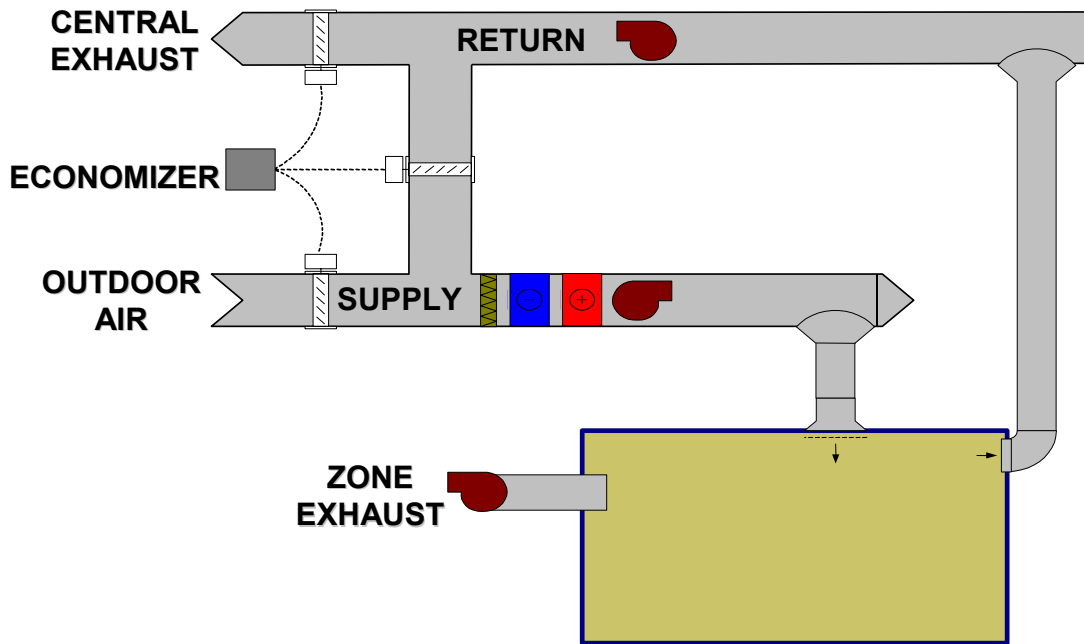
Figure 5-1 – System Air Flow Rates

Another type of fan commonly used, but not shown in Figure 5-1, can be considered to be a "Zonal Supply Fan". In distributed heat pump, fan coil, or induction unit systems, zone supply fans will be used to recirculate room air over a coil to condition the space. Dual duct systems contain a fan-powered mixing box to mix hot and cold air into the space. In these cases, the zone supply flow rate often exceeds the system supply flow rate (because air is recirculated within the space). In EE4, the characteristics of these fans are entered in Zone element, Mechanical tab. The zone supply fans for fan coil and heat pump systems only recirculate air that is already preconditioned by the system. No additional outdoor air is introduced to these supply fans; they are recirculation fans only.

Many VAV and constant volume systems also contain terminal fans for proper mixing or balancing. In EE4 the power for these fans must be accounted for in the central supply fan information. Note that distributed heat pump and fan coil systems are always 100% outdoor air systems. This means that recirculated airflow is always zero for these systems, so

Outdoor Air = Supply Flow = Central Exhaust + Zonal Exhaust

In EE4, the return fan does not exist for heat pump and fan coil systems. The reasoning for this is that the EE4 model assumes that the supply flow pressurizes the building and any air not exhausted by zonal exhaust fans migrates to the outdoors without fan assistance. An example of this is a fan-coil system in an apartment building, where central make-up air units pressurize corridors. Some of the air is exhausted through in-suite range hoods or bathroom exhaust fans (zone exhaust fans in EE4), although most air will be forced outside through suite windows, external doors, elevator shaft leaks, etc. For this reason, the "return fan" input in the System element is not available.

However, many modern fan coil and hydronic heat pump systems do have central return and exhaust fans, so that systems are balanced and heat recovery or recirculation can be utilized. If these fans exist, enter them as supply fans, in the System element, Supply fan tab. You can only enter the total power or combined static pressure of the supply and return fan as a central supply fan. You cannot enter the flow rate as the supply fan flow rate is calculated based upon the occupant density and minimum outdoor air requirements of all spaces served by the air handler for the fan coil and heat pump system.

Entering Central Supply Fans in EE4

For single-zone systems, the supply flow rate is entered in the Supply Fan Tab of the System Element. For water-based systems (water-loop heat pump, 2-pipe fan coil, 4-pipe fan coil), the air handling system is always a 100% outdoor-air make-up air unit, whose supply fan airflow rate must be greater than or equal to the outdoor air requirements of the spaces the make-up air unit serves. For multi-zone systems, the supply flow rate is the sum of the airflow rates entered in the various zones, so the supply flow rate is not entered.

For all systems, however, the fan power must be entered. The choice is up to the simulator to define power directly or by entering static pressure and efficiency. Entering power directly is usually easiest; enter the rated brake horsepower converted to Watts.. Derate the fan power only if the central fan will operate at a schedule other than that defined in the fan schedule (see Fan Operation paragraph below). "Fan power included in ratings" also may be checked at the bottom of the tab. Check this item if the rated heating and cooling capacities entered on the "General" and "Cooling" tabs take into account waste heat of the fan. For instance, a packaged rooftop unit manufacturer might report a unit has a heating capacity of 10 kW, because it contains a 9 kW heating coil and a 1 kW internal fan, with all electrical waste heat entering the air stream and delivered to the space. In this case, 10 kW may be entered for the heating capacity and the "fan power included in ratings" box should be checked. Alternatively, the "fan power included in ratings" box may not checked, but then the entered heating capacity should only be 9 kW.

If the simulator chooses to define fan power by static pressure/efficiency, choose blow-through (fan is upstream of filters and coils) or draw-through (fan is downstream of filters and coils). In either case, enter the total static pressure (not the external static pressure) as calculated by the designer. That is, the static pressure must take into account filters and coils in addition to ductwork and zone terminals. Also enter the combined efficiency (motor efficiency X fan efficiency, determined from fan curves or tables). For example, the fan efficiency can be determined from the brake horsepower tables and the equation below. If the motor is outside the air stream, enter these efficiency values separately. (If motor outside airstream is checked, the heat from the motor will not be delivered to the spaces served by the system). The equation used by EE4 to calculate fan power based on static pressure is

$$Power = \frac{Flow \times S.P.}{eff}$$

where

power is fan power in watts (using brake horsepower)
flow is central supply flow rate in m^3/s
S.P. is total static pressure in Pascals
eff is total combined efficiency (expressed as fraction) (use eff of table for reference from section 1.5)

Central Return Fans

Return fans can only be entered in terms of static pressure and efficiency. Always use total combined efficiency. In cases where static pressure or efficiency is not known, use the Power equation in the paragraph above to obtain values that are equivalent to the rated nameplate power. Note that the airflow rate is fixed and is equal to entered supply flow rate less any zonal exhaust fans. This should be taken into account when selecting values for efficiency and static pressure.

Example. Rated nameplate power on return fans is 10 kW; no static pressure or efficiency information is available. The supply flow rate is 6,000 L/s and a zonal exhaust fan of 1000 L/s have been entered. Solution: The return flow is calculated by subtracting zonal exhaust from supply flow, so return flow is 6,000 L/s – 1,000 L/s = 5000 L/s.

Converting to m^3/s, the return flow is 5 m^3/s. Estimate a static pressure by taking one-half of the supply static, (use 200 pa for example). Use the Power equation above to calculate the efficiency based on the guessed static pressure. Rearranging the equation gives efficiency = (flow x S.P) / power. Substituting the numbers gives efficiency = (5 x 200) / 10,000 W = 0.1 (10%). Enter 0.1 in the appropriate location in EE4.

Zone Supply Fans

As described in the overview of this section, "zone supply fans" refer to distributed heat pump or fan coil blowers, or fan-powered boxes found in dual duct systems. For VAV systems add the VAV zone terminal fans as part of the supply fan.

These fans are always entered in the Zone element, Mechanical tab. Both flow rate and power must be entered; always enter the total motor nameplate power. Be sure that COP values for heat pumps do not take into account fan power.

Zone Exhaust Fans

Power and flow rate of zone exhaust fans are defined in the Exhaust Fan Tab in the Space Element. As mentioned above, these are only small fans that exhaust directly to the outdoors. Note that if zone exhaust fans are entered, return fan flow is decreased. In ventilation air heat recovery systems, heat can only be captured from return air, so defining zone exhaust fans will decrease the effectiveness of heat recovery. See Section 5.6 on modeling heat recovery systems with zonal exhaust fans.

Fan Operating Schedules

For each zone, all fans (supply, return and exhaust) operate according to the same schedule. The schedule is defined in the Zone Element/Schedules Tab (see Section 3.6). If a different schedule applies to the exhaust fans, a weighted power usage may be entered to compensate. For example, if HVAC fans operate 18 hours a day, but bathroom exhaust fans operate 24 hours a day, the fan power entered in the exhaust fan tab should be:

Fan power = rated fan power X 24/18

If zone exhaust fans operate according to a sensor (occupant or washroom door switch) or timer, the simulator must derive a total daily operational time to adjust exhaust fan power.

5.5   Outdoor Air Flow Rates

The MNECB specifies that the reference building have the same outdoor ventilation rate as the proposed building.

The purpose of the CBIP program is to promote energy efficient design. Buildings that are ventilated far in excess of building code requirements cannot be considered energy efficient. As such, CBIP has restrictions on the maximum allowable outdoor air flow in the reference building. In general the reference building outdoor ventilation rate cannot exceed that required by the relevant code by more than 20%. (Note in this manual the term "ventilation rate" refers to the amount of outdoor air that is brought into the building, as opposed to the term "supply air rate" which is the amount of air (both outdoor and recirculated) delivered to the space.).

In EE4, the following are the variables used to determine the outdoor air requirement for the spaces and zones:

1.   Occupant density: value on the drawings or default value for support spaces

2.   Minimum outdoor air per occupant: from standard and drawings, default value for support spaces. Support spaces include washrooms and corridors.

3.   Additional ventilation: any background ventilation which is required in the space which is non-occupant dependent (fume hoods, kitchen exhausts, vehicle requirements) from standard and drawings. This additional outdoor air is added to the occupant ventilation requirements.

4.   Transfer Air: limited to washrooms and kitchen spaces, will use outdoor air from another space in the zone to allow a 0 L/sec/occupant value to be entered for the washroom or kitchen.

Determination of the Code Ventilation Rate

For most buildings the required ventilation rate is determined in accordance with ASHRAE 62-1999. The default values that are currently in EE4 (found in EE4 online help file and Appendix B of this document) are based on the metric values given in ASHRAE 62-1999. These or the imperial values given in ASHRAE 62-1999 can be used to determine the required ventilation rate.

In some circumstances, local building codes or codes developed for specific applications (e.g., hospitals) will have ventilation rates that are different from ASHRAE 62-1999. These codes are referred to as superceding codes and the values in these standards define the required ventilation rates. Examples include CSA Z317.2-01 for Hospitals and the National/Ontario Building Code for parking/vehicle storage garages.

In many cases these code ventilation rates have to be adjusted up or down to account for unique building applications. These situations include:

Diversity: the total ventilation rate can be reduced to account for diversity in occupancy or for intermittent or variable occupancy (see ASHRAE 62 Clause 6.1.3.4).

High Exhaust Flow: in some situations the exhaust flow rate requirements (for washrooms for example) may exceed the ASHRAE 62 rates for a particular HVAC system. In these cases the code ventilation rate is the higher of the required outdoor air and the required exhaust air.

Process Loads: many buildings have process loads that require additional exhaust and/or outdoor air flow. Examples include fume hoods, kitchen exhaust hoods, laundry dryers. These air flows would be included in the determination of the required building ventilation rate.

Multiple Space Correction: ASHRAE 62-1999 Clause 6.1.3.1 requires adjustment of the ventilation rate where multiple spaces are fed by a common system (e.g., VAV system). This correction cannot be greater than 20%.

Reference Building Ventilation Rate

No matter what code/standard is being followed, a spreadsheet is required for submission to show what outdoor airflow is required by the relevant codes along with the calculated proposed occupancy density and outside air per person inputs for EE4. The proposed or actual ventilation rates should also be included in the spreadsheet. If the proposed total building ventilation rate does not exceed the total building code ventilation rate by more than 20%, then no correction or adjust is required and the reference building ventilation rate will be equal to the proposed building ventilation rate.

If the total building ventilation rate for the design exceeds the 20% tolerance on a space by space basis, the reference building rate must be adjusted. The reference building ventilation rate is set to the code ventilation rate, whereas the proposed building ventilation rate must match the design outdoor airflows. For this situation, 2 EE4 files are to be simulated:

    Simulation #1 has the proposed case with the outdoor air matching the design
    values. In this case the simulator will run the proposed case only in EE4.

Simulation #2 has the proposed case with the outdoor air levels set to the code required values. In this case the simulator will run the reference case only in EE4.

The CBIP comparison is between the proposed case in simulation 1 and the reference case in simulation 2.

Proposed Building Ventilation Rates

With the submission, the simulator must also provide proper documentation and explanation of the outdoor air values entered into EE4 so that the reviewer can follow the simulation inputs with ease. The modeled EE4 values for the proposed design must match the design outdoor airflows that are specified on the drawings/specifications on a system level and the occupancy must match on a space level. The exception to this rule is when the design outdoor airflow is within 5% of the outdoor airflow generated by EE4 when using MNECB default values for the entire building for both occupancy and occupancy density. The default values may be used for this case only (although documentation proving the design is within 20% of the specified standard will still be required using the actual design occupancy).

When matching the modeled outdoor airflow to the design, certain workarounds may be required on a space-by-space basis. If modeling the outdoor airflow results in a "Minimum Outdoor Air" value that is lower than that allowed by EE4, occupant densities could be adjusted so as to correctly model the outdoor airflow for that space.

Another problem that can occur is due to certain spaces (i.e. stairwells) having no outdoor air being delivered directly to them. To model this, the outdoor airflow for this space is to be set to the default value, as generated by EE4, and this amount then 'transferred' from an adjacent space (reduce outdoor airflow for adjacent space by the amount transferred so the system outdoor airflow remains the same).

Example: Drawings show 10m² stairwell with no outdoor air and adjacent 100m², 4 person offices with 50 L/s of outdoor air.

Calculations:

   Stairwell: Space Function = Active Stairway

   Outdoor Air = .25 L/s/m² * 10m² = 2.5 L/s (Default values)

   Office: Outdoor Air = 50 – 2.5 = 47.5 L/s

Data Entry:

   Stairwell: Space Function = Active Stairway

      Occupant Density = 0 (Default)

      Min Outdoor Air = 0 (Default)

   Office: Space Function = Office – Category 1

      Occupant Density =100m² / 4 people = 25

      Min Outdoor Air = 47.5 L/s / 4 people = 11.9

Superceding Standard

If another standard is used to calculate the outdoor airflow for the building, permission will have to be obtained from NRCan. To receive consideration for permission, you must provide the following to NRCan:

1. Copy of the standard that you are applying
2. Description of which spaces within the building are applicable to this standard
3. Description of how you are proposing to accommodate the requirements of this standard within the EE4 simulation
4. Expression of Interest Number

If the requirement for ventilation utilizes an air change rate per hour method for specific space functions or parts of the building, the following procedures are required to generate minimum outdoor air levels and occupant densities consistent with the air change rate requirement:

The outdoor air will be calculated by:

OA = (ACH x 1000 x V) / 3600
 Where   OA = outdoor air flow rate (L/sec)
             V = heated volume of the specific space (m3)

The simulator will then convert the outdoor airflow rate to a minimum outdoor air level (L/sec/occ), by taking the calculated flow rate and dividing by the number of occupants in the space (from drawings). The number of occupants in the space is also to be used to determine the entered occupant density.

ASHRAE IAQ Standard

If the ASHRAE 62 "Indoor Air Quality Procedure" (e.g. CO_2 control) is used rather than the "Ventilation Rate Procedure", often the design drawing will not indicate minimum outdoor air rates. To model the minimum outdoor airflow in this situation, change the occupant density for each space to match the design and leave the "Minimum Outdoor Air" inputs at the default values. To obtain credit for the CO_2 sensors, refer to the "Demand Control Ventilation" section below.

SUPPLY vs. EXHAUST AIR REQUIREMENTS

The challenge with assessing ventilation rates for buildings is that there are multiple standards, different requirements for supply and exhaust air rates and different requirements for ventilation capacity and continuous operation. Ventilation capacity is the flow required of the fan but there is no requirement for this fan to operate continuously. To determine the ventilation air rate for a building, these steps must be followed:

Step 1:
    Determine required outdoor supply air based on ASHRAE
    62-1999 or superceding standard

Step 2:
Determine required exhaust air capacities. If the exhaust fan is intermittent, account for the expected run hours by applying a diversity factor to the required make-up air flow rate. For MURBS, 20 L/s is to be used for bathroom exhaust, 12 L/s for kitchen exhaust and 25% of the total capacity for all other exhaust fans (dryers, etc.)

Define the required ventilation rate as being the larger value of step 1 and 2.

Examples 1 & 2 below demonstrate how to use these calculations.

Hospital Systems

Hospitals may have specific code-mandated ventilation rates, total air-change rates, and filtration requirements. For example, in Ontario, the CSA standard for hospital ventilation requires 6 total air changes per hour and two-stage filtration. Since the MNECB does not account for higher total air changes and filtration based on building type, such a design results in fan electricity consumption that is much higher than the reference building. The procedure to adjust reference building fan characteristics is outlined below. Example 3, given below, also shows how to use this procedure.

1.   Determine any code-mandated ventilation, air change, or filtration requirements and specify in your modeling report the mandated code for the design.

2.   Determine the systems to which the special conditions are to be applied. (High filtration may not be necessary, for example, on air handling units serving only the lobby and gift shop areas of a hospital.).

3.   Prepare the EE4 simulation file and run the simulation, making sure that "delete DOE files after simulation" is NOT checked.

4.   Edit the reference building DOE input file ("mybuilding – reference.doe) and adjust total air change rate (supply CFM) and/or supply/return fan static pressure. The new reference values shall be equal to 1375 pascals (5.5 inches) supply static pressure or 375 pascals (1.5 inches) return static pressure.

5.   When editing the DOE files, clearly show changes by commenting out original lines (use the "$" symbol at the start of the line) and adding the new line immediately afterwards.

6.   Clearly document the changes that have been made and include calculations of extra pressure drop due to special in-duct devices (such as filters) with the CBIP submission. Manufacturer specifications of filter should also be included if there is a large pressure drop.

Non-Mechanically Ventilated Systems

Aircraft hangers, food terminals and loading warehouses rely on door openings for their ventilation requirements. These buildings are usually equipped with unit heaters, baseboards or infra-red heating for heating of the space, but do not provide mechanical ventilation to the space. Some of these spaces are mechanically exhausted to induce outdoor air to the space.

For CBIP compliance, the authorities have chosen that ventilation must be provided by mechanical means as per section 5 of the MNECB. This means that these building types do not meet the mandatory ventilation requirements of MNECB (section 5).

The simulator has the option to exclude this building type or this section of the building from the simulation for CBIP simulation purposes. Adding a mechanical ventilation system to this type of space is seen as an unnecessary measure. Therefore, CBIP has chosen to allow this type of space within the acceptable occupancy types.

Proposed Modeling Approach

A compromise solution is proposed to allow this type of building space to be equitably compared to the reference.

The compromise involves the turning off the fan via creating a custom fan schedule with 24 hours of 0 operation. This will still model a make-up air unit in the proposed case and a packaged VAV system in the reference case, but since the fans are off in both cases, zero fan energy would calculated and all of the heating will be provided by zone heating (unit heaters in the proposed case and hot water convectors in the reference case.

If an exhaust fan is installed in these zones, then they would also be turned off, which is an inaccurate modeling approach. Therefore the exhaust fan power should be converted to process sensible electrical energy to account for the exhaust fans. The process schedule should follow the fan schedule to this space definition. This same accounting would be completed in the proposed and reference cases.

If a process is already included within this space definition, then the exhaust fan energy should be added to process energy.

Examples

Example 1: Multi-Unit Residential building with make-up air unit supplying outdoor air to pressurized corridors. Fan coil units used to heat/cool apartments, with outdoor air transferred from corridor.

Design Information:

> 5 North facing one bedroom apartments, 5 South facing one bedroom apartments
>
> 75m² Corridor separating North & South Apartments

400 L/s make-up air unit supplying outdoor air to corridor

One Bedroom Apartment: Bathroom = 5m²

Kitchen = 15m²

Living Room = 80m²

Bedroom = 60m²

Wall Height = 2.4m

Outdoor Air Requirement:

According to ASHRAE 62-1999, Apartment living areas must have 0.35 ACH of outdoor air, but not less than 7.5 L/s/person. A one-bedroom apartment is assumed to have 2 people. Corridors are to have 0.25 L/s/m² of outdoor air.

OA / Apartment: Supply = 0.35 ACH x (5+15+80+60) x 2.4 x 1000/3600

= 37.3 L/s

SA Check: 7.5 l/s/person x 2 people

= 15 L/s < 37.3 L/s

EA Check: 20L/s/bathroom + 12L/s/kitchen

= 32 L/s < 37.3 L/s

North Apartments: OA   = 37.3 L/s / apt x 5 apt = 186.5 L/s

South Apartments: OA   = 37.3 L/s / apt x 5 apt = 186.5 L/s

Corridor: OA = 0.25 * 75 = 18.8 L/s

Total OA = 391.8 L/s (Design OA is 2% different than the code OA (< 20%); therefore the reference will match the proposed building.)

EE4 Data Entry:
N Apartment: Space Function = Multifamily Residential: Dwelling Units

Area = 5x (5+15+80+60) = 800 m²

Outdoor Air = 186.5 x (400 / 391.8) = 190.4 L/s

Minimum OA/occ = 190.4 / 10 = 19 L/s / occ

The default minimum outdoor air value for this space function is 18 L/s/occ (= 0.3 L/s/m²* 60 m²/person). This is less than the calculated value so the calculated value can be entered

Occupant Density = 800 / 10 = 80 m²/occ

S Apartment: Space Function = Multifamily Residential: Dwelling Units
Area = 5x (5+15+80+60) = 800 m²

Outdoor Air = 186.5 x (400 / 391.8) = 190.4 L/s

Minimum OA/occ = 190.4 / 10 = 19 L/s / occ

Occupant Density = 800 / 10 = 80 m²/occ

Corridor: Space Function = Service: Corridors

Area = 75 m²

Outdoor Air = 18.8 x (400 / 391.8) = 19.2 L/s

Occupant Density = Default (= 100 m² / person)

Minimum OA/occ = 19.2 / (75 / 100) = 25.6 L/s / occ

Example 2: Same apartment building as described above except each apartment is to also include a dryer with 50 L/s of exhaust and the make-up air unit is to supply 500 L/s of outdoor air to the corridor.

Outdoor Air Requirement:

Based on the calculations given above, using ASHRAE 62 gives you a maximum ventilation rate of 37.3 L/s of outdoor air per apartment. However, the exhaust air requirement for this apartment now becomes:

EA = 20 L/s/bathroom + 12 L/s/kitchen + .25x 50 L/s/dryer = 44.5 L/s

Since the exhaust air is now greater than the supply air calculated by the ASHRAE method, the exhaust air now dictates how much ventilation is to be supplied to each apartment.

North Apartments: OA   = 44.5 L/s / apt x 5 apt = 222.5 L/s

South Apartments: OA   = 44.5 L/s / apt x 5 apt = 222.5 L/s

Corridor: OA = 0.25 * 75 = 18.8 L/s

Total OA = 463.8 L/s (Design OA is 2% different than the code OA (< 20%); therefore the reference will match the proposed building.)

EE4 Data Entry:

N Apartment: Space Function = Multifamily Residential: Dwelling Units

Area = 5x (5+15+80+60) = 800 m²

Outdoor Air = 222.5 x (500 / 463.8) = 239.9 L/s

Minimum OA/occ = 239.9 / 10 = 24 L/s / occ

Occupant Density = 800 / 10 = 80 m²/occ

S Apartment: Space Function = Multifamily Residential: Dwelling Units

Area = 5x (5+15+80+60) = 800 m²

Outdoor Air = 222.5 x (500 / 463.8) = 239.9 L/s

Minimum OA/occ = 239.9 / 10 = 24 L/s / occ

Occupant Density = 800 / 10 = 80 m²/occ

Corridor: Space Function = Service: Corridors

Area = 75 m²

Outdoor Air = 18.8 x (500 / 463.8) = 20.3 L/s

Occupant Density = Default (= 100 m² / person)

Minimum OA/occ = 20.3 / (75 / 100) = 27.1 L/s / occ

Example 3: School with 1 AHU serving the gym and another AHU serving the auditorium, which is operating under a gym scenario (intermittent occupancy with peak occupancies occur less than 3 hours per day).

Design Information:

Gym: 500m², Peak occupancy = 100 people (2.5 hours/day), Average occupancy = 50 people, Outdoor Air Delivered = 500 L/s

Auditorium: 250 m², Ceiling height = 5m, Peak occupancy = 200 people (used 2.5 hours/day), Outdoor Air Delivered = 500 L/s

Outdoor Air Requirement:

Gym: According to ASHRAE 62-1999, OA = 10 L/s/person. Section 6.1.3.4 of this standard also allows for the average occupancy to be used to calculate ventilation rates as long as the "average occupancy used is not less than one-half the maximum". Therefore, OA = 10 L/s/person x 50 people = 500 L/s.

Auditorium: According to ASHRAE 62-1999, OA = 8 L/s/person. Section 6.1.3.4 of this standard also allows for derating of the outdoor air flow IF the AHU is started a specified amount of time earlier or run a specified time longer than the room is occupied (Lead or Lag time). Using the charts in this standard, it can be determined that with a lead time of 2 hrs, and an air capacity per person of 6.3 m³/person (=250*5 / 200), a ventilation rate of 2 L/s/person can be used. Therefore, the AHU needs to only deliver 400 L/s of outdoor air.

Total Building OA = 500 + 400 = 900 L/s. The design calls for 10,000 L/s of outdoor air delivered to the building. This is only 10% (<20%) greater than the standard so the reference outdoor air will match the proposed building.

EE4 Data Entry:
Gym: Space Function
Area = 500 m²

Example 4: 5000m² distribution warehouse located in Toronto, Ontario. 4 propane fork-lifts will be operating in this facility and the facility operates 24 hours per day. 1 AHU delivering 2500 L/s of outside air runs continuously. A 2nd make-up air unit is tied to the CO controls and delivers 20000 L/s of outdoor air when the CO concentration increases to more than 100ppm due to the operation of the fork-lifts.

Outdoor Air Requirement:

The fork-lifts may be considered process and could be excluded from the simulation, however it has been determined to include the additional ventilation requirements.

For example, the Ontario Building Code requires ventilation rates in garage areas to meet one of the following conditions:

limit the concentration of CO present to no more than 100ppm (6.2.2.3 (1)(a))
        OR
provide 3.9L/s/m² during operating hours (6.2.2.3(1)(b))

Based on clause (b) the required amount of ventilation air is 19500 L/s.

The main AHU will deliver the minimum outdoor air amount (2500 L/s) continuously while the 2nd make-up air unit is used to increase the outside air by 195000 L/s whenever the CO sensor signals it to do so. It was determined that this would occur 2 hours per day.

EE4 Data Entry:

Since the fan schedules call for the fans to be on 24 hours/day, the OA delivered by the 2nd make-up air unit is to be derated to account for unit only running 1 hour per day.

> OA = 2500 + 20000 * 2/24 = 4167 L/s
>
> Space Function = Material Handling Warehouse
>
> Occupant Density = 20m²/person (EE4 default)
>
> Min OA/occ = 4167 L/s / (5000m² / 20m²/person) = 16.7 L/s / occ

Demand Controlled Ventilation

Demand controlled ventilation schemes alter the volume of ventilation air supplied based on measured carbon dioxide levels in the spaces served by the system. NRCan has determined that the effect of a demand ventilation strategy is that ventilation air and fan power values are linked to the occupancy pattern and are reduced to zero for the equivalent of four full-load hours per day. Carbon dioxide sensors must be installed in all zones served by a system; no credit can be given for multi-zone demand ventilation systems that simply have one CO_2 sensor installed in the return ductwork. Demand control ventilation is available only with a reasonable control strategy of CO_2.

EE4 1.50 contains a demand control ventilation (DCV) check-box for all zones specific to the air handling system. The following are the rules govern using the application of this check-box.

What is Demand Control Ventilation?

For CBIP credit purposes, demand control ventilation refers to a self-contained carbon dioxide sensor installed in a space (see below for a definition) that measures carbon dioxide in that specific space as a proxy for indoor air quality and occupancy in that specific space. The sensor will govern the opening of an outdoor air damper and/or the supply of outdoor air either in the space itself or via the air handler through control logic.

Other sensors are currently not available for a CBIP credit for demand control ventilation credits unless written permission is obtained from CBIP. Simulation will likely be required via change in the occupancy schedule rather than checking the DCV box.

What is considered a space for sensor control?

The space definition closely follows the space definition in the CBIP Modelling Manual. However, the location of the sensor within a space requires a more detailed definition to qualify. For simplicity sake a sensor in each space (enclosed area with a door that is constructed for people) is preferable, but this may not be cost realistic in all instances.

A sensor located in each classroom or a patient room is a straightforward space definition. However, adjacent service spaces adjacent to these rooms, such as storage rooms, washrooms and, corridors, would probably likely not contain a CO_2 sensor, and this is acceptable.

The definition of a space for demand control ventilation credits is a space that has an occupancy schedule. Each space with an occupancy schedule should have a CO_2 sensor. However, CBIP permits groupings of certain small spaces under a single CO_2 sensor. These include a number of offices that are served by a single fresh air delivery device. A fresh air delivery device is a grille, vent or diffuser connected to a duct that provides a quantity of fresh air to spaces.

For instance, a school's administration area may contain a number of individual self-contained offices and a central work area, which is open-concept. The fresh air is supplied into the central work open area and allowed to naturally diffuse naturally to the adjacent offices. A single CO_2 sensor is considered acceptable for this grouping of spaces with a single fresh air delivery device. However, if the spaces have two fresh air delivery devices, then two CO_2 sensors are required to receive the full credit.

Can a return air plenum CO_2 sensor be considered for a credit?

If the return air plenum is dedicated to a single space and serves no other spaces under the air handler, this is equivalent to a CO_2 sensor within the space itself. For example, if a gymnasium space uses a central fresh air supply and a single return duct, a CO_2 sensor in the return duct is equivalent to a CO_2 sensor in the space.

If a return plenum serves multiples spaces, such as individual classrooms, or offices and a boardroom, then a CO_2 sensor in the return air plenum is not eligible for as a CBIP credit. A CO_2 sensor for each space would be required to receive the credit.

Can a single space separated into multiple zones for energy modelling purposes require multiple CO_2 sensors?

In some cases, it is necessary to separate a single space served by a single air handler into a number of zones. This is common with warehousing spaces. The perimeter of the warehouse space may have perimeter heating to offset wall heat losses, whereas the interior may contains very minimal heating. Grouping these zones into a single zone may result in heating loads not being met due to exterior wall losses. Therefore, the separation of a single space into multiple spaces and multiple zones may be necessary to correctly represent the heating requirements correctly. If a single CO_2 sensor is installed in this space, then this sensor can be used for all spaces and zones under the same air handler. This assumes that the separation of spaces and zones into multiple spaces and zones is done for energy modelling purposes only.

Can you check the Demand Control Ventilation box if only one sensor is installed?

To determine if the demand control ventilation check-box is activated for the zone, you must first consider all of the spaces within the zone. Support spaces, such as washrooms, corridors, small storage, and mechanical/electrical rooms, which depend on an adjacent space with a designated occupancy, do not need to be included in the consideration.

If a return plenum CO_2 sensor strategy is employed, the demand control ventilation can only be checked only if the plenum represents a single zone air handler with one space (excluding support spaces).

If a zone contains four spaces and two of those spaces have CO_2 sensors, a ventilation air requirement for the combined spaces will determine whether or not the check-box for the zone is activated. In the case where some spaces have DCV and others do not, the DCV checkbox is to be activated if the spaces in the zone using DCV have the majority of the ventilation air requirement. This is best illustrated via with an example:

Office Space 1:   area = 10 m2 , density = 2.5 m22/occ, OA = 10 L/sec/occ, CO_2 no sensor
Boardroom: area = 10 m22, density = 1.5 m22/occ, OA = 10 L/sec/occ, CO_2 sensor
Library: area = 12 m22, density = 2.0 m22/occ, OA = 10 L/sec/occ, CO_2 sensor
Office Space 2 :   area = 15 m22, density = 2.5 m22/occ, OA = 10 L/sec/occ, no sensor

Outside required air:

Office Space 1 = 50 L/sec without CO_2 sensor
Boardroom   = 66.67 L/sec with CO_2 sensor
Library   = 60 L/sec with CO_2 sensor
Office Space 2 = 60 L/sec without CO_2 sensor

Spaces with CO_2 sensors   = 60 L/sec + 66.67 L/sec = 126.67 L/sec
Spaces without CO_2 sensors   = 50 L/sec + 60 L/sec = 110 L/sec

Therefore, since there is a greater outside air supply control is provided directly by CO_2 sensors, check the box would be checked as under demand control ventilation.

If a space with or without CO_2 sensors receives its ventilation air via transfer air from an adjacent space, such as a corridor, add the required transfer air to the corresponding space for the equivalent supply air calculation.

This type of calculation will be required in cases of incomplete CO_2 sensor coverage for spaces under the zone.

How is the CO_2 control strategy applied in EE4?

The outdoor air will be reduced proportionately to the occupancy for the specific hour. If the occupancy level is greater than 50% for the hour, the outdoor airflow will not be reduced. If the occupancy level is below 50% for the hour the outdoor air will be reduced by the fraction of hourly occupancy to maximum occupancy in the daily schedule. A minimum value of 20% outdoor air as determined by the outdoor air calculation will be maintained for the hour. This will be completed for each hour for each occupancy schedule for each thermal zone (combination of spaces) entered for the air handling system. The air handling system will use a newly created operational schedule of outdoor airflow (converted to a new outdoor air fraction) to supply airflow for each hour which contains the new outdoor air rates. These will be applied to all zones for the air handling system. This allows some zones to contain CO_2 controls while others do not for the air handler. The outdoor air fraction that the air handler must provide to all zones will be adjusted by the ratio of outdoor air with controls to outdoor air without controls for each hour.

How do I enter Minimum Outdoor Air Levels where CO_2 sensors determine the minimum levels?

The air handler must be designed for a certain type of occupancy, therefore it will have a supply airflow capacity. The simulator will have to allocate those airflows amongst the spaces and provide this calculation for CBIP purposes.

Demand Control Ventilation Using Occupant Sensors

Occupant sensors normally control lights, but CBIP will allow in limited use the control of ventilation systems using occupant sensors. The following are the requirements for the use of occupant sensors as a demand control ventilation strategy:

1.   this is limited to schools and educational facilities only;
2.   the use of an occupancy sensor in a training room in an office building as demand control ventilation is not permitted at this time
3.   sensor installation will be limited to a 2 hour fan reduction from the MNECB default schedule

4.   the occupancy sensor must be located in the spaces served by the ventilation distribution system (i.e.: 4 classrooms served by the air handler, but only 3 classrooms have occupancy sensors means the whole installation is ineligible for the demand control ventilation credit)
5.   documentation provided must clearly demonstrate the control sequences between the occupancy sensor and the air handling system supply fan/fresh air damper

The method to model this in EE4 is as follows (2 EE4 runs required)

Reference Case:

1.   Do not check the Demand Control Ventilation box for the zone
2.   Use the MNECB default schedule for the zones where the occupancy sensors are located
3.   Complete all of your entries, save and run Reference case only
        Proposed Case:
4.   Alter the weekly fan schedule to "Off" (0%) when normally "On" (100%) for 2 hours for each day and save this new weekly schedule under a different name
5.   Complete this for each schedule which qualifies for the occupancy sensor as a ventilation controller
6.   Save your file under a unique name and run the Proposed case only
7.   Submit both EE4 runs as part of your CBIP submission

5.6   Ventilation Air Heat Recovery

Heat recovery units transfer sensible heat from the exhaust air stream to the incoming ventilation airflow. This transfer reduces the ventilation air heating load in the winter and cooling load in the summer. Energy recovery ventilators transfer both heat and moisture from the exhaust air stream to the incoming air stream. The moisture transfer reduces the demand for winter humidification and reduces the latent portion of the summer cooling load.

Only sensible heat recovery can apply towards a CBIP credit and can be modeled directly in EE4. The effectiveness is entered on the "Outdoor Air" tab in the System Element of EE4. Most heat recovery unit manufacturers can provide effectiveness values for their products. Ideally, these values should be in accordance with ARI 1060. Effectiveness values are dependent on the flow rate through the unit and the value used in EE4 should be for the specified supply and exhaust airflow rate. If both heating and cooling effectiveness values are available, the values should be averaged for input to EE4.

Effectiveness should be calculated according to the method described in the ASHRAE Handbook, HVAC Systems and Equipment:

$$\varepsilon = \frac{Ws}{W\min} \frac{(X_2 - X_1)}{(X_3 - X_1)}$$

where ε = effectiveness to be entered into EE4 (value between 0 and 1)

Ws = supply air flow

Wmin = minimum of supply and exhaust air flows

X_1 = Incoming supply air dry-bulb temperature at design condition

X_2 = Supply air dry-bulb temperature downstream of heat recovery unit

X_3 = Exhaust air dry-bulb temperature entering heat recovery unit from building

Often, all of these quantities are available on a manufacturer's product sheet, or in mechanical drawings and/or specs. If the flow through the unit is balanced, Ws=Wmin and the equation reduces to simple temperatures.

If a manufacturer's product has not been selected or test results are not available, a default value of 0.50 can be assumed. A default value of 0.45 is assumed for hot water or glycol loop heat exchangers unless engineering data is provided.

No credit is given for any reduction in the latent heating or cooling load associated with energy recovery units.

Heat recovery units introduce an air pressure drop into air streams that must be overcome by supply and return fans. If all central supply and return fans are accounted for as described in Section 5.4, the additional fan power is automatically accounted for. However, some heat recovery systems have small fans within a packaged heat recovery unit, often referred to as heat recovery ventilators (HRVs). It is necessary to account for the fan power used by a packaged HRV by adding additional fan power (or static pressure) to the central supply fan power. In the case of a heat recovery wheel also add the motor power to the central system. If fan power is entered directly, simply add the rated HRV fan wattage to the supply fan. In the case of a heat recovery wheel also add the motor power to the central system. If the static pressure/efficiency method is preferred, convert rated HRV wattage to static pressure as described in the equation below, and add to the supply fan static pressure.

$$SP = \frac{W \times ME}{F} \times 1000$$

SP = static pressure in Pascals

W = HRV total fan power (supply and exhaust fans) in Watts

ME = HRV fan motor efficiency (default value = 0.66)

F = HRV supply fan airflow rate in litres/second

Heat recovery is modeled only if a return fan is present (DOE2 requirement).

Exhaust Fan Heat Recovery

If heat recovery units are installed on zone-level exhaust fans, the fan should not be entered as an exhaust fan. Adjust the return fan static pressure and efficiency to account

for the power consumption of the fan, and increase the heat recovery effectiveness (on a flow-weighted basis) to account for heat recovered. For example, if a zone has a central HRV with 65% effectiveness on 900 cfm, and a 75% effective HRV on a 100 cfm mechanical room exhaust fan, the heat recovery effectiveness will be 66%. (65% x 90% of flow + 75% x 10% of flow).

In the above example, if a return fan is not present, then one would be created by:

SP = [(600 * 0.66) / (900 +100) * 0.472] * 1000 = 839 pascals

Assume total wattage of heat recovery units are 600 watts and both HRV units have a fan efficiency of 66%

In the above example, if a 1200 cfm return fan is available with a fan power of 1.5 kW and the heat recovery units are in addition to the return fan then the adjusted static pressure would be:

SP = [(1500 + 600) * 0.66 / (1200 + 900 + 100) * 0.472) * 1000 = 1335 pascals

Exhaust Fan Heat Recovery with Make-up Air Units

If heat recovery is via zone exhaust fans only and the system type does not support a return fan (fan coil and heat pump system) then the program reduces the outdoor airflow by the entered heat recovery effectiveness. If the entered heat recovery effectiveness is 45% for the zone exhaust, then EE4 reduces the outdoor air by 45%. This assumes that the exhaust flow equals the minimum outdoor air requirement (balanced system assumption). For unbalanced flows refer to the next section titled "Heat Recovery and Different Exhaust/Return and Supply Airflows".

Heat Recovery and Different Exhaust/Return and Supply Airflows

If the exhaust/return airflow through the heat recovery unit is less than the supply/outdoor airflow, the heat recovery effectiveness must be adjusted. The following equation is to be used to calculate the adjustment factor:

Adjustment factor = Exhaust air through unit / Supply air through unit

The rated effectiveness of the heat recovery unit (at the exhaust flow rate) is to be multiplied by this adjustment factor to obtain the entered effectiveness.

For example, a school has a minimum outdoor air requirement of 2500 L/sec and heat recovery is available on a number of washroom exhaust fans totaling 1000 L/sec and a central exhaust fan of 100 L/sec. The effectiveness would be adjusted by:

HRV adjustment factor = (1000 + 100) / 2500 = 0.44

If the manufacturer rated effectiveness is 66%, then the entered adjusted effectiveness would be 29% (0.66 * 0.44)

If the exhaust flow rate through the HRV is greater than the supply flow rate, no adjustment is required. Enter the HRV effectiveness at the supply air flow rate.

Heat Recovery and Differing Exhaust and Supply Fan Operation

One additional consideration related to heat recovery effectiveness is the assumption of identical operating schedules for the supply, return and exhaust fans. The entered fan schedule for all fans under the system with heat recovery should be flow weighted averaged by the fans in the system. If this is not the case, and the exhaust fans operate at different times than the supply and return fans then a further adjustment is required to the heat recovery effectiveness.

Example 1:

Exhaust fans operating 24 hrs / day and supply and return fans operating 18 hrs / day:

HRV time factor = 24 / 18 = 1.33

In the above example the 29% effectiveness would be adjusted to 38.7% because of higher available heat recovery. This would be a rare case because when the supply fans are off no heat recovery would be utilized.

Example 2:

Exhaust fans operating 12 hrs / day and supply and return fans operating 18 hrs / day:
HRV time factor = 12 / 18 = 0.66

In the above example the 29% effectiveness would be adjusted to 19.33% (29 * 0.66) because of non-operational heat recovery.

Heat Recovery with Make-Up Air Units (Fan Coil and Heat Pump Systems)

EE4/DOE-2 version 2.1E simulates heat recovery by a return air method. On make-up air units (fan coil systems, radiant systems, heat pump systems) outside air is tempered and supplied only to a central space(s). Therefore a return fan does not exist and is not entered. The method employed in EE4/DOE-2 version 2.1E is to reduce the outside air by the heat recovery equivalent. The entry for the heat recovery effectiveness is identical to the method described above. In addition, the make-up air unit supply fan must be entered using the static pressure and the fan efficiency method rather than the rated power. If entered using the rated power, this value will be reduced by the heat recovery effectiveness (DOE2 method of handling power), which is incorrect. Entering the static pressure and the fan/motor efficiency will not alter the calculated fan power and the heat energy added to the airstream. Use the above method to convert fan power to equivalent fan static pressure.

5.7 Humidifiers

Hot water or electric humidifiers can be modeled on the "Humidity" tab in System element. However, it is recommended that humidifiers should only be modeled in buildings with a very large humidification requirement. When modeling humidifiers, simulators should also be aware of MNECCB Sentence 5.2.11.1.(2), which states: "Humidistats required by Sentence (1) shall be capable of being set to prevent the use of energy to increase relative humidity above 30% or to decrease relative humidity below 60% for comfort purposes." Simulation of humidifiers acting in the proscribed range may be ineligible for credit. Demonstration of necessity may be required for acceptability of results.

Steam humidifiers should be modeled as "hot water" if the steam is from a central boiler or district plant. Stand-alone steam humidifiers should be modeled as electric.

If the steam/hot water humidifiers are fed from a central boiler that is dedicated to steam/hot water dehumidification, then this boiler has to be represented as part of the central heating plant. Unfortunately EE4 only allows 1 type of boiler per heating plant, therefore a combination space heating and humidification boiler is required for EE4.

Add the heating boiler capacity to the humidification boiler capacity and weight the efficiencies by space heating loads to humidification loads. This requires 2 EE4 runs.

Run 1: no humidification: run EE4 using the space heating efficiency and capacity
On the DOE2 PS-A report, write down the plant heating load (MBTU)

Run 2: with humidification: run EE4 with the humidifiers and the total boiler capacity and space heating boiler efficiency. On the DOE2 PS-A report, write down the plant heating load (MBTU) which now includes hot water humidification

The difference is the humidification load (MBTU)

Example: Space boiler = 500 kW, efficiency = 88%, steam boiler = 200 kW, efficiency = 70%

After EE4 runs: space heating only load = 3200 MBTU, humidification load = 1450 MBTU

efficiency = (humid eff * humid load + space eff * space load) / (humid + space load)
= (0.70 * 1450 + 0.88 * 3200) / (1450 + 3200) = 0.824

5.8 Economizers

Air-side economizers can be modeled for most system types on the "Outdoor Air" tab in the System element. In EE4, fan coil and hydronic heat pump systems are always 100% outdoor air so economizers are not applicable to these systems. Similarly, if a system is made 100% outdoor air (by matching the system or zone supply rates to the outdoor air rate), modeling an economizer will not have any impact. For a system with no cooling, an economizer is to still be modeled if the system uses an outdoor air damper to maintain a return or mixed air temperature for free cooling.

Water-side (or tower-side) economizers cannot be modeled directly in EE4. A separate manual calculation is required to predict the number of operating hours of the tower-side economizer. This calculation can then used to pro-rate the chiller COP.

5.9 Preheaters

Preheaters are available for all air handling systems in EE4, but EE4 assumes that all preheat coils are electric. EE4 will automatically size the coil such that sufficient capacity exists to preheat the air to the entered preheat supply temperature. The simulator does not have the ability to enter the size of the actual preheater.

If the preheat coil is hot water, do not enter a preheat coil and enter the hot water capacity (coil size) as part of the heating source for the air handler.

6. MODELING OF HVAC SYSTEMS

Choosing an appropriate HVAC system is one of the most important and most challenging aspects of building energy modeling. In EE4, there are 15 basic system types. Although there are virtually dozens of different system types used in practice today, most can be adequately modeled using one or more of the 15 base models. Some systems cannot be explicitly described using of the fundamental systems, but a work-around can be performed within EE4 that is a reasonable representation. On the other hand, sometimes it appears as if two or more of the 15 basic models could be used to describe a system. A fundamental understanding of these basic models is essential to choose the best one.

This section outlines the 15 "conventional" EE4 system types and includes instructions on how to apply these system types to model common, real-world systems. In addition, detailed work-around instructions on how to model some non-conventional systems within EE4 are presented. Detailed descriptions of the 15 basic system types, including graphical schematics and an explanation of all the required EE4 inputs, appear in Appendix C.

6.1 Fundamental System Types in EE4

EE4 can model 15 types of HVAC systems. The system types can be divided into two groups: zonal (water-based) systems and central air-handler systems. The system types are listed in Table 6.1. Zonal systems are sometimes referred to as distributed or water-based systems. A building often has more than one HVAC system type.

Table 6-1 – HVAC Systems Modeled in EE4

Zonal (Water-Based) Systems	Central Air Handler Systems
Hydronic Heat Pump (or Water-Loop Heat Pump)	DX Single Zone System
2-Pipe Fan Coil System	Packaged Constant Volume Multizone System
4-Pipe Fan Coil System	Built-Up Single-Duct Constant Volume System
2-Pipe Induction Unit System	Packaged Variable Air Volume (VAV)
4-Pipe Induction Unit System	Packaged Multizone
	Built-up Single Zone
	Built-up Variable Air Volume (VAV)
	Built-up Multizone
	Dual-Duct
	Dual-Duct Dual Fan

To fully describe the HVAC system requires specifying system information at the Central Plant, System, Zone and Space Elements. There are significant differences in the way EE4 handles zonal and central systems. 6.2 Table 6-2 defines the parameters required for each element.

Zonal (Water-based) Systems: In these systems, heating and cooling is performed primarily by a zone-level device. For these systems, the General Tab in the System

Element is used to describe the make-up air unit. The purpose of the make-up air unit is to deliver ventilation air only; as such the airflow rate in the System Element is determined by the minimum outdoor air requirement for the spaces served by the system. Make-up air units are intended to only temper the outdoor air. In EE4, the heating airflow temperature must always be lower than the cooling airflow temperature.

Central Air Handler Systems: in these systems, the central air-handling unit provides heating and cooling. Zone-level reheat units or baseboards may provide secondary heating or cooling. Since the central system provides heating and cooling as well as ventilation air, flow rates are typically much higher than zonal systems. Generally this flow rate will be specified by the user.

When using EE4, enter multi-zone systems in the building tree prior to entering single zone systems. There is no limit to the number of systems that may be entered into a building.

6.2   6.2 Table 6-2 – HVAC Data Summary

| *Plant* |
| For all systems define: |
| • Service water heater |
| • Boiler (if hydronic heating) |
| • Chiller (if hydronic cooling) |
| • Cooling Tower (if water-cooled chiller is defined) |
| • Heat Pump Loop Type (if applicable) |

| System |
| • Select 1 of 15 system types |

Water-Based Systems (Heat Pump and Fan Coil Systems)	*Air-Based Systems (Constant Volume and Variable Air Volume)*
Define: • Make-up Air Unit Heating and Cooling Characteristics • Make-up Air Supply Fan Characteristics • HRV Characteristics	Define: • Central Heating and Cooling Characteristics • Supply and Return Fan Characteristics • Economizer and HRV Characteristics • Reheat or Preheat Characteristics

| Zone |

Heat Pump	*Fan Coil/Induction Unit*	*VAV*	*CV*
• Terminal heat pump heating and cooling capacities, COPs • Terminal fan power and flow rate • Supply/exhaust fan operating times	• Fan coil unit heating and cooling capacities • Terminal fan power and flow • Supply/exhaust fan operating times	• Terminal reheat capacity (if applicable) • Zone maximum and minimum flow rates • Supply/Return exhaust fan operating times	• Terminal reheat capacity • Zone flow rate • Supply/Return and exhaust fan operating times

| *Space* |
| • Zonal exhaust fans |
| • Occupant densities and minimum outdoor air requirements |
| • Service water loads and maximum flow rates |

Selecting the Appropriate System

With 15 different basic system types, it sometimes may appear as if two or more EE4 models could be used to fit the system or none apply. Outlined below is a step-by-step procedure to arrive at the best model for the proposed system. This procedure will divide the 15 systems into five general system groups.

Cooling Dominated Systems

Step 1. How is cooling distributed to the space, by air or by water?

If the space is cooled by cold air blown from an air handling system, you have an "air-based" system; go on to step 2.

If the space is cooled by chilled or tempered water piped to the space, then you must model the system as a fan coil, induction unit, or distributed (hydronic) heat pump system. See Section 6.3.

Step 2. Does the system serve a single zone or multiple zones?

If the system is multi-zone system (i.e. an air-based system serving several zones), go on to step 3.

If the system only serves a single zone, you have a DX single zone system or Built-up Single Zone system. See Section 6.3.

Step 3. Is the air volume leaving the central air handler constant or variable?

If the airflow is variable, then you have a variable volume system; go to step 4.

If the airflow is constant, then you have a constant volume multi-zone system. See Section 6.3.

Step 4. How is air cooled at the central air handler, by a chilled water coil or by direct expansion of a refrigerant?

If air is cooled by direct expansion of a refrigerant, you have a packaged VAV system.

If air is cooled by a chilled water coil from a central air handler, the system is a built-up variable air volume system. See Section 6.3.

Heating Dominated Systems

Step 1. How is heating distributed to the space, by air, by water or electricity?

If the space is heated by hot air blown from an air handling system, you have an "air-based" system; go on to step 2.

If the space is heated by hot or tempered water piped to the space or strictly by baseboard electric heaters, then you must model the system as a fan coil, induction unit, or distributed (hydronic) heat pump system. See Section 6.3.
Step 2. Does the system serve a single zone or multiple zones?

If the system is multi-zone system (i.e. an air-based system serving several zones), go on to step 3.

If the system only serves a single zone, you have a DX single zone system or Built-up Single Zone system. See Section 6.3.

Step 3. Is the air volume leaving the central air handler constant or variable?

If the airflow is variable, then you have a variable volume system; go to step 4.
If the airflow is constant, then you have a constant volume multi-zone system. See Section 6.3.

Step 4. How is air heated at the central air handler, by a hot water coil or by a fossil-fuel or electric furnace/heater?

If air is heated by a fossil fuel or electric furnace/heater, you have a packaged VAV system.

If air is heated by a hot water coil in the central air handler, the system is a built-up variable air volume system. See Section 6.3.

6.3 System Types

Following the procedure described in Section 6.2 helps to select a general system type. This section defines the criteria to pick one of the 15 EE4 system types. See Appendix C for detailed descriptions of each of these 15 system types, schematic diagrams, and instructions for entry into EE4.

Ground / Water Source Heat Pump

If there are water-to-air heat pumps used to deliver conditioning to the space, select "hydronic heat pump" in the "system type" field on the General tab of the System element. "Hydronic heat pump" should be selected whether the heat pump is ground-source or water-loop; this distinction is made in the Plant element (see Chapter 4). The "heating type" field describes the make-up air unit for this system. This can be anything except hot water. If hot water is used to heat the ventilation air, then a dummy fossil-fuel furnace must be created. This furnace is to have the same fuel type (gas, propane, electric, oil), efficiency and capacity as the boiler. The heat pump information (capacities, COPs, etc) is to be entered in the zone tab, as described further in the "Zone Level Heating Devices" section of this manual (see Chapter 5).

Fan Coil, and Induction Unit Systems

If there are water-to-air heat pumps used to deliver conditioning to the space, select "hydronic heat pump" in the "system type" field on the General tab of the System element. "Hydronic heat pump" should be selected whether the heat pump is ground-source or water-loop.

Fan coil systems consist of terminal heating/cooling units that contain a fan, heating and/or cooling coil. Select "2-pipe fan coil" if one set of pipes delivers either hot water or chilled water. Under this system, the entire building must be in heating or cooling (not both) at any given time. Select "4-pipe fan coil" if there are dedicated chilled and hot water pipes, permitting simultaneous heating and cooling. With all fan coil systems, a boiler and chiller must be defined in the Central Plant. Select 4-pipe fan coil if the system is a radiant panel or in-floor heating or the heating is totally baseboard electric with a make-up air handling unit for ventilation. See Section 6.4 for more information.

Induction units differ from fan coil units in that there is no fan in the terminal unit; high velocity primary air is introduced to the induction unit from a central system and induces a secondary flow of room air. The mixed air is conditioned by a heating or cooling coil. Select "2-pipe induction" if one set of pipes delivers either hot water or chilled water. Under this system, the entire building must be in heating or cooling (not both) at any given time. Select "4-pipe induction" if there are dedicated chilled and hot water pipes, permitting simultaneous heating and cooling.

Single Zone Systems

If it has been determined that the system is a single zone system (and not a hydronic heat pump, fan coil, or induction system), it is either a "DX Single Zone" or "Built-up Single Zone" system.

Choose "DX single zone" if air is cooled by direct expansion of a refrigerant. These systems are very common in residential and smaller commercial buildings. For instance, packaged rooftop units on small stores or restaurants are DX Single Zones systems. A house with a forced-air furnace and central air conditioning is a DX single zone system. A hotel where heating, cooling and fresh air are provided by a packaged through-the-wall air conditioner/heating unit is a series of DX single zone systems.

Select "Built-up Single Zone" if there is a chiller that delivers chilled water to a coil in the air-handling unit. These systems are usually only found in large buildings.

Constant Volume Multi-zone Systems

There are 4 systems that belong to this family:

Packaged Constant Volume Multi-zone – air is cooled by direct expansion of a refrigerant, and only 1 air stream (hot or cold) leaves the central air handler. This is a common system type. An example is a medium-sized office building with direct-expansion rooftop units. The rooftop unit delivers either hot or cold air to 4 different zones. Thermostats in each of the 4 zones may control baseboards to reheat the air to

achieve the space temperature desired. Often the thermostats will report space temperatures back to a central control panel, which decides whether the rooftop unit should be delivering hot air or cold air. However, in EE4, the heating or cooling mode is determined by the demand of the first zone listed in the EE4 building tree under the system (this is known as the "control zone"). This should be kept in mind when choosing the order of the zones. To avoid unmet heating load errors, try to anticipate which zone will most often be in heating mode (a zone with many north-facing windows, for instance) and choose this as the first zone.

VVT (variable volume/variable temperature) systems or ceiling bypass systems should be modeled as constant volume systems because the airflow at the central fan does not vary.

Built-up Single Duct Constant Volume – air is cooled by a chilled water coil (the chilled water comes from a central chiller), and only one air stream (hot or cold) leaves the central air handler. This system behaves identical to a Packaged Constant Volume Multi-zone system, except that air is cooled with a chilled water coil, not a refrigerant coil.

Packaged Multi-zone – air is cooled by direct expansion of a refrigerant, and two air streams (one hot and one cold) leave the central system, to be mixed in proper proportions to meet zone-heating needs. In a packaged multi-zone system ("Packaged MZ" in EE4), air is heated and cooled by the central air handling year-round. Separate ducts – a hot duct and cold duct – deliver the air to zone mixing boxes, which combine the two air streams to meet the zone temperature demand. Although this system provides very precise zone temperature control, it is not very energy efficient.

Built-up Multi-zone – air is cooled by a chilled water coil (the chilled water comes from a central chiller), and two air streams (one hot and one cold) leave the central system, to be mixed in proper proportions to meet zone-heating needs. This system behaves identical to a Packaged Multi-zone system, except that air is cooled with a chilled water coil, not a refrigerant coil.

Packaged VAV System

In a packaged VAV (variable air volume) system, air is cooled by direct expansion of a refrigerant, and the system airflow can vary depending on the heating/cooling load required. In cooling mode, the supply air flow rate is set by the simulator, usually around 13ºC. Zone terminals contain dampers which allow more or less cold air into the zone, depending on the amount required for space conditioning (note the maximum and minimum airflow rates are set by the simulator). In heating mode, the temperature entering the zones is fixed at 13ºC and the airflow rate is constant at the user-specified minimum airflow rate. For perimeter zones, baseboard heaters (hot water or electric) MUST be defined to meet the heating load, or an EE4 heating error will result.

Packaged VAV systems are very common in medium sized office buildings, but should not be confused with VVT (variable volume/variable temperature) systems or ceiling bypass systems. VVT and ceiling bypass systems are actually constant volume systems, because the airflow rate from the central fan does not vary. VVT/ceiling bypass systems should be modeled as Packaged Constant Volume Multi-zone or Built-up Single Duct Constant Volume.

Built Up Variable Air Volume Systems

Built-up VAV system – only one air stream leaves the central air handler (hot or cold) and is throttled at the zone by means of a VAV box. This system is identical to the Packaged VAV system described above, except that cooling is provided by a chilled water coil instead of a refrigerant coil.

Dual duct system – two air streams leave the central air handler (one hot, one cold) and are mixed at the zone to meet the space requirements. One fan serves both hot and cold air streams. Dual duct systems are similar to Built-up Multizone systems, with one important difference – the airflow rates of the air streams are varied to improve energy efficiency. Mixing does not occur until one of the air streams is reduced to the user-defined minimum.

Dual duct, dual fan system – two air streams leave the central air handler (one hot, one cold) and are mixed at the zone to meet the space requirements. This system is similar to a dual duct system, but each air stream has a dedicated fan. One of the assumptions of the dual duct dual fan system is that outside air is delivered to the cold side initially (even in winter) and then heating is added. If the dual duct system contains controls that allow outside air to be initially introduced on either the cold side, the warm side or both, then, the system should be modeled as a built-up VAV. Based upon the assumptions in the software, dual duct and dual duct dual fan systems have reduced cooling energy but substantially higher heating requirements than a comparable built-up VAV system.

6.4   Special HVAC System Cases

In most cases, following the procedure described in Section 6.2 should narrow down the choice of system types. However, there are additional system types that may not seem to fit any specific model in EE4. This Section explains common "work-arounds" so that these special systems can be modeled in EE4 with reasonable accuracy.

Water-Based Radiant Heating and Cooling Systems

Radiant heating and/or cooling systems offer many advantages over conventional air-based HVAC systems. The principle advantage is that no fan energy is required to deliver the heating or cooling. These systems are to be modeled in EE4 by treating the radiant heating or cooling surface as a fan coil that requires no fan energy as long as they meet the following requirements:

1.   Air handling unit delivering air to the space is a 100% outdoor air system (make-up air unit)
2.   The supply air temperature is a constant temperature

If these requirements are met, the modeling procedure is as follows.

Select either a 2- or 4-pipe fan coil HVAC system in the System Element/General Tab,

Describe the ventilation make-up air heating system in the System Element/General Tab

Specify the zone heating and cooling capacities on the Zone Element/Mechanical Tab

Enter zero for terminal design fan power in the zone mechanical tab

Run the EE4 sizing calculator (CalcManager => Sizing => Calculate) and enter the resulting zone-level airflow rate from the "Loads" table into the Zone Element/Mechanical Tab as the terminal fan airflow rate. This is to work-around the fact that EE4 requires an airflow input.

If the unit delivering air to the space is a mixed air system or an exhaust or return system (HRV air handler) with radiant heating only (radiant panels or infra-red heaters), an air-based system (i.e. VAV or CV depending on the characteristics of the AHU) is to be selected. "Hot Water" must be selected in the System, Zone tab of these systems and the rules described in the "Zone-Level Heating Devices: Baseboard Radiators, Reheat Coils, Heating Panels" section of this manual are to be followed. If radiant cooling is also provided, NRCan is to be contacted for a work-around.

If there is no radiant cooling being provided and the supply air temperature for the make-up air unit varies (controlled for zone reset or outdoor air reset), the make-up air unit can be modeled as a CV Single Duct System. The supply airflow for this system is to be set equal to the outdoor airflow so as to model it as a 100% OA system. "Hot Water" must be selected in the System, Zone tab to model the radiant heating. The heating capacity will be entered in the zone element and the rules described in the "Zone-Level Heating Devices: Baseboard Radiators, Reheat Coils, Heating Panels" section of this manual are to be followed.

No matter what system type is selected, if the piping for the radiant heating/cooling is embedded in a concrete floor, set the floor weight (in the Zone Element/General Tab) one level heavier than actual construction to simulate the thermal mass effect. Floor weight is medium for most commercial concrete type buildings and light for wood frame construction.

Baseboard Electric Space Heating

The system selected should be based upon the delivery of the cooling system, but if cooling is not applicable, then the system should be modeled identically to the water-based radiant heating and cooling with 2 minor differences. These are:

1.   Do not alter the floor weight
2.   Since the simulated fan coil system in EE4 requires a boiler, a "dummy" boiler
        will need to be modeled. The boiler and heating pumps are to have the following
        characteristics:

Electric boiler with its capacity equal to the total heating capacity of the baseboards

fixed speed pump, pump head = 0 pascals, design temperature drop = 5.6 C, pump efficiency = 100% and motor efficiency = 100%

The only exception to this rule is when the make-up air unit has a heating coil being supplied hot water from a gas boiler. Since you cannot model both a gas and an electric boiler, the system type will have to be changed to a Built-up Single Duct CV system with electric baseboard heating. The supply airflow for this system is to be set equal to the outdoor airflow so as to model it as a 100% OA system.

Radiant (Gas-Fired) Unit Heaters

Gas-fired radiant heaters are often used to heat warehouses, arenas and light manufacturing areas. In EE4, it is assumed that all combustion takes place at either the Plant or System Element and not at the Zone Element. The procedure for modeling gas-fired radiant systems is as follows. A different procedure is used depending on whether there is a single HVAC system or multiple HVAC systems in the building. The procedure also varies depending on how whether the ventilation for these systems is supplied by one or more 100% outdoor air systems or mix air systems.

100% OA Single HVAC System

Select either a 2- or 4-pipe fan coil HVAC system on the System Element /General Tab Specify radiant heating fuel, total output of zone unit heaters, supply temperature, and efficiency; set central supply fan equal to the 100% OA system fan power in the System Element

Enter zero for heating and cooling capacity and terminal fan power in the Zone Element. Set terminal fan flow rate equal to value in EE4 sizing calculator as described in water-based radiant systems

100% OA Multiple HVAC Systems

Select either a 2- or 4-pipe fan coil HVAC system in the System Element/General Tab

Specify radiant heating fuel, heating output of 1 kW, supply temperature, and efficiency.

Set central supply fan power equal to the 100% OA system fan power in the System Element

Enter the total heating capacity for the zone in the Zone Element. Set terminal fan power to zero and set terminal fan flow rate equal to value in EE4 sizing calculator as described in water-based radiant systems

Model a dummy boiler with the same fuel type and efficiency as the radiant heater. The boiler capacity is to equal the total capacity of the radiant heaters. A heating pump is to also be modeled with the following characteristics: fixed speed, pump head = 0 pascals, design temperature drop = 5.6 C, pump efficiency = 100% and motor efficiency = 100%.

Mixed Air System: Single HVAC System

If mixed air is being supplied to a single zone with a radiant heater, select an air based single zone system (Built-up SZ or DX Single Zone). The type of single zone system is dependent on the type of cooling being supplied. The system inputs define the mixed air

system. The heating capacity for the radiant heater can then be added into the system if the system has the same heating fuel or is 'none'. If the fuel differs, select "Hot Water" in the system Zone tab and enter the total heating capacity for the radiant heater in the Zone Element.

Model a dummy boiler as described in the section above.

Mixed Air System: Multiple HVAC System

If mixed air is being supplied to multiple zones with radiant heaters, select an air based multi-zone system (i.e. Built-up single duct CV, Packaged VAV, etc.). The type of mutli-zone system is dependent on the type of cooling being supplied and whether the air is constant or variable. The system inputs define the mixed air system. The radiant heaters are to be modeled by selecting "Hot Water" in the system Zone tab and entering the total heating capacity for the radiant heaters in the Zone Elements.

Model a dummy boiler as described in the "100% OA: Multiple HVAC Systems" above.

Radiant Panel and Infra-Red Heating Systems

Radiant panel systems are identical to in-floor radiant heating, except that in most cases a boiler is not installed in the proposed design.

However, if following the rules defined in the "Water-based Radiant Heating and Cooling" section leads you to select the fan coil model within EE4, this does require a boiler. If a boiler does not exist, you must define a "dummy boiler" with the following characteristics:

- fixed speed, pump head = 0 pascals, design temperature drop = 5.6 C, pump efficiency = 100% and motor efficiency = 100%

- boiler capacity equals the total capacity of the infra-red heaters

- boiler fuel equal fuel of infra-red heaters

- boiler thermal efficiency equals the thermal efficiency of the infra-red heaters or 80% (if unknown)

If radiant panel cooling is installed select "Purchased Cooling" and use the same pump characteristics as the boiler.

Without defining a boiler or chiller, the software will not know where the panel is receiving hot water or electricity.

Combination Space and Water Heating Systems

Combination space and water heating systems or "combo" systems are often used in townhouses and apartments. In these systems, the water heater delivers hot water for both domestic uses and for space heating. These systems cannot be modeled directly in EE4; rather the space and water heating functions have to be separated. The following procedure is recommended.

Combine the heating capacity of all the combo systems

Enter the portion of the capacity of all the combo systems that is for heating hot water in the Plant Element/SHW tab

Enter the portion of all the combo systems that is for space heating in the Plant Element/Central Heating Tab

Select either a 2- or 4-pipe fan coil HVAC system in the System Element/General Tab

Specify the zone heating and cooling capacities in the Zone Element using the coil capacity installed in each zone

Enter the thermal efficiency of the combo system in both the "Service Water" tab and in the boiler information. The efficiency of the boiler and water heater is the same.

Solar Water and Ventilation Air Heating Systems

Any energy savings from installing solar heating systems can be counted towards the CBIP target of 25% energy savings.

Two common applications of solar heating in Canada are solar water heating and solar ventilation air heating. Solar water heaters preheat water for domestic and industrial uses. Solar collectors heat mains water and store the heated water in a preheat tank.

The conventional (fossil-fuel) water heater supplements the solar heating to ensure that the water is always delivered at the setpoint temperature. Unglazed collectors are used if the water-heating load is primarily in the summer. Glazed collectors are better suited to providing heated water year-round. Solar ventilation air systems (trade name Solarwall™) consist of a perforated metal cladding attached to the south façade of buildings. Ventilation air is preheated as it is pulled through the perforated plate. A bypass damper is installed to avoid summertime heating of the air.

Both of these solar heating systems can qualify for Natural Resources Canada's Renewable Energy Deployment Initiative (REDI). The REDI program provides a 25% incentive towards the cost of the system. The REDI program requires that detailed computer simulation be performed to determine the energy savings of these systems. The performance of solar water heating systems is determined using the WATSUN or RETScreen computer program. The performance of solar ventilation air heating systems is determined using the SWIFT or RETScreen computer program. RETScreen is available free-of-charge from the web site retscreen.gc.ca.

The computer simulated energy savings determined for the REDI program can be used as a credit in the CBIP program. The proposed building energy consumption is the value determined by EE4 assuming no solar heating system less the energy savings of the solar heating systems determined using RETScreen, WATSUN or SWIFT. The cost savings should be calculated based on the "virtual" energy rate for the building. The "virtual" energy rate can found by dividing the total energy cost (regulated and

unregulated) for the building by the total energy use or by using the "virtual rate" given in report ES-D in the generated .SIM file for the proposed building.

The only exception to the above rule is where the proposed building has both a solar ventilation air heating system and an HRV for the same ventilation airflow. In this case, the two technologies must be analyzed together to avoid double counting of the energy savings. Simulators should contact the Natural Resources Canada CBIP Technical Manager for the recommended procedure.

Parking Garages

To simplify the EE4 model, unheated parking garages may be excluded from the CBIP model. A garage is defined as being unheated when the set point temperature is not higher than 4°C (i.e. the space is heated to just above freezing point). Otherwise, parking garages must be included in the model. The procedure to model parking garages is outlined below:

Model the entire garage as a single zone/space with the classification "Active Storage-Bulky" for buildings defined by Space Function or "Warehouse" if building type classification is being used.

Define a heating schedule with a temperature set point of 4°C. This temperature reflects the fact that garages only need to be heated to keep pipes from freezing. No credit will be given for heating the garage above this temperature.

Define schedules. Select the same schedules for the garage as the rest of the building, with the exception of the heating schedule as described above.

Define ventilation requirements according to your provincial standard (for example the Ontario Building Code outdoor air requirement for a parking garage is 3.9 L/s / m²). For any other code/standard that is used, follow the guidelines specified in the "Outdoor Air Flow Rates" section of this manual. If CO/CO2 control is used to determine the amount of ventilation for the garage, the modeled outdoor airflow may be reduced to account for the number of hours that no ventilation is provided during the occupied schedule.

However, since CO sensors are mandatory, no credit is given for this design feature. The reference building is to therefore have the same outdoor air flow as the proposed building.

Determine where the ventilation air comes from. Certain designs use the exhaust air from the building as the ventilation air for the garage. To obtain credit for this, calculate the available heat in the portion of building exhaust air discharged via the parking garage and subtract this from the heating required in the parking garage each hour. This credit is limited to providing 9°C of heating for heated garages and 5°C for unheated garages.

This credit can be combined with space heating within the parking garage. For further details on how to obtain this credit, refer to Section 3 of the MURB Credits (Appendix D). Model any additional heating for the garage. If unit heaters are used to provide additional heating for the garage, follow the guidelines in the "Special HVAC System Cases"

section of this manual, depending on the type of heater. Make sure to adjust all schedules as described above.

6.5   System Modeling Examples

This section presents some common buildings and describes how to model the HVAC systems in EE4.

Example 1. Restaurant Served by Rooftop Units

Description: rooftop units condition a 1-storey restaurant. There are three rooftop units – two identical rooftop units serve different areas of the dining area (east side and west side) and are equipped with gas-fired heating and electric DX cooling. A third rooftop unit is a make-up air unit serving the kitchen area and also has a gas-fired heating section with electric cooling). Electric baseboard radiators serve all areas of the building. An electric hot water heater provides domestic hot water.

Solution: The building is first zoned according to HVAC system and space function. If the restaurant is relatively small, this building is best described as three zones – one for the each side of the dining area, one for the west side and one for the kitchen. Each rooftop unit is thus dedicated to one zone.

Since there is no central boiler or chiller, and no central heat pump loop, the only item to be defined in Plant is the domestic hot water system. On the Service Water tab of the plant element, "electricity" is selected for the Fuel source, and the input capacity and storage tank volume are entered. Thermal efficiency is not defined for electric systems because they are assumed to be 100% efficient.

This building has three systems each serving a single zone, thus they are all single zone systems. Since the systems cool air by direct expansion of a refrigerant (as opposed to chilled water coil), "DX Single Zone" is the appropriate system selection. On the General tab in the System element, choose "DX Single Zone". For heating type, choose "natural gas" and enter the heating capacity and thermal efficiency in the appropriate locations. Similarly, on the cooling tab, enter the cooling capacity and efficiency.

To include the electric baseboards, on the Zone tab, select "electricity". The baseboard heater capacity is not entered in the System element; instead, it is entered on the Mechanical tab of the Zone element.

Since two of the rooftop units are identical, the same system as defined above can be used again. Since the kitchen make-up air unit is slightly different, a new DX single zone system needs to be defined.

Example 2. Office Served by Ground Source Heat Pumps

Description: A medium sized 3-story office building is served by a large ground-source heat pump loop. Water is circulated through 30 heat pumps distributed throughout the building and a vertical ground heat exchanger. Three rooftop units condition the

ventilation air by natural gas fired heating and electric cooling. One rooftop unit serves the first floor, one serves the second floor, and the other serves the top floor. A small electric water heater provides domestic hot water.

Solution: Zones for this building are defined according to area of influence of the heat pumps. The three rooftop units represent three systems, so this building has three systems, each with ten zones.

In the Plant element, the domestic hot water system and ground temperature information must be entered. On the Service Water tab of the Plant element, "electricity" is selected for the Fuel source, and the input capacity and storage tank volume are entered. Thermal efficiency is not defined for electric systems because they are assumed to be 100% efficient. On the Heat Pump tab, "ground loop" is chosen as the heat pump loop source. Monthly predicted entering water temperatures are entered at the bottom of the tab. If these values are unknown, then the values from Table 4.4 can be entered.

In the system element, "hydronic heat pump" is selected as the system type. Under "heating type", "natural gas" is selected because the rooftop make-up air units are gas heated. The efficiency and capacity information for the rooftop unit is also entered on this tab. Similarly, the rooftop unit cooling information is entered on the Cooling tab.

On the Supply Fan tab, enter all supply fan information relating to the rooftop make-up air unit only.

In each of the 30 Zone elements, heat pump characteristics are defined on the Mechanical tab. Here, the heating and cooling capacity, heating and cooling efficiencies, and fan flow rate and power are entered. Note that if all 30 heat pumps are identical, it is necessary to enter the same information 30 times, on each zone Mechanical tab.

Example 3. Apartment Building with Hot Water Radiators and In-Suite Chilled Water Fan Coils

Description: An apartment building is heated with perimeter hot water baseboards. Chilled water fan coils located in each suite provide cooling. To maintain suite comfort, both boiler and chiller operate during shoulder seasons when some suites require heating and others require cooling. Ventilation air is delivered to the building by a large air handler located in the penthouse mechanical room, which delivers tempered air to corridors. The air handler contains both a chilled water coil and hot water coil. The building contains four natural gas boilers, each of capacity 300 kW (1200 kW total) that serve both heating water and domestic hot water. The mechanical engineer calculates the peak heating load to be 700 kW and the peak domestic hot water load to be 500 kW.

Solution: Following the procedure described in Section 6.2, cooling is provided to the space by means of chilled water (because fan coils are located within the apartment units), so the system type is either fan coil, induction unit, or heat pump. Since induction unit and heat pump certainly don't fit, the building must be modeled as a fan coil system. Since the building operates in heating and cooling modes simultaneously, 4-pipe fan coil is the best system choice. Note however, that heating is NOT provided by the fan coil; heat is transferred by natural convection and radiation from the baseboard unit (which

does not contain) a fan. Thus, this example is a system "workaround" because there is not an EE4 model that precisely fits. Details of the workaround are described below.

Theoretically, each apartment suite is a different zone. However, since the building is almost entirely one space use, suites of similar orientation can be grouped together. If the building is 8 stories high, it is best to group all south-facing suites on floors 2 through 7 together, all east-facing suites together on floors 2 though 7 etc. Using this strategy the building can be accurately described in about 12 zones. (Top and bottom floors are not grouped in with all other floors because they have different load characteristics). Since there is only one central air handler serving the entire building for ventilation, there is only one system in this building, with 12 zones.

In the Plant element, it is necessary to define several parameters – domestic hot water heaters, boilers, chiller, and cooling tower. Since the domestic hot water load is estimated to be 500 kW, 500 kW is entered as the water heater capacity on the Service Water tab. The storage tank volume is also entered, along with the thermal efficiency.

On the Central Heating tab, the boilers must be entered. After subtracting 500 kW from the total installed boiler capacity (because this is dedicated to domestic hot water production), 700 kW of capacity must be entered. This is probably best described as 2 boilers, each of capacity 350 kW. This does not precisely match the actual boiler capacity, but is better than the alternative of entering 3 boilers of capacity 233 kW. The simulator would enter the boiler size of 350 kW and efficiency, and then select a multiplier of 2. If the boilers are staged to come on at 90% of capacity, then 315 kW is entered for the sequencing capacity. Pump data also must be defined on this tab.

Chiller and cooling tower and associated pump information must also be entered on the appropriate tabs. Note that the cooling tower is only defined if the chiller is selected as "water cooled"; otherwise, a simple condenser fan is entered for the air-cooled condenser.

In the System element, "4-pipe fan coil" is selected. For Heating Type, "hot water" is selected because the central make-up air unit has a hot water coil. This coil capacity is also entered on this tab. For fan coil systems, the ventilation air is only tempered so the heating supply temperature will be relatively low, perhaps 18ºC.

On the Cooling tab, the characteristics of the central chilled water coil are entered. Again, since the ventilation air is only tempered, a modest cooling supply air temperature is entered, perhaps 20ºC. Under "cooling type for make-up air systems", "hydronic" is selected, meaning that the cooling coil in the air handler is chilled water, not refrigerant.

On the Supply fan tab, the characteristics of only the central ventilation fans are entered; fans within the suite fan coil units are defined later in the Zone element, Mechanical tab.

The terminal information is entered on the Zone element, Mechanical tab. This is where a work around is necessary. Since fan coil has been selected as the system type, EE4 is being instructed to model both heating and cooling delivered by the suite fan coil. In reality, however, only cooling makes use of the fan; only the baseboard radiator provides heating. From a modeling perspective, heating with a fan coil vs. a radiator are very similar, except that a fan coil consumes electrical energy. A fan coil also requires a

certain airflow to deliver the necessary heating from a thermodynamic analysis. The workaround to be employed in these situations is as follows:

On the Zone element, Mechanical tab, enter the rated heating output of the baseboard radiator under "Zone Heating Output". Enter the rated cooling output according to the fan coil spec sheet on under "Zone Cooling Output". Enter the cooling fan flow rate under "Airflow Rate". Next, derate the fan power of the fan coil according to the time of year that the building is expected to be in heating mode. For example, if an average suite is in heating mode 8 months of the year and cooling 4 months of the year, and the fan power in cooling mode is 1 kW, reduce it to 1/3 (333 watts) because the fan power is effectively zero for 8 months of the year.

Note: if the building had used electric baseboard heating rather than hot water baseboard heating, the procedure would have been identical, except that "electric" would be selected in the System element, Zone tab, instead of "hot water".

Example 4, Warehouse Served by Roof Top Units and Gas Infra-Red Heaters

Description: A warehouse is equipped with a gas-fired roof-top unit providing ventilation air tempering only and the tempered air is simply ducted to a few central drops. Gas-fired infra-red heaters are installed on a exterior walls and at the overhead bay door openings to meet envelope losses. A gas-fired unit heater with blower is installed at the man door entry blowing hot air into the warehouse space. This unit heater does not have a direct fresh air supply, only heating and circulating air at the entrance space.

Solution: Zone the building such that the infra-red heaters serve the exterior walls, overhead delivery doors by creating a 1 meter warehouse space strip with the exterior walls and a small portion of the roof included in these zones. There will be a series of perimeter zones (one per orientation) to accommodate the infra-red heaters.

The roof-top unit will be zoned for the center of the warehouse space with envelope losses through the slab and roof, but it will contain the majority of ventilation air heating. The roof-top unit is the make-up air unit for the building.

The gas unit heater at the entrance will be modeled as an entrance space zone. If entry is by building type, then the entrance can be defined as a separate zone. If the entry is using the space function method, then create a warehouse entrance zone with 2 spaces: a dummy 0.5 m2 space using the warehouse space function and a space called active stairway to represent the entrance space. The building will have 1 system: Four pipe fan coil system: this represents the make-up air unit for the central air tempering and the infra-red unit heaters (central zone for make-up air, plus infra-red unit heater zones).

The make-up air unit will be a natural gas furnace to represent the roof-top unit. All of the heating capacity will be represented at the System tab.

The central zone will have a heating capacity of 0 kW entered in the Zone mechanical tab. The airflows for the fan coil unit serving the central zone will be derived by running the sizing calculation and entering the airflows to represent the fan coil.

The perimeter zones will have individual infra-red heater capacities entered in the Zone mechanical tab. The airflows will be entered from the sizing calculation.

The entrance unit heater will be modeled as a Zone mechanical device in the fan coil system. The output of the unit heater will be the Zone capacity and the blower flow rate will be the fan coil rate.

At the Plant level, enter a dummy boiler to represent the heat source for the fan coil. The capacity of the boiler will equal the sum of the capacities of the infra-red heaters. The thermal efficiency of the boiler will equal the rated efficiency of the infra-red heater (usually greater than 80%). The circulation pump will have an effective head of 0 kPa, a design temperature drop of 5.6 C, a pump and motor efficiency of 100% (represent little pump energy). Do not enter a chiller.

7. MODELING OF BUILDING ENVELOPE

7.1 Level of Complexity Required

Heat transfer through the building envelope accounts for a significant proportion of energy use in a building. As such, an accurate representation of the building envelope is necessary for a reasonable estimate of energy use in both proposed and reference buildings, and to accurately assess building envelope and over sizing credits and penalties. However, measurement of walls, windows, and roofs can be extremely time consuming and it is necessary to keep the model simple for a timely simulation. Since reference building and proposed buildings will have identical envelope areas, moderate differences between modeled envelope areas and "actual" envelope areas may have a negligible impact on building energy results and final incentive determination. Listed below are some tips for an accurate, yet timely simulation.

Envelope construction should take priority over envelope area. EE4 always compares envelope areas of identical size, but credits and penalties are determined by the efficiency of the envelope system (i.e. R-values and U-values). Concentrate on calculating an accurate R-value as described in this chapter.

Do not model small wall "jut-outs". Many walls will have small turns and curves that need not be modeled for CBIP purposes. For example, a wall may face south, but may contain small west and east-facing jogs at bay windows.

Measure building wall orientation to within 15º. Wall orientations are used for solar gain calculations in EE4. In the year-end energy results, there will be a negligible difference between a wall facing 279º and once facing 285º. Round off orientation measurements to 15º.

Framing is extremely important. The effect of framing, particularly when the insulation layer is framed, can have a surprising impact on wall and roof R-values. It is not unusual for a nominal "R-20" wall to become "R-14" or worse when modeled correctly in EE4, with framing taken into account. Review the section on framing and the MNECB carefully when modeling walls and curtainwalls.

Model interior partitions only if a high degree of heat transfer is expected. Usually, all parts of the building are kept at a uniform temperature. Interior partitions do not need to be modeled in these circumstances. Only model interior partitions if there will regularly be high temperature differences between areas of the building. Also, do not use interior partitions to model inter-zone air transfer.

Include all area within the heated space within your area calculations. This includes all areas within the inside of the thermal shell of the building (elevator shafts, storage areas, stairwells included). If the area is outside of the thermal shell of the building (ex. Penthouse mechanical room, exterior storage) do not include these areas as spaces in the building.

Name walls effectively. Do not leave all walls named "exterior wall". Give them descriptive names that will assist NRCan in making a timely technical review. One strategy is to name all walls and clearly label these wall names on the submitted drawings.

7.2 Above-Grade Walls, Roofs and Floors

Area Calculation

Wall, roof and floor areas should be calculated based on inside building dimensions (MNECB Clauses 2.2.2.3 to 2.2.2.5). While theoretically the heat loss should be based on the mid-point of the wall R-value or insulation layer, the complex nature of building assemblies makes it difficult to determine where this dimension would be. Wall height should include the full floor-to-floor height (i.e. include dimensions for interior floors and return plenums). Note the discussion on area measurement is Section 7.1.

In EE4, the area entered for walls, roofs and floors should be the gross value including any areas for windows, doors and skylights. (EE4 will subtract the areas of any windows, doors and skylights defined as part of the exterior elements to determine the "net" opaque area.) If the envelope element includes a projecting product, like a pyramid skylight, the gross area should include the projected area of all the surfaces, not just the area of the rough opening (see Section 4.3).

Wall, Roof and Floor U-values

The MNECB is based on total assembly U-values. Appendix C of the MNECB gives the method for determining the total assembly U-value accounting for thermal bridging of steel or wood framing. The MNECB procedure is coded into EE4. However, the user must select the type of framing and the percentage of the assembly that is framing. The framing percentage is NOT automatically adjusted when the framing type is changed. The framing percentages to be used are given in Table 4.1. This table can also be found in Appendix C of the MNECB. These framing percentages include the studs as well as the extra framing required around windows and doors.

Table 7-1 – Framing Percentages (taken from MNECB Appendix C)

Assembly	Framing Spacing, mm	Wood Framing		Steel Framing	
		Area With Framing, %	Area Without Framing, %	Area With Framing, %	Area Without Framing, %
Roofs, ceilings, floors	<500	10	90	0.33	99.67
	≥500	7	93	0.23	99.77
Above-grade walls and strapping	<500	19	81	0.63	99.37
	≥500	11	89	0.37	99.63
Below-grade walls and strapping	<500	17	83	0.57	99.43
	≥500	10	90	0.33	99.67
Sheet steel wall	<2100	–	–	0.08	99.92
	≥2100	–	–	0.06	99.94

The EE4 program includes a library of most building materials (taken from the MNECB Appendix C). Caution should be exercised in using material property values supplied by manufacturers. Some expanded or extruded insulation products have high material R-values when initially manufactured. But the R-value decreases as the blowing agent diffuses out and is replaced by air. The values in the MNECB are representative of long-term performance. Any insulation with conductivity lower than 0.024 W/mK (or greater than R6/inch) should be verified with a Canadian Construction Materials Centre (CCMC) evaluation.

Some materials include a reflective foil to reduce radiation heat transfer. Manufacturers sometimes quote an "effective" R-value to account for this benefit. These materials are only effective if the foil faces an air space. It is required to model these materials by entering the thermal conductivity of the material disregarding the foil and adding an air space with reflective surface.

Similarly, "effective" R-values are sometimes quoted for massive materials. These materials should be modeled by entering the conductivity and thermal capacitance of each layer separately. The EE4 program will account for the thermal mass benefit in its calculation. However, if the U-value is entered directly, instead of entering each material that makes up the assembly, the thermal mass is not taken into account.

If an exterior wall contains an exterior hanging facade (metal cladding) with an air space separation of greater than 100 mm between the facade from the exterior wall, then exclude the facade and airspace from the exterior wall U-value calculation. In this case convective heat loss will exceed the reduction in conductive losses from the total assembly. If the air space between the exterior wall and the facade cladding is less than 100 mm then include the air space and cladding in the total assembly U-value calculation.

7.3 Assemblies in Contact with Ground

Below-Grade and Earth-Bermed Walls

Partially buried walls should be divided in two: the above grade portion and the below grade portion. The modeling of above grade walls is discussed in Section 4.1. Below-grade walls are entered in the "Wall in Contact with Ground" Element.

For earth-bermed walls, the entire area covered by earth should be treated as an Underground Wall Element. The depth of the wall is calculated as the depth of the wall below grade plus the height of the earth berm provided it extends 1.2 meters out from the wall. For the portion of the earth berm that extends out less then 1.2 meters, use one half the height of this portion of the earth berm (see Figure 7.1). This height would also be used in the calculation of underground wall area.
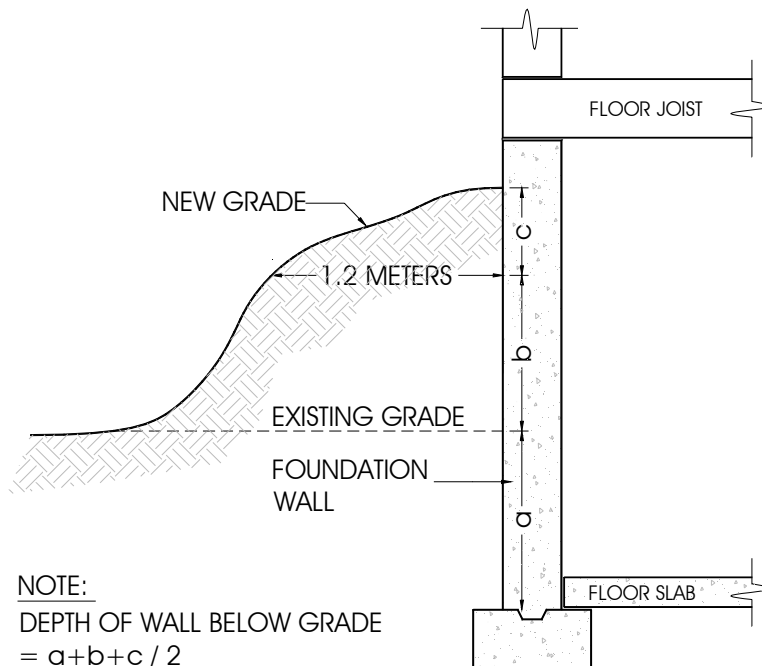
Figure 7-1 – Depth of Below-Grade Wall When Earth Berms Are Used

Below-Grade and Earth-Bermed Roofs

Below-grade and earth-bermed roofs are treated as Underground Walls Elements as per MNECB Table A-3.2.3.1. However, if there is less than 600 mm of soil on top of the roof, the roof should be treated as an above-ground roof. In the Underground Wall Element, Area is the roof area, Depth is the depth of soil on the roof and Perimeter is the longest dimension of the roof.

7.4   Windows and Skylights

Window and Skylight Area

Window and skylight areas are calculated as the total area including glazing and frame (MNECB Clause 2.2.2.8-1). Many designers mistakenly use the term window area when referring to glazing area. For EE4, the window area (and thermal properties) should be based on the total window area (glazing plus framing, sashes and mullions). Window rough opening area can be used for ease of checking on construction documents.

A skylight is entered as a window in the roof assembly and is assumed to be on the same tilt angle as the roof. Many commercial buildings have pyramid or domed skylights. These skylights have a much larger surface area than the opening in the roof. The total area of all the angled surfaces should be used in EE4, not just the rough opening. For small skylights, the total skylight area can be estimated as 1.5 times the opening (MNECB Clause 2.2.2.8-3). A value of 1.3 times the opening is recommended for domed skylights. While this approach is reasonable to account for heat loss, it over estimates the solar heat gain through the skylight (see next section).

The fenestration area should include the total area (including framing elements) of windows, sliding glass doors, glass revolving doors, and window portions of swinging doors. All of these components should be defined in the EE4 building tree.

Note that the reference building and proposed building will have the same amount of window area up to a maximum of 40% window-to-wall ratio (WWR). If the proposed building has a WWR greater than 40%, the reference building is fixed at 40%. This results in an energy penalty because the proposed building will have a greater window area (and thus higher heating and cooling energy needs).

Similarly, the skylight area in proposed and reference buildings is the same up to a maximum of 2% skylight-to-roof ratio (SRR). If the proposed building is greater that 2% SRR, the reference building remains at 2%.

Window and Skylight U-values

The U-value for windows should be based on the entire window (including glazing and framing). There are several sources for window and skylight U-values. They are, in recommended order of use, as follows:

1.   Manufacturer: Some manufacturers publish U-values for their products. The only acceptable values are those rated in accordance with CSA A440.2 or NFRC 100 (note NFRC values are usually listed in IP units – multiply by 5.678 to obtain SI value). Some manufacturers list values that are for the glazing only; these can not be used.

2.   FRAMEplus Online: FRAMEplus Online can be used to determine the window U-value. The program can be found at www.frameplus.net. FRAMEplus generates U-values for the glazing system only, the total window U-value for the CSA rated size and the total window U-value for the specified window size. The total window

U-value for the actual size is to be used in the CBIP model. A printout of the results must be included in the submission package if this option is selected.

3.   Default values in the EE4 fenestration library: These values are equivalent to those published in the ASHRAE Fundamentals Handbook, and should be used whenever precise total-window information is not available.

Window and Skylight Solar Heat Gain Coefficients (SHGC)

The SHGC values required by EE4 are for the total window – not just for the glazing. Sometimes manufacturers quote shading coefficient (SC). The SHGC value is 0.87 times the SC value. Again, however, SC values are often listed for the glazing only. There are several sources of information on SHGC values. They are, in recommended order of use, as follows:

1.   Window Manufacturer: Some manufacturers publish SHGC values for their products. The only acceptable values are those rated in accordance with CSA A440.2 or NFRC 200. Some manufacturers list values that are for the glazing only; these values need to be adjusted (see below).

2.   Glazing Manufacturer: Glazing manufacturers will often supply SHGC values for their glazing systems. The values are accurate for the glazing but ignore any frame effects. To correct these values, multiply the glazing SHGC by the ratio of the glazing area to the total window area. If this area ratio is not known or difficult to calculate, values of 80% and 70% can be assumed for fixed and operable windows respectively.

3.   FRAMEplus Online: FRAMEplus Online can be used to determine the SHGC. The program can be found at www.frameplus.net. The total window SHGC for the actual size is to be used. A printout of the results must be included in the submission package if this option is selected.

4.   ASHRAE Fundamentals Handbook: Chapter 29 Table 11 of the 1997 ASHRAE Fundamentals Handbook provides a fairly comprehensive list of total window SHGC values (see Appendix)

5.   EE4 Program: The EE4 program contains a very short list of values and their use is not recommended for CBIP or MNECB compliance.

If the skylight area was increased to account for the extra heat loss because of the domed or pyramid shape, it is necessary to reduce the SHGC to compensate. Skylight SHGC is SHGC divided by 1.5 for pyramid skylights and 1.3 for domed skylights.

7.5   Doors

Many types of doors are used in commercial construction: swinging doors, sliding doors, revolving doors and overhead doors. Residential sliding glass doors (patio doors) should be treated as operable windows (see Section 4.3). Similarly, doors with over 50%

glazing should be entered as operable windows (based on the total areas of the door) and not entered as doors.

U-values for swinging doors should be determined in accordance with A453 (where applicable). Typical U-values for commercial swinging, revolving and overhead doors can be found in the 1997 ASHRAE Fundamentals Handbook Chapter 29 Table 7. The reference building uses the same U-values for doors as the proposed building, so the door U-value selected will not have a large impact on the simulated results.

7.6   Curtain Wall Systems

Curtain wall systems are common in commercial buildings. They are made up of two portions: vision panels (glazed portion) and spandrel panels (opaque portion). Curtainwalls are defined in EE4 the same way as a normal wall – opaque portions are "wall", and glazed portions are "windows".

Vision Panel

The U-value and SHGC for vision panels can be determined in the same manner as described in Section 7.4. Because most manufacturers do not have published values, the ASHRAE Fundamentals Handbook Chapter 29 likely provides the most accurate values (see Appendix).

FRAMEplus Online: FRAMEplus Online can be used to determine the performance properties of curtain wall vision panels. The program can be found at www.frameplus.net. The total window U-value and SHGC for the actual size is to be used in the EE4.CBIP simulation. A printout of the results must be included in the submission package if this option is selected.

Spandrel Panel

There are two generic types of spandrel panels. The first type is constructed using precast concrete (or other material) that are hung off the building structure. This spandrel system is insulated by spray applying insulation to the back of the panel or by constructing an interior insulated wall. These two methods have modest thermal bridging, and the wall R-value can be calculated using the procedure defined in Appendix C of the MNECB and as programmed in EE4.

The second type of spandrel panel is made up of aluminum mullions with a glass exterior - the so-called all-glass building look. A steel metal pan is attached to the mullions and is filled with semi-rigid fiberglass or mineral wool insulation. The mullions and steel pan cause considerable thermal bridging which reduces the effectiveness of the insulation by more than 50%. The most accurate means of evaluating the U-value of spandrel panels is with a 2-D heat transfer program (e.g., FRAME see web site www.frameplus.net).

FRAMEplus Online: FRAMEplus Online can be used to determine the performance properties of curtain wall spandrel panels. The program can be found at

www.frameplus.net. The total spandrel U-value for the actual size is to be used in the EE4.CBIP simulation. A printout of the results must be included in the submission package if this option is selected.

In lieu of this analysis, the U-value of the assembly can be calculated using the procedure in EE4 with some modifications. The procedure is as follows:

- Calculate the wall (spandrel) area represented by the mullions (typically the mullions represent 5 to 20% of the wall area). Where mullions are shared by a spandrel panel and a vision panel, only include half the mullion area in the wall area.

- In the EE4 Construction Assembly Library, check metal framing greater than 500 mm and enter the mullion percentage

- In the Construction Components box describe each layer in the spandrel panel. The insulation portion should be indicated as containing framing.

- Add a continuous layer of gypsum wall board (i.e., does not contain framing) above the insulation layer to represent the mullion thermal break. The thickness of the gypsum board would be the same as the thickness of the thermal break.

Figure 4.2 shows a typical entry for a spandrel panel with a 4 mm thermal break. This procedure provides reasonable U-values, however, for wide thermal break products, a thermal test report in accordance with CSA A440.2 is recommended.

In many cases the U-value of the spandrel panel will be higher than 167% of the reference wall U-value and a warning message will be generated.
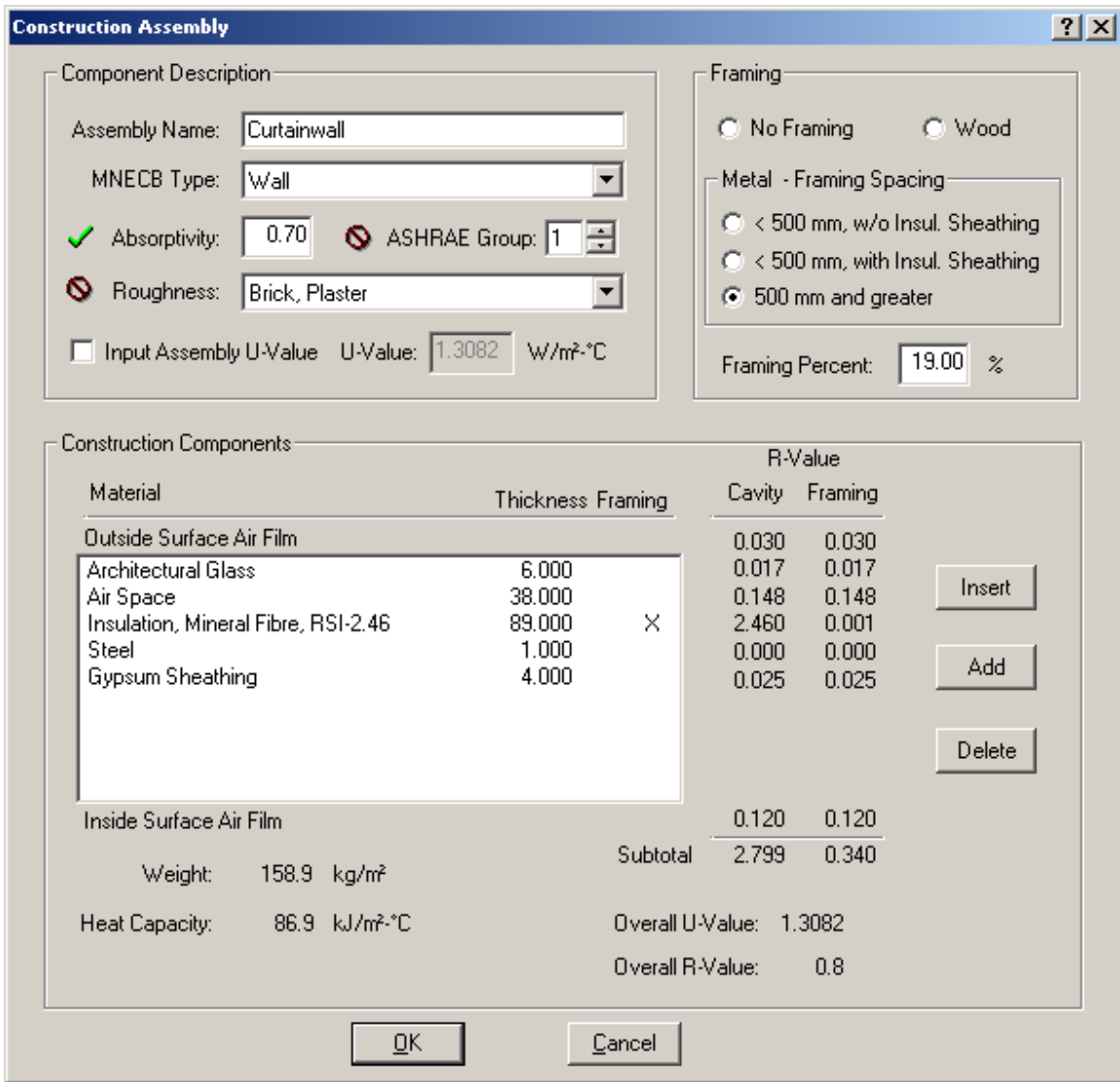
Figure 7-2 – EE4 Description for a Spandrel Panel

7.7   Balconies and Wall/Floor Junctions

Junctions

Wall/floor or wall/roof junctions can be an area of high heat loss because of the difficulty in insulating these constructions. The MNECCB (Sentence 3.2.1.2.(3)) requires that the U-value of these junctions be no more than twice the prescriptive values for the walls (as given in MNECB Appendix A). If this clause is met, it is permissible to model the entire wall using the U-value of the wall (for both the reference and proposed cases) and

ignore the extra heat transfer at the junctions. In attic-type roofs, the impact of insulation reductions at the junction between the roof and the ceiling can also be ignored provided the thermal transmittance is less than two times that given by Appendix A for the wall, roof, or exposed floor.

If MNECCB Sentence 3.2.1.2.(3) is <u>not</u> met, the junction area and its U-value need to be entered as a separate wall assembly. The junction assembly should be built up of construction elements in the junction.

Miscellaneous small envelope penetrations due to pipes, ducts, HVAC equipment, shelf angles, ties, fasteners and other minor structural members, can be ignored provided that insulation is installed tightly against the outline of the envelope penetration. (MNECB Sentence 3.2.1.2.(4)).

Major structural penetrations such as fire walls and floor or roof slabs that penetrate the building envelope may be ignored provided that insulation is installed tight to the edge of the penetration and that the sum of the cross sectional areas of envelope penetrations is less than 2% of the above ground building envelope area. (MNECCB Sentence 3.2.1.2.(5))

Balconies

Concrete balconies are common in high-rise residential buildings. The thermal impact of these penetrations can be ignored provided that the penetration area does not exceed 2% of the above grade building envelope area (MNECB Sentences 3.2.2.(1)-(5)). To meet this requirement, balconies cannot cover more than half of the building perimeter. For large balcony areas, a separate wall assembly should be entered for the balcony. The balcony U-value can be calculated using the FRAME or other 2-D heat transfer program. Alternatively, a U-value of 5.5 W/m^2°C (based on the wall area represented by the balcony cross-section) can be used.

7.8 Modeling Unconditioned or Partially Conditioned Zones

Unconditioned Space (unheated vestibules, parking garages)

As discussed in Section 2.4, most unconditioned zones can be ignored. However, if desired, these zones can be modeled using the procedure described below. Note: for some HVAC systems (e.g. heat pump, fan coil, induction systems), the EE4 program does not allow unconditioned spaces. In these cases, the unconditioned zone should be ignored and treated as described in Section 2.4.

1.   Define the area as a separate zone (unconditioned zones cannot be the first zone listed in a system in the EE4 building tree).

2.   Define the zone as indirectly conditioned (Zone Element General Tab).

3.   Define exterior walls, floors and roof in the conventional manner.

4.   Define walls, floors, and roofs between unconditioned zone and conditioned zone as an "interior partitions." These partitions should be defined in each conditioned zone.

5.   Define appropriate zone function or set occupant density to 1750 m^2/occupant for unoccupied areas.

6.   Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads.

7.   For parking garages, define lighting power; for unlit spaces add one small light (this allows the EE4 simulation to run).

Partially Conditioned Space (crawlspaces, heated parking garage)

Partially conditioned zones are areas of the building that are not heated or cooled to standard thermostat settings. This definition also includes adjacent zones operated at significantly different temperatures (see Section 3.2) or when an air-conditioned zone is adjacent to a non-air-conditioned zone. This last case is common in light industrial buildings where the front office is air-conditioned but the back production area is not.

The procedure for modeling partially conditioned zones is as follows.

1.   Define the area as a separate zone.

2.   Define zone as directly conditioned (Zone Element General tab).

3.   Define exterior walls, floors and roof in the conventional manner.

4.   Define walls, floors, roofs between the partially conditioned zone and conditioned zone as an "interior partition"

5.   Define the space function as "storage/warehouse inactive storage" for most spaces or "storage/warehouse material handling" for parking garages.

6.   Set minimum outdoor air, occupant density to zero to accept MNECB defaults.

7.   Enter the desired heating and cooling setpoints (on the Room Element/General Tab) and create the corresponding heating/cooling temperature schedules (in the Schedules Library).

8.   Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads.

9.   Enter the heating and cooling capacity of HVAC system serving the partially conditioned zone.

10.   For lit spaces define lighting power or for unlit spaces add 3.2 Watts/m2 of lighting to correspond to the MNECB reference lighting level for "storage/warehouse inactive storage"

Unconditioned Space as a Supply Air Plenum (crawlspace, mechanical penthouse or floor)

The procedure for modeling these spaces is as follows.

1.   Define the area as a separate zone.

2.   Define zone as indirectly conditioned (Zone Element General Tab).

3.   Define exterior walls, floors and roof in the conventional manner.

4.   Define walls, floors, roofs between unconditioned zone and conditioned zone as an "interior partition". These partitions should be defined in each conditioned zone.

5.   Set occupant density to 1750 m^2/occupant to accept MNECB defaults.

6.   Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads.

7.   Leave summer and winter setpoints and heating/cooling schedules at the default setting.

8.   In the System Element/Outdoor Air Tab, increase the heat recovery effectiveness by 2%. If no heat recovery ventilator is installed, set the heat recovery effectiveness at 2%.

9.   Add one light of minimal wattage to the zone to allow the calculation to proceed.

Partially Conditioned Space as a Supply Air Plenum (crawlspace, mechanical penthouse or floor)

The procedure for modeling these spaces is as follows.

1.   Define the area as a separate zone.

2.   Define zone as directly conditioned (Zone Element General Tab).

3.   Define exterior walls, floors and roof in the conventional manner.

4.   Define walls, floors, roofs between the partially conditioned zone and conditioned zone as an "interior partition". These partitions should be defined in each conditioned zone.

5.   Define space function as "inactive storage" .

6.   Set minimum outdoor air, occupant density to zero to accept MNECB defaults.

7.   Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads.

8.   Enter desired heating and cooling setpoints and create corresponding schedule.

9.   Add heating and cooling capacity of zone HVAC system.

10.   In the System Element, increase the heat recovery effectiveness by 5%. If no heat recovery ventilator is installed, set the heat recovery effectiveness at 4%.

11.   For lit spaces, define lighting power or for unlit spaces add 3.2 Watts/m2 of lighting to correspond to the MNECB reference lighting level for "storage/warehouse inactive storage".

7.9 Interior Partitions

Interior partitions are used to describe interior heat transfer between zones. Interior partitions only need to be modeled if there is significant heat transfer between adjacent zones, which can only occur if there is a temperature difference between the zones. If adjacent zones are kept at the same setpoint temperature, and follow the same heating and cooling schedule, there is no need for an interior partition to be modeled in EE4. However, there are three cases when interior partitions should be specified:

- Adjacent zones have significantly different operating schedules (difference in operating hours is greater than 28 hours per week)
- Adjacent zones are conditioned to different temperatures (difference of greater than 3 Celsius degrees)
- One zone is air conditioned while the other adjacent zone is not

Interior partitions are defined much like exterior walls. Various construction components are entered to determine a total wall R-value. After specifying the construction type, the space to which the interior partition is adjacent must be specified. Interior partitions are only defined in one zone of the two adjacent zones. The same partition should not be entered in two different zones.

8.   MODELING OF ELECTRICAL SYSTEMS

8.1   Lighting Systems

The modeling of lighting systems is relatively straightforward. The lighting power in the proposed design is the sum of the power draws of the lighting fixtures. This value should include the power for the bulbs and the ballasts. Most lights (other than incandescent and halogen) require ballasts. Ballasts increase power requirements by 10 to 25% over the rated bulb power. Lighting power can be taken from manufacturers literature or from the EE4 list of fixtures.

The space function or building type defines the lighting power density in the reference building. If space function is used to define building use, the lighting power density is multiplied by the lighting "Area Factor" to determine the "Lighting Power Allowance". This factor accounts for the increase in lighting power required in small rooms with high ceilings. Figure 6.1 presents graphs of lighting Area Factor. The Area Factor is 1.0 for corridors, electrical/mechanical rooms, spaces in office categories 2 and 3 and indoor athletic areas (MNECB Clause 4.3.3.5). For CBIP simulations, the Area Factor is also 1.0 for office category 1.

Different Lighting Power Densities are given for three types of office spaces. It is important to select the proper office category in the EE4 software.

Office Category 1 (small office areas and open plan offices) applies to:

- Office areas less than 85 m^2 and

- Open plan offices with no partitions or low-rise partitions, i.e. distance between ceiling and top of partition is greater than 1370 mm (4'6")

Office Category 2 (large office areas – medium partition height) applies to:

- Office areas greater than 85 m^2 with medium-height partitions i.e., distance between ceiling and top of partition is between 1070 mm (3'6") and 1370 mm (4'6")

Office Category 3 (large office areas – high partition height) applies to:

- Office areas greater than 85 m^2 with high-rise partitions, i.e. distance between ceiling and top of partition is less than 1070 mm (3'6")

For some projects, the lighting layout may not be defined at the time of CBIP submission, for example speculative office or retail space, where the tenant will be responsible for the lighting design. In these cases, the proposed building should use the same lighting power density (and area factor) as the reference building. In other words, there is no credit or penalty given for the lighting design.
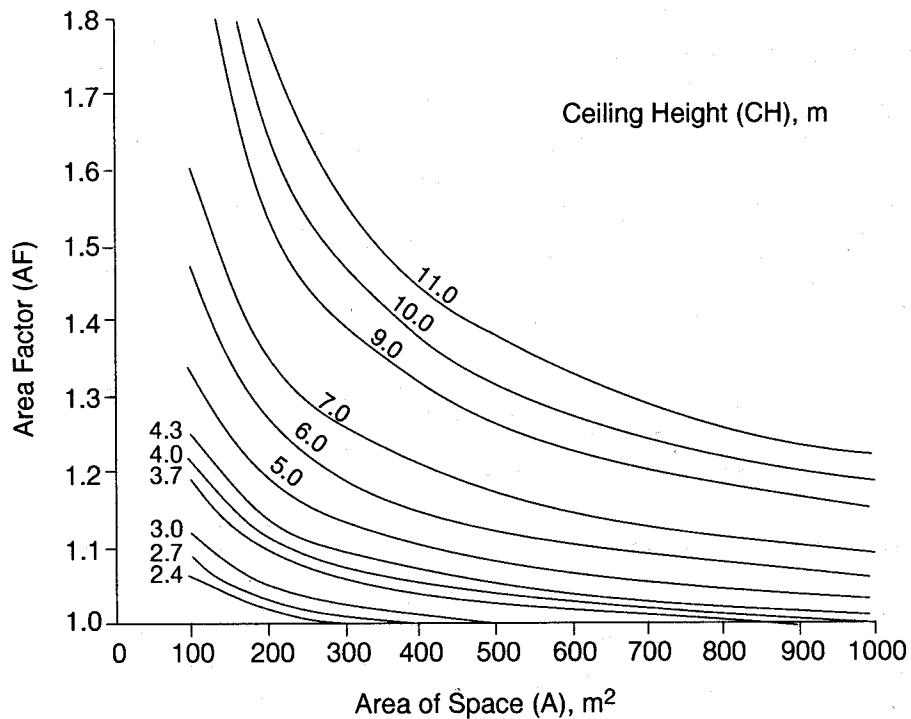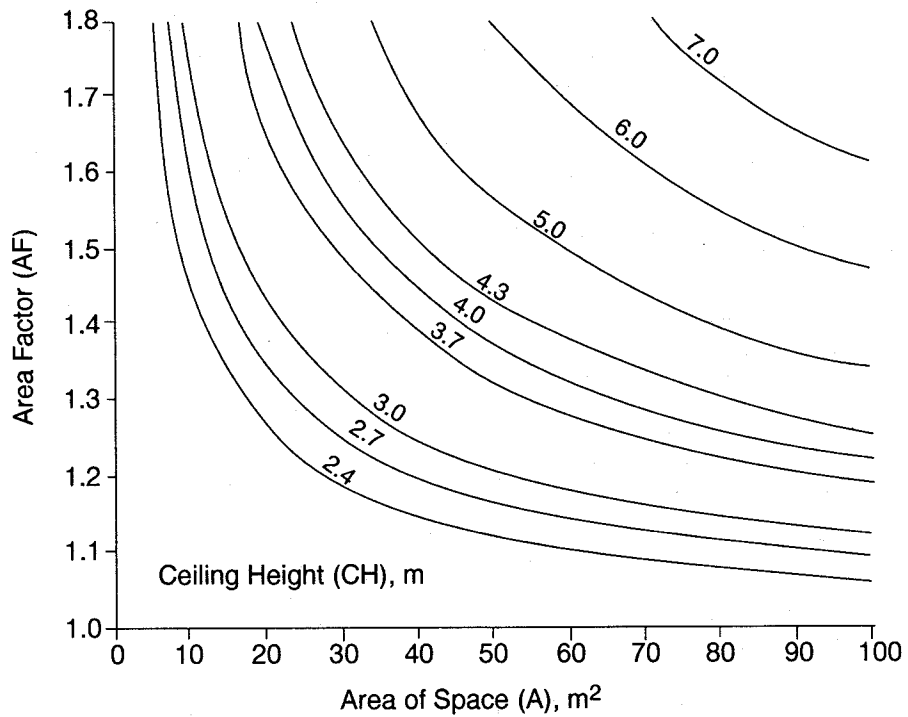
Figure 8-1 – Lighting Area Factor as a Function of Floor Area and Ceiling Height

Lighting Controls

Unlike the MNECB, the CBIP program provides energy credits for lighting controls in order to achieve the 25% energy reduction. Lighting control strategies include occupancy sensors, continuous and staged dimming in response to daylighting, and combinations of these two strategies. Table 6.1 lists the strategies and percentage reduction in lighting power that is given as an energy credit.

Table 8-1 – Lighting Control Strategies

Lighting Control Strategy	Percent Reduction in Lighting Power
Daylighting Sensing Control – Continuous Dimming	30%
- Multiple Step Dimming	20%
- On/Off	10%
Occupancy Sensor	30%
Occupancy & Daylight Sensing – Continuous Dimming	40%
– Multi Step Dimming	40%
– On/Off Dimming	40%

If only daylighting or occupancy sensors control part of the zone, the control fraction should be set to the fraction of the floor area that is controlled. Daylighting control is only effective for those areas that receive natural light. The maximum depth of light penetration is 1.5 times the height of the window head above the floor (see Figure 6.2) or 2.5 if interior or exterior light shelves are used. The window-to-wall ratio must also be at least 20% to receive the daylighting credit. Similarly, the skylight area to floor area must be at least 5% to receive the daylighting credit.
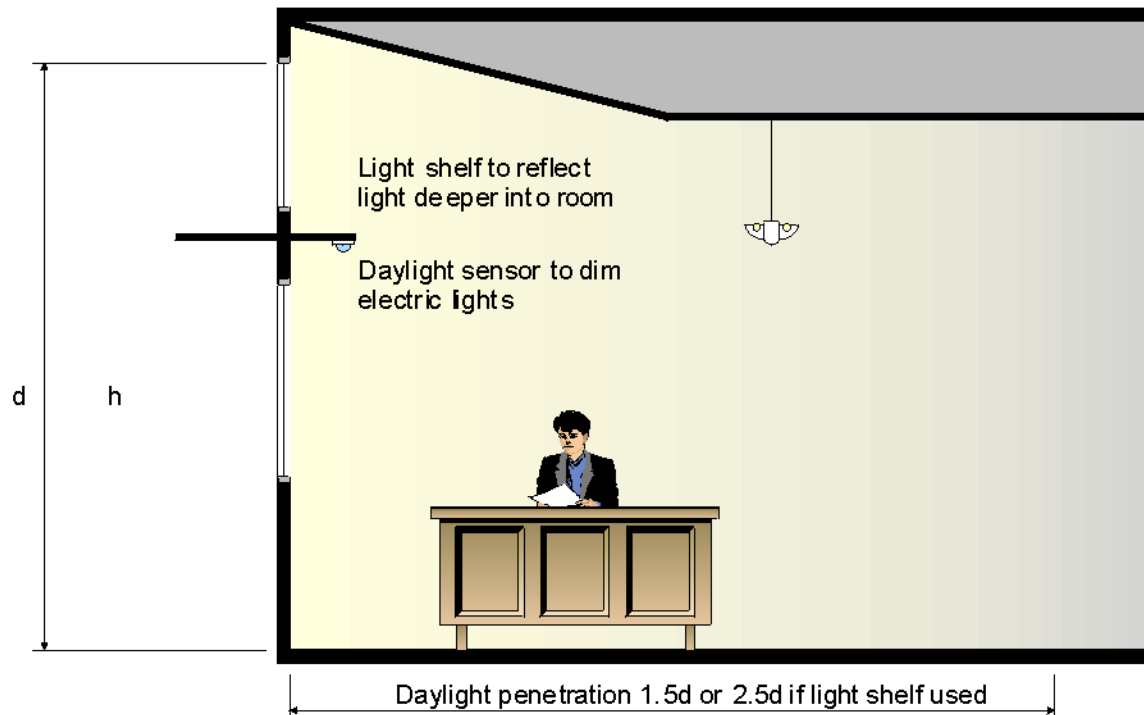
Figure 8-2 – Maximum Daylighting Penetration

It is assumed that occupancy sensors turn the lights off completely. If the lights only dim or not all lights shut off, the control fraction should be adjusted accordingly. For example, if 25% of the lights stay on, the control fraction should be set to 0.75.

Exclusions from Lighting Power Density

Several types of specialty lighting should not be included in the lighting power density. These are listed in the Model National Energy Code Table 4.3.1.2. Included are:

- Lighting for theatrical performances and entertainment
- Display lighting for galleries
- Specialized lighting for research, medical, or dental applications
- Signs and exterior fixtures
- Lighting in high security areas
- Emergency lighting

8.2 Other Electrical Systems

Elevators and Refrigeration Loads

The energy use for elevators and other vertical conveyance devices is not included in the EE4.CBIP model. Nor is energy for commercial or process refrigeration included. The energy use for domestic refrigerators is included in the default building receptacle loads. The same value is used in both the proposed and reference cases. In some buildings (e.g., supermarkets and industrial processes), process loads may be significantly higher than the default receptacle value for the space function or building type. A higher value may be used if deemed appropriate by the designer (the same value will be used in the reference building).

On a case-by-case basis, energy savings are available for using more efficient elevators and heat recovery on refrigeration systems. Simulators should contact the CBIP Technical Manager to inquire whether your application is eligible and for details on how to evaluate these systems.

Renewable Electricity Systems

Any electricity supplied from renewable sources on the building or on the building site and directly connected to the building can be counted towards the CBIP target of 25% energy savings. Renewable energy sources include photovoltaics and wind turbines.

The performance of photovoltaic systems should be determined using the WATSUN-PV or RETScreen computer programs. The performance of wind turbines can be determined using the RETScreen software. RETScreen is available free-of-charge from the web site http://retscreen.gc.ca.

The computer simulated energy savings can be used as a credit in the CBIP program. The proposed building energy consumption is the value determined by EE4 (assuming no renewable energy system) less the electricity supplied by the renewable energy system as determined using WATSUN-PV or RETScreen.

The cost savings should be based on the electricity cost in the last block used by the building. No demand savings are applicable unless it can be demonstrated that the peak monthly building demand will be reduced because of the renewable energy system.

9.   CBIP SUBMISSION GUIDELINES

The CBIP submission procedure is described on the CBIP website at http://cbip.nrcan.gc.ca. Before sending a file to NRCan for submission, the following list should be considered for a timely and successful technical review:

Make sure that simulations have been completed using the very latest version of EE4, downloaded from the site www.ee4.com.

Never submit any simulation files from a building energy program other than EE4 unless NRCan has given written permission. Include a copy of the written permission with the submission.

 Always include the most recent drawings and specifications for the project, including addenda and any change orders.

Include a short written report explaining the important energy efficient features of the building, zoning and modeling strategies employed, any calculations done outside of EE4, and any difficulties encountered during the modeling process.

Take note of the checklist on page 4 of the Performance Path Worksheet, available at http://cbip.nrcan.gc.ca/cbipprocedure/pdfs/performance_e.pdf.

10. TROUBLESHOOTING

Listed in this chapter are suggested solutions to some common system modeling problems or errors. Consult the EE4 on-line help and the website www.ee4.com for further troubleshooting tips.

Q. In the middle of the hourly simulation, the program suddenly crashes and exits.

A. A program crash may be due to insufficient memory or other computer problems, but often occurs because an integral system component has not been defined. For example, if one of the systems is left at "MNECB default or undefined", the program may crash. If a 2-pipe fan coil system has been defined but a chiller has not been defined (a chiller is a necessary component in a 2-pipe fan coil system), the program may crash. Double check to make sure all necessary equipment and systems have been defined. If the crash still occurs, try running the file on a different computer.

Q. I have selected to run both "Proposed" and "Reference" buildings, but at the end of the simulation, all of the Proposed results are zero, and I get a whole bunch of EE4 errors that say "Unable to find SS-F Report".

A. A DOE2 error has likely occurred in the proposed building. Make sure that in the "DOE2 options" tab, "Delete DOE files after run" is NOT selected. Try running the simulations, and when the errors occur again, in the CBIP\DOE directory, find the file named "filename – Proposed.BDL" and open with a text viewer (such as Windows WordPad). Scan the text for the word "error" to locate the problem.

Q. I have found a DOE2 error "Coil leaving temperature must be 6F higher than entering water temperature".

A. Usually this error message occurs due to a high cooling load on the central coil. Try entering a higher supply cooling temperature. (e.g. increase cooling supply temperature from 12.8ºC to 15ºC). Decreasing the central supply fan power is also effective in eliminating this error, because it decreases the cooling load on the coil.

Q. I have a water-loop heat pump system with a boiler/cooling tower source. The proposed DOE file crashes but I cannot seem to find any errors in the BDL file.

A. This situation occurs when the cooling tower is not large enough. Increase the cooling tower capacity and try running the file again.

Q. After the simulation is complete, I get an error "The zone had 500 hours during which the Heating load was not met in the simulation." I have tried to increase the heating capacity but it doesn't seem to do anything.

A. Heating loads may not be met because of insufficient capacity, but can also be due to airflow that is too low or too high, or because of a scheduling problem. Check that the airflow to each zone is sufficient to deliver the heating energy required from a thermodynamic basis. Some zones may have schedules that turn off fans overnight. If "Operate Fans According to Schedule" has been selected, remember that air will not be delivered to zones when the fans are set to be off, so heating loads will need to met with baseboards. If the baseboards do not have sufficient heating capacity to meet the overnight heating load, you may need to select "Fans are always on".

If the system type is "Packaged Constant Volume Multizone" or "Built-up Single Duct Constant Volume", remember that the first zone listed in EE4 is the "control zone", which controls the operation of the central air handler. For example, if the control zone selected is an internal room with no windows or envelope, the zone will demand cooling 365 days per year. The central system will deliver cold air to all zones all the time, even if the secondary zones demand heating. If the secondary zones do not have sufficient baseboard heating capacity to meet the heating load, the unmet heating load error will result. In some cases, it will be impossible to select a control zone that will not result in heating load errors. In these instances, it may be necessary to change the zoning strategy.

If the system is 2-pipe fan coil or 2-pipe induction unit, heating loads might not be met if the Spring/Fall changeover dates are not appropriately defined. Unfortunately, EE4 only allows one spring changeover date and one fall changeover date. (There is no switching back and forth between heating and cooling allowed in the shoulder seasons.) To avoid heating errors, make sure the cooling season is minimal. (June 1 and September 15 are good changeover dates for most Canadian climate regions)

Q.   I get the error "The Plant has a Boiler which will not meet the Heating Load". But I don't even have a boiler or any heating water in the whole building.

A.   During the course of an EE4 simulation, a modeler may try modeling this several different ways. If a boiler was selected at one time, and then later removed, the command may remain in the EE4/DOE2 code. If you are certain that no system, preheat coil, reheat coil, or humidifier is demanding hot water, this error can be ignored.

Q.   I have selected "Purchased Cooling", but I get an error telling me that a chiller is required.

A.   This is a bug in the EE4 software. On the Plant element, uncheck "Purchased Cooling" for a moment and select any default chiller from the list. Then check "Purchased Cooling" again. EE4 will not use the chiller you selected, but will size one based on loads, as it should for purchased cooling situations.

Q: When I try to print a report (or select print preview), I receive an error message: pwdll.dll ERROR: The File: C:\CBIP\FORMS\COVER.TF could not be found! What's wrong?

A: You are probably using Windows 95/98, and when you installed the software, you chose a directory (or folder) name longer than eight characters. The print formatting routines do not work with long filenames under   Windows   95/98. Uninstall the software, then reinstall using a short directory name.

Q: I have the Windows 3.1 operating system. Why doesn't the installation program run?

A: EE4 CBIP is a 32 bit application. It requires either Windows NT or Windows 95/98 to work.

Q: I just opened a sample project. How do I view the entire Building Tree?

A: Click the right mouse button anywhere in the project window, and select Expand Tree from the popup menu to display the entire project.   Right   mouse   clicks

are used in many places in EE4 CBIP to provide quick access to commonly used commands.

Q: The program ran successfully until I installed the latest version of EE4 CBIP. The installation was successful, but every time I try to run the program, it crashes

A: If you already have a version of EE4 CBIP installed on your computer, you must uninstall it before installing a new version. You cannot install the new version over the old one.

Q: Several of the dialogue boxes are too big for my screen. I can't see all the controls.

A: Check your monitor resolution in the Windows   Control Panel. It is probably set to 640 x 480 pixels. The minimum setting to ensure proper software operation is 800 x 600 pixels.

Q: During preparation of the InstallShield(r) Wizard by EE4 CBIP Setup, my computer becomes unresponsive.

A: You are probably using Windows 95/98 in conjunction with a virus detection utility. It is recommended that all virus detection software be disabled during installation of EE4 CBIP. The virus detection software may be re-enabled immediately following successful installation.

Q: I did a "non-compliance" run and the consumption of all fuels came out as zero. What's wrong?

A: When you do a compliance run many of the data required to perform a simulation (e.g. outdoor air ventilation rates) are defaulted according to the compliance rules. However, when you do a non-compliance run you must supply a complete set of data in order for the simulation to progress.

Q: I defined a central system with certain characteristics which working within the building tree. I then added a second system node and defined for it a different set of characteristics. When I go back to the first system I notice that its characteristics have changed, its data now being the same as for the second system. Is this a bug?

A: EE4 CBIP holds the detailed characteristics for central systems within the System Library. The system library may be accessed from the building   tree system nodes, but the data is stored within the library, not the node. The node simply points to a library entry. In this way, you can enter the detailed information on a system in only a single library entry, and reference it from numerous system nodes. This is a powerful, but potentially confusing feature of EE4 CBIP. When you make a change to a library entry all nodes that refer to that library are updated. In your case, you have   probably made a change to the same library item referenced by the first system node when you were defining your second system node. This is why the characteristics of your original system seem to have changed. Note that other nodes in the building tree also access library items and behave in a similar manner.

Q: Why am I not able to access the Service Water tab on the Plant Element of the Building Tree?

A: This is a problem with EE4 users that have the first release of the Windows 95 operating system installed on their computers. Unfortunately, this is a problem unique to this first release of Windows 95 and no patch is available.

Q: I attempted to perform a run with EE4 but noticed that a DOE-2 BDL error occurred indicating that the wall was "too thick or too dense".

A: The case is erroneous data for the material"Insulation, Expanded Rubber (rigid)" in the EE4 materials database. This has been fixed. For any projects which you have created with version 1.20 of EE4 or earlier, you will now need to export the default material library to your project library. Any new project you define will not require that you do this.

Appendix A

Default Window U-Values and Solar Heat Gain Coefficients

Table 5   U-Factors for Various Fenestration Products in W/(m²·K)

	Glass Only		Operable (including sliding and swinging glass doors)					Fixed				
Frame Type / ID Glazing Type	Center of Glass	Edge of Glass	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Insulated Fiberglass/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Insulated Fiberglass/ Vinyl
Single Glazing												
1 3.2 mm glass	5.91	5.91	7.24	6.12	5.14	5.05	4.61	6.42	6.07	5.55	5.55	5.35
2 6.4 mm acrylic/polycarb	5.00	5.00	6.49	5.43	4.51	4.42	4.01	5.60	5.25	4.75	4.75	4.58
3 3.2 mm acrylic/polycarb	5.45	5.45	6.87	5.77	4.82	4.73	4.31	6.01	5.66	5.15	5.15	4.97
Double Glazing												
4 6.4 mm airspace	3.12	3.63	4.93	3.70	3.25	3.13	2.77	3.94	3.56	3.19	3.17	3.04
5 12.7 mm airspace	2.73	3.36	4.62	3.42	3.00	2.87	2.53	3.61	3.22	2.86	2.84	2.72
6 6.4 mm argon space	2.90	3.48	4.75	3.54	3.11	2.98	2.63	3.75	3.37	3.00	2.98	2.85
7 12.7 mm argon space	2.56	3.24	4.49	3.30	2.89	2.76	2.42	3.47	3.08	2.73	2.70	2.58
Double Glazing, e = 0.60 on surface 2 or 3												
8 6.4 mm airspace	2.95	3.52	4.80	3.58	3.14	3.02	2.67	3.80	3.41	3.05	3.03	2.90
9 12.7 mm airspace	2.50	3.20	4.45	3.26	2.85	2.73	2.39	3.42	3.03	2.68	2.66	2.54
10 6.4 mm argon space	2.67	3.32	4.58	3.38	2.96	2.84	2.49	3.56	3.17	2.82	2.80	2.67
11 12.7 mm argon space	2.33	3.08	4.31	3.13	2.74	2.62	2.28	3.28	2.89	2.54	2.52	2.40
Double Glazing, e = 0.40 on surface 2 or 3												
12 6.4 mm airspace	2.78	3.40	4.66	3.46	3.03	2.91	2.56	3.66	3.27	2.91	2.89	2.76
13 12.7 mm airspace	2.27	3.04	4.27	3.09	2.70	2.58	2.25	3.23	2.84	2.49	2.47	2.35
14 6.4 mm argon space	2.44	3.16	4.40	3.21	2.81	2.69	2.35	3.37	2.98	2.63	2.61	2.49
15 12.7 mm argon space	2.04	2.88	4.09	2.93	2.55	2.43	2.10	3.04	2.65	2.31	2.29	2.17
Double Glazing, e = 0.20 on surface 2 or 3												
16 6.4 mm airspace	2.56	3.24	4.49	3.30	2.89	2.76	2.42	3.47	3.08	2.73	2.70	2.58
17 12.7 mm airspace	1.99	2.83	4.05	2.89	2.52	2.39	2.07	2.99	2.60	2.26	2.24	2.13
18 6.4 mm argon space	2.16	2.96	4.18	3.01	2.63	2.51	2.17	3.13	2.74	2.40	2.38	2.26
19 12.7 mm argon space	1.70	2.62	3.83	2.68	2.33	2.21	1.89	2.75	2.36	2.03	2.01	1.90
Double Glazing, e = 0.10 on surface 2 or 3												
20 6.4 mm airspace	2.39	3.12	4.36	3.17	2.78	2.65	2.32	3.32	2.93	2.59	2.56	2.45
21 12.7 mm airspace	1.82	2.71	3.92	2.77	2.41	2.28	1.96	2.84	2.45	2.12	2.10	1.99
22 6.4 mm argon space	1.99	2.83	4.05	2.89	2.52	2.39	2.07	2.99	2.60	2.26	2.24	2.13
23 12.7 mm argon space	1.53	2.49	3.70	2.56	2.22	2.10	1.79	2.60	2.21	1.89	1.86	1.76
Double Glazing, e = 0.05 on surface 2 or 3												
24 6.4 mm airspace	2.33	3.08	4.31	3.13	2.74	2.62	2.28	3.28	2.89	2.54	2.52	2.40
25 12.7 mm airspace	1.70	2.62	3.83	2.68	2.33	2.21	1.89	2.75	2.36	2.03	2.01	1.90
26 6.4 mm argon space	1.87	2.75	3.96	2.81	2.44	2.32	2.00	2.89	2.50	2.17	2.15	2.03
27 12.7 mm argon space	1.42	2.41	3.61	2.48	2.15	2.02	1.71	2.50	2.11	1.79	1.77	1.67
Triple Glazing												
28 6.4 mm airspace	2.16	2.96	4.11	2.89	2.51	2.45	2.16	3.10	2.73	2.38	2.33	2.25
29 12.7 mm airspace	1.76	2.67	3.80	2.60	2.25	2.19	1.91	2.76	2.39	2.05	2.01	1.93
30 6.4 mm argon space	1.93	2.79	3.94	2.73	2.36	2.30	2.01	2.90	2.54	2.19	2.15	2.07
31 12.7 mm argon space	1.65	2.58	3.71	2.52	2.17	2.12	1.84	2.66	2.30	1.96	1.91	1.84
Triple Glazing, e = 0.20 on surface 2,3,4, or 5												
32 6.4 mm airspace	1.87	2.75	3.89	2.69	2.32	2.27	1.98	2.86	2.49	2.15	2.10	2.03
33 12.7 mm airspace	1.42	2.41	3.54	2.36	2.02	1.97	1.70	2.47	2.10	1.77	1.73	1.66
34 6.4 mm argon space	1.59	2.54	3.67	2.48	2.13	2.08	1.80	2.61	2.25	1.91	1.87	1.80
35 12.7 mm argon space	1.25	2.28	3.40	2.23	1.91	1.86	1.59	2.32	1.96	1.63	1.59	1.52
Triple Glazing, e = 0.20 on surfaces 2 or 3 and 4 or 5												
36 6.4 mm airspace	1.65	2.58	3.71	2.52	2.17	2.12	1.84	2.66	2.30	1.96	1.91	1.84
37 12.7 mm airspace	1.14	2.19	3.31	2.15	1.84	1.78	1.52	2.23	1.86	1.54	1.49	1.43
38 6.4 mm argon space	1.31	2.32	3.45	2.27	1.95	1.90	1.62	2.37	2.01	1.68	1.63	1.56
39 12.7 mm argon space	0.97	2.05	3.18	2.03	1.72	1.67	1.41	2.08	1.71	1.39	1.35	1.29
Triple Glazing, e = 0.10 on surfaces 2 or 3 and 4 or 5												
40 6.4 mm airspace	1.53	2.49	3.63	2.44	2.10	2.05	1.77	2.57	2.20	1.86	1.82	1.75
41 12.7 mm airspace	1.02	2.10	3.22	2.07	1.76	1.71	1.45	2.13	1.76	1.44	1.40	1.33
42 6.4 mm argon space	1.19	2.23	3.36	2.19	1.87	1.82	1.55	2.27	1.91	1.58	1.54	1.47
43 12.7 mm argon space	0.80	1.92	3.05	1.90	1.61	1.56	1.30	1.93	1.57	1.25	1.21	1.15
Quadruple Glazing, e = 0.10 on surfaces 2 or 3 and 4 or 5												
44 6.4 mm airspaces	1.25	2.28	3.40	2.23	1.91	1.86	1.59	2.32	1.96	1.63	1.59	1.52
45 12.7 mm airspaces	0.85	1.96	3.09	1.94	1.65	1.60	1.34	1.98	1.62	1.30	1.26	1.19
46 6.4 mm argon spaces	0.97	2.05	3.18	2.03	1.72	1.67	1.41	2.08	1.71	1.39	1.35	1.29
47 12.7 mm argon spaces	0.68	1.83	2.96	1.82	1.54	1.48	1.23	1.84	1.47	1.16	1.11	1.05
48 6.4 mm krypton spaces	0.68	1.83	2.96	1.82	1.54	1.48	1.23	1.84	1.47	1.16	1.11	1.05

Notes:
1. All heat transmission coefficients in this table include film resistances and are based on winter conditions of −18°C outdoor air temperature and 21°C indoor air temperature, with 24 km/h outdoor air velocity and zero solar flux. With the exception of single glazing, small changes in the indoor and outdoor temperatures will not significantly affect overall U-factors. The coefficients are for vertical position except skylight values, which are for 20° from horizontal with heat flow up.

2. Glazing layer surfaces are numbered from the outdoor to the indoor. Double, triple and quadruple refer to the number of glazing panels. All data are based on 3 mm glass, unless otherwise noted. Thermal conductivities are: 0.917 W/(m·K) for glass, and 0.19 W/(m·K) for acrylic and polycarbonate.
3. Standard spacers are metal. Edge-of-glass effects assumed to extend over the 65 mm band around perimeter of each glazing unit as in Figure 3.

Table 5   U-Factors for Various Fenestration Products in W/(m²·K) (Concluded)

| Vertical Installation | | | | | Sloped Installation | | | | | | | | | | |
| Garden Windows | | Curtainwall | | | Glass Only (Skylights) | | Manufactured Skylight | | | | Site-Assembled Sloped/Overhead Glazing | | | |
Aluminum without Thermal Break	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing	Center of Glass	Edge of Glass	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/ Aluminum Clad Wood	Wood/ Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing	ID
14.76	13.13	6.93	6.30	6.30	6.76	6.76	11.24	10.73	9.96	8.34	7.73	7.09	7.09	1
13.23	11.71	6.11	5.48	5.48	5.85	5.85	10.33	9.82	9.07	7.45	6.90	6.26	6.26	2
14.00	12.42	6.52	5.89	5.89	6.30	6.30	10.79	10.27	9.52	7.89	7.31	6.67	6.67	3
10.30	9.16	4.47	3.84	3.59	3.29	3.75	7.44	6.32	5.94	4.79	4.64	3.99	3.74	4
9.72	8.68	4.14	3.51	3.26	3.24	3.71	7.39	6.27	5.90	4.74	4.59	3.95	3.70	5
9.97	8.88	4.28	3.65	3.40	3.01	3.56	7.19	6.06	5.70	4.54	4.40	3.75	3.50	6
9.47	8.47	3.99	3.36	3.11	3.01	3.56	7.19	6.06	5.70	4.54	4.40	3.75	3.50	7
10.05	8.95	4.33	3.70	3.45	3.07	3.60	7.24	6.11	5.75	4.59	4.45	3.80	3.55	8
9.38	8.40	3.94	3.31	3.06	3.01	3.56	7.19	6.06	5.70	4.54	4.40	3.75	3.50	9
9.63	8.61	4.09	3.46	3.21	2.78	3.40	6.98	5.86	5.49	4.34	4.20	3.56	3.31	10
9.13	8.19	3.80	3.17	2.92	2.78	3.40	6.98	5.86	5.49	4.34	4.20	3.56	3.31	11
9.80	8.75	4.18	3.55	3.30	2.90	3.48	7.09	5.96	5.59	4.44	4.30	3.66	3.41	12
9.05	8.12	3.75	3.12	2.87	2.84	3.44	7.03	5.91	5.54	4.39	4.25	3.61	3.36	13
9.30	8.33	3.89	3.26	3.01	2.50	3.20	6.73	5.60	5.24	4.09	3.96	3.32	3.07	14
8.71	7.83	3.55	2.92	2.67	2.61	3.28	6.83	5.70	5.34	4.19	4.06	3.41	3.16	15
9.47	8.47	3.99	3.36	3.11	2.61	3.28	6.83	5.70	5.34	4.19	4.06	3.41	3.16	16
8.62	7.76	3.50	2.87	2.63	2.61	3.28	6.83	5.70	5.34	4.19	4.06	3.41	3.16	17
8.88	7.98	3.65	3.02	2.77	2.22	3.00	6.47	5.34	4.99	3.84	3.72	3.07	2.83	18
8.19	7.40	3.26	2.63	2.38	2.27	3.04	6.52	5.39	5.04	3.89	3.77	3.12	2.87	19
9.21	8.26	3.84	3.22	2.97	2.50	3.20	6.73	5.60	5.24	4.09	3.96	3.32	3.07	20
8.36	7.55	3.36	2.73	2.48	2.50	3.20	6.73	5.60	5.24	4.09	3.96	3.32	3.07	21
8.62	7.76	3.50	2.87	2.63	2.04	2.88	6.31	5.18	4.84	3.69	3.57	2.93	2.68	22
7.94	7.18	3.11	2.48	2.23	2.16	2.96	6.41	5.29	4.94	3.79	3.67	3.03	2.78	23
9.13	8.19	3.80	3.17	2.92	2.39	3.12	6.62	5.50	5.14	3.99	3.87	3.22	2.97	24
8.19	7.40	3.26	2.63	2.38	2.44	3.16	6.67	5.55	5.19	4.04	3.91	3.27	3.02	25
8.45	7.62	3.41	2.78	2.53	1.93	2.79	6.21	5.08	4.73	3.58	3.48	2.83	2.58	26
7.76	7.04	3.01	2.39	2.14	2.04	2.88	6.31	5.18	4.84	3.69	3.57	2.93	2.68	27
see	see	3.58	2.97	2.65	2.22	3.00	6.38	5.07	4.77	3.63	3.65	3.02	2.71	28
note	note	3.24	2.63	2.31	2.04	2.88	6.22	4.92	4.62	3.48	3.51	2.88	2.56	29
7	7	3.39	2.77	2.46	1.99	2.83	6.17	4.86	4.56	3.43	3.46	2.83	2.51	30
		3.14	2.53	2.21	1.87	2.75	6.07	4.76	4.46	3.33	3.36	2.73	2.41	31
see	see	3.34	2.73	2.41	1.93	2.79	6.12	4.81	4.51	3.38	3.41	2.78	2.46	32
note	note	2.95	2.33	2.02	1.76	2.67	5.96	4.65	4.36	3.22	3.26	2.63	2.32	33
7	7	3.09	2.48	2.16	1.59	2.54	5.81	4.50	4.21	3.07	3.11	2.49	2.17	34
		2.80	2.19	1.87	1.53	2.49	5.75	4.44	4.15	3.02	3.07	2.44	2.12	35
see	see	3.14	2.53	2.21	1.65	2.58	5.86	4.55	4.26	3.12	3.16	2.53	2.22	36
note	note	2.70	2.09	1.77	1.53	2.49	5.75	4.44	4.15	3.02	3.07	2.44	2.12	37
7	7	2.85	2.24	1.92	1.36	2.36	5.60	4.29	4.00	2.86	2.92	2.29	1.97	38
		2.55	1.94	1.62	1.25	2.28	5.49	4.18	3.90	2.76	2.82	2.19	1.87	39
see	see	3.05	2.43	2.11	1.53	2.49	5.75	4.44	4.15	3.02	3.07	2.44	2.12	40
note	note	2.60	1.99	1.67	1.42	2.41	5.65	4.34	4.05	2.91	2.97	2.34	2.02	41
7	7	2.75	2.14	1.82	1.19	2.23	5.44	4.13	3.84	2.71	2.77	2.14	1.82	42
		2.40	1.79	1.47	1.14	2.19	5.38	4.07	3.79	2.66	2.72	2.09	1.78	43
		2.80	2.19	1.87	1.25	2.28	5.49	4.18	3.90	2.76	2.82	2.19	1.87	44
see	see	2.45	1.84	1.52	1.08	2.14	5.33	4.02	3.74	2.60	2.67	2.04	1.73	45
note	note	2.55	1.94	1.62	1.02	2.10	5.28	3.97	3.69	2.55	2.62	1.99	1.68	46
7	7	2.31	1.69	1.38	0.91	2.01	5.17	3.86	3.59	2.45	2.52	1.90	1.58	47
		2.31	1.69	1.38	0.74	1.87	5.01	3.70	3.43	2.29	2.38	1.75	1.43	48

Table 11   Visible Transmission (VT), Shading Coefficient (SC), and Solar Heat Gain Coefficient (SHGC) at Normal Incidence for Single Pane Glass and Insulating Glass

Glass Thick, ID mm	Center Glazing VT	Center Glazing SC	Glazing SHGC at Specified Incidence Angles — Normal 0°	40°	50°	60°	70°	Hemis. (Diffuse)	Total Window SHGC at Normal Incidence — Aluminum Operable	Fixed	Other Frames Operable	Fixed	Total Window VT at Normal Incidence — All Frames Operable	Fixed
Uncoated Single Glazing														
1a 3.2 Clear	0.90	1.00	0.86	0.85	0.83	0.78	0.67	0.78	0.75	0.78	0.63	0.75	0.65	0.78
1b 6.4 Clear	0.89	0.94	0.81	0.80	0.77	0.73	0.62	0.73	0.71	0.74	0.60	0.71	0.65	0.78
1c 3.2 Bronze	0.68	0.85	0.73	0.71	0.69	0.64	0.55	0.65	0.64	0.67	0.54	0.64	0.49	0.59
1d 6.4 Bronze	0.55	0.73	0.62	0.60	0.58	0.54	0.46	0.55	0.55	0.57	0.46	0.54	0.40	0.48
1e 3.2 Green	0.82	0.82	0.71	0.68	0.66	0.62	0.53	0.63	0.62	0.65	0.53	0.62	0.60	0.71
1f 6.4 Green	0.74	0.68	0.58	0.56	0.54	0.51	0.44	0.52	0.51	0.53	0.43	0.51	0.54	0.64
1g 3.2 Gray	0.62	0.82	0.70	0.68	0.66	0.61	0.53	0.63	0.61	0.64	0.52	0.61	0.45	0.54
1h 6.4 Gray	0.43	0.65	0.56	0.53	0.51	0.48	0.41	0.49	0.50	0.51	0.42	0.49	0.31	0.37
1i 6.4 Bluegreen	0.75	0.72	0.62	0.59	0.57	0.54	0.46	0.55	0.55	0.57	0.46	0.54	0.54	0.65
Reflective Single Glazing														
1j 6.4 SS on CLR 8%	0.08	0.22	0.19	0.19	0.18	0.17	0.15	0.17	0.18	0.18	0.15	0.17	0.06	0.07
1k 6.4 SS on CLR 14%	0.14	0.29	0.25	0.25	0.24	0.23	0.20	0.23	0.23	0.24	0.19	0.22	0.10	0.12
1l 6.4 SS on CLR 20%	0.20	0.36	0.31	0.30	0.30	0.28	0.24	0.28	0.28	0.29	0.24	0.27	0.15	0.17
1m 6.4 SS on GRN 14%	0.12	0.29	0.25	0.25	0.24	0.23	0.20	0.23	0.23	0.24	0.19	0.22	0.09	0.10
1n 6.4 TI on CLR 20%	0.20	0.34	0.29	0.29	0.28	0.26	0.23	0.27	0.27	0.27	0.22	0.26	0.15	0.17
1o 6.4 TI on CLR 30%	0.30	0.45	0.39	0.38	0.37	0.35	0.30	0.35	0.35	0.36	0.29	0.34	0.22	0.26
Uncoated Double Glazing														
5a 3.2 CLR CLR	0.81	0.87	0.75	0.73	0.70	0.63	0.49	0.65	0.66	0.68	0.55	0.66	0.59	0.71
5b 6.4 CLR CLR	0.78	0.81	0.70	0.68	0.65	0.58	0.45	0.60	0.61	0.64	0.52	0.61	0.57	0.68
5c 3.2 BRZ CLR	0.62	0.72	0.62	0.59	0.57	0.51	0.39	0.53	0.55	0.57	0.46	0.54	0.45	0.54
5d 6.4 BRZ CLR	0.48	0.59	0.50	0.47	0.45	0.40	0.31	0.42	0.45	0.46	0.37	0.44	0.35	0.42
5e 3.2 GRN CLR	0.74	0.70	0.60	0.57	0.55	0.49	0.38	0.51	0.53	0.55	0.45	0.53	0.54	0.64
5f 6.4 GRN CLR	0.66	0.54	0.47	0.44	0.42	0.38	0.30	0.40	0.42	0.43	0.35	0.41	0.48	0.57
5g 3.2 GRY CLR	0.56	0.69	0.59	0.57	0.54	0.48	0.37	0.50	0.52	0.54	0.44	0.52	0.41	0.49
5h 6.4 GRY CLR	0.40	0.51	0.44	0.42	0.40	0.35	0.28	0.38	0.39	0.41	0.33	0.39	0.29	0.35
5i 6.4 BLUGRN CLR	0.67	0.58	0.50	0.47	0.45	0.40	0.32	0.43	0.45	0.46	0.37	0.44	0.49	0.58
5j 6.4 HI-P GRN CLR	0.59	0.46	0.39	0.37	0.35	0.31	0.25	0.33	0.35	0.36	0.29	0.34	0.43	0.51
Reflective Double Glazing														
5k 6.4 SS on CLR 8%,CLR	0.07	0.15	0.13	0.13	0.12	0.12	0.10	0.12	0.13	0.13	0.10	0.12	0.05	0.06
5l 6.4 SS on CLR 14%, CLR	0.13	0.20	0.17	0.17	0.16	0.15	0.12	0.15	0.17	0.16	0.13	0.15	0.09	0.11
5m 6.4 SS on CLR 20%, CLR	0.18	0.26	0.22	0.21	0.21	0.19	0.16	0.19	0.21	0.21	0.17	0.20	0.13	0.16
5n 6.4 SS on GRN 14%, CLR	0.11	0.18	0.16	0.16	0.15	0.14	0.12	0.14	0.16	0.16	0.13	0.14	0.08	0.10
5o 6.4 TI on CLR 20%, CLR	0.18	0.24	0.21	0.20	0.20	0.18	0.15	0.19	0.20	0.20	0.16	0.19	0.13	0.16
5p 6.4 TI on CLR 30%, CLR	0.27	0.33	0.29	0.28	0.27	0.25	0.20	0.25	0.27	0.27	0.22	0.26	0.20	0.24
Low-e Double Glazing, e = 0.2 on Surface 2														
17a 3.2 LE CLR	0.76	0.76	0.65	0.63	0.61	0.55	0.43	0.57	0.57	0.59	0.48	0.57	0.55	0.66
17b 6.4 LE CLR	0.73	0.70	0.60	0.58	0.56	0.51	0.40	0.52	0.53	0.55	0.45	0.53	0.53	0.64
Low-e Double Glazing, e = 0.2 on Surface 3														
17c 3.2 CLR LE	0.76	0.81	0.70	0.68	0.65	0.59	0.46	0.61	0.61	0.64	0.52	0.61	0.55	0.66
17d 6.4 CLR LE	0.73	0.75	0.65	0.63	0.60	0.54	0.42	0.56	0.57	0.59	0.48	0.57	0.53	0.64
17e 3.2 BRZ LE	0.58	0.66	0.57	0.54	0.52	0.46	0.36	0.48	0.50	0.52	0.42	0.50	0.42	0.51
17f 6.4 BRZ LE	0.45	0.52	0.45	0.42	0.40	0.35	0.27	0.37	0.40	0.41	0.34	0.40	0.33	0.39
17g 3.2 GRN LE	0.70	0.63	0.55	0.52	0.50	0.44	0.34	0.46	0.49	0.50	0.41	0.48	0.51	0.61
17h 6.4 GRN LE	0.61	0.48	0.42	0.39	0.37	0.33	0.25	0.35	0.38	0.39	0.32	0.37	0.44	0.53
17i 3.2 GRY LE	0.53	0.63	0.54	0.51	0.49	0.43	0.33	0.46	0.48	0.50	0.40	0.47	0.38	0.46
17j 6.4 GRY LE	0.37	0.46	0.39	0.36	0.34	0.31	0.24	0.33	0.35	0.36	0.29	0.34	0.27	0.32
17k 6.4 BLUGRN LE	0.62	0.52	0.45	0.42	0.40	0.35	0.27	0.37	0.40	0.41	0.34	0.40	0.45	0.54
17l 6.4 HI-P GRN LE	0.55	0.40	0.34	0.31	0.29	0.26	0.20	0.28	0.31	0.32	0.26	0.30	0.40	0.48
Low-e Double Glazing, e = 0.1 on Surface 2														
21a 3.2 LE CLR	0.75	0.62	0.54	0.52	0.49	0.44	0.34	0.46	0.48	0.50	0.40	0.47	0.54	0.65
21b 6.4 LE CLR	0.72	0.59	0.51	0.49	0.47	0.42	0.32	0.44	0.45	0.47	0.38	0.45	0.52	0.63
21l 6.4 HI-P GRN W/LE CLR	0.57	0.36	0.31	0.30	0.29	0.26	0.21	0.27	0.28	0.29	0.24	0.27	0.41	0.50
Low-e Double Glazing, e = 0.1 on Surface 3														
21c 3.2 CLR LE	0.75	0.69	0.60	0.58	0.56	0.51	0.41	0.53	0.53	0.55	0.45	0.53	0.54	0.65
21d 6.4 CLR LE	0.72	0.66	0.56	0.54	0.52	0.47	0.38	0.49	0.50	0.51	0.42	0.49	0.52	0.63
21e 3.2 BRZ LE	0.57	0.56	0.48	0.46	0.43	0.39	0.31	0.41	0.43	0.44	0.36	0.42	0.41	0.50
21f 6.4 BRZ LE	0.45	0.45	0.39	0.37	0.34	0.31	0.24	0.33	0.35	0.36	0.29	0.34	0.33	0.39
21g 3.2 GRN LE	0.68	0.57	0.49	0.47	0.44	0.40	0.31	0.42	0.44	0.45	0.37	0.43	0.49	0.59
21h 6.4 GRN LE	0.61	0.45	0.39	0.36	0.34	0.30	0.24	0.33	0.35	0.36	0.29	0.34	0.44	0.53
21i 3.2 GRY LE	0.52	0.53	0.46	0.44	0.41	0.37	0.29	0.39	0.41	0.42	0.34	0.41	0.38	0.45
21j 6.4 GRY LE	0.37	0.40	0.35	0.33	0.31	0.28	0.22	0.29	0.32	0.33	0.26	0.31	0.27	0.32
21k 6.4 BLUGRN LE	0.62	0.48	0.42	0.39	0.37	0.33	0.26	0.35	0.38	0.39	0.32	0.37	0.45	0.54

Table 11   Visible Transmission (VT), Shading Coefficient (SC), and Solar Heat Gain Coefficient (SHGC) at Normal Incidence for Single Pane Glass and Insulating Glass (*Continued*)

Glazing System Glass Thick, ID mm	Center Glazing VT	Center Glazing SC	Glazing SHGC at Specified Incidence Angles Normal 0°	40°	50°	60°	70°	Hemis. (Diffuse)	Total Window SHGC at Normal Incidence Aluminum Operable	Fixed	Other Frames Operable	Fixed	Total Window VT at Normal Incidence All Frames Operable	Fixed
Low-e Double Glazing, e = 0.05 on Surface 2														
25a 3.2 LE CLR	0.72	0.48	0.41	0.38	0.34	0.26	0.14	0.35	0.37	0.38	0.31	0.36	0.52	0.63
25b 6.4 LE CLR	0.70	0.43	0.37	0.34	0.31	0.24	0.13	0.32	0.33	0.34	0.28	0.33	0.51	0.61
25c 6.4 BRZ W/LE CLR	0.42	0.30	0.26	0.24	0.22	0.18	0.10	0.23	0.24	0.24	0.20	0.23	0.31	0.37
25d 6.4 GRN W/LE CLR	0.60	0.35	0.30	0.28	0.25	0.20	0.11	0.26	0.28	0.28	0.23	0.27	0.44	0.52
25e 6.4 GRY W/LE CLR	0.35	0.27	0.24	0.22	0.20	0.16	0.10	0.20	0.22	0.23	0.18	0.21	0.25	0.30
25f 6.4 BLUE W/LE CLR	0.45	0.32	0.27	0.25	0.23	0.18	0.10	0.23	0.25	0.25	0.21	0.24	0.33	0.39
25g 6.4 HI-P GRN W/LE CLR	0.53	0.31	0.27	0.26	0.25	0.23	0.18	0.24	0.00	0.00	0.22	0.25	0.38	0.46
Triple Glazing														
29a 3.2 CLR CLR CLR	0.74	0.78	0.67	0.65	0.61	0.53	0.39	0.57	0.59	0.61	0.50	0.59	0.54	0.64
29b 6.4 CLR CLR CLR	0.70	0.71	0.61	0.58	0.55	0.48	0.35	0.51	0.54	0.56	0.45	0.54	0.51	0.61
29c 6.4 HI-P GRN CLR CLR	0.53	0.39	0.34	0.31	0.29	0.25	0.19	0.27	0.31	0.32	0.26	0.30	0.38	0.46
Triple Glazing, e = 0.2 on Surface 2														
32a 3.2 LE CLR CLR	0.68	0.69	0.60	0.58	0.55	0.48	0.35	0.51	0.53	0.55	0.45	0.53	0.49	0.59
32b 6.4 LE CLR CLR	0.64	0.62	0.53	0.50	0.47	0.41	0.30	0.44	0.47	0.49	0.39	0.47	0.46	0.56
Triple Glazing, e = 0.2 on Surface 5													0.00	0.00
32c 3.2 CLR CLR LE	0.68	0.72	0.62	0.60	0.56	0.49	0.36	0.52	0.55	0.57	0.46	0.54	0.49	0.59
32d 6.4 CLR CLR LE	0.64	0.65	0.56	0.53	0.50	0.44	0.32	0.47	0.50	0.51	0.42	0.49	0.46	0.56
Triple Glazing, e = 0.1 on Surface 2 and 5														
40a 3.2 LE CLR LE	0.62	0.52	0.45	0.43	0.40	0.36	0.26	0.38	0.40	0.41	0.34	0.40	0.45	0.54
40b 6.4 LE CLR LE	0.59	0.47	0.41	0.39	0.37	0.32	0.24	0.34	0.37	0.38	0.31	0.36	0.43	0.51
Triple Glazing, e = 0.05 on Surface 2 and 4						0.00	0.00							
40c 3.2 LE LE CLR	0.58	0.37	0.32	0.30	0.29	0.26	0.19	0.27	0.29	0.30	0.24	0.28	0.42	0.51
40d 6.4 LE LE CLR	0.55	0.36	0.31	0.29	0.28	0.25	0.19	0.26	0.28	0.29	0.24	0.27	0.40	0.48

KEY:
CLR = clear, GRN = green, GRY = gray, SS = stainless steel reflective coating, TI = titanium reflective coating
Reflective coating decsriptors include percent visible transmittance as x%.
Hi-P GRN = high performance green tinted glass, LE = glass with a low-emissivity coating with an emittance of e = 0.xx

Low-e coating with an emittance of 0.2 is a pyrolytic coating. Other low-e coatings are sputtered coatings.
VT is Visible Transmittance, SC is Shading Coefficient, SHGC, is Solar Heat Gain Coefficient, and HEMIS is the hemispherical SHGC
ID numberss refer to U-factors in Table 5
SHGC at 90° is 0.

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Appendix B

Building Type & Space Functions: Default Assumptions

Table 4.3.2.A Building Type Categories: Default Assumptions						
Space Function	Occupant Density (m²/person)	Receptacle Power (W/m²)	Service Water Heating (W/person)	Minimum O.A. (L/s/m²)	Operating Schedule (Table 3.2.2C)	Lighting Power Density (W/m²)
	(1)	(2)	(3)	(4)	(5)	(6)
Office	25	7.5	90	0.40	A	18
Restaurant	10	1.0	115	1.25	B	15
Retail	30	2.5	40	1.00	C	30
Mall/Concourse/Atria	30	2.5	40	1.00	C	16
School	8	5.0	60	1.00	D	19
Service Establishment	30	2.5	80	1.00	C	22
Warehouse	1500	1.0	300	0.25	E	6
Hotel/motel	25	2.5	500	0.60	F	15
Dwelling Unit	60	5.0	500	0.30	G	9

Table 4.3.2.B Space Functions: Default Assumptions						
Space Function	Occupant Density (m²/person)	Receptacle Power (W/m²)	Service Water Heating (W/person)	Minimum O.A. (L/s/m²)	Operating Schedule (Table 3.2.2C)	Lighting Power Density (W/m²)
	(1)	(2)	(3)	(4)	(5)	(6)
Assembly						
Auditorium/Exhibit	5	2.5	30	1.5	C	17.2
Religious Worship	5	1.0	15	1.5	I	26.9
Theatre - Performance	7.5	2.5	30	1.0	I	16.2
Theratre- Motion Picture	5	2.5	30	1.5	I	16.2
Lobby	10	1.0	0	1.0	C	10.8
Atria	10	2.5	0	0.5	C	7.5
Recreation/Lounge	10	1.0	60	3.0	B	7.5
Conference/Meeting	5	1.0	45	2.0	C	19.4
Indoor Athletics Seating	5	0.0	30	1.5	I	10.8
Recreational Sports Area	5	1.0	90	2.0	I	13.0
Professional Sports Area	5	1.5	60	2.0	I	28.0
Locker Room and Shower	10	2.5	0	2.5	*	8.6
Health/Institutional						
Dental Suite/Exam	20	10.0	90	0.4	C	22.6
Emergency	20	10.0	180	0.75	H	24.7
Laboratory	20	10.0	180	0.75	H	20.4
Medical Supplies	20	1.0	0	0.75	H	25.8
Nursery	20	10.0	90	0.6	H	21.5
Nurse Station	20	2.5	45	0.4	H	22.6
Occ./Physical Therapy	20	10.0	45	0.6	C	17.2
Patient Rooms	20	10.0	90	0.6	H	15.1
Pharmacy	20	2.5	45	0.4	C	18.3
Radiology	20	10.0	90	0.4	H	22.6
Surgical/O.B. Suites	20	10.0	180	0.75	H	22.6
Operating Room	20	10.0	300	0.75	H	75.3
Recovery	20	10.0	180	0.4	H	24.8

Table 4.3.2.B Space Functions: Default Assumptions						
Space Function	Occupant Density (m²/person) (1)	Receptacle Power (W/m²) (2)	Service Water Heating (W/person) (3)	Minimum O.A. (L/s/m²) (4)	Operating Schedule (Table 3.2.2C) (5)	Lighting Power Density (W/m²) (6)
Hotel/Motel						
Banquet Room	10	1.0	90	0.75	B	25.8
Hotel Prefunction	10	2.5	60	0.75	C	25.8
Guest Rooms	25	2.5	600	0.60	F	15.1
Exhibition Hall	10	2.5	60	0.75	C	28.0
Lobby/Recreation Desk	10	2.5	30	0.75	H	21.5
Shop (Non-Industrial)						
Machinery	30	1.0	50	2.50	C	26.9
Electrical/Electronic	30	10.0	50	1.25	C	26.9
Painting	30	1.0	90	5.00	C	17.2
Carpentry	30	10.0	50	1.25	C	24.8
Welding	30	10.0	90	5.00	C	12.9
Auto Repair	20	5.0	90	7.50	C	10.8
Office						
Category 1: Enclosed offices, all open plan offices w/o partitions or w/partitions lower than 1.37m below the ceiling. Offices less than 84 m²	20	7.5	90	0.50	A	19.4
Category 2: Open plan offices 84 m² or larger w/partitions 1.07 m to 1.37 m below the ceiling.	20	7.5	90	0.50	A	20.4
Category 3: Open plan offices 84 m² or larger w/partitions higher than 1.07 m below the ceiling.	20	7.5	90	0.50	A	23.7
Computer/Office Equip.	20	7.5	90	0.50	A	22.6
Filing/Inactive	50	0	0	0.20	A	10.8
Sorting and Mailing	20	7.5	90	0.50	A	19.4
Bank Business Area	20	7.5	90	0.20	A	30.1
Bank Customer Area	30	2.5	0	0.25	A	11.8

Table 4.3.2.B Space Functions: Default Assumptions						
Space Function	Occupant Density (m²/person) (1)	Receptacle Power (W/m²) (2)	Service Water Heating (W/person) (3)	Minimum O.A. (L/s/m²) (4)	Operating Schedule (Table 3.2.2C) (5)	Lighting Power Density (W/m²) (6)
Retail						
Type A: Jewelry merchandising, where minute examination of displayed merchandise is critical.	30	2.5	40	1.00	C	53.8
Type B: Fine merchandising, such as fine apparel and accessories, china, art, crystal and silver where detailed dispay and examination of merchandise is important.	30	2.5	40	1.00	C	34.4
Type C: Mass merchandising such as general apparel, variety, stationery, books, sporting goods, hobby, cameras, gifts, luggage displayed in a warehouse type of building, where focused display and detailed examination of merchandise is important.	30	2.5	40	1.00	C	33.4
Type D: General merchandising such as general apparel, variety, stationery, books, sporting goods, hobby, cameras, gifts, luggage displayed in a department store type of building where general display and examination of merchandise is adequate.	30	2.5	40	1.00	C	35.5
Type E: Food and miscellaneous such as bakeries, hardware and house-wares, grocery, appliances and furniture where appetizing appearance is important.	30	2.5	40	1.00	C	30.1
Type F: Service establishments where functional performance is important.	30	2.5	40	1.00	C	29.1
Tailoring	30	2.5	40	1.00	C	22.6
Dressing / Fitting Rooms	30	0	40	0.25	C	15.1

Table 4.3.2.B
Space Functions: Default Assumptions

Space Function	Occupant Density (m²/person) (1)	Receptacle Power (W/m²) (2)	Service Water Heating (W/person) (3)	Minimum O.A. (L/s/m²) (4)	Operating Schedule (Table 3.2.2C) (5)	Lighting Power Density (W/m²) (6)
Food Service						
Bar/Lounge	10	1.0	90	1.50	B	26.9
Leisure Dining	10	1.0	90	1.00	B	26.9
Fast Food/Cafeteria	10	1.0	120	1.00	B	14.0
Kitchen	20	10.0	120	1.50	B	15.1
Dormitory						
Bedroom	25	2.5	500	0.30	G	11.8
Bedroom/Study	25	2.5	500	0.30	G	15.1
Study Hall	25	2.5	90	0.30	C	19.4
Dwelling Unit	60	5.0	500	0.30	G	9.0
Education						
Classroom	7.5	5.0	65	1.00	D	21.5
Library						
Audio/Visual	20	5.0	90	0.40	C	11.8
Stack - Stack Mounted Lighting	20	0.0	90	0.40	C	16.2
Stack - Ceiling Lighting	20	0.0	90	0.40	C	32.3
Card File/Cataloguing	20	2.5	90	0.40	C	17.2
Reading	20	1.0	90	0.40	C	20.4
Laboratories						
Laboratories	20	10.0	180	0.50	A	24.8
Storage/Warehouse						
Inactive Storage	1750	0.0	300	0.25	E	3.2
Active Storage, Bulky	100	1.0	65	0.25	E	3.2
Active Storage, Fine	50	1.0	65	0.25	E	7.5
Material Handling	20	1.0	65	0.40	E	10.8

Table 4.3.2.B
Space Functions: Default Assumptions

Space Function	Occupant Density (m²/person) (1)	Receptacle Power (W/m²) (2)	Service Water Heating (W/person) (3)	Minimum O.A. (L/s/m²) (4)	Operating Schedule (Table 3.2.2C) (5)	Lighting Power Density (W/m²) (6)
Service and Common						
Mechanical/Electrical Room	200	1.0	0	0.25	*	7.5
Corridors	100	0.0	0	0.25	*	8.6
Toilet and Washrooms	30	1.0	0	1.00	*	8.7
Active Stairway	100	0.0	0	0.25	*	6.5
Emergency Stairway Exit	500	0.0	0	0.25	*	4.3
Air/Bus/Rail Terminals						
Baggage Area	20	2.5	65	0.50	H	10.8
Concourse/Main Thruway	20	0.0	65	0.50	H	9.7
Ticket Counter	10	2.5	65	1.00	H	26.9
Waiting and Lounge	10	0.0	65	1.00	H	12.9
Fire/Police						
Fire Engine Room	25	2.5	325	0.40	H	8.6
Jail Cell	25	2.5	325	0.40	H	8.6
Museum/Gallery						
General Exhibition	5	2.5	60	1.50	C	20.4
Inspection/Restoration	20	5.0	50	0.50	A	45.0
Storage (Artifacts) - Inactive	1000	0.0	60	0.25	E	6.5
Storage (Artifacts) - Active	100	1.0	60	0.25	E	7.5
Laundry						
Washing	20	20.0	60	0.60	C	9.7
Ironing and Sorting	20	20.0	60	0.50	C	14.0

Appendix C

Detailed EE4 System Descriptions

EE4 models 15 types of air handling systems directly. These 15 system types can be used as proxies for a number of other systems not supported by EE4/DOE2 directly or for combination systems. All air handling system types have common elements which are described in section 5 and 6 of this manual.

The following are the common elements to all system types which are described in the central system library:

1. Heating Type and Capacity
2. Enter the source of heat for the heating coil and the output capacity. The coil may be fed by hot water from a central boiler or district system; in this case "hot water" is selected from the drop-down list. Electricity, fossil fuels, or heat pump may also be chosen. If heat pump is selected, electric back-up heating is assumed and the capacity of the back-up heater must be specified. If the heat source does not appear, "other" can be selected; however, this selection corresponds to an MNECB Energy Source Adjustment Factor of 1 and an electric system will be assumed.
3. Heating Rating Type and Efficiency
4. If a fossil fuel source or heat pump is selected as the heat source, the rating type must be selected. For fossil sources, choose between AFUE (Annual Fuel Utilization Efficiency) and thermal efficiency. For heat pump, select either COP (Coefficient of Performance) or EER. (Energy Efficiency Ratio) The heating efficiency value is entered at the bottom of the tab. If hot water or electricity is selected as the heating type, the efficiency is not applicable and cannot be entered.
5. Cooling Characteristics
6. Enter the cooling capacity of the DX, heat pump or chilled water system and the percent of the capacity that is sensible. If the sensible fraction is unknown, choose the default value of 75%.
7. Enter the minimum temperature to which the air is cooled by the unit before being distributed throughout the building.
8. Select the efficiency type (COP or EER) and enter the value at the bottom of the tab. Include the condensing fan power in the COP or EER, but do not include supply fan electrical power.
9. Outdoor Air Ratio, Economizer Characteristics
10. On the outdoor air tab, indicate whether outdoor air is constant at the minimum flow rate, or an economizer is installed. If an economizer is installed, enter the maximum outdoor air ratio (ratio of fresh air to total air) and specify the economizer operation. There are 4 types of economizer operation available:
11. Fixed dry bulb: The economizer will operate when the outdoor air temperature is lower than the cooling setpoint (including setback temperatures) to the limit temperature.
12. Differential dry bulb: The economizer operates when the outdoor air-dry bulb temperature is below the return air-dry bulb temperature.

13. Fixed enthalpy: The economizer will operate when the outdoor air enthalpy is lower than the cooling setpoint (including setback temperatures) to the limit temperature.
14. Differential enthalpy: The economizer will operate when the outdoor air enthalpy is below the return air enthalpy.
    Outdoor air economizers are not available for fan coil and heat pump   make-up air handlers (which is defined as the air handling system)
15. Heat Recovery Effectiveness
16. The sensible heat recovery effectiveness is entered on the "Outdoor Air" tab. The rated effectiveness at ARI conditions should be entered.
17. Supply Fan Operation and Power
18. Three choices are available for supply fan operation:
19. Operate Fans According to Schedule – The fan operates according to the "Fans" schedule entered in the zone element.
20. Fans Are Always On – The fans run continuously.
21. Cycle Main Fans with Setback – The fan operates according to heating setback, defined in the "Heating" setback in the zone element.
22. Fan power can be entered directly in watts, or it can be defined by entering static pressure and efficiency. If static pressure/efficiency is chosen, it must also be indicated whether the fan is a blow-through or draw-through type.
23. The supply fan flow rate must also be entered. The flow rate must be equal to or greater than the minimum outdoor airflow rate required by code for the zone that is served by the system.
    Fan operation options are not available for fan coil and heat pump make-up air handlers (which is defined as the air handling system), because   these fans always follow the fan schedule.
24. Return Fan
25. Enter the return fan static pressure and combined brake horsepower efficiency (motor plus impeller). If a heat recovery ventilator is included, average the efficiency of the return fan and the HRV fan as an approximation of the combined efficiency of the return air system.
26. Return fans are not available for fan coil and heat pump make-up air handlers (which is defined as the air handling system), as the make-up air unit is a supply only system.
27. Humidity
28. If an electric or hot water humidifier is installed, specify the type and minimum humidity setpoint on the "Humidity" tab. Humidifiers are modeled identically in proposed and reference buildings.
29. Preheat Coil
30. If the system contains a preheat coil, select the heat source (electric or hot water) and the setpoint temperature. If the outdoor air temperature is below the setpoint temperature, the preheat coil operates.

The following are the common elements to all system types which are described in the space/room entry tab:

1. In the Room Element/Exhaust Tab, define:
2. Exhaust Fan Flow rate and Power
3. Exhaust fans defined in the Room Element will operate according to the "Fans" schedule entered in the zone element. If the fans are operated intermittently (e.g., kitchen range hood fans that may only operate for 2 hours per day), de-rate

the flow rate and fan power accordingly. For example, if the schedule indicates that fans run 18 hours a day, but the intermittent fan operates only 2 hours per day, reduce the fan power and flow rate by a factor of 9. (18/2)
4. If the intermittent fans are direct fresh air supply and exhaust, enter power under process energy and alter the schedule to match your operation.

System Types

DX Single Zone System

The DX Single Zone System provides constant volume air to a single zone. The system cools by the direct expansion of a refrigerant and may heat with a fuel-fired furnace, hot water from a boiler, an electric resistance heater, or an air-source heat pump. If you use a heat pump for heating, you must define a backup heating system with the fuel type corresponding to the fuel type selected in the mechanical element zone heating inputs. The temperature of the supply air is varied (depends upon the heating load and the output of the system) and heat may be supplemented by an independent heating system (i.e. baseboards) to maintain space temperature (user input for space and schedules for the zone). DX Single Zone Systems can be either packaged (rooftop) units or split systems.

In the Central System Library, in addition to the common elements, define:

1. Zone Reheat Source
2. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If all heat is provided by the rooftop unit, and no reheat units are installed, select "none".
3. In the Zone Element/Mechanical Tab, define:
4. Zone Heating Output
5. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.

Figure 10-1.

DX Single Zone Schematic

Packaged Constant Volume Multizone System

The Packaged Constant Volume Multizone System provides constant volume air to a single control zone plus a number of optional sub-zones. The system cools by the direct expansion of a refrigerant and may heat with a fuel-fired furnace, hot water, an electric resistance heater, or a heat pump. The temperature of the supply air is varied and heat may be supplemented by an independent heating system (i.e. baseboards) to maintain space temperature. Packaged Constant Volume Multizone Systems can be either packaged (rooftop) units or split systems.

In the Central System Library, in addition to the common elements, define:

1. Zone Reheat Source
2. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If all heat is provided by the rooftop unit, and no reheat units are installed, select "none".
3. In the Zone Element/Mechanical Tab, define:
4. Zone Heating Output

5. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.
6. Zone Airflow Rate
7. Enter the zonal airflow rate for each zone served by the system. The value must be greater than or equal to the minimum fresh air requirement.
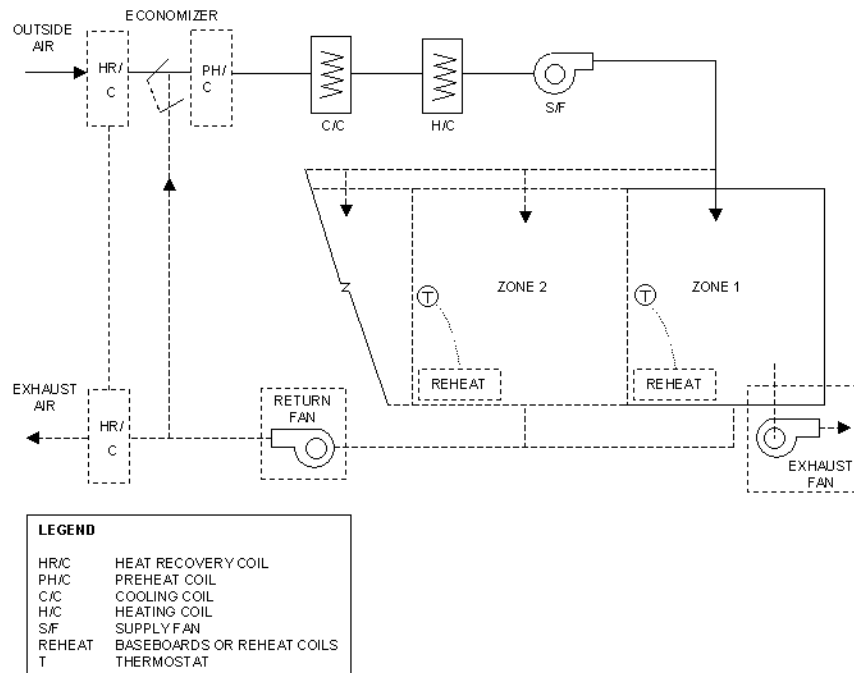

Figure 10-2.

Packaged Constant Volume Multizone System Schematic

Built-Up Single-Duct CV System

The built-up single-duct CV system consists of a central air-handling unit that contains a heating device, cooling coil and a supply air fan. The system provides constant volume heating and cooling to multiple, individually controlled zones. The temperature of the supple air leaving the air-handling unit may be constant, or reset based on the cooling needs of the warmest zone served by the system. Reheat coils or baseboards then provide the heating energy to heat the supply air to the temperatures required to meet the individual zone loads.

In the Central System Library, in addition to the common elements, define:

1. Zone Reheat Source
2. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water

baseboard convectors, or radiant in-floor coils. If all heat is provided by the rooftop unit, and no reheat units are installed, select "none".

3. In the Zone Element/Mechanical Tab, define:
4. Zone Heating Output
5. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.
6. Zone Airflow Rate
7. Enter the zonal airflow rate for each zone served by the system. The value must be greater than or equal to the minimum fresh air requirement.

Figure 10-3.

Built-Up Single-Duct CV System Schematic

Hydronic Heat Pump

In this system, unitary hydronic heat pumps provide both heating and cooling to individually controlled zones. The individual water-to-air heat pumps in each zone accept energy from a common water loop when in heating mode and reject energy to the common water loop when in cooling mode. Heat addition/extraction may be required to maintain the loop temperature if the heating and cooling loads are not balanced. The heat addition/extraction required may be provided by a boiler/cooling tower or by a ground loop. If cooling demand is such that the energy rejected to the loop exceeds the energy added to the loop, heat is rejected. If the heating demand exceeds the cooling demand, heat is added.

A central make-up air unit supplies tempered outdoor air for the zonal heat pumps. EE4 CBIP sets the outdoor airflows to each of the zones to the airflow needed to meet the MNECB minimum outdoor air requirement. You may specify a higher outdoor airflow to each zone in the Room Element/Occupant Tab.

Central System Library inputs are reserved for defining the make-up air system, while the individual heat pump characteristics are defined in the Zone Element/Mechanical Tab. Note that the heat pump heating and cooling outputs and the rated heat pump performance characteristics (heating/cooling COP) defined in the Zone Element/Mechanical Tab should not include the influence of fan power.

In the Zone Element/Mechanical Tab, define:

1. Zone Heating and Cooling Output
2. Enter the heating and cooling capacity of the heat pump serving the zone.
3. Heat Pump Performance
4. Enter the COP for the heat pump in heating and cooling modes at ARI-rated conditions.
5. Airflow Rate and Fan Power
6. Enter the heat pump rated airflow rate and fan power consumption. If the specified COP includes fan power, enter only the flow rate and specify "0" for the fan power. The flow rate must greater than the minimum outdoor air requirement.
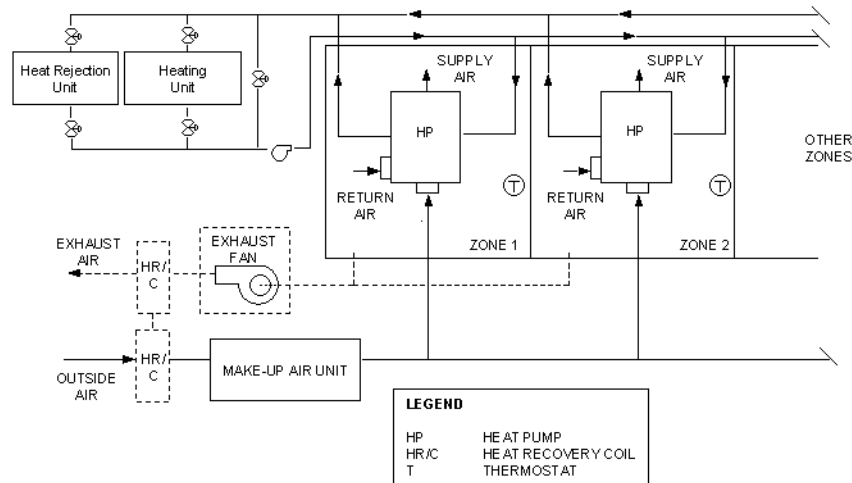
Figure 10-4.

Hydronic Heat Pump Schematic

Packaged VAV

The packaged VAV system is a variable-volume system. Cooling is provided to the zones by the direct expansion of a refrigerant and heating by a fossil fuel-fired furnace, hot water, an electric resistance heater, or a heat pump. The system operates differently in the cooling mode than it does in the heating mode. In cooling mode, zone reset schedules are assumed to control the supply air temperature from the cooling coil. During heating, the volume of air is held constant at the minimum airflow value specified

by the user and the supply air temperature from the air handling unit's heating coil is held constant at 13 °C (55 °F). Reheat coils or baseboards provide the heating energy to heat the supply air from 13 °C (55 °F) to the temperature required to meet the zone loads.

In the Central System Library, in addition to the common elements, define:

1. Zone Reheat Source
2. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If all heat is provided by the rooftop unit, and no reheat units are installed, select "none".
3. In the Zone Element/Mechanical Tab, define:
4. Zone Heating Output
5. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.
6. Zone Airflow Rate
7. Enter the zonal airflow rate for each zone served by the system. The value must be greater than or equal to the minimum fresh air requirement.

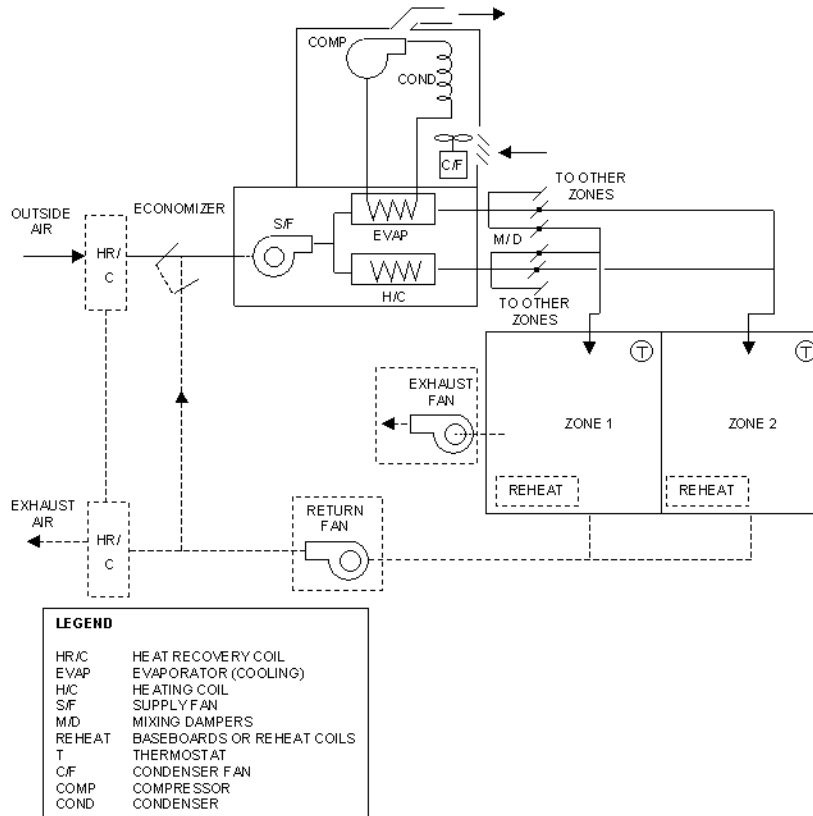

Figure 10-5.

Packaged VAV Schematic

Packaged MZ

This is a multizone constant volume system that provides cooling by the direct expansion of a refrigerant and provides heating either with a fossil fuel-fired furnace, hot

water, or an electric resistance heater. Multizone air handling units contain hot deck and cold deck air streams that are maintained above and below the desired supply temperature. Zone temperatures are maintained by mixing hot and cold air in the proper proportions in response to zone loads. The two air streams are mixed using dampers located within the air-handling unit and the proper temperature air is provided as it leaves the unit. Heat may be supplemented by an independent heating system (i.e. baseboards) to maintain space temperatures in the zones.

The three possible strategies for controlling the heating coil and cooling coil exit temperatures are constant temperature, zone reset and outside air reset. If the user specifies constant temperature coil control, the temperature of the air leaving the associated coil is set to a fixed value, specified by the user. If the user specifies the heating coil control to be zone reset, the hot deck temperature is reset to meet the needs of the coldest zone. Similarly, if zone reset is specified for cooling coil control, the cold deck temperature is reset to meet the needs of the warmest zone. Finally, if the user specifies outside air reset as the heating or cooling coil strategy, the heating and/or cooling supply air temperature is based upon outside air temperature.

In the Central System Library, define:

1. Coil Control
2. For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:
3. Constant Temperature – The cooling supply temperature is set to a constant value.
4. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
5. Outdoor Air Reset – The cooling coil discharge temperature is set hourly based upon the temperature difference between the outdoor air temperature and zone temperature.
6. Heating Supply Temperature
7. Enter the temperature of air leaving the hot deck.
8. Cooling Characteristics
9. Enter the cooling capacity of the DX system and the percent of the capacity that is sensible. If the sensible fraction is unknown, choose the default value of 75%.
10. Enter the temperature of air leaving the cold deck.
11. Select the efficiency type (COP or EER) and enter the value at the bottom of the tab. Include the condensing fan power in the COP or EER, but do not include supply fan electrical power.
12. Zone Reheat Source
13. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If all heat is provided by the rooftop unit, and no reheat units are installed, select "none".
14. In the Zone Element/Mechanical Tab, define:
15. Zone Heating Output
16. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.
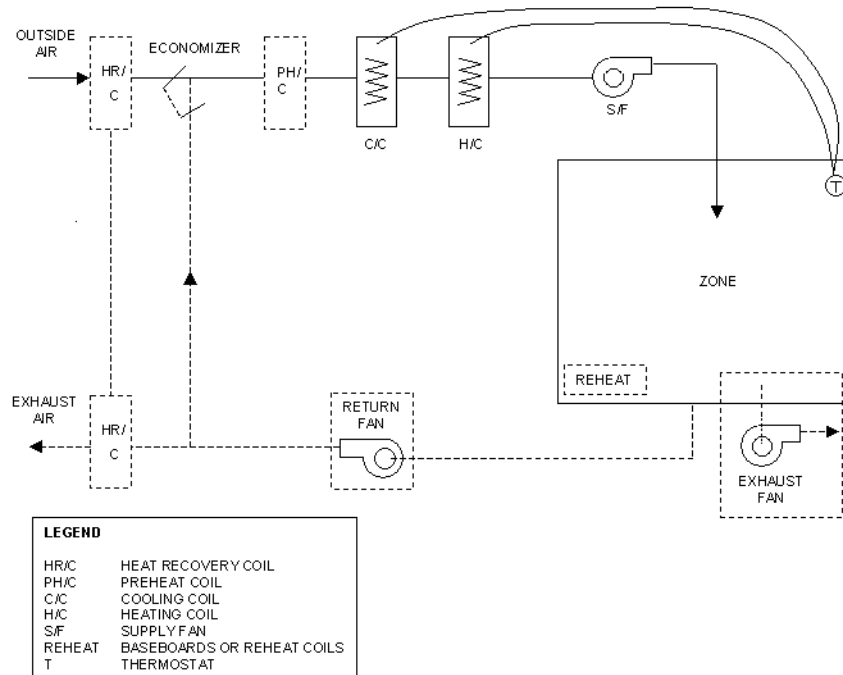17. Zone Airflow Rate

18. Enter the zonal airflow rate for each zone served by the system. The value must be greater than or equal to the minimum fresh air requirement.

Figure 10-6.

Packaged MZ Schematic

Built-up Single Zone

The built-up single zone system is a variable air temperature system that provides constant volume, forced air heating and cooling for a single zone. The air-handling unit contains a heating device, a cooling coil and a supply fan. The temperature of the air supplied to the zone is controlled from a thermostat that senses the space conditions in the zone. Heat may be supplemented by an independent heating system (i.e. baseboards) to maintain the space temperature in the zone.

Optional features: return fan, outdoor air economizer, heat recovery, zone reheat coils/baseboards, preheat coil, exhaust fans in any or all zones.

In the Central System Library, in addition to the common elements, define:

1. Zone Reheat Source
2. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water

baseboard convectors, or radiant in-floor coils. If the rooftop unit provides all heat and no reheat units are installed, select "none".

3. In the Zone Element/Mechanical Tab, define:
4. Zone Heating Output
5. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.

Figure 10-7.

Built-up Single Zone Schematic

Built-up VAV

The built-up VAV system consists of a central air-handling unit that contains a heating device, cooling coil and a supply air fan. Variable-air-volume terminal units are located in each zone. To meet peak cooling loads, the VAV terminal units allow a maximum airflow (input by the user). The airflow rate is reduced proportionally to meet reduced cooling loads and zone reset schedules are assumed to control the supply air temperature from the cooling coil. The system operates differently during heating. The supply airflow rate is held constant at the minimum allowable and the supply air temperature is held constant at 13°C (55 °F). Reheat coils or baseboards then provide the heating energy to heat the supply air from 13°C (55 °F) to the temperature required to meet the zone loads.

Choose one of 4 options for supply fan control in the Central Systems Library:

1. Riding the fan curve
2. Air foil or backward inclined with vanes

3. Forward curved with vanes
4. Variable speed
5. Each of these fan control options alter the fan capacity in accordance with flow requirements and minimum outside air to determine a fan power versus air flow rate factor. The coefficients of the fan curves for the riding fan curve, backward incline airfoil and forward inclined foil are given in MNECB Performance Supplement Figure 5.4.9.A.
6. Fan power can be entered directly in watts, or it can be defined by entering static pressure and efficiency. If static pressure/efficiency is chosen, it must also be indicated whether the fan is a blow-through or draw-through type.
7. Zone Reheat Source
8. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If the rooftop unit provides all heat and no reheat units are installed, select "none".
9. In the Zone Element/Mechanical Tab, define:
10. Terminal Type
11. Select the zone-level terminal type from the dropdown list. Choices are (1) baseboard, (2) VAV terminal, (3) VAV terminal with series fan, or (4) VAV terminal with parallel fan.
12. Zone Heating Output
13. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.
14. Maximum and Minimum Airflow Rates
15. Enter the rated minimum and maximum VAV terminal flow rates. The minimum flow rate must be equal to or greater than the minimum fresh air requirement.
16. Terminal Fan Flow rate and Power
17. If VAV terminal with series or parallel fan is selected as the terminal type, enter the flow rate attributed to the VAV box fan. This is the flow rate of the return or induced air. Also enter the power at this flow rate.
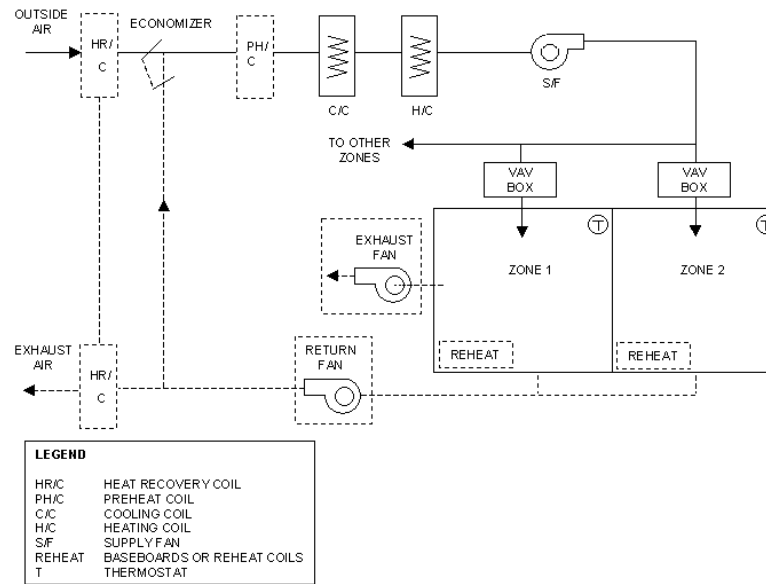
Figure 10-8.

Built-up VAV Schematic

Built-up Multizone

The built-up multizone system is a constant volume system that provides heating and/or cooling to individually controlled zones. The air-handling unit contains a heating device, cooling coil and a supply fan. Multizone air handling units contain hot deck and cold deck air streams which are maintained above and below the desired supply temperature in response to zone loads. The two air streams are mixed using dampers located within the air-handling unit and the proper temperature air is provided as it leaves the unit. Heat may be supplemented by an independent heating system (i.e. baseboards) to maintain the space temperature in the zone.

The three possible strategies for controlling the heating coil and cooling coil exit temperatures are constant temperature, zone reset and outside air reset. If the user specifies constant temperature coil control, the temperature of the air leaving the associated coil is set to a fixed value, specified by the user. If the user specifies the heating coil control to be zone reset, the hot deck temperature is reset to meet the needs of the coldest zone. Similarly, if zone reset is specified for cooling coil control, the cold deck temperature is reset to meet the needs of the warmest zone. Finally, if the user specifies outside air reset as the heating or cooling coil strategy, the heating and/or cooling supply air temperature is based upon outside air temperature.

In the Central System Library, define:

1. Coil Control
2. For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:

3. Constant Temperature – The cooling supply temperature is set to a constant value.
4. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
5. Outdoor Air Reset – The cooling coil discharge temperature is set hourly based upon the temperature difference between the outdoor air temperature and zone temperature.
6. Heating Supply Temperature
7. Enter the temperature of air leaving the hot deck.
8. Cooling Characteristics
9. Enter the cooling capacity of the system and the percent of the capacity that is sensible. If the sensible fraction is unknown, choose the default value of 75%.
10. Enter the temperature of air leaving the cold deck.
11. Zone Reheat Source
12. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If the rooftop unit provides all heat and no reheat units are installed, select "none".
13. In the Zone Element/Mechanical Tab, define:
14. Zone Heating Output
15. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.
16. Zone Maximum and Minimum Airflow Rate
17. Enter the rated minimum and maximum VAV terminal flow rates. The minimum flow rate must be equal to or greater than the minimum fresh air requirement.
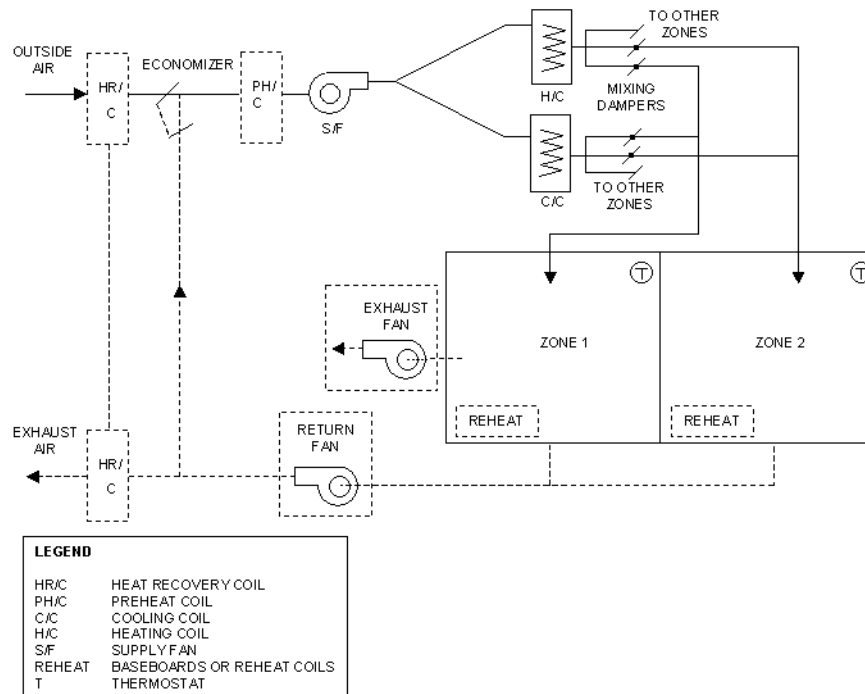
Figure 10-9.

Built-up Multizone Schematic

Dual-Duct

The dual-duct single fan system is a variable-air-volume system. The central air-handling unit maintains hot deck and cold deck temperatures above and below the desired supply temperatures of all zones served. Mixing the hot and cold air streams maintain space temperatures in proper proportions in individual VAV mixing boxes in each zone being served. In order to save energy, dual-duct systems only allow mixing once the airflow has been reduced to the user-specified minimum in a particular zone.

The three possible strategies for controlling the heating coil and cooling coil exit temperatures are constant temperature, zone reset and outside air reset. If the user specifies constant temperature coil control, the temperature of the air leaving the associated coil is set to a fixed value, specified by the user. If the user specifies the heating coil control to be zone reset, the hot deck temperature is reset to meet the needs of the coldest zone. Similarly, if zone reset is specified for cooling coil control, the cold deck temperature is reset to meet the needs of the warmest zone. Finally, if the user specifies outside air reset as the heating or cooling coil strategy, the heating and/or cooling supply air temperature is based upon outside air temperature.

In the Central System Library, define:

1. Coil Control

2. For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:

3. Constant Temperature – The cooling supply temperature is set to a constant value.

4. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.

5. Outdoor Air Reset – The cooling coil discharge temperature is set hourly based upon the temperature difference between the outdoor air temperature and zone temperature.

6. Heating Supply Temperature

7. Enter the temperature of air leaving the hot deck.

8. Cooling Characteristics

9. Enter the cooling capacity of the system and the percent of the capacity that is sensible. If the sensible fraction is unknown, choose the default value of 75%.

10. Enter the temperature of air leaving the cold deck.

11. Choose one of 4 options for supply fan control in the Central Systems Library:

12. Riding the fan curve

13. Air foil or backward inclined with vanes

14. Forward curved with vanes

15. Variable speed

16. Each of these fan control options alter the fan capacity in accordance with flow requirements and minimum outside air to determine a fan power versus air flow rate factor. The coefficients of the fan curves for the riding fan curve, backward incline airfoil and forward inclined foil are given in MNECB Performance Supplement Figure 5.4.9.A.

17. Fan power can be entered directly in watts, or it can be defined by entering static pressure and efficiency. If static pressure/efficiency is chosen, it must also be indicated whether the fan is a blow-through or draw-through type.

18. Zone Reheat Source

19. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If the rooftop unit provides all heat and no reheat units are installed, select "none".

20. In the Zone Element/Mechanical Tab, define:

21. Zone Heating Output

22. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.

23. Zone Airflow Rate

24. Enter the zonal airflow rate for each zone served by the system. The value must be greater than or equal to the minimum fresh air requirement.
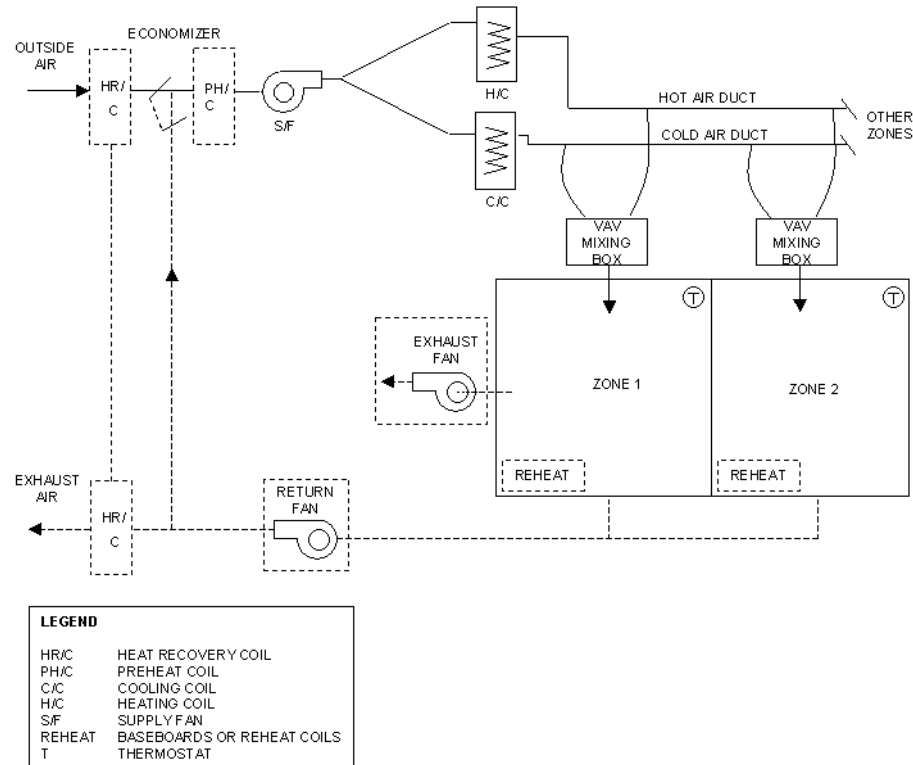
Figure 10-10.

Dual-Duct Schematic

Dual-Fan Dual Duct System

The dual-fan dual duct system is a variable-air-volume system. The central air-handling unit has two supply fans: one supply fan moves air through a cold duct and a second supply fan moves air through a hot duct. The two air streams are mixed in individual mixing boxes that serve each zone. Outdoor air is supplied to the cold duct only. A return fan, if present, delivers air to both the cold duct and the hot duct supply fans. Space temperatures are maintained by mixing the hot air stream and the cold air stream in proper proportions.

The three possible strategies for controlling the heating coil and cooling coil exit temperatures in the hot duct and cold duct, respectively, are constant temperature, zone temperature reset and outside air reset. If the user specifies constant temperature coil control, the temperature of the air leaving the associated coil is set to a fixed value, specified by the user. If the user specifies the heating coil control to be zone temperature reset, the temperature of the air leaving the heating coil in the hot duct is reset to meet the needs of the coldest zone. Similarly, if zone temperature reset is specified for the cooling coil control, the temperature of the air leaving the cooling coil in the cold duct is reset to meet the needs of the warmest zone. Finally, if the user specifies outside air reset as the heating or cooling coil strategy, the heating and/or cooling supply air temperature is based upon outside air temperature.

Optional features: return fan, outdoor air economizer, heat recovery, zone reheat coils/baseboards, preheat coil, exhaust fans in any or all zones.

In the Central System Library, define:

1. Coil Control
2. For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:
3. Constant Temperature – The cooling supply temperature is set to a constant value.
4. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
5. Outdoor Air Reset – The cooling coil discharge temperature is set hourly based upon the temperature difference between the outdoor air temperature and zone temperature.
6. Heating Supply Temperature
7. Enter the temperature of air leaving the hot deck.
8. Cold Duct and Hot Duct Supply Fan Operation
9. Enter the characteristics of the cold duct fan on the "Supply Fan" tab. The characteristics of the hot duct fan are entered on the "Heating Supply Fan" tab.
10. Specify the supply fan operation on the "Supply Fan" tab only. The hot duct fan operates according to the same schedule. The choices are:
11. Operate Fans According to Schedule – The fan operates according to the "Fans" schedule entered in the zone element.
12. Fans Are Always On – The fans run continuously.
13. Cycle Main Fans with Setback – The fan operates according to heating setback, defined in the "Heating" setback in the zone element.
14. For both the cold duct fan and hot duct fan, choose one of 4 options for fan control:
15. Riding the fan curve
16. Air foil or backward inclined with vanes
17. Forward curved with vanes
18. Variable speed
19. Each of these fan control options alter the fan capacity in accordance with flow requirements and minimum outside air to determine a fan power versus air flow rate factor. The coefficients of the fan curves for the riding fan curve, backward incline airfoil and forward inclined foil are given in MNECB Performance Supplement Figure 5.4.9.A.
20. Cold Duct and Hot Duct Supply Fan Power
21. For both the hot duct and cold duct fans, enter the fan power. Fan power can be entered directly in watts, or it can be defined by entering static pressure and efficiency. If static pressure/efficiency is chosen, it must also be indicated whether the fan is a blow-through or draw-through type.
22. Zone Reheat Source
23. On the "Zone" tab, select the heating source for zone-level reheat. Zone level reheat sources include reheat coils installed in the ductwork, electric or hot water baseboard convectors, or radiant in-floor coils. If the rooftop unit provides all heat and no reheat units are installed, select "none".
24. In the Zone Element/Mechanical Tab, define:
25. Zone Heating Output

26. If zone-level reheat has been specified in the System Element, enter the heating capacity of the baseboard/radiant floor/reheat coil. If reheat has not been specified, no information needs to be entered in the Zone Heating Output box.
27. Maximum and Minimum Zone Airflow Rate
28. Enter the maximum and minimum airflow rates for both hot duct and cold duct. The minimum airflow rate of the cold duct must be greater than or equal to the minimum fresh air requirement, since outdoor air is provided by the cold duct only.
29. Terminal Fan Flow Rate and Power
30. Enter the flow rate attributed to the VAV box fan. This is the flow rate of the return or induced air. Also enter the power at this flow rate.
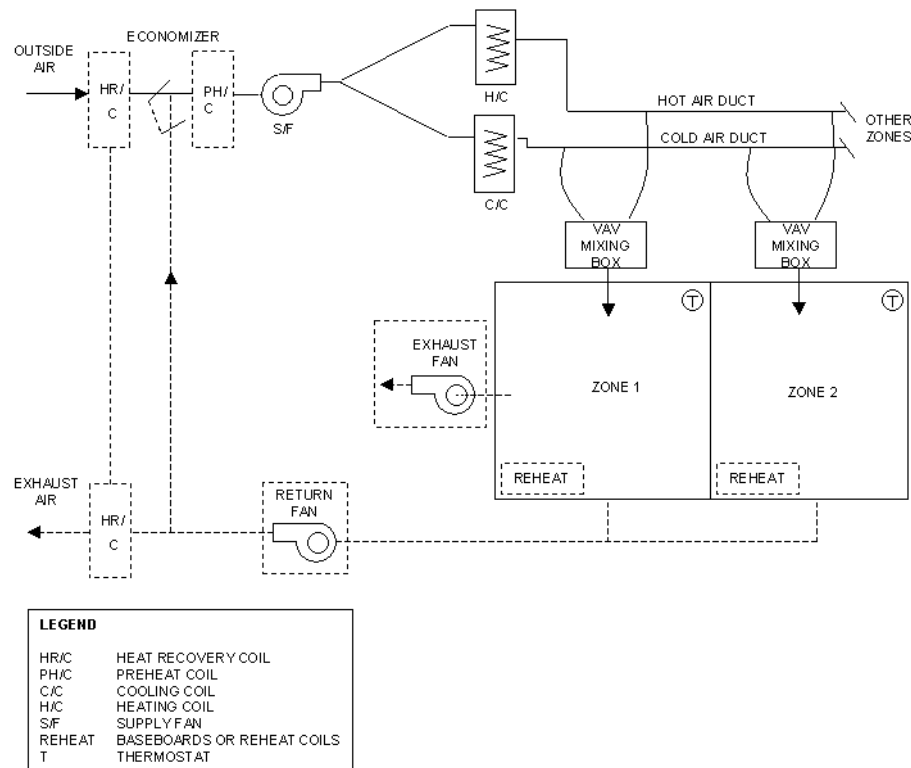
Figure 10-11.

Dual Fan Dual Duct Schematic

2-Pipe Fan Coil System

The 2-pipe fan coil system provides heating and cooling to individually controlled zones via combination heating/cooling coils. All zones served by the system must be operating in the same mode (i.e. heating or cooling) at any given time. The individual fan coils supply constant volume air to the zones. Cooling or heating is provided by circulating chilled water or hot water through the coil. The temperature of the supply air is controlled by throttling the flow of water through the coil. Seasonal changeover is required and must be scheduled in the Plant Element/Heat Pump Tab.

Tempered outdoor air is supplied to the fan coils via a central make-up air unit system. EE4 CBIP sets the outdoor airflows to each of the zones to the airflow needed to meet the MNECB minimum outdoor air requirements. Alternatively, higher outdoor airflows can be supplied in the Room Element/Occupant Tab.

Central System Library inputs are reserved for defining the make-up air system, while the individual fan coil unit characteristics are defined in the Zone Element/Mechanical Tab. Heating and cooling outputs of the fan coil units, defined in the Zone Element/Mechanical Tab, should not include the influence of fan power.

If the make-up air system has cooling capability and is served by a chiller that also serves the fan coil units, the performance characteristic (COP) of the chiller should be the value entered in the Central System Library/Cooling Tab.

In the Zone Element/Mechanical Tab, define:

1. Zone Heating and Cooling Output
2. Enter the heating and cooling capacity of the fan coil serving the zone.
3. Airflow Rate and Fan Power
4. Enter the fan coil rated airflow rate and fan power consumption. The flow rate must greater than the minimum outdoor air requirement.
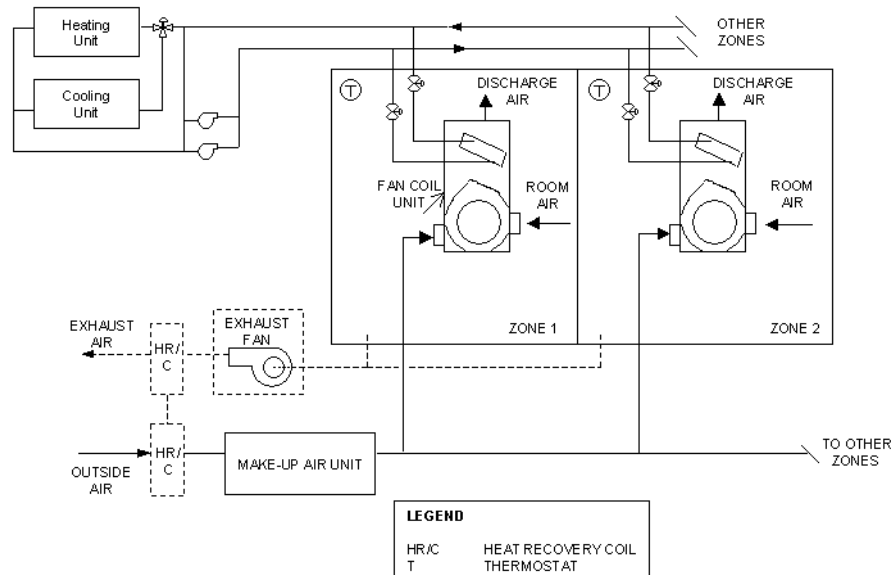

Figure 10-12.

2-Pipe Fan Coil System Schematic

4-Pipe Fan Coil System

The 4-pipe fan coil system is identical to the 2-pipe fan coil system with the exception that the fan coil units in this system have separate heating and cooling coils rather than a combined heating/cooling coil. This configuration allows simultaneous cooling and heating loads in different zones to be met concurrently. The individual fan coils supply

constant volume air to the zones. Circulating chilled water through the cooling coil provides cooling and circulating hot water through the heating coil provides heating. The temperature of the supply air is controlled by throttling the flow of water through the coils.

Tempered outdoor air is supplied to individual zone fan coils from a central make-up air unit system. The outdoor airflows to each of the zones are set to the airflow needed to meet the MNECB minimum outdoor air requirements. Alternatively, higher outdoor airflows may be specified in the Room Element/Occupant Tab.

Central System Library inputs are reserved for defining the make-up air system, while the individual fan coil unit characteristics are defined in the Zone Element/Mechanical Tab. Note that the heating and cooling outputs of the fan coil units defined in the Zone Elements/Mechanical Tab should not include the influence of fan power.

If the make-up air system has cooling capability and is served by a chiller that also serves the fan coil units, the performance characteristic (COP) of the chiller should be the value entered in Central System Library/Cooling Tab.

In the Zone Element/Mechanical Tab, define:

1. Zone Heating and Cooling Output
2. Enter the heating and cooling capacity of the fan coil serving the zone.
3. Airflow Rate and Fan Power
4. Enter the fan coil rated airflow rate and fan power consumption. The flow rate must greater than the minimum outdoor air requirement.
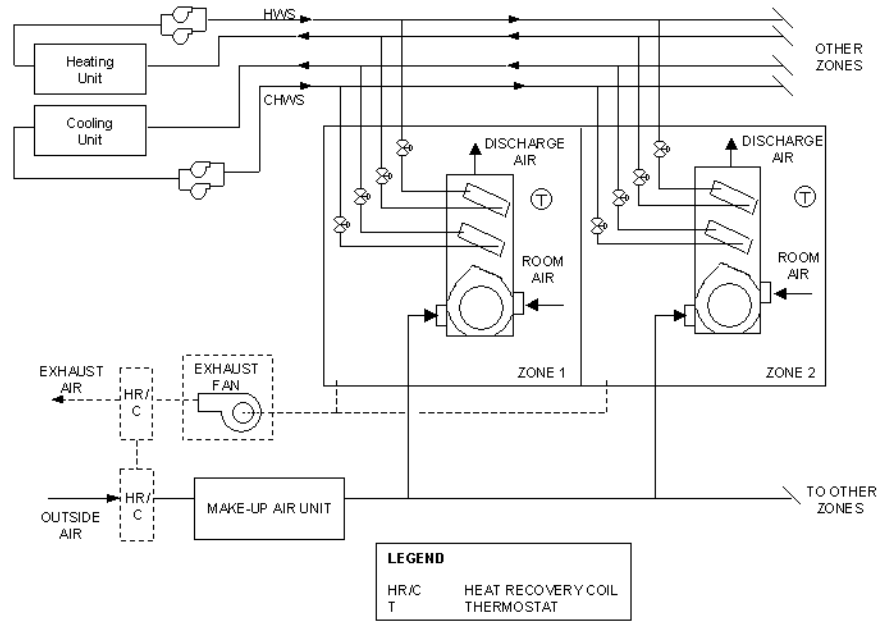
Figure 10-13.

4-Pipe Fan Coil System Schematic

2-Pipe Induction Unit System

The 2-pipe induction unit system is a mixed air-hydronic system that can provide both heating and cooling to a number of individually controlled zones via combination heating/cooling coils. All zones served by the system must be operating in the same mode (i.e. heating or cooling) at any given time. A constant flow rate of primary air is supplied to induction-type terminal devices in each zone. Primary air is discharged through the nozzles in each unit, a secondary or induced flow of room air results. The combined airflow is then heated or cooled by the combination heating/cooling coil. Temperature control is achieved by throttling the flow of water to the combination heating/cooling coil. Seasonal changeover is required and must be scheduled in the Plant Element/Heat Tab.

Note that the maximum airflow rate entered by the user in Zone Element/Mechanical Tab airflow rate is the amount of air from the central air-handling unit delivered to the zone and does not include the induced air.

In the Central System Library, in addition to the common elements, define:

1. Induction Terminals
2. On the "Zone" tab, in the Central System Library, specify the induction ratio for the zone-level induction terminals. The induction ratio is defined as the ratio of induced airflow to primary airflow. The induction ratio must be between 1.0 and 10.
3. In the Zone Element/Mechanical Tab, define:
4. Zone Heating and Cooling Output
5. Enter the heating and cooling capacity of the induction unit.

6. Maximum Airflow Rate
7. Enter the primary airflow rate delivered to the zone. This does not include the induced secondary flow. The value must be greater than the minimum MNECB outdoor air requirement.
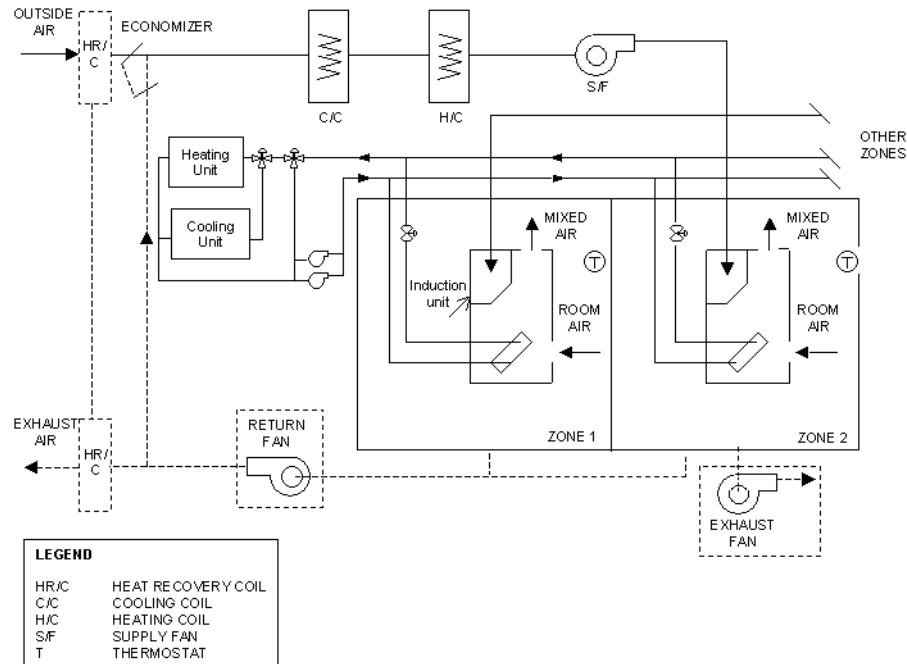

Figure 10-14.

2-Pipe Induction Unit System Schematic

4-Pipe Induction Unit System

The 4-pipe induction unit system is identical to the 2-pipe induction unit system, with the exception that 4-pipe induction units have separate heating and cooling coils. Thus, the induction unit in one zone can provide heating at the same time that a unit in another zone provides cooling. The control system for each unit provides automatic switchover from cooling to heating (and vice versa) as required to maintain space temperature conditions.

Note that the maximum airflow rate entered by the user in Zone Element/Mechanical Tab airflow rate is the amount of air from the central air-handling unit delivered to the zone and does not include the induced air.

In the Central System Library, in addition to the common elements, define:

1. Induction Terminals
2. On the "Zone" tab, specify the induction ratio for the zone-level induction terminals. The induction ratio is defined as the ratio of induced airflow to primary airflow. The induction ratio must be between 1.0 and 10.
3. In the Zone Element/Mechanical Tab, define:

4. Zone Heating and Cooling Output
5. Enter the heating and cooling capacity of the induction unit.
6. Maximum Airflow Rate
7. Enter the primary airflow rate delivered to the zone. This does not include the induced secondary flow. The value must be greater than the minimum MNECB outdoor air requirement.
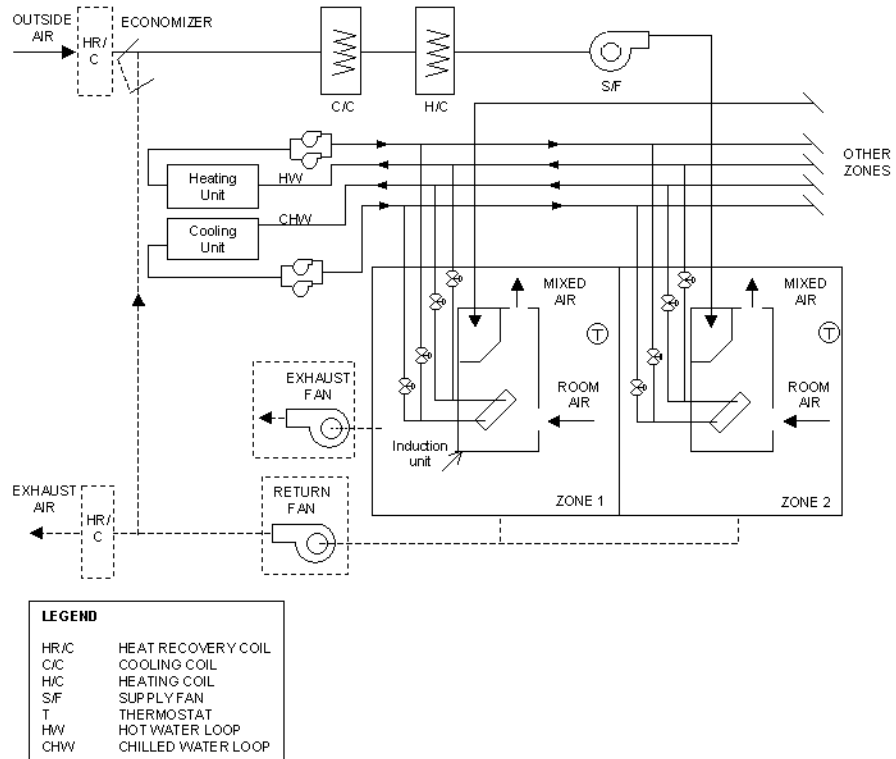

Figure 10-15.

4-Pipe Induction Unit System Schematic

Appendix D

MURB Credit Options

1.   Background

Multi-unit residential buildings (MURBs) have a difficult challenge meeting the Commercial Building Incentive Program (CBIP) 25 percent energy threshold. This is mainly due to the difficulties in specifying exterior walls with high levels of insulation, high costs for high-performance fenestration products (curtain walls, patio doors and windows) and mechanical design strategies focusing on corridor pressurization systems for ventilation. In addition, typical MURB lighting and appliance loads offer minimal energy saving potential for credit towards CBIP compliance.

This note describes additional credits that will be available to MURBs only. If a building is a MURB, these credits are available only if the residential portion of the building (suites only) comprises more than 50 percent of the total floor area (excluding parking garages) of the building.

These credits are available for the EE4 performance simulation only.

2.   Parking Garage Lighting

Currently, parking garages are not considered eligible for CBIP unless they are heated and are mechanically ventilated. Credits for efficient lighting in garages are not accepted without the garage being fully included in the conditioned space.

Option: Consider lighting in parking garages (heated and unheated). This credit will be available in combination buildings provided that the MURB portion (floor area) comprises 50 percent of the total building area.

Reference: ASHRAE Standard 90.1-2001 lists 3 W/m^2 as lighting power density for parking garages with pedestrian movement.

There are two procedures:

2.1 Heated Garages

Use Space Function: Storage/Warehouse: Active Storage: Bulky to describe the parking space (Model National Energy Code for Buildings [MNECB] lighting reference is 3.2 W/m2), and apply your lighting level.

2.2 Unheated Garages

To be included in the CBIP comparison, all spaces must be heated. Therefore, unheated parking garages must be converted to minimally heated garages to apply the lighting analysis. Create a space using Space Function: Storage/Warehouse: Active Storage:

Bulky to describe the parking space. Create a heating constant schedule of 4ºC and enter a design space temperature of 4ºC. Add a packaged single zone system to describe the required air handler. Enter an air handler ventilation air-heating type of "none," fan power of 0 watts, fan supply airflow of 0 L/sec. Enter no zone heating. This will create negligible heating in the proposed and reference case. Then apply your lighting design.

Note: Simulators should be aware that any above-grade walls/roofs in a heated garage reference, will be insulated to the MNECB U-values. Selecting the "exempt" checkbox in the EE4 wall/roof assembly entry will result in the proposed U-value and the reference U-value being represented as identical (penalty/credit neutral).

3.   Parking Garage Use of Building Exhaust Air as Low-Grade Heating

If a garage requires heating, then a heating device, such as a unit heater, infra-red heater or fresh-air duct heater, is required. If the building discharges exhaust air via the parking garage, less purchased mechanical/electrical heating is required; therefore, this measure saves energy. Simulators/designers need to be aware that this measure may contravene some municipal and provincial building codes and that this measure is acceptable energy conservation measure only where permitted by code.

Option: Calculate available heat in the portion of building exhaust air discharged via the parking garage and subtract this from the heating required in the parking garage each hour. This credit is limited to providing 9ºC of heating for heated garages and 5ºC for unheated garages. This credit can be combined with space heating within the parking garage.

Reference: Full mechanical/electrical heating each hour to the entered set-point as per drawings and specifications.

Procedures: There are two options available.

3.1 Heated Garage

3.1.1 Option 1: Convert Available Heat to Process Energy

1.   Calculate creditable building exhaust heat available using the following:

       Exh = 1.21 x flow × 9
       1.21 = (m^3/1000 L) × 1000 g/0.8333 m^3 [identify the "g" unit – it's not clear to me how this part of the equation works or what it is supposed to represent]
       flow = exhaust airflow into garage (L/sec)
       9 = temperature (ºC)
       Exh = exhaust heat (watts)

2. Convert this value to a W/m^2 value by dividing it by the area of the parking garage, and enter this value as the sensible process load.

3. Ensure that the Process and Fan Schedule for the parking garage is changed from "A" to "H" to correspond to 24-hour, 7-day operation of the building exhaust and process (8760 hours). Ensure that the garage heating schedule is set to a constant 9ºC, and the design temperature is 9ºC for the space.

4. Set the air-handling system for the parking garage to packaged single zone system serving a single parking garage zone with a single space having a function of "active storage: bulky." If the air handler does not contain any ventilation air-heating device and the design relies on the building exhaust air for space heating, then set an electric ventilation air-heating device with a capacity of 0.1 kW. This will allow the reference case to heat the ventilation air to the set-point. The principal heating source may need to be set to electricity if zero zone heating is installed.

5. Complete the calculations: proposed and reference cases.

6. Manually remove the process calculation from the proposed and reference cases, using the following:

Process (MJ) = (Exh/1000) × 3.6 × 8760
Process (kWh) = (Exh/1000) × 8760
Process (cost) = (Exh/1000) × 8760 × Average cost per kWh

3.1.2 Option 2: Allow High Unheated Hours

1. Calculate creditable building exhaust heat available, using the following:
Exh = 1.21 × flow × 9
1.21 = (m^3/1000 L) × 1000 g/0.8333 m^3
flow = exhaust airflow into garage (L/sec)
9 = temperature (ºC)
Exh = exhaust heat (watts)

2. Ensure that the Fan Schedule for the parking garage is changed from "A" to "H" to correspond to 24-hour, 7-day operation of the building exhaust (8760 hours). Ensure that the garage heating schedule is set to a constant 9ºC and the design temperature is 9ºC for the space.

3. Set the air-handling system for the parking garage to packaged single zone system serving a single parking garage zone with a space with a function of "active storage: bulky." If the air handler does not contain any ventilation air-heating device and the design relies on the building exhaust air for space heating, then set an electric ventilation air-heating device with a capacity of 0.1 kW. This will allow the reference case to heat the ventilation air to the set-point. The principal heating source may need to be set to electricity if zero zone heating is installed.

4.   Run the sizing calculation to determine the garage heating (ventilation and space) design load.

5.   Ensure that the garage design load is less than the building exhaust heat available (Exh) converted to kilowatts (kW). This ensures that the building exhaust has sufficient heat to meet the design heating load, which should be enough to maintain the 9ºC temperature in the space. If the building exhaust heat available is less than the design requirement, then additional mechanical heating (ventilation or zone heating) is required, or the set-point needs to be lowered from 9ºC.

6.   Run the calculations and accept the high number of unmet heating hours as the building exhaust air-heating load will met this requirement. The reference case will be mechanically heated to the set-point.

3.2 Unheated Garage

3.2.1 Option 1: Convert Available Heat to Process Energy

1.   In order to obtain any credits for building exhaust air heat, the unheated garage must be converted to a heated space. This is accomplished by creating a constant 5ºC heating schedule and a design set-point of 5ºC.

2.   Calculate creditable building exhaust heat available, using the following:
Exh = 1.21 × flow × 5
$1.21 = (m^3/1000 \text{ L}) \times 1000 \text{ g}/0.8333 \text{ m}^3$
flow = exhaust airflow into garage (L/sec)
5 = temperature (ºC)
Exh = exhaust heat (watts)

3.   Convert this value to a W/m^2 value by dividing it by the area of the parking garage, and enter this value as the sensible process load.

4.   Ensure that the Process and Fan Schedule for the parking garage is changed from "A" to "H" to correspond to 24-hour, 7-day operation of the building exhaust and process (8760 hours). Ensure that the garage heating schedule is set to a constant 5ºC and the design temperature is 5ºC for the space.

5.   Set the air-handling system for the parking garage to packaged single zone system serving a single parking garage zone with a space with a function of "active storage: bulky." If the air handler does not contain any ventilation air-heating device and the design relies on the building exhaust air for space heating, then set an electric ventilation air-heating device with a capacity of 0.1 kW. This will allow the reference case to heat the ventilation air to the set-point. The principal heating source may need to be set to electricity if zero zone heating is installed.

6.   Simulators should be aware that any above-grade walls/roofs in a heated garage will now be insulated to the MNECB U-values, but simply selecting the "exempt" checkmark in the EE4 wall/roof assembly entry will mean that this assembly is

exempt from meeting the MNECB minimal insulation requirements. The proposed U-value and the reference U-value will be identical (penalty/credit neutral).

7.   Complete the calculations: proposed and reference cases.

8.   Manually remove the process calculation from the proposed and reference cases, using the following:

Process (MJ) = (Exh/1000) × 3.6 × 8760
Process (kWh) = (Exh/1000) × 8760
Process (cost) = (Exh/1000) × 8760 × Average cost per kWh

3.2.2 Option 2: Allow High Unheated Hours

1.   In order to obtain any credits for building exhaust air heat, the unheated garage must be converted to a heated space. This is accomplished by creating a constant 5ºC heating schedule and a design set-point of 5ºC.

2.   Calculate creditable building exhaust heat available, using the following:
Exh = 1.21 × flow × 5
1.21 = (m^3/1000 L) × 1000 g/0.8333 m^3
flow = exhaust airflow into garage (L/sec)
5 = temperature (ºC)
Exh = exhaust heat (watts)

3.   Ensure that the Fan Schedule for the parking garage is changed from "A" to "H" to correspond to 24-hour, 7-day operation of the building exhaust (8760 hours). Ensure that the garage heating schedule is set to a constant 5ºC and the design temperature is 5ºC for the space.

4.   Set the air-handling system for the parking garage to packaged single zone system serving a single parking garage zone with a space with a function of "active storage: bulky." If the air handler does not contain any ventilation air-heating device and the design relies on the building exhaust air for space heating, then set an electric ventilation air-heating device with a capacity of 0.1 kW. This will allow the reference case to heat the ventilation air to the set-point. The principal heating source may need to be set to electricity if zero zone heating is installed.

5.   Run the sizing calculation to determine the garage heating (ventilation and space) design load.

6.   Ensure that the garage design load is less than the building exhaust heat available (Exh) converted to kW. This ensures that the building exhaust has sufficient heat to meet the design heating load, which should be enough to maintain the 5ºC temperature in the space. If the building exhaust heat available is less than the design requirement, then additional mechanical heating (ventilation or zone heating) is required, or the set-point needs to be lowered from 5ºC.

7.   Simulators should be aware that any above-grade walls/roofs in a heated garage will now be insulated to the MNECB U-values, but simply selecting the "exempt" checkmark in the EE4 wall/roof assembly entry will mean that this assembly is exempt from meeting the MNECB minimal insulation requirements. The proposed U-value and the reference U-value will be identical (penalty/credit neutral).

8.   Run the calculations and accept the high number of unmet heating hours, as the building exhaust air-heating load will meet this requirement. The reference case will be mechanically heated to the set-point.

4.   Residential Suite Lighting Credit

Currently, lighting controls and energy-efficient lighting are not considered a potential credit or penalty, as with other spaces. This is because tenant-supplied lighting could be all of the lighting in the particular space (e.g. bedroom). The proposed design could theoretically have zero lighting because all of the lighting is tenant supplied and not indicated on the drawings or specifications.

Option: Consider energy-efficient lighting design and installed sensors as a credit, as with other spaces. Occupant behaviour would be a non-issue if sensors (daylighting, occupancy) are installed.

Reference: 11.8 W/m^2 (MNECB for Dormitory – Bedroom Space Function).

Procedures: EE4 automatically sets the residential lighting power to 9 W/m^2 of floor space. Therefore, the user does not have an option in EE4 to simulate energy-efficient lighting and lighting controls. If the space function is altered to Dormitory – Bedroom, lighting credits are now available. This will be the space function selected for the residential spaces. The operating schedules, water heating requirements and ventilation rate per occupant are identical between the residential and dormitory spaces. The occupant densities will have to be adjusted to the residential levels (60 m^2/occupant).

Because suites spaces usually require tenant lighting fixtures, lighting levels may not be shown on the drawings. The design cannot receive a zero lighting consumption for spaces where the tenant is required to provide lighting. In spaces where the tenant is required to provide lighting, those spaces shall be modelled at 11.8 W/m^2 (same as reference). The simulator is required to determine a suite weighted lighting level based on the combination of tenant lighting and hard-wired fixtures. The user is required to complete a table, as follows, to determine the lighting level for the suites:

Space	Area (m^2)	Lighting Level (W)	Comments
Foyer	3.50	15.0	One globe fluorescent hard-wired fixture
Kitchen	9.60	80.0	Two U-tube stained glass fixtures - 40W ea.
Dining Area	11.15	131.6	Tenant supplied 11.15 x 11.8
Bathroom	9.20	106.0	Two 13W PL had-wired, plus switchable vanity with two 40W globes, heat lamp excluded, PL on occupancy sensors
Walk-in closet	4.50	26.0	Two 13W PL hard-wired, on occ. sensors
Bedroom	10.25	121.0	Tenant supplied 10.25 x 11.8
Master Bedrm	14.87	175.5	Tenant supplied 14.87 x 11.8
Living Room	17.84	210.5	Tenant supplied 17.84 x 11.8
Laundry Room	4.50	26.0	Two 13W PL hard-wired
Totals	85.41	891.6	W/m^2 = 891.6 W / 85.41 m^2 = 10.44

The control fraction for occupancy sensors applies only to the bathroom PL lamps and the walk-in closet PL lamps. Calculate the lighting control fraction as the ratio of wattage under control to total wattage:

Control Fraction = 52 W / 891.6 W = 5.8 percent

5.   Energy-Efficient Appliances and Hot-Water-Conserving Appliances

Appliances and base loads are considered neutral in the proposed and reference, even if the design is equipped with energy- and water-conserving appliances. While appliances are easily removable, common sense dictates that appliances would not be replaced with less efficient ones following the CBIP review.

Option: Consider ENERGYSTAR® appliances as a credit.
            Consider EnerGuide appliances as a credit, provided their annual energy use is a minimum of 25 percent lower than the reference values.

Procedures:

EE4 and MNECB do not consider appliances within the simulation; therefore, they will be considered a process load.

The reference appliance values shall be the 2002 EnerGuide average annual energy consumption from Natural Resources Canada's Office of Energy Efficiency Web site (oee.nrcan.gc.ca/equipment/).

> Refrigerators (top mounted, 16.5–18.4 cu. ft.) 526 kWh/yr
> Dishwashers: standard   623 kWh/yr (includes hot water)
> Clothes washers: top loading   876 kWh/yr (includes hot water)
> Clothes dryers: electric standard   909 kWh/yr
> Ranges: electric self-cleaning   750 kWh/yr

There will not be an adjustment for the hot water energy, as the ENERGYSTAR appliances also include hot water energy requirements.[1] Therefore, the overall ENERGYSTAR energy use (electrical plus hot water) will be compared with the EnerGuide use as a fair credit. The appliance types must match the proposed and reference. For example, if the proposed case does not contain clothes washers and dryers, then the reference condition will also exclude washers and dryers. Gas-fired equipment will be considered electrical for this analysis, as EE4 does not have the ability to enter gas processes. If you have a combination washer/dryer on of the following procedures should be used for modeling. In both cases, the appliance selection in the proposed and the reference cases must match.

5.1 Option A: EE4 Modelling

Steps Involved in Proposed Case:

1.   Total the number of each of the appliances in the building and multiply by the specified ENERGYSTAR or EnerGuide rating (kWh/yr/bldg). If the proposed case appliance energy use is higher or at the EnerGuide rating (above), simply enter the reference value for this appliance.

2.   Convert to an hourly value: kWh/yr/bldg / 8760.

3.   Divide this total by the area of the residential suites (m^2) and multiply by 1000 W/kW.
     W/m^2 = [(kWh/yr/bldg) / (365 × suite area)] × 1000

4.   This is the "proposed" sensible process load that you apply to each residential space. If the proposed design has different levels of appliances, such as 20

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[1] New hot/cold water-conserving dishwashers and clothes washers can reduce hot water consumption by 50 percent over conventional appliances, thereby reducing hot water energy. ASHRAE data suggest 114 L/day/person of hot water use in an apartment on average (low = 53, high = 204). The appliance credit has already considered the hot water energy savings, as these are included in the ENERGYSTAR/EnerGuide rating of the appliance (clothes washers and dishwashers). CBIP already credits low-flow showerheads, using the MNECB reference of 9.5 L/minute flow. CBIP already credits low-flow hot water faucets, using the MNECB reference of 8.3 L/minute flow.

Therefore, hot water conservation via flow reductions has already been credited, either under the appliance measures or within CBIP itself.

suites with a dishwasher and the balance without a dishwasher, still apply the building average process sensible load to all suites. Completing a suite-by-suite or group-of-suites calculation of the proposed and reference different process loads is not necessary; as the overall outcome will be a building result. Ensure that the schedule for the process is the Fan Schedule "H" (24-hours-per-day operation).

Run the proposed case only.

5.   Complete steps 1–3 using the EnerGuide appliance reference values, and run the reference case only.

If the exact energy specifications of the ENERGYSTAR appliances are not available at the design stage, use the following default values (source: *The EnerGuide Appliance Directory 2002)*.

Refrigerators	426 kWh/yr
(top mounted 16.5–18.4 cu. ft)	
Dishwashers: standard	481 kWh/yr (includes hot water)
Clothes washers: top loading	389 kWh/yr (includes hot water) need to adjust these reported values to take out the hot water component – compare on electricity alone or develop a model that actually factors hot water as well as electricity.
Clothes dryers: electric standard	909 kWh/yr (no ENERGYSTAR data)
Ranges: electric self-cleaning	750 kWh/yr (no ENERGYSTAR data)

This option will provide the correct electrical consumption credits (use and cost), but will not reflect the demand costs (since the appliance annual energy use is converted to an hourly average). This option places the appliances in the suites, which will affect the heating and cooling loads via internal heat gains (all of the process load is applied as a space-heat gain).

5.2 Option B: Manual Adjustments

Another option, which will not affect heating/cooling loads via the internal heat gain calculation, is to simply complete a manual adjustment on the final EE4 simulation using the annual ENERGYSTAR/EnerGuide appliance values.

Appliance	No. in Bldg. A	Proposed Use (kWh/yr/appliance) B	Proposed Use (kWh/yr/bldg) A × B	Reference Use (kWh/yr/appliance) C	Reference Use (kWh/yr/bldg) A × C
Dishwasher				623	
Stove/Range				750	
Refrigerator				526	
Clothes Washer				876	
Clothes Dryer				909	

Convert the kWh/yr/bldg to MJ/yr/bldg (multiply by 3.6) and add the resulting annual energy use in MJ to the proposed and reference cases. Complete the CBIP threshold calculation.

Convert the kWh/yr/bldg to $/yr/bldg (multiply by average $/kWh from your electrical energy file or from ES-D DOE2 report) , and add the resulting annual energy cost to both the proposed and reference cases, respectively.

In both cases, the appliance selection in the proposed and the reference cases must match.

6. Energy-Efficient Elevators

Data exists on the energy use of elevators (horsepower). The size of the elevator motor depends on the weight-carrying capacity of the elevator and the hydraulic lift. Equations to size the motor exist. Elevator carrying weight for MURBs can be assumed. Knowing the number of elevators and the number of stories of lift, a generic motor can be determined. The user would enter the power rating of the elevator motor (hp or kW), and a potential credit could be offered for innovative hydraulic motor options (e.g. KONE EcoDisc®, Otis Gen2™).

Option: Allow a credit for energy-saving elevator motors/gear boxes/lighter-weight devices.
Reference: Traction two-speed, eight-person (630 kg) elevator
              Assume 200 000 starts/yr/elevator (source KONE Web site)
              Annual energy consumption = 5000 kWh/yr/elevator for 16 stories and up
              Annual energy consumption = 3000 kWh/yr/elevator for 15 stories and lower)

(Source: Kone website, "Market Assessment for Energy Efficient Elevators and Escalators" by Enermodal Engineering, September 2004)

Procedures:

1. Multiply the number of elevators by 5000 kWh to obtain reference consumption/yr.

2. Add all lobby/corridor spaces to determine total building lobby/corridor area (m^2).

3. Divide consumption by area and convert to W/m^2.

4. Add this to "Process" (sensible) in the EE4 simulation for all lobby/corridor spaces.

5. Run "reference" case only.

6. Complete steps 1–4 for the energy-efficient elevators and run "proposed" case only.
At this time, credits for escalators and the elimination of elevators are not considered. The number of elevators in the proposed and reference cases must match.

Appendix E

Fume Hood Load in Institutional
Laboratory Educational Facilities

Two Compliance Options:

Since it is acknowledged that fume hoods form an integral part of the building functional requirements for some institutional laboratory educational facilities, two submission options are available for the Commercial Building Incentive Program (CBIP) are allowed. The first and simplest option is to use the standard CBIP application process in which 25% savings for building alone must be demonstrated. The second option is to provide a submission with 15% savings on the building and 10% process savings related to fume hoods similar to the Industrial Building Incentive Program (IBIP) (15 building savings/10 process saving) methodology.

To qualify hood process load savings, the building designers must show that their "proposed" building design is expected to consume 15% less building energy than a standard or "reference" building due to building improvements, and 10% less energy due to process improvements related to heat recovery on fume hood exhaust and/or low velocity or area restricted fume hoods. Thus the building must achieve the same 25% energy reduction that a CBIP-eligible building must achieve. The only acceptable process load for education laboratory facilities are fume hoods.

This document explains the details for the second option where fume hood process load are included in the submission.

The CBIP maximums for technical assistance and incentive amount are applicable no matter which submission option is used.

Eligible Process and Building Type

The building itself must be an institutional laboratory educational facility. This option is not available for other building types. The only permissible process loads are those associated with fume hoods.

Only Allowable Process Measures

Allowable process energy savings are listed below.

Heat recovery on fume hood exhaust: Potential credit for heat recovery on fume hood exhaust. Credit is dependent on type of fume hood (laboratory, kitchen, industrial). The recovered heat must be applied to reduce the building heating load.

Low velocity or area restricted fume hoods: Potential credit for reduced airflow through fume hoods. Credit is dependent on type of fume hood.

Energy efficiency requirements for hoods are covered in Section 6.3.6 of ASHRAE 90.1-2001. The ASHRAE requirements are considered standard practice and credits are only achieved for exceeding these requirements.

ASHRAE requires exhaust air heat recovery where the supply fan air flow is both 2400 L/s (5000 CFM) or greater and 70% outdoor air or greater. The heat recovery system must be at least 50% effective. Exceptions include:

- Commercial kitchen (grease) hoods
- Systems exhausting paint, toxic, flammable or corrosive fumes or dust

For fume hood systems with an exhaust rate greater than 7500 L/s, ASHRAE 90.1-2001 states that the fume hood shall have a heat recovery system with at least 50% recovery effectiveness or a variable air volume system that is capable of reducing the exhaust and makeup air by 50% or more (i.e., demand control, special ventilation rate control). There are no exceptions for these large systems.

Thus for simulation purposes, the reference building with exhaust air heat recovery is assumed to have a 50% effective heat recovery system when required by ASHRAE 90.1. If the proposed building uses a demand controlled ventilation system to comply with ASHRAE 90.1, then the reference building has a demand controlled system and no heat recovery.

Heat Recovery Exempt Systems:

For systems that do not require heat recovery (e.g., small systems), the modeling procedure should be completed in EE4. The MNECB reference simulation is done with room ventilation requirements defined by the space function. A second simulation is done for the proposed simulation with hoods. The ventilation rate is increased to the total fume hood exhaust flow. The heat recovery effectiveness is then defined and the fan power increased to account for the additional pressure drop of the heat recovery system. The difference between the proposed building and the reference building of this second simulation is the process integration energy saving.

Systems Requiring Heat Recovery:

If ASHRAE requires the system to have heat recovery savings are only counted for fume hoods that have effectiveness greater than 50%.

To determine the process integration energy savings, two simulations are done. In the first simulation, the total ventilation load and a 50% effective heat recovery system is added to the Proposed Building Excluding Process Load model to create the reference. The second simulation will use the "as-designed" heat recovery effectiveness. The fan powers in the reference and Proposed simulations are kept the same.

Systems Using Special Ventilation Rate Controls:

If the proposed building uses special ventilation rate controls (VRC), the operating schedule in the proposed simulation is reduced according to the MNECB rules for modeling occupancy sensors controls of the ventilation rate.   It is acknowledged that

fumehood VRC will not use the same control equipment as other non-industrial type spaces. However for compliance purposes, the parameters of operation can be simulated using the modeling strategy for occupancy sensors.

If demand control was used for compliance to ASHRAE 90.1, then the reference building would use the same operating schedule as the Proposed building (The complete measure simulation would be done in EE4.).

If demand control ventilation was not used to comply with ASHRAE then the reference building is left at the longer operating schedule. This would be modeled with outside determination of the expected energy consumption of the proposed and standard process then input into EE4. The reference simulation will be done using the longer schedule.

If the proposed building uses both demand control and heat recovery ventilation, the reference building would have demand control and the heat recovery energy savings is calculated using the procedure described in "Heat Recovery Exempt Systems" in Section 4.1.1. This situation can be modeled entirely in EE4.

It is important to note that energy savings credits are only given for process designs that demonstrate savings beyond standard practice and exceed the requirements of both the Model National Energy Code and ASHRAE 90.1-1999. The heat recovery system must be at least 50% efficient. Please refer to *Procedures for Modeling Buildings to Show Compliance to the IBIP* for complete further details.

> To determine the annual energy targets, multiply the CBIP reference building energy use by 10% for the process energy target and by 15% for the building energy target. The process energy savings target must be expressed in terms of MBTU or GJ, not as a percentage.

The incentive is based on two times the process and building dollar savings.

Appendix F

Drainwater Heat Recovery Systems

In buildings and industry, substantial energy savings can be achieved through reclaiming heat from drainwater (or waste-water), a process commonly called drainwater heat recovery (DHR). The reclaimed heat is almost always used to preheat cold fresh water. The most cost-effective class of drainwater heat exchangers are counter-flow.

Many DHR systems are in operation in Multi-Unit Residential Buildings (MURBs), hotels, recreation facilities, restaurants, laundromats, industry, and homes. There are many other excellent applications including high schools and hospitals (cafeteria, laundry, showers, kidney dialysis, cart washers, and steam condensate).

In MURBs the overall savings on domestic water heating is typically 25-30%, but the potential range is 5% to 46%. The lower end of this range is for centralized systems that reclaim heat from a single building-wide drainwater source. In restaurants and health clubs the range of savings is 40-75%.

The following guidelines and procedures form an abbreviated methodology for drainwater heat recovery in buildings. For clarification and/or confirmation that your design staff are applying these procedures correctly, it is recommended that you contact a DHR manufacturer or experienced sales engineer.

Design Considerations

There is a range of design options for DHR systems. Design considerations include trade-offs between overall performance, system cost, and fresh water pressure drop. The design for DHR in a MURB typically calls for a heat exchanger for every 3-4 washrooms; however to maximize performance it could call for a heat exchanger for each washroom. Alternatively, one could use one centralized system for an entire building. Where maximum flows are above 34 litres per minute (9 usgpm) - such as those found in health clubs - or where it is best to maximize heat exchanger performance (in large restaurants for instance) multiple heat exchanger systems are preferred.

CBIP Credit Calculations: Hotels/Motels, and MURBs

The effect of DHR on the water heating load depends on a combination of a few design factors that are multiplied together. The following equation and subsequent sections detail how to determine these factors.

DHW Load Reduction = DHW Heating Load * DHRsavings * DHReff * DHRutil

DHW Heating Load = hot water heating load from EE4 calculation (DOE2 BEPU report)

DHRsavings   = % savings due to DHR installation (see Table F-1)

DHReff   = % effectiveness of DHR equipment

DHRutil   = utilization factor of DHR in a building (0 – 100% coverage)

Potential DHW Savings from Drainwater Heat Recovery (DHRsavings)

In MURBs the fresh water that is heated by DHR unit(s) can be plumbed as the cold water stream (preferably washroom CW), the hot water stream to the boiler room, or both. With distributed DHR units, which are located throughout the building, it is not feasible (except in some small buildings) to preheat the HW stream. With a centralized system it is not practical to preheat the CW stream. Select the maximum savings from Table 1 depending upon your design. This number would be the estimated DHW load reduction if the DHR unit(s) have a 100% effectiveness and they serve all the washroom (WC) loads in the building.

Table F-1

Maximum Potential DWH Savings for Various Plumbing Schemes Options				
	Distributed DHR [1]			Centralized DHR
	1-2 WC/unit[2]	3-4 WC/unit[1]	5-6 WC/unit	>=7 WC/unit
HW and CW Heating	61.7%	56.0%	44.7%	18.0%
CW Heating*	46.7%	42.4%*	33.4%	13.6%
HW Pre-Heating	46.6%	42.3%	33.3%	13.6%
*most common method in MURBs W/C = washrooms installed per DHR unit HW = hot water CW = cold water				

Rated Effectiveness of DHR Unit(s) (DHReff)

Design, installation, heat transfer surface area, and fluid flow rates all contribute to the performance of any heat exchanger. The numbers in the Distributed DHR column of Table 1 are based upon a study in a real MURB with a counter flow heat exchanger that has a known rated effectiveness of 50.0%. This value shall be used for MURB and Hotel/Motel installations where test data has not been provided. The effectiveness of centralized DHR systems shall be 25% unless a detailed test report has been provided.

Rated Effectiveness for Distributed DHR

Heat exchange effectiveness shall be determined from bench-scale testing at an ISO certified independent laboratory (such as Bodycote-Ortech) and signed by a professional engineer.

The steady-state heat exchange effectiveness at these conditions shall be used. The unit model number, heat transfer area, and pressure drops at the flowrates in table 1 shall be clearly reported. The summary test report must be submitted with the CBIP application.

It is common that model sizes vary from project to project. In this case, three options for selecting heat exchange effectiveness are allowed:

Have every model tested and reported.

Test at least 3 different heat exchanger models. Have the testing agency interpolate and/or extrapolate the heat exchange effectiveness for a wide variety of sizes with a recognized heat exchanger modelling method. The results shall be included in the test report in tabular form.

Use the reported heat exchanger effectiveness for a smaller model (by surface area).

Rated Effectiveness for Centralized DHR

It is recommended that the test report cover a wide flow rate range. If more than one heat exchanger is used then the design flow rate shall be divided between the heat exchangers and the rated effectiveness per unit at that flow rate shall be used.

Percent Utilization Adjustment (DHRutil)

Due to design constraints, in some buildings not every drainwater source is utilized for heat recovery. As a result, the rating must be reduced accordingly. This fraction will simply be:

Percent Utilization =   Number of Washrooms feeding the DHR System(s) /
                               Total Number of Washrooms in Building

CBIP Credit for Recreation Facilities, High Schools, Hospitals, and Restaurants

The key issue in estimating DHR energy savings in these building types is that there are many types of hot water loads. Furthermore, there is a wide variation in the proportion of these loads within a building. For this reason the accepted practice is to estimate the proportion of total drainwater that feeds the DHR system(s) by using fixture counts and peak hourly flow, as detailed by ASHRAE Fundamentals 1999 Table 9** for each fixture type. Where there is more than one DHR system within the building, the savings must be calculated separately for each one according to this procedure.

DHW Load Reduction = DHW Heating Load * DHRloadf * DHReff * Flowf

DHW Heating Load = hot water heating load from EE4 calculation (DOE2 BEPU report)
DHRloadf   = % of hot water load connected to DHR saystem
DHReff   = % effectiveness of DHR equipment at 50% flow
Flowf   = flow balance correction factor

Proportion of Load Feeding the DHR system(s) (DHRloadf)

First, a count of all fixture types is made for the building. Next the total flow for each
fixture type is calculated as the product of the total number of fixtures and the Peak
Hourly Flow for each fixture type. The fixtures that can feed the one or more DHR
systems are then used to calculate the total flow for each DHR system. Finally, the
percent of the total HW load that is fed to each DHR system is calculated.

Estimated Service HW Load Breakdowns by fixture type for a Sample High School

| | Table 9 Calculations from ASHRAE | | | | | | |
| | Peak Hourly Flow | All Fixtures | | DWHR Gym | | DWHR Cafeteria | |
	LitresHW/hour	Fixtures	Total Flow	Fixtures	Total Flow	Fixtures	Total Flow
Basin, Private Lavitory	7.6	21	159.6	2	15.2	2	15.2
Basin, Public Lavitory	57	26	1482	8	456	0	0
Dishwasher (average)	228	1	228	0	0	1	228
Foot Basin	11	1	11	0	0	0	0
Kitchen Sink	76	3	228	0	0	3	228
Pantry	38	3	114	0	0	2	76
Shower	850	11	9350	10	8500	0	0
Service Sink	76	0	0	0	0	0	0
Circular Wash Sink	114	0	0	0	0	0	0
Semi-circular Wash Sink	57	0	0	0	0	0	0
TOTALS			11572.6		8971.2		547.2
		Percent of Total HW Load		**77.5%**		**4.7%**	

Sample Chart Showing Calculation of Load Proportion that could feed two DHR systems

Rated Effectiveness of DHR unit(s) at 50% flow (DHReff)

In reality it is rare that all fixtures will operate at once. The DHR system performance
shall therefore be benchmarked at 50% of peak total flow, as calculate above and based
upon test results from a testing agency. If test results are unavailable, the default is 50%.

Flow Balance Correction Factor (Flowf)

If the flow is balanced on both sides of the DHR system then this factor is 1.0; otherwise
it is 0.75. For example, the DHR system might only preheat the CW supply to the
showers. In this case the flow would not be balanced and the performance of the unit
would be about 25% less than if it were to heat both HW and CW supply streams. In the
case of a dishwasher where there is only HW supply this factor would be 1.0.

Appendix G

Renovation Requirements

The following list covers the questions that must be answered in order to input and confirm the elements of an EE4 energy simulation:

Architectural / Structural

1. construction assemblies and thermal values (do drawings and specifications match energy model);
2. roof type and insulation levels;
3. perimeter insulation on the slab or insulation extended >0.6 metres   below grade (document complete slab subgrade insulation where   required);
4. window specifications (make, model, u-value, frame type, shading coefficient);
5. door types and u-values;

Mechanical HVAC

6. air handing unit(s) total airflow capacity;
7. air handling unit(s) total supply and return fan power;
8. economizer cycle on air handling unit(s);
9. airflows per space if VAV system;
10. flow balance between supply and exhaust fans
11. zone and balancing dampers/valves
12. air and heat/cool distribution related to duct runs, static pressures, air supplied to each occupied space
13. duct diameters for sufficient airflow capability
14. duct insulation in unheated spaces
15. heating capacities per space (for unit heaters, baseboards, heat   pumps, fan coils, radiant panels, radiant in-floor);
16. heat recovery ventilator effectiveness, make and model number;
17. heat recovery ventilator fan airflow and total available air for heat recovery;
18. fume hood airflows and source of make-up air
19. special equipment operation characteristics (ex. car wash equipment and water heating specs.)

Mechanical Plumbing

20. heating/cooling system pump characteristics (motor type, flows, pump head, controls);
21. cooling tower specs: type, fan power, fan type, entering water temperatures, leaving water temperatures, number of cells,   fan/pump/spray control sequence;
22. water heating equipment specs: type, tank size, tank insulation, piping insulation, heat traps, low flow taps/shower heads

Mechanical Controls

23.   temperature setpoints per space
24.   temperature setpoint for heating and cooling coil in air handling unit(s)
25.   control specifications (night setbacks, equipment operation, optimal start/stop sequences, demand shedding, carbon dioxide ventilation   control)

Electrical Lighting

26.   exterior lighting controls
27.   exterior lighting levels
28.   lighting types and lighting control percentages

MNECB clauses relevant to additions and renovations

Definitions

1.1.3.2.1)
Addition means any conditioned space that is added to an existing building and that increases the building's floor surface area by more than 10 m^2.

Procedures

2.2.2.8.
(6) For the purpose of fenestration-to-wall ratio and skylight-to-roof ratio calculations, the compliance of additions shall be based upon either
        a) the addition being considered by itself, or
        b) the addition being considered together with the existing building.

Envelope Trade-offs

3.4.1.2.1)
In calculating trade-offs for an addition, it is not permitted to take into account improvements being made to existing components of the building. (See also sentence 2.2.2.8.(6)) (See Appendix E)

HVAC

5.1.1.1.3)
This Part does not apply to the existing components of systems that are extended to serve additions.

Performance Path

8.2.1.5
(1) For the purpose of performance compliance calculations, the compliance of additions shall be based on either
        a) the addition being considered by itself, or

b) the addition being considered together with the existing building, in which case both the building energy target and the annual adjusted energy consumption of the building shall be determined using the existing thermal characteristics of existing components of the building envelope.

(2) When evaluating an addition together with the existing building for compliance with this Part, the existing characteristics of a component that is already built shall be its actual characteristics as determined, to the extent possible, in the same way as required in Part 2 of this Code for new components.