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Modelling Guide

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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 provincial government or local authority having jurisdiction adopts the code.

Because the MNECB is a code, it represents a minimum level of energy efficiency. Natural Resources Canada’s (NRCan) Office of Energy Efficiency (OEE) works to improve energy conservation and energy efficiency through the ecoENERGY Initiative and activities under the ecoENERGY for Buildings and Houses Program (<http://ecoaction.gc.ca/buildings>). NRCan’s validation of new building designs service is intended to encourage the design and construction of energy-efficient commercial and institutional buildings. The service provides support to building owners and their design team by identifying energy efficiency opportunities, practices, standards, case studies, tips, key energy efficiency measures, tools and validation of new building designs prepared in NRCan’s approved software. The validation is considered successful if the “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 NRCan rules where a conflict exists with the MNECB or the MNECB does not address the design issue.

The EE4 computer software developed by NRCan was specifically designed as a compliance-checking tool for the MNECB and NRCan’s validation. Under NRCan 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 NRCan 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 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://irc.nrc-cnrc.gc.ca/pubs/index_e.html).

The EE4 software simulates the energy use of the proposed building design and the reference building design. (The software can also simulate 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 NRCan 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 of assumptions that are not alterable. 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 NRCan's validation and MNECB be performed accurately and consistently. However buildings and building systems are sometimes extremely complex and simulators can achieve different results on the same building because of assumptions made. This manual provides guidance on how to model new buildings, in accordance with MNECB and NRCan requirements, so as to minimize these differences.

The purpose of these simulations is NOT to develop an accurate prediction of annual energy use. Rather, the purpose is to develop fair and consistent evaluations of the effects of the deviations (in whatever direction) from MNECB prescriptive requirements. As such, many simplifying assumptions were made to rationalize the modeling exercise without compromising the intent. The simulation provides a uniform and consistent means of verifying compliance to MNECB and NRCan, and comparing the energy efficiency of building designs. MNECB and validation 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 modelled within the software and the inherent software assumptions. EE4 and DOE2 simulations submitted under NRCan's validation 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, NRCan and the EE4 software.

1.2 Scope of the Manual

This manual gives recommended simulation procedures in three keys areas:

- Rules for dividing buildings into thermal zones and spaces
- Sources of information for performance values of envelope components and building equipment
- Guidance on modelling simple and complex HVAC systems

This manual also includes some modelling examples for showing compliance to the MNECB and NRCan's validation of new buildings design service.

This manual should be used in conjunction with the MNECB, the EE4 help system, and NRCan training courses. These documents can be obtained from the following Web sites:

- NRCan's OEE : <http://oe.e.nrcan.gc.ca/commercial/newbuildings.cfm>
- NRCan EE4 : http://www.sbc.nrcan.gc.ca/software_and_tools/ee4_e.asp
- NRC : http://irc.nrc-cnrc.gc.ca/pubs/index_e.html

The procedures within this document will be used to assess compliance with the MNECB and NRCan rules; therefore the user should consult this document in preparation of the data for entry into the EE4 software.

This manual must be used as the basis for all EE4 simulations. The modelling rules within this manual supersede previous manuals and EE4 help files. The EE4 Web site (link above) provides additional modelling methods and workarounds that have not been included in the manual or have been derived after this manual issuance.

In some cases, EE4 may not be sufficient to model certain energy efficiency measures, and adjustments of the EE4 outputs are sometimes allowed. 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 NRCAN rules have been developed are available from NRCAN. If the proposed modifications do not have established NRCAN 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.

Screening Tool

The on-line Screening Tool allows simulators to quickly estimate the energy performance of a proposed building design relative to the MNECB and the rules established by NRCAN. By conducting this preliminary screening, simulators can assess the expected impact of a single measure, or a combination of measures, to maximize the energy efficiency of a proposed design. Access to the Screening Tool is available via the following Web site: (<http://screen.nrcan.gc.ca>)

1.3 Manual Organization

This manual 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”.

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 NRCAN’s validation of new building designs, and the differences between them. Tables compare how energy efficiency measures are handled in the MNECB and NRCAN’s validation.

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 modelling procedures that relate to defining building function and operating parameters, including utility rates.

Chapter 4: Central Plant Equipment

Describes modelling 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 modelling 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: Modelling of HVAC Systems

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

Chapter 7: Building Envelope Modelling

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

Chapter 8: Electrical System Modelling

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

Chapter 9: NRCan Submission Guidelines

Present information to be considered before a validation of new building designs submission is made to NRCan.

Chapter 10: Troubleshooting

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

1.4 Overview of the MNECB and NRCan's validation of new building designs requirements

1.4.1 Eligible Buildings

For buildings to be eligible for NRCan's validation, they must have a building permit issued on or after Jan 1, 2006. Eligible buildings include:

- New commercial and institutional buildings with a building area greater than 10 m²:
- New multi-unit residential buildings (MURBs) and Mixed-use Residential Buildings (1.4.2)
- Major renovations (1.4.3)
- Additions to existing buildings (1.4.4)

Non-mechanically ventilated buildings may also be eligible for NRCan's validation depending on their occupancy; however, the corresponding reference building will also be non-mechanically ventilated (contact NRCan if you are uncertain). See section 5.5.9 for modelling procedures.

NRCan's validation of new building designs is not available to:

- Agricultural buildings whose primary function is not based upon human occupancy conditions (ventilation, space conditioning) are not eligible.
- Any building covered by the Model National Energy Code for Houses.

"Building area" is a defined term under the MNECB (MNECB 1.1.3.2.[1] and 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 centre line of firewalls."

1.4.2 Multi-unit Residential Buildings (MURBs) and Mixed-use Residential Buildings

Multi-Unit Residential Buildings:

For a MURB project to be eligible for NRCan's validation, it must meet the following:

- Be greater than 3 stories in building height (i.e., 4 stories 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.
- Have a common entrance.

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

A garage is not accepted as the sole common entrance.

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

Mixed-use Residential Buildings:

A mixed-use residential building is one where there is a mix of residential suites with other commercial/institutional space uses. There are specific requirements related to this type of building submission:

- All conditioned spaces, both residential and commercial, are to be modelled for the purposes of a validation submission to NRCan.
- NRCan Validation MURB credits do not apply in the residential spaces of mixed-use residential buildings.

The NRCan validation MURB qualification rules remain in place and unchanged for buildings with four stories or more of residential space or a footprint of 600m² or more, whether or not they have a mixed-use component.

1.4.3 Renovations

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

- 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.
- The owner/proponent must intend to modify architectural, ventilation, space conditioning and lighting systems in combination; All systems must be affected.

1.4.4 Additions

Additions to existing buildings are eligible under NRCan's validation of new building designs service; however, only the addition's heated area is eligible for validation. 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 calculator. 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 not eligible for NRCan's validation.

1.5 Energy Efficiency Measures

This section contains a list of common energy efficiency measures that can be implemented and modelled in EE4 for credit in reaching NRCan's validation 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 day lighting, occupancy control of lighting, and demand controlled ventilation.

Night time 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 night time 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 CO₂ 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 sections 5.5.10 and 5.5.11.

Building Envelope

Wall/Roof RSI-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 RSI-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 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 is fixed at 40% and the resultant increased reference wall area will be insulated to MNECB RSI-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: 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%, the reference building is fixed at 2% and the resultant increased reference roof area will be insulated to MNECB RSI-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 modelling purposes, the infiltration rate in both proposed and reference buildings is fixed at 0.25 L/s per m² of gross above grade envelope area.

Overhangs and Side fins: Credit may be offered for overhangs and side fins 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 side fins. Simulators should note that the practice of aggregating all windows into a single area on a wall segment distorts the recorded geometry of an individual window and drastically reduces the effectiveness of represented overhangs and side fins.

Wall/Roof Absorptivity and Roughness: No credit available for these wall parameters. They are modelled 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 be able to 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).

Modelling of High Efficiency Combustion Equipment (furnaces) - EE4 supports the modelling of high efficiency combustion equipment if it is present for your building (i.e. furnace). A new field entitled "High Efficiency Combustion" has been added to the Central System dialogue, General Tab. This is only active if your fuel selection type is one of propane, oil or natural gas. If this new "High Efficiency Combustion" field is selected with a valid fuel type for the admin region selected, a different set of part load curves is referenced to model the equipment in part load mode which typically results in energy savings over the conventional part load curves which are used.

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:

| Required 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%, therefore a credit is available for specifying a higher thermal efficiency.

Pump Characteristics: The reference building pump characteristics are shown in the following table. Credits or penalties are possible, depending on the proposed building pump characteristics.

| 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 adopted for the make-up air. The reference building will be limited to a 20% oversizing factor, see section 5.5 for details.

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 and/or credit for operating a boiler at a lower return water temperature is available. This credit involves increasing the boiler efficiency when the return water temperature is less than 160°F (70°C). The modelled boiler efficiency is increased by the simulator according to the equation in section 4.2.6.

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

Modulating/Multi-stage Burners: Credit for multi-stage firing of boilers. The credit involves the break-up of the boiler capacity into smaller virtual boilers of equal capacity and sequencing them at a 90% sequencing ratio. The thermal efficiency is left unchanged from manufacturer’s data. The number of stages of firing determines the number of boilers, up to a maximum of 10 virtual boilers per physical boiler. Modulating boilers are modelled via return water temperature. Modulating condensing units are not supported in EE4 version 1.7, see section 4.2.4 for details.

Multi-Staging Rooftop Units: A credit is available for efficiency improvements of multi-staging rooftop units. The credit is limited to a 1.5% thermal efficiency increase for regions with less than 5000 heating degree days, and 2% thermal efficiency increase for locations with 5000 and greater 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 virtual chillers to match the number of modulation stages, up to a maximum of 10 per physical chiller. The chillers are sequenced at a 90% sequencing ratio. The entered COP or EER is set to that of the manufacturer’s data.

Ground Source Heat Pumps: Credit is available for the use of ground source heat pump technology with or without a supplemental boiler. The reference case will normally be an electric hot water boiler with a COP equivalent of 1.0; therefore credits are available via the COP improvements in compressor technology. In addition, when the ground source heat pump provides cooling, the reference case installs a centrifugal chiller with a cooling tower; therefore credits are potentially available to the proposed design from the elimination of the cooling tower and associated pumps, and the use of higher COP heat pump technology.

Variable Speed Drives: Credit for variable speed drives on pumps, supply fans (VAV systems only) and cooling tower fans; the 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 section 5.5 for more information.

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

Humidification: No credit is given to the use of heat wheels and desiccant 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 for NRCan's validation; it is not modelled in EE4 and is not eligible for credit.

Vertical Transportation: Elevators/escalators are not considered for validation purposes and not eligible for credit.

Appliances: Credit for energy-efficient appliances installed in MURBs (refer to Appendix D).

Miscellaneous

Cogeneration (Combined Heat and Power) 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 modelled 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 see sections 4.5 and 4.8.3.

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 not an available credit from NRCan and should not be modelled. However, laboratory fume hood heat recovery may be an eligible item; for more information see Appendix E.

Fuel Switching: Fuel switching from a fossil fuel to another type of fossil fuel or electricity is not an available validation 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, such as solar PV, solar thermal (air and hydronic), and wind.

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

Domestic Hot Water Heat Recovery: Credit is available for drain water heat recovery systems. See Appendix F for calculation on drain water 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 modelled 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 modelled in EE4. These technologies may be recognized by NRCan. 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 NRCan for approved techniques to handle technologies not considered in this manual.

2. **BUILDING ZONING PRINCIPLES**

One of the first steps in the modelling process is to examine the plans and specifications thoroughly and come up with a strategy to subdivide the building into “zones”. The process to develop a zoning strategy is described in this section.

2.1 **Dividing Buildings into Zones**

Buildings are made up of thermal *zones*. A thermal zone, generally referred to as a zone, are portions of a building served by a common HVAC system that have 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 *spaces*. A space is a room, or a number of rooms with similar heat gains and losses and used for the same *function*. For example, the office zone from the previous example 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 methods of lighting, occupant densities, and ventilation rates may be different.

One of the most difficult aspects in modelling buildings is dividing the building into zones and spaces. There is no one correct approach; 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.

2.1.1 **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, 2 rooftop units may serve a small retail building in a plaza. 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 to heat and cool individual apartments. In this case, there is only one 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 modelling 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 modelled 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 modelling 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.

2.1.2 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 modelled 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.

2.1.3 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 criterion means that rooms with exterior walls facing in different directions should be modelled as separate zones (different solar gains). Interior floor areas are modelled separately from perimeter areas. High internal heat gain computer rooms are modelled 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 modelled as separate zones.

Perimeter areas should be modelled 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 NRCan's definition of a lighting control zone for day lighting 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 day lighting zone.

2.1.4 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:

- Similar rooms with individual thermostats. These rooms can be grouped together provided they have similar heating and cooling loads.
- Same area on different floors. In many office buildings and apartments, the same floor plan is repeated on each story. The same areas on each floor can be grouped into a zone. Top and bottom floors are modelled separately because of the extra heat transfer out of the roof and floor. In Figure 2-1 - Typical Zoning for Offices and MURBS, the second and third storeys can be grouped together.

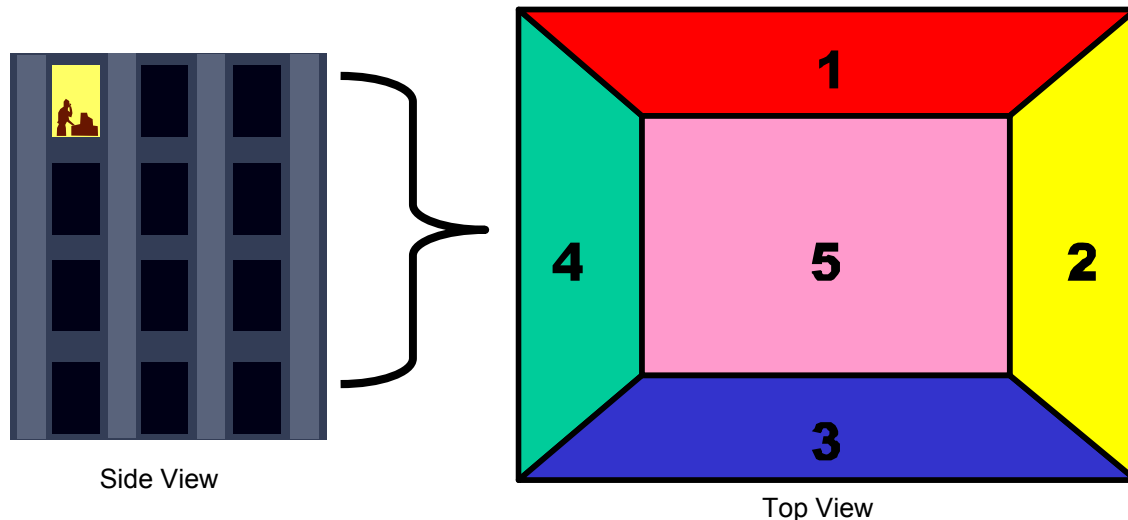


Figure 2-1 - Typical Zoning for Offices and MURBS

- 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.
- 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 during the same hours as the office areas they serve and therefore should be included with the office zone.

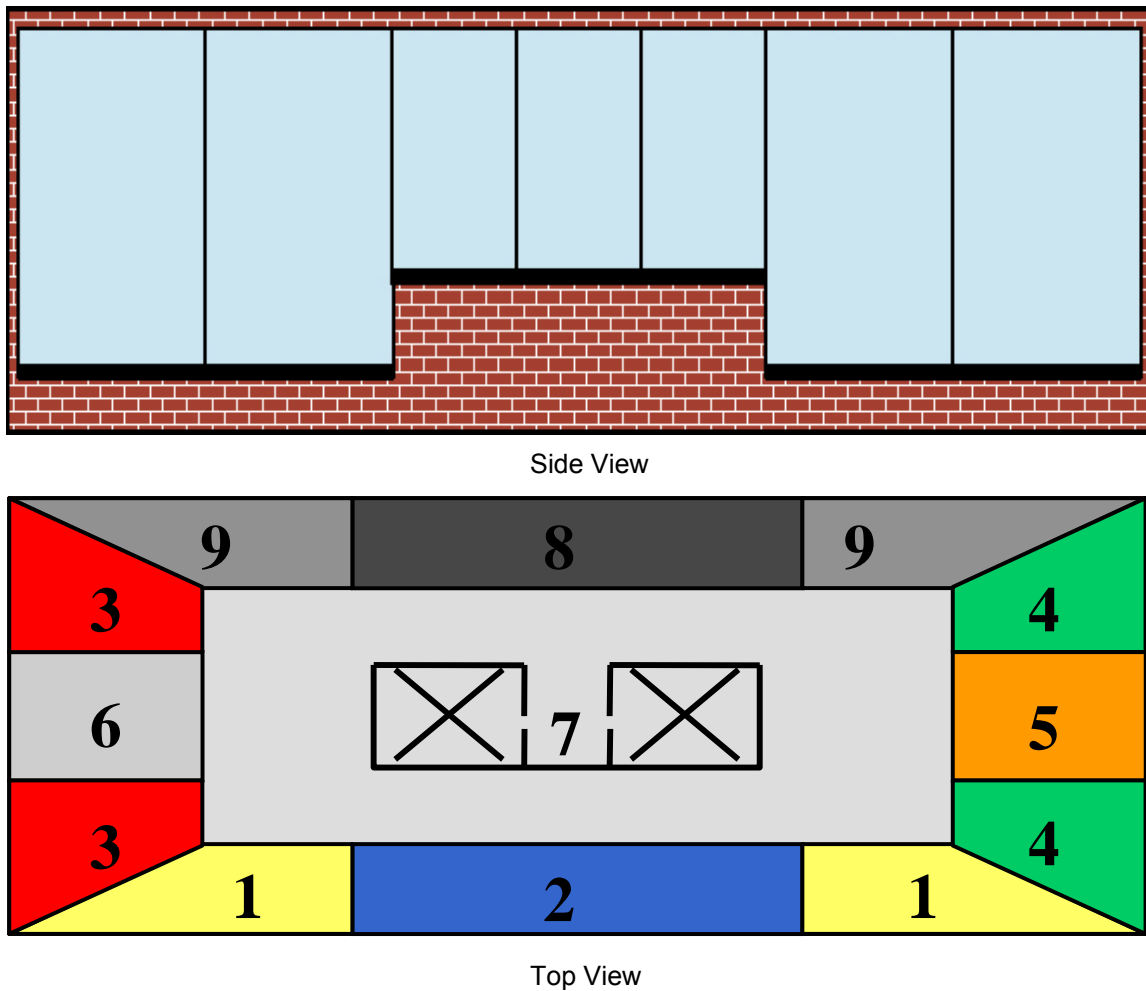


Figure 2-2 - Grouping Zones According to Heating and Cooling Loads

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 modelled 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 MNECB/CS 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 schedule, according to MNECB/CS Table 4.3.2.B and also 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 schedule “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 as 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 in 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 a separate 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:

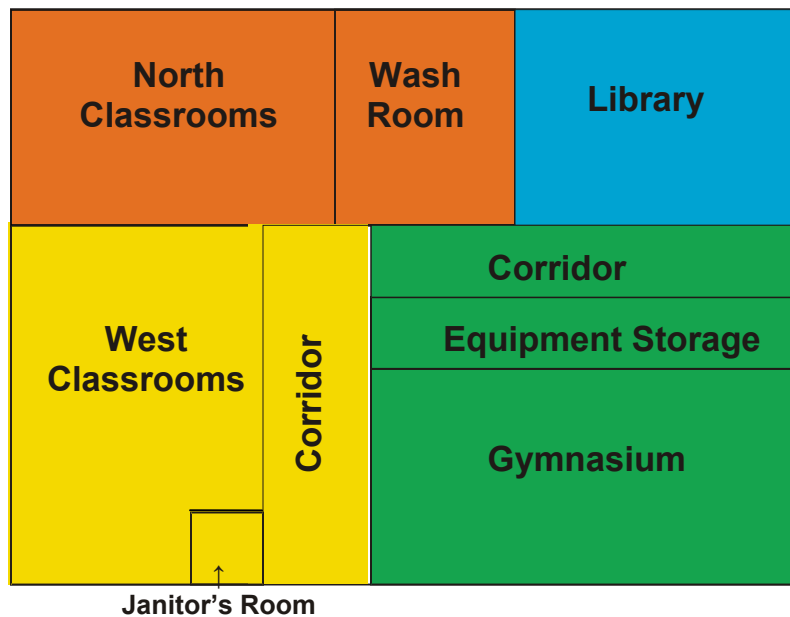


Figure 2-3 - Defining Spaces

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 $0.16 \text{ m}^2\text{-}^\circ\text{C/W}$ (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 7.8.

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 modelled 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 MNECB/CS 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 m^2 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 m^2 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 modelled 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 $0.16 \text{ m}^2\text{-}^\circ\text{C/W}$ (MNECB Clause 3.3.1.4-1).

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

2.4 Zoning Example

A zoning strategy for a “big-box” retail store appears in Figure 2-4 below.

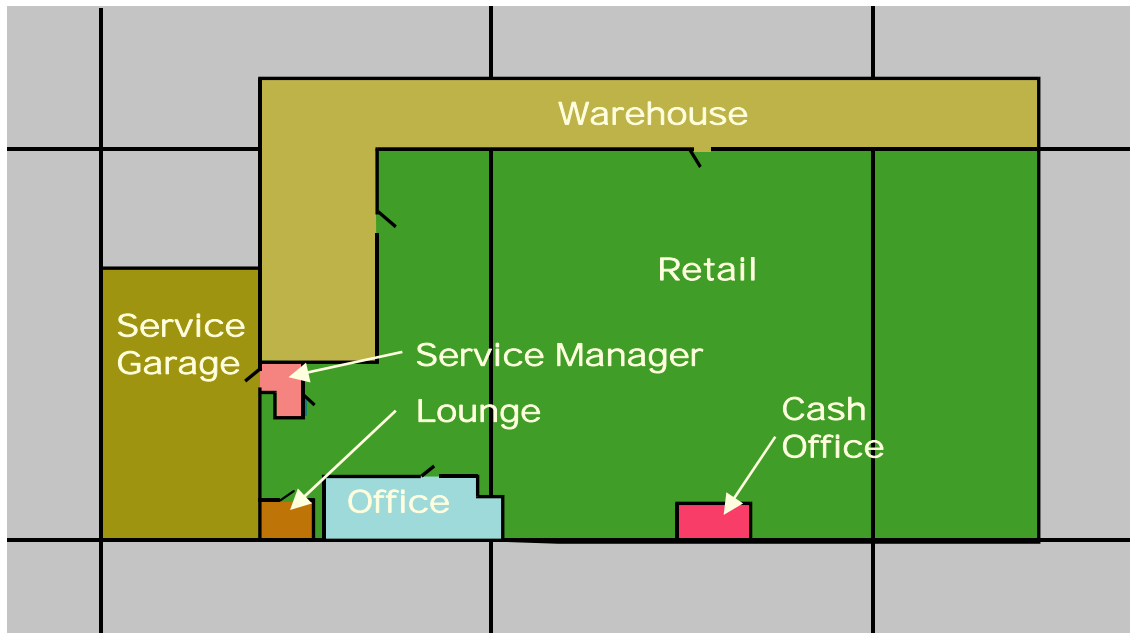


Figure 2-4 - Zoning Strategy for Big-Box Retailer

The store is primarily retail space, with two small office areas and an adjacent service garage. Six 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 modelled 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 modelled 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 modelled 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 modelled 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, and 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 software 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.

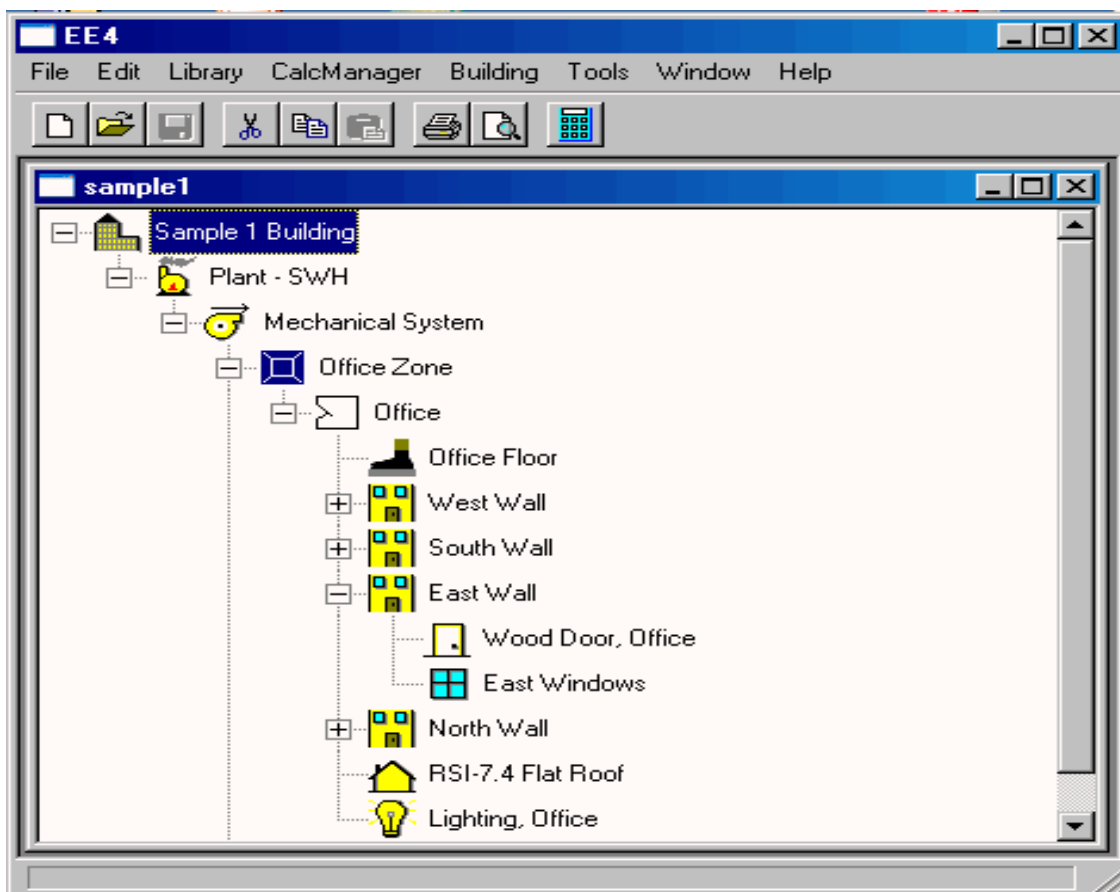


Figure 3-1 - EE4 Building Tree Hierarchy

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 HVAC systems; 15 types available.
- 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 NRCAn and MNECB rules to construct two input files: one for the proposed building and one for the MNECB reference building. The building energy analysis software DOE-2.1 then analyzes each input file. 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 versus Space Function

A key decision in modelling buildings is whether to model by *building type* or by *space function*. This decision defines many of the simulation inputs, including occupant density, outdoors 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
- MURB

Modelling 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 within a 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 strongly recommended in almost all 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 modelling of service functions (corridors, vestibules, washrooms, mechanical rooms) as separate zones because of the definition of the *building type*. If the selection of *building type* contains a very high proportion of a non-representative *space function* (e.g., 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.

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 NRCAN to obtain a written ruling.

3.3 Energy Savings versus Cost Savings

To qualify for NRCAN’s validation, in addition to meeting all of the mandatory MNECB requirements, the energy consumption of the proposed building must be 25% lower than that of the MNECB reference building. Because of the different costs of energy, it is possible (but not likely) that a building design could meet the 25% energy savings target but achieve no energy cost savings.

To meet the NRCAN requirements and maximize energy savings, 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 maximize energy cost savings.

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 totalled for entry into EE4. The electricity structure should include both consumption and demand charges. All rates should exclude any provincial taxes and GST. In the submission package, details on how the utility rate and additional charges were calculated must be included.

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 m³, another rate for the next 1000 m³, and anything greater than 1100 m³ 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) is 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 latter rate structure is entered in the Tab labelled "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.

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

3.4.1 Time of Use Rates: Data Entry

If you wish to enter time-of-use rates, calculate the entries according to the following example:

Note:

- 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 – June 15) | 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 (Sept 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 were 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 will 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 averaging 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 9 pm (8:30 pm is rounded to 9 pm)
 Period 3: 9 pm to midnight (8:30 pm is rounded to 9 pm)

From 1 am to 7 am and from 9 pm to midnight, the rate is a constant \$ 0.04 /kWh throughout the week, therefore averaging is required to include the weekend to determine an average daily rate.

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

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

| | | |
|----------------|---------------|---|
| Average price: | 1 am - 7 am = | $(0.92 + 0.48 + 0.84 + 0.48 + 0.84 + 0.6) / (23 + 8 + 21 + 8 + 21 + 10) = \$ 0.0457/\text{kWh}$ |
|----------------|---------------|---|

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

From 7 am to 9 pm (period 2), various time-of-use rates are available for different months, therefore time averaging is required as follows:

- Determine a winter average daily rate from 7am to 8:30 pm.
 $\text{Average} = (3 \text{ hrs} * 0.12 + 7 \text{ hrs} * 0.08 + 4 \text{ hrs} * 0.12) / (3 \text{ hrs} + 7 \text{ hrs} + 4 \text{ hrs}) = \$0.10 /\text{kWh}$
 The average daily rate for the wintertime period of 7 am to 9 pm is \$0.10 /kWh for all days within the week.
- Weekend rates for wintertime period are constant throughout the weekend at \$ 0.06 /kWh, therefore no averaging is required.
- 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 | * \$ 0.1 /kWh | = 2.3 |
| Jan weekends: | 8 days | * \$ 0.06 /kWh | = 0.48 |
| Feb weekdays: | 21 days | * \$ 0.1 /kWh | = 2.1 |
| Feb weekends: | 8 days | * \$ 0.06 /kWh | = 0.48 |
| Mar weekdays: | 21 days | * \$ 0.1 /kWh | = 2.1 |
| Mar weekends: | 10 days | * \$ 0.06 /kWh | = 0.6 |

| | | |
|----------------|---------------|---|
| Average price: | 7 am - 9 pm = | $(2.3 + 0.48 + 2.1 + 0.48 + 2.1 + 0.6) / (23 + 8 + 21 + 8 + 21 + 10) = \$ 0.08637 /kWh$ |
|----------------|---------------|---|

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
(8:30 has been rounded to 9 = EE4 modified periods)

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 a Monday

| | | | | |
|-------------------|----------------|----|----------------|--------|
| June 16 – June 30 | Weekdays | 10 | * \$ 0.06 /kWh | = 0.6 |
| June 16 – June 30 | Weekend Days : | 5 | * \$ 0.08 /kWh | = 0.4 |
| July | Weekdays | 23 | * \$ 0.06 /kWh | = 1.38 |
| July | Weekend Days | 8 | * \$ 0.08 /kWh | = 0.64 |
| August | Weekdays | 22 | * \$ 0.06 /kWh | = 1.32 |
| August | Weekend Days : | 9 | * \$ 0.08 /kWh | = 0.72 |
| Sept 1-15 | Weekdays | 10 | * \$ 0.06 /kWh | = 0.6 |

| | | | | |
|-----------|--------------|---|----------------|-------|
| Sept 1-15 | Weekend Days | 5 | * \$ 0.08 /kWh | = 0.4 |
|-----------|--------------|---|----------------|-------|

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 a Monday.

| | | | | |
|-------------------|----------------|----|----------------|--------|
| June 16 – June 30 | Weekdays: | 10 | * \$ 0.16 /kWh | = 1.6 |
| June 16 – June 30 | Weekend Days : | 5 | * \$ 0.08 /kWh | = 0.4 |
| July | Weekdays : | 23 | * \$ 0.16 /kWh | = 3.68 |
| July | Weekend Days: | 8 | * \$ 0.08 /kWh | = 0.64 |
| August | Weekdays : | 22 | * \$ 0.16 /kWh | = 3.52 |
| August | Weekend Days : | 9 | * \$ 0.08 /kWh | = 0.72 |
| Sept 1-15 | Weekdays: | 10 | * \$ 0.16 /kWh | = 1.6 |
| Sept 1-15 | Weekend Days: | 5 | * \$ 0.08 /kWh | = 0.4 |

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 a Monday

| | | | | |
|-------------------|---------------|----|----------------|--------|
| June 16 – June 30 | Weekdays: | 10 | * \$ 0.06 /kWh | = 0.6 |
| June 16 – June 30 | Weekend Days: | 5 | * \$ 0.08 /kWh | = 0.4 |
| July | Weekdays : | 23 | * \$ 0.06 /kWh | = 1.38 |
| July | Weekend Days: | 8 | * \$ 0.08 /kWh | = 0.64 |
| August | Weekdays : | 22 | * \$ 0.06 /kWh | = 1.32 |
| August | Weekend Days: | 9 | * \$ 0.08 /kWh | = 0.72 |
| Sept 1-15 | Weekdays: | 10 | * \$ 0.06 /kWh | = 0.6 |
| Sept 1-15 | Weekend Days: | 5 | * \$ 0.08 /kWh | = 0.4 |

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 & Weekends | 7 am - 8:30 pm | * \$ 0.08 /kWh |
| Sept 16 – Nov 30 | Weekdays & Weekends : | 8:30 pm to 7 am | * \$ 0.04 /kWh |

| | | | |
|------------|------------|-----------------|----------------|
| Dec 1 – 31 | Weekdays | 7 am to 8:30 pm | * \$ 0.1 /kWh |
| Dec 1 - 31 | Weekdays | 8:30 pm to 7 am | * \$ 0.04 /kWh |
| Dec 1 - 31 | Weekends : | 7 am to 8:30 pm | * \$ 0.06 /kWh |
| Dec 1 - 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 weekdays and weekends 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 a Monday.

| | | | |
|-------------------|----------|----------------|--------|
| Sept 16 – Sept 30 | 16 days | * \$ 0.04 /kWh | = 0.64 |
| October: | 31 days: | * \$ 0.04 /kWh | = 1.24 |
| November: | 30 days | * \$ 0.04 /kWh | = 1.2 |
| December Weekdays | 22 days | * \$ 0.04 /kWh | = 0.88 |
| December Weekends | 9 days | * \$ 0.06 /kWh | = 0.54 |

$$\text{Average} = (0.64 + 1.24 + 1.2 + 0.88 + 0.54) / (16+31+30+8+22+9)$$

$$= \$ 0.0412 /\text{kWh (rate for 1 am to 7 am)}$$

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

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

| | | | |
|-------------------|----------|----------------|--------|
| Sept 16 – Sept 30 | 16 days | * \$ 0.08 /kWh | = 1.28 |
| October: | 31 days: | * \$ 0.08 /kWh | = 2.48 |
| November: | 30 days | * \$ 0.08 /kWh | = 2.4 |
| December Weekdays | 22 days | * \$ 0.1 /kWh | = 2.2 |
| December Weekends | 9 days | * \$ 0.06 /kWh | = 0.54 |

$$\text{Average} = (1.28 + 2.48 + 2.4 + 2.2 + 0.54) / (16+31+30+8+22+9) =$$

$$0.0824 /\text{kWh (rate for 7 am to 9 pm)}$$

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

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

| | | | |
|-------------------|---------|----------------|--------|
| Sept 16 – Sept 30 | 16 days | * \$ 0.04 /kWh | = 0.64 |
|-------------------|---------|----------------|--------|

| | | | |
|-------------------|----------|----------------|--------|
| October: | 31 days: | * \$ 0.04 /kWh | = 1.24 |
| November: | 30 days | * \$ 0.04 /kWh | = 1.2 |
| December Weekdays | 22 days | * \$ 0.4 /kWh | = .88 |
| December Weekends | 9 days | * \$ 0.06 /kWh | = 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: | Ending Hour: | Blocks: | Rate : |
|---------|--------------|---------|---------------|
| 1 | 7 | 1 | \$0.0457 /kWh |
| 2 | 21 | 1 | \$0.0864 /kWh |
| 3 | 24 | 1 | \$0.0457 /kWh |

Season : 2 Ending Month: 09 Ending Day: 15

| Period: | Ending Hour: | Blocks: | Rate : |
|---------|--------------|---------|---------------|
| 1 | 7 | 1 | \$0.0659 /kWh |
| 2 | 21 | 1 | \$0.1365 /kWh |
| 3 | 24 | 1 | \$0.0659 /kWh |

Season : 3 Ending Month: 12 Ending Day: 31

| Period: | Ending Hour: | Blocks: | Rate : |
|---------|--------------|---------|---------------|
| 1 | 7 | 1 | \$0.0412 /kWh |
| 2 | 21 | 1 | \$0.0824 /kWh |
| 3 | 24 | 1 | \$0.0412 /kWh |

3.4.2 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, enter 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.

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

3.4.3 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, use the utility cost from the local utility supplier as if the building were not connected to the campus grid.

3.4.4 Deregulated Pricing

NRCan requires a referenced price to determine the estimated savings. 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. You must investigate how the utility pricing is generated. For example, Ontario has an independent energy market operator (IMO) web site (<http://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 modelling 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 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 - Energy Source Adjustment Factors (taken from MNECB Appendix D). The ESAF is roughly the ratio of the cost of the heating source relative to electric resistance heating.

Common Question

What is the principal heating source for water-loop heat pump system: heat pump or the energy source for the boiler loop ?

The principal heating source for a zone is the fuel source that provides more than 10% of the space-heating capacity (ventilation air and space heating) for the zone and has the highest Energy Source Adjustment Factor (ESAF) as specified in Table D-1 of Appendix D of the MNECB.

If water-loop heat pumps in a zone provide more than 10% of the space-heating capacity for the zone, and have the highest ESAF of any fuel providing more than 10% of the space-heating capacity to that zone, heat pump is selected as the principal heating source for the zone. However, if the water-loop heat pump in the zone is fed by a central boiler with a fuel having a higher ESAF than the heat pump, the principal heating source for the zone is the fuel source of the central boiler.

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 | 0.45 | 0.33 | 1 |
| New Brunswick | A | 1 | 0.87 | 0.34 | 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 |
| Nunavut | 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, renewable or diesel enter the fuel type it is replacing.

To accommodate natural gas availability in New Brunswick Region A and Nova Scotia Region A, the capability to select Natural Gas as a fuel option for these MNECB regions has been added. Note that although some cities in these regions still do not have access to natural gas, it was required to add the fuel as an available option for all cities that belong to the Administrative Region. If this fuel is not available for the city in which the simulated building is intended to be built, do not select it as an option. If an unavailable fuel is selected for the city in which you are modelling your building, you will be asked to revise your file.

The Northwest Territories Regions E through H have been renamed Nunavut Regions E through H.

3.6 Building Schedules and Equipment Operation

When the *building type* or *space function* is selected for each zone or space, default values of building operation are assigned. The same default 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 set points, and hourly schedules for occupancy, lighting, receptacles, process loads and HVAC operation. The default schedules are listed in the MNECB/CS and EE4 Help system. The fan operation is summarized in Table 3-2 - Fan Operating Schedules. The fan operation is also indicative of the hours of occupancy, cooling system operation and temperature set-up.

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 set point 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 often recommended that the default values be used unless there is a significant difference between the proposed operation and default values; this assumes that the zoning principles outlined in section 2 have been followed and all spaces in a zone utilize the same default operating schedule. A “significant” difference is considered to be a difference of greater than 25% in any of the building operation parameters (e.g. 25% more or less operating hours per week).

If the expected thermostat set point differs from the default values (21°C for heating and 23°C for cooling) by more than 3°C, 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

3.6.1 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 set point (Celsius or Fahrenheit depending on the units in which the user is working).

3.6.2 Process Loads

Very high process loads have a high impact on heating and cooling loads and should be modelled 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. Performing a hand calculation and using the following procedure must do this:

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") 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 files for the proposed and reference buildings (of the simulation with process loads).

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

Natural gas process loads (steam humidifier, health care laundry, gas-fired pool) cannot be modelled as gas process loads in EE4. These will have to be modelled 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 cases. As NRCan is interested in the energy savings, no adjustment is required for the energy costs for NRCan’s validation purposes; however, the ES-D reports of the .SIM file can be used to adjust the energy costs if desired.

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 a simulation.

3.6.3 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 heating 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 NRCan’s validation, 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; 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 value), 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, based on the MNECB flow rates and actual fixture counts (see the example that follows).

- 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 (see example below).

Low-flow plumbing fixture example:

| Category | Fixture Name | Fixture Count | MNECB Flow Rate (L/min) | | Proposed Flow Rate (L/min) | |
|-----------------|--------------|---------------|-------------------------|-------|----------------------------|-------|
| | | | Per Fixture | Total | Per Fixture | Total |
| Lavatory Faucet | L-1 | 45 | 8.3 | 373.5 | 1.9 | 85.5 |
| | L-2 | 56 | 8.3 | 464.8 | 2.2 | 123.2 |
| | Total | 101 | - | 838.3 | - | 208.7 |
| Shower Head | SH-1 | 45 | 9.5 | 427.5 | 5.7 | 256.5 |
| | SH-2 | 25 | 9.5 | 237.5 | 6.5 | 162.5 |
| | Total | 70 | - | 665.0 | - | 419 |
| Other | Slop-1 | 18 | 8.3 | 149.4 | 8.3 | 149.4 |
| | J-1 | 5 | 8.3 | 41.5 | 8.3 | 41.5 |
| | Total | 23 | - | 190.9 | - | 190.9 |

| | <u>L/min</u> | |
|--|--------------|-------------------------|
| Total Flow Rate in Ref Building | 1694.2 | (838.8 + 665.0 + 190.9) |
| % Shower Heads | 39.3% | (665.0/1694.2) |
| % Lavatories | 49.5% | (838.3/1694.2) |

| Proposed Building Entries: | <u>L/min</u> | |
|-----------------------------------|--------------|-----------------------|
| Shower Heads | 5.99 | (419L/70 fixtures) |
| Lavatories | 2.07 | (208.7L/101 fixtures) |

| | <u>L/sec</u> | |
|---------------------|--------------|-----------|
| Shower Heads | 0.10 | (5.99/60) |
| Lavatories | 0.03 | (2.07/60) |

In the SHW (Service Hot Water) tab of the Room element of EE4 enter the calculated MNECB flow rate percentages and flow rates for the shower heads and faucets; in the example above each of the spaces (rooms) of the EE4 simulation file would have the shower head and faucet % and flow rates as 39% (Sh), 50% (Faucet), 0.10 L/s (Sh) and 0.03 L/s (Faucet), respectively.

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

3.7 Weather File Selection

The MNECB divides Canada into 34 climatic regions. These regions are used to establish the thermal requirements for the MNECB reference building which is the minimum acceptable level of performance used 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 of available cities, the one that is nearest the actual building site location, and within the same MNECB administrative region.

However, 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, due to differences in altitude (mountainous regions) and differences between coastal sites and inland sites. In such cases, the MNECB conditions may 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 (see section 3.5 for available fuel types and their associated ESAFs in EE4). In these cases there may be a benefit to the simulator in using a 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 NRCan's Validation Technical Committee prior to the submission being received. The reasons for the change must be described in the simulator's notes submitted with the 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.

For example, in one case, 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 Newfoundland, using natural gas as the principal heating fuel. As the MNECB region for Newfoundland 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; however, at least one plant must be defined in EE4 for all building simulations.

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 3.6.3). 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 modelling of the service water heating.

There are several methods available for heating service hot water in EE4. The “Service Water” tab in the Plant element allows the following methods, which are described in subsequent subsections:

- Tanks
- Dedicated boiler(s)
- Tankless heaters
- Coil within space heating boiler (indirect water heating)
- Ground source heat pump (GSHP) coil or direct fed GSHP
- Air source heat pump

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, small electric storage or instantaneous heaters that serve only a small load in one area of the building meet service hot water needs. 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. If the proposed service hot water capacity is not large enough to meet the simulated load, EE4 will transfer the unmet load to the central plant or create additional service hot water heating capacity.

When the SHW type selected is “Tank(s)”, “Dedicated boiler(s)”, or “Tankless heaters” the simulator can select “Chiller Heat Recovery” if there is a chiller heat recovery system in the proposed design that is at least partially used towards heating the SHW. The chiller heat recovery is used first to satisfy the SHW load. Chiller heat recovery is available with reciprocating and centrifugal chillers. The fraction of available chiller capacity must be greater than 0. See section 4.3.4 for more information on modelling chiller heat recovery.

If the check box “not included in the analysis” on the SHW tab is checked EE4 will exclude the energy consumption related to service hot water heating from the analysis. Note that this differs from previous versions of EE4 where checking this box would cause EE4 to auto-size an electric hot water heater to meet the default service hot water load in both the proposed and reference buildings.

Note that multiple tanks are modeled as a single tank in EE4; the same single tank approach is used for all SWH types that support the input for "Number of Heaters". The inputs to DOE account for the number of tanks to set the proper volume and capacity

4.1.1 Storage Tank Type Heating Systems

Storage tank water heaters are hot water reservoirs, similar to conventional residential water heaters, with integral electric heating elements or fuel-fired burner. 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.

This type of service hot water system is modelled by selecting "Tanks" in the "Service Water" tab of the Plant element. This type requires the definition of the number of tanks, the average volume of each tank, the average input rate of each tank, the input rate-weighted thermal efficiency, as well as whether chiller heat recovery is available to apply towards meeting the SHW load.

If there are multiple storage water tank heaters of the same fuel type, but differing capacities and efficiencies, the storage capacities (L) and input rates of all the heaters should be combined and divided by the number of storage heaters to calculate the average storage capacity and average input rate to be entered in EE4. The capacity-weighted thermal efficiency is calculated as shown in the example of section 4.1.7; this section also covers the scenario where there are multiple systems fed by different energy sources.

4.1.2 Dedicated Boiler(s)

As the name implies this SHW heating type corresponds to one or more dedicated boilers for SHW heating that are separate from the main central space heating plant. This system type requires that the number of boilers, volume per boiler, average heat input rate and thermal efficiency of the boiler be entered in the SHW tab of the Plant element. If there are multiple boilers, the capacity-weighted thermal efficiency is calculated as shown in the example of section 4.1.7. Dedicated SHW boilers are assumed to be non-condensing units and follow a non-condensing part-load performance curve.

4.1.3 Tankless Heaters

Tankless, or on-demand heaters have no water storage capacity but heat the SHW on an as-needed basis. These heaters reduce the standing losses typically associated with storage type heaters; however, EE4 does not model standing losses, therefore there is no advantage from modelling tankless heaters over other heater types in EE4. Tankless heaters require that the number of heaters, input rate and thermal efficiency be entered in the SHW tab of the Plant element. If there are multiple boilers, the capacity-weighted thermal efficiency is calculated as shown in the example of section 4.1.7. Dedicated SHW boilers are assumed to be non-condensing units and follow a non-condensing part-load performance curve.

4.1.4 Coil Within Space Heating Boiler or from Purchased Heating

In this SHW type the service hot water is provided via a heat exchanger on the common space heating/water heating boiler or purchased heating (district/campus heating) loop. A plant boiler or purchased heating must be defined to select this SHW type. The input rate is the only entry accepted; this data is not actually used by EE4 as it auto-sizes the required capacity and extracts it

from the central heating plant. It is assumed that the heat exchanger is sized large enough to meet the entire SHW load.

4.1.5 **GSHP Coil or Direct Fed GSHP**

When the central plant is defined as a ground source heat pump (GSHP) or ground loop fed distributed heat pump system the SHW can be provided from a heat exchanger on the central unit or be directly fed by a separate GSHP. It is assumed that the heat exchanger is sized large enough to meet the entire SHW load.

The input rate and COP are the only input entries required. With a central GSHP these values are not actually used as the COP of the central unit is utilized and the input rate is auto-sized to meet the SHW load. If a separate GSHP is utilized to provide the SHW, with a ground loop fed distributed heat pump system providing the space heating, the COP of the separate GSHP providing SHW should be entered; the input rate of the GSHP is auto-sized by EE4.

4.1.6 **SHW Heating With Air source heat pump**

In this type of system one or more air source heat pumps are coupled with one or more water storage tanks to provide the SHW. The number of tanks, volume of each tank, input rate of each tank, and COP are the required fields in the "SHW" tab of the Plant element. The air source heat pump follows the same performance curve as is utilized by units at the system level.

4.1.7 **Multiple Water Heating Systems**

EE4 allows one service hot water 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 that fuel meets the entire load.

Example:

| Tank | Capacity (L) | Input Rate (kW) | Fuel Source | Efficiency (%) |
|------|--------------|-----------------|-------------|----------------|
| 1 | 225 | 10 | Electricity | 100 |
| 2 | 200 | 17.5 | Natural gas | 80 |
| 3 | 100 | 12.5 | Propane | 82 |

Solution:

- Entered EE4 fuel = gas
- Entered EE4 tank type = "Tank(s)"
- Entered EE4 number of water heaters = 3
- Entered EE4 volume = $(225 + 200 + 100)/3 = 175$ litres (average for each tank)
- Entered EE4 input rate = $(10 + 17.5 + 12.5)/3 = 40/3 = 13$ kW (13.3 rounded to 13kW)
- 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: a MURB with 340 water heaters

| SHW by type | Capacity (L) | Input Rate (kW) | Fuel Source | Efficiency (%) |
|-------------|--------------|-----------------|-------------|----------------|
| 100 | 100 | 7.5 | Electricity | 100 |
| 100 | 100 | 12 | Natural Gas | 82 |
| 100 | 250 | 20 | Natural Gas | 83.5 |
| 40 | 0 (tankless) | 10 | Natural Gas | 88 |

Solution:

- Entered EE4 type = "Tank(s)"
- Entered EE4 number of water heaters = 1
- Entered EE4 volume = $(100*100) + (100*100) + (100*250) + (40*0) = 45,000$ 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 underestimate 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%.

$$\text{Sequencing Factor} = (\text{sum of above \%}) / (\# \text{ of boilers} * 100)$$

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 are provided.

Example:

Five water heaters, each 135 litres volume with a heating capacity of 5 kW

Unadjusted values are:

volume = 5 x 135 = 675 litres (entered into EE4)
 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 = $(100 + 80 + 60 + 40 + 20) / (5 \times 100) = 0.6$

This would be applied to the total heating capacity = $25 \times 0.6 = 15$ kW as the average heating capacity entered into EE4.

4.1.8 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.

4.1.9 Renewable Energy Water Heating

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

| | | |
|------------|---|--|
| SHW type | = | “Tank(s)” |
| Volume | = | average capacity per tank of the renewable system plus the backup |
| Input rate | = | average 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 NRCan approved renewable energy analysis software. The renewable energy delivered is manually removed from final EE4 output to calculate the building energy use. Energy cost savings are manually removed by multiplying the renewable energy savings multiplied by the average energy unit cost from the ES-D report from the proposed building's .SIM file.

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, boiler type (atmospheric, modulating, or condensing) and efficiency (AFUE or thermal efficiency; choose whichever rating is stated on the manufacturer’s literature). EE4 does not model boilers that are both modulating and condensing; in such cases it is best to model condensing only units.

4.2.1 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.

4.2.2 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).

Only separate heating plants, which serve distinct parts of the building, can accommodate different boilers. 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.

4.2.3 Multiple Boilers of Different Efficiencies

At present, EE4 cannot model multiple boilers of different operating efficiencies. If the boilers are operated to provide uniform run hours, 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 boiler cases, the following procedure is to be followed:

Note: This procedure involves 2 EE4 simulations. The first is used to determine the average boiler efficiency. The second is used for determining compliance for NRCan’s validation.

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 a 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 fire, 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 by 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: $(95 \times 500 + 80 \times 800) / (500 + 800) = 85.8\%$.

| 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 following table, 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 compliance for NRCan’s validation.

4.2.4 Multi-stage / Modulating Boilers

Boilers with multi-stage or fully modulating firing capability allow improved part-load efficiency performance and are credited in EE4. If a boiler is multi-stage, simply divide the boiler capacity into smaller virtual boilers according to the number of stages of firing, and model as multiple boilers as described in section 4.2.2 above. For instance, a 100 kW, 84% efficient, 2-stage boiler should be modelled as two 50 kW boilers, each with 84% efficiency. The sequencing capacity should be 45 kW (90% of 50 kW) or the value defined in the mechanical drawings.

Fully modulating non-condensing boilers can be modelled directly in EE4 by selecting “Modulating” as the “Boiler Type” from the drop-down box in the boiler definition. EE4 does not support boilers that are both modulating and condensing; in such cases it is best to model condensing only units.

Modulating boilers can be modelled using the boiler return water temperature and outdoor air reset approach (see section 4.2.6).

4.2.5 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 130°F). 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 “Condensing” as the “Boiler Type” from the drop-down box in the boiler definition.

4.2.6 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:

$$\text{Modelled Efficiency} = (70 - \text{Average Boiler Inlet Water Temp}) * 0.1 + \text{Rated Efficiency}$$

If the boiler average inlet water temperature is above 70°C, use the actual inlet water temperature instead of the 70° in the equation above.

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 modelled boiler efficiency is $0.81 = (70-60)*.0.1 + 80 = 81\%$.

When using the above equation, the efficiency cannot exceed 88% 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.

4.2.7 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 then complete 2 EE4 runs:

First EE4 run: simulation without flue gas heat recovery.

Second EE4 run: volume = 0 litres (tankless SHW), input rate = recovered energy rate, efficiency = 1.0, and the fuel type must be the same as the first simulation above.

Subtract the results of the two proposed simulations to obtain the annual flue gas heat recovery savings (energy in MJ and cost savings); the credit is to be manually subtracted from the EE4 run without flue gas heat recovery (first simulation).

Use the first EE4 run (without flue gas heat recovery) reference building energy usage and cost as the base for compliance.

Boiler Loop Water Heating: Flue Gas Heat Recovery

This credit is modelled as an increase in the boiler design temperature drop, and is based on the following equation:

$$(\text{flue gas temperature} * \text{flow rate}) / (\text{hot water temperature} * \text{total water flow rate})$$

Example:

The flue gas temperature is 93.3°C with a flow rate, via a recovery coil, of 10 Litres/minute; the boiler water loop is maintaining 60°C water at a flow rate of 200 Litres/minute; the design temperature drop increase would be:

$$\text{Temp drop increase} = (93.3 * 10) / (60 * 200) = 0.07775$$

The boiler design temperature drop would be increased by 7.8%.

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.

4.3.1 Electric Chillers

Three types of chillers can be specified in the EE4 software: reciprocating, centrifugal and absorption. For screw and scroll-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” tab under “Central Cooling”. If water-cooled is selected, a cooling tower must be defined. Chiller heat recovery is now available, see section 4.3.4 for details.

If the design incorporates seasonal cooling (i.e.: 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.

Note: The IPLV (integrated part load value) in EE4 is to be entered in kW/kW, and not in kW/ton.

4.3.2 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 3.8. 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 NRCan's validation, 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 actual energy performance and energy cost savings.

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).

4.3.3 Modulating Chillers

Modulating chillers are handled identically as with modulating boilers. Take the total chiller capacity and divide by the number of steps of modulation control to derive an average capacity of each modulating stage. Create a virtual chiller of this capacity and the overall COP. Enter the number of modulation stages as the chiller multiplier and enter the sequencing capacity (90% of the virtual chiller capacity).

Example:

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

Enter a chiller capacity of 200 kW (800 kW/ 4 stages) capacity and a COP of 4.0.

Enter a chiller multiplier of 4 (number of stages = number of virtual chillers) and a sequencing capacity of 180 kW (90% of each virtual chiller capacity – the capacity at which the next stage is brought on-line).

4.3.4 Chiller Heat Recovery

Chiller heat recovery can be modelled when the chiller type defined in the “Central Cooling” tab of the Plant element is either reciprocating or centrifugal. The heat recovery can be applied towards space heating only, water heating only, or to both. Chiller heat recovery is modelled by entering a positive non-zero value in the “Available Capacity” field of the chiller definition; this value corresponds to the effective percent installed chiller capacity that can be recovered by the heat recovery system. This percent available capacity can be applied towards meeting the space heating load by selecting the “Reject Heat for Space Heating” check box. If this check box is selected without a non-zero value being entered in the “Available Capacity” field, an error will be generated.

Note that if the “Chiller heat recovery” check box is selected in the SHW tab of the Plant element, the chiller heat recovery is first used to meet the SHW load, and then applied to meet the space heating load if the “Reject Heat for Space Heating” check box is also selected. Where there are multiple chillers, EE4 assumes that the chiller supporting heat recovery is the first to be turned on to meet the building's cooling load.

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 (section 4.2).

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 are large plants that serve several buildings in addition to the one being modelled. One form of district heating is a cogeneration plant, where hot water/steam is a by-product of electrical generation. For NRCan’s validation purposes, district heating/cooling and cogeneration systems are to be modelled 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 as purchased cooling because the client is purchasing chilled water. However a client who installs their own lake/pond water-cooling system, such as a water source heat pump, would be considered as 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 as purchased heating unless the client owned the hydro, industrial or cogeneration plant. If the client owns their own cogeneration plant and it is installed on-site (within the building envelope), then it would no longer be considered purchased heating, but a boiler plant (see cogeneration plants section 4.8.3).

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 4.5.3).

4.5.1 District / Purchased Heating

If purchased heating is selected, EE4 defaults to an initial 80% boiler fuelled 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 and air handler heating (if applicable) capacities as the boiler capacity.

4.5.2 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-weighted method is to be used to create a representative boiler in EE4. The steps in the following example are to be used:

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 required boiler/district heating combo plant.
3. The difference between the installed capacity (200 kW) and the required capacity (the capacity calculated in step 2 above) is the size of the district heating plant; 85 kW in this example.
4. Calculate a capacity-weighted efficiency using the following equation:

$$\begin{aligned} \text{Eff} &= [\text{boiler cap} * \text{boiler eff} + \text{plant cap} * \text{plant eff}] / \text{total cap} \\ &= [200 * 0.88 + 85 * 0.80] / 285 = 0.8561403 \end{aligned}$$
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.

4.5.3 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. EE4 assumes that the purchased cooling is 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 lake water-to-water heat pump or flow-through water system plant is within the building, 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 within the building create a load-weighted representative chiller.

Example:

District cooling provides base cooling; a 4.2 COP scroll chiller of 200 kW capacity provides peak cooling.

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 for this example, DOE2 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 = type of chiller providing highest portion of load = centrifugal (313 kW) (entered into Central Cooling tab)

4.5.4 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 modelled 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 modelling heat pump systems.

Air source heat pumps condition ventilation air and are modelled 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 “Hydronic/Distributed Heat Pump Loop” tab or “Combination GSHP” tab, whereas the air tempering at the specific zones is defined at the system and zone level by the size and airflow of the air source heat pumps.

The Combination GSHP and Hydronic/Distributed Heat Pump Loop (whether fed by ground loop or boiler/cooling tower) are the only heat pump heating plant types available to centrally heat and cool circulating loop water.

4.6.1 Ground Source (or Geothermal) Heat Pumps

A ground source heat pump plant consists of either centralized or 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 loop types can be defined as using ground water directly (open-loop) or consisting of in-ground heat exchangers (closed-loop).

Centralized ground source heat pumps heat a water loop that then distributes this heat to fan coils/radiant panels and other heaters in the zones; these are defined under the “Combination Ground Source Heat Pump” tab in the Plant (see section 4.6.4 for details).

Distributed heat pump systems have small heat pumps distributed in the zones which absorb, or reject, heat to a common hydronic loop and are described in this section. To model a ground loop distributed heat pump, select “Ground Loop” under the “Hydronic/Distributed Heat Pump Loop” tab, in the Plant element. EE4 requires that monthly “ground temperatures” or “Entering water temperatures” be entered in the appropriate boxes.

The recommended source of information for the monthly “ground temperature” fields is the “Soil Temperature Averages” from Atmospheric Environment Service in Downsview, Ontario. Table 4-2 provides some representative values from the AES document. When modelling in EE4 version 1.70, a minimum ground temperature of -2°C (28°F) is required to avoid under heated hours being calculated.

Table 4-2 - Open Loop Temperatures (Depth 1.5 metres) ($^{\circ}\text{C}$)

| 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 in bore holes many metres below ground). For horizontal loop systems, the soil temperatures corresponding to the loop depth should be entered into EE4. Although the actual design monthly entering water temperatures should be entered, Table 4-3 - Monthly Entering Water Temperatures for Horizontal Closed-Loop Heat Pumps (°C), offers 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 (°C)

| 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 |

Source: "Soil Temperature Averages" from Atmospheric Environment Service

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 the actual monthly design entering water temperatures when available rather than the following tables, especially for well/lake water loops.

Table 4-4 - Monthly Entering Water Temperatures for Vertical Closed Loop Heat Pumps (°C)

| 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 |

Source: "Soil Temperature Averages" from Atmospheric Environment Service

In addition to ground temperatures, the pump flow rate and pump 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 loop distributed heat pumps, as the name implies, use 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 (System element) 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.

If the ground source heat pump is connected to a complex air handling system (e.g., VAV, Dual-Duct), contact NRCAN for technical assistance. 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.

4.6.2 Boiler/Cooling Tower Source Heat Pumps

This heat pump system may also be referred to as 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 “Hydronic/Distributed Heat Pump Loop” tab, under the 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: hydronic/distributed heat pump tab, boiler tab, and cooling tower tab. The pump head entered on the hydronic/distributed heat pump tab is for the pumps that operate continuously to circulate water around the interior water 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 pump data.

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.

4.6.3 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.

4.6.4 Combination Ground Source Heat Pump/Boiler Plants

This system provides heating and cooling by delivering hot and/or cold water to decentralized equipment (hydronic coils, fancoils, etc.) along a hydronic loop. Centralized water-water heat pumps extract energy from a ground source exchanger when in heating mode, and discharge energy to the exchanger when in cooling mode. Additional heat may be required to meet the

building's heating demand and can be provided by an auxiliary boiler. This combination ground source heat pump with boiler configuration does not allow an additional chiller/cooling tower. All of the chilled water for the hydronic loop is provided via the ground source heat pump. The simulator however is still permitted to model additional cooling at the air handler via a direct expansion coil or an air-to-air heat pump.

The method developed in EE4 to model this combination ground source heat pump with supplemental boiler also allows the use of different air handling systems to be accommodated. Therefore, a ground source heat pump with boiler combination can be simulated with VAV, constant volume, fan coil, dual-duct, packaged, and built-up air handling systems in addition to make-up air units.

Heat pump heating and cooling power ratings, nominal performance characteristics (heating COP and cooling COP), and pumping characteristics are defined in the Plant Element/Combination Ground Source Heat Pump tab.

According to the ARI, the conditions for classifying a water-water ground source heat pump in heating mode are as follows: The water intake temperature (from ground source exchanger) is 0°C, and the water output (heating water) temperature is 40°C. The conditions for classifying a water-water ground source heat pump in cooling mode are as follows: The water intake temperature is 25°C, and the water output (cooled water) temperature is 12°C.

If a backup boiler is required to meet heating load requirements, its characteristics (e.g. efficiency, capacity, multiplier, etc.) must be indicated in the section Plant Element/Central Heating.

If the heating or cooling capacity of an HVAC system is provided by a boiler or chiller operating independently of the ground source system, the performance characteristics of these (i.e. thermal performance and COP) must be entered in the Systems Library/General Tab or Cooling Tab for the HVAC system concerned. For this to be done for a boiler the type of heating must be natural gas and the performance rating must be that of the boiler. For a chiller, the type of cooling must be modelled as direct-expansion (DX) and the performance rating must be that of the chiller.

Optional characteristics are: return fan, outdoor air economizer, heat recovery, reheating coils/baseboard heaters, exhaust fans in some or all zones.

In the section Plant Element/Combination Ground Source Heat Pump (GSHP), define:

- central heat pump plant heating and cooling power capacities (kW) – if there are multiple centralized GSHPs, enter the average capacity of each central GSHP
- performance characteristics of unit (COP) – if there are multiple centralized GSHPs, enter the capacity-weighted COP
- configuration of backup boiler (parallel operation or alternate operation, see definition below)
- characteristics of primary (building hot/chilled water distribution pump) and secondary (central GSHP plant pump connected to ground/lake/well water source) pumps
- number of central heat pumps in the plant (will be sequenced based upon capacity)

Boiler operation with Combination GSHP: EE4 allows 2 types of boiler operation with the Combination GSHP, parallel and alternate. In both operations, EE4 assumes that the central GSHP is first to meet the hourly heating load. If your design operates such that the boiler is the initial operator to meet the heating load, then the combination GSHP with boiler option should not

be selected, and you should simply model the boiler as the heating source with a weighted efficiency (see Multiple Boilers of Different Efficiencies, section 4.2.3).

If the Combination GSHP is the initial operator to meet the hourly load and the boiler is brought into service, and operates simultaneously with the GSHP, to meet any supplemental hourly load beyond the capacity of the GSHP, then select "Parallel" boiler operation. In this situation, the boiler is a true back up and operates in parallel with the heat pump to meet the hourly heating load.

If the Combination GSHP is the initial operator to meet the hourly load but turns off, and the boiler is brought into service to meet the entire heating load when the hourly heating load exceeds the heating capacity of the GSHP, then select "Alternate" boiler operation. In this case, the boiler and the central GSHP alternate to meet the hourly heating load.

In both operation cases, should there be more than 1 central GSHP, they are turned on sequentially to meet the hourly heating load. If the sum of the GSHPs can no longer meet the hourly heating load, will the boiler turn on and operate with the Combination GSHP (parallel operation) or take over to meet the hourly heating load (alternate operation).

Boiler operation that is dependent on energy prices or activation under an electrical demand limiting automation strategy is not supported using this method.

In the Plant Element/Central Heating tab, define:

- boiler heating power capacity (if applicable)

In the section Systems Library, define:

- type of HVAC system (15 types of systems available)
- heating source (fossil fuel, electric, hot water from the combination GSHP loop, air source heat pump)
- heating and cooling power capacities
- performance characteristics of unit
- unit fan power
- heat recovery efficiency
- power capacity and regulation of supply fan
- outdoor air ratio, characteristics of economizer (if applicable) and heat recovery efficiency (if applicable)
- characteristics of return fan (static pressure and efficiency)
- zone reheating source
- preheaters

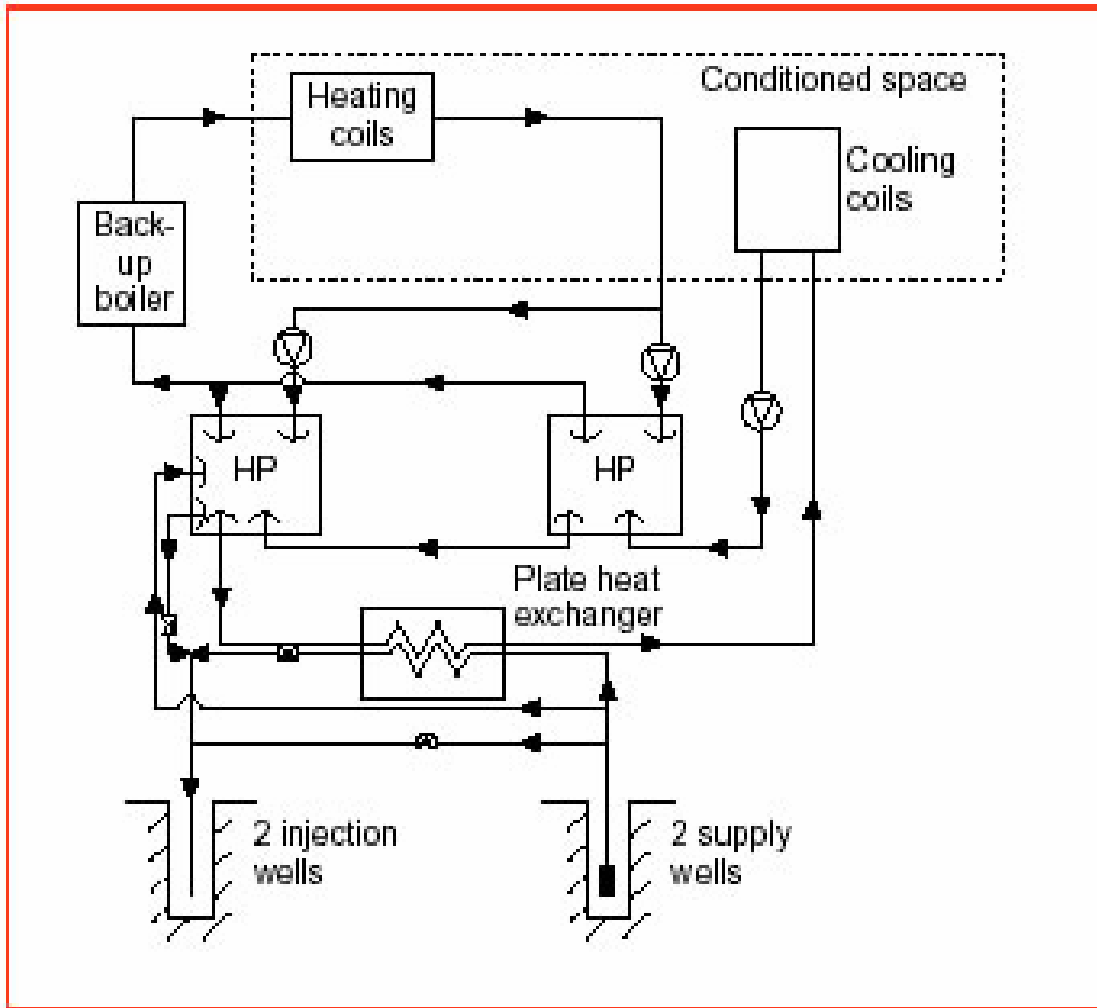
In the section Zone Element/Mechanical tab, define:

- zone heating (and, where applicable, cooling) power capacities
- air flow rate
- characteristics of limit fan, if applicable (air flow rate and power capacity of fan)
- principal heating source for the zone (not limited to heat pump, see section 3.5 for selection of principal heating source)

In the section Room Element /Exhaust Fan tab, define:

- Characteristics of exhaust fan (air flow rate and power capacity of fan).

Figure 4-1 - Example of Combination Ground Source Heat Pump



Common Questions

How do I model a combination heat pump system with supplemental boiler that is also connected to my domestic hot water loop?

This specific type of system is not directly supported in EE4. The combination GSHP/boiler is to be modelled as described above, if space heating is the primary function of the GSHP/boiler combination.

If the combination plant is providing hot water for the DHW loop via a heat recovery device on the return water to the ground loop, then this is effectively free domestic hot water heating (when this is available). Enter an electric hot water heater, with a tank size of 0 Litres and an input capacity of 0 kW. Run both the proposed and reference cases. Go to the Proposed sim report in the DOE subdirectory and search for the BEPU report. The annual domestic hot water energy consumption will be listed in kWh. Manually remove this value from the EE4 electrical consumption (mult by 3.6 to obtain MJ) to determine compliance for NRCan's validation. Go to the Proposed .sim report and search for the ES-D report. Multiply the electrical virtual rate (\$/kWh) by the kWh reported in the BEPU report and subtract this annual hot water energy cost from the EE4 annual costs. Doing this will generate a proposed design without any hot water energy usage and hot water energy costs. If the heat recovery device is only intended to offset a portion of the domestic hot water heating energy, such as cooling heat recovery then only subtract a portion of the hot water energy consumption. Apportioning the hot water energy consumption to a daily value and reducing only during the cooling season is a reasonable approximation. The simulator must justify their calculations in order to obtain this credit.

If the combination plant is simply providing hot water for the DHW loop, then it is behaving similar to 2 water heaters piped together. Model the water heater as a single water heater with a fuel corresponding to the higher combo plant capacity (remember to sum multiple GSHPs). If the supplemental boiler is electric, then simply accept 100% efficiency as the best that EE4 can offer. If the supplemental boiler is fossil fuel and it has the higher installed capacity, then model a fossil fuel domestic water heater, with a capacity-weighted efficiency.

Example: GSHP = 100 kW, COP = 4.00, Boiler = 150 kW, efficiency = 75%
 DHW weighted efficiency = $(100 * 4 + 150 * 0.75) / 250 = 205\%$ (enter 0.99)

Remember to derate the capacity of the GSHP and the supplemental boiler by the domestic hot water heating requirements.

When I model a combination GSHP with boiler, I am no longer allowed to alter the ground water temperatures, but I am allowed to alter the ground water temperatures if I model only a GSHP plant. What is the rationale here?

In a combination GSHP/boiler plant, the ground source heat pump is converted to an equivalent centrifugal chiller and electric boiler and sequenced with the other entered boiler. DOE2 only allows a single supply water temperature for the boiler and chiller, therefore, the monthly ground temperatures are run through a function to develop an adjusted COP for the equivalent boiler and chiller. In the GSHP only scenario, DOE2 does allow monthly and hourly supply water temperatures to model a central heat pump only. DOE2 does not have the capability to model a GSHP and a boiler operating simultaneously on the same water loop.

How do I model a combination plant?**Can I now enter different air handlers instead of a make-up air unit only?**

Yes, since the combination plant generates an equivalent chiller and boiler from the entered GSHP, all systems available for the chiller and boiler are now available for the combination plant. The only air handling system that is not available in the combination plant scenario is the hydronic heat pump. This will be corrected in a future release. However to model a hydronic heat pump scenario, you will have to enter a GSHP only plant. If your combination plant contains a make-up air unit, you could either enter a constant volume system with the airflow sized according to the make-up air unit or you could enter a fan coil system.

One benefit of the combination GSHP/boiler plant relates to the use of different air handling systems. If you have a unique air handling system such as a VAV system that could not be accommodated in earlier versions of EE4, it is now fully supported in the combination GSHP/boiler plant. However you could use this feature even if you do not have a combination plant, but only a GSHP with a VAV. You simply select: "Combination Ground Source Heat Pump" under the Central Heating tab, but do not define a boiler. Select "None" as the boiler operation in the Combination Ground Source Heat Pump tab. This method allows a ground source heat pump with a wide variety of air handling systems.

Why did my reference heating not change to natural gas when I installed a large supplemental gas boiler in my combination plant?

Normally EE4 checks the capacities of the installed plant equipment to set the reference fuel, however in a combination plant, this may not be a valid method. This is because the electric ground source heat pump has been set to operate first in meeting the hourly heating load, and then the boiler (fossil fuel or electric) operates either in parallel operation or solely to meet the hourly load. Even if the fossil fuel boiler is larger than the central ground source heat pump, the central ground source heat pump may be able to meet the majority of hourly load for the year, thereby actually using more energy than the supplemental boiler.

The calculation sequence has been altered in EE4 to determine this. Since EE4 version 1.6, the proposed case is run completely and then the results are assessed to determine whether the ground source heat pump or the boiler has the larger annual energy consumption. The larger annual energy consumption now determines the reference boiler fuel.

4.7 Pumps

Pumps often represent a significant portion of building energy use. Pumps are entered in 5 different locations in the Plant element: "Central Heating", "Central Cooling", "Cooling Tower", "Hydronic/Distributed Heat Pump Loop" and "Combination Ground Source Heat Pump" tabs.

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 a boiler serves the building, 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 in section 4.7.2.

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.

4.7.1 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 motor 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% which is the default value shown in the EE4 software).

4.7.2 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 (20 L/s) had a motor efficiency of 85% and a pump efficiency of 70% and pump 2 (also 20 L/s) 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 = $(20 * 0.70 + 20 * 0.66) / (20 + 20) = 0.680$

4.7.3 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 71.1°C (160°F) and return to the boiler at 60°C (140°F). In this case, the design temperature drop is 11.1°C (20°F). Similarly, a chiller may supply water at 4.4°C (40°F) and it returns to the chiller at 10°C (50°F). In this case, the design temperature drop is 5.6°C (10°F). 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.

4.7.4 Pump Type

EE4 supports 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.

4.7.5 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.

4.8.1 Natural Cooling

Some designers incorporate natural cooling concepts into the building design and do not install a mechanical cooling system. Under the MNECB and NRCAN 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.

4.8.2 Under-cooled Hours

Detailed explanations must be provided in the case of warning messages indicating 1000 or more under cooled hours for one zone. Detailed explanation of the warning must be provided. In particular, details must be given on the zone strategy for these under-cooled zones, and the presence of free-cooling systems must be indicated.

4.8.3 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 envelope of the proposed building, then it is considered as a potential credit towards NRCAN's validation. If electricity or waste heat is purchased or delivered from a CHP plant located outside of the envelope 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 envelope, 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 EE4 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.

4.8.4 Condensate Heat Recovery

This is not an eligible item for NRCAN's validation 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 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 NRCAN for consideration.

4.8.5 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. Modelling 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 NRCan if you wish to use hand calculations or DOE 2.1 to modify EE4 results.

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 modelling 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).

5.1.1 Heating Coils

Central heating coil characteristics are entered in the System element, "General" tab, in the box labelled "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 modelled. 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 zones.

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 (supply air temperature is adjusted depending on the heating needs of the coldest zone at that time) or OA reset (supply air temperature is adjusted depending on the 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 temperature (generally 43°C for air-based systems). For fan coil and hydronic heat pump systems (water-source or ground-source), the heating supply temperature must always be less than the cooling supply temperature. A good default temperature to use for these systems is 18°C. 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 lower the need for zone conditioning. Enter in the heating capacity of the heating device. If multi-stage heating exists, enter the total heating capacity.

Finally, efficiency is 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) and the furnace type (atmospheric, modulating (fully modulating only), or condensing). 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 modelled with poorer performance than the ground/water source.

5.1.2 Cooling Coils

Cooling coils are similar to heating coils, as discussed above. Enter only the cooling coil information attributable to a central rooftop unit or air-handling system. Depending on the 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 20°C.

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 central chiller will serve the unit, choose “hydronic heat pump”. 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 5.1.2 (cooling coils) for information on modelling cooling characteristics.

As outside temperature decreases, the efficiency and capacity of an air source heat pump decreases significantly, and the operating times 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 23°F (-5° 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 the efficiency is entered in COP or EER (generally, heat pump heating efficiency is 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 35°C (95°F). For heating mode, the COP and output should be at 8.3°C (47°F). EE4 de-rates the efficiency automatically depending on the outside air temperature predicted in the simulation, using an MNECB standard part-load curve. The entered 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 modelled in the Zone element, Mechanical tab.

5.3.1 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 and electric reheat panels in a zone under 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 type.

Where mixed hot water and electric heating devices are present in a zone, simulators need to be aware of the fact that the reference building will set the zone envelope requirements to the levels defined 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 a MURB, 5 kW of electric heat supplements a natural gas-fired furnace. 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 to the zone is conditioned first, with the zone heating providing supplementary heating, then reallocate more of the zone heating capacity to the 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 become under-heated.

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

5.3.2 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 section 6.3 “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 include fan power, enter a value of zero in the fan power field.

Ground and water source heat pumps may be rated according to the newer ARI/ISO 13256-1 standard. The main difference between this standard and the commonly accepted ARI 320, 325, 330 standards is that the ISO method excludes the heat generated and electrical use of fans and pumps from the heating/cooling capacity and corresponding COP/EER rating. If you are entering heat pumps using ARI/ ISO 13256-1, ensure that fan energy is entered in the mechanical tab and pumping power is entered in the central heat pump tab.

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 modelled as zone heating/cooling devices. In this case they are to be modelled as separate air handling systems; either packaged single zones or multi-zones (if grouped) and an adjustment made to the air-handling unit serving these zones.

5.4 System Air Flow Rates and Fans

5.4.1 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. Refer to Figure 5-1 - System Air Flow Rates.

$$\text{Supply Flow} = \text{Return Flow} + \text{Zone Exhaust Flow}$$

also,

$$\text{Supply Flow} = \text{Outside Air Flow} + \text{Recirculated Air Flow}$$

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 the 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 exhausts) and central exhaust. Central exhaust systems are not entered; EE4 assumes that the central system exhausts air not exhausted by zone-level fans. In other words,

$$\text{Central Exhaust Flow} = \text{Outdoor Air Flow} - \text{Zone Exhaust Flow}$$

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 section 5.5, Outdoor Air Flow Rates.

Heat recovery can only occur on central exhaust air, not on zone exhaust air (see discussion on ventilation heat recovery, section 5.7). 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).

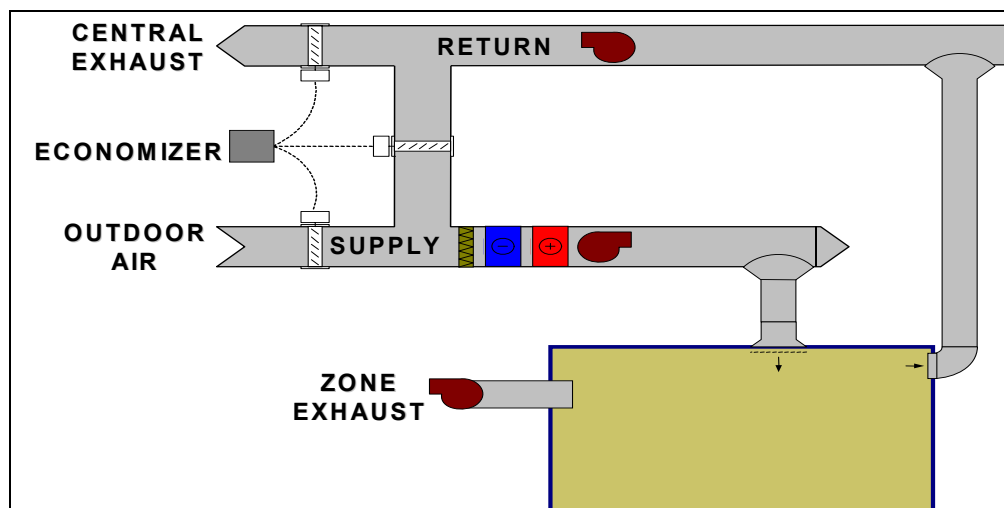


Figure 5-1 - System Air Flow Rates

Another type of fan commonly used, but not shown in Figure 5-1 - System Air Flow Rates, 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

$$\text{Outdoor Air} = \text{Supply Flow} = \text{Central Exhaust} + \text{Zonal Exhaust}$$

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 a MURB, 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 air handler for the fan coil and heat pump system calculates the supply fan flow rate based upon the occupant density and minimum outdoor air requirements of all spaces served.

5.4.2 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, section 5.4.6, 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 be left unchecked, but then the entered heating capacity should be only 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. The equation used by EE4 to calculate fan power based on static pressure is:

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

Where,

Power is the fan power in watts (using brake horsepower)

Flow is the central supply flow rate in m³/s

S.P. is the total static pressure in Pascals

eff is the total combined efficiency (expressed as a fraction; if it unknown, use the reference efficiency from the table for HVAC Systems, shown in section 0)

5.4.3 Central Return Fans

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

Example:

The rated nameplate power on the return fan 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 has been entered.

Solution:

The return flow is calculated by subtracting zonal exhaust from supply flow, therefore, the return flow is 6,000 L/s – 1,000 L/s = 5000 L/s.

Converting to m³/s, the return flow is 5 m³/s. Estimate a static pressure by taking one-half of the supply static pressure (use 200 Pa for example). Use the power equation above to calculate the efficiency based on the estimated total return static pressure.

Rearranging the equation gives:

$$eff = (flow \times S.P.) / power.$$

Substituting the numbers gives:

$$eff = (5 \times 200) / 10,000 W = 0.1 (10\%).$$

Therefore, enter 0.1 in the System, Return Fan tab for the appropriate system in EE4.

5.4.4 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.

The zone supply 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.

5.4.5 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 5.7 on modelling heat recovery systems with zonal exhaust fans.

5.4.6 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:

$$\text{Fan power} = \text{rated fan power} \times 24/18$$

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 NRCAN's validation is to promote energy efficient building design. Buildings that are ventilated far in excess of building code requirements cannot be considered energy efficient. As such, NRCAN 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, defaults 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 transfer outdoor air from another space into the zone to allow a 0 L/sec/occupant value to be entered for the washroom or kitchen (see section 5.6).

5.5.1 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 superseding 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 airflow. Examples include fume hoods, kitchen exhaust hoods, and laundry dryers. These airflows 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% and must be approved in writing by NRCan.

5.5.2 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 adjustment 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 results 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 results only in EE4.

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

5.5.3 Proposed Building Ventilation Rate

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 understand the simulation inputs with ease. The modelled 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 modelled outdoor airflow to the design, certain workarounds may be required on a space-by-space basis. If modelling 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 subtracted from an adjacent space (reduce outdoor airflow to adjacent space by the amount added to the space in question to meet minimum outdoor air requirement so that the system outdoor airflow remains the same).

5.5.4 Examples

Example 1:

Drawings show 10m² stairwell with no outdoor air and adjacent 100m², 4 person offices with 50 L/s of outdoor air. (See Section 5.6)

Calculations:

| | |
|---------------|---|
| Stairwell:: | <i>Space Function</i> = Active Stairway |
| Outdoor Air = | 0.25 L/s/m ² * 10m ² = 2.5 L/s (default values) |
| Office: | Outdoor Air = 50 – 2.5 = 47.5 L/s (office minimum OA adjusted for stairway outdoor air) |

Data Entry:

| | |
|------------|---|
| Stairwell: | <i>Space Function</i> = Active Stairway |
| | Occupant Density = 0 (default value used) |
| | Min Outdoor Air = 0 (default value used) |
| Office: | <i>Space Function</i> = Office – Category 1 |
| | Occupant Density = 100m ² / 4 people = 25 m ² /occupant |
| | Min Outdoor Air = 47.5 L/s |

Example 2:

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 : | 500m ² , Peak occupancy = 100 people (2.5 hours/day), Average occupancy = 50 people, Outdoor Air Delivered = 500 L/s |
| Auditorium : | 250 m ² , 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 airflow 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 m ² /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 1,000 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 3:

5000m² distribution warehouse located in Toronto, Ontario. 4 propane forklifts 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 20,000 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 forklifts 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 19,500 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 20,000 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.

$$\begin{aligned}
 \text{OA} &= 2500 + 20000 * 2/24 &&= 4167 \text{ L/s} \\
 \text{Space Function} &= \text{Material Handling, Warehouse} \\
 \text{Occupant Density} &= 20\text{m}^2/\text{person (EE4 default)} \\
 \text{Min OA/occ} &= 4167 \text{ L/s} / (5000\text{m}^2 / 20\text{m}^2/\text{person}) = 16.7 \text{ L/s} / \text{occ}
 \end{aligned}$$

5.5.5 Superseding Standard

If another standard is used to calculate the reference 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:

- Copy of the standard that you are applying
- Description of which spaces within the building are applicable to this standard
- Description of how you are proposing to accommodate the requirements of this standard within the EE4 simulation
- NRCan submission number (eco number)

Please be aware that NRCan will typically ACCEPT:

- Published building standards issued by the provincial Department of Public Health (for hospitals and LTC facilities)
- Published building standards issued by the provincial Department of Education (for schools or universities)
- Published building standards issued by the provincial department responsible for Codes (which may be a different department)
- Published building standards issued by an authorized, qualified and responsible third-party agent in the technical area under discussion (national animal care facility regulations for labs, etc)

NRCan will typically NOT ACCEPT:

- Published building standards issued by a person or team that is not acting under oversight (e.g. a Department of Public Works may decide it would be "a good idea" to apply a certain rule for a specific reason, but it is not accepted as a superseding standard unless supported by some kind of independent oversight, for example, a national engineering advisory or the authority of a clearly delegated responsibility, such as public health).

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:

$$OA = (ACH \times 1000 \times V) / 3600$$

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.

5.5.6 ASHRAE IAQ Standard

If the ASHRAE 62 “Indoor Air Quality Procedure” (e.g. CO₂ 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 CO₂ sensors, refer to section 5.5.10, Demand Controlled Ventilation.

5.5.7 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 the required outdoor air based on ASHRAE 62-1999 or superseding standard
- Step 2: Determine the required exhaust air capacities. If an 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.

Example 1:

MURBs 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 the north & south apartments, and
- 400 L/s make-up air unit supplying outdoor air to corridor.

| | | |
|------------------------|-------------|--------------------|
| One Bedroom Apartment: | Bathroom | = 5m ² |
| | Kitchen | = 15m ² |
| | Living Room | = 80m ² |
| | Bedroom | = 60m ² |
| | 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* = MURBs

- 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 + 0.25 x 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

5.5.8 Hospital Systems

Hospitals may have specific code-mandated ventilation rates, total air-change rates, and filtration requirements; 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 higher than the reference building. The procedure used to adjust the reference building fan characteristics is outlined below. The “alterations”, given below, provide more detail on the implementation of this procedure.

1. Determine any code-mandated ventilation, air change, or filtration requirements and specify in your modelling 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 2after 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 (to account for additional filtration requirements, if any). 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 the original lines (use the "\$" symbol at the start of the line) and adding the new line immediately below.
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 submission. Manufacturer specifications of the filtration should also be included if there is a large pressure drop.

ALTERATION #1 – Minimum Total Air Changes per Hour

The first item that needs to be adjusted is the air circulation rates. The CSA standard specifies the minimum outdoor air changes per hour (ACH) as well as the minimum total ACH, dependent on the room type. The air circulation rate is required to maintain adequate pressure difference between different hospital spaces and to reduce infection by filtering large quantities of air. Currently, the EE4 (MNECB) reference building has a VAV system. This allows the model to throttle back the air flow rate to the outdoor air rate under conditions of low loads, and therefore not maintain the specified minimum total ACH. To obtain a more accurate hospital reference building, the DOE2.1 file for the reference building needs to be altered. The modification is quite simple and only requires the value of one or two keywords (ASSIGNED-CFM and MIN-CFM-RATIO) per zone to be edited. The value for ASSIGNED-CFM is only to be changed if it is less than the required minimum air circulation rate. If this is the case, the value is to be set equal to the air circulation rate specified in the CSA standard and the MIN-CFM-RATIO is to be set to equal 1. However, if the ASSIGNED-CFM value is greater than the CSA-required minimum air circulation rate, the value is to be left as is and the MIN-CFM-RATIO is to be adjusted. The new MIN-CFM-RATIO value is to be equal to the minimum air circulation rate divided by the ASSIGNED-CFM value. The following examples demonstrate these changes:

Example 1: 1593 ft² Patient Room, 12 ft high.

The CSA standard states that a patient room must have a minimum of 6 total air changes per hour. For the given room, this results in 1912 cfm. The reference data for that zone must therefore be changed as follows:

- Generated Reference DOE2.1 file: ASSIGNED-CFM = 1443
MIN-CFM-RATIO = 0.44
- Altered Reference DOE2.1 file: ASSIGNED-CFM = 1912
MIN-CFM-RATIO = 1.0

Example 2: 2067 ft² Patient Room, 12 ft high

A minimum of 2481 cfm is required for this zone. However, due to the heating/cooling loads, the current reference building has a maximum value of 2895 cfm and a MIN-CFM-RATIO of 0.41. For this case, the ASSIGNED-CFM value can be left and the MIN-CFM-RATIO is to be changed to 0.86 (0.86 x 2895 cfm ≈ 2481 cfm).

ALTERATION #2 – Increased Pressure Drop

An air handler for an office building is only required to have a 25% effective filter. According to CSA Z317.2-01, hospitals are required to have a minimum of two stages of filtration. The first stage of filtration is similar to an office filter. However, the second stage is required to have a minimum efficiency of 90% for patient care areas. This extra filter typically results in an added 1.5" of pressure drop on the supply side when compared to a typical air handling unit. A hospital air handling unit also must contain more equipment, such as a silencer and a humidifier, which add to the increase in pressure drop. The silencer is required to dampen the noise of the larger fan, which is a result of the higher-pressure drop due to the extra filter. The humidifier is required to maintain the humidity levels specified in the CSA standard. Currently, the reference building assumes a 4" static pressure drop in the supply side. This is not obtainable for hospitals, due to

the extra high efficiency filter and equipment, and therefore the static pressure should be increased by 2.0". This results in a 6.0" static pressure for the supply side for a reference building. To model this, the SUPPLY-STATIC value in the DOE2.1 file must be changed from 4.0 to 6.0 for each of the systems where the superseding hospital standard is applicable. The reference return static pressure can be similarly modified by searching for RETURN-STATIC in the reference .doe file, and increasing the default return static pressure from 1" to 1.5" on the systems where the superseding hospital standard is applicable.

5.5.9 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 infrared 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 validation purposes, 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 validation purposes. Adding a mechanical ventilation system to this type of space is seen as an unnecessary measure. Therefore, NRCan has chosen to allow this type of space within the acceptable occupancy types.

Proposed Modelling 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 is 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 were installed in these zones, then they would also be turned off, which is an inaccurate modelling 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.

5.5.10 Demand Controlled Ventilation

Demand controlled ventilation (DCV) strategies alter the volume of ventilation air supplied based on measured carbon dioxide levels in the zones/spaces served by a system. With a DCV strategy the ventilation air and fan power values are related to the occupancy pattern. NRCan has determined that this should be modelled as a reduction of ventilation air and fan power to zero for the equivalent of four full-load hours per day. Carbon dioxide sensors must be installed in all zones and enclosed spaces served by a system; no credit can be given for multi-zone demand ventilation systems that simply have one CO₂ sensor installed in the return ductwork. A minimum of one CO₂ sensor per thermal zone is required. The DCV credit is available only where a

reasonable ventilation control strategy, based on CO₂ levels in thermal zones and enclosed spaces, exists.

What is Demand Control Ventilation?

For NRCan's validation credit purposes, demand control ventilation refers to a self-contained carbon dioxide sensor installed in a thermal zone or enclosed 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 zone or enclosed space itself or via the air handler through control logic.

Only occupancy sensors and CO₂ sensors are currently available for the DCV credit unless written permission is obtained from NRCan.

The procedure to model DCV systems requires two separate EE4 simulations to be performed as follows:

Complete all necessary EE4 modelling, defining all systems as normal. DCV should be the very last item performed in the modelling process. Ensure that on the System element, Supply fan tab, "Operate fan according to schedule" is selected.

Run the simulation file as normal and save it with a name such as "MyBuilding-reference.BLD". This will be the reference building file submitted.

On the Zone element, Schedule tab, define a new weekly schedule, based on the previous schedule. For 4 hours of the day, change the fan setting from 100% to 0%. The user can decide which four hours in the day best describes the effect of demand controlled ventilation on their specific building.

Select the new schedule for all zones served by the DCV strategy. Save the new file using SAVE AS and type a new name, such as "MyBuilding-proposed with DCV.BLD"

Run the file and compare the proposed building energy use of the new file to the reference building energy results of the first EE4 simulation run. Include both EE4 files with the submission package sent to NRCan, along with a detailed explanation, in the simulator's notes, of how the DCV feature was implemented.

What is considered a zone or enclosed space for sensor control?

The definition closely follows the space definition used in this document, see section 2.2. However, the location of the sensor within a space requires a more detailed definition to qualify. For simplicity sake a sensor in each enclosed 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 CO₂ 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 CO₂ sensor. However, NRCan permits groupings of certain small spaces under a single CO₂ 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 diffuse naturally to the adjacent offices. A single CO₂ 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 CO₂ sensors are required to receive the full credit.

Can a return air plenum CO₂ 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 CO₂ sensor within the space itself. For example, if a gymnasium space uses a central fresh air supply and a single return duct, a CO₂ sensor in the return duct is equivalent to a CO₂ sensor in the space.

If a return plenum serves multiples spaces, such as individual classrooms, or offices and a boardroom, then a CO₂ sensor in the return air plenum is not eligible for DCV credit. A CO₂ 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 CO₂ 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 CO₂ 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.

How do I enter Minimum Outdoor Air Levels where CO₂ 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 this airflow among the spaces served by the system and provide this calculation for NRCAN's validation purposes.

5.5.11 Demand Control Ventilation Using Occupant Sensors

Occupant sensors normally control lights, but NRCAN will allow, in limited use, the control of ventilation systems in classrooms (only). This decision is based on demonstrated savings in classroom settings. 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.: if there are 4 classrooms served by an air handler, but only 3 classrooms have occupancy sensors, it means that 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 the same as for DCV using CO₂ sensors, and is as follows (2 EE4 runs required):

Reference Case:

1. Use the MNECB default schedule for the zones where the occupancy sensors are located
2. Complete all of your entries, save and run Reference case only

Proposed Case:

1. 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 new name;
2. Complete this for each schedule which qualifies for the occupancy sensor as a ventilation controller;
3. Save your file under a unique name and run the Proposed case only;
4. Submit both EE4 runs as part of your validation submission.

5.6 *Transfer Air*

The "Transfer Air" checkbox in the Room/Occupant tab provides a way to identify rooms that receive their ventilation air from other spaces in the same zone.

When users check the "Transfer Air" check box, EE4 sets the Minimum Outdoor Air rate for that room to 0. The user must then edit the "Occupant" tab for the room providing the air to be transferred, increasing the outdoor air to that space in order that the entire zone receives the correct amount of ventilation air. The specified outside air for the room where the transfer air is originating will include the outside air requirements for both that room and the room where the air is received (kitchen or washroom only).

For example, one of the rooms in a two-room zone is a kitchen (Area = 10 m²) and another is a Retail Type A room (Area = 100 m²). The designer wishes to keep kitchen odours out of the retail space by exhausting air from the kitchen and providing the kitchen ventilation air from the retail space. In this case, the "Occupant" tab for the kitchen indicates "Transfer Air".

Assume the outdoor air (OA) requirement for the Retail room is the same as the MNECB default (occupant density = 30 m²/occ and minimum OA = 1 L/s/m²). Total OA needed for Retail room = 100 m² x 1 L/s/m² = 100 L/s. Assume the OA needed for the kitchen is also based on the MNECB default values, and is given by 1.5 L/s/m² x 10 m² = 15 L/s. As the Retail room now provides OA for both it and the kitchen, the total OA that needs to be specified for the Retail room is = 100 + 15 = 115 L/s. Occupant density for both rooms is left at default.

5.7 *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 by reducing the humidity of the incoming air.

Only sensible heat recovery can be applied towards a credit, and can be modelled 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; however, if the HRV does not operate in the cooling season, only the heating effectiveness should be used.

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

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

Where,

- ε = effectiveness to be entered into EE4 (value between 0 and 1)
- W_s = supply air flow
- W_{min} = 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. If the flow through the unit is balanced, $W_s = W_{min}$ and the equation reduces to simple temperatures.

If a manufacturer’s product has not yet 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 – except for make up air units, see section 5.7.2) to the central supply fan power.

If fan power is entered directly into EE4, 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.

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

Where,

- 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

Note: Heat recovery is modelled only if a return fan is present (DOE2 requirement).

5.7.1 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 60% effectiveness on 900 cfm, and a 75% effective HRV on a 100 cfm mechanical room exhaust fan, the heat recovery effectiveness will be 62%. (60% 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 as follows, using the equation from section 5.7 above:

$$SP = [(600 * 0.66) / (900 + 100) * 0.472] * 1000 = 839 \text{ pascals}$$

Assuming that the total wattage for the heat recovery units is 600 watts, and both HRV units have a fan efficiency of 66% (See section 5.7 for default value of HRV fan motor efficiency. The factor of 0.472, in the above equation, converts from cfm to L/s.)

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:

$$SP = [(1500 + 600) * 0.66 / (1200 + 900 + 100) * 0.472] * 1000 = 1335 \text{ pascals}$$

5.7.2 Exhaust Fan Heat Recovery with Make-up Air Units

EE4/DOE-2 version 2.1E simulates heat recovery by a central exhaust air method. On make-up air units (fan coil systems, radiant systems, and heat pump systems) outside air is tempered and supplied to the space(s). Therefore a return fan does not exist in EE4 and is not entered; however, the actual design obviously requires a central return fan which is added to the supply fan data and entered into EE4.

The method employed to model heat recovery in EE4/DOE-2 version 2.1E is to reduce the outside air by the heat recovery effectiveness. The entry for the heat recovery effectiveness is identical to the method described above in the subsections of 5.7.

For example, 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, "Heat Recovery and Different Exhaust/Return and Supply Airflows".

In addition, the make-up air unit supply fan MUST be entered using the rated power rather than the static pressure and the fan efficiency method. If the supply fan is entered using the static pressure and fan efficiency method the MUA fan power will be reduced in proportion to the outside air to simulate heat recovery effectiveness (DOE2 method of handling power), which is incorrect. Entering the rated power will not alter the calculated fan power and the heat energy added to the airstream.

5.7.3 Heat Recovery and Different Exhaust and Supply Airflows – with Make-up Air Units

In make-up air units feeding distributed heat pumps or fan coils, the HRV effectiveness must be corrected if there is a mismatch in flow between HRV supply and exhaust. The following equation is to be used to calculate the adjustment factor:

MUA 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, totalling 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 60%, then the entered adjusted effectiveness would be 26% ($0.60 * 0.44$).

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 airflow rate.

5.7.4 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 fan schedule defined under the system operates all of the fans (supply, return, and exhaust) identically. 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 model the heat recovery effectiveness.

Example:

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 26% effectiveness would be adjusted to 17% ($26 * 0.66$) because of the non-operational exhaust from heat recovery.

5.7.5 Heat Recovery with Solar Thermal (Air) Preheat

Designs utilizing a solar thermal air heating system combined with a heat recovery ventilator to preheat incoming outdoor air must take into account the cross-coupling effect of these two systems; not all of the thermal energy generated by the solar air heating system can be used to reduce the building ventilation air heating load.

The available energy captured by the solar thermal (air) system is typically approximated by using a tool such as RETScreen. In order to approximate the actual usable energy provided by the solar air heating system when coupled with an HRV, one should estimate the ventilation air heating load for each month, subtract the energy recovered by the HRV from this total, and then calculate the usable solar air heating system output. The ventilation air heating load is to be calculated using the maximum outside air temperature for each month.

Example monthly calculation:

Ventilation air heat load for January:

= air flow rate (cfm) x 1.08 x ventilation air temperature differential / 3413 x hrs/mth
 = 5000 cfm x 1.08 x (65 – 21.6) / 3413 x (22 days x 10 hrs/day) kWh/mth

= 21,287 kWh/mth

Where,

- 5000 cfm is the ventilation rate;
- 65 (the desired outdoor air delivery temperature in °F);
- 21.6 (the maximum average daytime temperature °F);

The energy recovered by the HRV is calculated:

- = monthly heating load x HRV effectiveness
- = 21,287 kWh/mth x 0.72 (sensible effectiveness)
- = 15,326 kWh/mth

RETScreen solar thermal (air) estimated output:

- = available insolation/m² x area of solar air system x % efficiency x % availability during operating hours
- = 3.28 kWh/m²/day x 22 days/mth x 60 m² x 73% efficient solar x 65% availability during operating hours
- = 2895 kWh/mth

Result:

Maximum usable solar thermal output:

- = lesser of (Heating load – HRV energy) or RETScreen output
- = (21,287 – 15,326) = 5,961 kWh/mth, or
- = 2895 kWh/mth

The lesser of the two is 2895 kWh/mth (this is the useful solar thermal energy for January).

The same calculation should be performed, preferably in a spreadsheet, for each of the months of the year, keeping in mind that most buildings will not be able to claim any useful energy for the solar thermal systems for the months of May through September.

Once the total useful solar thermal energy has been calculated, it can be subtracted from the heating fuel that is used to heat the ventilation air.

Continuing the example above:

Assuming that the HRV/solar thermal systems feed into a MUA unit with a hydronic heating coil that is fed from a GSHP plant, the energy saved by using the solar thermal system is the total usable energy calculated divided by the COP of the GSHP.

- = 8650 kWh (total calculated usable solar thermal energy) / 3.0 (COP of GSHP)
- = 965 kWh (usable solar thermal energy subtracted from the proposed building electrical energy consumption).

5.8 Humidifiers

Hot water or electric humidifiers can be modelled on the “Humidity” tab in the System element. However, it is recommended that humidifiers only be modelled in buildings with a very large humidification requirement.

When modelling humidifiers, simulators should also be aware of MNECB Sentence 5.2.11.1. (2), which states: “Humidistat 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 modelled as “hot water” if the steam is from a central boiler or district plant. Stand-alone steam humidifiers should be modelled 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. From the DOE2 PS-A report, write down the plant-heating load (MBTU)

Run 2 - with humidification:

Run EE4 with the humidifiers, the total boiler capacity, and the space heating boiler efficiency. On the DOE2 PS-A report, record the plant-heating load (MBTU), which now includes hot water humidification; the difference between the two simulations 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

Overall efficiency:

$$\begin{aligned} &= (\text{humid eff} * \text{humid load} + \text{space eff} * \text{space load}) / (\text{humid} + \text{space load}) \\ &= (0.70 * 1450 + 0.88 * 3200) / (1450 + 3200) = 0.824 \text{ (value entered into EE4)} \end{aligned}$$

5.9 Economizers

Air-side economizers can be modelled 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, therefore, 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), modelling an economizer will have no impact. For a system with no cooling, an economizer is to still be modelled 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 modelled 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 be used to pro-rate the chiller COP.

5.10 Preheaters

Preheaters are available for all air handling systems in EE4, and allows preheat coils to be either electric or hydronic. 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, it can be entered as a preheat coil or entered as additional hot water capacity (coil size) in the air handler.

6. MODELLING OF HVAC SYSTEMS

Choosing an appropriate HVAC system is one of the most important and most challenging aspects of building energy modelling. 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 modelled 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 most appropriate 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 Modelled 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 a building’s HVAC system requires specifying system information in the Central Plant, System, Zone and Space Elements. There are significant differences in the way EE4 handles zonal and central systems. Table 6-2 defines the parameters required for each element.

Zonal (water-based) Systems: in these systems, primarily a zone-level device performs heating and cooling. 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 tempered ventilation air only; as such the airflow rate in the System Element is determined by the minimum outdoor air requirement of the spaces served by the system. Make-up air units are intended to only temper the outdoor air; final conditioning of the air/spaces is done in the zones. 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 ventilation, 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 the user will specify this flow rate.

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.

Table 6-2 - HVAC Data Summary

| | | | |
|--|--|---|--|
| <p>Plant</p> <p>For all systems define:</p> <ul style="list-style-type: none"> 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) | | | |
| <p>System</p> <ul style="list-style-type: none"> Select 1 of 15 system types | | | |
| <p>Water-Based Systems (Heat Pump and Fan Coil Systems)</p> | | <p>Air-Based Systems (Constant Volume and Variable Air Volume)</p> | |
| <p>Define:</p> <ul style="list-style-type: none"> Make-up Air Unit Heating and Cooling Characteristics Make-up Air Supply Fan Characteristics HRV Characteristics | | <p>Define:</p> <ul style="list-style-type: none"> Central Heating and Cooling Characteristics Supply and Return Fan Characteristics Economizer and HRV Characteristics Reheat or Preheat Characteristics | |
| <p>Zone</p> | | | |
| <p>Heat Pump</p> | <p>Fan Coil/ Induction Unit</p> | <p>VAV</p> | <p>CV</p> |
| <p>Terminal heat pump heating and cooling capacities, COPs Terminal fan power and flow rate Supply/exhaust fan operating times (schedules)</p> | <p>Fan coil unit heating and cooling capacities Terminal fan power and flow Supply/exhaust fan operating times (schedules)</p> | <p>Terminal reheat capacity (if applicable) Zone maximum and minimum flow rates Supply/Return exhaust fan operating times (schedules)</p> | <p>Terminal reheat capacity Zone flow rate Supply/Return and exhaust fan operating times (schedules)</p> |
| <p>Space</p> <ul style="list-style-type: none"> Zonal exhaust fans Occupant densities and minimum outdoor air requirements Service water loads and maximum flow rates | | | |

6.2 *Selecting the Appropriate System*

With 15 different basic system types, it sometimes may appear as though two or more EE4 models could be used to model a system, or that none apply. Outlined below is a step-by-step procedure to arrive at the most appropriate 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 sections 6.3.1 and 6.3.2.

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 6.3.3.

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 6.3.4.

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. See section 6.3.5.

If a chilled water coil from a central air handler cools air, the system is a built-up variable air volume system. See section 6.3.6.

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 sections 6.3.1 and 6.3.2.

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 6.3.3.

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 6.3.4.

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. See section 6.3.5

If a hot water coil in the central air handler heats air, the system is a built-up variable air volume system. See section 6.3.6.

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 data entry into EE4.

6.3.1 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 section 4.6).

The “heating type” field describes the type of heating used at the make-up air unit to temper the ventilation air 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 5.3.

6.3.2 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 at a time. Under this system, the entire building hydronic loop must either be in heating or cooling at any given time. Select “4-pipe fan coil” if there are dedicated chilled water pipes 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. A heating or cooling coil conditions the mixed air. 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 simultaneously) at any given time. Select “4-pipe induction” if there are dedicated chilled and hot water pipes, permitting simultaneous heating and cooling.

6.3.3 *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 units 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.

6.3.4 *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 heated or cooled 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 heated air or cooled 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 modelled 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 identically 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 identically to a Packaged Multi-zone system, except that air is cooled with a chilled water coil, not a refrigerant coil.

6.3.5 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 temperature is set by the simulator, usually around 13°C. Zone terminals contain dampers which allow more or less cold air to be fed into the zone, depending on the amount of cooling 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 13°C 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 modelled as Packaged Constant Volume Multi-zone or Built-up Single Duct Constant Volume.

6.3.6 Built Up Variable Air Volume Systems

In a built-up VAV system only a single 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 a chilled water coil cools the air stream instead of a refrigerant coil.

6.3.7 Dual Duct Systems

Dual duct systems have two air streams that 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.

6.3.8 Dual Duct, Dual Fan

Dual duct, dual fan systems have two air streams that 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 hot side, or both, then the system should be modelled as a built-up VAV (see section 6.3.6). 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 modelled in EE4 with reasonable accuracy.

6.4.1 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 modelled 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 modelling 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 Element/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 Element/Zone tab of these systems and the rules described in the “Zone-Level Heating Devices: Baseboard Radiators, Reheat Coils, Heating Panels” section 5.3.1, are to be followed. EE4 does not support radiant cooling with mixed air systems; if radiant cooling is included in the proposed design it will be necessary to select a built-up air-based system following the same approach as described for modelling mixed air radiant heating systems above.

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 modelled 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 Element/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 5.3.1 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 the actual construction to simulate the thermal mass effect. Floor weight is medium for most commercial concrete type buildings, and light for wood frame construction.

6.4.2 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 modelled as closely as possible to the heating air handling system using a system that supports zone heating via baseboards. In most cases a constant volume multi-zone system with baseboard reheat can be used to model a make-up air unit.

The use of a fan coil system is only recommended if there exists some type of space cooling other than the air handler. The fan coil approach is handled identically to Water-Based Radiant Heating and Cooling Systems, section 6.4.1, 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 modelled. 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.

6.4.3 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 modelling gas-fired radiant systems is described below:

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 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, design supply temperature, and efficiency; set central supply fan equal to the 100% OA system fan power in the System Element/Supply Fan tab.

Enter zero for heating capacity, cooling capacity, and terminal fan power in the Zone Element. Set terminal fan flow rate equal to the value shown in the EE4 sizing calculator as described in section 6.4.1, Water-Based Radiant Heating and Cooling 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, design supply temperature, and efficiency; set the central supply fan power equal to the 100% OA system fan power in the System Element/Supply Fan tab.

Enter the total heating capacity for the zone in the Zone Element. Set the terminal fan power to zero and set the terminal fan flow rate equal to the value shown in the EE4 sizing calculator as described in section 6.4.1, Water-Based Radiant Heating and Cooling 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 modelled 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 subsection above, 100% OA Multiple HVAC Systems.

Mixed Air System: Multiple HVAC Systems

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 multi-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 modelled 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 subsection above, 100% OA Multiple HVAC Systems.

6.4.4 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 Systems section 6.4.1, 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 is the fuel used by the infra-red heaters

Boiler thermal efficiency equals the thermal efficiency of the infrared heaters or 80% (if unknown).

If radiant panel cooling is installed select "Purchased Cooling" and use the same pump characteristics as used for the boiler.

Without defining a boiler or chiller, the software will auto-size this equipment to meet the load.

6.4.5 **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 modelled directly in EE4; rather the space and water heating functions must be separated. The following procedure is recommended:

1. Combine the heating capacity of all the combo systems.
2. Enter the portion of the capacity of all the combo systems that is for heating domestic hot water in the Plant Element/Service Water tab.
3. Enter the portion of the capacity of all the combo systems that is for space heating in the Plant Element/Central Heating tab.
4. Select either a 2 or 4-pipe fan coil HVAC system in the System Element/“General” tab.
5. Specify the zone heating and cooling capacities in the Zone Element using the coil capacity installed in each zone.
6. 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 are the same.

6.4.6 **Solar Water and Ventilation Air Heating Systems**

Any energy savings from installing solar heating systems can be counted towards the validation target of 25% energy savings relative to the MNECB-based reference building.

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 set point 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 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 NRCan’s *ecoEnergy for Renewable Heat* program. The program provides an incentive of up to 25% of the cost to purchase and install qualifying systems; certain other costs may also be covered. The program requires a detailed computer simulation as described on the following Web site: <http://ecoaction.gc.ca/heat>

The computer simulated energy savings determined for the *ecoEnergy for Renewable Heat* program can be used as a credit in NRCan’s validation. 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 by one of the software tools accepted by the program. The cost savings should be calculated based on the “virtual” energy rate for the building. The “virtual” energy rate can be 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 ES-D report of 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 coupled for the same ventilation airflow, as described in section

5.7.5. In this case, the two technologies must be analyzed together to avoid double counting of the energy savings.

6.4.7 Parking Garages

To simplify the EE4 model, unheated parking garages may be excluded from the 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 “Inactive Storage” 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 the operating 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 the applicable 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 “Outdoor Air Flow Rates”, section 5.5. If CO/CO₂ control is used to determine the amount of ventilation for the garage, the modelled outdoor airflow may be reduced to account for the number of hours that no ventilation is provided during the occupied schedule. NRCan recognizes a standard run-time of 6hrs (2hrs morning, 2hrs mid day and 2hrs evening) for ventilation control using CO sensors. Because 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 in the garage, follow the guidelines in the “Special HVAC System Cases” section 6.4, for the appropriate type of heater. Make sure to adjust all schedules as described above.

6.5 System Modelling Examples

This section presents some common buildings and describes how to model their typical 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 DX 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 a 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, furnace type (atmospheric, modulating {fully modulating only}, or condensing) 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 DX 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 Hydronic/Distributed 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 use the values from Table 4-4 - Monthly Entering Water Temperatures for Vertical Closed Loop Heat Pumps (°C).

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 (an archetypal zone can be created with the most common information included, then copied and pasted under the appropriate systems; the remainder of the required zonal information can be added to each zone (e.g. name, area, floor number, etc.)).

Example 3. MURBs with Hot Water Radiators and In-Suite Chilled Water Fan Coils

Description: A MURB 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. A large air handler located in the penthouse mechanical room, which delivers tempered air to corridors, delivers ventilation air to the building. 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 calculated peak heating load is 700 kW, and the peak domestic hot water load is 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 modelled 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 through 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 is entered. This is probably best described as 2 boilers, each with a capacity of 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, 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 18°C.

On the System element/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 20°C. 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; baseboard radiators which do not have fans provide heating. From a modelling 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 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 or 1kW x 4/12 cooling months) 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 Infrared Heaters

Description: A warehouse is equipped with a gas-fired rooftop unit providing ventilation air tempering only and the tempered air is simply ducted to a few central drops. Gas-fired infrared heaters are installed on 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 metre 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 infrared heaters.

The rooftop unit will be zoned for the centre of the warehouse space with envelope losses through the slab and roof, but it will contain the majority of ventilation air heating. The rooftop unit is the make-up air unit for the building.

The gas unit heater at the entrance will be modelled 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: a 4-pipe fan coil system; this represents the make-up air unit for the central air tempering and the infrared 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 rooftop 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. Run the sizing calculation (described in section 6.4.1) and enter the airflows to represent the virtual fan coils serving the central zone.

The perimeter zones will have individual infrared heater capacities entered in the Zone mechanical tab. The airflows will be entered from the sizing calculation.

The entrance unit heater will be modelled 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 coils. The capacity of the boiler will equal the sum of the capacities of the infrared heaters. The thermal efficiency of the boiler will equal the rated efficiency of the infrared 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% (to minimize pump energy consumption). Do not enter a chiller.

7. MODELLING 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 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 modelled envelope areas and “actual” envelope areas may have a negligible impact on building energy results. 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 modelled for NRCan’s validation 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 15°. 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 279° and one facing 285°. Round off orientation measurements to 15°.

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 “RSI 3.52 (R20)” wall to become “RSI 2.47 (R-14)” or worse when modelled correctly in EE4, with framing taken into account. Review the section on framing and the MNECB carefully when modelling walls and curtain walls.

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 modelled 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

7.2.1 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 7.4).

7.2.2 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 7-1. This table can also be found in Appendix C (Table C-1) 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 software 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 RSI-values when initially manufactured, but the RSI-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” RSI-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” RSI-values are sometimes quoted for massive materials. These materials should be modelled by entering the conductivity and thermal capacitance of each layer separately. The EE4 software 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 facades 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

7.3.1 Below-Grade and Earth-Bermed Walls

Partially buried walls should be divided in two: the above grade portion and the below grade portion. The modelling of above grade walls is discussed in section 7.2.2; 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. 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 than 1.2 meters, use one half the height of this portion of the earth berm (see Figure 7-1 - Depth of Below-Grade Wall When Earth Berms Are Used). This height would also be used in the calculation of underground wall area.

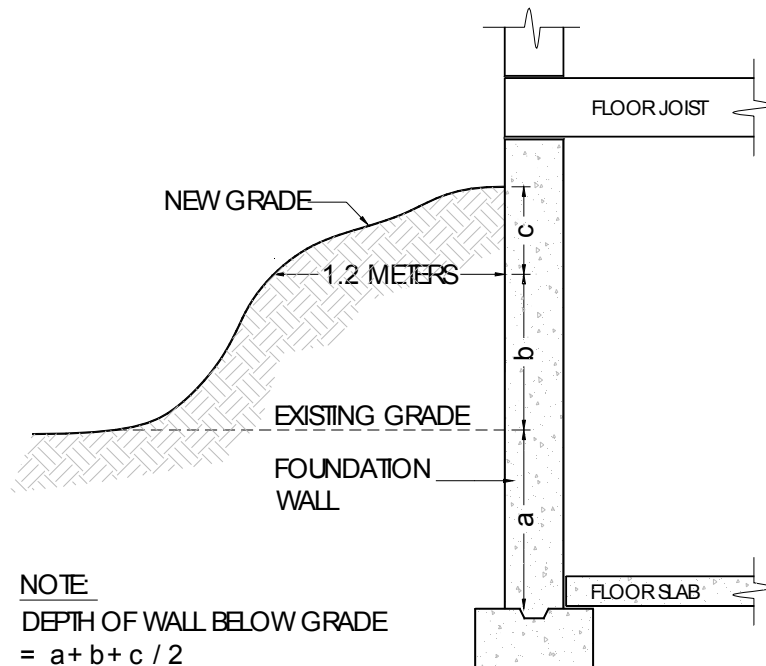


Figure 7-1 - Depth of Below-Grade Wall When Earth Berms Are Used

7.3.2 Below-Grade and Earth-Bermed Roofs

Below-grade and earth-bermed roofs are treated as underground walls 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 aboveground 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.

Common Question :

What if my slab perimeter insulation does not match the options with EE4?

If the slab insulation is greater than the options, simply select the closest option
If the slab insulation on the perimeter extends outward on an angle from the exterior of the foundation wall, interpret this as equivalent to exterior slab insulation as long as it extends outward 0.6 meters or greater.

7.4 Windows and Skylights

7.4.1 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 section 7.4.3).

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 limited to 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 SRR is greater than 2%, and the WWR of the proposed is greater than or equal to 40%, the reference building SRR remains at 2%.

7.4.2 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 cannot be used.
2. **FRAMEplus Online:** FRAMEplus Online can be used to determine the window U-value. The software can be found at <http://frameplus.ca>. 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 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.

7.4.3 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:

- **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 following sections).

- **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.
- **FRAMEplus Online:** FRAMEplus Online can be used to determine the SHGC. The software can be found at <http://frameplus.ca>. The total window SHGC for CSA rated size is to be used. A printout of the results must be included in the submission package if this option is selected.
- **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 A of this manual).
- **EE4 software:** The EE4 software contains a very short list of values and their use is not recommended for NRCan's validation 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 divided by 1.5 for pyramid skylights and 1.3 for domed skylights.

Common Question:

Are canopies, balconies, building extensions considered shading devices and included in the overhang geometry of a window ?

Yes, in the proposed building canopies, balconies, and building extensions are considered shading devices and are included in the geometry of the window. However this does not carry through to the reference building. Therefore no overhang geometry would be included on any window or glazed door in the reference case. The shading that a covered walkway provides to the windows beneath the walkway of the proposed design is not included in the definition of the reference case. Section 5.3.5.5 sentence 4 of the MNECB Supplement (Performance Compliance for Buildings) states:

"The compliance shell shall set all windows of the reference case to have no shading by exterior shading devices, regardless of whether or not these were input for the proposed design in accordance with Sentence 4.3.5.5 (3)."

This is interpreted as including canopies, balconies, overhangs, building extensions, etc.

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 7.4.1). 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). Curtain walls are defined in EE4 the same way as a normal wall – opaque portions are “wall”, and glazed portions are “windows”.

7.6.1 *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 A).

FRAMEplus Online: FRAMEplus Online can be used to determine the performance properties of curtain wall vision panels. The software can be found at <http://frameplus.ca>. The total window U-value and SHGC for the actual size is to be used in the EE4 simulation. A printout of the results must be included in the submission package if this option is selected.

7.6.2 *Spandrel Panel*

There are two generic types of spandrel panels. The first type is constructed using pre-cast 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 aluminium 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 fibreglass 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 <http://frameplus.ca>).

FRAMEplus Online: FRAMEplus Online can be used to determine the performance properties of curtain wall spandrel panels. The program can be found at <http://frameplus.ca>. The total spandrel U-value for the actual size is to be used in the EE4 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 a spandrel panel and a vision panel share mullions, 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 7-2 - EE4 Description for a Spandrel Panel 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. When using the performance path method for validation, it is required that the overall thermal conductance (U-value) of all of the proposed building's above ground opaque building components not exceed 167% of the reference building's overall U-value for its opaque building components.

Construction Assembly

Component Description

Assembly Name:

MNECB Type:

Absorptivity: ASHRAE Group:

Roughness:

Input Assembly U-Value U-Value: W/m²·°C

Framing

No Framing Wood

Metal - Framing Spacing

< 500 mm, w/o Insul. Sheathing

< 500 mm, with Insul. Sheathing

500 mm and greater

Framing Percent: %

Construction Components

| Material | Thickness | Framing | R-Value | |
|-------------------------------------|----------------------------|------------------|---------|---------|
| | | | Cavity | Framing |
| Outside Surface Air Film | | | 0.030 | 0.030 |
| Architectural Glass | 6.000 | | 0.017 | 0.017 |
| Air Space | 38.000 | | 0.148 | 0.148 |
| Insulation, Mineral Fibre, RSI-2.46 | 89.000 | X | 2.460 | 0.001 |
| Steel | 1.000 | | 0.000 | 0.000 |
| Gypsum Sheathing | 4.000 | | 0.025 | 0.025 |
| Inside Surface Air Film | | | 0.120 | 0.120 |
| Weight: | 158.9 kg/m ² | Subtotal | 2.799 | 0.340 |
| Heat Capacity: | 86.9 kJ/m ² ·°C | Overall U-Value: | 1.3082 | |
| | | Overall R-Value: | 0.8 | |

Buttons: OK, Cancel, Insert, Add, Delete

Figure 7-2 - EE4 Description for a Spandrel Panel

7.7 Balconies and Wall/Floor Junctions

7.7.1 Junctions

Wall/floor or wall/roof junctions can be an area of high heat loss because of the difficulty in insulating these constructions. The MNECB (Sentence 3.2.1.2 (3)) requires that the U-value of these junctions be no more than twice the prescriptive value 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 MNECB Sentence 3.2.1.2 (3) is not 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. (MNECB Sentence 3.2.1.2. (5)).

7.7.2 Balconies

Concrete balconies are common in high-rise residential buildings. The thermal impact of these penetrations can be ignored provided that the penetration cross-sectional area does not exceed 2% of the above grade building envelope area (MNECB Sentences 3.2.1.2 (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 calculators. Alternatively, a U-value of 5.5 W/m²C (based on the wall area represented by the balcony cross-section) can be used.

7.8 Modelling Unconditioned or Partially Conditioned Zones

7.8.1 Unconditioned Space (unheated vestibules, parking garages)

As discussed in section 2.3, most unconditioned zones can be ignored. However, if desired, these zones can be modelled using the procedure described below. Note: for some HVAC systems (e.g. heat pump, fan coil, induction systems), the EE4 software does not allow unconditioned spaces. In these cases, the unconditioned zone should be ignored and treated as described in section 2.3.

1. Define the area as a separate zone (unconditioned zones cannot be the first zone listed in a system in the EE4 building tree; the first zone listed is considered the control zone for the system).
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 m²/occupant for unoccupied areas.

6. Define a schedule with 0 fractional time for each hour of each day and apply this schedule to 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).

7.8.2 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 2.1, Dividing Buildings into Zones) or when an air-conditioned zone is adjacent to one that is not. This last case is common in light industrial buildings where the front office is air-conditioned but the back production area is not.

The procedures for modelling partially conditioned zones are as follows:

1. Define the area as a separate zone.
2. Define the 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.
6. Define ventilation requirements according to the applicable provincial standard. If CO control is used to determine the amount of ventilation for the garage, the modelled outdoor airflow may be reduced to account for the number of hours that no ventilation is provided during the occupied schedule. NRCan recognizes a standard run-time of 6hrs (2hrs morning, 2hrs mid day and 2hrs evening) for ventilation control using CO sensors. Because 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.
7. Enter the desired heating and cooling set points (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 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".

7.8.3 Unconditioned Space as a Supply Air Plenum (crawlspaces, mechanical penthouse or floor)

The procedure for modelling 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 m²/occupant to accept MNECB defaults.
6. Define a schedule with 0 fractional time for each hour of each day and apply this schedule to fan, service water heating, plug loads, occupants, and process loads.
7. Leave summer and winter set points 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.

7.8.4 Partially Conditioned Space as a Supply Air Plenum (crawlpace, mechanical penthouse or floor)

The procedures for modelling these spaces are 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 fan, service water heating, plug loads, occupants, and process loads.
8. Enter desired heating and cooling set points 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 modelled 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 set point temperature, and follow the same heating and cooling schedule, there is no need

for an interior partition to be modelled 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);
- 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. MODELLING OF ELECTRICAL SYSTEMS

8.1 Lighting Systems

The modelling 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 8-1 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 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 m² 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 m² 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 m² 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 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.

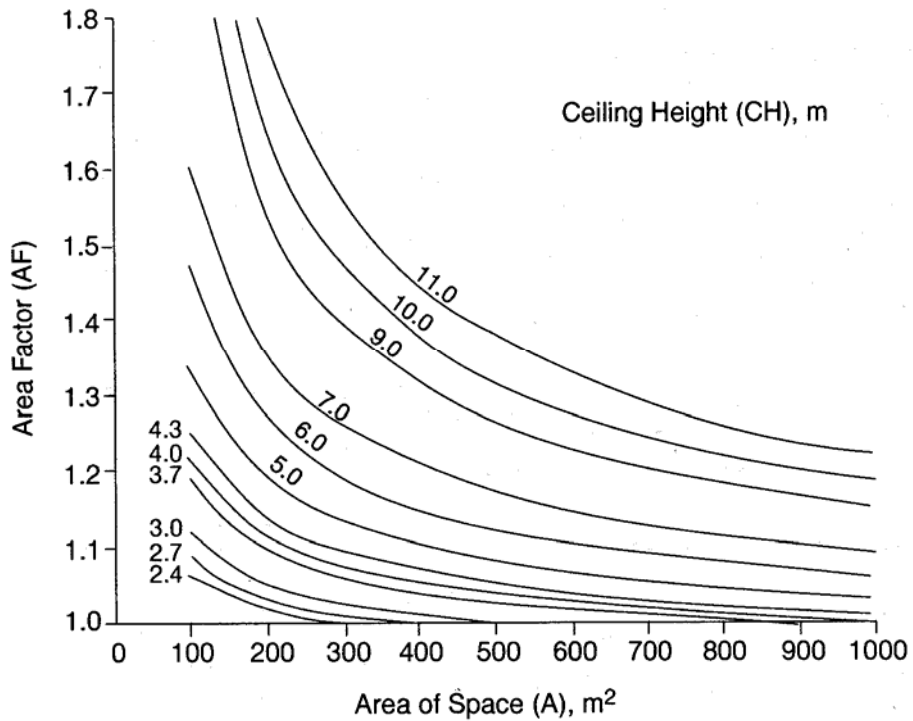
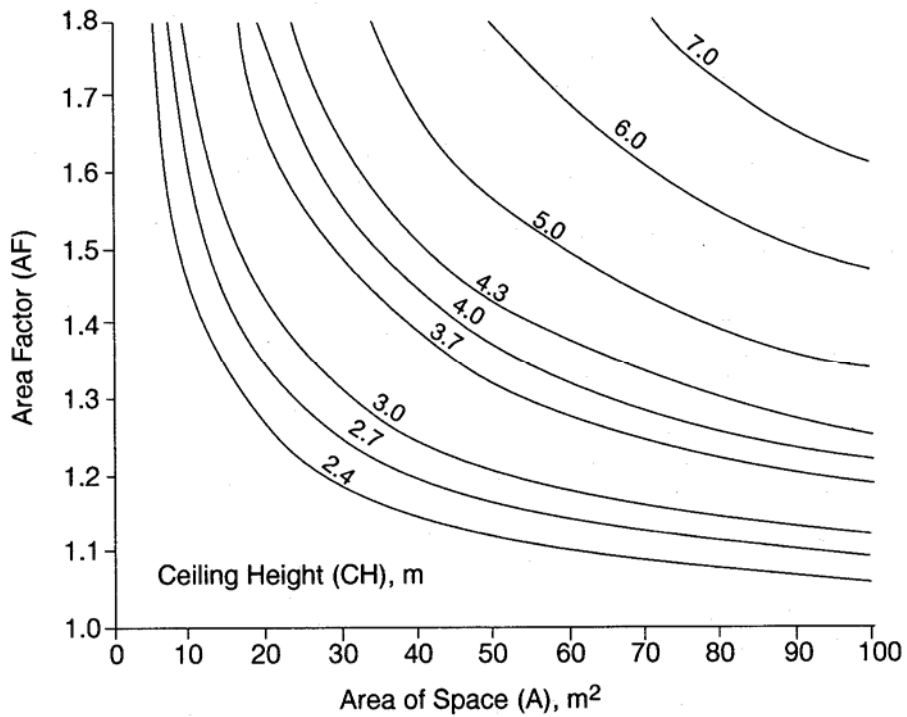


Figure 8-1 - Lighting Area Factor as a Function of Floor Area and Ceiling Height

8.1.1 Lighting Controls

Unlike the MNECB, NRCan's validation provides energy credits for lighting controls in order to achieve the energy savings target of 25% less energy consumption than the MNECB reference building. Lighting control strategies include occupancy sensors, continuous and staged dimming in response to day lighting, and combinations of these two strategies. Table 8-1, lists the strategies and their associated 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 |
|------------------------------|-------------------------|-------------------------------------|
| Day lighting 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 day lighting or occupancy sensors control only a part of the zone, the control fraction should be set to the fraction of the floor area that is controlled. Day lighting control is only effective for those areas that receive natural day light. The maximum depth of light penetration is considered to be 1.5 times the height of the window head above the floor, or 2.5 times this distance if interior or exterior light shelves are used (see Figure 8-2). The window-to-wall ratio must also be at least 20% to receive the day lighting credit. Similarly, the skylight area to floor area must be at least 5% to receive the day lighting credit.

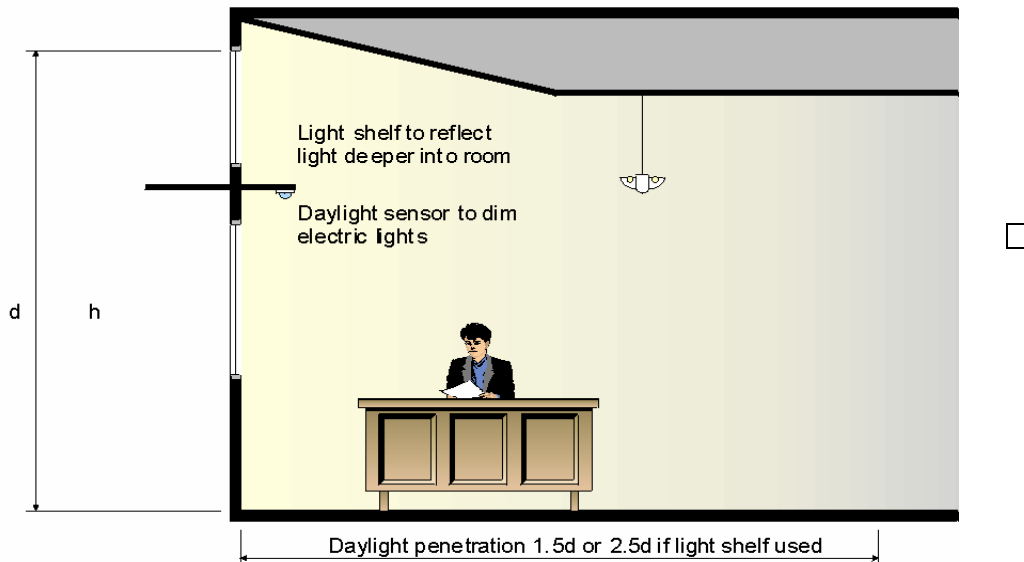


Figure 8-2 - Maximum Day lighting Penetration

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.

8.1.2 Exclusions from Lighting Power Density

Several types of specialty lighting should be excluded from the lighting power density calculation. These are listed in the MNECB Table 4.3.1.2; excluded 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

8.1.3 Treatment of Screw-in Compact Fluorescent Light Bulbs

Screw-in compact fluorescent light bulbs for NRCan's validation.

1. What is a compact fluorescent light bulb (CFL)?

A compact fluorescent light bulb (CFL) provides the same amount of light (lumens) as standard incandescent bulbs. It has lower wattage ratings which means it uses less energy, causes less pollution and is always a sound investment

2. Are screw-in compact fluorescent light bulbs (CFL's) eligible under NRCan's validation?

Yes, NRCan's validation will accept the screw-in CFL's as long as the following is specified in the tender documents submitted for technical review:

- The make and model of the bulb
- The manufacturer's specifications
- Location and quantity of CFL's are identified on the drawings
- It is specified that the bulb is installed by a contractor

NRCan will not accept a submission where the CFL's are being installed or replaced by the tenant/occupant of a building. This becomes an issue that no longer is in the control of the designer and rendered not eligible for the validation.

8.2 Other Electrical Systems

8.2.1 Elevators and Refrigeration Loads

The energy use for elevators and other vertical conveyance devices is not included in the EE4 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, 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 proposed and reference buildings).

8.2.2 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 NRCan's energy savings target of 25% below the MNECB reference building. Renewable energy sources include photovoltaics and wind turbines.

The performance of photovoltaic systems should be determined using the WATSUN-PV or RETScreen software. The performance of wind turbines can be determined using RETScreen which is available free of charge (<http://www.retscreen.net>).

The computer simulated energy savings can be used as a credit towards meeting the energy savings target. 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. NRCAN'S VALIDATION SUBMISSION GUIDELINES

The submission procedure for NRCan's validation of new building designs is described on the NRCan Web site at <http://oee.nrcan.gc.ca/newbuildings>. 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 latest version of EE4, downloaded from the Web site http://www.sbc.nrcan.gc.ca/software_and_tools/ee4_soft_e.asp.

Never submit any simulation files from a building energy software 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 modelling strategies employed, any calculations done outside of EE4, and any difficulties encountered during the modelling process.

Consult the following site for a detailed procedure to submit a project for validation:
<http://oee.nrcan.gc.ca/commercial/newbuildings/validation.cfm>.

10. TROUBLESHOOTING

Listed in this chapter are suggested solutions to some common system modelling problems or errors. Consult the EE4 on-line help and the Web site <http://www.sbc.nrcan.gc.ca> for further troubleshooting tips.

- Q:** In the middle of the hourly simulation, the software suddenly crashes and exits.
- A:** A software 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 software 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 software may crash. Confirm that all necessary equipment and systems have been defined. If the crash still occurs, try running the software on a different computer. If the problem continues, please contact NRCan for assistance.
- 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 EE4E\DOE directory, find the file named “filename – Proposed.BDL” and open with a text viewer (such as 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 12.8°C to 15°C). 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 be 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 building.
- A:** During the course of an EE4 simulation, a modeller may try modelling 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 be for purchased cooling situations.
- Q:** When I try to print a report (or select print preview), I receive an error message: pwwll.dll ERROR: The File: F C:\EE4E\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 software run?
- A:** EE4 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 to provide quick access to commonly used commands.
- Q:** The software ran successfully until I installed the latest version of EE4. The installation was successful, but every time I try to run the software, it crashes
- A:** If you already have a version of EE4 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 Install Shield(r) Wizard by EE4 Set-up, 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. 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. 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 matches those of the second system. Is this a bug?
- A:** EE4 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. 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.

Appendix A

Default Window U-Values and Solar Heat Gain Coefficients

1997 ASHRAE Fundamentals Handbook (SI)

Table 5 U-Factors for Various Fenestration Products in W/(m²·K)

| Product Type | Glass Only | | Vertical Installation | | | | | | | | | | |
|--|------------|------|---|-----------------------------|-------------------------------|------------------|----------------------------|--------------------------------|-----------------------------|-------------------------------|------------------|----------------------------|------|
| | | | Operable (including sliding and swinging glass doors) | | | | | Fixed | | | | | |
| | | | Aluminum without Thermal Break | Aluminum with Thermal Break | Reinforced Aluminum Clad Wood | Vinyl/Wood/Vinyl | Insulated Fiberglass/Vinyl | Aluminum without Thermal Break | Aluminum with Thermal Break | Reinforced Aluminum Clad Wood | Vinyl/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 | 5.35 |
| 2 6.4 mm acrylic/polycarb | 5.00 | 5.00 | 6.49 | 5.45 | 4.51 | 4.42 | 4.01 | 5.60 | 5.25 | 4.75 | 4.75 | 4.58 | 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 | 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 | 3.04 |
| 5 12.7 mm airspace | 2.73 | 3.36 | 4.62 | 3.42 | 3.00 | 2.87 | 2.55 | 3.61 | 3.22 | 2.86 | 2.84 | 2.72 | 2.72 |
| 6 6.4 mm argon space | 2.90 | 3.48 | 4.75 | 3.54 | 3.11 | 2.98 | 2.65 | 3.75 | 3.37 | 3.00 | 2.98 | 2.85 | 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 | 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 | 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 | 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 | 2.67 |
| 11 12.7 mm argon space | 2.33 | 3.08 | 4.34 | 3.15 | 2.74 | 2.62 | 2.28 | 3.28 | 2.89 | 2.54 | 2.52 | 2.40 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 2.05 | 2.05 |
| 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 | 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 | 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 | 1.93 |
| 30 6.4 mm argon space | 1.93 | 2.79 | 3.94 | 2.75 | 2.36 | 2.30 | 2.01 | 2.90 | 2.54 | 2.19 | 2.15 | 2.07 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 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 | 1.56 |
| 39 12.7 mm argon space | 0.97 | 2.05 | 3.18 | 2.05 | 1.72 | 1.67 | 1.41 | 2.08 | 1.71 | 1.39 | 1.35 | 1.29 | 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 | 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 | 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 | 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 | 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 | 1.51 | 1.51 |
| 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 | 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 | 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 | 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 | 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 standard around perimeter of each glazing unit as in Figure 3.

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Fenestration

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Table 5 U-Factors for Various Fenestration Products in W/(m²·K) (Concluded)

| Vertical Installation | | | | | Sloped Installation | | | | | | | | ID | |
|--------------------------------|------------|--------------------------------|-----------------------------|--------------------|------------------------|---------------|--------------------------------|-----------------------------|--------------------------------|------------|--|-----------------------------|------|--------------------|
| 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/Vinyl | Aluminum without Thermal Break | Aluminum with Thermal Break | | Structural Glazing |
| 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 note 7 | see note 7 | 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 |
| see note 7 | see note 7 | 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 |
| see note 7 | see note 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 |
| see note 7 | see note 7 | 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 note 7 | see note 7 | 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 |
| see note 7 | see note 7 | 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 |
| see note 7 | see note 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 |
| see note 7 | see note 7 | 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 note 7 | see note 7 | 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 |
| see note 7 | see note 7 | 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 |
| see note 7 | see note 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 |
| see note 7 | see note 7 | 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 note 7 | see note 7 | 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 |
| see note 7 | see note 7 | 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 |
| see note 7 | see note 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 |
| see note 7 | see note 7 | 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 |
| see note 7 | see note 7 | 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 note 7 | see note 7 | 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 |
| see note 7 | see note 7 | 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 |
| see note 7 | see note 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 |
| see note 7 | see note 7 | 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 |

4 Product sizes are described in Figure 3 and frame U-factors are from Table 2.
 5 Use U = 3.40 W/(m²·K) for glass block with mortar but without reinforcing or framing.
 6 The use of this table should be limited to that of an estimating

7. Values for triple- and quadruple-glazed garden windows are not listed as these are not common products.
 8. Minor differences exist between the data in Table 5 and U-factors determined using NFRC 100-91 because the data in Table 5 are generated using modified heat transfer correlations for glazing cavities (Wright 1996) and indoor fenestration surfaces (Curcija and Cass 1993).

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Fenestration

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Table 11 Visible Transmission (VT), Shading Coefficient (SC), and Solar Heat Gain Coefficient (SHGC) at Normal Incidence for Single Pane Glass and Insulating Glass

| Glazing System | Glass Thick, D mm | Center Glazing VT | Center Glazing SC | Glazing SHGC at Specified Incidence Angles | | | | | Total Window SHGC at Normal Incidence | | | | Total Window VT at Normal Incidence | | |
|---|------------------------|-------------------|-------------------|--|------|------------------|------|------|---------------------------------------|-------|--------------|-------|-------------------------------------|-------|------|
| | | | | Normal | | Hemis. (Diffuse) | | | Aluminum | | Other Frames | | All Frames | | |
| | | | | 0° | 40° | 50° | 60° | 70° | Operable | Fixed | Operable | Fixed | Operable | Fixed | |
| <i>Uncoated Single Glazing</i> | | | | | | | | | | | | | | | |
| 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 |
| <i>Reflective Single Glazing</i> | | | | | | | | | | | | | | | |
| 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 |
| <i>Uncoated Double Glazing</i> | | | | | | | | | | | | | | | |
| 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 |
| <i>Reflective Double Glazing</i> | | | | | | | | | | | | | | | |
| 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 |
| <i>Low-e Double Glazing, e = 0.2 on Surface 2</i> | | | | | | | | | | | | | | | |
| 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 |
| <i>Low-e Double Glazing, e = 0.2 on Surface 3</i> | | | | | | | | | | | | | | | |
| 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 |
| <i>Low-e Double Glazing, e = 0.1 on Surface 2</i> | | | | | | | | | | | | | | | |
| 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 |
| 21i | 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 |
| <i>Low-e Double Glazing, e = 0.1 on Surface 3</i> | | | | | | | | | | | | | | | |
| 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 |

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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 | | | | | Total Window SHGC at Normal Incidence | | | | Total Window VT at Normal Incidence | | |
|--|-------------------|-------------------|--|------|------|------|------|---------------------------------------|----------|-------|--------------|-------------------------------------|------------|-------|
| | | | Normal | | | | | Hemis. (Diffuse) | Aluminum | | Other Frames | | All Frames | |
| | | | 0° | 40° | 50° | 60° | 70° | | Operable | Fixed | Operable | Fixed | Operable | Fixed |
| <i>Low-e Double Glazing, e = 0.05 on Surface 2</i> | | | | | | | | | | | | | | |
| 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 |
| <i>Triple Glazing</i> | | | | | | | | | | | | | | |
| 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 |
| <i>Triple Glazing, e = 0.2 on Surface 2</i> | | | | | | | | | | | | | | |
| 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 |
| <i>Triple Glazing, e = 0.2 on Surface 5</i> | | | | | | | | | | | | | | |
| 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 |
| <i>Triple Glazing, e = 0.1 on Surface 2 and 5</i> | | | | | | | | | | | | | | |
| 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 |
| <i>Triple Glazing, e = 0.05 on Surface 2 and 4</i> | | | | | | | | | | | | | | |
| 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 descriptors 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 $\epsilon = 0.xx$

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 numbers refer to U-factors in Table 5
 SHGC at 90° is 0.

Domed Skylights

Solar and total heat gains for domed skylights can be determined by the same procedure used for windows. The SHGF values for such calculations should be consistent with the dome orientations. For horizontal roofs, Tables 15 through 21 give approximate SHGF values. For sloping roofs, an approximate SHGF can be found from $SHGF = E_t/1.15$, where E_t = total solar irradiation on the sloping surface. Table 12 lists shading coefficients for plastic domed skylights. Manufacturers' literature has further details.

Glass Block Walls

Glass block can be used for light transmission through exterior walls when the optical clarity of a view is not needed or wanted. Table 13 describes the glass block patterns discussed in the following text and gives solar heat gain coefficients to be applied to the solar irradiances from Tables 15 through 21 so that approximate instantaneous solar heat gains can be calculated.

Convection and low-temperature radiation heat gains for all hollow glass block panels fall in a narrow range. Differences in SHGC values are largely the result of difference in the transmittance of the glass blocks to solar radiation. Solar heat gain coefficients for any particular glass block pattern vary depending on orientation and time of day. The SHGC for western exposures in the morning (in the shade) is depressed because of the heat storage within the block.

Table 12 Shading Coefficients for Domed Horizontal Skylights

| Dome | Light Diffuser (Translucent) | Height, in. | Width to Height Ratio | Shading Coefficient |
|------------------------------|------------------------------|-------------|-----------------------|---------------------|
| Clear $\tau = 0.86$ | Yes $\tau = 0.58$ | 0 | — | 0.61 |
| | | 9 | 5 | 0.58 |
| | | 18 | 2.5 | 0.50 |
| Clear $\tau = 0.86$ | None | 0 | — | 0.99 |
| | | 9 | 5 | 0.88 |
| Translucent | None | 0 | — | 0.80 |
| | | 18 | 2.5 | 0.80 |
| Translucent $\tau = 0.52$ | None | 0 | — | 0.57 |
| | | 9 | 5 | 0.46 |
| | | 18 | 2.5 | 0.46 |
| Translucent $\tau = 0.27$ | None | 0 | — | 0.34 |
| | | 9 | 5 | 0.30 |
| | | 18 | 2.5 | 0.28 |

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Appendix B

Building Type & Space Functions: Default Assumptions

(Refer to Performance Compliance for Buildings MNECB/CS)

| Table 4.3.2.A Building Type Categories: Default Assumptions | | | | | | |
|--|--|---|-------------------------------------|---------------------------------------|--------------------------------------|---|
| Space Function | Occupant Density (m ² /person) | Receptacle Power (W/m ²) | Service Water Heating (W/person) | Minimum O.A. (L/s/m ²) | Operating Schedule (Table 3.2.2C) | Lighting Power Density (W/m ²) |
| | (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 (m ² /person) | Receptacle Power (W/m ²) | Service Water Heating (W/person) | Minimum O.A. (L/s/m ²) | Operating Schedule (Table 3.2.2C) | Lighting Power Density (W/m ²) |
| | (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 |
| Theatre- 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 (m ² /person) (1) | Receptacle Power (W/m ²) (2) | Service Water Heating (W/person) (3) | Minimum O.A. (L/s/m ²) (4) | Operating Schedule (Table 3.2.2C) (5) | Lighting Power Density (W/m ²) (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 m ² | 20 | 7.5 | 90 | 0.50 | A | 19.4 |
| Category 2: Open plan offices 84 m ² 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 m ² 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 (m ² /person) (1) | Receptacle Power (W/m ²) (2) | Service Water Heating (W/person) (3) | Minimum O. A. (L/s/m ²) (4) | Operating Schedule (Table 3.2.2C) (5) | Lighting Power Density (W/m ²) (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 display 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 housewares, 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 (m ² /person) (1) | Receptacle Power (W/m ²) (2) | Service Water Heating (W/person) (3) | Minimum O.A. (L/s/m ²) (4) | Operating Schedule (Table 3.2.2C) (5) | Lighting Power Density (W/m ²) (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 (m ² /person) (1) | Receptacle Power (W/m ²) (2) | Service Water Heating (W/person) (3) | Minimum O.A. (L/s/m ²) (4) | Operating Schedule (Table 3.2.2C) (5) | Lighting Power Density (W/m ²) (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:

Heating Type and Capacity

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. The selection of a fossil fuel furnace also allows the choice of the following types: atmospheric, modulating (fully modulating only), and condensing.

Heating Rating Type and Efficiency

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.

Cooling Characteristics

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%.

Enter the minimum temperature to which the air is cooled by the unit before being distributed throughout the building.

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.

Outdoor Air Ratio, Economizer Characteristics

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. Outdoor air economizers are not available for fan coil and heat pump make-up air handlers (which is defined as the air handling system). There are 4 types of economizer operation available:

Fixed dry bulb: The economizer will operate when the outdoor air temperature is lower than the cooling set point (including setback temperatures) to the limit temperature.

Differential dry bulb: The economizer operates when the outdoor air-dry bulb temperature is below the return air-dry bulb temperature.

Fixed enthalpy: The economizer will operate when the outdoor air enthalpy is lower than the cooling set point (including setback temperatures) to the limit temperature.

Differential enthalpy: The economizer will operate when the outdoor air enthalpy is below the return air enthalpy.

Heat Recovery Effectiveness

The sensible heat recovery effectiveness is entered on the “Outdoor Air” tab. The rated effectiveness at ARI conditions should be entered.

Supply Fan Operation and Power

Three choices are available for supply fan operation:

Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.

Fans Are Always On – The fans run continuously.

Cycle Main Fans with Setback – The fan operates according to heating setback, defined in the “Heating” setback in the zone element.

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. 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.

Return Fan

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.

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.

Humidity

If an electric or hot water humidifier is installed, specify the type and minimum humidity set point on the “Humidity” tab. Humidifiers are modelled identically in proposed and reference buildings.

Preheat Coil

If the system contains a preheat coil, select the heat source (electric or hot water) and the set point temperature. If the outdoor air temperature is below the set point temperature, the preheat coil operates.

The following are the common elements to all system types, which are described in the space/room entry tab:

Exhaust Fan Flow rate and Power

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).

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:

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

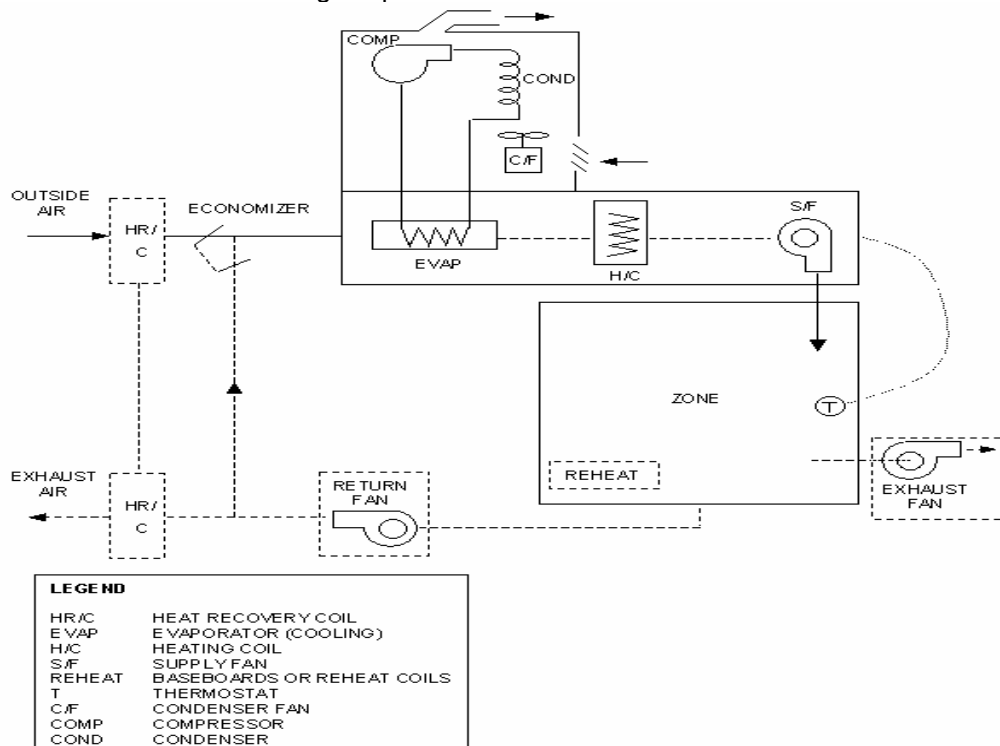


Figure C - 1 - DX Single Zone Schematic

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 system is considered a “hot-deck” system with a high supply air temperature (default 43.3°C), which can be varied; heat may be supplemented by an independent heating system (i.e. baseboards) to maintain space temperature. Note in the figure that the system supply air temperature is controlled by the control zone - the first zone listed under the system in EE4. 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:

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

Zone Airflow Rate

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.

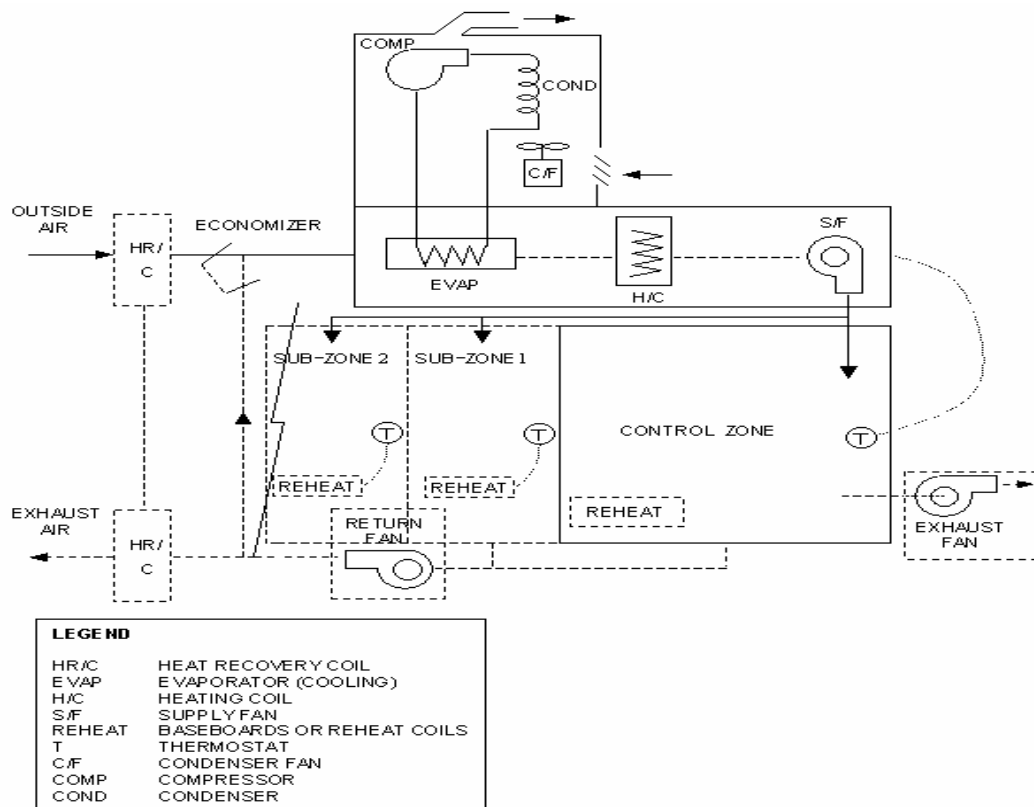


Figure C - 2 - Packaged Constant Volume Multizone System Schematic

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 supply air leaving the air-handling unit may be constant, or reset based on the cooling needs of the warmest zone served by the system; this system is generally considered a “warm-deck” system that supplies air at 13-19°C. 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:

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

Zone Airflow Rate

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.

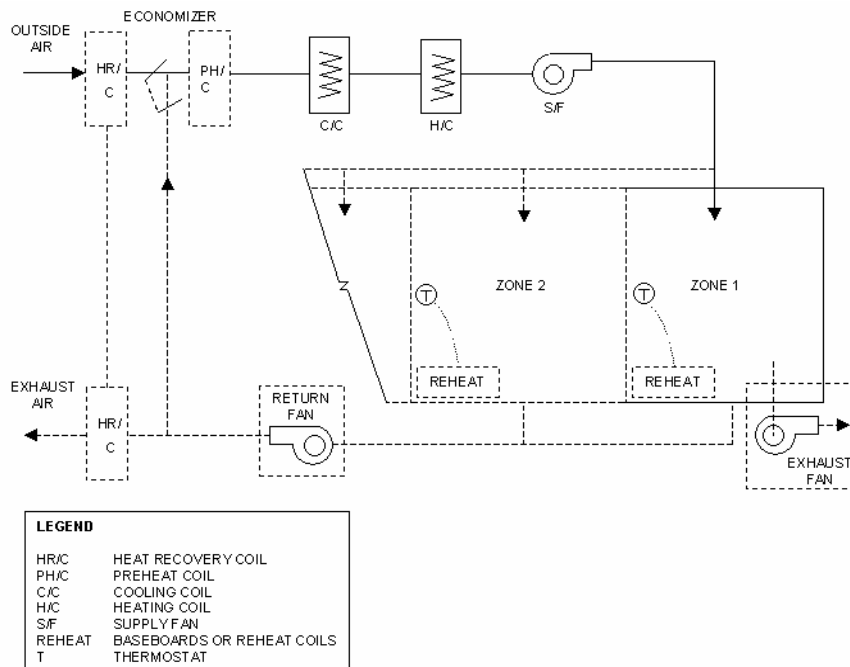


Figure C - 3 - Built-Up Single-Duct CV System Schematic

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. See section 4.6 for additional information.

Central make-up air unit supplies tempered outdoor air for the zonal heat pumps. EE4 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:

Zone Heating and Cooling Output

Enter the heating and cooling capacity of the heat pump serving the zone.

Heat Pump Performance

Enter the COP for the heat pump in heating and cooling modes at ARI-rated conditions.

Airflow Rate and Fan Power

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 be greater than the minimum outdoor air requirement.

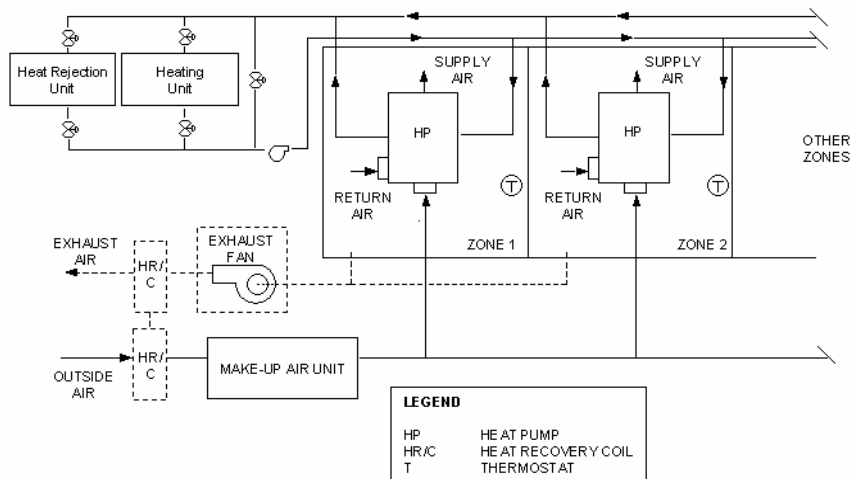


Figure C - 4 - Hydronic Heat Pump Schematic

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:

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

Zone Airflow Rate

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.

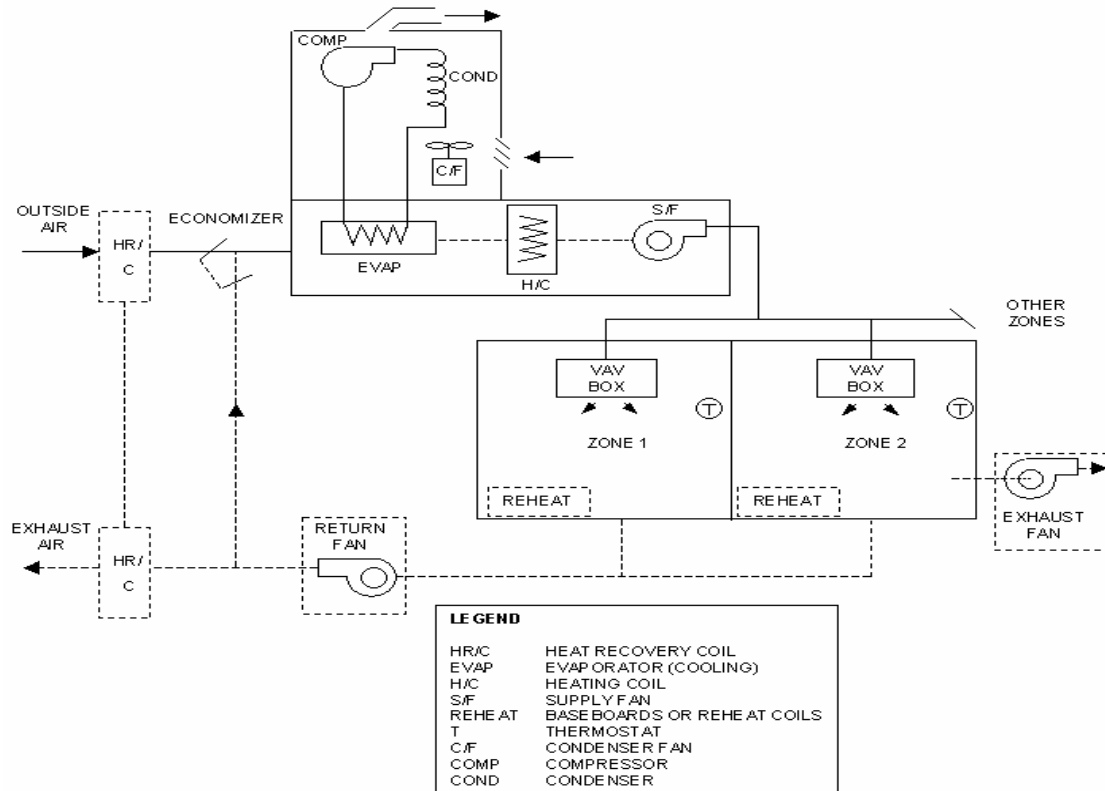


Figure C - 5 - Packaged VAV Schematic

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:

Coil Control

For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:

Constant Temperature – The cooling supply temperature is set to a constant value.

Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.

Outdoor Air Reset – The cooling coil discharge temperature is set hourly based upon the outdoor air temperature.

Heating Supply Temperature

Enter the temperature of air leaving the hot deck.

Cooling Characteristics

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%.

Enter the temperature of air leaving the cold deck.

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.

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

Zone Airflow Rate

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.

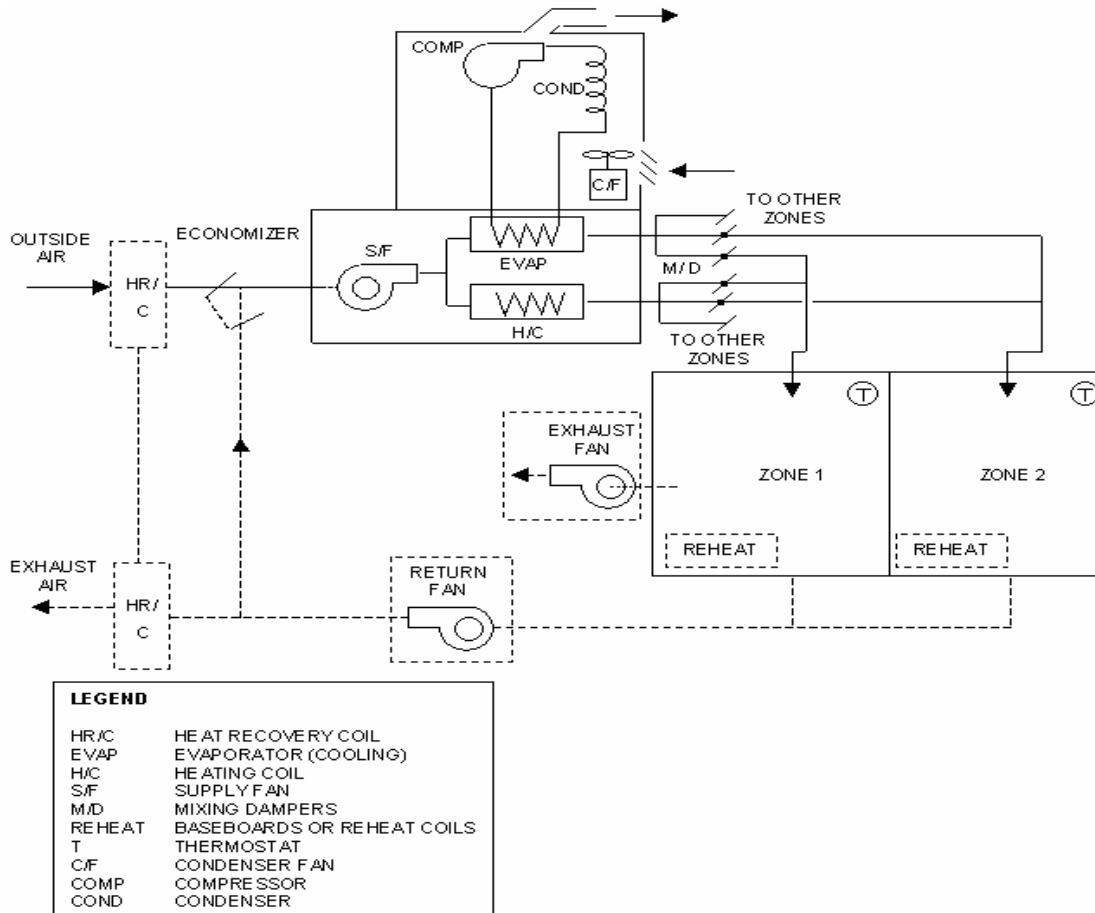


Figure C - 6 - Packaged VAV Schematic

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, and exhaust fans in any or all zones.

In the Central System Library, in addition to the common elements, define:

Zone Reheat Source

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".

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

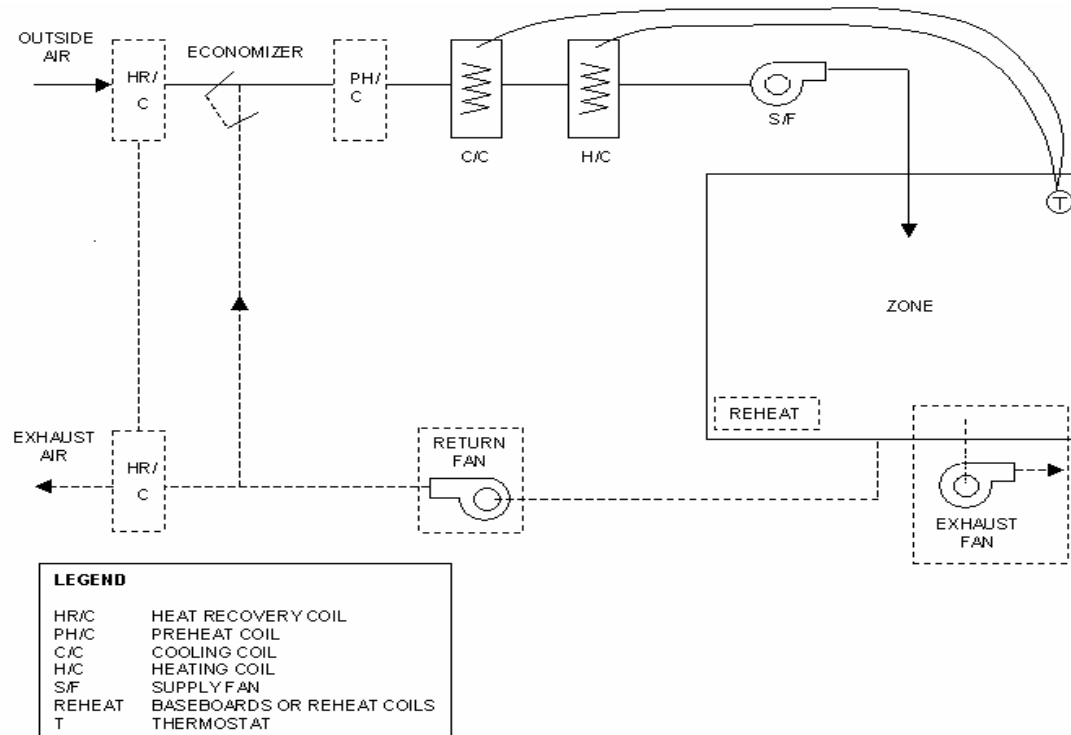


Figure C - 7 - Built-up Single Zone Schematic

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:

- Riding the fan curve
- Air foil or backward inclined with vanes
- Forward curved with vanes
- Variable speed

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.

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.

Zone Reheat Source

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”.

On the Zone Element/Mechanical Tab, define:

Terminal Type

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.

Zone Heating Output

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.

Maximum and Minimum Airflow Rates

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.

Terminal Fan Flow rate and Power

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.

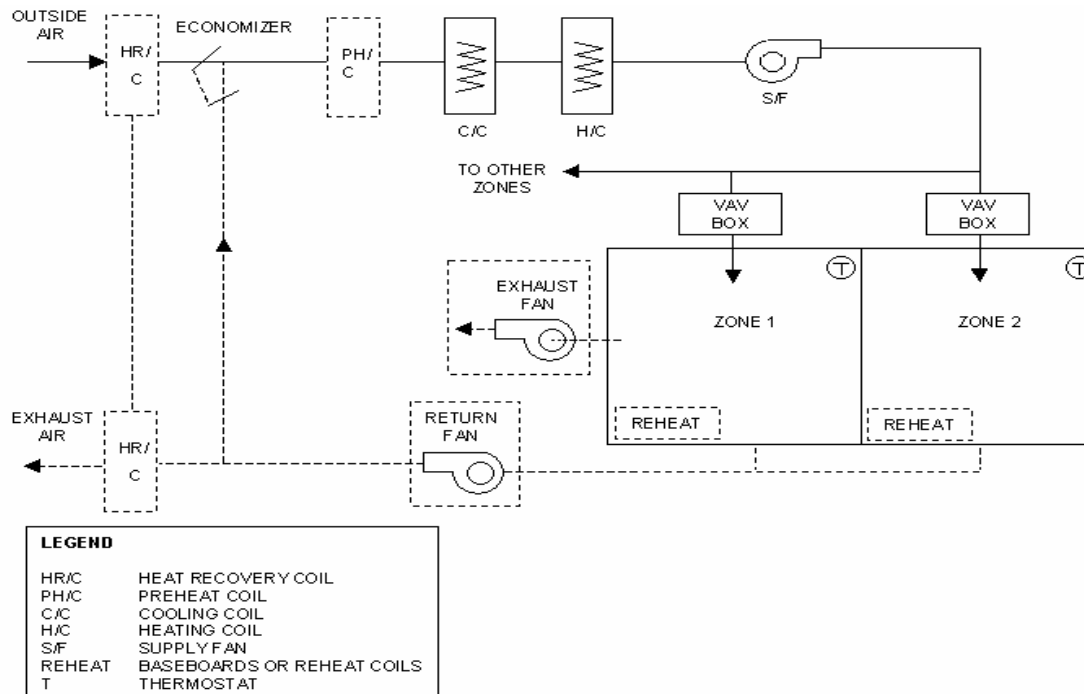


Figure C - 8 - Built-up VAV Schematic

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:

Coil Control

For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:

- **Constant Temperature** – The cooling supply temperature is set to a constant value.
- **Zone Reset** – The cooling coil is set hourly to cool the zone with the highest temperature.

- **Outdoor Air Reset** – The cooling coil discharge temperature is set hourly based upon the outdoor air temperature.

Heating Supply Temperature

Enter the temperature of air leaving the hot deck.

Cooling Characteristics

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%.

Enter the temperature of air leaving the cold deck.

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

Zone Maximum and Minimum Airflow Rate

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.

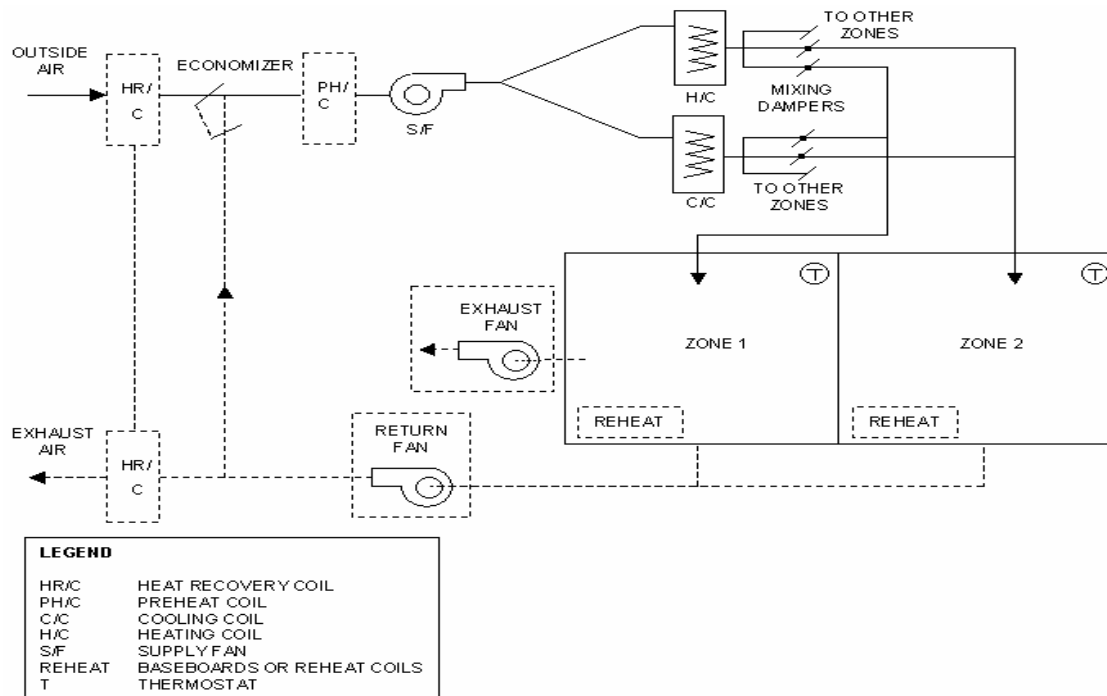


Figure C - 9 - Built-up Multizone Schematic

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:

Coil Control

For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:

- **Constant Temperature** – The cooling supply temperature is set to a constant value.
- **Zone Reset** – The cooling coil is set hourly to cool the zone with the highest temperature.
- **Outdoor Air Reset** – The cooling coil discharge temperature is set hourly based upon the outdoor air temperature.

Heating Supply Temperature

Enter the temperature of air leaving the hot deck.

Cooling Characteristics

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%.

Enter the temperature of air leaving the cold deck.

Choose one of 4 options for supply fan control in the Central Systems Library:

- **Riding the fan curve**
- **Air foil or backward inclined with vanes**
- **Forward curved with vanes**
- **Variable speed**

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. 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.

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

Zone Airflow Rate

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.

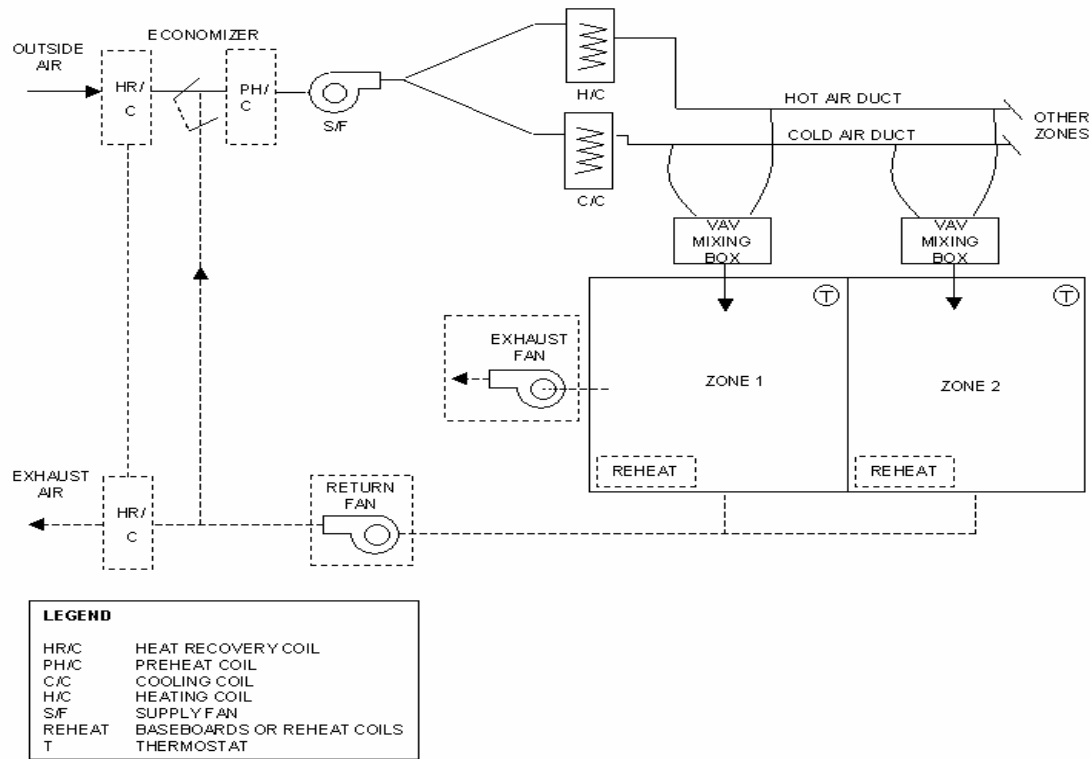


Figure C - 10 - Dual-Duct Schematic

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:

Coil Control

For both heating and cooling, indicate the type of control for supply air leaving the air-handling unit. Three options are available:

- **Constant Temperature** – The cooling supply temperature is set to a constant value.
- **Zone Reset** – The cooling coil is set hourly to cool the zone with the highest temperature.
- **Outdoor Air Reset** – The cooling coil discharge temperature is set hourly based upon the temperature difference between the outdoor air temperature and zone temperature.

Heating Supply Temperature

Enter the temperature of air leaving the hot deck.

Cold Duct and Hot Duct Supply Fan Operation

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.

Specify the supply fan operation on the “Supply Fan” tab only. The hot duct fan operates according to the same schedule. The choices are:

- **Operate Fans According to Schedule** – The fan operates according to the “Fans” schedule entered in the zone element.
- **Fans Are Always On** – The fans run continuously.
- **Cycle Main Fans with Setback** – The fan operates according to heating setback, defined in the “Heating” setback in the zone element.

For both the cold duct fan and hot duct fan, choose one of 4 options for fan control:

- **Riding the fan curve**
- **Air foil or backward inclined with vanes**
- **Forward curved with vanes**
- **Variable speed**

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.

Cold Duct and Hot Duct Supply Fan Power

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.

Zone Reheat Source

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”.

In the Zone Element/Mechanical Tab, define:

Zone Heating Output

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.

Maximum and Minimum Zone Airflow Rate

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 the cold duct provides outdoor air only.

Terminal Fan Flow Rate and Power

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.

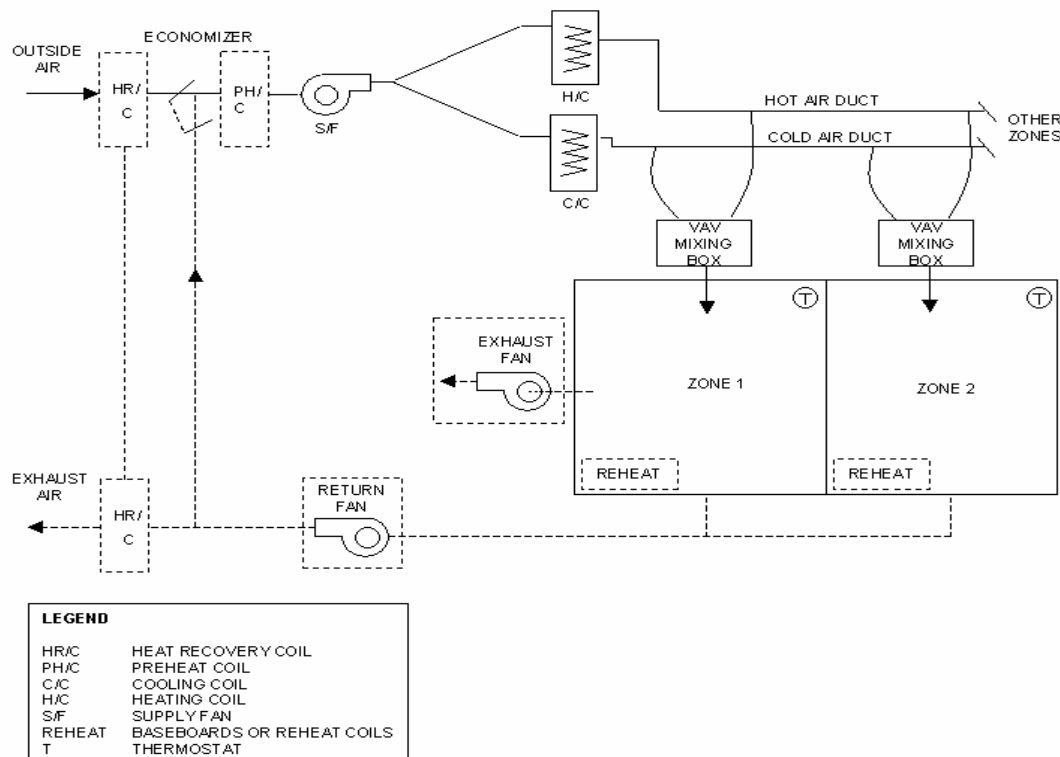


Figure C - 11 - Dual Fan Dual Duct Schematic**2-Pipe Fan Coil System**

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. Throttling the flow of water through the coil controls the temperature of the supply air. Seasonal changeover is required and must be scheduled in the Plant Element/ Spring Fall Changeover tab. Note that the heating pumps in 2-pipe fan coil systems are ignored and only the cooling pumps are used for both the heating and cooling seasons (see section 4.7 for more information).

Tempered outdoor air is supplied to the fan coils via a central make-up air unit system. EE4 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:

Zone Heating and Cooling Output

Enter the heating and cooling capacity of the fan coil serving the zone.

Airflow Rate and Fan Power

Enter the fan coil rated airflow rate and fan power consumption. The flow rate must be greater than the minimum outdoor air requirement.

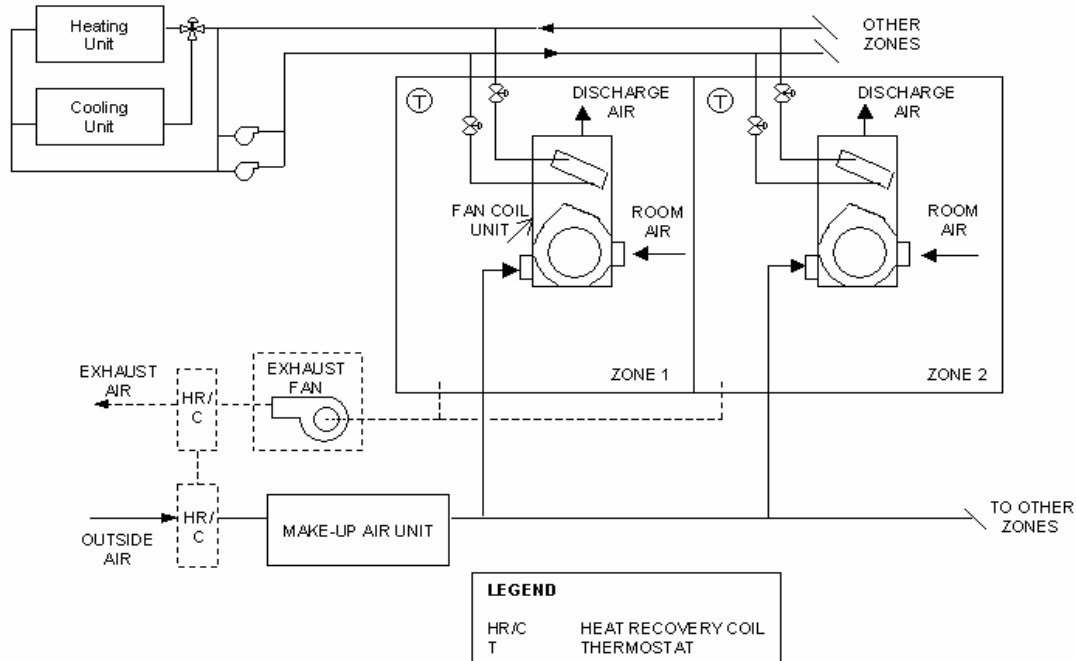


Figure C - 12 - 2-Pipe Fan Coil System Schematic

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. Throttling the flow of water through the coils controls the temperature of the supply air.

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:

Zone Heating and Cooling Output

Enter the heating and cooling capacity of the fan coil serving the zone.

Airflow Rate and Fan Power

Enter the fan coil rated airflow rate and fan power consumption. The flow rate must be greater than the minimum outdoor air requirement.

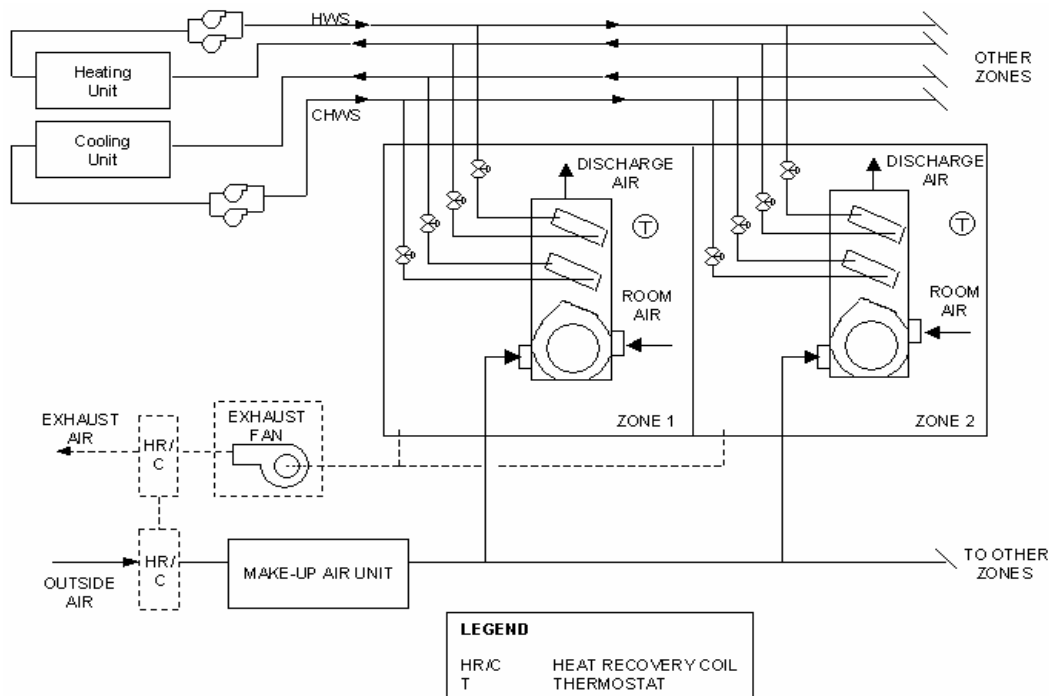


Figure C - 13 - 4-Pipe Fan Coil System Schematic

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:

Induction Terminals

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.

In the Zone Element/Mechanical Tab, define:

Zone Heating and Cooling Output

Enter the heating and cooling capacity of the induction unit.

Maximum Airflow Rate

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.

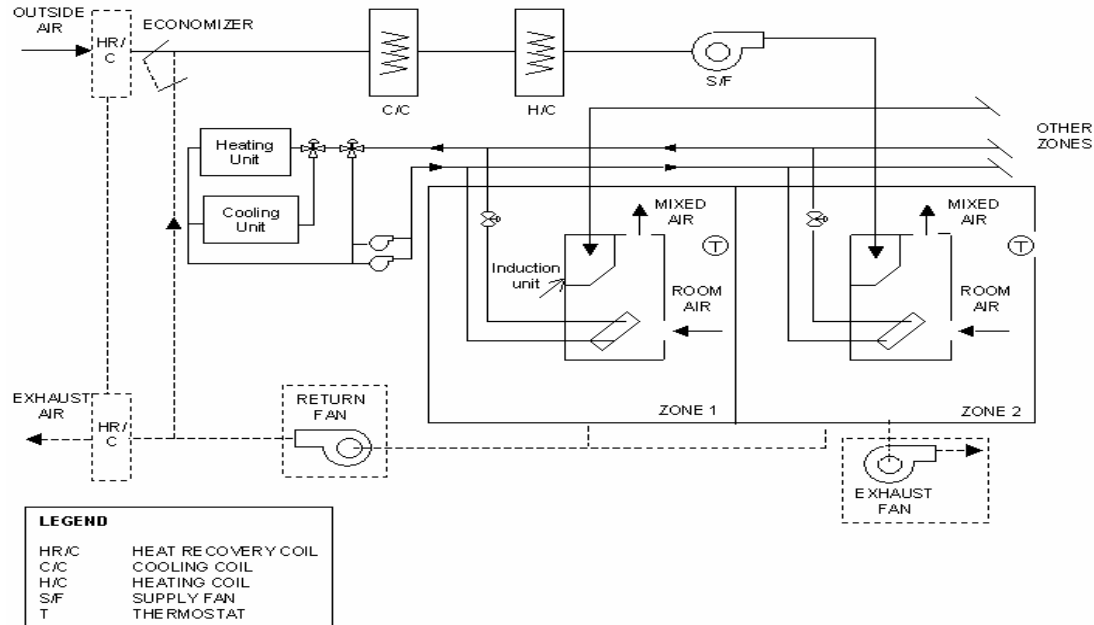


Figure C - 14 - 2-Pipe Induction Unit System Schematic

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:

Induction Terminals

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.

In the Zone Element/Mechanical Tab, define:

Zone Heating and Cooling Output

Enter the heating and cooling capacity of the induction unit.

Maximum Airflow Rate

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.

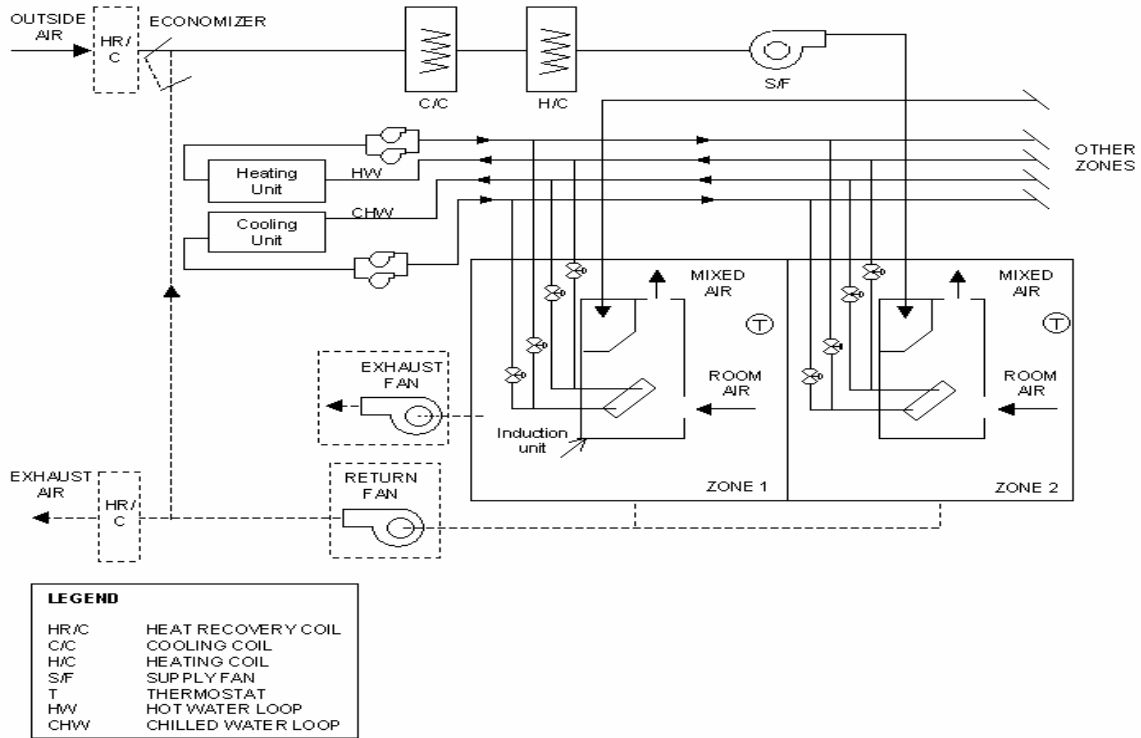


Figure C - 15 - 4-Pipe Induction Unit System Schematic

Appendix D

MURB Credit Options

1. Background

Multi-unit residential buildings (MURBs) have a difficult challenge meeting NRCan's validation performance threshold of 25 percent energy savings relative to the MNECB reference building. 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 savings potential for credit towards NRCan's validation compliance.

This section describes additional credits that are available only to MURBs and 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.

2. Parking Garage Lighting

Currently, parking garages are not considered eligible for validation 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/m² 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

Unheated parking garages must be converted to minimally heated garages to apply the lighting analysis. Create a space using Space Function: Storage/Warehouse: Inactive Storage: to describe the parking space. Create a heating constant schedule of 4°C and enter a design space temperature of 4°C. 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.

Note: 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).

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, infrared 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 an 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 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.

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*

Calculate creditable building exhaust heat available using the following:

$$\text{Exh} = 1.21 \times \text{flow} \times 9^\circ\text{C}$$

1.21 = (m³/1000 L) × 1000 g/0.8333 m³ (factor includes specific heat and air density when dry, at sea level, and 0°C)

flow = exhaust airflow into garage (L/sec)

9 = temperature (°C)

Note: Specific heat of air is rounded to 1.00 J/g-K

Exh = exhaust heat (Watts)

Convert this value to a W/m² value by dividing it by the area of the parking garage, and enter this value as the sensible process load.

Ensure that the Process and Fan schedules for the parking garage are changed from “A” to “H” to correspond to 24-hour, 7-day operation of the building exhaust and process (8760 hours/yr).

Ensure that the garage heating schedule is set to a constant 9°C, and the design temperature is 9°C for the space.

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 “inactive storage.” 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.

Run the simulation in EE4 : proposed and reference cases.

Manually remove the process calculation from the proposed EE4 simulation results, using the following:

$$\begin{aligned} \text{Process (kWh)} &= (\text{Exh}/1000) \times 8760 \text{ hrs/yr} \\ \text{Process (MJ)} &= (\text{Exh}/1000) \times 3.6 \text{ MJ/kWh} \times 8760 \text{ hrs/yr} \\ \text{Process (cost)} &= (\text{Exh}/1000) \times 8760 \times \text{Average cost per kWh} \end{aligned}$$

3.1.2 Option 2: Allow High Unheated Hours

Calculate creditable building exhaust heat available, using the following:

$$\text{Exh} = 1.21 \times \text{flow} \times 9^\circ\text{C}$$

1.21 = (m³/1000 L) x 1000 g/0.8333 m³ (factor includes specific heat and air density when dry, at sea level, and 0°C)

flow = exhaust airflow into garage (L/sec)

9 = temperature (°C)

Note: Specific heat of air is rounded to 1.00 J/g·K

Exh = exhaust heat (Watts)

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/yr). Ensure that the garage heating schedule is set to a constant 9°C and the design temperature is 9°C for the space.

Set the air-handling system for the parking garage to packaged single zone system serving a single parking garage zone with a *space function* of “inactive storage.” 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.

Run the sizing calculation to determine the garage heating (ventilation and space) design load. (Calc Manager → Sizing → Calculate)

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 9°C 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 9°C. Run the simulations 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.

3.2 Unheated Garage

3.2.1 Option 1: Convert Available Heat to Process Energy

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 5°C heating schedule and a design set point of 5°C.

Calculate creditable building exhaust heat available, using the following:

$$\text{Exh} = 1.21 \times \text{flow} \times 5^\circ\text{C}$$

1.21 = (m³/1000 L) x 1000 g/0.8333 m³ (factor includes specific heat and air density when dry, at sea level, and 0°C)

flow = exhaust airflow into garage (L/sec)

5 = temperature (°C)

Note: Specific heat of air is rounded to 1.00 J/g-K

Exh = exhaust heat (Watts)

Convert this value to a W/m² value by dividing it by the area of the parking garage, and enter this value as the sensible process load.

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 5°C and the design temperature is 5°C for the space.

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 “inactive storage. 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.

Note: The 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).

Complete the simulations: proposed and reference cases.

Manually remove the process calculation from the proposed EE4 results, using the following:

$$\text{Process (kWh)} = (\text{Exh}/1000) \times 8760 \text{ hrs/yr}$$

$$\text{Process (MJ)} = (\text{Exh}/1000) \times 3.6 \text{ MJ/kWh} \times 8760 \text{ hrs/yr}$$

$$\text{Process (cost)} = (\text{Exh}/1000) \times 8760 \times \text{Average cost per kWh}$$

3.2.2 Option 2: Allow High Unheated Hours

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 5°C heating schedule and a design set point of 5°C.

Calculate creditable building exhaust heat available, using the following:

$$\text{Exh} = 1.21 \times \text{flow} \times 5^{\circ}\text{C}$$

1.21 = $(\text{m}^3/1000 \text{ L}) \times 1000 \text{ g}/0.8333 \text{ m}^3$ (factor includes specific heat and air density when dry, at sea level, and 0°C)

flow = exhaust airflow into garage (L/sec)

5 = temperature (°C)

Exh = exhaust heat (Watts)

Note: Specific heat of air is rounded to 1.00 J/g·K

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 5°C and the design temperature is 5°C for the space.

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 “inactive storage.” 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.

Run the sizing calculation to determine the garage heating (ventilation and space) design load.

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 5°C 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 5°C.

Note: The 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).

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 in suites 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 (day lighting, occupancy) were installed.

Reference: 11.8 W/m² (MNECB for Dormitory – Bedroom *Space Function*).

Procedures:

EE4 automatically sets the residential lighting power to 9 W/m² 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 suites. The operating schedules, water heating requirements and ventilation rate per occupant are identical between the “Dwelling Unit” and “Dormitory - Bedroom” spaces. The occupant densities are to be adjusted to the residential levels (60 m²/occupant).

Because suite 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/m² (equal to 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 hard-wired, plus switch able 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 occur. 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/m² = 891.6 W / 85.41 m² = 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:

e.g. Control Fraction = 52 W / 891.6 W = 5.8 percent
 (2 x 13W PL (closet) + 2 x 13W PL (bathroom)) / Total lighting power

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, it is assumed that appliances will not be replaced with less efficient ones following NRCan's validation.

Option: To be eligible for this credit select ENERGYSTAR[®] appliances; EnerGuide rated appliances that have an annual energy consumption rating that is a minimum of 25 percent less than the reference values are also eligible.

Procedures:

EE4 and MNECB do not consider appliances within the simulation; therefore, they are considered a process load for this credit.

The reference appliance values shall be the 2004 EnerGuide average annual energy consumption from NRCan's Office of Energy Efficiency web site (oe.e.nrcan.gc.ca/equipment/).

| | | |
|--|------------|----------------------|
| Refrigerators (top mounted, 16.5–18.4 cu. ft.) | 465 kWh/yr | |
| Dishwashers: standard | 457 kWh/yr | (includes hot water) |
| Clothes washers: top loading | 573 kWh/yr | (includes hot water) |
| Clothes dryers: electric standard | 912 kWh/yr | |
| Ranges: electric self-cleaning | 622 kWh/yr | |

There should be no adjustment made to the hot water energy consumption of the proposed building from the implementation of energy saving appliances; ENERGYSTAR appliance ratings also include hot water energy requirements¹. 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 one of the following procedures should be used for modelling. In both cases, the appliance selection in the proposed and the reference cases must match.

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). NRCan already credits low-flow showerheads, using the MNECB reference of 9.5 L/minute flow. NRCan 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 NRCan itself.

5.1 Option A: EE4 Modelling

Steps involved in Proposed case:

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.

Convert to an hourly value: kWh/yr/bldg / 8760.

Divide this total by the area of the residential suites (m²) and multiply by 1000 W/kW.

$$\text{Result : W/m}^2 = [(\text{kWh/yr/bldg}) / (8760 \text{ total x suite area})] \times 1000.$$

The value calculated above 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 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 with 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.

Complete steps 1–3 using the EnerGuide appliance reference values, and run the reference case only (this may cause inaccurate results if the proposed building is heated with a GSHP – the reference boiler fuel for the reference is selected based on the percentage of annual load met by the GSHP versus other fuels, see “Common Questions” at the end of section 4.6.4 for a more detailed explanation).

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 loads are 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/building) A x B | Reference Use (kWh/yr/appliance) C | Reference Use (kWh/yr/building) A x C |
|----------------|-------------------|---|--|--|---|
| Dishwasher | | | | 457 | |
| Stove/Range | | | | 622 | |
| Refrigerator | | | | 465 | |
| Clothes Washer | | | | 573 | |
| Clothes Dryer | | | | 912 | |

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; recalculate the performance of the proposed building relative to the reference using these adjusted energy consumption values.

Convert the kWh/yr/bldg to \$/yr/bldg (multiply by average \$/kWh from your electrical utility file or from the ES-D DOE2 report), and add the resulting annual energy cost to both the proposed and reference cases, respectively.

In all cases, the appliance selection in the proposed and the 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 NRCan's validation.

The first and simplest option is to use the standard NRCan application process in which 25% energy savings are demonstrated relative to the MNECB reference building alone (without fume hoods, as they can be considered a process load).

The second option is to provide a submission that demonstrates that the proposed building design is expected to consume 15% less energy than the MNECB reference building due to building improvements, and 25% less energy due to combined building and process improvements related to heat recovery on fume hood exhaust, and/or low velocity or area restricted fume hoods. The only acceptable 'process' load for education laboratory facilities are laboratory fume hoods.

This section explains the details for the second option where the fume hood process loads are included in the submission.

Eligible Process Load 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.

Heat recovery on fume hood exhaust:

Potential credit for heat recovery on fume hood exhaust.

Credit is dependent on the 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 fumes hoods.

Credit is dependent on type of fume hood.

Energy efficiency requirements for hoods are covered in Section 6.5.6 of ASHRAE 90.1-2004. 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. The exceptions below are not covered by the above requirement and are considered process loads by NRCan.

- 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 modelling procedure should be completed entirely in EE4. The MNECB reference simulation is done with room ventilation requirements defined by the *space function*; the fan power is derated based on the relative flow rates. A second simulation is done for the proposed simulation with fume 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.

See “Systems Using Special Ventilation Rate Controls” below for additional information if special ventilation rate controls are implemented in a building that is heat recovery exempt.

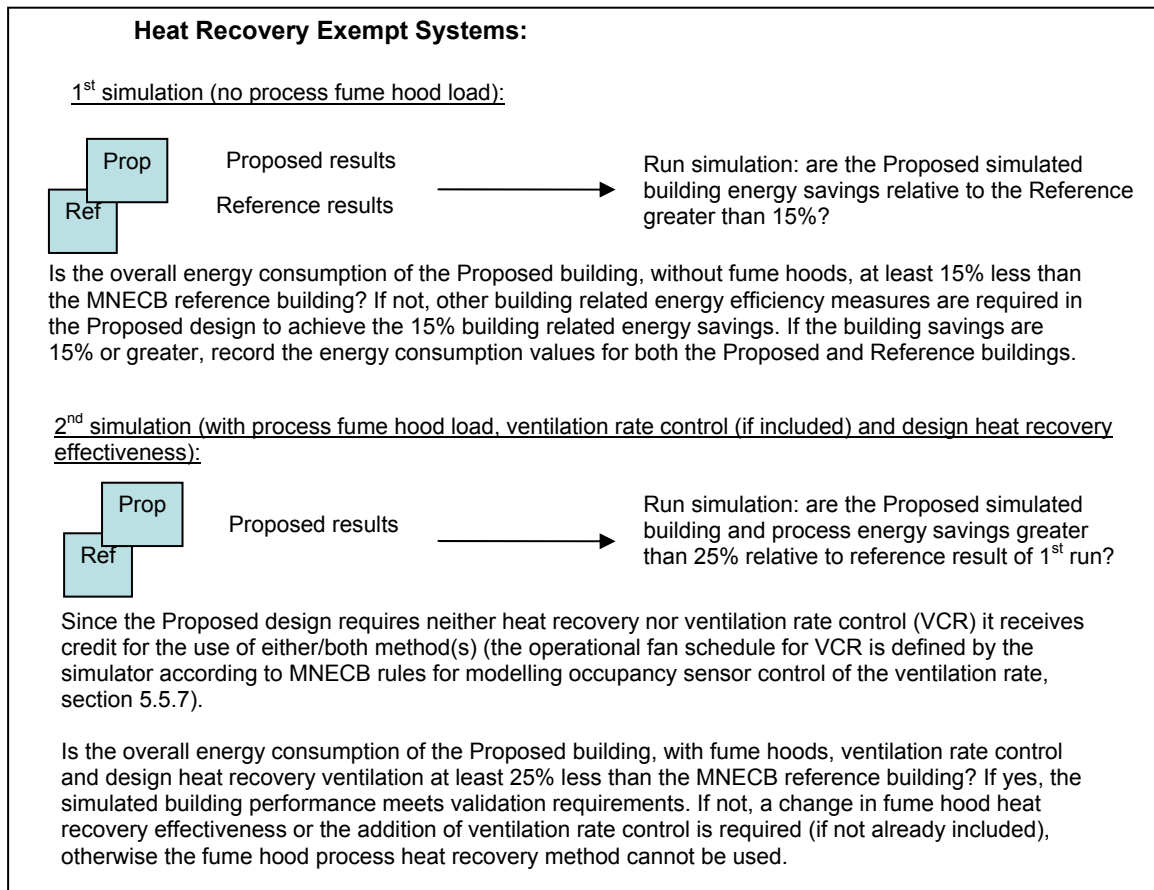


Figure E - 1 - Summary of Heat Recovery Exempt Systems

Systems Requiring Heat Recovery:

If ASHRAE requires the system to have heat recovery, energy savings are only counted for a fume hood heat recovery system with an effectiveness greater than 50%. As the majority of heat recovery systems on laboratory fume hoods are less than 50% effective, heat recovery is typically combined with ventilation rate control.

To determine the energy savings, two simulations are done. The first simulation does not include the process load. The Proposed building design energy consumption must be at least 15% less than the MNECB reference building energy consumption. The second simulation is performed with the process load, ventilation rate control and heat recovery included. Both the Proposed and Reference buildings follow the same fan operating schedule; the Proposed building receives credit for any fume hood heat recovery implemented.

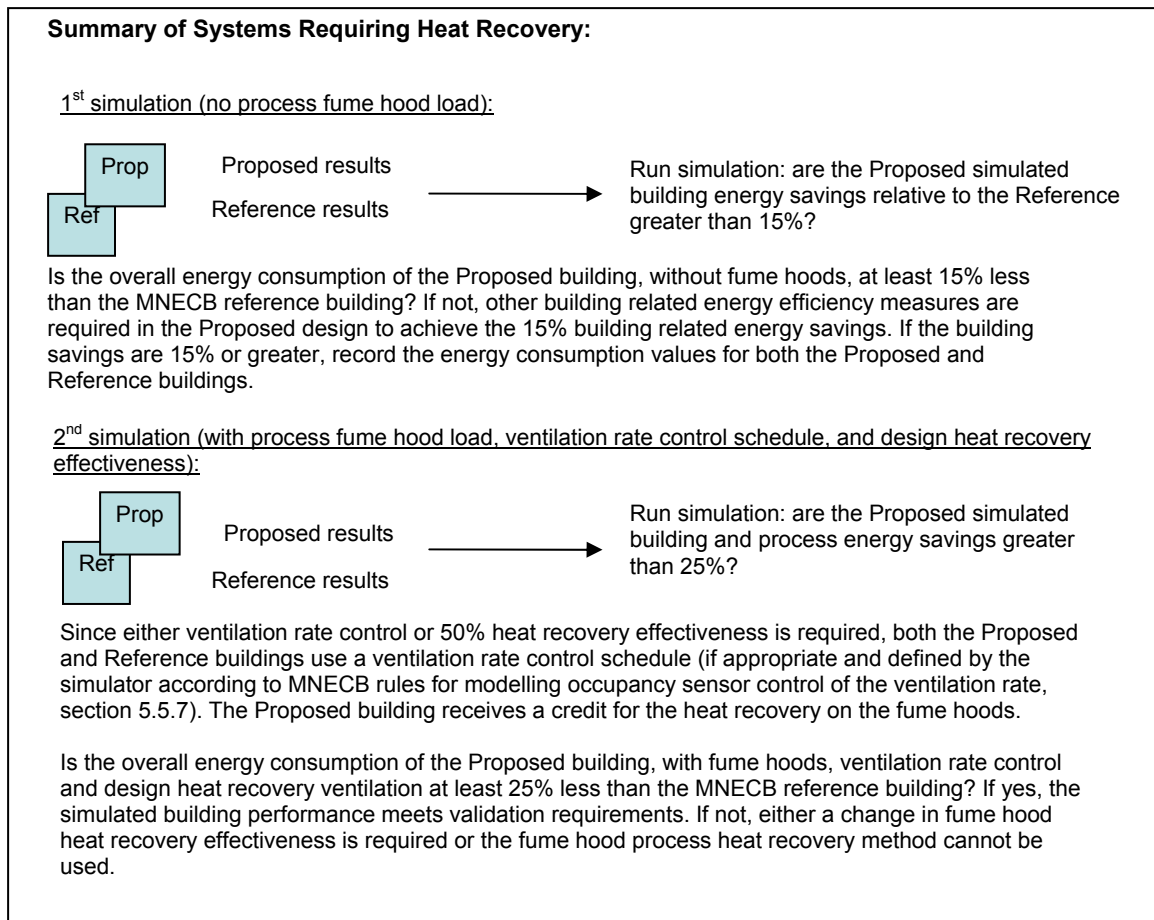


Figure E - 2 - Summary of Systems Requiring Heat Recovery

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 modelling occupancy sensor control of the ventilation rate. It is acknowledged that fume hood 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 modelling strategy for occupancy sensors.

If demand control is used for compliance to ASHRAE 90.1, then the reference building also uses the same operating schedule as the proposed building (the complete simulation is done in EE4).

Appendix F

Drain water Heat Recovery Systems

In buildings and industry, substantial energy savings can be achieved through reclaiming heat from drain water (or waste-water), a process commonly called drain water heat recovery (DHR). The reclaimed heat is almost always used to preheat cold fresh water. The most cost-effective class of drain water 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 drain water source. In restaurants and health clubs the range of savings is 40-75%.

The following guidelines and procedures form an abbreviated methodology for drain water heat recovery in buildings.

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.

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.

$$\text{DHW Load Reduction} = \text{DHW heating load} * \text{DHR savings} * \text{DHR eff} * \text{DHR util}$$

Where,

| | | |
|------------------|---|--|
| DHW heating load | = | hot water heating load from EE4 calculation (DOE2 BEPU report) |
| DHR savings | = | % savings due to DHR installation (see Table F-1) |
| DHR eff | = | % effectiveness of DHR equipment |
| DHR util | = | utilization factor of DHR in a building (0 – 100% coverage) |

Potential DHW Savings from Drain water Heat Recovery (DHR savings) :

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) has 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 | | | Centralized DHR |
|--|-----------------|--------------------------|-------------|-----------------|
| | 1-2 WC/unit | 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) (DHR eff)

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 F-1 above 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 flow rates in Table F-1 shall be clearly reported. The summary test report must be submitted with NRCan's validation 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 (DHR util)

Due to design constraints, in some buildings not every drain water 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

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 drain water 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 * DHR loadf * DHR eff * Flowf

Where,

DHW heating load = hot water heating load from EE4 calculation (DOE2 BEPU report)
DHR loadf = % of hot water load connected to DHR system
DHR eff = % effectiveness of DHR equipment at 50% flow
Flowf = flow balance correction factor

Proportion of Load Feeding the DHR system(s) (DHR loadf) :

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.

Table F - 2 - Sample Chart Showing Calculation of Load Proportion that could feed two DHR systems

| 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 Lavatory | 7.6 | 21 | 159.6 | 2 | 15.2 | 2 | 15.2 |
| Basin, Public Lavatory | 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% |

Rated Effectiveness of DHR unit(s) at 50% flow (DHR eff)

In reality it is rare that all fixtures will operate concurrently. The DHR system performance shall therefore be benchmarked at 50% of peak total flow, as calculated 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

Additional Information

For additional information related to EE4, the MNECB or NRCan's validation of new building designs, please contact us in any of the following ways:

Websites :

EE4 : http://www.sbc.nrcan.gc.ca/software_and_tools/ee4_soft_e.asp
NRCan's Validation : <http://oeo.nrcan.gc.ca/commercial/newbuildings/validation.cfm>
MNECB : http://irc.nrc-cnrc.gc.ca/pubs/codes/nrcc38731_e.html
Web contact form: www.oeo.nrcan.gc.ca/buildings/contact

Other

Toll-free number : 877-360-5500
Fax: 613-947-4121
E-mail: info.services@nrcan.gc.ca

Mailing address :

Buildings Division
Office of Energy Efficiency
Natural Resources Canada
1 Observatory Crescent, Building # 3
Via Canada Post: Ottawa, ON K1A 0E4
Via Courier : Ottawa, ON K1Y 4X2