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

FINAL REPORT

Version 2.0

November 2002

**Prepared for:
Natural Resources Canada
Ottawa, Ontario**

Table of Contents

Table of Contents	ii
List of Figures	vii
List of Tables	viii
1. INTRODUCTION	1-1
1.1 Background.....	1-1
1.2 Manual Organization	1-5
1.3 Overview of MNECB and CBIP	1-7
1.4 Energy Efficiency Measures	1-8
2. BUILDING ZONING PRINCIPLES	2-17
2.1 Dividing Buildings into Zones	2-17
Same HVAC System	2-18
Similar Operation and Function	2-19
Similar Heating/Cooling Loads	2-19
Grouping Similar Zones.....	2-20
2.2 Dividing Zones into Spaces	2-22
2.3 Defining Unconditioned/Partially Conditioned Zones	2-23
2.4 Zoning Example	2-25
3. BUILDING FUNCTION AND OPERATION	3-1
3.1 Overview of EE4	3-1
3.2 Building Type vs. Space Function	3-4
3.3 Energy Savings Versus Cost Savings	3-6
3.4 Utility Rates.....	3-6
Time of Use Rates: Data Entry.....	3-8
Renewable Pricing	3-18
Deregulated Pricing.....	3-19
3.5 Determination of Principal Heating Source	3-19
3.6 Building Schedules and Equipment Operation	3-23
Changing Schedules in EE4.....	3-25
Process Loads	3-26
Service Water Loads.....	3-27
3.7 Weather File Selection	3-28
4. CENTRAL PLANT EQUIPMENT	4-29
4.1 Service Water Heaters	4-29

Multiple Water Heating Systems	4-30
Indirect Water Heating.....	4-31
Seasonal Boilers	4-31
Renewable Water Heating	4-32
Process Water Heating	4-32
4.2 Boilers.....	4-33
Multiple Boilers.....	4-33
Condensing Boilers	4-35
Outdoor Air Reset	4-35
Flue Gas Heat Recovery	4-36
4.3 Chillers.....	4-37
Electric Chillers	4-37
Gas-Fired/Absorption Chillers	4-38
Modulating Chillers.....	4-39
Double-Bundled Chillers and Chiller Heat Recovery	4-39
4.4 Cooling Towers	4-39
4.5 District Heating and Cooling.....	4-40
Central Cooling	4-40
Utility Rate Considerations	4-41
4.6 Heat Pumps	4-42
Ground Source (or Geothermal) Heat Pumps	4-42
Boiler/Cooling Tower Source Heat Pumps	4-45
Air Source Heat Pumps.....	4-46
Combination Ground Source Heat Pump/Boiler Plants.....	4-47
4.7 Pumps.....	4-47
Pump and Motor Efficiency	4-48
Calculating Pump Head.....	4-48
Design Temperature Drop.....	4-50
Pump Type.....	4-51
Pump Operation and Control.....	4-51
4.8 Special Central Plant Cases.....	4-51
Natural Cooling	4-51
Cogeneration Systems	4-52
Fuel Cells	4-52
Condensate Heat Recovery	4-52
Thermal Storage	4-1
5. HVAC EQUIPMENT	5-1
5.1 Central Heating and Cooling Coils	5-1
Heating Coils.....	5-1
Cooling Coils.....	5-3
5.2 Air Source Heat Pumps.....	5-3
5.3 Zone-Level Heating Devices	5-5
Baseboard Radiators, Reheat Coils, Heating Panels.....	5-5
Fan Coils and Hydronic Heat Pumps.....	5-6
5.4 System Air Flow Rates and Fans	5-7

Supply and Exhaust Fan Overview.....	5-7
Entering Central Supply Fans in EE4	5-9
Central Return Fans	5-11
Zone Supply Fans	5-11
Zone Exhaust Fans	5-12
Fan Operating Schedules.....	5-12
5.5 Outdoor Air Flow Rates	5-12
Ventilation Rates Above ASHRAE 62-1999.....	5-13
Hospital Systems	5-14
Demand-Controlled Ventilation.....	5-15
5.6 Ventilation Air Heat Recovery.....	5-16
Exhaust Fan Heat Recovery.....	5-18
Exhaust Fan Heat Recovery with Make-up Air Units	5-18
Heat Recovery and Differing Exhaust and Supply Fan Operation	5-19
Heat Recovery with Make-Up Air Units (Fan Coil and Heat Pump Systems)	5-20
5.7 Humidifiers	5-20
5.8 Economizers	5-21
5.9 Preheaters	5-22
6. MODELING OF HVAC SYSTEMS	6-23
6.1 Fundamental System Types in EE4	6-23
6.2 Table 6-2 – HVAC Data Summary	6-26
Selecting the Appropriate System.....	6-27
6.3 System Types	6-29
Fan Coil, Heat Pump, and Induction Unit Systems	6-29
Single Zone Systems	6-30
Constant Volume Multi-zone Systems.....	6-30
Packaged VAV System	6-31
Built Up Variable Air Volume Systems.....	6-32
6.4 Special HVAC System Cases	6-33
Water-Based Radiant Heating and Cooling Systems.....	6-33
Baseboard Electric Space Heating	6-34
Radiant (Gas-Fired) Unit Heaters	6-34
Radiant Panel and Infra-Red Heating Systems	6-35
Combination Space and Water Heating Systems	6-35
Solar Water and Ventilation Air Heating Systems.....	6-36
6.5 System Modeling Examples	6-37
Example 1. Restaurant Served by Rooftop Units.....	6-37
Example 2. Office Served by Ground Source Heat Pumps.....	6-38
Example 3. Apartment Building with Hot Water Radiators and In-Suite Chilled Water Fan Coils.....	6-39
Example 4, Warehouse Served by Roof Top Units and Gas Infra-Red Heaters ..	6-42
7. MODELING OF BUILDING ENVELOPE.....	7-1
7.1 Level of Complexity Required	7-1

7.2	Above-Grade Walls, Roofs and Floors	7-2
	Area Calculation	7-2
	Wall, Roof and Floor U-values	7-3
7.3	Assemblies in Contact with Ground	7-5
	Below-Grade and Earth-Bermed Walls	7-5
	Below-Grade and Earth-Bermed Roofs	7-6
7.4	Windows and Skylights	7-7
	Window and Skylight Area	7-7
	Window and Skylight U-values	7-8
	Window and Skylight Solar Heat Gain Coefficients (SHGC)	7-8
7.5	Doors	7-9
7.6	Curtain Wall Systems	7-9
	Vision Panel	7-9
	Spandrel Panel	7-10
7.7	Balconies and Wall/Floor Junctions	7-12
	Junctions	7-12
	Balconies	7-13
7.8	Modeling Unconditioned or Partially Conditioned Zones	7-13
	Unconditioned Space (unheated vestibules, parking garages)	7-13
	Partially Conditioned Space (crawlspaces, heated parking garage)	7-14
	Unconditioned Space as a Supply Air Plenum (crawlspace, mechanical penthouse or floor)	7-15
	Partially Conditioned Space as a Supply Air Plenum (crawlspace, mechanical penthouse or floor)	7-16
7.9	Interior Partitions	7-16
8.	MODELING OF ELECTRICAL SYSTEMS	8-1
8.1	Lighting Systems	8-1
	Lighting Controls	8-4
	Exclusions from Lighting Power Density	8-6
8.2	Other Electrical Systems	8-6
	Elevators and Refrigeration Loads	8-6
	Renewable Electricity Systems	8-6
9.	CBIP SUBMISSION GUIDELINES	9-8
10.	TROUBLESHOOTING	10-9
Appendix A.	Default Window U-Values and Solar Heat Gain Coefficients	1
Appendix B.	Building Type & Space Functions: Default Assumptions	1
Appendix C.	Detailed EE4 System Descriptions	1

List of Figures

Figure 2-1 – Typical Zoning for Offices and Apartments	2-21
Figure 2-2 – Grouping Zones According to Heating and Cooling Loads	2-22
Figure 2-3 – Zoning Strategy for Big-Box Retailer	2-25
Figure 3-1 – EE4 Building Tree Hierarchy	3-2
Figure 5-1 – System Air Flow Rates	5-8
Figure 7-1 – Depth of Below-Grade Wall When Earth Berms Are Used.....	7-6
Figure 7-2 – EE4 Description for a Spandrel Panel	7-12
Figure 8-1 – Lighting Area Factor as a Function of Floor Area and Ceiling Height.....	8-3
Figure 8-2 – Maximum Daylighting Penetration	8-5
Figure 10-1 – DX Single Zone Schematic.....	4
Figure 10-2 – Packaged Constant Volume Multizone System Schematic.....	7
Figure 10-3 – Built-Up Single-Duct CV System Schematic.....	11
Figure 10-4 – Hydronic Heat Pump Schematic.....	14
Figure 10-5 – Packaged VAV Schematic.....	18
Figure 10-6 – Packaged MZ Schematic.....	22
Figure 10-7 – Built-up Single Zone Schematic.....	26
Figure 10-8 – Built-up VAV Schematic	30
Figure 10-9 – Built-up Multizone Schematic	34
Figure 10-10 – Dual-Duct Schematic.....	38
Figure 10-11 – Dual Fan Dual Duct Schematic.....	43
Figure 10-12 – 2-Pipe Fan Coil System Schematic	46
Figure 10-13 – 4-Pipe Fan Coil System Schematic	50
Figure 10-14 – 2-Pipe Induction Unit System Schematic.....	53
Figure 10-15 – 4-Pipe Induction Unit System Schematic.....	57

List of Tables

Table 3-1 – Energy Source Adjustment Factors (taken from MNECB Appendix D)	3-21
Table 3-2 – Fan Operating Schedules	3-25
Table 4-1 – Rating Conditions for Chillers	4-38
Table 4-2 – Open Loop Temperatures (Depth 1.5 metres)	4-43
Table 4-3 – Monthly Entering Water Temperatures for Horizontal Closed-Loop Heat Pumps (°C)	4-44
Table 4-4 – Monthly Entering Water Temperatures for Vertical Closed Loop Heat Pumps (°C)	4-45
Table 4-5 – Pump Effective Head Calculation Example.....	4-49
Table 6-1 – HVAC Systems Modeled in EE4.....	6-24
6.2 Table 6-2 – HVAC Data Summary	6-26
Table 7-1 – Framing Percentages (taken from MNECB Appendix C)	7-4
Table 8-1 – Lighting Control Strategies	8-4

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

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

This manual was prepared by Stephen Carpenter and Craig McIntyre of Enermodal Engineering Limited of Kitchener, Ontario and reviewed by Natural Resources Canada CBIP staff.

1. INTRODUCTION

1.1 Background

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

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

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

The reference building is architecturally identical to your proposed design, thus having the same wall orientations, areas, windows, level of air-tightness, number of occupants, indoor set-point temperatures (space heating, cooling, hot water), fan operation, appliance and electrical usage and process equipment. The

reference building will be insulated to the MNECB prescriptive levels as outlined in Appendix A of MNECB and applicable to the climatic region and space heating fuel for your location. The reference building will have a defined heating and cooling plant (if applicable), a representative air handling system (single zone direct expansion cooling, variable air volume or self contained heating/cooling unit). The type of air handling system selected for the reference building is dependent upon the building's function, and the type of air handling system contemplated in the proposed design. The reference air handling system will use calculated fan energy based upon good duct design practices and shall include free cooling where applicable. The circulation pumps for heating and cooling shall be sized based upon the proposed design's allowable temperature difference and the proposed design's pump head. The reference building will be constructed with a certain mass level and not incorporate any window shading devices. For a complete understanding of how the reference building is created and how the equipment is sized and operated, see "Performance Compliance for Buildings: Specifications for Calculation Procedures for Demonstrating Compliance to the Model National Energy Code for Buildings Using Whole Building Performance" (<http://nrc.ca/irc/catalogue/energy2.html>)

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

It is important that EE4 simulations for CBIP and MNECB buildings be performed accurately and consistently, so as not to undermine the credibility of the programs. Buildings and building systems are, however, extremely complex. Simulators can achieve different results on the same building because of

assumptions made about the performance of the various building components. This manual provides guidance on how to model buildings in accordance with MNECB and CBIP requirements, so as to minimize these differences.

The purpose of these simulations is NOT to accurately predict the expected energy use of the building. Rather it is to provide a uniform and consistent means of verifying compliance to MNECB and CBIP and comparing the energy efficiency of building designs. MNECB and CBIP simulations assume typical building use patterns and standards of construction (as identified in the “Performance Compliance for Buildings: Specifications for Calculation Procedures for Demonstrating Compliance to the MNECB Using Whole Building Performance”). Because use patterns and standards of construction vary from building to building, simulations based on these assumptions may or may not be indicative of the actual building energy consumption. Also EE4 was not intended to simulate all energy uses in a building (exterior lights, elevator usage, steam humidifiers, dehumidification, gas appliances, solid fuel heating, special process equipment, refrigeration), therefore energy usage as predicted by EE4 is limited only to the features modeled within the program and the inherent program assumptions. EE4 and DOE2 simulations submitted under the CBIP program are not intended to predict the actual energy usage of the design due to underlying assumptions in the software such as occupancy patterns, schedule of equipment operation, interior temperatures, etc. The simulations are intended to provide a comparison between the proposed design and the generated reference building using the assumptions of MNECB, CBIP and the EE4 software.

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 modeling simple and complex HVAC systems

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

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

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

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

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

BASE APPROACH

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

VARIATION 1

EE4 must be used first, in accordance to the base approach, to create the reference building. Adjustments of the EE4 outputs are allowed and must be all documented. Modifying EE4-generated building files is not acceptable as a standard procedure, however NRCan recognizes that this may be the most appropriate solution in some particular cases. The EE4 outputs can be either supplemented with engineering data or edited through changes to the DOE files. Instructions for performing modifications of EE4 outputs for which special CBIP rules have been developed are available from NRCan. If the proposed modifications do not have established CBIP rules then the proponent shall notify NRCan prior to application submission. The engineering data used to directly modify the EE4 results can be generated by manual calculations or software outputs such as RETScreen. Changes made to the DOE files generated by EE4 are allowed with the use of a DOE-2 software version authorized by NRCan.

VARIATION 2

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

1.2 Manual Organization

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

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

Chapter 1: Introduction

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

Chapter 2: Building Zoning Principles

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

Chapter 3: Building Function and Operation

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

Chapter 4: Central Plant Equipment

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

Chapter 5: HVAC Equipment

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

Chapter 6: Modeling of HVAC Systems

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

Chapter 7: Building Envelope Modeling

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

Chapter 8: Electrical System Modeling

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

Chapter 9: CBIP Submission Guidelines

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

Chapter 10: Troubleshooting

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

Part 2: EE4 Simulation Example

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

1.3 Overview of MNECB and CBIP

The MNECB and CBIP apply to almost all new commercial, multi-unit residential, institutional and light-industrial buildings (see MNECB Appendix E). The following building types are excluded:

- Residential buildings less than 600 square meters in floor area OR up to 3 storeys or less (e.g., detached, semi-detached and small townhouse complexes)
Basements (full or semi) will count as a storey if 75% of the total basement floor area is livable space (dwelling units). Total basement floor area includes all conditioned and unconditioned spaces such as garage, storage and laundry.
- Agricultural buildings whose primary function is not based upon human occupancy conditions (ventilation, space conditioning)

- Industrial buildings (excluded in CBIP, included in MNECB) Industrial buildings and buildings with high process loads are covered by the Industrial Building Incentive Program, IBIP, contact NRCAN for more information on this program.

Renovations of existing buildings are eligible for CBIP provided the renovations are major and meet all mandatory provisions of the MNECB. Major renovations involve either major changes to the building envelope or HVAC systems. Modifications to lighting and interior partitions typically done at a change in tenant are not considered a major renovation. For renovations, the reference MNECB building will contain a building envelope, lighting and HVAC systems that meet the new building requirements of the MNECB. Thus renovated buildings face the difficult task of being upgraded to current energy efficiency standards and then exceeding them by 25% to qualify for CBIP.

Additions to existing buildings are eligible under CBIP, however only the addition heated area is eligible for the CBIP incentive. The addition is treated as a separate building for compliance purposes. 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 MNECB mandatory requirements.

Certain building types that are included in the commercial, multi-unit residential, institutional and light-industrial buildings definition require specialized modeling beyond the scope of this manual. These will have to be discussed with CBIP program officers on an individual basis to initially determine eligibility in the program. These buildings include refrigerated warehouses, pool and arena complexes, supermarkets, process dominated light-industrial buildings. In some cases specialty software and modeling rules are being developed to accommodate these special commercial buildings. An on-line retail food store Wizard is available for use with CBIP compliance at <http://cbip.nrcan.gc.ca> A similar Wizard for arenas will be available in December 2002.

1.4 Energy Efficiency Measures

This section contains a list of common energy efficiency measures that can be implemented and modeled in EE4 for credit in reaching the CBIP target. Note that some of these parameters may also be penalties if the default reference

building system has a better performance (as described in the MNECB and Compliance Supplement). If viewing this manual on-line, click the item in the list to view more information on that particular measure (reader will be taken elsewhere in this manual). Information is subdivided into building operation, building envelope, and HVAC systems.

BUILDING OPERATION AND CONSTRUCTION

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

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

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

Demand Controlled Ventilation: Credit for schemes to reduce outside air ventilation by means of a device that senses the demand for ventilation in a building. (eg. CO₂ sensors and controls) 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). Credit is limited to a maximum 4 hour reduction in the fan schedule only within EE4 and only using the EE4 default schedule based upon building type or space use function. Details on how to apply the 4 hour fan schedule reduction is given in section 5.13.

BUILDING ENVELOPE

Wall/Roof R-values: Potential credit if better than reference building value or penalty if worse than reference building value. Reference building R-value is based on MNECB Appendix A.

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

Window U-values: Potential credit if better than reference building value or penalty if worse than reference building value. Reference building U-value is based on MNECB Appendix A.

Window to wall ratio: Penalty if the window to wall ratio is greater than 40% in each space. If the proposed window to wall ratio (WWR) is less than 40%, both buildings have the same WWR. If the proposed building WWR is greater than 40%, the reference building's window area for the specific space is fixed at 40% and the resultant increased reference wall area will be insulated to MNECB R-values.

Window solar heat gain coefficient: Simulator has the option of choosing to give proposed building and reference building the same (entered) SHGC, or fixing the reference at a value of 0.65.

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

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

Infiltration/Air Tightness: No credit for improved air tightness of walls or windows. For modeling purposes, the infiltration rate in both proposed and reference buildings is fixed at 0.25 L/s per m² of gross above grade envelope area.

Overhangs and Sidesfins: Credit (or penalty) for overhangs and sidesfins on windows. The reference building windows do not have any overhangs or sidesfins.

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

HVAC SYSTEMS

HVAC System Type: Potential credit or penalty for certain HVAC system types. Reference building systems are usually constant volume single-zone systems if the proposed building uses single-zone systems, and 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 type units will be equipped with a packaged terminal air conditioning unit, known as an accommodation unit. See the MNECB Compliance Supplement for details. The following are the reference fan characteristics which may could be a credit or penalty in comparison with the proposed fan/duct design.

<u>System Type</u>	<u>Cooling Type</u>	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%	-	-

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

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

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

Boilers, heaters and burners will have reference thermal efficiency of 80%.

The following are the reference pump characteristics which may result in a credit or penalty compared to the proposed design

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

Equipment Sizing: Penalty if boilers or chillers are greater than 30% oversized based on EE4 load calculations. Heating equipment cannot be undersized.

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

Ventilation Air Heat Recovery: Credit for sensible heat recovery systems, including plate heat exchangers, energy wheels, heat pipes and glycol/hot water run-around heat recovery loops.

Economizers: Potential penalty if the proposed building does not have “free cooling” economizers on air handling equipment. Reference building always has enthalpy economizers.

Outdoor Air Boiler Reset: Credit for reset of supply water temperature based on outdoor air temperature. Two options are available for outdoor air temperature reset:

1. increase boiler thermal efficiency by 1.5% for locations of less than 5000 heating degree days and 2% for locations of greater than 5000 heating degree days

OR

2. break up the boiler capacity into up to 10 smaller boilers and sequence them at a 90% sequencing ratio, but leave the entered thermal efficiency unchanged from manufacturers data.

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

Modulating/Multi-stage Burners: Credit for multi-stage firing of boilers only (no credit for multi-stage firing of direct-fired air handling equipment or unit heaters). The credit involves the break-up of the boiler capacity into up to 10 smaller boilers and sequence them at a 90% sequencing ratio, but leave the entered thermal efficiency unchanged from manufacturers data.

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

Variable Speed Drives: Credit for variable speed drives on pumps, supply fans (VAV systems only) and cooling tower fans as reference systems have constant speed pumps and fans. No credit is available for 2-speed pumps/fans. 2-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 and must be at least equal to the ASHRAE 62 standard.

Garage Demand Ventilation: CO/CO₂ ventilation control of a heated or unheated parking garage (interlocked supply and exhaust) is not an eligible CBIP credit, as CO/CO₂ 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 for total connected lighting power density that is lower than MNECB levels.

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

Vertical Transportation: Elevators/escalators are not considered in CBIP and not eligible for credit.

Appliances: No credit for energy-efficient appliances or receptacles. Appliances can be modeled in EE4 (receptacle and process loads), but are identical in proposed and reference buildings and assume that they are electrical

An on-line retail food store Wizard is available for use with CBIP compliance at <http://cbip.nrcan.gc.ca> A similar Wizard for arenas will be available in December 2002.

MISCELLANEOUS

Cogeneration Systems: No credit is available for cogeneration systems (use of electric generator waste heat for building heating or cooling needs). If the building is served by waste heat from a central cogeneration plant (i.e. at a university or hospital), the heating plant should be modeled as district heating and select the “purchased heating” option for your central heating plant.

Process Heat Recovery: In CBIP, no credit is available from the use of heat generated from an industrial, manufacturing, service or electrical generation process to directly heat ventilation air, service water heating, and hydronic loop heating. Currently laboratory fume hood heat recovery for any purpose is a non-CBIP eligible item. Savings in process energy use, such as the preceding items, are covered by IBIP. Contact the IBIP NRCan manager for more details. The process energy can be included in the calculation of the building loads (will be added to both the proposed and the reference case) and in the approximation of the utility costs, but the proposed design's annual energy usage cannot be reduced by using process waste heat. If the design incorporates waste heat as its principal heating source, then select the "purchased heating" option for your central heating plant.

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

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

Domestic Hot Water Heat Recovery: Credit available for drainwater heat recovery systems. These are treated on an individual basis.

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

There are some energy-saving technologies that are not considered in the MNECB and as such are not currently modeled in EE4. These technologies may be recognized by CBIP. These items require special treatment outside of EE4 using DOE 2.1 software or other software to predict energy savings. Building simulators should review Chapters 5 and 6 in this manual and contact the CBIP

Technical Manager for the approved techniques to handle technologies not considered in this manual which you feel may warrant a credit.

2. BUILDING ZONING PRINCIPLES

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

2.1 Dividing Buildings into Zones

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

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

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

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

The following sections discuss each of these criteria.

Same HVAC System

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

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

On the other hand, a high-rise apartment building may have one central make-up air unit providing ventilation air to the corridors, and individual heat pumps distributed throughout the building heat and cool individual apartments. In this case, there is only 1 system. To subdivide the building further, it is necessary to look at the secondary zoning criteria (similar loads and/or operation).

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

Multi-zone systems (multi-zone, dual-duct, VAV) will normally serve several zones and should be modeled as such. As a guide to zoning for these systems, use a zone for each set of areas controlled by a single thermostat. This may result in a large number of zones, which significantly increases the level of effort to model a building. In many cases zones can be grouped together without loss

of accuracy. For example, rooms that are similar but have individual thermostats to handle random occupancy patterns can be grouped together. Consider a multi-zone system serving a group of meeting rooms. The meeting rooms will be used sporadically and the HVAC must be able to take that into account. But from a modeling point of view, all the rooms are the same and can be grouped into a single zone. Another example is hotel/motel rooms. Each room has its own thermostat to handle variations in room use, but each room is just as likely to be full or empty. In this case, all rooms can be treated as one zone (provided they have the same heating and cooling loads under normal operation – see next section). Other rules for grouping zones are discussed later.

Similar Operation and Function

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

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

Similar Heating/Cooling Loads

The third step is to divide building areas into rooms or groups of rooms that have similar heating and cooling loads. Applying this criteria means that exterior rooms facing in each direction should be modeled as separate zones (different solar gains). Interior floor areas are modeled separately from perimeter areas. High-internal-heat-gain computer rooms are modeled separately from general office areas. To a large extent, this is the same as dividing the building into areas served by the same HVAC system and thermostat. It is likely that the building

designer took variations in heating and cooling loads into consideration when laying out the HVAC systems.

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

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

- Position of full-height walls separating perimeter areas from interior areas
- Area of influence of perimeter HVAC systems. Separate HVAC systems are often used for perimeter areas and interior areas. The area conditioned by the perimeter HVAC system defines the perimeter zone.
- Five meters from exterior walls

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. See example of multiple meeting rooms and hotel/motel rooms described in “Same HVAC System and Thermostat”.
- Same area on different floors. In many office buildings and apartments, the same floor plan is repeated on each storey. The same areas on each floor can be grouped into a zone. Top and bottom floors are modeled separately because of the extra heat transfer out of the roof and floor. In Figure 2-1, the second and third storeys can be grouped together.

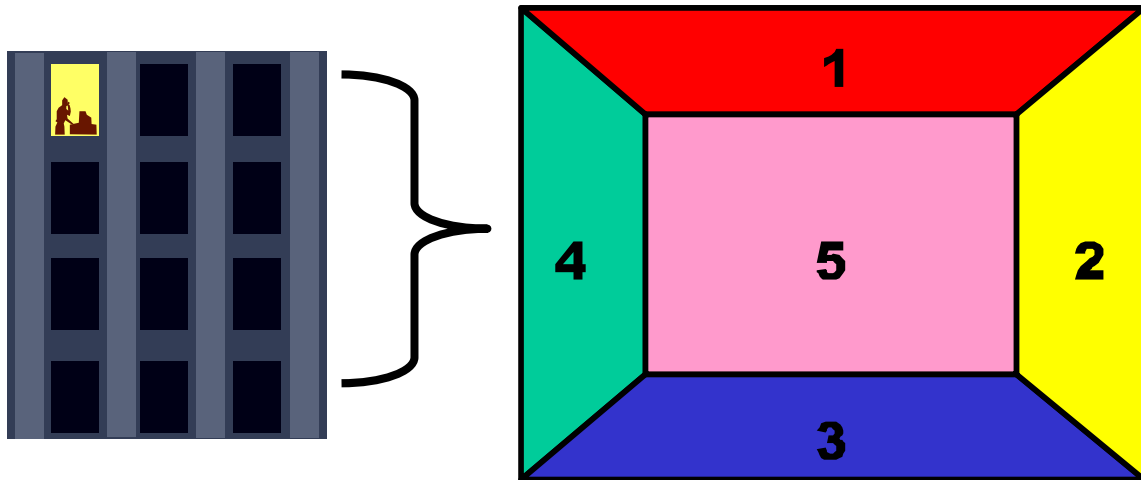


Figure 2-1 – Typical Zoning for Offices and Apartments

- 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.
- Washrooms, corridors and mechanical/electrical rooms, stairways, and locker rooms. These room types cannot be defined as a stand-alone zone; they must be included with areas that have similar operating schedules. For example, corridors and washrooms will likely be used the same hours as the office areas they serve and therefore should be included with the office zone.

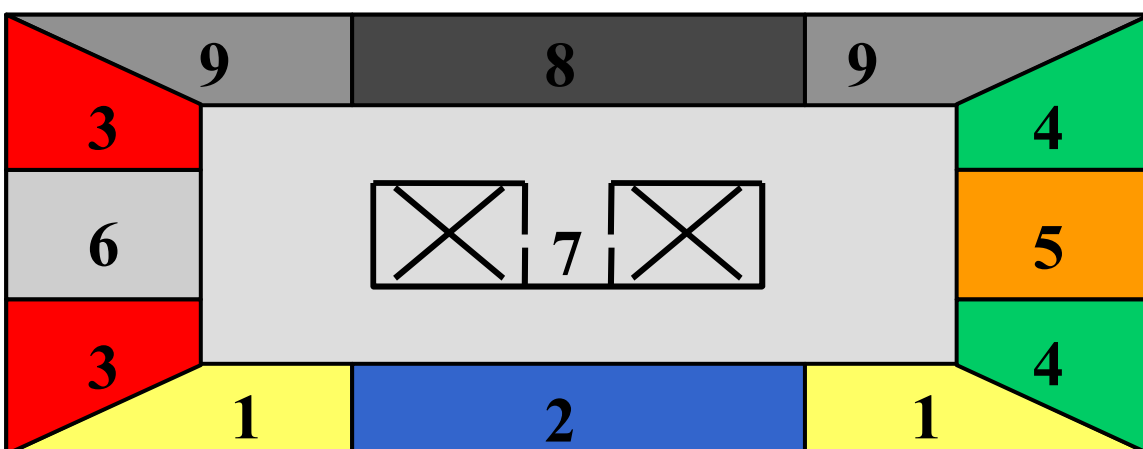
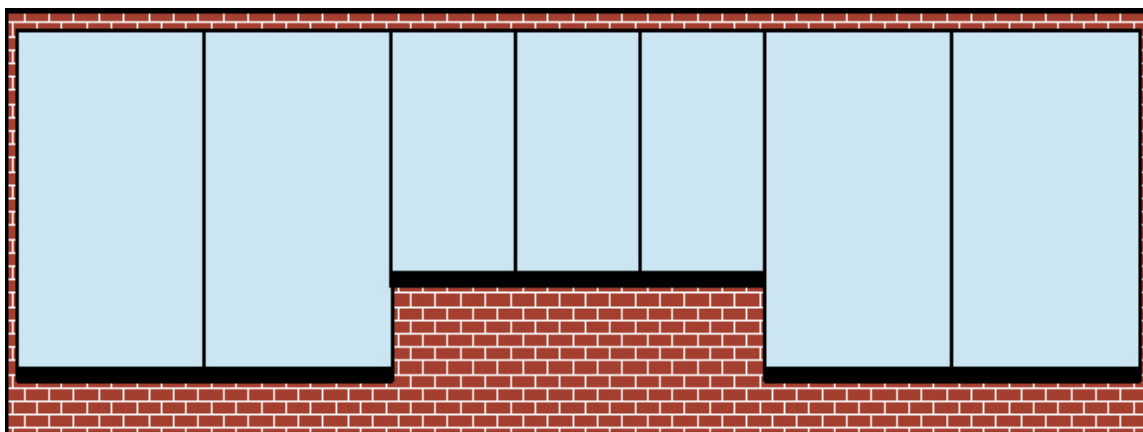


Figure 2-2 – Grouping Zones According to Heating and Cooling Loads

2.2 Dividing Zones into Spaces

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

Defining spaces is a simple way of specifying variations within a zone. For example, a zone in an office building may contain drafting areas, a photocopy room and general office areas. The function in each of these spaces is different, that is, they each have their own lighting, ventilation and occupancy

requirements. These areas can be modeled as individual spaces assuming they are served by the same HVAC system and would all be either heated or cooled as a group according to the same schedule. In EE4, corridors, mechanical rooms, washrooms, stairwells and locker rooms do not have a valid operating schedule, i.e. the schedule in Table 4.3.2.B is marked with a *. These rooms must be combined with an adjacent space that has a valid operating schedule.

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

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 3.4.

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

Dummy Zones

Because a vestibule space is a service type space and does not have a valid schedule (the schedule in Table 4.3.2.B is marked with a *), this zone must contain a space that has a valid operating schedule. In this case the simulator would create a small space of 0.5 m² area of a valid space representing the building with a single light and then define the vestibule space as a service space. The schedule and temperatures in the vestibule will follow the 0.5 m² space unless custom schedules are created. This is referred to as a dummy zone to allow the service space to be simulated as a separate zone. This is only accepted if there is a clear need to adopt this method such as a corridor having its own heating, separate air handling system or the space function method already contains four defined spaces. An alternative method of entering a vestibule with its own system is to model using “building type” rather than “space function” as the input designation type.

Parking Garages and Crawl Spaces

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

Heating a garage or a crawl space with exhaust air is not considered a heating source and in this case the crawl space or the garage should be modeled as an exposed floor.

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

2.4 Zoning Example

A zoning strategy for a “big-box” retail store is appears in Figure 2-3 below.

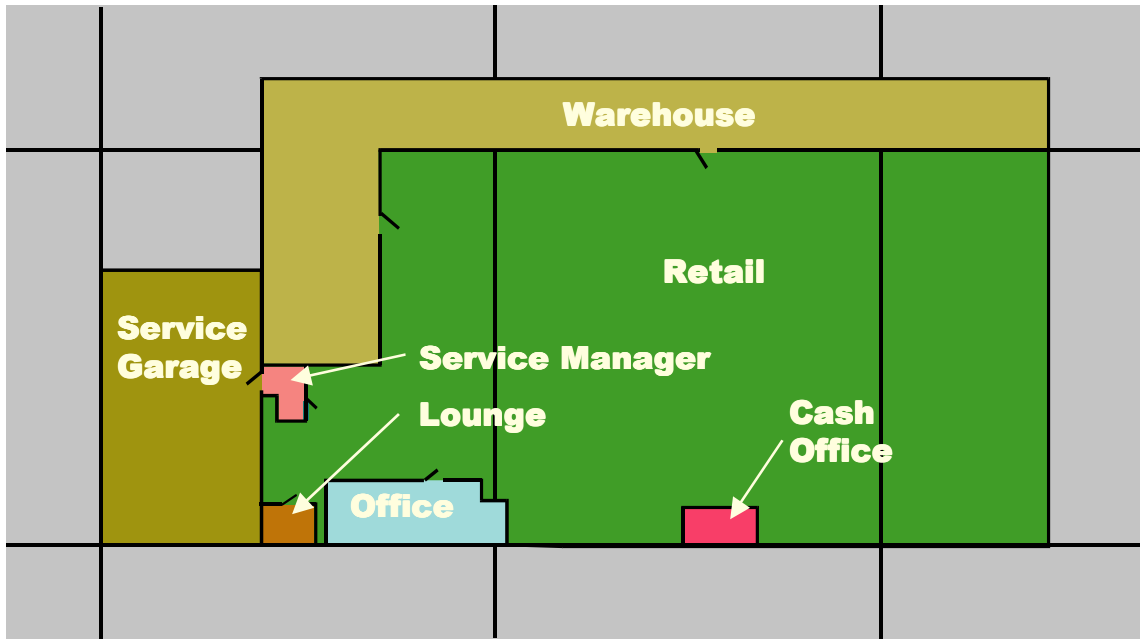


Figure 2-3 – Zoning Strategy for Big-Box Retailer

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

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

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

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

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

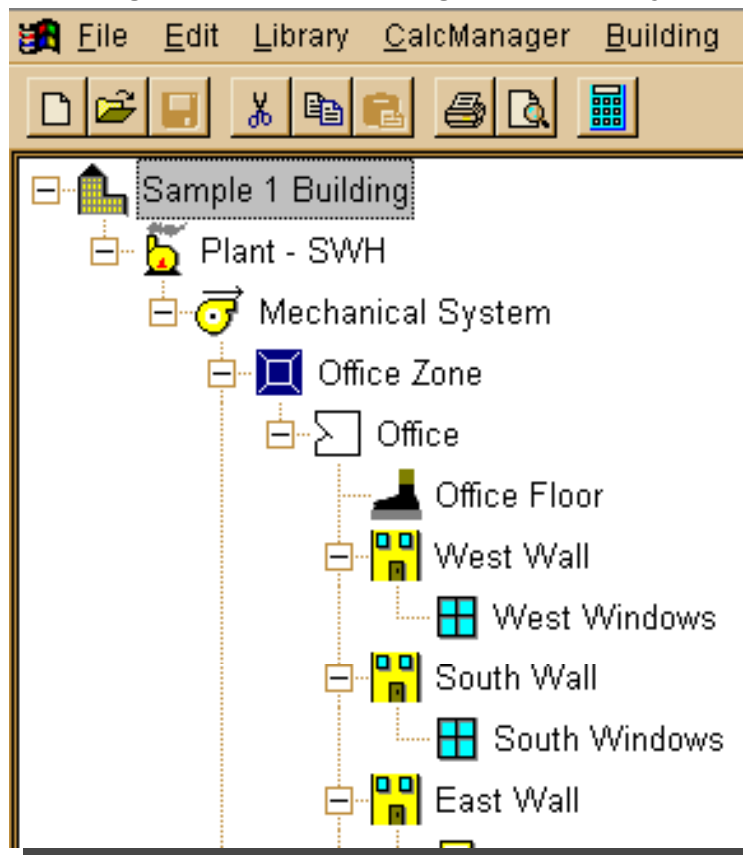
3. BUILDING FUNCTION AND OPERATION

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

3.1 Overview of EE4

The EE4 program uses a “Building Tree” graphical interface (See Figure 1.1). The Building Tree is presented in a hierarchical manner, using icons to represent the various elements of the building. A building element cannot be defined until its predecessor in the tree hierarchy is defined. The Building Tree elements and their important input parameters are listed below in the order of entry.

Figure 3-1 – EE4 Building Tree Hierarchy



Building:

- Project and designer name and general information
- Location selection
- Utility rate information
- Selection of “Building Type” or “Space Function”

Plant:

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

System:

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

Zone:

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

Space:

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

Envelope Components:

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

Windows, Doors, and Skylights:

- Entered as elements within walls and roofs

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

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

3.2 Building Type vs. Space Function

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

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

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

type approach a single set of operating parameters is defined for the entire building area .

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

- Speculative commercial buildings where the tenant leaseholds are not known
- Single-purpose buildings that are clearly typical of one of the nine building type categories (e.g., fast-food restaurant)

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

The principle advantage of the building type approach is that it reduces the level of effort in describing the building in the EE4 software. Provided that the building is typical of one of the nine building types, the building type approach should provide results similar to the space function approach (see example given below). The building type also allows the modeling of service functions (corridors, vestibules, washrooms, mechanical rooms) as separate zones because of the definition of the building type. The average lighting, ventilation rate, occupancy includes the effects service functions. If the selection of building type contains a very high proportion of a non-representative space function (eg. Office space with a very large atria), then space function selection should be used.

Not all space functions are represented in EE4, although the list is extensive. If the space function is not explicit then select the closest type using occupant density and minimum outdoor air requirements as the governing factor and change the schedules to match the specific space function. For example, if the space function is a car wash space, with a high process water load, few occupants, open 24-hours per day and minimal lighting; selecting the a “Non-Industrial Shop “ space function will require considerably more outdoor air for ventilation purposes than likely designed (2.5 L/sec/m²). 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/m² to 0.4 L/sec/m²) and the simulator can alter the process loads, hours of operation, temperatures and electrical loads in the zone schedule to match the car wash design conditions. These schedules will also be transferred to the reference design, whereas the

EE4 calculation will not proceed unless the minimum outdoor air requirements of the space function selected are met.

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

3.3 Energy Savings Versus Cost Savings

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

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

3.4 Utility Rates

The utility rate structures are entered in the Building Element, Energy Cost tab. Most rate structures used in Canada can be entered. The natural gas price structure should include the cost of gas, transportation to the utility, and delivery

to the customer. These are often listed as separate items on the utility bill, but need to be totaled for entry into EE4. The electricity structure should include both consumption and demand charges. All rates should include any provincial taxes but should NOT include GST. For provinces with harmonized provincial/federal sales taxes, contact NRCan to determine the taxes that should 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) are entered. Electric utilities use two approaches to define the block sizes (or limits), either a fixed block size of kWh and kW or a variable kWh block size depending on the peak monthly kW consumed. The later rate structure is entered in the Tab labeled “Energy/Demand Rate (kWh/kW)”.

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

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.

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

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

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

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

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

If your natural gas rate varies seasonally (summer charge from May 1 to September 30 and winter charge from October 1 to April 30) then you must enter periods instead of just the summer and winter period. The first period would be the winter period from January 1 to April 30, the second period from May 1 to September 30 and the third period from October 1 to December 31.

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

Time of Use Rates: Data Entry

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

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

Electrical Example:

Winter (dec 1 – mar 31)	Time of use rate:	7 am to 10 am: \$0.12 /kWh
	Time of use rate:	10 am to 5 pm: \$0.08 /kWh
	Time of use rate:	5 pm to 8:30 pm: \$0.12 /kWh
	Time of use rate:	8:30 pm to 7 am: \$0.04 /kWh
	Weekends/holiday all day:	\$0.06 /kWh
Spring (apr 1 – june15)	Time of use rate:	7 am to 8:30 pm: \$0.08 /kWh

Time of use rate: 8:30 pm to 7 am: \$0.04 /kWh

Summer (june 16 – sep 15) Time of use rate: 7 am to 8:30 pm: \$0.16 /kWh

Time of use rate: 8:30 pm to 7 am: \$0.06 /kWh

Weekends/holidays all day:
\$0.08 /kWh

Autumn (sep 16 – nov 30) Time of use rate: 7 am to 8:30 pm:
\$0.08/kWh

Time of use rate: 8:30 pm to 7 am: \$0.04 /kWh

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

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

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

Season 1: Jan 1 – June 15

Season 2: June 16 – Sep 15

Season 3: Sep 16 – Dec 31

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

Season 1: Jan 1 – Mar 31

Season 2: Apr 1 – Nov 30

Season 3: Dec 1 – Dec 31

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

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

Season 1: Jan 1 to June 15

Season 2: June 16 to Sep 15

Season 3: Sep 15 to Dec 31

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

Period 1: 1 am to 7 am

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

Period 3: 8:30 pm to 24 :

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

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

Jan weekdays: 23 days 23 days * 0.04 /kWh = 0.92

Jan weekends: 8 days 8 days * 0.06 /kWh = 0.48

Feb weekdays: 21 days 21 days * 0.04 /kWh = 0.84

Feb weekends: 8 days 8 days * 0.06 / kWh = 0.48

Mar weekdays: 21 days 21 days * 0.04 /kWh = 0.84

Mar weekends: 10 days 10 days * 0.06 /kWh = 0.6

Ave price 1 am - 7 am =

$(0.92 + 0.48 + 0.84 + 0.48 + 0.84 + 0.6) / (23 + 8 + 21 + 8 + 21 + 10)$

= 0.0457 cents/kWh

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

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

1. Determine a winter average daily rate from 7 am to 8:30 pm

Ave = $(3 \text{ hrs} * 0.12 + 7 \text{ hrs} * 0.08 + 4 \text{ hrs} * 0.12) / (3 \text{ hrs} + 7 \text{ hrs} + 4 \text{ hrs})$

= \$0.10 /kWh

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

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

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

Jan weekdays: 23 days $23 \text{ days} * 0.1 \text{ /kWh} = 2.3$

Jan weekends: 8 days $8 \text{ days} * 0.06 \text{ /kWh} = 0.48$

Feb weekdays: 21 days $21 \text{ days} * 0.1 \text{ /kWh} = 2.1$

Feb weekends: 8 days $8 \text{ days} * 0.06 \text{ / kWh} = 0.48$

Mar weekdays: 21 days $21 \text{ days} * 0.1 \text{ /kWh} = 2.1$

Mar weekends: 10 days $10 \text{ days} * 0.06 \text{ /kWh} = 0.6$

Ave price 7 am to 9 pm =

$2.3 + 0.48 + 2.1 + 0.48 + 2.1 + 0.6) / (23 + 8 + 21 + 8 + 21 + 10)$

= 0.08637 cents/kWh

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

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

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

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

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

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

The rates are: weekdays: 7 am to 8:30 pm: \$ 0.16 /kWh

8:30 pm to 7 am: \$ 0.06 /kWh

weekends: all day: \$0.08 /kWh

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

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

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

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

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

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

July: weekdays:	23	$23 * 0.06 = 1.38$
-----------------	----	--------------------

July weekend days:	8	$8 * 0.08 = 0.64$
--------------------	---	-------------------

August weekdays:	22	$22 * 0.06 = 1.32$
------------------	----	--------------------

August weekend days:	9	$9 * 0.08 = 0.72$
----------------------	---	-------------------

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

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

Ave rate =

$$(0.6 + 0.4 + 1.38 + 0.64 + 1.32 + 0.72 + 0.6 + 0.4) / (10 + 5 + 23 + 8 + 22 + 9 + 10 + 5)$$

= 0.0659 /kWh (rate for 1 am to 7 am)

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

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

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

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

July: weekdays: 23 $23 * 0.16 = 3.68$

July weekend days: 8 $8 * 0.08 = 0.64$

August weekdays: 22 $22 * 0.16 = 3.52$

August weekend days: 9 $9 * 0.08 = 0.72$

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

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

Ave rate =

$(1.6 + 0.4 + 3.68 + 0.64 + 3.52 + 0.72 + 1.6 + 0.4) / (10+5+23+8+22+9+10+5)$

= 0.1365 /kWh (rate for 7 am to 9 pm)

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

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

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

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

July: weekdays: 23 $23 * 0.06 = 1.38$

July weekend days: 8 $8 * 0.08 = 0.64$

August weekdays: 22 $22 * 0.06 = 1.32$

August weekend days: 9 $9 * 0.08 = 0.72$

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

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

Ave rate =

$(0.6 + 0.4 + 1.38 + 0.64 + 1.32 + 0.72 + 0.6 + 0.4) / (10+5+23+8+22+9+10+5)$

= 0.0659 /kWh (rate for 9 pm to midnight)

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

The rates are:

Sept 16 – Nov 30: weekdays and weekends: 7 am to 8:30 pm: \$ 0.08 /kWh

Sept 16 – Nov 30: weekdays and weekends: 8:30 pm to 7 am: \$ 0.04 /kWh

Dec 1 - Dec 31: weekdays 7 am to 8:30 pm: \$0.1 /kWh ave)

Dec 1 – Dec 31: weekdays 8:30 pm to 7 am: \$ 0.04 /kWh

Dec 1 – Dec 31: weekends: 7 am to 8:30 pm: \$ 0.06 / kWh

Dec 1 – Dec 31: weekends: 8:30 pm to 7 am: \$0.06 /kWh

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

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

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

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

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

October : days: 31 $31 * 0.04 = 1.24$

November: days: 30 $30 * 0.04 = 1.2$

December weekdays: 22 $22 * 0.04 = 0.88$

December weekend days: 9 $9 * 0.06 = 0.54$

Ave = $(0.64 + 1.24 + 1.2 + 0.88 + 0.54) / (16+31+30+8+22+9)$

= 0.0412 /kWh (rate for 1 am to 7 am)

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

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

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

October : days: 31 $31 * 0.08 = 2.48$

November: days: 30 $30 * 0.08 = 2.4$

December weekdays: 22 $22 * 0.1 = 2.2$

December weekend days: 9 $9 * 0.06 = 0.54$

Ave = $(1.28 + 2.48 + 2.4 + 2.2 + 0.54) / (16+31+30+8+22+9)$

= 0.0824 /kWh (rate for 7 am to 9 pm)

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

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

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

October : days: 31 $31 * 0.04 = 1.24$

November: days: 30 $30 * 0.04 = 1.2$

December weekdays: 22 $22 * 0.04 = 0.88$

December weekend days: 9 $9 * 0.06 = 0.54$

Ave = $(0.64 + 1.24 + 1.2 + 0.88 + 0.54) / (16+31+30+8+22+9)$

= 0.0412 /kWh (rate for 9 pm to midnight)

EE4 Input for Time of Use Rates:

Season 1: Ending Month: 06 Ending Day: 15

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

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

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

Season 2: Ending Month: 09 Ending Day: 15

Period 1: Ending Hour: 7, Blocks: 1 Rate: \$0.0659 /kWh

Period 2: Ending Hour: 21, Blocks 1: Rate: \$0.1365 /kWh

Period 3: Ending Hour: 24, Blocks 1: rate: \$0.0659 /kWh

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

Renewable Pricing

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

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

Solution:

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

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

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

This will represent the pricing for the reference case electricity. The simulator would use another analysis (Retscreen for example) to determine the contribution of micro-hydro and diesel for the proposed case electrical cost. The

proposed case wood cost would be the cost of propane or oil, but converted to the energy equivalent for wood heating (MJ per cord or cubic foot or wood purchase units).

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

Deregulated Pricing

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

3.5 Determination of Principal Heating Source

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

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

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

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

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

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

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

Province or Territory	Region	Energy Source					
		Electricity	Propane	Oil	Natural Gas	Heat Pump, Electric	Other
Newfoundland	A	1	0.70	0.22	—	0.33	1
	B	1	0.70	0.17	—	0.33	1
	C	1	0.70	0.57	—	0.33	1
	D	1	0.70	0.79	—	0.33	1
P.E.I.	A	1	0.49	0.30	—	0.33	1
Nova Scotia	A	1	0.45	0.23	—	0.33	1
New Brunswick	A	1	0.87	0.34	—	0.33	1
Quebec	A	1	0.54	0.54	0.53	0.33	1
	B	1	0.54	0.54	0.53	0.33	1
	C	1	0.54	0.54	—	0.33	1
Ontario	A	1	0.28	0.28	0.20	0.33	1
	B	1	0.28	0.28	0.20	0.33	1
Manitoba	A	1	0.48	0.48	0.31	0.33	1

Province or Territory	Region	Energy Source					
		Electricity	Propane	Oil	Natural Gas	Heat Pump, Electric	Other
Saskatchewan	B	1	0.48	0.48	0.31	0.33	1
	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
Yukon	E	1	0.58	0.58	0.41	0.33	1
	A	1	0.26	0.29	—	0.33	1
	B	1	0.17	0.17	—	0.33	1

Province or Territory	Region	Energy Source					
		Electricity	Propane	Oil	Natural Gas	Heat Pump, Electric	Other
Northwest Territories	C	1	—	0.18	—	0.33	1
	A	1	0.19	0.19	—	0.33	1
	B	1	0.27	0.24	—	0.33	1
	C	1	0.17	0.17	0.05	0.33	1
	D	1	0.11	0.11	—	0.33	1
	E	1	0.10	0.10	—	0.33	1
	F	1	0.10	0.10	—	0.33	1
	G	1	0.09	0.09	—	0.33	1
	H	1	0.10	0.10	—	0.33	1

If the principal heating source is biomass, renewables, diesel or coal, contact NRCan for assistance.

3.6 Building Schedules and Equipment Operation

When the building type or space function is selected for each zone or space, default or standard values of building operation are assigned. The same values are assigned to both the proposed building and the reference building. The

operating parameters include occupant density, process loads, receptacle loads, ventilation rates, heating and cooling thermostat setpoints, and hourly schedules for occupancy, lighting, receptacles, process loads and HVAC operation. The default schedules are listed in the MNECB Help System and the fan operation is summarized in Table 3.2. The fan operation is also indicative of the hours of occupancy, cooling system operation and temperature setup.

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

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

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

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

Changing Schedules in EE4

In EE4, building operation schedules are changed in the Zone element, “Schedules” tab. There are 8 schedules that can be changed: lighting,

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

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

Process Loads

Very high process loads (high density equipment rooms, refrigeration equipment, etc) have a high impact on heating and cooling loads and should be modeled in EE4. However, in determining whether the building meets the 25% energy reduction target, exclude the process energy directly consumed by these loads. This must be done by performing a hand calculation and using the following procedure:

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

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

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

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).

Grocery stores and ice arenas have very high process loads that contribute a substantial portion of the total building energy use. . An on-line retail food store Wizard is available for use with CBIP compliance at <http://cbip.nrcan.gc.ca> A similar Wizard for arenas will be available in December 2002.

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

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 CBIP this requirement has been relaxed and there are potential energy savings from using low-flow showerheads and faucets.

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

- Select the SWH tab in the Room Element
- Enter the anticipated hot water load in Watts per person, or enter zero for “Total SWH Load” to accept the MNECB default water consumption.
- Enter the percentages of the peak water consumption for that space attributable to shower heads and faucets
- Enter the maximum flow rate for the showerheads and faucets in L/s. The maximum flow rates permitted by the MNECB for showerheads and faucets are 9.5 and 8.3 L/min respectively. (Warning: fixtures are often rated in L/min; be sure to divide these values by 60 for EE4 input.

Potential energy savings are also obtained from a **wastewater heat recovery system**. Since these systems recovery some of the heat that would normally go down the drain, the load on the hot water plant is reduced. Wastewater heat recovery systems are then modeled as low-flow showerheads or faucets as described above. NRCan allows an effective flow reduction of 27.5%; this is modeled by entering maximum flow rates for showerheads and faucets as 6.9 L/min and 6.0 L/min respectively.

3.7 Weather File Selection

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

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

The weather file selection should be based upon the closest representative weather file for the administrative region or province.

4. CENTRAL PLANT EQUIPMENT

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

4.1 Service Water Heaters

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

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

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

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

In some cases, service hot water needs are met by small electric storage or instantaneous heaters that serve only a small load in one area of the building. These water heaters need not be considered in the model.

EE4 assumes an inlet water temperature of 21 C and a supply temperature of 60 C throughout the year.

Multiple Water Heating Systems

EE4 only allows one water heating system per plant, therefore you must sum the capacities of a number of tanks, derive an average efficiency and input rate.

Example:

Tank 1: capacity = 100 litres, input rate = 15 kW, efficiency = 85%

Tank 2: capacity = 250 litres, input rate = 17.5 kW, efficiency = 80%

Tank 3: capacity = 0 litres (space heating boiler coil), input rate = 5 kW, efficiency = 88% (boiler efficiency)

Entered EE4 capacity = $100 + 250 + 0 = 350$ litres

Entered EE4 input rate = $15 + 17.5 + 5 = 37.5$ kW

Entered EE4 efficiency = $(15 * 0.85 + 17.5 * 0.8 + 5 * 0.88) / 37.5 = 0.8307$

If the water heating is provided by different fuels (electricity and natural gas), select the fuel with the higher output capacity or the circuit that is considered the main hot water circuit and assume that the entire hot water needs are met by that fuel.

Example School with Natural gas kitchen/cafeteria hot water, electric washroom/change room hot water:

Tank 1: electric, capacity = 500 litres, input = 28 kW

Tank 2: natural gas, capacity = 500 litres, input = 35 kW, efficiency = 0.8

These are virtually identical as the output of the natural gas tank is also 28 kW. While both water usages are discretionary, the natural gas usage in the kitchen and cafeteria is likely required whereas hot showers in schools are minimal. Therefore, natural gas would be considered the hot water source fuel and the capacity would be set to 1000 litres and the input rate set to 70 kW ($35 + 28/0.8$) and the efficiency set to 0.8. In this case we are assuming that the entire hot water is being met by a natural gas -fired tank system. Please remember that the resulting energy usage and costs will not be representative of the actual design, but allows a valid EE4 comparison between the proposed design and a corresponding reference design.

Indirect Water Heating

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

Seasonal Boilers

If the design includes seasonal boilers, such as a school with a dedicated natural gas boiler for the school year and a small electric tank boiler for the summer months (cleaning crew use) enter the natural gas school year boiler as the representative boiler for the entire year.

Renewable Water Heating

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

capacity = capacity of the renewable system plus the backup

input rate = input rate of the renewable system plus the back up

efficiency = efficiency of backup, or 100% if no backup and electric would have been the fuel without renewables, or 80% if no backup and fossil fuel would have been the fuel without renewables

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

Process Water Heating

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

Run #1 (With Process Water)

1. Convert the process to a W/occ value and add to occupant value to determine a total water heating for the building. Add the process in the zones and spaces where the process occurs.
2. Add process volume to service DHW volume
3. Add process heating input rate to service DHW input rate
4. Calculate a volume or capacity rate efficiency as the total efficiency:

$$\text{Eff} = (200 \text{ kW} * 0.75 + 50 \text{ kW} * 0.84) / (200 + 50) = 0.768$$

Where: 200 kW = capacity of process boiler, 75% = thermal eff of process boiler

50 kW = capacity of Service DHW, 84% = thermal eff of service DHW

5. Run the calculations (with process)
6. Create a duplicate EE4 file and remove the process inputs leaving the service DHW
7. Run the calculations (without process)
8. Subtract the MJ and energy costs to determine the process water heating contribution

4.2 Boilers

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

Multiple Boilers

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

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

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

At present, EE4 cannot model lead/lag or peaking boilers of different operating efficiency. If this is the case, determine the capacity-weighted average efficiency.

Example: 3 boilers:

boiler 1: output capacity = 450 kW, efficiency = 88% (lead boiler)

boiler 2: output capacity = 150 kW, efficiency = 72% (peaking boiler)

boiler 3: output capacity = 150 kW, efficiency = 75% (separate addition to the building)

Solution:

boiler 3 would be entered as a separate plant with a single boiler and a separate system, zones, spaces etc as if it was a stand-alone building

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

The benefits of the lead and peaking boiler are averaged into 2 boilers for simulation compliance only Modulating/Multi-Stage Boilers

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

Infinitely modulating boilers should be modeled as 10 individual boilers, each with a capacity of $1/10^{\text{th}}$ of the actual full boiler output.

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, enter the weighted seasonal efficiency by estimating the proportion of the heating season the boiler will operate at high temperatures (130°F +) versus low temperatures. Assume the boiler operates at maximum rated efficiency during low return water temperature periods, and the boiler operates at maximum non-condensing efficiency (88%) during higher temperature periods. If this information is not known, use the efficiency value halfway between 88% and the rated efficiency.

Outdoor Air Reset

Resetting the loop temperature based upon outdoor air is similar to right-sizing your boiler. Resetting credits are not available for modulating boilers, since the reset is accounted for in the modulating technology and the resulting load/part load boiler performance curves.

There are 2 methods of applying the reset in EE4: simple efficiency improvement or a boiler sequencing method (both are equal).

The simple efficiency improvement is a 1.5% efficiency credit (added to the AFUE value) if the boiler is located in a region with less than 5000 HDD and a 2% efficiency credit if the boiler is located in a region with greater than 5000 HDD.

In the sequencing method, the single boiler is divided into 10 equally sized boilers with a total capacity equal to the single boiler. The boiler multiplier (10) and sequencing capacity (usually 90% of the size of the smaller boilers) are entered in EE4. The circulating pumps are entered as variable speed to mimic the reduced pump energy of a modulating boiler. (see Section 4.7 on pumps)

Either of the 2 methods is acceptable, however they cannot be combined.

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: as is file without any flue gas heat recovery component

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

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

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

Boiler Loop Water Heating: Flue Gas Heat Recovery

Increase the design temperature drop by a percentage rated:

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

Example: if the flue gas temperature was 93.3 C and the flow rate via

a recovery coil was 10 Litres/minute and the water loop was maintaining

60 C water and the flow rate was 200 Litres/minute the design

temperature drop increase would be:

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

temperature drop. Therefore the temperature drop would be increased by 7.78%.

4.3 Chillers

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

Electric Chillers

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

Table 4-1 – Rating Conditions for Chillers

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

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

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

Gas-Fired/Absorption Chillers

Typical gas-fired and steam absorption chillers have COPs of under 1.0, well below the MNECB requirement for electric chillers of 2.7. When showing compliance to the MNECB, the cooling energy consumption is multiplied by the ESAF of the fuel powering the absorption chiller. The low ESAF for fuels generally more than makes up the differences in COP, and absorption chillers can be an energy-efficiency measure. In the CBIP program, ESAFs are not used and a special procedure must be used to evaluate gas-fired chillers. Two simulations must be performed. First, select gas-fired absorption chiller but enter

the COP of the reference building electric chiller (not the COP of the gas-fired chiller). This simulation is done to see if the 25% energy target has been met. Second, if the energy target has been met, enter the actual COP of the gas-fired chiller (typically less than 1.0) to determine the annual cost savings for incentive calculation purposes.

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

Modulating Chillers

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

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

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

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

Double-Bundled Chillers and Chiller Heat Recovery

Contact NRCan for a specific method to model these types of chillers.

4.4 Cooling Towers

If a water-cooled chiller is defined in the “Central Cooling” tab, or if the building uses a cooling tower to reject heat from a central heat pump loop, a cooling

tower must be defined. In EE4, no distinction is made between open cooling towers and closed-circuit fluid coolers.

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

4.5 District Heating and Cooling

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

Central Cooling

For these cases, check the “Purchased Cooling” box on the Plant Element/Central Cooling Tab. The program assumes that the purchased cooling was produced at the same COP as used in the reference building. If purchased cooling comes from lake or seawater, define a chiller with a COP of 10 and do not use the purchased cooling option. (The value of 10 accounts for the electricity required to pump the water out of the lake/sea.)

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

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

Solution:

1. Enter the building with purchased cooling selected and run EE4.
2. From the BEPS DOE2 report read the cooling load in MBTU (1 BTU = 0.000293 kW)
3. If the cooling load is:
 - less than 700 kW: purchased cooling COP = 3.8 (reciprocating type)
 - greater than 700 kW: purchased cooling COP = 5.2 (centrifugal)
4. Assume DOE BEPS report cooling load = 1,750,000 BTUH (512.87 kW)
5. Weighted chiller capacity = 513 kW
6. $COP = [200 * 4.2 + (513 - 200) * 3.8] / 513 = 3.96$
7. Type = highest load provided = centrifugalCentral Heating

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

Utility Rate Considerations

In purchased heating/cooling situations, the actual utility rate charge is sometimes not available or not directly applicable. For instance, utilities may be charged to the building in units \$/m³ chilled water or \$/GJ steam. The effective rate may be difficult to convert to utility units for entry into EE4 because seasonal average COPs and heating efficiencies must be taken into account. In these cases, enter the utility rate paid by the district heating/cooling company for utilities, if available. If not, it is acceptable to use the local rate from the utility that would have served the building.

4.6 Heat Pumps

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

Air source heat pumps condition ventilation air and are modeled as systems rather than heating and cooling plants. Air 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, whereas the air tempering at the specific zones is defined at system and zone level by the size and airflow of the air source heat pumps.

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

Ground Source (or Geothermal) Heat Pumps

A ground source heat pump plant consists of single or multiple (distributed) heat pumps, which reject heat to, or accept heat from the ground via a “ground loop”. The loop can use ground water directly (open-loop) or consist of in-ground heat exchangers (closed-loop).

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

The recommended source of information is “Soil Temperature Averages” from Atmospheric Environment Service in Downsview, Ontario. Table 4-2 provides some representative values from the AES document.

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

Source: "Soil Temperature Averages" from Atmospheric Environment Service

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

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

Table 4-4 for each month of the year. However, always use calculated monthly design entering water temperatures instead of the following tables if the information is available.

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

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

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

Additional information must be entered in the System and Zone elements to completely model a ground source heat pump system; refer to Chapters 5 and 6.

Boiler/Cooling Tower Source Heat Pumps

This heat pump system may also be referred to as simply a “water-loop heat pump” or “distributed heat pump” system. In these systems, a low-temperature

water loop runs throughout the building. Heat pumps located in individual building zones reject heat to or extract heat from the central loop as required. When the central loop drops below a specified temperature (i.e. most zones are extracting heat from the loop), a boiler fires to add heat to the loop. When the central loop becomes too hot, (i.e. most zones are rejecting heat to the loop) water is diverted to a central cooling tower (or closed circuit fluid cooler) to reduce the loop temperature.

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

Additional information must be entered in the System and Zone elements to completely model a water source heat pump system; refer to Chapters 5 and 6.

Air Source Heat Pumps

Although similarities exist between water-source and ground-source heat pumps, air source heat pumps are an entirely different concept and are handled differently in EE4.

Air source heat pumps, which extract heat from outside air, are considered “System equipment” rather than “Plant equipment” and no specific heat pump information is entered in the Plant element. See Section 5.2 for detailed information on air-source heat pumps.

Combination Ground Source Heat Pump/Boiler Plants

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

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

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

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

4.7 Pumps

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

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

EE4 does not support primary and secondary loop pumps, but only one heating circulation circuit, one cooling circulating circuit and one cooling tower circuit. If secondary loop pumps exist, these need to be combined with the primary loop

pump for a single circuit entry only if the secondary circuit pumps operate continuously as distribution pumps and not as zone flow control pumps. If the secondary loop pumps are simply flow control measures, enter only the boiler and chiller distribution pumps as the plant pumps using the method for effective pump head described later in this section..

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

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

Pump and Motor Efficiency

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

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

Calculating Pump Head

EE4 requires the “effective” pump head to be entered. If the pipe design is as simple as one pump, then the pump head should be entered (pump head and flow rates are generally listed in mechanical specifications and/or drawings). However, most piping schemes consist of several pumps in series, some in

parallel, boiler and chiller circulation pumps, glycol pumps, etc. In these cases, follow this procedure to determine effective pump head:

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

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

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

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

Table 4-5 – Pump Effective Head Calculation Example

Pump No.	Head (kPa)	Flow (L/s)	Head x Flow
P-1: Distribution Pump 1	75	20	1500
P-2: Distribution Pump 2	75	20	1500
P-7: Boiler #1 Circulation Pump	40	8	320

P-8: Boiler #2 Circulation Pump	40	8	320
P-14: Glycol preheat pump	20	10	200
Sum of Head x Flow			3840
Net System Flow			40 L/s
Effective Head			96 kPa

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

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

$$\text{Motor eff} = (20 * 0.85 + 20 * 0.82) / (20 + 20) = 0.835$$

$$\text{Pump eff} = (20 * 0.70 + 20 * 0.66) / (20 + 20) = 0.68$$

Design Temperature Drop

Design temperature drop is the design temperature differential around a single loop of the piping system. For chilled water systems, this is better named “design temperature rise”. A typical heating system may deliver hot water at 160°F and return to the boiler at 140°F. In this case, the design temperature drop is 20°F. Similarly, a chiller may supply water at 40°F and it returns to the chiller at 50°F. In this case, the design temperature drop is 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.

Pump Type

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

Pump Operation and Control

Pump controls such as variable frequency drive control and pump reset based on loop temperatures are not supported in EE4., Minimum operating speed controls are not simulated, but defaulted to 50% of capacity. Also pumps are assumed to be operating continuously throughout the heating and cooling seasons, except for a ground source heat pump design in which the pump is activated when heating and cooling is required.

The pumps are defaulted to provide 60 C heated supply water and 7.3 C chilled supply water.

4.8 Special Central Plant Cases

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

Natural Cooling

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

building. Thus, there is no credit given for reduced cooling energy use for naturally cooled buildings.

Cogeneration Systems

Cogeneration systems burn a fossil fuel to generate electricity and process heat. For CBIP purposes, the heat provided by the cogeneration system is considered “purchased heating” (see description above). Similarly the electricity is assumed to be “purchased” from the cogeneration system. The local utility electricity rate structure should be used. If the combined electricity and heat conversion efficiency is greater than 80%, a boiler with the combined efficiency can be used. (In this case, do not select purchased heating and enter the boiler efficiency in the Boiler Library.) Thus, unless the system has a higher combined efficiency, no credit is given for the cogeneration system. CBIP and MNECB deal strictly with measures that reduce energy required by a building and do not take into account the source of the energy or energy source switching.

Fuel Cells

Fuel cells are modeled identically to cogeneration systems. They are considered “purchased energy” and the energy selected matches the fuel cell energy.

Condensate Heat Recovery

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

Thermal Storage

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

5. HVAC EQUIPMENT

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

5.1 Central Heating and Cooling Coils

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

Heating Coils

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

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

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

If the central system contains an air-source heat pump, then “heat pump” should be selected as the heating type. This should not be confused with ground-source or water-source heat pump. If the system type in the building is ground-source or water-source heat pump, choose the heating type that is used to heat the

ventilation air. It is rare that an air-source heat pump will be used to heat air at the central air handler in these systems. If, however, a ground or water-source heat pump is used to heat the ventilation air, do not select “heat pump” as the heating type. In this case, choose “none” as the heating type.

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

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

Depending on the system type selected, “coil control” and “supply temperature” may be defined. Options for “coil control” are: constant temp (air is delivered to all zones at the specified temperature), zone reset (temperature is reduced depending on the heating needs of the coldest zone at that time) or OA reset (temperature reduces with increasing outdoor air temperature). The specifics of these reset schemes (factor by which the supply temperature changes in response to zone or outdoor air temperature change) are fixed in EE4.

Several systems require “supply temperature” to be entered. Always enter the warmest design supply temperatures (generally 43°C for air-based systems). For fan coil and hydronic heat pump systems (water-source or ground-source), the heating supply temperature always must be less than the cooling supply temperature. A good default temperature to use for these systems is 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 reduced need to specific zone conditioning.

Finally, efficiency might be entered, depending on the heating type selected. For electric and hot water systems, efficiency is not applicable and this entry is greyed out. For fossil fuels, enter the efficiency as a number between 0 and 1 (usually 0.80 to 0.82). If the heating type is air-source heat pump, enter the EER

or COP. Do not enter an EER/COP for ground or water-source heat pumps in this location.

Cooling Coils

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

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

For supply temperature, enter the lowest cooling design temperature. For fan coil or hydronic heat pump systems, the supply temperature must be greater than the heating supply temperature. A good default value to use is 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 unit will be served by the central chiller, choose “hydronic”.

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

5.2 Air Source Heat Pumps

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

ventilation air when selected as the heating or cooling source for the air handling system.

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

As outside temperature decreases, the efficiency and capacity of an air source heat pump decreases significantly, and the operating time for defrost cycles increases. Generally, at a specified outdoor temperature, the heat delivered by unit is negligible and is turned off. When the heating load exceeds the capacity of the heat pump, a back-up heater is used to deliver the necessary heat. In EE4, the back-up heater type is limited to an electric resistance heater. Furthermore, below an outside temperature of 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 efficiency is to be entered in COP or EER (generally, heat pump heating capacities are stated in COP). Always enter the ARI-rated COP, not operating COP. Use ARI 210/240 rated conditions. For cooling mode, the COP and output of these heat pumps should be at 35°C (95°F). For heating mode, the COP and output should be at 47°F. EE4 will de-rate the efficiency automatically depending on the outside air temperature predicted in the simulation, using an MNECB standard part-load curve. COP should not account for energy use due to the fan or blower.

5.3 Zone-Level Heating Devices

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

Baseboard Radiators, Reheat Coils, Heating Panels

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

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

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

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

Fan Coils and Hydronic Heat Pumps

Fan coil and heat pump systems are similar to baseboard radiators in that heating output is defined on the Zone element, Mechanical tab. However, fan coil and hydronic heat pump systems do not require that electric or hot water reheat be specified in the System element, Zone tab.

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.

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.

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

5.4 System Air Flow Rates and Fans

Supply and Exhaust Fan Overview

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

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

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 outdoors. Return fan characteristics are entered in the System element, Return Fan tab.

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

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

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 the next section.

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

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

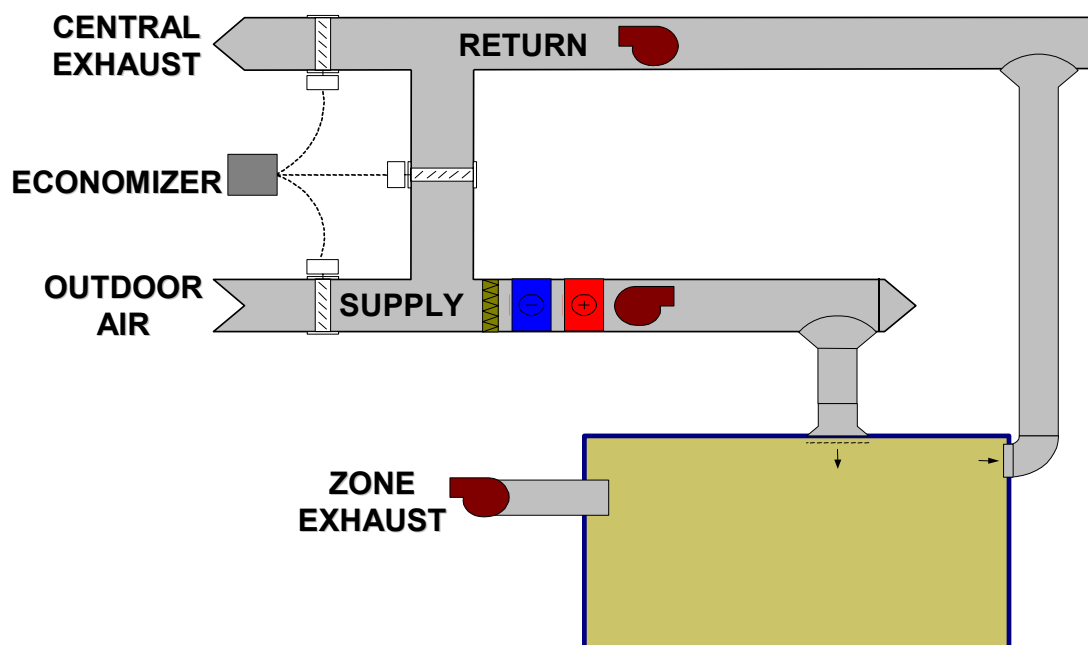


Figure 5-1 – System Air Flow Rates

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

Many VAV and constant volume systems also contain terminal fans for proper mixing or balancing. In EE4 version 1.33, the power for these fans must be accounted for in the central supply fan information. Future versions of EE4 may include an option for these fans to be entered in the Zone element, Mechanical tab, although this is currently not the case. 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 an apartment building, where central make-up air units pressurize corridors. Some of the air is exhausted through in-suite range hoods or bathroom exhaust fans (zone exhaust fans in EE4), although most air will be forced outside through suite windows, external doors, elevator shaft leaks, etc. For this reason, the “return fan” input in the System element is not available.

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

Entering Central Supply Fans in EE4

For single-zone systems, the supply flow rate is entered in the Supply Fan Tab of the System Element. For water-based systems (water-loop heat pump, 2-pipe fan coil, and 4-pipe fan coil), the central system is always a 100% outdoor-air make-up air unit, so the supply flow is not entered. 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 nameplate power draw. Derate the fan power only if the central fan will operate at a schedule other than that defined in the fan schedule (see Fan Operation paragraph below). “Fan power included in ratings” also may be checked at the bottom of the tab. Check this item if the rated heating and cooling capacities entered on the “General” and “Cooling” tabs take into account waste heat of the fan. For instance, a packaged rooftop unit manufacturer might report a unit has a heating capacity of 10 kW, because it contains a 9 kW heating coil and a 1 kW internal fan, with all electrical waste heat entering the air stream and delivered to the space. In this case, 10 kW may be entered for the heating capacity and the “fan power included in ratings” box should be checked. Alternatively, the “fan power included in ratings” box may not be checked, but then the entered heating capacity should only be 9 kW.

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

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

where

power is fan power in watts

flow is central supply flow rate in m^3/s

S.P. is total static pressure in Pascals

eff is total combined efficiency (expressed as fraction) (use eff = 0.55 if unknown)

Central Return Fans

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

Example. Rated nameplate power on return fans is 10 kW; no static pressure or efficiency information is available. The supply flow rate is 6,000 L/s and a zonal exhaust fan of 1000 L/s have been entered. Solution: The return flow is calculated by subtracting zonal exhaust from supply flow, so return flow is 6,000 L/s – 1,000 L/s = 5000 L/s. Converting to m^3/s , the return flow is 5 m^3/s . Estimate a static pressure by taking one-half of the supply static, (use 200 pa for example). Use the Power equation above to calculate the efficiency based on the guessed static pressure. Rearranging the equation gives efficiency = (flow x S.P) / power. Substituting the numbers gives efficiency = $(5 \times 200) / 10,000 \text{ W} = 0.1$ (10%). Enter 0.1 in the appropriate location in EE4.

Zone Supply Fans

As described in the overview of this section, “zone supply fans” refer to distributed heat pump or fan coil blowers, or fan-powered boxes found in dual duct systems.

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

Zone Exhaust Fans

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

Fan Operating Schedules

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

Fan power = rated fan power X 24/18

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

5.5 Outdoor Air Flow Rates

The MNECB specifies that the reference building have the same outdoor ventilation rate as the proposed building. Thus, for most cases changes in ventilation flow rate will have little impact on the energy savings of the proposed design. If the ventilation rates were selected based on ASHRAE 62-1999, the default ventilation values in EE4 are sufficient for compliance modeling purposes. EE4 determines the outdoor (ventilation) air flow rate from the space use characteristic selected in the Zone tab (if Building Type) or Space tab (if Space Function). If a value of “0” is selected, EE4 uses the flow rates found in the MNECB Table 4.3.2.A (Building Type) and MNECB Table 4.3.2.B (Space

Function). These values can be found in the EE4 online help file and Appendix B of this document. Multiply the value in the “Minimum O.A. (L/s/m²)” column in MNECB Table 4.3.2 by the floor area specified in the Room element to determine the amount of outdoor air being delivered by the HVAC system.

In fan coil and hydronic heat pump cases, the reference case airflow is increased by 20% compared to the value derived for the proposed case. This is due to the reference case being described as a variable air volume system with an outdoor air economizer for free cooling. The reference case airflow is therefore increased to allow a higher amount of free cooling, but this imposes a higher amount of outdoor air heating energy requirements. Variable air volume systems by design are higher outdoor air volume systems to take full advantage of free cooling and utilizing zone mixing boxes to regulate the amount of zone conditioned air. Thus the reference system will incur an additional ventilation air heating and fan energy requirement than the fan coil or heat pump system minimum outdoor air handler (make-up air unit). In addition, EE4 assumes the make-up air unit is not equipped with any economizer strategy, therefore all cooling must be mechanically provided. Modern make-up air units are equipped with economizer features and variable speed drives to provide sufficient minimum outdoor air and take advantage of free cooling opportunities.

Ventilation Rates Above ASHRAE 62-1999

If the actual outdoor airflow rate is significantly greater than the EE4 default values (greater than 25%), the actual outdoor airflow rate should be used. The outdoor airflow rate can be specified in the Room Element/Occupant tab. Two values must be specified: Occupant Density and Minimum Outdoor Air. The resulting outdoor airflow rate must be equal to or greater than the value in MNECB Table 4.3.2.

Prior written justification is required if a ventilation rate in excess of two air changes per hour or 50% above the default EE4 (ASHRAE 62-1999) is used.

$ACH = \text{volume}/60 * \text{flow}$ (volume in ft³, flow in cfm)

$ACH = \text{volume}/3600 * \text{flow}$ (volume in litres, flow in litres/sec)

The CBIP Technical Manager may limit the maximum ventilation in the reference building if it is deemed that the proposed building has excessive ventilation rates.

Hospital Systems

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

Determine any code-mandated ventilation, air change, or filtration requirements.

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.)

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

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

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

Clearly document the changes that have been made and include calculations of extra pressure drop due to special in-duct devices (such as filters) with the CBIP submission.

Demand-Controlled Ventilation

Demand-controlled ventilation schemes alter the volume of ventilation air supplied based on measured carbon dioxide levels in the spaces served by the system. NRCan has determined that the effect of a demand ventilation strategy is that ventilation air and fan power values are linked to the occupancy pattern and are reduced to zero for the equivalent of four full-load hours per day. Carbon dioxide sensors must be installed in all zones served by a system; no credit can be given for multi-zone demand ventilation systems that simply have one CO₂ sensor installed in the return ductwork. Demand control ventilation is available only with a reasonable control strategy of CO₂.

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

Complete all necessary EE4 modeling, defining all systems as normal. Demand ventilation should be the very last item performed in the modeling 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 with a name like “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.

Select the new schedule for all zones served by the demand ventilation strategy.

Save the new file using SAVE AS and type a new name, like “MyBuilding-proposed.BLD”

Run the file and compare the proposed building energy use of the new file to the reference building energy results of the old file. Send both files in with the submission package with a clear explanation.

5.6 Ventilation Air Heat Recovery

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

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

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

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

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, or in mechanical drawings and/or specs. 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 been selected or test results are not available, a default value of 0.50 can be assumed. A default value of 0.45 is assumed for hot water or glycol loop heat exchangers unless engineering data is provided.

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

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

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

SP = static pressure in Pascals

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

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

F = HRV supply fan airflow rate in litres/second

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

Exhaust Fan Heat Recovery

If heat recovery units are installed on zone-level exhaust fans, the fan should not be entered as an exhaust fan. Adjust the return fan static pressure and efficiency to account for the power consumption of the fan, and increase the heat recovery effectiveness (on a flow-weighted basis) to account for heat recovered. For example, if a zone has a central HRV with 65% effectiveness on 900 cfm, and a 75% effective HRV on a 100 cfm mechanical room exhaust fan, the heat recovery effectiveness will be 66%. ($65\% \times 90\% \text{ of flow} + 75\% \times 10\% \text{ of flow}$).

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

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

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

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

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

Exhaust Fan Heat Recovery with Make-up Air Units

If heat recovery is via zone exhaust fans only and the system type does not support a return fan (fan coil and heat pump system) then the program reduces the outdoor airflow by the entered heat recovery effectiveness. If the entered heat recovery effectiveness is 45% for the zone exhaust, then EE4 reduces the outdoor air by 45%. This assumes that the exhaust flow equals the minimum outdoor air requirement (balanced system assumption).

If the exhaust airflow does not equal the minimum calculated outdoor air requirement, then the HRV effectiveness must be adjusted by the ratio of exhaust with heat recovery to minimum calculated outdoor air. For example, a

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

$$\text{HRV adjustment factor} = (1000 + 100) / 2500 = 0.44$$

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

Heat Recovery and Differing Exhaust and Supply Fan Operation

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

Example 1:

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

$$\text{HRV time factor} = 24 / 18 = 1.33$$

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

Example 2:

Exhaust fans operating 12 hrs / day and supply and return fans operating 18 hrs / day:

$$\text{HRV time factor} = 12 / 18 = 0.66$$

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

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

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

5.7 Humidifiers

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

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

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

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

Run 1: no humidification: run EE4 using the space heating efficiency and capacity

On the DOE2 PS-A report, write down the plant heating load (MBTU)

Run 2: with humidification: run EE4 with the humidifiers and the total boiler capacity and space heating boiler efficiency

On the DOE2 PS-A report, write down the plant heating load (MBTU) which now includes hot water humidification

The difference is the humidification load (MBTU)

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

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

efficiency = (humid eff * humid load + space eff * space load) / (humid + space load)

= (0.70 * 1450 + 0.88 * 3200) / (1450 + 3200) = 0.824

5.8 Economizers

Air-side economizers can be modeled for most system types on the “Outdoor Air” tab in the System element. In EE4, fan coil and hydronic heat pump systems are always 100% outdoor air so economizers are not applicable to these systems. Similarly, if a system is made 100% outdoor air (by matching the system or zone supply rates to the outdoor air rate), modeling an economizer will not have any impact.

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

5.9 Preheaters

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

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

6. MODELING OF HVAC SYSTEMS

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

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

6.1 Fundamental System Types in EE4

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

Table 6-1 – HVAC Systems Modeled in EE4

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

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

Zonal (Water-based) Systems: In these systems, heating and cooling is performed primarily by a zone-level device. For these systems, the General Tab in the System Element is used to describe the make-up air unit. The purpose of

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

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

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

6.2 Table 6-2 – HVAC Data Summary

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

Selecting the Appropriate System

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

Cooling Dominated Systems

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

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

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

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

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

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

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

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

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

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

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

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

Heating Dominated Systems

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

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

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

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

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

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

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

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

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

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

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

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

6.3 System Types

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

Fan Coil, Heat Pump, 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; this distinction is made in the Plant element (see Chapter 4).

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

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

Single Zone Systems

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

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

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

Constant Volume Multi-zone Systems

There are 4 systems that belong to this family:

Packaged Constant Volume Multi-zone – air is cooled by direct expansion of a refrigerant, and only 1 air stream (hot or cold) leaves the central air handler. This is a common system type. An example is a medium-sized office building with direct-expansion rooftop units. The rooftop unit delivers either hot or cold air to 4 different zones. Thermostats in each of the 4 zones may control baseboards to reheat the air to achieve the space temperature desired. Often the thermostats will report space temperatures back to a central control panel, which decides whether the rooftop unit should be delivering hot air or cold air. However, in EE4, the heating or cooling mode is determined by the demand of the first zone listed in the EE4 building tree under the system (this is known as the “control zone”). This should be kept in mind when choosing the order of the zones. To avoid unmet heating load errors, try to anticipate which zone will most often be in heating mode (a zone with many north-facing windows, for instance) and choose this as the first zone.

VVT (variable volume/variable temperature) systems or ceiling bypass systems should be modeled as constant volume systems because the airflow at the central fan does not vary.

Built-up Single Duct Constant Volume – air is cooled by a chilled water coil (the chilled water comes from a central chiller), and only one air stream (hot or cold) leaves the central air handler. This system behaves identical to a Packaged Constant Volume Multi-zone system, except that air is cooled with a chilled water coil, not a refrigerant coil.

Packaged Multi-zone – air is cooled by direct expansion of a refrigerant, and two air streams (one hot and one cold) leave the central system, to be mixed in proper proportions to meet zone-heating needs. In a packaged multi-zone system (“Packaged MZ” in EE4), air is heated and cooled by the central air handling year-round. Separate ducts – a hot duct and cold duct – deliver the air to zone mixing boxes, which combine the two air streams to meet the zone temperature demand. Although this system provides very precise zone temperature control, it is not very energy efficient.

Built-up Multi-zone – air is cooled by a chilled water coil (the chilled water comes from a central chiller), and two air streams (one hot and one cold) leave the central system, to be mixed in proper proportions to meet zone-heating needs. This system behaves identical to a Packaged Multi-zone system, except that air is cooled with a chilled water coil, not a refrigerant coil.

Packaged VAV System

In a packaged VAV (variable air volume) system, air is cooled by direct expansion of a refrigerant, and the system airflow can vary depending on the heating/cooling load required. In cooling mode, the supply air flow rate is set by the simulator, usually around 13°C. Zone terminals contain dampers which allow more or less cold air into the zone, depending on the amount required for space conditioning (note the maximum and minimum airflow rates are set by the simulator). In heating mode, the temperature entering the zones is fixed at 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 modeled as Packaged Constant Volume Multi-zone or Built-up Single Duct Constant Volume.

Built Up Variable Air Volume Systems

Built-up VAV system – only one air stream leaves the central air handler (hot or cold) and is throttled at the zone by means of a VAV box. This system is identical to the Packaged VAV system described above, except that cooling is provided by a chilled water coil instead of a refrigerant coil.

Dual duct system – two air streams leave the central air handler (one hot, one cold) and are mixed at the zone to meet the space requirements. One fan serves both hot and cold air streams. Dual duct systems are similar to Built-up Multizone systems, with one important difference – the airflow rates of the air streams are varied to improve energy efficiency. Mixing does not occur until one of the air streams is reduced to the user-defined minimum.

Dual duct, dual fan system – two air streams leave the central air handler (one hot, one cold) and are mixed at the zone to meet the space requirements. This system is similar to a dual duct system, but each air stream has a dedicated fan. One of the assumptions of the dual duct dual fan system is that outside air is delivered to the cold side initially (even in winter) and then heating is added. If the dual duct system contains controls that allow outside air to be initially introduced on either the cold side, the warm side or both, then, the system should be modeled as a built-up VAV. Based upon the assumptions in the software, dual duct and dual duct dual fan systems have reduced cooling energy but substantially higher heating requirements than a comparable built-up VAV system.

6.4 Special HVAC System Cases

In most cases, following the procedure described in Section 6.2 should narrow down the choice of system types. However, there are additional system types that may not seem to fit any specific model in EE4. This Section explains common “work-arounds” so that these special systems can be modeled in EE4 with reasonable accuracy.

Water-Based Radiant Heating and Cooling Systems

Radiant heating and/or cooling systems offer many advantages over conventional air-based HVAC systems. The principle advantage is that no fan energy is required to deliver the heating or cooling. These systems are modeled in EE4 by treating the radiant heating or cooling surface as a fan coil that requires no fan energy. Specifically the procedure is as follows.

Select either a 2- or 4-pipe fan coil HVAC system in the System Element/General Tab,

Describe the ventilation make-up air heating system in the System Element/General Tab

Specify the zone heating and cooling capacities on the Zone Element/Mechanical Tab

Enter zero for terminal design fan power in the zone mechanical tab

Run the EE4 sizing calculator (CalcManager => Sizing => Calculate) and enter the resulting zone-level airflow rate from the “Loads” table into the Zone Element/Mechanical Tab as the terminal fan airflow rate. This is to work-around the fact that EE4 requires an airflow input.

If the piping for the radiant heating/cooling is embedded in a concrete floor, set the floor weight (in the Zone Element/General Tab) one level heavier than actual construction to simulate the thermal mass effect. Floor weight is medium for most commercial concrete type buildings and light for wood frame construction.

Baseboard Electric Space Heating

The system selected should be based upon the delivery of the cooling system, but if cooling is not applicable, then the system should be modeled identically to the water-based radiant heating and cooling. The only exception is that the floor weight is not altered.

Radiant (Gas-Fired) Unit Heaters

Gas-fired radiant heaters are often used to heat warehouses, arenas and light manufacturing areas. In EE4, it is assumed that all combustion takes place at either the Plant or System Element and not at the Zone Element. The procedure for modeling gas-fired radiant systems is as follows. A different procedure is used depending on whether there is a single HVAC system or multiple HVAC systems in the building.

Single HVAC System

Select either a 2- or 4-pipe fan coil HVAC system on the System Element /General Tab

Specify radiant heating fuel, total output of zone unit heaters, supply temperature, and efficiency; set central supply fan power to zero in the System Element

Enter zero for heating and cooling capacity and terminal fan power in the Zone Element. Set terminal fan flow rate equal to value in EE4 sizing calculator as described in water-based radiant systems

Multiple HVAC Systems

Select either a 2- or 4-pipe fan coil HVAC system in the System Element/General Tab

Specify radiant heating fuel, heating output of 1 kW, supply temperature, and efficiency; set central supply fan power to zero In the System Element

Enter the total heating capacity for the zone in the Zone Element. Set terminal fan power to zero and set terminal fan flow rate equal to value in EE4 sizing calculator as described in water-based radiant systems

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, the fan coil model within EE4, which is being used to simulate the radiant panel system does require a boiler. If a boiler does not exist, you must define a “dummy boiler” with the following characteristics:

- fixed speed, pump head = 0 pascals, design temperature drop = 5.6 C, pump efficiency = 100% and motor efficiency = 100%
- boiler capacity equals the total capacity of the infra-red heaters
- boiler fuel equal fuel of infra-red heaters
- boiler thermal efficiency equals the thermal efficiency of the infra-red heaters or 80% (if unknown)

If radiant panel cooling is installed select “Purchased Cooling” and use the same pump characteristics as the boiler.

Without defining a boiler or chiller, the software will not know where the panel is receiving hot water or electricity.

Combination Space and Water Heating Systems

Combination space and water heating systems or “combo” systems are often used in townhouses and apartments. In these systems, the water heater delivers hot water for both domestic uses and for space heating. These systems cannot be modeled directly in EE4; rather the space and water heating functions have to be separated. The following procedure is recommended.

Combine the heating capacity of all the combo systems

Enter the portion of the capacity of all the combo systems that is for heating hot water in the Plant Element/SHW tab

Enter the portion of all the combo systems that is for space heating in the Plant Element/Central Heating Tab

Select either a 2- or 4-pipe fan coil HVAC system in the System Element/General Tab

Specify the zone heating and cooling capacities in the Zone Element using the coil capacity installed in each zone

Enter the thermal efficiency of the combo system in both the “Service Water” tab and in the boiler information. The efficiency of the boiler and water heater is the same.

Solar Water and Ventilation Air Heating Systems

Any energy savings from installing solar heating systems can be counted towards the CBIP target of 25% energy savings.

Two common applications of solar heating in Canada are solar water heating and solar ventilation air heating. Solar water heaters preheat water for domestic and industrial uses. Solar collectors heat mains water and store the heated water in a preheat tank. The conventional (fossil-fuel) water heater supplements the solar heating to ensure that the water is always delivered at the setpoint temperature. Unglazed collectors are used if the water-heating load is primarily in the summer. Glazed collectors are better suited to providing heated water year-round.

Solar ventilation air systems (trade name Solarwall™) consist of a perforated metal cladding attached to the south façade of buildings. Ventilation air is preheated as it is pulled through the perforated plate. A bypass damper is installed to avoid summertime heating of the air.

Both of these solar heating systems can qualify for Natural Resources Canada's Renewable Energy Deployment Initiative (REDI). The REDI program provides a 25% incentive towards the cost of the system. The REDI program requires that detailed computer simulation be performed to determine the energy savings of these systems. The performance of solar water heating systems is determined using the WATSUN or RETScreen computer program. The performance of solar ventilation air heating systems is determined using the SWIFT or RETScreen computer program. RETScreen is available free-of-charge from the web site retscreen.gc.ca.

The computer simulated energy savings determined for the REDI program can be used as a credit in the CBIP program. The proposed building energy consumption is the value determined by EE4 assuming no solar heating system less the energy savings of the solar heating systems determined using RETScreen, WATSUN or SWIFT. The cost savings should be based on the cost of energy in the last rate block used by the building.

The only exception to the above rule is where the proposed building has both a solar ventilation air heating system and an HRV for the same ventilation airflow. In this case, the two technologies must be analyzed together to avoid double counting of the energy savings. Simulators should contact the Natural Resources Canada CBIP Technical Manager for the recommended procedure.

6.5 System Modeling Examples

This section presents some common buildings and describes how to model the HVAC systems in EE4.

Example 1. Restaurant Served by Rooftop Units

Description: rooftop units condition a 1-storey restaurant. There are three rooftop units – two identical rooftop units serve different areas of the dining area (east side and west side) and are equipped with gas-fired heating and electric DX cooling. A third rooftop unit is a make-up air unit serving the kitchen area and also has a gas-fired heating section with electric cooling). Electric baseboard

radiators serve all areas of the building. An electric hot water heater provides domestic hot water.

Solution: The building is first zoned according to HVAC system and space function. If the restaurant is relatively small, this building is best described as three zones – one for the each side of the dining area, one for the west side and one for the kitchen. Each rooftop unit is thus dedicated to one zone.

Since there is no central boiler or chiller, and no central heat pump loop, the only item to be defined in Plant is the domestic hot water system. On the Service Water tab of the plant element, “electricity” is selected for the Fuel source, and the input capacity and storage tank volume are entered. Thermal efficiency is not defined for electric systems because they are assumed to be 100% efficient.

This building has three systems each serving a single zone, thus they are all single zone systems. Since the systems cool air by direct expansion of a refrigerant (as opposed to chilled water coil), “DX Single Zone” is the appropriate system selection. On the General tab in the System element, choose “DX Single Zone”. For heating type, choose “natural gas” and enter the heating capacity and thermal efficiency in the appropriate locations. Similarly, on the cooling tab, enter the cooling capacity and efficiency.

To include the electric baseboards, on the Zone tab, select “electricity”. The baseboard heater capacity is not entered in the System element; instead, it is entered on the Mechanical tab of the Zone element.

Since two of the rooftop units are identical, the same system as defined above can be used again. Since the kitchen make-up air unit is slightly different, a new DX single zone system needs to be defined.

Example 2. Office Served by Ground Source Heat Pumps

Description: A medium sized 3-story office building is served by a large ground-source heat pump loop. Water is circulated through 30 heat pumps distributed throughout the building and a ground heat exchanger. Three rooftop units condition the ventilation air by natural gas fired heating and electric cooling. One

rooftop unit serves the first floor, one serves the second floor, and the other serves the top floor. A small electric water heater provides domestic hot water.

Solution: Zones for this building are defined according to area of influence of the heat pumps. The three rooftop units represent three systems, so this building has three systems, each with ten zones.

In the Plant element, the domestic hot water system and ground temperature information must be entered. On the Service Water tab of the Plant element, “electricity” is selected for the Fuel source, and the input capacity and storage tank volume are entered. Thermal efficiency is not defined for electric systems because they are assumed to be 100% efficient. On the Heat Pump tab, “ground loop” is chosen as the heat pump loop source. Monthly predicted entering water temperatures are entered at the bottom of the tab.

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 is also entered on this tab. Similarly, cooling information is entered on the Cooling tab.

On the Supply Fan tab, enter all supply fan information relating to the rooftop make-up air unit only.

In each of the 30 Zone elements, heat pump characteristics are defined on the Mechanical tab. Here, the heating and cooling capacity, heating and cooling efficiencies, and fan flow rate and power are entered. Note that if all 30 heat pumps are identical, it is necessary to enter the same information 30 times, on each zone Mechanical tab.

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

Description: An apartment building is heated with perimeter hot water baseboards. Chilled water fan coils located in each suite provide cooling. To maintain suite comfort, both boiler and chiller operate during shoulder seasons when some suites require heating and others require cooling. Ventilation air is

delivered to the building by a large air handler located in the penthouse mechanical room, which delivers tempered air to corridors. The air handler contains both a chilled water coil and hot water coil. The building contains four natural gas boilers, each of capacity 300 kW (1200 kW total) that serve both heating water and domestic hot water. The mechanical engineer calculates the peak heating load to be 700 kW and the peak domestic hot water load to be 500 kW.

Solution: Following the procedure described in Section 6.2, cooling is provided to the space by means of chilled water (because fan coils are located within the apartment units), so the system type is either fan coil, induction unit, or heat pump. Since induction unit and heat pump certainly don't fit, the building must be modeled as a fan coil system. Since the building operates in heating and cooling modes simultaneously, 4-pipe fan coil is the best system choice. Note however, that heating is NOT provided by the fan coil; heat is transferred by natural convection and radiation from the baseboard unit (which does not contain) a fan. Thus, this example is a system "workaround" because there is not an EE4 model that precisely fits. Details of the workaround are described below.

Theoretically, each apartment suite is a different zone. However, since the building is almost entirely one space use, suites of similar orientation can be grouped together. If the building is 8 stories high, it is best to group all south-facing suites on floors 2 through 7 together, all east-facing suites together on floors 2 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 must be entered. This is probably best described as 2 boilers, each of capacity 350 kW. This does not precisely match the actual boiler capacity, but is better than the alternative of entering 3 boilers of capacity 233 kW. The simulator would enter the boiler size of 350 kW and efficiency, and then select a multiplier of 2. If the boilers are staged to come on at 90% of capacity, then 315 kW is entered for the sequencing capacity. Pump data also must be defined on this tab.

Chiller and cooling tower and associated pump information must also be entered on the appropriate tabs. Note that the cooling tower is only defined if the chiller is selected as “water cooled”; otherwise, a simple condenser fan is entered for the air-cooled condenser.

In the System element, “4-pipe fan coil” is selected. For Heating Type, “hot water” is selected because the central make-up air unit has a hot water coil. This coil capacity is also entered on this tab. For fan coil systems, the ventilation air is only tempered so the heating supply temperature will be relatively low, perhaps 18°C.

On the Cooling tab, the characteristics of the central chilled water coil are entered. Again, since the ventilation air is only tempered, a modest cooling supply air temperature is entered, perhaps 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; only the baseboard radiator provides heating. From a modeling perspective, heating with a fan coil vs. a radiator are very similar, except that a fan coil consumes electrical energy. A fan coil also requires a certain airflow to deliver the

necessary heating from a thermodynamic analysis. The workaround to be employed in these situations is as follows:

On the Zone element, Mechanical tab, enter the rated heating output of the baseboard radiator under “Zone Heating Output”. Enter the rated cooling output according to the fan coil spec sheet on under “Zone Cooling Output”. Enter the cooling fan flow rate under “Airflow Rate”. Next, derate the fan power of the fan coil according to the time of year that the building is expected to be in heating mode. For example, if an average suite is in heating mode 8 months of the year and cooling 4 months of the year, and the fan power in cooling mode is 1 kW, reduce it to 1/3 (333 watts) because the fan power is effectively zero for 8 months of the year.

Note: if the building had used electric baseboard heating rather than hot water baseboard heating, the procedure would have been identical, except that “electric” would be selected in the System element, Zone tab, instead of “hot water”.

Example 4, Warehouse Served by Roof Top Units and Gas Infra-Red Heaters

Description: A warehouse is equipped with a gas-fired roof-top unit providing ventilation air tempering only and the tempered air is simply ducted to a few central drops. Gas-fired infra-red heaters are installed on exterior walls and at the overhead bay door openings to meet envelope losses. A gas-fired unit heater with blower is installed at the man door entry blowing hot air into the warehouse space. This unit heater does not have a direct fresh air supply, only heating and circulating air at the entrance space.

Solution: Zone the building such that the infra-red heaters serve the exterior walls, overhead delivery doors by creating a 1 meter warehouse space strip with the exterior walls and a small portion of the roof included in these zones. There will be a series of perimeter zones (one per orientation) to accommodate the infra-red heaters.

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

The gas unit heater at the entrance will be modeled as an entrance space zone. If entry is by building type, then the entrance can be defined as a separate zone. If the entry is using the space function method, then create a warehouse entrance zone with 2 spaces: a dummy 0.5 m² space using the warehouse space function and a space called active stairway to represent the entrance space. The building will have 1 system:

System 1: Four pipe fan coil system: this represents the make-up air unit for the central air tempering and the infra-red unit heaters (central zone for make-up air, plus infra-red unit heater zones).

The make-up air unit will be a natural gas furnace to represent the roof-top unit. All of the heating capacity will be represented at the System tab.

The central zone will have a heating capacity of 0 kW entered in the Zone mechanical tab. The airflows for the fan coil unit serving the central zone will be derived by running the sizing calculation and entering the airflows to represent the fan coil.

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

The entrance unit heater will be modeled as a Zone mechanical device in the fan coil system. The output of the unit heater will be the Zone capacity and the blower flow rate will be the fan coil rate.

At the Plant level, enter a dummy boiler to represent the heat source for the fan coil. The capacity of the boiler will equal the sum of the capacities of the infra-red heaters. The thermal efficiency of the boiler will equal the rated efficiency of the infra-red heater (usually greater than 80%). The circulation pump will have an effective head of 0 kPa, a design temperature drop of 5.6 C, a pump and motor efficiency of 100% (represent little pump energy). Do not enter a chiller.

7. MODELING OF BUILDING ENVELOPE

7.1 Level of Complexity Required

Heat transfer through the building envelope often accounts for the greatest use of energy in a building. As such, an accurate representation of the building envelope is necessary for a reasonable estimate of energy use in both proposed and reference buildings, and to accurately assess building envelope and over sizing credits and penalties. However, measurement of walls, windows, and roofs can be extremely time consuming and it is necessary to keep the model simple for a timely simulation. Since reference building and proposed buildings will have identical envelope areas, moderate differences between modeled envelope areas and “actual” envelope areas may have a negligible impact on building energy results and final incentive determination. Listed below are some tips for an accurate, yet timely simulation.

Envelope construction should take priority over envelope area. EE4 always compares envelope areas of identical size, but credits and penalties are determined by the efficiency of the envelope system (i.e. R-values and U-values). Concentrate on calculating an accurate R-value as described in this chapter.

Do not model small wall “jut-outs”. Many walls will have small turns and curves that need not be modeled for CBIP purposes. For example, a wall may face south, but may contain small west and east-facing jogs at bay windows.

Measure building wall orientation to within 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 once 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 “R-20” wall to become “R-14” or worse when modeled correctly in EE4, with framing taken into account. Review the section on framing and the MNECB carefully when modeling walls and curtainwalls.

Model interior partitions only if a high degree of heat transfer is expected. Usually, all parts of the building are kept at a uniform temperature. Interior partitions do not need to be modeled in these circumstances. Only model interior partitions if there will regularly be high temperature differences between areas of the building. Also, do not use interior partitions to model inter-zone air transfer.

Include all area within the heated space within your area calculations. This includes all areas within the inside of the thermal shell of the building (elevator shafts, storage areas, stairwells included). If the area is outside of the thermal shell of the building (ex. Penthouse mechanical room, exterior storage) do not include these areas as spaces in the building.

Name walls effectively. Do not leave all walls named “exterior wall”. Give them descriptive names that will assist NRCAN in making a timely technical review. One strategy is to name all walls and clearly label these wall names on the submitted drawings.

7.2 Above-Grade Walls, Roofs and Floors

Area Calculation

Wall, roof and floor areas should be calculated based on inside building dimensions (MNECB Clauses 2.2.2.3 to 2.2.2.5). While theoretically the heat loss should be based on the mid-point of the wall R-value or insulation layer, the complex nature of building assemblies makes it difficult to determine where this dimension would be. Wall height should include the full floor-to-floor height (i.e. include dimensions for interior floors and return plenums). Note the discussion on area measurement is Section 7.1.

In EE4, the area entered for walls, roofs and floors should be the gross value including any areas for windows, doors and skylights. (EE4 will subtract the areas of any windows, doors and skylights defined as part of the exterior elements to determine the “net” opaque area.) If the envelope element includes a projecting product, like a pyramid skylight, the gross area should include the projected area of all the surfaces, not just the area of the rough opening (see Section 4.3).

Wall, Roof and Floor U-values

The MNECB is based on total assembly U-values. Appendix C of the MNECB gives the method for determining the total assembly U-value accounting for thermal bridging of steel or wood framing. The MNECB procedure is coded into EE4. However, the user must select the type of framing and the percentage of the assembly that is framing. The framing percentage is NOT automatically adjusted when the framing type is changed. The framing percentages to be used are given in Table 4.1. This table can also be found in Appendix C of the MNECB. These framing percentages include the studs as well as the extra framing required around windows and doors.

Table 7-1 – Framing Percentages (taken from MNECB Appendix C)

Assembly	Framing Spacing, mm	Wood Framing		Steel Framing	
		Area With Framing, %	Area Without Framing, %	Area With Framing, %	Area Without Framing, %
Roofs, ceilings, floors	<500	10	90	0.33	99.67
	≥500	7	93	0.23	99.77
Above-grade walls and strapping	<500	19	81	0.63	99.37
	≥500	11	89	0.37	99.63
Below-grade walls and strapping	<500	17	83	0.57	99.43
	≥500	10	90	0.33	99.67
Sheet steel wall	<2100	–	–	0.08	99.92
	≥2100	–	–	0.06	99.94

The EE4 program includes a library of most building materials (taken from the MNECB Appendix C). Caution should be exercised in using material property values supplied by manufacturers. Some expanded or extruded insulation

products have high material R-values when initially manufactured. But the R-value decreases as the blowing agent diffuses out and is replaced by air. The values in the MNECB are representative of long-term performance. Any insulation with a conductivity lower than 0.024 W/mK (or greater than R6/inch) should be verified with a Canadian Construction Materials Centre (CCMC) evaluation.

Some materials include a reflective foil to reduce radiation heat transfer. Manufacturers sometimes quote an “effective” R-value to account for this benefit. These materials are only effective if the foil faces an air space. It is better to model these materials by entering the thermal conductivity of the material disregarding the foil and adding an air space with reflective surface.

Similarly, “effective” R-values are sometimes quoted for massive materials. These materials should be modeled by entering the conductivity and thermal capacitance of each layer separately. The EE4 program will account for the thermal mass benefit in its calculation. However, if the U-value is entered directly, instead of entering each material that makes up the assembly, the thermal mass is not taken into account.

If an exterior wall contains an exterior hanging facade (metal cladding) with an air space separation of greater than 100 mm between the facade from the exterior wall, then exclude the facade and airspace from the exterior wall U-value calculation. In this case convective heat loss will exceed the reduction in conductive losses from the total assembly. If the air space between the exterior wall and the facade cladding is less than 100 mm then include the air space and cladding in the total assembly U-value calculation.

7.3 Assemblies in Contact with Ground

Below-Grade and Earth-Bermed Walls

Partially buried walls should be divided in two: the above grade portion and the below grade portion. The modeling of above grade walls is discussed in Section 4.1. Below-grade walls are entered in the “Wall in Contact with Ground” Element.

For earth-bermed walls, the entire area covered by earth should be treated as an Underground Wall Element. The depth of the wall is calculated as the depth of the wall below grade plus the height of the earth berm provided it extends 1.2 meters out from the wall. For the portion of the earth berm that extends out less than 1.2 meters, use one half the height of this portion of the earth berm (see Figure 7.1). This height would also be used in the calculation of underground wall area.

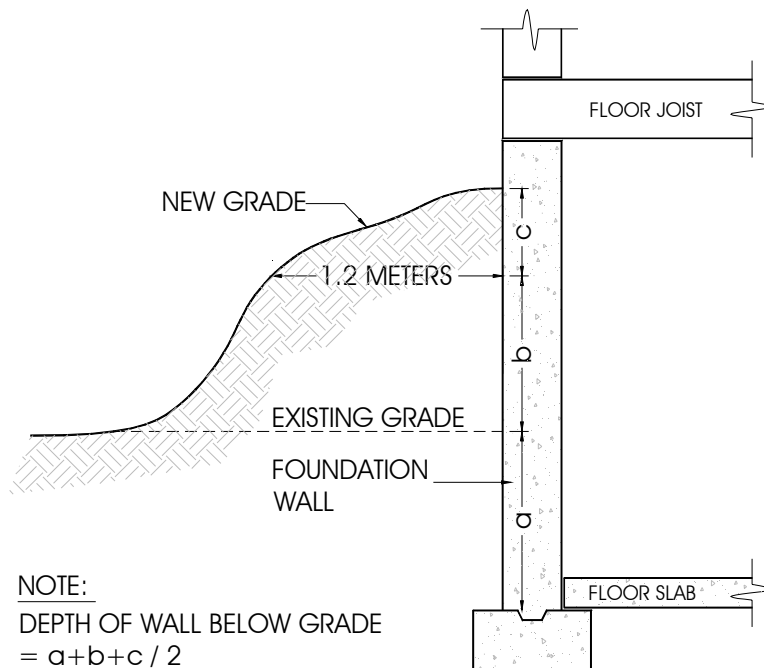


Figure 7-1 – Depth of Below-Grade Wall When Earth Berms Are Used

Below-Grade and Earth-Bermed Roofs

Below-grade and earth-bermed roofs are treated as Underground Walls Elements as per MNECB Table A-3.2.3.1. However, if there is less than 600 mm of soil on top of the roof, the roof should be treated as an above-ground roof. In the Underground Wall Element, Area is the roof area, Depth is the depth of soil on the roof and Perimeter is the longest dimension of the roof.

7.4 Windows and Skylights

Window and Skylight Area

Window and skylight areas are calculated as the total area including glazing and frame (MNECB Clause 2.2.2.8-1). Many designers mistakenly use the term window area when referring to glazing area. For EE4, the window area (and thermal properties) should be based on the total window area (glazing plus framing, sashes and mullions).

A skylight is entered as a window in the roof assembly and is assumed to be on the same tilt angle as the roof. Many commercial buildings have pyramid or domed skylights. These skylights have a much larger surface area than the opening in the roof. The total area of all the angled surfaces should be used in EE4, not just the rough opening. For small skylights, the total skylight area can be estimated as 1.5 times the opening (MNECB Clause 2.2.2.8-3). A value of 1.3 times the opening is recommended for domed skylights. While this approach is reasonable to account for heat loss, it over estimates the solar heat gain through the skylight (see next section).

The fenestration area should include the total area (including framing elements) of windows, sliding glass doors, glass revolving doors, and window portions of swinging doors. All of these components should be defined in the EE4 building tree.

Note that the reference building and proposed building will have the same amount of window area up to a maximum of 40% window-to-wall ratio (WWR). If the proposed building has a WWR greater than 40%, the reference building is fixed at 40%. This results in an energy penalty because the proposed building will have a greater window area (and thus higher heating and cooling energy needs).

Similarly, the skylight area in proposed and reference buildings is the same up to a maximum of 2% skylight-to-roof ratio (SRR). If the proposed building is greater than 2% SRR, the reference building remains at 2%.

Window and Skylight U-values

The U-value for windows should be based on the entire window (including glazing and framing). There are several sources for window and skylight U-values. They are, in recommended order of use, as follows:

- **Manufacturer:** Some manufacturers publish U-values for their products. The only acceptable values are those rated in accordance with CSA A440.2 or NFRC 100 (note NFRC values are usually listed in IP units – multiply by 5.678 to obtain SI value). Some manufacturers list values that are for the glazing only; these can not be used.
- **Default values in the EE4 fenestration library:** These values are equivalent to those published in the ASHRAE Fundamentals Handbook, and should be used whenever precise total-window information is not available.

Window and Skylight Solar Heat Gain Coefficients (SHGC)

The SHGC values required by EE4 are for the total window – not just for the glazing. Sometimes manufacturers quote shading coefficient (SC). The SHGC value is 0.87 times the SC value. Again, however, SC values are often listed for the glazing only. There are several sources of information on SHGC values. They are, in recommended order of use, as follows:

- **Window Manufacturer:** Some manufacturers publish SHGC values for their products. The only acceptable values are those rated in accordance with CSA A440.2 or NFRC 200. Some manufacturers list values that are for the glazing only; these values need to be adjusted (see below).
- **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.
- **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)
- **EE4 Program:** The EE4 program contains a very short list of values and their use is not recommended for CBIP or MNECB compliance.

If the skylight area was increased to account for the extra heat loss because of the domed or pyramid shape, it is necessary to reduce the SHGC to compensate. Skylight SHGC is SHGC divided by 1.5 for pyramid skylights and 1.3 for domed skylights.

7.5 Doors

Many types of doors are used in commercial construction: swinging doors, sliding doors, revolving doors and overhead doors. Residential sliding glass doors (patio doors) should be treated as operable windows (see Section 4.3). Similarly, doors with over 50% glazing should be entered as operable windows (based on the total areas of the door) and not entered as doors.

U-values for swinging doors should be determined in accordance with A453 (where applicable). Typical U-values for commercial swinging, revolving and overhead doors can be found in the 1997 ASHRAE Fundamentals Handbook Chapter 29 Table 7. The reference building uses the same U-values for doors as the proposed building, so the door U-value selected will not have a large impact on the simulated results.

7.6 Curtain Wall Systems

Curtain wall systems are common in commercial buildings. They are made up of two portions: vision panels (glazed portion) and spandrel panels (opaque portion). Curtainwalls are defined in EE4 the same way as a normal wall – opaque portions are “wall”, and glazed portions are “windows”.

Vision Panel

The U-value and SHGC for vision panels can be determined in the same manner as described in Section 7.4. Because most manufacturers do not have published values, the ASHRAE Fundamentals Handbook Chapter 29 likely provides the most accurate values (see Appendix).

Spandrel Panel

There are two generic types of spandrel panels. The first type is constructed using precast concrete (or other material) that are hung off the building structure. This spandrel system is insulated by spray applying insulation to the back of the panel or by constructing an interior insulated wall. These two methods have modest thermal bridging, and the wall R-value can be calculated using the procedure defined in Appendix C of the MNECB and as programmed in EE4.

The second type of spandrel panel is made up of aluminum mullions with a glass exterior - the so-called all-glass building look. A steel metal pan is attached to the mullions and is filled with batt insulation. The mullions and steel pan cause considerable thermal bridging which reduces the effectiveness of the insulation by more than 50%. The most accurate means of evaluating the U-value of spandrel panels is with a 2-D heat transfer program (e.g., FRAME see web site www.frameplus.net). In lieu of this analysis, the U-value of the assembly can be calculated using the procedure in EE4 with some modifications. The procedure is as follows:

- Calculate the wall (spandrel) area represented by the mullions (typically the mullions represent 5 to 20% of the wall area). Where mullions are shared by a spandrel panel and a vision panel, only include half the mullion area in the wall area.
- In the EE4 Construction Assembly Library, check metal framing greater than 500 mm and enter the mullion percentage
- In the Construction Components box describe each layer in the spandrel panel. The insulation portion should be indicated as containing framing.
- Add a continuous layer of gypsum wall board (i.e., does not contain framing) above the insulation layer to represent the mullion thermal break. The thickness of the gypsum board would be the same as the thickness of the thermal break.

Figure 4.2 shows a typical entry for a spandrel panel with a 4 mm thermal break. This procedure provides reasonable U-values, however, for wide thermal break products, a thermal test report in accordance with CSA A440.2 is recommended.

In many cases the U-value of the spandrel panel will be higher than 167% of the reference wall U-value an error will be generated. To overcome this problem,

increase the U-value of the vision area, so that the total assembly UA value is correct.

$$U_{\text{vision new}} = U_{\text{vision}} + (U_{\text{spandrel}} - 1.66 \cdot U_{\text{reference}}) \cdot A_{\text{spandrel}} / A_{\text{vision}}$$

$$U_{\text{spandrel new}} = 1.66 \cdot U_{\text{reference}}$$

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	

Figure 7-2 – EE4 Description for a Spandrel Panel

7.7 Balconies and Wall/Floor Junctions

Junctions

Wall/floor or wall/roof junctions can be an area of high heat loss because of the difficulty in insulating these constructions. The MNECB (Clause 3.2.1.2-3) requires that the U-value of these junctions be no more than twice the

prescriptive values for the walls (as given in MNECB Appendix A). If this clause is met, it is permissible to model the entire wall using the U-value of the wall (for both the reference and proposed cases) and ignore the extra heat transfer at the junctions. If this clause 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.

In attic-type roofs, the impact of insulation reductions at the junction between the roof and the ceiling can be ignored (MNECB Clause 3.2.2.1-3).

Envelope penetrations due to ducts, shelf angles, and HVAC equipment can also be ignored (MNECB Clause 3.2.1.2-4).

Balconies

Concrete balconies are common in high-rise residential buildings. The thermal impact of these penetrations can be ignored provided that the penetration area does not exceed 2% of the above grade building envelope area (MNECB Clause 3.2.2.1-5). To meet this requirement, balconies cannot cover more than half of the building perimeter. For large balcony areas, a separate wall assembly should be entered for the balcony. The balcony U-value can be calculated using the FRAME or other 2-D heat transfer program. Alternatively, a U-value of 5.5 W/m²°C (based on the wall area represented by the balcony cross-section) can be used.

7.8 Modeling Unconditioned or Partially Conditioned Zones

Unconditioned Space (unheated vestibules, parking garages)

As discussed in Section 2.4, most unconditioned zones can be ignored. However, if desired, these zones can be modeled using the procedure described below. Note: for some HVAC systems (e.g. heat pump, fan coil, induction systems), the EE4 program does not allow unconditioned spaces. In these

cases, the unconditioned zone should be ignored and treated as described in Section 2.4.

- Define the area as a separate zone (unconditioned zones cannot be the first zone listed in a system in the EE4 building tree)
- Define the zone as indirectly conditioned (Zone Element General Tab)
- Define exterior walls, floors and roof in the conventional manner
- Define walls, floors, and roofs between unconditioned zone and conditioned zone as an “interior partitions.” These partitions should be defined in each conditioned zone.
- Define appropriate zone function or set occupant density to 1750 m²/occupant for unoccupied areas
- Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads
- For parking garages, define lighting power; for unlit spaces add one small light (this allows the EE4 simulation to run)

Partially Conditioned Space (crawlspace, heated parking garage)

Partially conditioned zones are areas of the building that are not heated or cooled to standard thermostat settings. This definition also includes adjacent zones operated at significantly different temperatures (see Section 3.2) or when an air-conditioned zone is adjacent to a non-air-conditioned zone. This last case is common in light industrial buildings where the front office is air-conditioned but the back production area is not. The procedure for modeling partially conditioned zones is as follows.

- Define the area as a separate zone
- Define zone as directly conditioned (Zone Element General tab)
- Define exterior walls, floors and roof in the conventional manner
- Define walls, floors, roofs between the partially conditioned zone and conditioned zone as an “interior partition”
- Define the space function as “storage/warehouse inactive storage” for most spaces or “storage/warehouse material handling” for parking garages

- Set minimum outdoor air, occupant density to zero to accept MNECB defaults
- Enter the desired heating and cooling setpoints (on the Room Element/General Tab) and create the corresponding heating/cooling temperature schedules (in the Schedules Library)
- Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads
- Enter the heating and cooling capacity of HVAC system serving the partially conditioned zone
- For lit spaces define lighting power or for unlit spaces add 3.2 Watts/m² of lighting to correspond to the MNECB reference lighting level for “storage/warehouse inactive storage”

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

The procedure for modeling these spaces is as follows.

- Define the area as a separate zone
- Define zone as indirectly conditioned (Zone Element General Tab)
- Define exterior walls, floors and roof in the conventional manner
- Define walls, floors, roofs between unconditioned zone and conditioned zone as an “interior partition”. These partitions should be defined in each conditioned zone.
- Set occupant density to 1750 m²/occupant to accept MNECB defaults
- Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads
- Leave summer and winter setpoints and heating/cooling schedules at the default setting
- 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%.
- Add one light of minimal wattage to the zone to allow the calculation to proceed

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

The procedure for modeling these spaces is as follows.

- Define the area as a separate zone
- Define zone as directly conditioned (Zone Element General Tab)
- Define exterior walls, floors and roof in the conventional manner
- 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.
- Define space function as “inactive storage”
- Set minimum outdoor air, occupant density to zero to accept MNECB defaults
- Define a schedule with 0 fractional time for each hour of each day and apply this schedule to process, fan, service water heating, plug loads, occupants, and process loads
- Enter desired heating and cooling setpoints and create corresponding schedule
- Add heating and cooling capacity of zone HVAC system
- 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%.
- For lit spaces, define lighting power or for unlit spaces add 3.2 Watts/m² of lighting to correspond to the MNECB reference lighting level for “storage/warehouse inactive storage”

7.9 Interior Partitions

Interior partitions are used to describe interior heat transfer between zones. Interior partitions only need to be modeled if there is significant heat transfer between adjacent zones, which can only occur if there is a temperature difference between the zones. If adjacent zones are kept at the same setpoint temperature, and follow the same heating and cooling schedule, there is no need for an interior partition to be modeled in EE4. However, there are three cases when interior partitions should be specified:

- Adjacent zones have significantly different operating schedules (difference in operating hours is greater than 28 hours per week)
- Adjacent zones are conditioned to different temperatures (difference of greater than 3 Celsius degrees)
- One zone is air conditioned while the other adjacent zone is not

Interior partitions are defined much like exterior walls. Various construction components are entered to determine a total wall R-value. After specifying the construction type, the space to which the interior partition is adjacent must be specified. Interior partitions are only defined in one zone of the two adjacent zones. The same partition should not be entered in two different zones.

8. MODELING OF ELECTRICAL SYSTEMS

8.1 Lighting Systems

The modeling of lighting systems is relatively straightforward. The lighting power in the proposed design is the sum of the power draws of the lighting fixtures. This value should include the power for the bulbs and the ballasts. Most lights (other than incandescent and halogen) require ballasts. Ballasts increase power requirements by 10 to 25% over the rated bulb power. Lighting power can be taken from manufacturers literature or from the EE4 list of fixtures.

The space function or building type defines the lighting power density in the reference building. If space function is used to define building use, the lighting power density is multiplied by the lighting “Area Factor” to determine the “Lighting Power Allowance”. This factor accounts for the increase in lighting power required in small rooms with high ceilings. Figure 6.1 presents graphs of lighting Area Factor. The Area Factor is 1.0 for corridors, electrical/mechanical rooms, spaces in office categories 2 and 3 and indoor athletic areas (MNECB Clause 4.3.3.5). For CBIP simulations, the Area Factor is also 1.0 for office category 1.

Different Lighting Power Densities are given for three types of office spaces. It is important to select the proper office category in the EE4 software.

Office Category 1 (small office areas and open plan offices) applies to

- Office areas less than 85 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 CBIP submission, for example speculative office or retail space, where the tenant will be responsible for the lighting design. In these cases, the proposed building should use the same lighting power density (and area factor) as the reference building. In other words, there is no credit or penalty given for the lighting design.

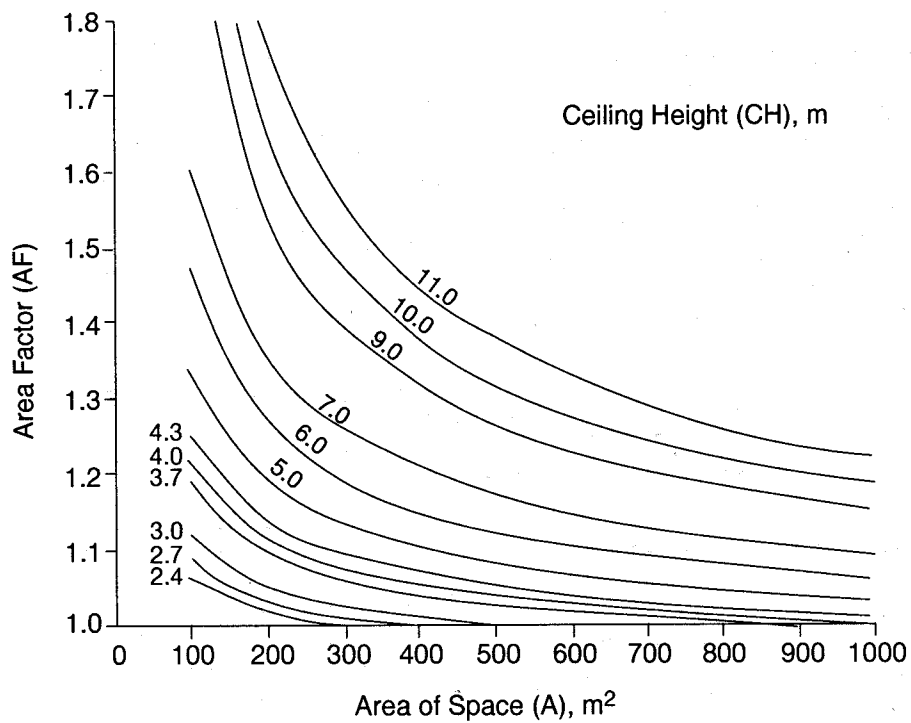
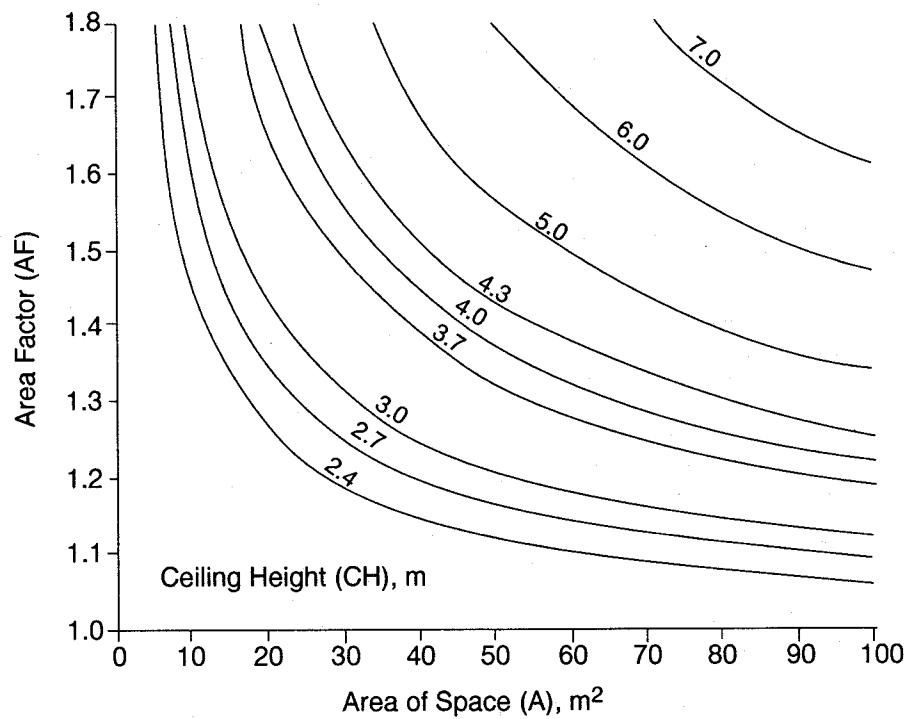


Figure 8-1 – Lighting Area Factor as a Function of Floor Area and Ceiling Height

Lighting Controls

Unlike the MNECB, the CBIP program provides energy credits for lighting controls in order to achieve the 25% energy reduction. Lighting control strategies include occupancy sensors, continuous and staged dimming in response to daylighting, and combinations of these two strategies. Table 6.1 lists the strategies and percentage reduction in lighting power that is given as an energy credit.

Table 8-1 – Lighting Control Strategies

Lighting Control Strategy		Percent Reduction in Lighting Power
Daylighting Sensing Control	– Continuous	30%
Dimming		
	- Multiple Step	20%
Dimming		
	- On/Off	10%
Occupancy Sensor		30%
Occupancy & Daylight Sensing	– Continuous	40%
Dimming		
	– Multi Step Dimming	40%
	– On/Off Dimming	40%

If only daylighting or occupancy sensors control part of the zone, the control fraction should be set to the fraction of the floor area that is controlled. Daylighting control is only effective for those areas that receive natural light. The

maximum depth of light penetration is 1.5 times the height of the window head above the floor (see Figure 6.2) or 2.5 if interior or exterior light shelves are used. The window-to-wall ratio must also be at least 20% to receive the daylighting credit. Similarly, the skylight area to floor area must be at least 5% to receive the daylighting credit.

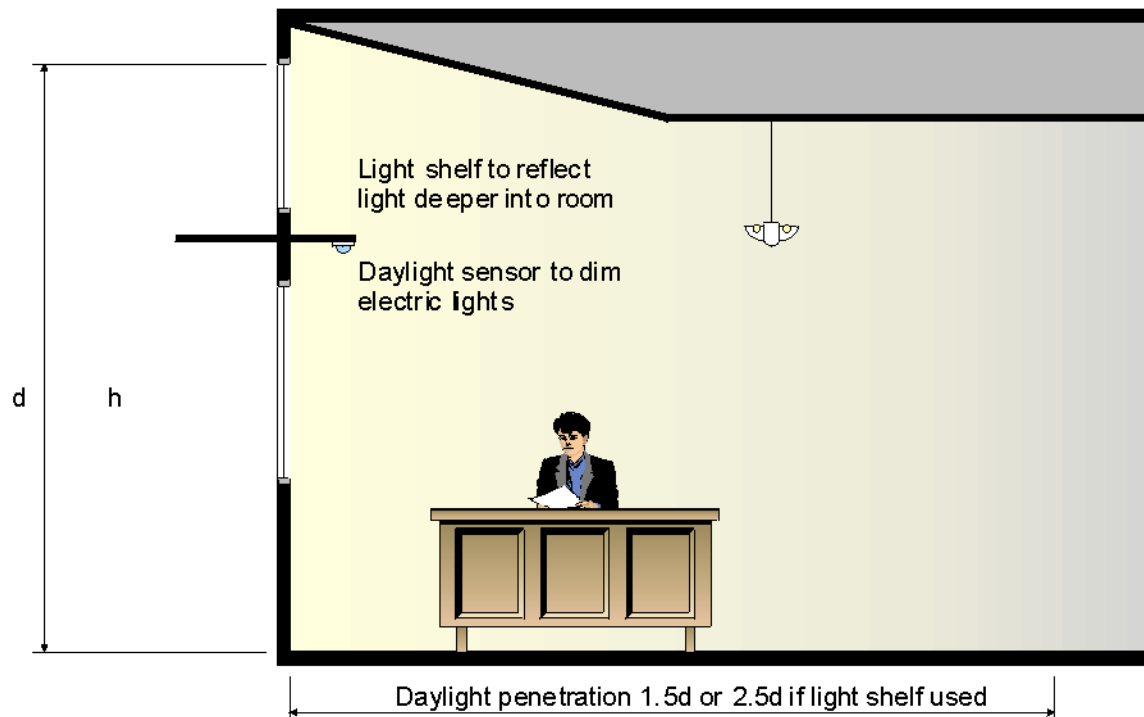


Figure 8-2 – Maximum Daylighting Penetration

It is assumed that occupancy sensors turn the lights off completely. If the lights only dim or not all lights shut off, the control fraction should be adjusted accordingly. For example, if 25% of the lights stay on, the control fraction should be set to 0.75.

Exclusions from Lighting Power Density

Several types of specialty lighting should not be included in the lighting power density. These are listed in the Model National Energy Code Table 4.3.1.2. Included are:

- Lighting for theatrical performances and entertainment
- Display lighting for galleries
- Specialized lighting for research, medical, or dental applications
- Signs and exterior fixtures
- Lighting in high security areas
- Emergency lighting

8.2 Other Electrical Systems

Elevators and Refrigeration Loads

The energy use for elevators and refrigerators is included in the default building receptacle loads. The same value is used in both the proposed and reference cases. In some buildings (e.g., supermarkets and industrial processes), process loads may be significantly higher than the default receptacle value for the space function or building type. A higher value may be used if deemed appropriate by the designer (the same value will be used in the reference building).

On a case-by-case basis, energy savings are available for using more efficient elevators and heat recovery on refrigeration systems. Simulators should contact the CBIP Technical Manager to inquire whether your application is eligible and for details on how to evaluate these systems.

Renewable Electricity Systems

Any electricity supplied from renewable sources on the building or on the building site and directly connected to the building can be counted towards the CBIP

target of 25% energy savings. Renewable energy sources include photovoltaics and wind turbines.

The performance of photovoltaic systems should be determined using the WATSUN-PV or RETScreen computer programs. The performance of wind turbines can be determined using the RETScreen software. RETScreen is available free-of-charge from the web site retscreen.gc.ca.

The computer simulated energy savings can be used as a credit in the CBIP program. The proposed building energy consumption is the value determined by EE4 (assuming no renewable energy system) less the electricity supplied by the renewable energy system as determined using WATSUN-PV or RETScreen.

The cost savings should be based on the electricity cost in the last block used by the building. No demand savings are applicable unless it can be demonstrated that the peak monthly building demand will be reduced because of the renewable energy system.

9. CBIP SUBMISSION GUIDELINES

The CBIP submission procedure is described on the CBIP website at <http://cbip.nrcan.gc.ca>. Before sending a file to NRCan for submission, the following list should be considered for a timely and successful technical review:

Make sure that simulations have been completed using the very latest version of EE4, downloaded from the site www.ee4.com.

Never submit any simulation files from a building energy program other than EE4 unless NRCan has given written permission. Include a copy of the written permission with the submission.

Always include the most recent drawings and specifications for the project, including addenda and any change orders.

Include a short written report explaining the important energy efficient features of the building, zoning and modeling strategies employed, any calculations done outside of EE4, and any difficulties encountered during the modeling process.

Take note of the checklist on page 4 of the Performance Path Worksheet, available at http://cbip.nrcan.gc.ca/cbipprocedure/pdfs/performance_e.pdf

10. TROUBLESHOOTING

Listed in this chapter are suggested solutions to some common system modeling problems or errors. Consult the EE4 on-line help and the website www.ee4.com for further troubleshooting tips.

Q. In the middle of the hourly simulation, the program suddenly crashes and exits.

A. A program crash may be due to insufficient memory or other computer problems, but often occurs because an integral system component has not been defined. For example, if one of the systems is left at “MNECB default or undefined”, the program may crash. If a 2-pipe fan coil system has been defined but a chiller has not been defined (a chiller is a necessary component in a 2-pipe fan coil system), the program may crash. Double check to make sure all necessary equipment and systems have been defined. If the crash still occurs, try running the file on a different computer.

Q. I have selected to run both “Proposed” and “Reference” buildings, but at the end of the simulation, all of the Proposed results are zero, and I get a whole bunch of EE4 errors that say “Unable to find SS-F Report”.

A. A DOE2 error has likely occurred in the proposed building. Make sure that in the “DOE2 options” tab, “Delete DOE files after run” is NOT selected. Try running the simulations, and when the errors occur again, in the CBIP\DOE directory, find the file named “filename – Proposed.BDL” and open with a text viewer (such as Windows WordPad). Scan the text for the word “error” to locate the problem.

Q. I have found a DOE2 error “Coil leaving temperature must be 6F higher than entering water temperature”.

A. Usually this error message occurs due to a high cooling load on the central coil. Try entering a higher supply cooling temperature. (e.g. increase cooling supply temperature from 12.8°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 met with baseboards. If the baseboards do not have sufficient heating capacity to meet the overnight heating load, you may need to select “Fans are always on”.

If the system type is “Packaged Constant Volume Multizone” or “Built-up Single Duct Constant Volume”, remember that the first zone listed in EE4 is the “control zone”, which controls the operation of the central air handler. For example, if the control zone selected is an internal room with no windows or envelope, the zone will demand cooling 365 days per year. The central system will deliver cold air to all zones all the time, even if the secondary zones demand heating. If the secondary zones do not have sufficient baseboard heating capacity to meet the heating load, the unmet heating load error will result. In some cases, it will be impossible to select a control zone that will not result in heating load errors. In these instances, it may be necessary to change the zoning strategy.

If the system is 2-pipe fan coil or 2-pipe induction unit, heating loads might not be met if the Spring/Fall changeover dates are not appropriately defined. Unfortunately, EE4 only allows one spring changeover date and one fall changeover date. (There is no switching back and forth between heating and cooling allowed in the shoulder seasons.) To avoid heating errors, make sure the

cooling season is minimal. (June 1 and September 15 are good changeover dates for most Canadian climate regions)

Q. I get the error “The Plant has a Boiler which will not meet the Heating Load”. But I don’t even have a boiler or any heating water in the whole building.

A. During the course of an EE4 simulation, a modeler may try modeling this several different ways. If a boiler was selected at one time, and then later removed, the command may remain in the EE4/DOE2 code. If you are certain that no system, preheat coil, reheat coil, or humidifier is demanding hot water, this error can be ignored.

Q.I have selected “Purchased Cooling”, but I get an error telling me that a chiller is required.

A. This is a bug in the EE4 software. On the Plant element, uncheck “Purchased Cooling” for a moment and select any default chiller from the list. Then check “Purchased Cooling” again. EE4 will not use the chiller you selected, but will size one based on loads, as it should for purchased cooling situations.

Appendix A. Default Window U-Values and Solar Heat Gain Coefficients

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		
Frame Type	Center of Glass	Edge of Glass	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/Aluminum Clad Wood	Wood/Vinyl	Insulated Fiberglass/Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/Aluminum Clad Wood	Wood/Vinyl	Insulated Fiberglass/Vinyl
ID Glazing Type												
Single Glazing												
1 3.2 mm glass	5.91	5.91	7.24	6.12	5.14	5.05	4.61	6.42	6.07	5.55	5.55	5.35
2 6.4 mm acrylic/polycarb	5.00	5.00	6.49	5.43	4.51	4.42	4.01	5.60	5.25	4.75	4.75	4.58
3 3.2 mm acrylic/polycarb	5.45	5.45	6.87	5.77	4.82	4.73	4.31	6.01	5.66	5.15	5.15	4.97
Double Glazing												
4 6.4 mm airspace	3.12	3.63	4.93	3.70	3.25	3.13	2.77	3.94	3.56	3.19	3.17	3.04
5 12.7 mm airspace	2.73	3.36	4.62	3.42	3.00	2.87	2.53	3.61	3.22	2.86	2.84	2.72
6 6.4 mm argon space	2.90	3.48	4.75	3.54	3.11	2.98	2.63	3.75	3.37	3.00	2.98	2.85
7 12.7 mm argon space	2.56	3.24	4.49	3.30	2.89	2.76	2.42	3.47	3.08	2.73	2.70	2.58
Double Glazing, e = 0.60 on surface 2 or 3												
8 6.4 mm airspace	2.95	3.52	4.80	3.58	3.14	3.02	2.67	3.80	3.41	3.05	3.03	2.90
9 12.7 mm airspace	2.50	3.20	4.45	3.26	2.85	2.73	2.39	3.42	3.03	2.68	2.66	2.54
10 6.4 mm argon space	2.67	3.32	4.58	3.38	2.96	2.84	2.49	3.56	3.17	2.82	2.80	2.67
11 12.7 mm argon space	2.33	3.08	4.31	3.13	2.74	2.62	2.28	3.28	2.89	2.54	2.52	2.40
Double Glazing, e = 0.40 on surface 2 or 3												
12 6.4 mm airspace	2.78	3.40	4.66	3.46	3.03	2.91	2.56	3.66	3.27	2.91	2.89	2.76
13 12.7 mm airspace	2.27	3.04	4.27	3.09	2.70	2.58	2.25	3.23	2.84	2.49	2.47	2.35
14 6.4 mm argon space	2.44	3.16	4.40	3.21	2.81	2.69	2.35	3.37	2.98	2.63	2.61	2.49
15 12.7 mm argon space	2.04	2.88	4.09	2.93	2.55	2.43	2.10	3.04	2.65	2.31	2.29	2.17
Double Glazing, e = 0.20 on surface 2 or 3												
16 6.4 mm airspace	2.56	3.24	4.49	3.30	2.89	2.76	2.42	3.47	3.08	2.73	2.70	2.58
17 12.7 mm airspace	1.99	2.83	4.05	2.89	2.52	2.39	2.07	2.99	2.60	2.26	2.24	2.13
18 6.4 mm argon space	2.16	2.96	4.18	3.01	2.63	2.51	2.17	3.13	2.74	2.40	2.38	2.26
19 12.7 mm argon space	1.70	2.62	3.83	2.68	2.33	2.21	1.89	2.75	2.36	2.03	2.01	1.90
Double Glazing, e = 0.10 on surface 2 or 3												
20 6.4 mm airspace	2.39	3.12	4.36	3.17	2.78	2.65	2.32	3.32	2.93	2.59	2.56	2.45
21 12.7 mm airspace	1.82	2.71	3.92	2.77	2.41	2.28	1.96	2.84	2.45	2.12	2.10	1.99
22 6.4 mm argon space	1.99	2.83	4.05	2.89	2.52	2.39	2.07	2.99	2.60	2.26	2.24	2.13
23 12.7 mm argon space	1.53	2.49	3.70	2.56	2.22	2.10	1.79	2.60	2.21	1.89	1.86	1.76
Double Glazing, e = 0.05 on surface 2 or 3												
24 6.4 mm airspace	2.33	3.08	4.31	3.13	2.74	2.62	2.28	3.28	2.89	2.54	2.52	2.40
25 12.7 mm airspace	1.70	2.62	3.83	2.68	2.33	2.21	1.89	2.75	2.36	2.03	2.01	1.90
26 6.4 mm argon space	1.87	2.75	3.96	2.81	2.44	2.32	2.00	2.89	2.50	2.17	2.15	2.03
27 12.7 mm argon space	1.42	2.41	3.61	2.48	2.15	2.02	1.71	2.50	2.11	1.79	1.77	1.67
Triple Glazing												
28 6.4 mm airspace	2.16	2.96	4.11	2.89	2.51	2.45	2.16	3.10	2.73	2.38	2.33	2.25
29 12.7 mm airspace	1.76	2.67	3.80	2.60	2.25	2.19	1.91	2.76	2.39	2.05	2.01	1.93
30 6.4 mm argon space	1.93	2.79	3.94	2.73	2.36	2.30	2.01	2.90	2.54	2.19	2.15	2.07
31 12.7 mm argon space	1.65	2.58	3.71	2.52	2.17	2.12	1.84	2.66	2.30	1.96	1.91	1.84
Triple Glazing, e = 0.20 on surface 2,3,4, or 5												
32 6.4 mm airspace	1.87	2.75	3.89	2.69	2.32	2.27	1.98	2.86	2.49	2.15	2.10	2.03
33 12.7 mm airspace	1.42	2.41	3.54	2.36	2.02	1.97	1.70	2.47	2.10	1.77	1.73	1.66
34 6.4 mm argon space	1.59	2.54	3.67	2.48	2.13	2.08	1.80	2.61	2.25	1.91	1.87	1.80
35 12.7 mm argon space	1.25	2.28	3.40	2.23	1.91	1.86	1.59	2.32	1.96	1.63	1.59	1.52
Triple Glazing, e = 0.20 on surfaces 2 or 3 and 4 or 5												
36 6.4 mm airspace	1.65	2.58	3.71	2.52	2.17	2.12	1.84	2.66	2.30	1.96	1.91	1.84
37 12.7 mm airspace	1.14	2.19	3.31	2.15	1.84	1.78	1.52	2.23	1.86	1.54	1.49	1.43
38 6.4 mm argon space	1.31	2.32	3.45	2.27	1.95	1.90	1.62	2.37	2.01	1.68	1.63	1.56
39 12.7 mm argon space	0.97	2.05	3.18	2.03	1.72	1.67	1.41	2.08	1.71	1.39	1.35	1.29
Triple Glazing, e = 0.10 on surfaces 2 or 3 and 4 or 5												
40 6.4 mm airspace	1.53	2.49	3.63	2.44	2.10	2.05	1.77	2.57	2.20	1.86	1.82	1.75
41 12.7 mm airspace	1.02	2.10	3.22	2.07	1.76	1.71	1.45	2.13	1.76	1.44	1.40	1.33
42 6.4 mm argon space	1.19	2.23	3.36	2.19	1.87	1.82	1.55	2.27	1.91	1.58	1.54	1.47
43 12.7 mm argon space	0.80	1.92	3.05	1.90	1.61	1.56	1.30	1.93	1.57	1.25	1.21	1.15
Quadruple Glazing, e = 0.10 on surfaces 2 or 3 and 4 or 5												
44 6.4 mm airspaces	1.25	2.28	3.40	2.23	1.91	1.86	1.59	2.32	1.96	1.63	1.59	1.52
45 12.7 mm airspaces	0.85	1.96	3.09	1.94	1.65	1.60	1.34	1.98	1.62	1.30	1.26	1.19
46 6.4 mm argon spaces	0.97	2.05	3.18	2.03	1.72	1.67	1.41	2.08	1.71	1.39	1.35	1.29
47 12.7 mm argon spaces	0.68	1.83	2.96	1.82	1.54	1.48	1.23	1.84	1.47	1.16	1.11	1.05
48 6.4 mm krypton spaces	0.68	1.83	2.96	1.82	1.54	1.48	1.23	1.84	1.47	1.16	1.11	1.05

Notes:

1. All heat transmission coefficients in this table include film resistances and are based on winter conditions of -18°C outdoor air temperature and 21°C indoor air temperature, with 24 km/h outdoor air velocity and zero solar flux. With the exception of single glazing, small changes in the indoor and outdoor temperatures will not significantly affect overall U-factors. The coefficients are for vertical position except skylight values, which are for 20° from horizontal with heat flow up.

2. Glazing layer surfaces are numbered from the outdoor to the indoor. Double, triple and quadruple refer to the number of glazing panels. All data are based on 3 mm glass, unless otherwise noted. Thermal conductivities are: 0.917 W/(m·K) for glass, and 0.19 W/(m·K) for acrylic and polycarbonate.

3. Standard spacers are metal. Edge-of-glass effects assumed to extend over the 65 mm band around perimeter of each glazing unit as in Figure 3.

Copyright 1997, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. www.ashrae.org. Reprinted by permission, ASHRAE 1997 Fundamentals Handbook.

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	2.93	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
		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
		3.39	2.77	2.46	1.99	2.83	6.17	4.86	4.56	3.43	3.46	2.83	2.51	30
		3.14	2.53	2.21	1.87	2.75	6.07	4.76	4.46	3.33	3.36	2.73	2.41	31
see 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
		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
		3.09	2.48	2.16	1.59	2.54	5.81	4.50	4.21	3.07	3.11	2.49	2.17	34
		2.80	2.19	1.87	1.53	2.49	5.75	4.44	4.15	3.02	3.07	2.44	2.12	35
see 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
		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
		2.85	2.24	1.92	1.36	2.36	5.60	4.29	4.00	2.86	2.92	2.29	1.97	38
		2.55	1.94	1.62	1.25	2.28	5.49	4.18	3.90	2.76	2.82	2.19	1.87	39
see 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
		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
		2.75	2.14	1.82	1.19	2.23	5.44	4.13	3.84	2.71	2.77	2.14	1.82	42
		2.40	1.79	1.47	1.14	2.19	5.38	4.07	3.79	2.66	2.72	2.09	1.78	43
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
		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
		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
		2.31	1.69	1.38	0.91	2.01	5.17	3.86	3.59	2.45	2.52	1.90	1.58	47
		2.31	1.69	1.38	0.74	1.87	5.01	3.70	3.43	2.29	2.38	1.75	1.43	48

Copyright 1997, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. www.ashrae.org. Reprinted by permission, ASHRAE 1997 Fundamentals Handbook.

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			Glazing SHGC at Specified Incidence Angles							Total Window SHGC at Normal Incidence			Total Window VT at Normal Incidence	
Glass Thick, ID mm	Center Glazing VT	Center Glazing SC	Normal					Hemis. (Diffuse)	Aluminum		Other Frames	All Frames		
			0°	40°	50°	60°	70°		Operable	Fixed		Operable	Fixed	
Uncoated Single Glazing														
1a 3.2 Clear	0.90	1.00	0.86	0.85	0.83	0.78	0.67	0.78	0.75	0.78	0.63	0.75	0.65	0.78
1b 6.4 Clear	0.89	0.94	0.81	0.80	0.77	0.73	0.62	0.73	0.71	0.74	0.60	0.71	0.65	0.78
1c 3.2 Bronze	0.68	0.85	0.73	0.71	0.69	0.64	0.55	0.65	0.64	0.67	0.54	0.64	0.49	0.59
1d 6.4 Bronze	0.55	0.73	0.62	0.60	0.58	0.54	0.46	0.55	0.55	0.57	0.46	0.54	0.40	0.48
1e 3.2 Green	0.82	0.82	0.71	0.68	0.66	0.62	0.53	0.63	0.62	0.65	0.53	0.62	0.60	0.71
1f 6.4 Green	0.74	0.68	0.58	0.56	0.54	0.51	0.44	0.52	0.51	0.53	0.43	0.51	0.54	0.64
1g 3.2 Gray	0.62	0.82	0.70	0.68	0.66	0.61	0.53	0.63	0.61	0.64	0.52	0.61	0.45	0.54
1h 6.4 Gray	0.43	0.65	0.56	0.53	0.51	0.48	0.41	0.49	0.50	0.51	0.42	0.49	0.31	0.37
1i 6.4 Bluegreen	0.75	0.72	0.62	0.59	0.57	0.54	0.46	0.55	0.55	0.57	0.46	0.54	0.54	0.65
Reflective Single Glazing														
1j 6.4 SS on CLR 8%	0.08	0.22	0.19	0.19	0.18	0.17	0.15	0.17	0.18	0.18	0.15	0.17	0.06	0.07
1k 6.4 SS on CLR 14%	0.14	0.29	0.25	0.25	0.24	0.23	0.20	0.23	0.23	0.24	0.19	0.22	0.10	0.12
1l 6.4 SS on CLR 20%	0.20	0.36	0.31	0.30	0.30	0.28	0.24	0.28	0.28	0.29	0.24	0.27	0.15	0.17
1m 6.4 SS on GRN 14%	0.12	0.29	0.25	0.25	0.24	0.23	0.20	0.23	0.23	0.24	0.19	0.22	0.09	0.10
1n 6.4 TI on CLR 20%	0.20	0.34	0.29	0.29	0.28	0.26	0.23	0.27	0.27	0.27	0.22	0.26	0.15	0.17
1o 6.4 TI on CLR 30%	0.30	0.45	0.39	0.38	0.37	0.35	0.30	0.35	0.35	0.36	0.29	0.34	0.22	0.26
Uncoated Double Glazing														
5a 3.2 CLR CLR	0.81	0.87	0.75	0.73	0.70	0.63	0.49	0.65	0.66	0.68	0.55	0.66	0.59	0.71
5b 6.4 CLR CLR	0.78	0.81	0.70	0.68	0.65	0.58	0.45	0.60	0.61	0.64	0.52	0.61	0.57	0.68
5c 3.2 BRZ CLR	0.62	0.72	0.62	0.59	0.57	0.51	0.39	0.53	0.55	0.57	0.46	0.54	0.45	0.54
5d 6.4 BRZ CLR	0.48	0.59	0.50	0.47	0.45	0.40	0.31	0.42	0.45	0.46	0.37	0.44	0.35	0.42
5e 3.2 GRN CLR	0.74	0.70	0.60	0.57	0.55	0.49	0.38	0.51	0.53	0.55	0.45	0.53	0.54	0.64
5f 6.4 GRN CLR	0.66	0.54	0.47	0.44	0.42	0.38	0.30	0.40	0.42	0.43	0.35	0.41	0.48	0.57
5g 3.2 GRY CLR	0.56	0.69	0.59	0.57	0.54	0.48	0.37	0.50	0.52	0.54	0.44	0.52	0.41	0.49
5h 6.4 GRY CLR	0.40	0.51	0.44	0.42	0.40	0.35	0.28	0.38	0.39	0.41	0.33	0.39	0.29	0.35
5i 6.4 BLUGRN CLR	0.67	0.58	0.50	0.47	0.45	0.40	0.32	0.43	0.45	0.46	0.37	0.44	0.49	0.58
5j 6.4 HI-P GRN CLR	0.59	0.46	0.39	0.37	0.35	0.31	0.25	0.33	0.35	0.36	0.29	0.34	0.43	0.51
Reflective Double Glazing														
5k 6.4 SS on CLR 8%,CLR	0.07	0.15	0.13	0.13	0.12	0.12	0.10	0.12	0.13	0.13	0.10	0.12	0.05	0.06
5l 6.4 SS on CLR 14%, CLR	0.13	0.20	0.17	0.17	0.16	0.15	0.12	0.15	0.17	0.16	0.13	0.15	0.09	0.11
5m 6.4 SS on CLR 20%, CLR	0.18	0.26	0.22	0.21	0.21	0.19	0.16	0.19	0.21	0.21	0.17	0.20	0.13	0.16
5n 6.4 SS on GRN 14%, CLR	0.11	0.18	0.16	0.16	0.15	0.14	0.12	0.14	0.16	0.16	0.13	0.14	0.08	0.10
5o 6.4 TI on CLR 20%, CLR	0.18	0.24	0.21	0.20	0.20	0.18	0.15	0.19	0.20	0.20	0.16	0.19	0.13	0.16
5p 6.4 TI on CLR 30%, CLR	0.27	0.33	0.29	0.28	0.27	0.25	0.20	0.25	0.27	0.27	0.22	0.26	0.20	0.24
Low-e Double Glazing, e = 0.2 on Surface 2														
17a 3.2 LE CLR	0.76	0.76	0.65	0.63	0.61	0.55	0.43	0.57	0.57	0.59	0.48	0.57	0.55	0.66
17b 6.4 LE CLR	0.73	0.70	0.60	0.58	0.56	0.51	0.40	0.52	0.53	0.55	0.45	0.53	0.53	0.64
Low-e Double Glazing, e = 0.2 on Surface 3														
17c 3.2 CLR LE	0.76	0.81	0.70	0.68	0.65	0.59	0.46	0.61	0.61	0.64	0.52	0.61	0.55	0.66
17d 6.4 CLR LE	0.73	0.75	0.65	0.63	0.60	0.54	0.42	0.56	0.57	0.59	0.48	0.57	0.53	0.64
17e 3.2 BRZ LE	0.58	0.66	0.57	0.54	0.52	0.46	0.36	0.48	0.50	0.52	0.42	0.50	0.42	0.51
17f 6.4 BRZ LE	0.45	0.52	0.45	0.42	0.40	0.35	0.27	0.37	0.40	0.41	0.34	0.40	0.33	0.39
17g 3.2 GRN LE	0.70	0.63	0.55	0.52	0.50	0.44	0.34	0.46	0.49	0.50	0.41	0.48	0.51	0.61
17h 6.4 GRN LE	0.61	0.48	0.42	0.39	0.37	0.33	0.25	0.35	0.38	0.39	0.32	0.37	0.44	0.53
17i 3.2 GRY LE	0.53	0.63	0.54	0.51	0.49	0.43	0.33	0.46	0.48	0.50	0.40	0.47	0.38	0.46
17j 6.4 GRY LE	0.37	0.46	0.39	0.36	0.34	0.31	0.24	0.33	0.35	0.36	0.29	0.34	0.27	0.32
17k 6.4 BLUGRN LE	0.62	0.52	0.45	0.42	0.40	0.35	0.27	0.37	0.40	0.41	0.34	0.40	0.45	0.54
17l 6.4 HI-P GRN LE	0.55	0.40	0.34	0.31	0.29	0.26	0.20	0.28	0.31	0.32	0.26	0.30	0.40	0.48
Low-e Double Glazing, e = 0.1 on Surface 2														
21a 3.2 LE CLR	0.75	0.62	0.54	0.52	0.49	0.44	0.34	0.46	0.48	0.50	0.40	0.47	0.54	0.65
21b 6.4 LE CLR	0.72	0.59	0.51	0.49	0.47	0.42	0.32	0.44	0.45	0.47	0.38	0.45	0.52	0.63
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
Low-e Double Glazing, e = 0.1 on Surface 3														
21c 3.2 CLR LE	0.75	0.69	0.60	0.58	0.56	0.51	0.41	0.53	0.53	0.55	0.45	0.53	0.54	0.65
21d 6.4 CLR LE	0.72	0.66	0.56	0.54	0.52	0.47	0.38	0.49	0.50	0.51	0.42	0.49	0.52	0.63
21e 3.2 BRZ LE	0.57	0.56	0.48	0.46	0.43	0.39	0.31	0.41	0.43	0.44	0.36	0.42	0.41	0.50
21f 6.4 BRZ LE	0.45	0.45	0.39	0.37	0.34	0.31	0.24	0.33	0.35	0.36	0.29	0.34	0.33	0.39
21g 3.2 GRN LE	0.68	0.57	0.49	0.47	0.44	0.40	0.31	0.42	0.44	0.45	0.37	0.43	0.49	0.59
21h 6.4 GRN LE	0.61	0.45	0.39	0.36	0.34	0.30	0.24	0.33	0.35	0.36	0.29	0.34	0.44	0.53
21i 3.2 GRY LE	0.52	0.53	0.46	0.44	0.41	0.37	0.29	0.39	0.41	0.42	0.34	0.41	0.38	0.45
21j 6.4 GRY LE	0.37	0.40	0.35	0.33	0.31	0.28	0.22	0.29	0.32	0.33	0.26	0.31	0.27	0.32
21k 6.4 BLUGRN LE	0.62	0.48	0.42	0.39	0.37	0.33	0.26	0.35	0.38	0.39	0.32	0.37	0.45	0.54

Copyright 1997, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. www.ashrae.org. Reprinted by permission, ASHRAE 1997 Fundamentals Handbook.

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			Glazing SHGC at Specified Incidence Angles							Total Window SHGC at Normal Incidence				Total Window VT at Normal Incidence	
Glass Thick, ID mm	Center Glazing VT	Center Glazing SC	Normal		Hemis. (Diffuse)				Aluminum		Other Frames		All Frames		
			0°	40°	50°	60°	70°	Operable	Fixed	Operable	Fixed	Operable	Fixed		
Low-e Double Glazing, e = 0.05 on Surface 2															
25a 3.2 LE CLR	0.72	0.48	0.41	0.38	0.34	0.26	0.14	0.35	0.37	0.38	0.31	0.36	0.52	0.63	
25b 6.4 LE CLR	0.70	0.43	0.37	0.34	0.31	0.24	0.13	0.32	0.33	0.34	0.28	0.33	0.51	0.61	
25c 6.4 BRZ W/LE CLR	0.42	0.30	0.26	0.24	0.22	0.18	0.10	0.23	0.24	0.24	0.20	0.23	0.31	0.37	
25d 6.4 GRN W/LE CLR	0.60	0.35	0.30	0.28	0.25	0.20	0.11	0.26	0.28	0.28	0.23	0.27	0.44	0.52	
25e 6.4 GRY W/LE CLR	0.35	0.27	0.24	0.22	0.20	0.16	0.10	0.20	0.22	0.23	0.18	0.21	0.25	0.30	
25f 6.4 BLUE W/LE CLR	0.45	0.32	0.27	0.25	0.23	0.18	0.10	0.23	0.25	0.25	0.21	0.24	0.33	0.39	
25g 6.4 HI-P GRN W/LE CLR	0.53	0.31	0.27	0.26	0.25	0.23	0.18	0.24	0.00	0.00	0.22	0.25	0.38	0.46	
Triple Glazing															
29a 3.2 CLR CLR CLR	0.74	0.78	0.67	0.65	0.61	0.53	0.39	0.57	0.59	0.61	0.50	0.59	0.54	0.64	
29b 6.4 CLR CLR CLR	0.70	0.71	0.61	0.58	0.55	0.48	0.35	0.51	0.54	0.56	0.45	0.54	0.51	0.61	
29c 6.4 HI-P GRN CLR CLR	0.53	0.39	0.34	0.31	0.29	0.25	0.19	0.27	0.31	0.32	0.26	0.30	0.38	0.46	
Triple Glazing, e = 0.2 on Surface 2															
32a 3.2 LE CLR CLR	0.68	0.69	0.60	0.58	0.55	0.48	0.35	0.51	0.53	0.55	0.45	0.53	0.49	0.59	
32b 6.4 LE CLR CLR	0.64	0.62	0.53	0.50	0.47	0.41	0.30	0.44	0.47	0.49	0.39	0.47	0.46	0.56	
Triple Glazing, e = 0.2 on Surface 5															
32c 3.2 CLR CLR LE	0.68	0.72	0.62	0.60	0.56	0.49	0.36	0.52	0.55	0.57	0.46	0.54	0.49	0.59	
32d 6.4 CLR CLR LE	0.64	0.65	0.56	0.53	0.50	0.44	0.32	0.47	0.50	0.51	0.42	0.49	0.46	0.56	
Triple Glazing, e = 0.1 on Surface 2 and 5															
40a 3.2 LE CLR LE	0.62	0.52	0.45	0.43	0.40	0.36	0.26	0.38	0.40	0.41	0.34	0.40	0.45	0.54	
40b 6.4 LE CLR LE	0.59	0.47	0.41	0.39	0.37	0.32	0.24	0.34	0.37	0.38	0.31	0.36	0.43	0.51	
Triple Glazing, e = 0.05 on Surface 2 and 4															
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								Low-e coating with an emittance of 0.2 is a pyrolytic coating. Other low-e coatings are sputtered coatings.							
Reflective coating descriptors include percent visible transmittance as x%.								VT is Visible Transmittance, SC is Shading Coefficient, SHGC, is Solar Heat Gain Coefficient, and HEMIS is the hemispherical SHGC							
Hi-P GRN = high performance green tinted glass, LE = glass with a low-emissivity coating with an emittance of e = 0.xx								ID numbers refer to U-factors in Table 5							
								SHGC at 90° is 0.							

Copyright 1997, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. www.ashrae.org.

Reprinted by permission, ASHRAE 1997 Fundamentals Handbook.

Appendix B. Building Type & Space Functions: Default Assumptions

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

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, define:

- 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.

- 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 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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.

- 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 all heat is provided by the rooftop unit, and no reheat units are installed, select “none”.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

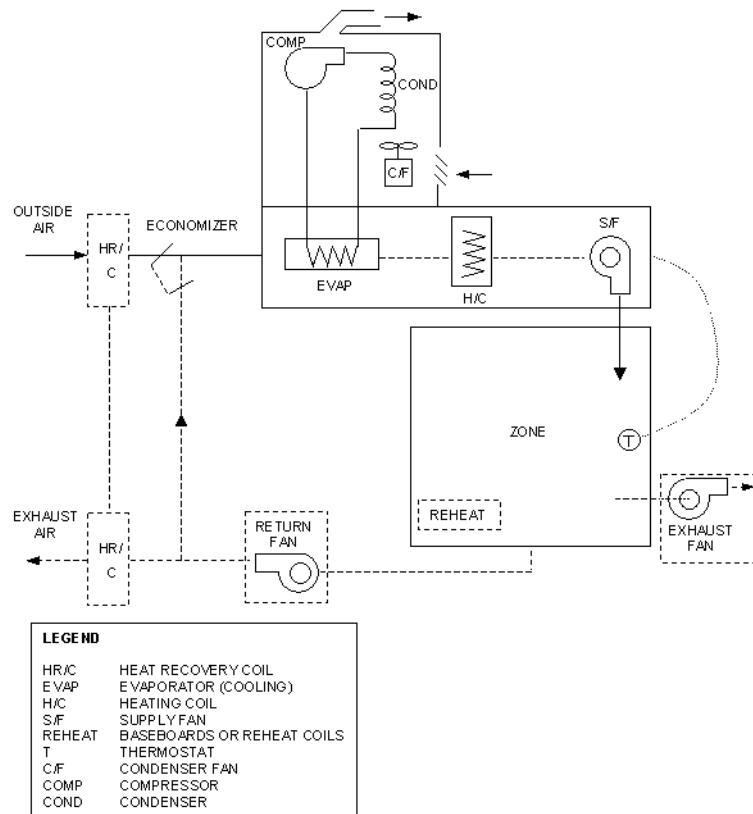


Figure 10-1 – DX Single Zone Schematic

Packaged Constant Volume Multizone System

The Packaged Constant Volume Multizone System provides constant volume air to a single control zone plus a number of optional sub-zones. The system cools by the direct expansion of a refrigerant and may heat with a fuel-fired furnace, hot water, an electric resistance heater, or a heat pump. The temperature of the supply air is varied and heat may be supplemented by an independent heating system (i.e. baseboards) to maintain space temperature. Packaged Constant Volume Multizone Systems can be either packaged (rooftop) units or split systems.

In the Central System Library, define:

- Heating Type and Capacity

Enter the source of heat for the heating coil in the packaged unit 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.

- 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 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- 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 all heat is provided by the rooftop unit, and no reheat units are installed, select “none”.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

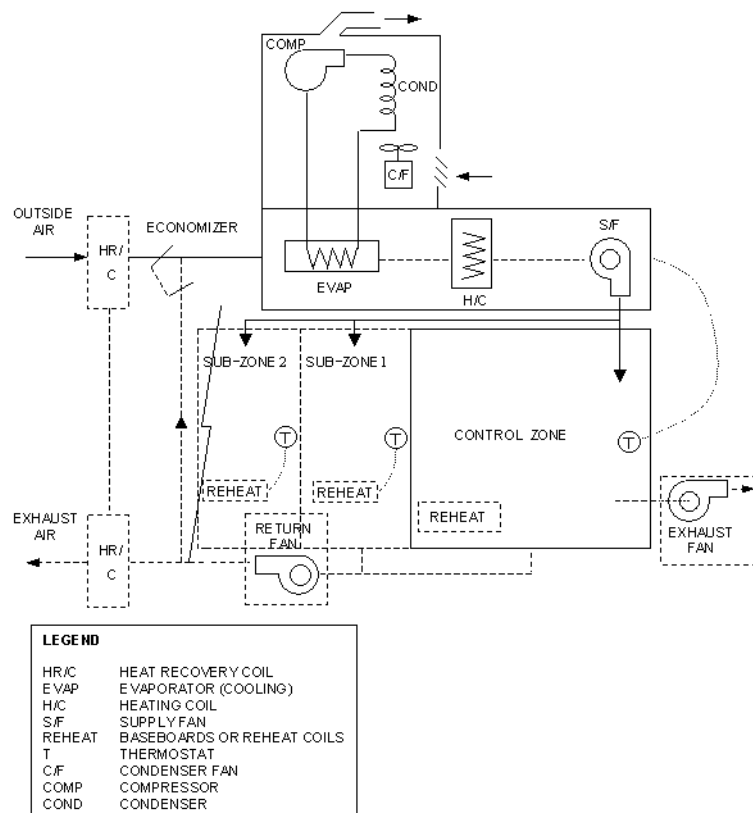


Figure 10-2 – Packaged Constant Volume Multizone System Schematic

Built-Up Single-Duct CV System

The built-up single-duct CV system consists of a central air-handling unit that contains a heating device, cooling coil and a supply air fan. The system provides constant volume heating and cooling to multiple, individually controlled zones. The temperature of the 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. 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, define:

- Heating Type and Capacity

Enter the source of heat for the heating coil in the built-up system 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.

- 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

Indicate the type of control for supply air leaving the air-handling unit. Three options are available:

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

2. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
3. Outdoor Air Reset – The cooling coil discharge temperature is set hourly based upon the temperature difference between the outdoor air temperature and zone temperature.

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

- 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- 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 all heat is provided by the rooftop unit, and no reheat units are installed, select “none”.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

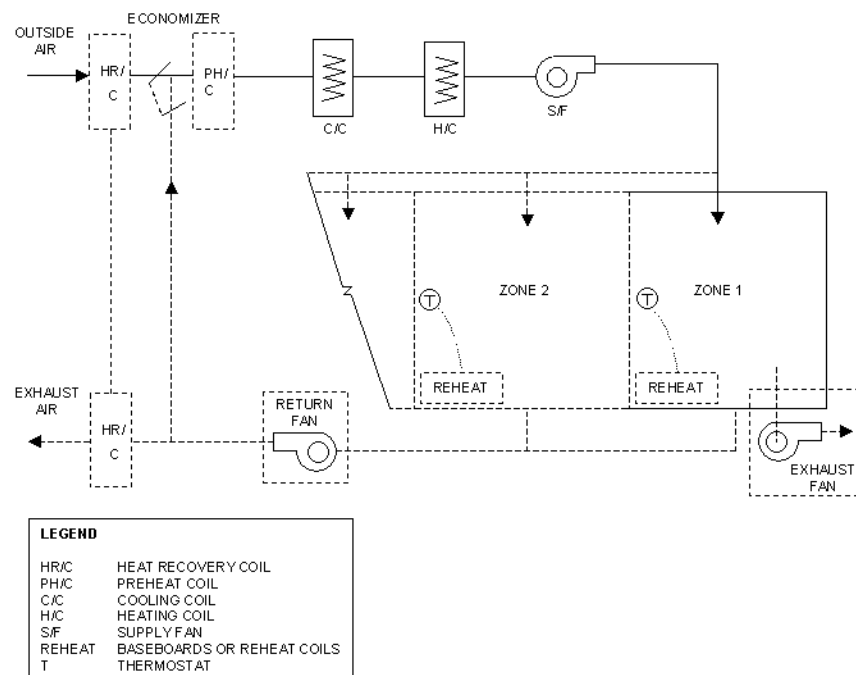


Figure 10-3 – Built-Up Single-Duct CV System Schematic

Hydronic Heat Pump

In this system, unitary hydronic heat pumps provide both heating and cooling to individually controlled zones. The individual water-to-air heat pumps in each zone accept energy from a common water loop when in heating mode and reject energy to the common water loop when in cooling mode. Heat addition/extraction may be required to maintain the loop temperature if the heating and cooling loads are not balanced. The heat addition/extraction required may be provided by a boiler/cooling tower or by a ground loop. If cooling demand is such that the

energy rejected to the loop exceeds the energy added to the loop, heat is rejected. If the heating demand exceeds the cooling demand, heat is added.

A central make-up air unit supplies tempered outdoor air for the zonal heat pumps. EE4 CBIP sets the outdoor airflows to each of the zones to the airflow needed to meet the MNECB minimum outdoor air requirement. You may specify a higher outdoor airflow to each zone in the Room Element/Occupant Tab.

Central System Library inputs are reserved for defining the make-up air system, while the individual heat pump characteristics are defined in the Zone Element/Mechanical Tab. Note that the heat pump heating and cooling outputs and the rated heat pump performance characteristics (heating/cooling COP) defined in the Zone Element/Mechanical Tab should not include the influence of fan power.

In the Central System Library, define:

- Heating Type and Capacity

Enter the source of heat for the make-up air unit 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.

- 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.

- Supply Temperature

Enter the temperature to which the make-up air heated before being distributed throughout the building. The heating supply temperature should be relatively low because a make-up air heater is intended to only temper the outdoor air; most of the

heating is provided by the zone-level system. The heating supply temperature must be lower than the cooling supply temperature or an error will result.

- **Cooling Characteristics**

Enter the make-up air unit cooling capacity and the percent of the capacity that is sensible. If the sensible fraction is unknown, choose the default value of 75%.

Enter the temperature to which the air is tempered by the make-up air unit before being distributed throughout the building. The cooling supply temperature must be greater than the heating supply temperature or an error will result.

Choose the type of cooling for the make-up air unit. If the unit contains a direct expansion coil, choose "DX". If the unit is supplied with chilled water from central chiller, choose "hydronic" and specify the chiller in the central plant.

If DX is selected as the cooling type, 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.

- **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**

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 is not entered for this system type. The flow rate of the make-up air unit will be fixed at the minimum outdoor air requirement specified by the occupancy type.

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.

In the Room Element/Exhaust Tab, define:

- 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.

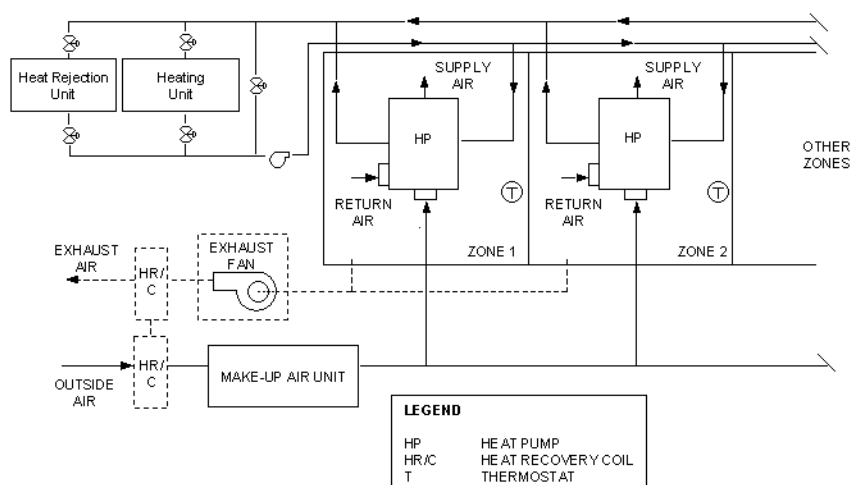


Figure 10-4 – Hydronic Heat Pump Schematic

Packaged VAV

The packaged VAV system is a variable-volume system. Cooling is provided to the zones by the direct expansion of a refrigerant and heating by a fossil fuel-

fired furnace, hot water, an electric resistance heater, or a heat pump. The system operates differently in the cooling mode than it does in the heating mode. In cooling mode, zone reset schedules are assumed to control the supply air temperature from the cooling coil. During heating, the volume of air is held constant at the minimum airflow value specified by the user and the supply air temperature from the air handling unit's heating coil is held constant at 13 °C (55 °F). Reheat coils or baseboards provide the heating energy to heat the supply air from 13 °C (55 °F) to the temperature required to meet the zone loads.

In the Central System Library, define:

- Heating Type and Capacity

Enter the source of heat for the heating coil in the packaged unit 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.

- 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 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- 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 all heat is provided by the rooftop unit, and no reheat units are installed, select “none”.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

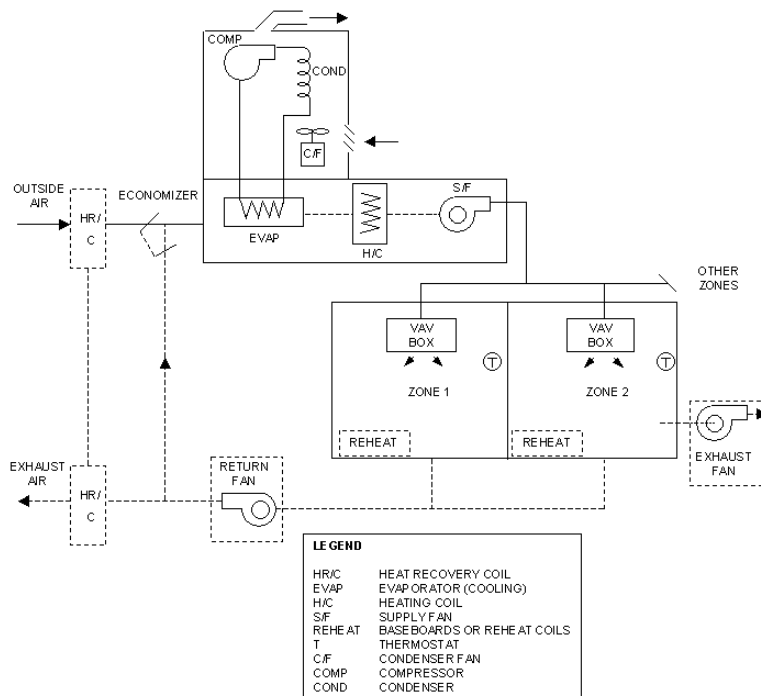


Figure 10-5 – Packaged VAV Schematic

Packaged MZ

This is a multizone constant volume system that provides cooling by the direct expansion of a refrigerant and provides heating either with a fossil fuel-fired furnace, hot water, or an electric resistance heater. Multizone air handling units contain hot deck and cold deck air streams that are maintained above and below the desired supply temperature. Zone temperatures are maintained by mixing hot and cold air in the proper proportions in response to zone loads. The two air streams are mixed using dampers located within the air-handling unit and the proper temperature air is provided as it leaves the unit. Heat may be supplemented by an independent heating system (i.e. baseboards) to maintain space temperatures in the zones.

The three possible strategies for controlling the heating coil and cooling coil exit temperatures are constant temperature, zone reset and outside air reset. If the user specifies constant temperature coil control, the temperature of the air leaving the associated coil is set to a fixed value, specified by the user. If the

user specifies the heating coil control to be zone reset, the hot deck temperature is reset to meet the needs of the coldest zone. Similarly, if zone reset is specified for cooling coil control, the cold deck temperature is reset to meet the needs of the warmest zone. Finally, if the user specifies outside air reset as the heating or cooling coil strategy, the heating and/or cooling supply air temperature is based upon outside air temperature.

In the Central System Library, define:

- Heating Type and Capacity

Enter the source of heat for the heating coil in the packaged unit 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.

- Coil Control

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

1. Constant Temperature – The cooling supply temperature is set to a constant value.
2. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
3. 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.

- 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 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.

- **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. 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 setpoint (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 setpoint (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:

1. **Operate Fans According to Schedule** – The fan operates according to the “Fans” schedule entered in the zone element.
2. **Fans Are Always On** – The fans run continuously.
3. **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.

- Return Fan

Enter the return fan static pressure and combined 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

- 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 all heat is provided by the rooftop unit, and no reheat units are installed, select “none”.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

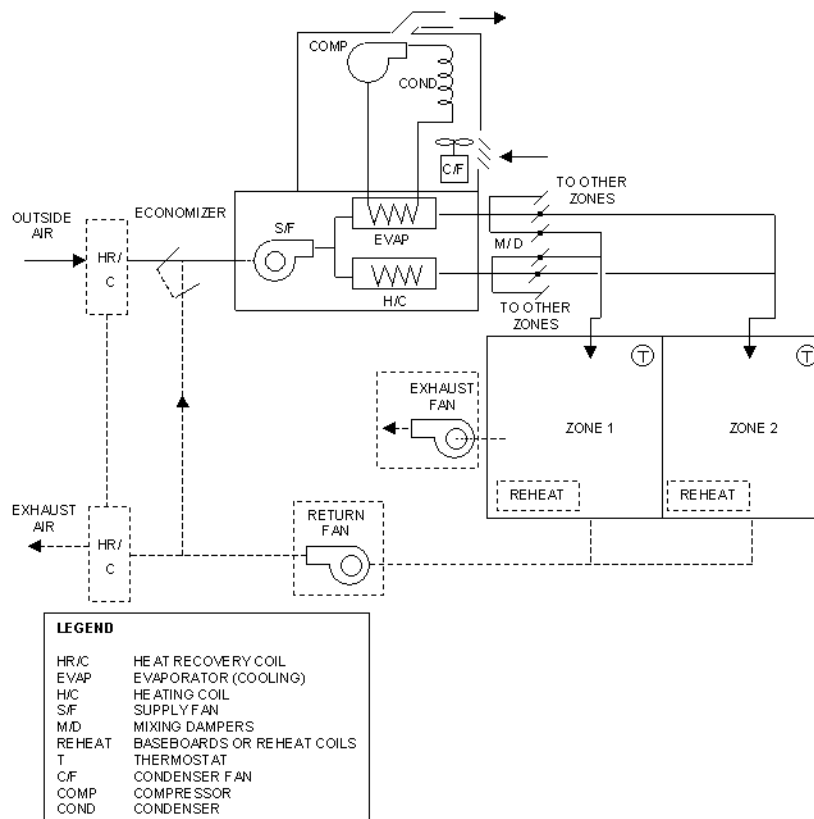


Figure 10-6 – Packaged MZ Schematic

Built-up Single Zone

The built-up single zone system is a variable air temperature system that provides constant volume, forced air heating and cooling for a single zone. The air-handling unit contains a heating device, a cooling coil and a supply fan. The temperature of the air supplied to the zone is controlled from a thermostat that senses the space conditions in the zone. Heat may be supplemented by an independent heating system (i.e. baseboards) to maintain the space temperature in the zone.

Optional features: return fan, outdoor air economizer, heat recovery, zone reheat coils/baseboards, preheat coil, exhaust fans in any or all zones.

In the Central System Library, define:

- 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.

- 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 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.

- 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- 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”.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

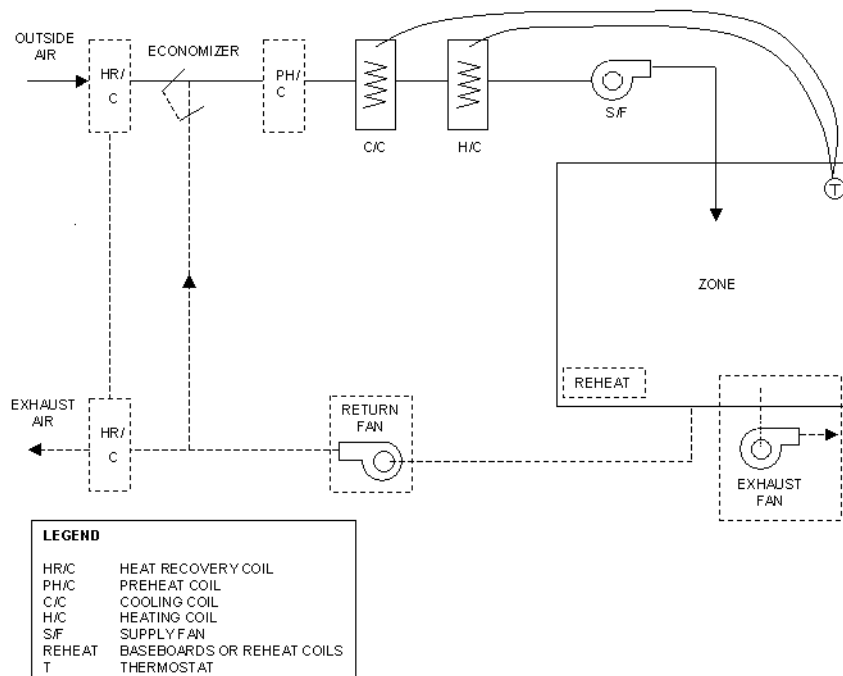


Figure 10-7 – Built-up Single Zone Schematic

Built-up VAV

The built-up VAV system consists of a central air-handling unit that contains a heating device, cooling coil and a supply air fan. Variable-air-volume terminal units are located in each zone. To meet peak cooling loads, the VAV terminal units allow a maximum airflow (input by the user). The airflow rate is reduced proportionally to meet reduced cooling loads and zone reset schedules are assumed to control the supply air temperature from the cooling coil. The system operates differently during heating. The supply airflow rate is held constant at the minimum allowable and the supply air temperature is held constant at 13°C (55 °F). Reheat coils or baseboards then provide the heating energy to heat the supply air from 13°C (55 °F) to the temperature required to meet the zone loads.

In the Central System Library, define:

- 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.

- 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 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.

- 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. 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 setpoint (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 setpoint (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:

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

Choose one of 4 options for fan control:

1. Riding the fan curve
2. Air foil or backward inclined with vanes
3. Forward curved with vanes
4. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- 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”.

- Humidity

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

In 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 consumption at this flow rate.

In the Room Element/Exhaust Tab, define:

- 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.

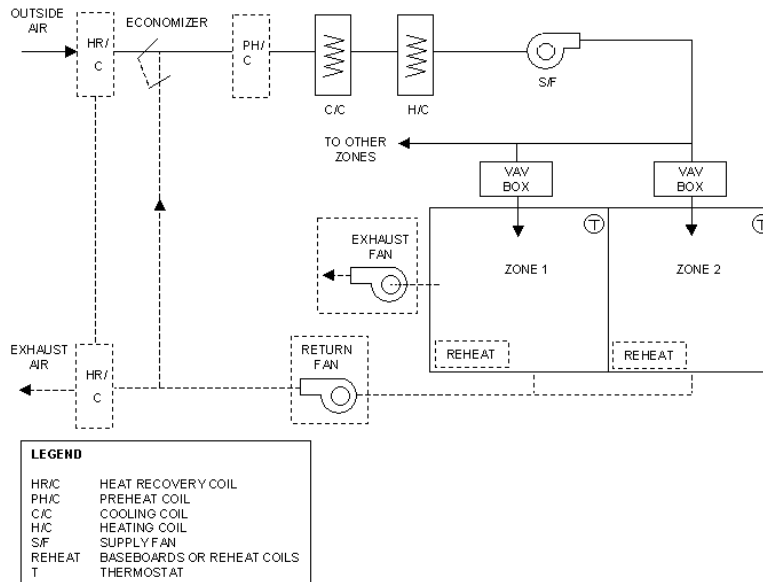


Figure 10-8 – Built-up VAV Schematic

Built-up Multizone

The built-up multizone system is a constant volume system that provides heating and/or cooling to individually controlled zones. The air-handling unit contains a heating device, cooling coil and a supply fan. Multizone air handling units contain hot deck and cold deck air streams which are maintained above and below the desired supply temperature in response to zone loads. The two air streams are mixed using dampers located within the air-handling unit and the proper temperature air is provided as it leaves the unit. Heat may be supplemented by an independent heating system (i.e. baseboards) to maintain the space temperature in the zone.

The three possible strategies for controlling the heating coil and cooling coil exit temperatures are constant temperature, zone reset and outside air reset. If the user specifies constant temperature coil control, the temperature of the air leaving the associated coil is set to a fixed value, specified by the user. If the user specifies the heating coil control to be zone reset, the hot deck temperature is reset to meet the needs of the coldest zone. Similarly, if zone reset is specified for cooling coil control, the cold deck temperature is reset to meet the needs of the warmest zone. Finally, if the user specifies outside air reset as the heating or

cooling coil strategy, the heating and/or cooling supply air temperature is based upon outside air temperature.

In the Central System Library, define:

- 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.

- Coil Control

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

1. Constant Temperature – The cooling supply temperature is set to a constant value.
2. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
3. 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.

- 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 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.

- 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- **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”.

- **Humidity**

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

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.

In the Room Element/Exhaust Tab, define:

- **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.

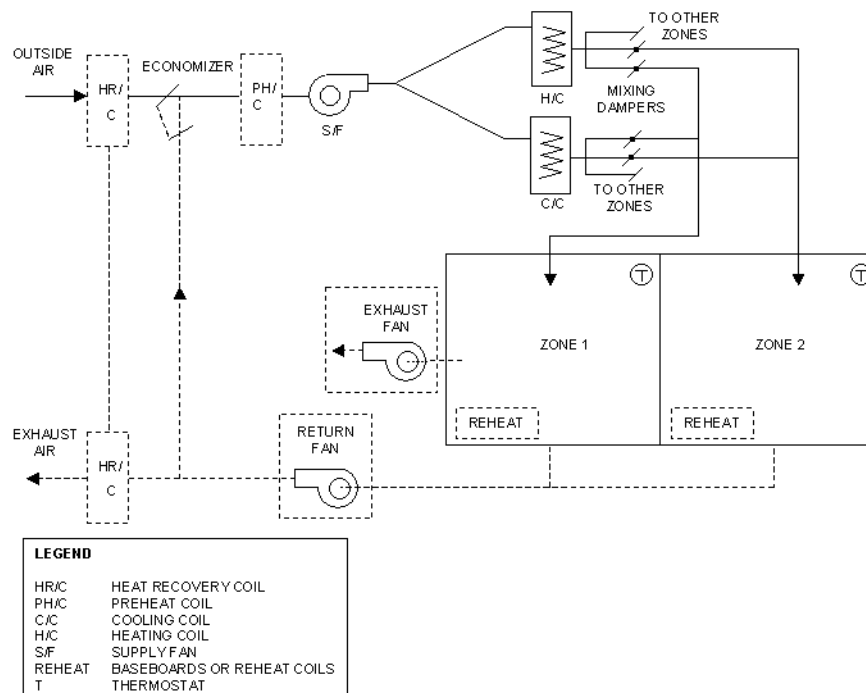


Figure 10-9 – Built-up Multizone Schematic

Dual-Duct

The dual-duct 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:

- 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.

- Coil Control

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

1. Constant Temperature – The cooling supply temperature is set to a constant value.
2. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
3. 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.

- 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 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.

- 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. 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 setpoint (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 setpoint (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:

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

Choose one of 4 options for fan control:

1. Riding the fan curve
2. Air foil or backward inclined with vanes
3. Forward curved with vanes
4. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- 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”.

- Humidity

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

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.

- 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 consumption at this flow rate.

In the Room Element/Exhaust Tab, define:

- 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.

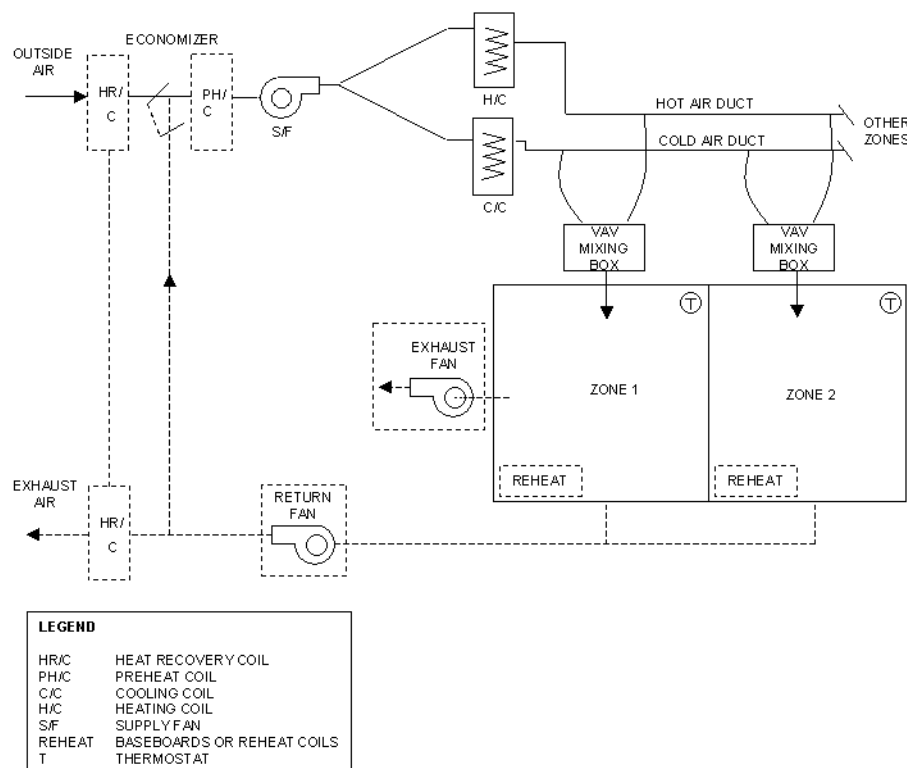


Figure 10-10 – Dual-Duct Schematic

Dual-Fan Dual Duct System

The dual-fan dual duct system is a variable-air-volume system. The central air-handling unit has two supply fans: one supply fan moves air through a cold duct and a second supply fan moves air through a hot duct. The two air streams are mixed in individual mixing boxes that serve each zone. Outdoor air is supplied to the cold duct only. A return fan, if present, delivers air to both the cold duct and the hot duct supply fans. Space temperatures are maintained by mixing the hot air stream and the cold air stream in proper proportions.

The three possible strategies for controlling the heating coil and cooling coil exit temperatures in the hot duct and cold duct, respectively, are constant temperature, zone temperature reset and outside air reset. If the user specifies constant temperature coil control, the temperature of the air leaving the associated coil is set to a fixed value, specified by the user. If the user specifies the heating coil control to be zone temperature reset, the temperature of the air leaving the heating coil in the hot duct is reset to meet the needs of the coldest zone. Similarly, if zone temperature reset is specified for the cooling coil control, the temperature of the air leaving the cooling coil in the cold duct is reset to meet the needs of the warmest zone. Finally, if the user specifies outside air reset as the heating or cooling coil strategy, the heating and/or cooling supply air temperature is based upon outside air temperature.

Optional features: return fan, outdoor air economizer, heat recovery, zone reheat coils/baseboards, preheat coil, exhaust fans in any or all zones.

In the Central System Library, define:

- 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.

- Coil Control

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

1. Constant Temperature – The cooling supply temperature is set to a constant value.
2. Zone Reset – The cooling coil is set hourly to cool the zone with the highest temperature.
3. 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.

- 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 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.

- 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. 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 setpoint (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 setpoint (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.

- 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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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:

1. Riding the fan curve
2. Air foil or backward inclined with vanes
3. Forward curved with vanes
4. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- **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”.

- **Humidity**

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

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 outdoor air is provided by the cold duct 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 consumption at this flow rate.

In the Room Element/Exhaust Tab, define:

- **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.

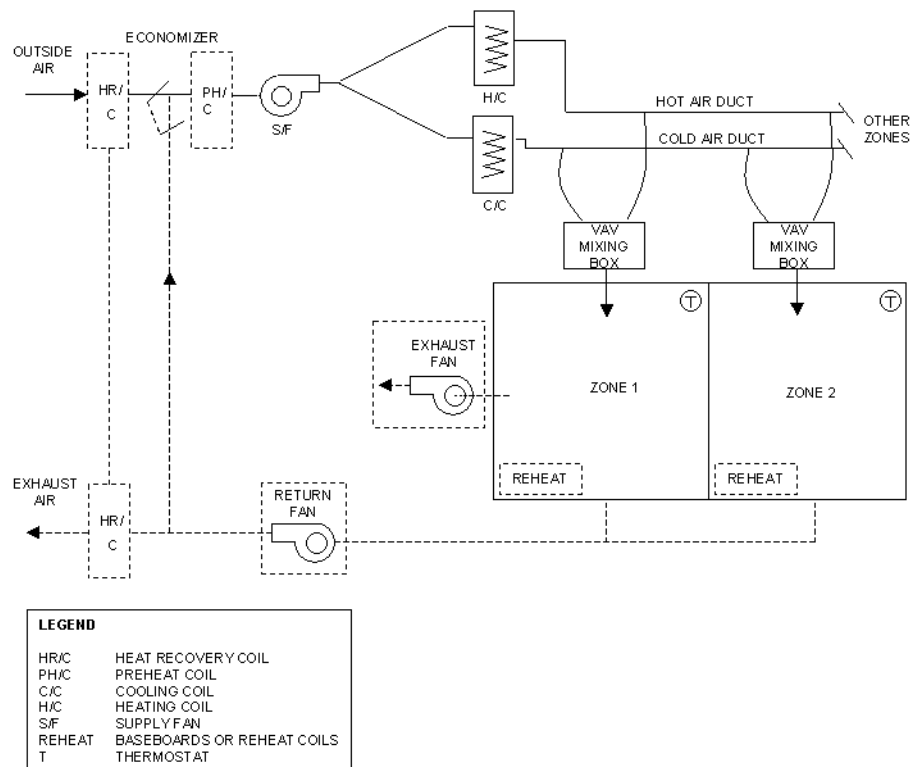


Figure 10-11 – Dual Fan Dual Duct Schematic

2-Pipe Fan Coil System

The 2-pipe fan coil system provides heating and cooling to individually controlled zones via combination heating/cooling coils. All zones served by the system must be operating in the same mode (i.e. heating or cooling) at any given time. The individual fan coils supply constant volume air to the zones. Cooling or heating is provided by circulating chilled water or hot water through the coil. The temperature of the supply air is controlled by throttling the flow of water through the coil. Seasonal changeover is required and must be scheduled in the Plant Element/Heat Pump Tab.

Tempered outdoor air is supplied to the fan coils via a central make-up air unit system. EE4 CBIP sets the outdoor airflows to each of the zones to the airflow needed to meet the MNECB minimum outdoor air requirements. Alternatively, higher outdoor airflows can be supplied in the Room Element/Occupant Tab.

Central System Library inputs are reserved for defining the make-up air system, while the individual fan coil unit characteristics are defined in the Zone Element/Mechanical Tab. Heating and cooling outputs of the fan coil units, defined in the Zone Element/Mechanical Tab, should not include the influence of fan power.

If the make-up air system has cooling capability and is served by a chiller that also serves the fan coil units, the performance characteristic (COP) of the chiller should be the value entered in the Central System Library/Cooling Tab.

In the Central System Library, define:

- Heating Type and Capacity

Enter the source of heat for the make-up air unit 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.

- 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.

- Supply Temperature

Enter the temperature to which the make-up air heated before being distributed throughout the building. The heating supply temperature should be relatively low because a make-up air heater is intended to only temper the outdoor air; most of the

heating is provided by the zone-level system. The heating supply temperature must be lower than the cooling supply temperature or an error will result.

- **Cooling Characteristics**

Enter the make-up air unit cooling capacity and the percent of the capacity that is sensible. If the sensible fraction is unknown, choose the default value of 75%.

Enter the temperature to which the air is tempered by the make-up air unit before being distributed throughout the building. The cooling supply temperature must be greater than the heating supply temperature or an error will result.

Choose the type of cooling for the make-up air unit. If the unit contains a direct expansion coil, choose "DX". If the unit is supplied with chilled water from central chiller, choose "hydronic" and specify the chiller in the central plant.

If DX is selected as the cooling type, 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.

- **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**

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 is not entered for this system type. The flow rate of the make-up air unit will be fixed at the minimum outdoor air requirement specified by the occupancy type.

- **Humidity**

If an electric or hot water humidifier is installed, specify the type and minimum humidity setpoint on the "Humidity" tab. Humidifiers are modeled identically in proposed and reference buildings.

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.

In the Room Element/Exhaust Tab, define:

- 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.

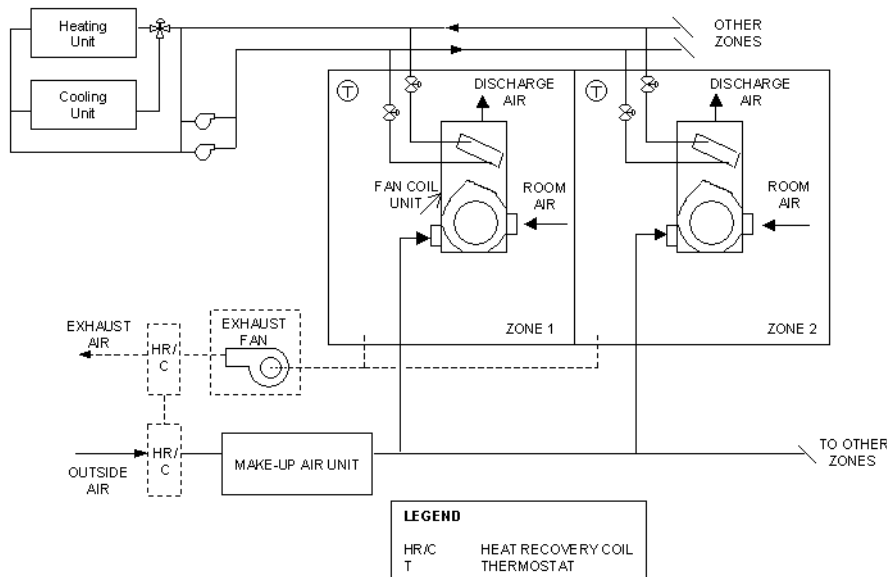


Figure 10-12 – 2-Pipe Fan Coil System Schematic

4-Pipe Fan Coil System

The 4-pipe fan coil system is identical to the 2-pipe fan coil system with the exception that the fan coil units in this system have separate heating and cooling

coils rather than a combined heating/cooling coil. This configuration allows simultaneous cooling and heating loads in different zones to be met concurrently. The individual fan coils supply constant volume air to the zones. Circulating chilled water through the cooling coil provides cooling and circulating hot water through the heating coil provides heating. The temperature of the supply air is controlled by throttling the flow of water through the coils.

Tempered outdoor air is supplied to individual zone fan coils from a central make-up air unit system. The outdoor airflows to each of the zones are set to the airflow needed to meet the MNECB minimum outdoor air requirements. Alternatively, higher outdoor airflows may be specified in the Room Element/Occupant Tab.

Central System Library inputs are reserved for defining the make-up air system, while the individual fan coil unit characteristics are defined in the Zone Element/Mechanical Tab. Note that the heating and cooling outputs of the fan coil units defined in the Zone Elements/Mechanical Tab should not include the influence of fan power.

If the make-up air system has cooling capability and is served by a chiller that also serves the fan coil units, the performance characteristic (COP) of the chiller should be the value entered in Central System Library/Cooling Tab.

In the Central System Library, define:

- Heating Type and Capacity

Enter the source of heat for the make-up air unit 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.

- 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.

- Supply Temperature

Enter the temperature to which the make-up air heated before being distributed throughout the building. The heating supply temperature should be relatively low because a make-up air heater is intended to only temper the outdoor air; most of the heating is provided by the zone-level system. The heating supply temperature must be lower than the cooling supply temperature or an error will result.

- Cooling Characteristics

Enter the make-up air unit cooling capacity and the percent of the capacity that is sensible. If the sensible fraction is unknown, choose the default value of 75%.

Enter the temperature to which the air is tempered by the make-up air unit before being distributed throughout the building. The cooling supply temperature must be greater than the heating supply temperature or an error will result.

Choose the type of cooling for the make-up air unit. If the unit contains a direct expansion coil, choose "DX". If the unit is supplied with chilled water from central chiller, choose "hydronic" and specify the chiller in the central plant.

If DX is selected as the cooling type, 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.

- 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

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 is not entered for this system type. The flow rate of the make-up air unit will be fixed at the minimum outdoor air requirement specified by the occupancy type.

Heat is provided by the rooftop unit and no reheat units are installed, select "none".

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

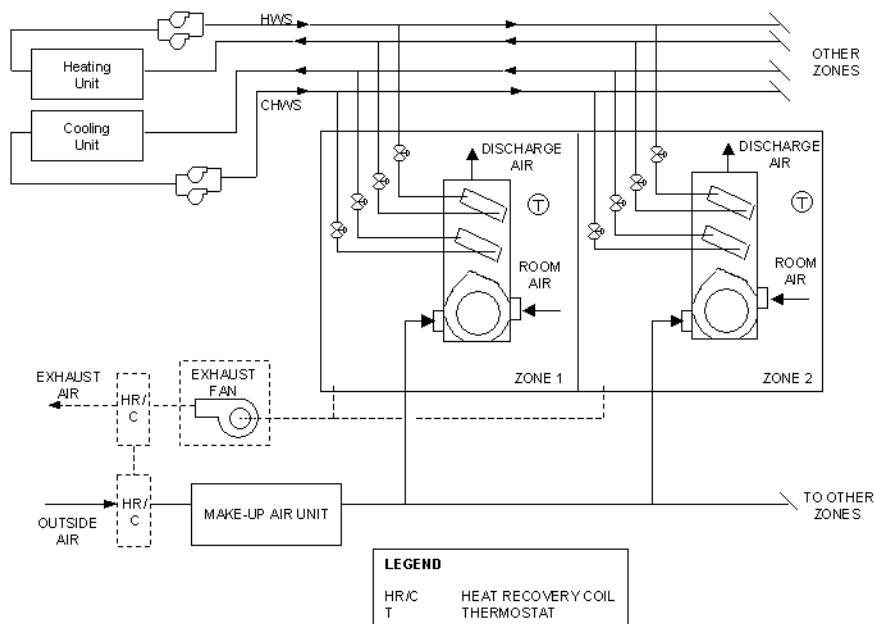


Figure 10-13 – 4-Pipe Fan Coil System Schematic

2-Pipe Induction Unit System

The 2-pipe induction unit system is a mixed air-hydronic system that can provide both heating and cooling to a number of individually controlled zones via combination heating/cooling coils. All zones served by the system must be operating in the same mode (i.e. heating or cooling) at any given time. A constant flow rate of primary air is supplied to induction-type terminal devices in each zone. Primary air is discharged through the nozzles in each unit, a secondary or induced flow of room air results. The combined airflow is then heated or cooled by the combination heating/cooling coil. Temperature control is achieved by throttling the flow of water to the combination heating/cooling coil. Seasonal changeover is required and must be scheduled in the Plant Element/Heat Tab.

Note that the maximum airflow rate entered by the user in Zone Element/Mechanical Tab airflow rate is the amount of air from the central air-handling unit delivered to the zone and does not include the induced air.

In the Central System Library, define:

- 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.

- 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 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.

- 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- 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.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

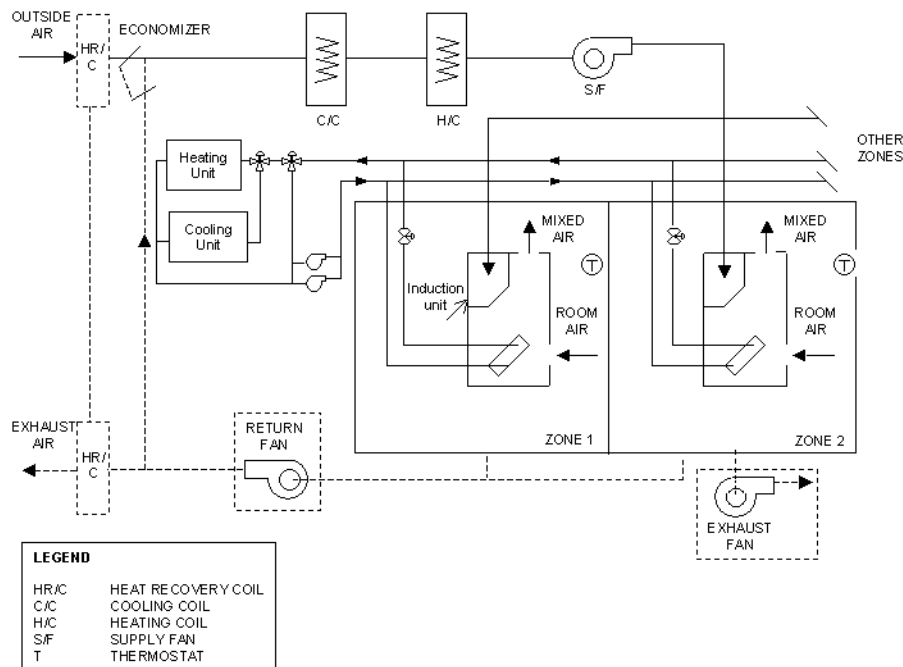


Figure 10-14 – 2-Pipe Induction Unit System Schematic

4-Pipe Induction Unit System

The 4-pipe induction unit system is identical to the 2-pipe induction unit system, with the exception that 4-pipe induction units have separate heating and cooling coils. Thus, the induction unit in one zone can provide heating at the same time that a unit in another zone provides cooling. The control system for each unit provides automatic switchover from cooling to heating (and vice versa) as required to maintain space temperature conditions.

Note that the maximum airflow rate entered by the user in Zone Element/Mechanical Tab airflow rate is the amount of air from the central air-handling unit delivered to the zone and does not include the induced air.

In the Central System Library, define:

- 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.

- 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 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.

- 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. 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 setpoint (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 setpoint (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:

1. Operate Fans According to Schedule – The fan operates according to the “Fans” schedule entered in the zone element.
2. Fans Are Always On – The fans run continuously.
3. 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.

- Return Fan

Enter the return fan static pressure and combined 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

- Preheat Coil

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

- 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.

- Humidity

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

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.

In the Room Element/Exhaust Tab, define:

- 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.

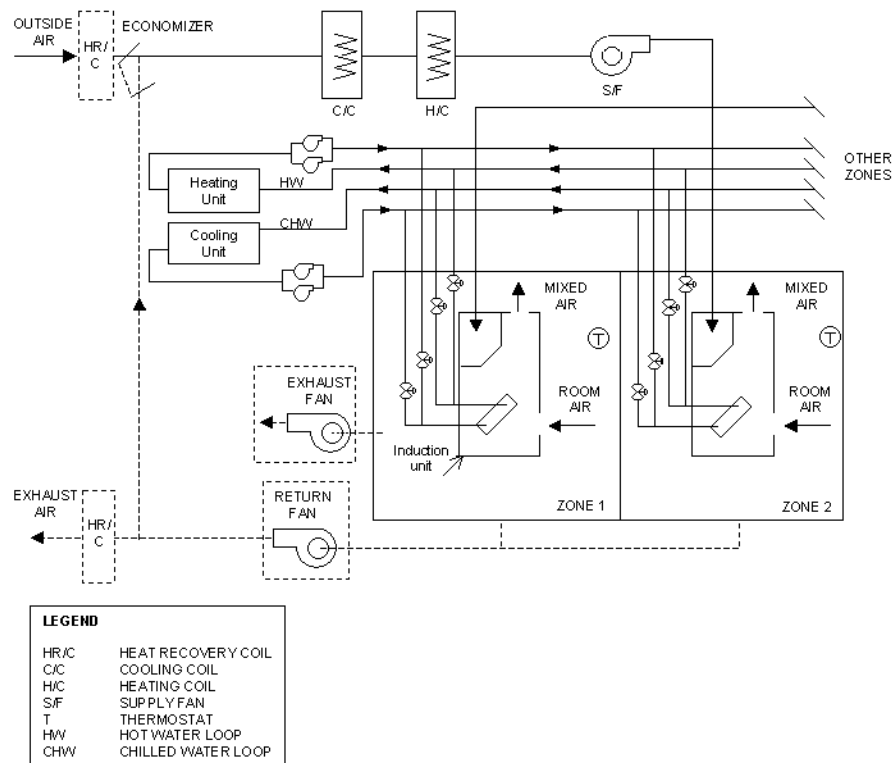


Figure 10-15 – 4-Pipe Induction Unit System Schematic