Bridging mechanical design & compliance modeling

Title 24 Complex HVAC Energy Models and Resources

Guidance and example models that translate real mechanical systems into accurate Title 24 compliance models - closing the design-to-model gap for California energy modelers.

THE PROCESS

Version 1

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About this Guide

California Title 24 compliance modeling sits at the intersection of two very different worlds: mechanical system design and energy simulation software. Mechanical drawings show equipment. CBECC asks for objects. The gap between those two things - figuring out which software objects represent the system in front of you, what choices they require, and what compliance implications follow - is where practitioners get stuck.

This guide was built to close that gap.

Each example starts with a recognizable HVAC system type, the kind you would find on a set of California mechanical drawings or in an equipment schedule. From there, it walks through how that system translates into CBECC 2025 objects, what inputs matter, what the code requires, and what assumptions were made along the way. Working model files accompany each example so you can open them, inspect them, and adapt them to your own projects.

The examples were selected based on where the design-to-model translation gap is most consequential: single-zone systems that span the Air and Zone System classes, dedicated outdoor air systems, VRF configurations, and multifamily ventilation setups that practitioners have described as the single most pressing gap in available guidance.

Project Background

This resource was developed as part of the Addressing Complex HVAC Systems in Code Compliance project, funded by Southern California Edison through the CalBEM working group. The project grew out of a clear finding: no clear resource available to California compliance practitioners addresses how to translate mechanical system designs into accurate compliance models.

Project Team

This project was developed by A2 Efficiency with support from West Monroe.

How to Use This Guide

Each section of this guide corresponds to a single HVAC example. The examples are independent; you do not need to read them in order. Navigate to the system type that matches what you are working on.

What Each Example Includes

- **Mechanical description** - a plain-language overview of how the system works and how it is typically encountered in California design practice
- **System diagram** - a schematic showing the primary components and how they connect
- **CBECC object hierarchy** - a component tree showing how the system is structured in the software, with notes on object types and key settings
- **Equipment sizing and efficiency tables** - capacities, efficiencies, and setpoints organized by system level
- **Code section references** - the Title 24 2025 Part 6 sections that govern each major modeling decision
- **Software screenshots** - annotated CBECC input screens highlighting settings that require particular attention
- **Modeling assumptions log** - documentation of non-code-mandated choices including schedules, infiltration, and internal loads

Prototype Buildings

All examples are applied to one of two prototype buildings: a single-story small office of approximately 13,830 sf, or a five-story mid-rise multifamily building with 88 dwelling units and ground-floor retail. Both are fictitious and are not intended for permitting. All examples are modeled in Climate Zone 9.

Working Model Files

CBECC project files (.xml) accompany each example and follow a consistent naming convention. File names identify the building type, the system type, and any key variant. You can open these files directly in CBECC 2025, inspect the object configuration, and use them as a starting point for your own models.

Project Scope and Feedback

This guide covers systems that can be accurately modeled in CBECC 2025 at the time of writing. Systems that cannot currently be represented in compliance software are documented separately, with an explanation of the limitation and a pointer toward future software development priorities. Where the software permits multiple valid modeling approaches for the same physical system, both pathways are documented along with the compliance implications of each.

The examples reflect Title 24 2025 Part 6 requirements and are modeled in Climate Zone 9. Equipment efficiencies are set to code minimum unless noted otherwise. Modeling assumptions that go beyond what the code requires are called out explicitly so you can adjust them for your own projects.

Questions and Feedback

This resource was developed for the practicing compliance modeling community, and it will improve with practitioner input. If you encounter a configuration that is not covered here, find an error in the modeling approach, or have questions about how to apply these examples to your own work, the CalBEM working group and EnergyCodeAce platform are the best places to raise those questions with the broader community.

Terminology and Acronyms

Below is the key terminology at a glance for quick reference. Full definitions for each term are included in the appendix.

ORGANIZATIONAL

EOR
Engineer of Record

CEC
California Energy Commission

—
Design Team

HERS
Home Energy Rating System

AHJ
Authority Having Jurisdiction

CalBEM
CA Building Energy Modeling Symposium

CZ
Climate Zone

BUILDING & CODE

T24
Title 24 Part 6

CBECC
CA Building Energy Code Compliance

NR
Non-Residential Buildings

—
Proposed Design

—
Performance Compliance

—
Thermal Zone

ACM
Alternate Calculation Method

MF
Multi-Family Buildings

HVAC
Heating, Ventilation & Air Conditioning

—
Standard Design

—
Prescriptive Compliance

—
Efficiency Metrics

CBECC SOFTWARE

—
DwellUnitType

—
Air Systems

—
Terminal Units

—
Outdoor Air Object

—
Plant System

—
Heat Recovery (object)

—
DOASVAV (Air System type)

—
Zone Systems

—
Air Segment

—
Fluid Loop

—
Dwelling Unit

Terminology and acronym quick reference continued.

MECHANICAL SYSTEMS		SYSTEM TYPES	
AHU Air Handling Unit	**IAQ** Indoor Air Quality	**VAV** Variable Air Volume	**CAV** Constant Air Volume
DCV Demand-Controlled Ventilation	**DHW** Domestic Hot Water	**PVAV** Packaged VAV Air Handler	**DOAS** Dedicated Outdoor Air System
HPWH Heat Pump Water Heater	**VSD** Variable Speed Drive	**VRF** Variable Refrigerant Flow	**DFHP** Dual Fuel Heat Pump
CRAC Computer Room Air Conditioner	— Plant Systems	**HRV** Heat Recovery Ventilator	**ERV** Energy Recovery Ventilator
— Distribution Systems	— Zone Terminal Units	**AWHP** Air-to-Water Heat Pump	**WSHP** Water Source Heat Pump
— Zone Conditioning Systems	— Single Zone System	**FPFC** Four-Pipe Fan Coil	**PTHP** Packaged Terminal Heat Pump
— Multi-Zone System	— Cooling Tower	**SZHP** Single-Zone Heat Pump	**SZAC** Single-Zone Air Conditioner
— Boiler	— Chiller	**SZVAVDFHP** Single-Zone VAV Dual Fuel Heat Pump	
ISUP/CEXH Individual Supply / Central Exhaust	— HP Lockout / Compressor Lockout		

Prototype Models Overview

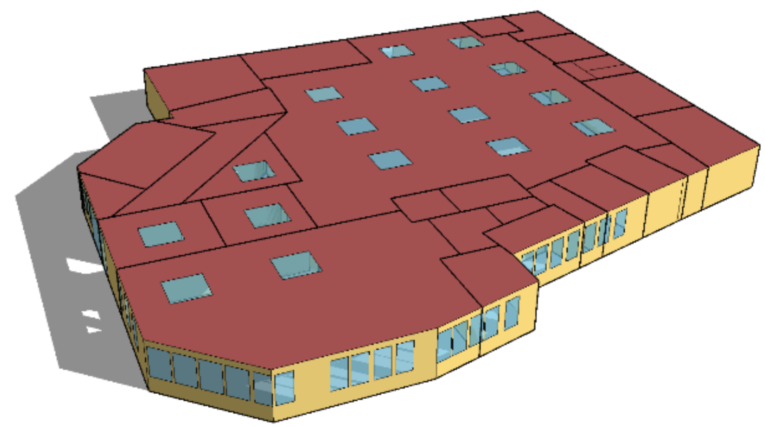
Custom Small Office

A2 Efficiency utilized a small office building to develop example non-residential HVAC system examples, providing more varied space and zoning definitions for the model and system architecture.

The building is based on a single-story office in California and includes several typical support spaces, such as conference rooms, IT/electrical space, breakroom and lounge, and an entrance reception area. The model granularity enabled the team to assign specific space types in CBECC and group those spaces under larger thermal zones based on each HVAC system architecture and level of control.

A summary of the building space use and key assumptions is provided here, with additional detail in the appendix. The model aligns all major non-HVAC inputs with the Title 24, 2025 standard for climate zone 9.

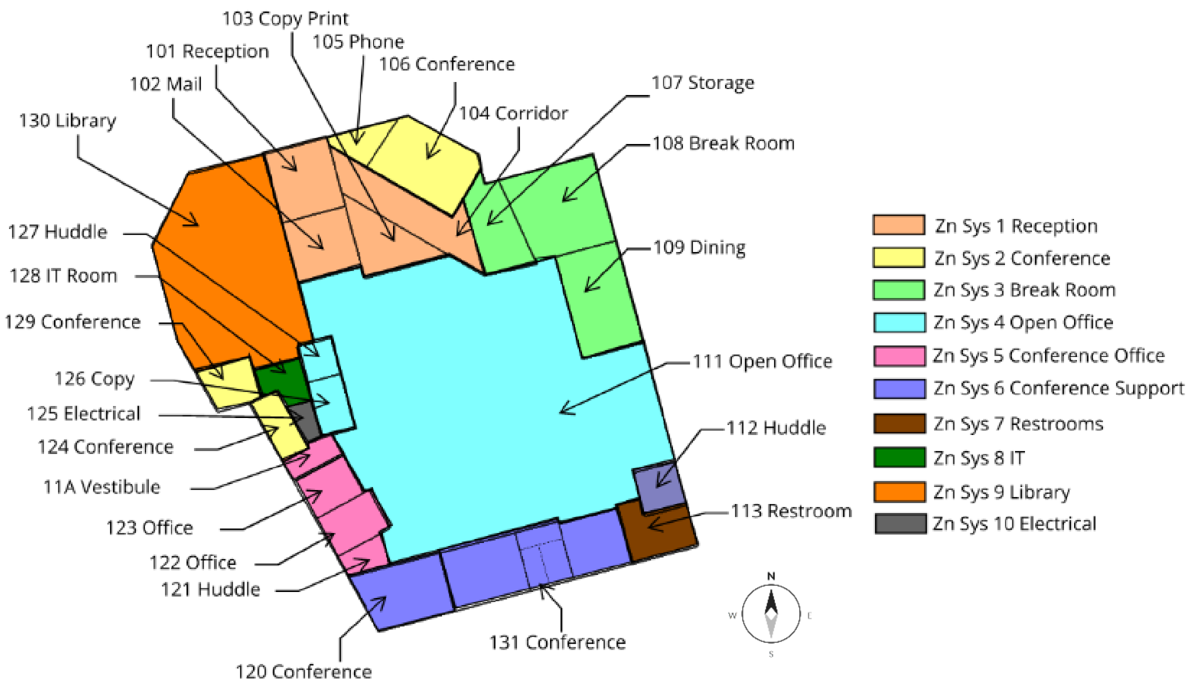
Characteristic	Input
Envelope	Standard Code, T24 2025
Lighting	Standard Code, T24 2025
HVAC	Custom, Prescriptive and Beyond Code
DHW	Standard Code, T24 2025
Solar/Battery	Standard Code, T24 2025



Characteristic	Value
Building Type	Small Office
Building Category	Nonresidential
Space Uses	Lobby, Corridor, Office, Conference, Lounge, Computer Room, E/M Room, Storage, Restroom
Conditioned Floor Area	13,830 sf
Total Floor Area	13,894 sf
Shape & Dimensions	Primarily square form with perimeter articulation
Number of Floors	1
Windows	892 sf WWR 20%: N 29%, E 13%, S 2%, W 28%.
Skylights	SRR 5.8%: 16 units · ~49 sf ea.
Shading Exterior	none
Floor to floor/ceiling	10 ft / 10 ft

Spaces and Thermal Zones

The floor plan below shows each space in the model, labeled by name and room number. The colored sections indicate the thermal zones where one system serves all spaces within. The areas of the thermal zones are shown for reference.



Thermal Zone	Area (ft²)
Zn Sys 1 Reception	1,392
Zn Sys 2 Conference	929
Zn Sys 3 Break Room	1,414
Zn Sys 4 Open Office	5,962
Zn Sys 5 Conference-Office	578
Zn Sys 6 Conference-Support	1,359
Zn Sys 7 Restrooms	245
Zn Sys 8 IT and Elec	132
Zn Sys 9 Library	1,818
Zn Sys 10 Elec	64
Total (conditioned zones)	**13,830**

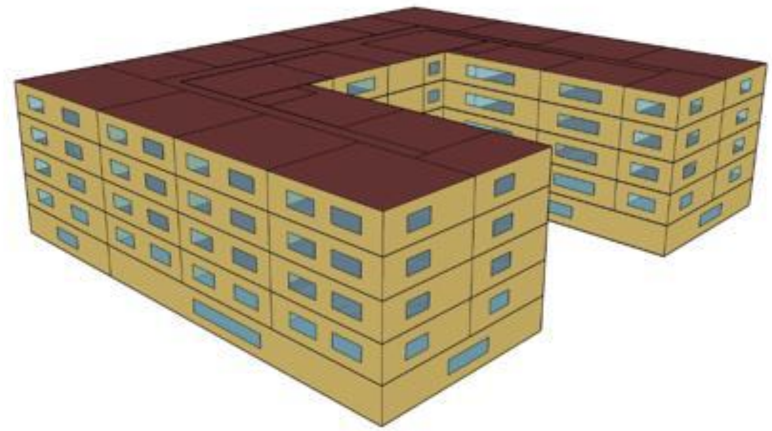
Further details on base building assumptions, including envelope, lighting and internal gains, PV and battery, DHW, base building systems, the IDF electrical HVAC system, and building elevations, are included in the appendix.

Multifamily, Midrise

A midrise multifamily building was used by A2 Efficiency to develop example residential HVAC system examples. The selected prototype model provides a common multifamily building configuration with a typical construction approach and floor plan layout.

The building is based on a five-story multifamily structure, including a first floor made up of non-residential retail spaces. The model provides a familiar base for comparing different multifamily HVAC systems and configurations.

A summary of the building space uses and key assumptions is provided here, with additional detail in the appendix. The model aligns all major non-HVAC inputs with the Title 24, 2025 standard for climate zone 9.



Characteristic	Input
Envelope	Standard Code, T24 2025
Lighting	Standard Code, T24 2025
HVAC	Custom, Beyond Code
DHW	Standard Code, T24 2025
Solar/Battery	Standard Code, T24 2025

Characteristic	Value
Building Type	Multifamily Mixed-Occupancy
Building Category	Mid-Rise Residential (Residential + Nonresidential)
Space Uses	Dwelling Units, GF Retail, Corridors, Amenities
Residential Conditioned Area	95,028 sf (Floors 2–5)
NR Conditioned Area	17,613 sf (GF Retail + F1 Common Areas)
Total Conditioned Area	112,641 sf
Total Unconditioned Area	28,284 sf (parking garage, mechanical spaces)
Residential Dwelling Units	88 (8 Studio, 40 1-Bed, 32 2-Bed, 8 3-Bed)
Shape & Dimensions	Rectangular with central courtyard layout
Number of Floors	5 above grade (GF NR / FL 2–5 Residential)
Windows - NR (GF)	659 sf, WWR 10%
Windows - Res (FL 2-5)	10,183 sf, WWR 30.1%: N 29.7, E 30%, S 31%, W 29.9%.
Shading Exterior	None
Floor to Ceiling Height	10 ft typical

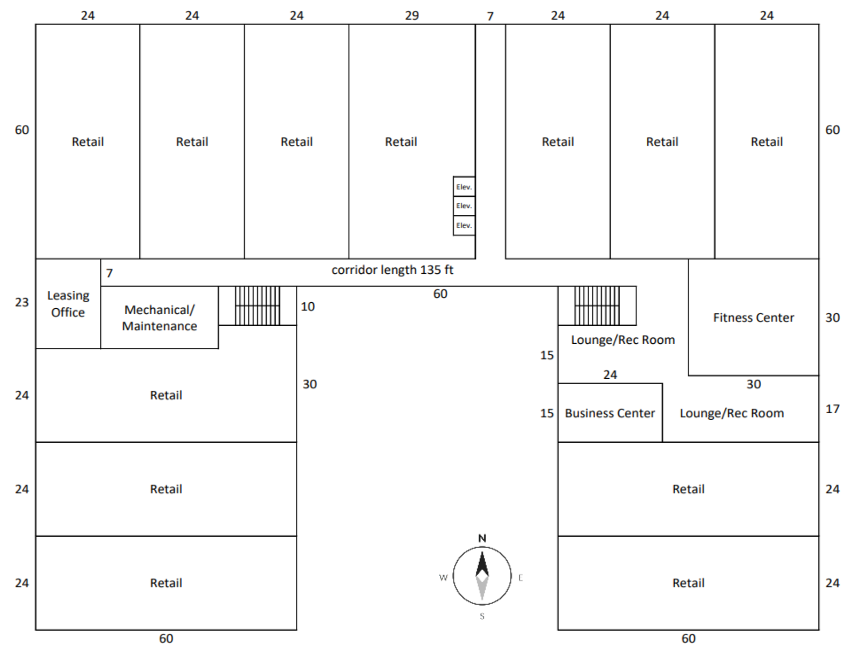
Spaces and Thermal Zones

The areas used and building massing are shown below for context. Spaces are denoted in the following table by use type assigned.

Further details on base building assumptions, including envelope, lighting and internal gains, PV and battery, DHW, base building systems, the IDF electrical HVAC system, and building elevations, are included in the appendix.

Non-Residential Spaces, Floor 1 and Common Areas Floors 2-5

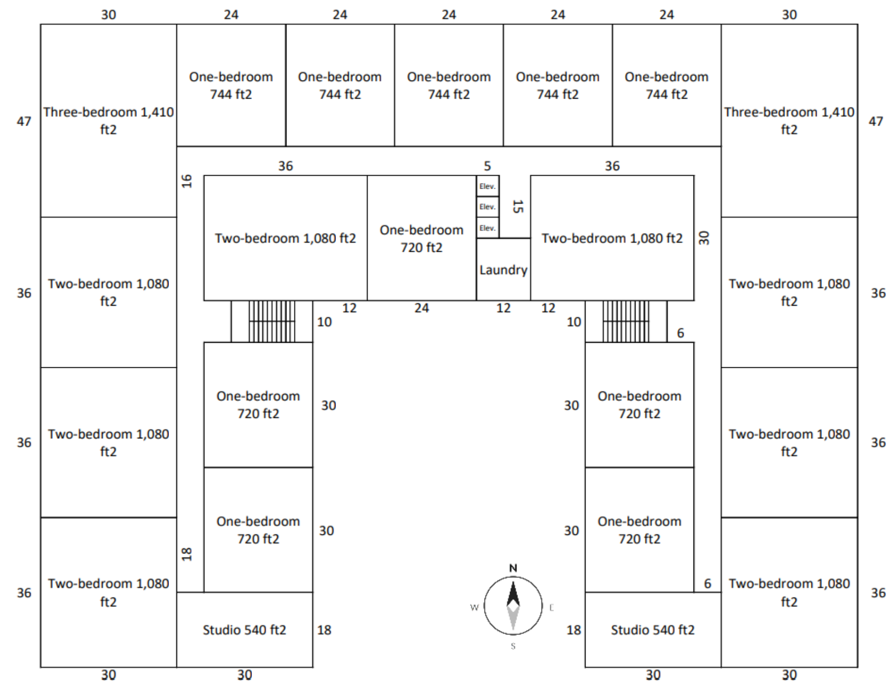
Zone Name	Floor	Area (sf)	Space Function
Retail N-NW	F1	5985	Retail Sales Area
Retail NE	F1	4320	Retail Sales Area
Retail SE	F1	2880	Retail Sales Area
Retail SW	F1	4428	Retail Sales Area
Business Center	F1	360	Conference / Multipurpose
Corridor	F1	1464	Corridor Area
Fitness Center	F1	900	Exercise Center / Gym
Leasing Office	F1	414	Office > 250 sf
Lobby	F1	1050	Lobby / Main Entry
Stairs E	F1	180	Stairwell
Stairs W	F1	180	Stairwell
Corridor	F2–F5	2340	Corridor Area
Break Room	F2–F5	180	Lounge / Break Room
Stairs E	F2–F5	180	Stairwell
Stairs W	F2–F5	180	Stairwell



Residential Spaces, Floors 2 - 5

Each floor is made up of thermal spaces comprised of dwelling units, applied to the massing. The dwelling unit types are shown below with a representative floor plan.

Unit Type	Bedrooms	Count	Unit Area (sf)	Total Area (sf)	% Res Area	OA (cfm)
Studio	0	8	540	4320	5%	31.2
1-Bed	1	40	720	28800	30%	36.6
2-Bed	2	32	1080	34560	36%	54.9
3-Bed	3	8	1410	11280	12%	72.3
Total (cond.)	-	88	-	78960	83%	-



Common Area HVAC Assumptions

The 88 dwelling unit multi-family model includes several non-residential spaces on the first floor with dedicated HVAC systems. The systems are configured with their own unique type of CBECC components, built from CSE elements and depicted in the compliance software in a tree-structure similar to non-residential EnergyPlus objects. This section documents the system configurations and efficiencies which were maintained in each example for multi-family housing for these areas.

HVAC Capacities & Efficiencies

The following tables show the non-residential zones in the first floor of the model. Each zone is configured with a single zone heat pump.

HP Lockout: 35°F OAT (common area SZHP). Supplemental heat from electric resistance. Retail served by separate PVAV with HW reheat, not shown in this table. Residential efficiencies (SEER2/EER2/HSPF2) are 2025 Title 24 minimums for ducted split HPs. Common area SZHP ratings (SEER/EER/HSPF) reflect the nonresidential minimum at autosized capacities.

Heat Pump Efficiencies	Value
EER	11.95
SEER	15.05
COP (47)	3.4
HSPF	8.8
Backup Electric Heat	100%

The table below documents the supply fan efficiencies for the single zone heat pumps.

Zone	Sup. CFM	W/cfm	Economizer
SZHP - F1 Amenities			
Business Center	290	0.742	None
Corridor	337	0.742	None
Fitness Center	421	0.742	None
Leasing Office	271	0.742	None
Lobby	355	0.742	None
SZHP - Corridors & Common, F2–F5 (typical per floor)			
Corridor	404	0.742	None
Break Room	140	0.742	None
Stairs E/W	31	0.742	None
PVAV - Ground Floor Retail			
Retail (4 VAV zones)	4,881–16,708	0.946 [1]	DB 71°F [2]

*1 VSD fan control (PVAV retail only)

*2 Fixed Dry Bulb economizer, 71°F lockout (retail only)

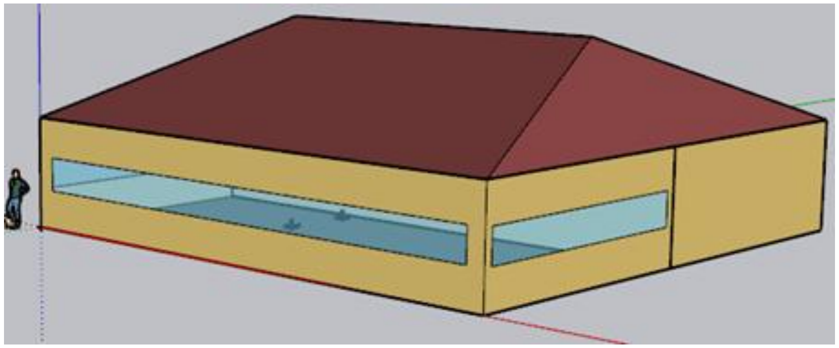
Restaurant, Small

A quick-service restaurant building was used by A2 Efficiency to develop a real-world example of a common construction complexity: dedicated outdoor air system (DOAS) units installed in a partially recirculating rooftop unit (RTU) configuration. The base prototype is the CEC nonresidential restaurant prototype, configured to reflect a single-story, two-zone restaurant with a kitchen exhaust and separate dining area.

The model represents the equipment, geometry, and operating configuration of a typical California quick-service restaurant in climate zone 9. It pairs the standard CEC prototype envelope, lighting, DHW, and P inputs with two custom-configured packaged SZ-VAV-AC rooftop units that are manufactured and rated as DOAS equipment but specified and installed with return air connections, operating as recirculating RTUs.

A summary of the building space uses and key assumptions is provided here, with additional detail in the appendix. The model aligns all major non-HVAC inputs with the Title 24, 2025 standard for climate zone 9.

Characteristic	Input
Envelope	Standard Code, T24 2025
Lighting	Standard Code, T24 2025
HVAC	Custom, Code Minimum (DOAS/RTU rating mismatch)
DHW	Standard Code, T24 2025
Solar/Battery	Standard Code, T24 2025

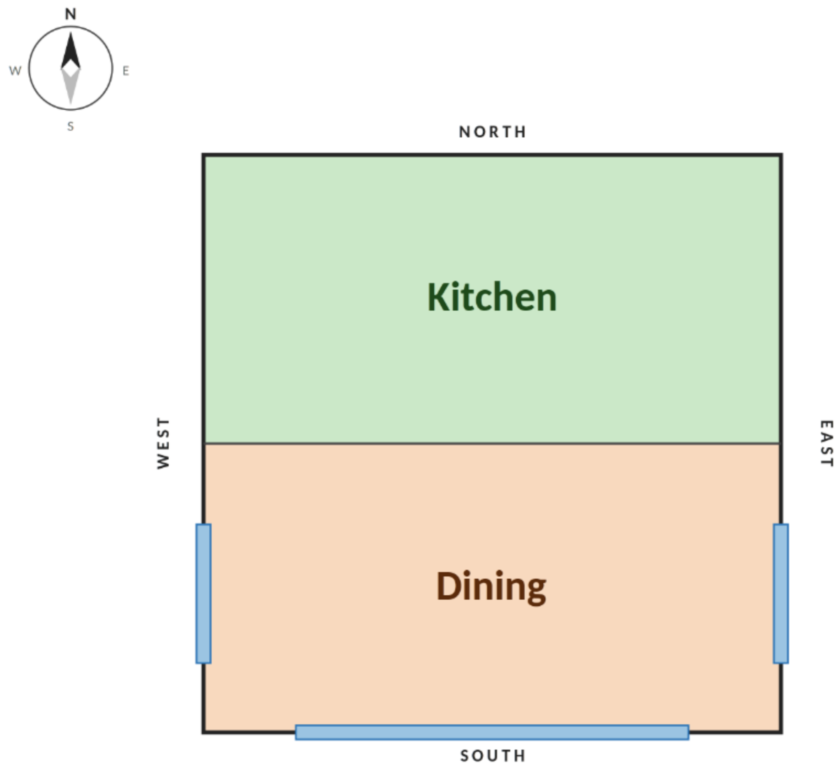


Characteristic	Value
Building Type	Quick-Service Restaurant (single-story)
Building Category	Nonresidential
Space Uses	Dining, Kitchen / Food Preparation (Unconditioned Attic)
Residential Conditioned Area	2,501 sf
Total Conditioned Area	2,501 sf (conditioned) attic excluded from gross floor area
Shape & Dimensions	Rectangular footprint with gabled roof
Number of Floors	1 (plus unconditioned attic)
Windows	280 sf, WWR 14% overall: N 0%, E 14%, S 28%, W 14%
Shading Exterior	None
Floor to Ceiling Height	10 ft typical

Spaces and Thermal Zones

The floor plan shows each space in the model, labeled by name and thermal zone assignment.

Zone Name	Floor	Area (sf)	Space Function
Dining	F1	1250	Dining Area (Cafeteria/Fast Food)
Kitchen	F1	1251	Kitchen Food Preparation Area
Attic Space	F1	-	Unoccupied-Exclude from Gross Floor Area

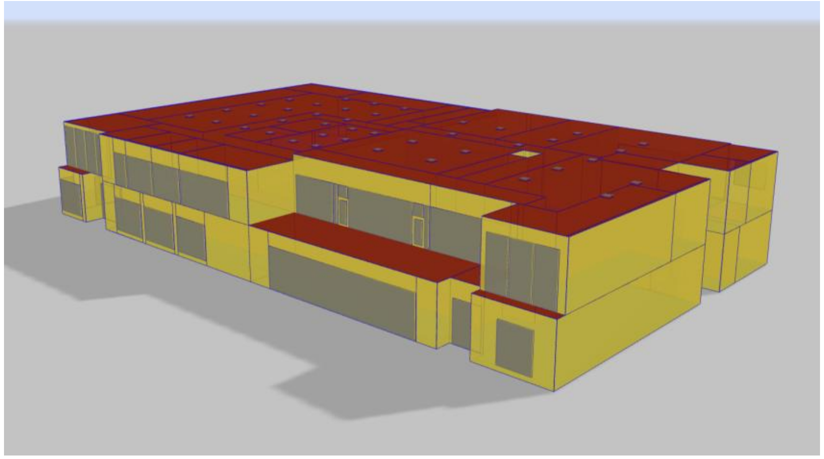


Classroom / Laboratory Building

A two-story classroom and laboratory building was used by A2 Efficiency to develop examples of complex nonresidential HVAC systems. The prototype provides a mixed occupancy base with classrooms, open offices, conference rooms, and laboratory exhaust zones requiring fume hood integration.

Characteristic	Input
Envelope	Standard Code, T24 2025
Lighting	Standard Code, T24 2025
HVAC	Custom, Prescriptive and Beyond Code
DHW	Standard Code, T24 2025
Solar/Battery	Standard Code, T24 2025

Characteristic	Value
Building Type	Classroom / Laboratory
Building Category	Nonresidential
Space Uses	Classrooms, Labs, Open Office, Conference, Corridors, Breakroom, Lobby, IT, Electrical
Conditioned Floor Area	~26,900 sf
Number of Floors	2



Spaces and Thermal Zones

The floor plan spans two levels (L1 and L2). Space uses include classrooms, laboratories with fume hood exhaust, open and private offices, conference rooms, corridors, a lobby, breakroom, and mechanical/IT spaces.

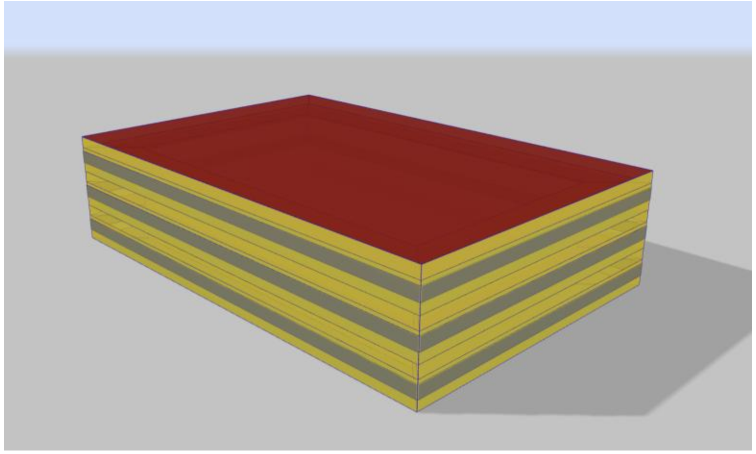
Further details on base building assumptions, including envelope, lighting, DHW, and base building systems, are included in the appendix. Laboratory exhaust zones are shown on the thermal zone data screen within each example.

Medium Office Building

A three-story medium office building was used by A2 Efficiency to develop examples of multi-zone nonresidential HVAC systems including packaged VAV air handling units with parallel fan-powered terminal boxes and a central air-to-water heat pump hot water plant. The prototype represents a typical mid-size California commercial office building served by floor-by-floor air handling units.

Characteristic	Input
Envelope	Standard Code, T24 2025
Lighting	Standard Code, T24 2025
HVAC	Custom, Prescriptive and Beyond Code
DHW	Standard Code, T24 2025
Solar/Battery	Standard Code, T24 2025

Characteristic	Value
Building Type	Medium Office
Building Category	Nonresidential
Space Uses	Open Office, Conference, Corridors, Support — verify with team
Conditioned Floor Area	~53,500 sf
Number of Floors	3
Climate Zone	9
Floor to Ceiling Height	~12 ft typical — verify with team
HVAC	Packaged VAV with Parallel Fan-Powered Boxes, Air-to-Water Heat Pump
AHU Configuration	One PVAV per floor (Bottom, Mid, Top VAV)



Spaces and Thermal Zones

Zone-level floor plans and detailed thermal zone areas for this prototype were not separately documented at the time of publication. Each floor is served by 5 thermal zones.

Example HVAC Systems Included

Multifamily Examples

1	**MF Ventilation Options and Split Heat Pumps**	Individual supply fans at each dwelling unit draw outdoor air through dedicated exterior wall penetrations. A central exhaust fan collects stale air via a shared duct. Space heating and cooling is provided by individual single-zone heat pumps in each unit. **Additional alternatives included; see following section.**
2	**MF Central VRF Heat Pump**	Space heating and cooling is provided by a central variable refrigerant flow system serving all dwelling units, modeled using the EnergyPlus-based central VRF zone system object.
3	**MF Water Source Heat Pumps with Cooling Tower and Boiler**	Each unit is conditioned by a water source heat pump connected to a shared condenser water loop maintained by a cooling tower and boiler.

Non-Residential Examples

4	**Small Office, Single Zone, Variable Flow, Dual Fuel Heat Pump**	A single-zone air system with a variable speed fan, heat pump heating and cooling, and a gas furnace for backup heating. Airside economizer and demand-controlled ventilation.
5	**Small Office, DOAS with Heat Recovery and Multi-Zone VRF**	A decoupled ventilation and conditioning system. A dedicated outdoor air unit with a heat recovery ventilator provides ventilation to all zones. Heating and cooling are handled independently by variable refrigerant flow terminal units in each zone.
6	**Classroom Lab, DOAS with Four-Pipe Fan Coils, Chiller, and Air-to-Water Heat Pump**	A decoupled ventilation and conditioning system. A dedicated outdoor air unit provides ventilation and manages latent loads. Zone-level heating and cooling is delivered by four-pipe fan coil units supplied by a central chilled water and hot water plant, with an air-to-water heat pump serving as the primary heating source.
7	**Medium Office, Packaged VAV with Variable-Volume Reheat, Fan-Powered Boxes, Air-to-Water HP**	A multi-zone air handling unit with direct expansion cooling, serving zones through a combination of variable air volume reheat boxes and parallel fan-powered terminal boxes. Hot water for reheating is supplied by a central air-to-water heat pump plant.
8	**Restaurant, Single Zone, Variable Flow, Heat Pumps**	A fast-food restaurant with two single zone systems and kitchen exhaust, utilizing variable speed fans, heat pumps, and demonstrating how to translate confusing equipment naming based on the system configuration to component selections.

Alternate Example HVAC System

For a subset of the examples, an alternate configuration was built to demonstrate a unique variation of the system.

#	System	Base Example	Description
1b	**MF Central Supply, Local Exhaust**	MF Single-Zone Heat Pumps	A central fan delivers outdoor air to all units via a shared supply duct, with each unit exhausting independently through its own local fan.
1c	**MF Local Supply, Local Exhaust, Facade-Mounted**	MF Single-Zone Heat Pumps	Each unit has independent supply and exhaust fans penetrating the exterior wall at separate locations with no shared ductwork. No heat recovery is possible. Base conditioning system unchanged.
1d	**MF Local Ventilator with Heat Recovery**	MF Single-Zone Heat Pumps	Each unit has a single through-wall device handling both supply and exhaust, with a heat exchanger core recovering energy from the exhaust stream. Base conditioning system unchanged.
1e	**MF Central Supply, Central Exhaust**	MF Single-Zone Heat Pumps	Central fans serve both supply and exhaust via shared ducts. Base conditioning system unchanged.
5b	**NR DOAS with VRF, No Heat Recovery, Coupled Ventilation**	NR DOAS with VRF	Ventilation air is delivered directly through the VRF fan coil units rather than through a dedicated outdoor air system, and no heat recovery ventilator is present.
8b	**NR Restaurant Single Zone Variable Flow HP, Dual Fuel**	NR Single-Zone VAV Dual-Fuel Heat Pump	Each thermal zone contains a variable speed single zone heat pump with dual fuel heating sources,

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Example 1: MF Ventilation Options and Split Heat Pumps

Local Supply, Central Exhaust

System Tag: MF-CEXH_ISUP-SZHP

Mechanical Description

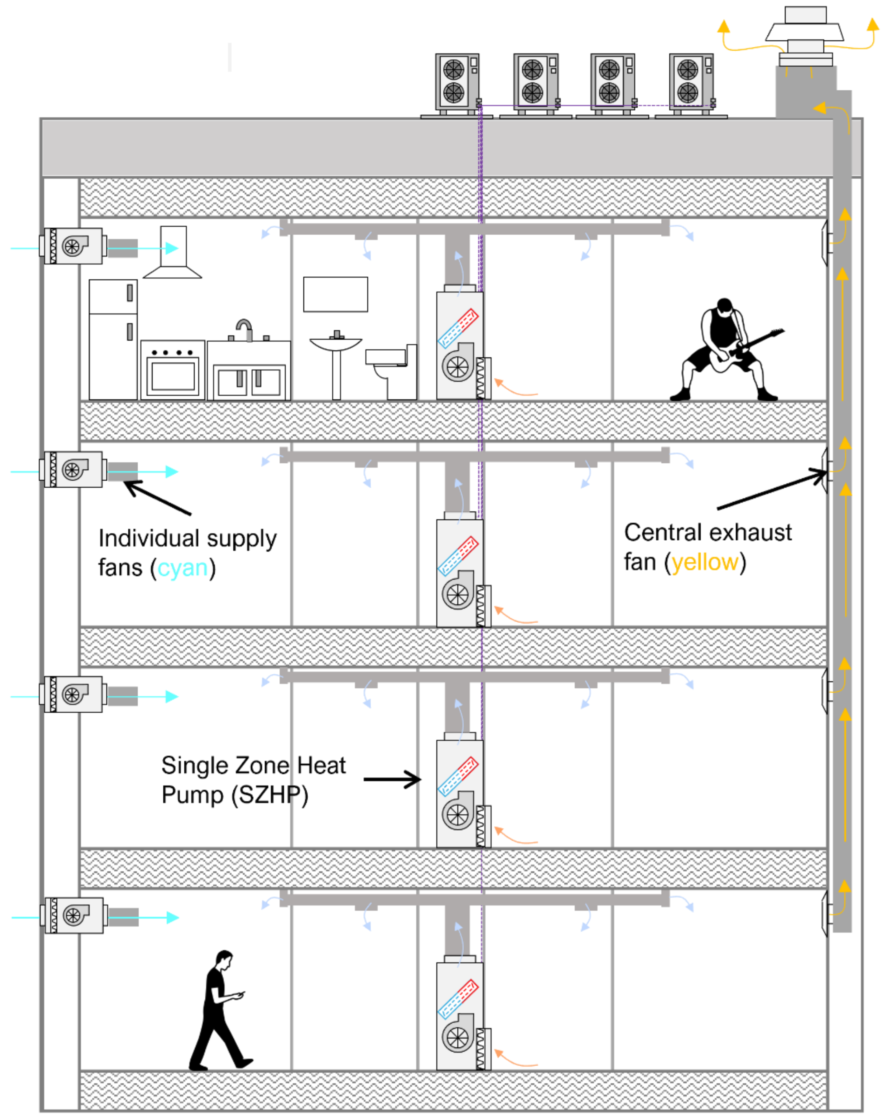
This multi-family model provides an example of ventilation configuration options in the compliance software. The option depicts one configuration here, referred to as option 1a, with additional alternate configurations in the additional example portion of this report for options 1b through 1e.

In this multi-family building, each residential dwelling unit is ventilated by an active supply fan and exhausted by a shared single exhaust fan system. The dwelling units are each conditioned by a dedicated ducted split heat pump, providing both heating and cooling. Heat pumps include electric resistance backup heat with no gas usage.

Domestic hot water is provided by a central heat pump water heater plant located in the first-floor mechanical room, with six outdoor-air-source compressors feeding a 750-gallon storage tank and a recirculation loop serving all units (not shown in diagram).

Diagram

The diagram shows a sample of four residential floors, each with an individual supply fan unit (left, cyan arrows) pushing outdoor air into the dwelling units, a central ducted split heat pump per floor serving the corridor zone, and a building-wide central exhaust riser (right, yellow arrows) collecting exhaust air to the roof. Outdoor condensing units are grouped on the rooftop.



Mechanical Details

Ventilation: Individual supply fan per dwelling unit; building-wide central exhaust

Ventilation control: Fixed flow, no DCV

Cooling: DX cooling via heat pump, all-electric

Heating: Heat pump primary; electric resistance backup (no gas)

Capacity control: Constant volume, fixed supply air temperature

Economizing: None on residential/common units; Fixed Dry Bulb on retail PVAV

Ventilation is handled entirely separately from the heat pump systems through an Individual Supply / Central Exhaust (ISUP/CEXH) strategy. Each unit has a small, dedicated supply fan that draws outdoor air directly into the unit; sized by bedroom count, from 31.2 cfm for studios to 72.3 cfm for three-bedroom units.

A single building-wide central exhaust fan collects stale air from all units and expels it at the roof. Supply and exhaust airflows are balanced at approximately 4,050 cfm total. Because ventilation is driven independently by these fans, the heat pump unit fan only runs when the thermostat calls for heating or cooling, reducing fan energy during mild weather conditions.

All heat pumps share the same rated cooling and heating efficiencies, set in the equipment table below. The model uses code-minimum federal SEER2, EER2, and HSPF2 to demonstrate baseline compliance behavior. Electric resistance backup is provided at each unit; there is no gas heating in the residential portion.

Mechanical Capacities and Sizing

Residential systems are autosized per dwelling unit by the simulation engine. This was done to streamline the HVAC configuration example. The capacity range shown reflects variation in zone exposure and floor level; all units share identical input efficiency ratings.

Residential Ventilation Fans

Unit Type	OA (cfm)	Supply W/cfm
Studio	31.2	0.35
1-Bed	36.6	0.35
2-Bed	54.9	0.35
3-Bed	72.3	0.35

Central exhaust fan: 0.302 W/cfm. Supply fans are supply-only type.

Residential Dwelling Units

Residential dwelling unit split heat pumps were set to code minimum efficiencies for heating, cooling, and the backup electric heating device.

Unit Type	Area (sf)	Autosized Cap. kBtu (range) *	COP	SEER2	EER2	HSPF2	Backup
Studio	540	6.3 – 10.7	3.4	14.3	11.7	7.5	Elec Res.
1-Bed	720	5.5 – 39.0	3.4	14.3	11.7	7.5	Elec Res.
2-Bed	1,080	10.6 – 31.6	3.4	14.3	11.7	7.5	Elec Res.
3-Bed	1,410	14.4 – 22.3	3.4	14.3	11.7	7.5	Elec Res.

Code Compliance Software Configuration

In CBECC, the residential building is configured differently from the nonresidential side. Rather than a single air system object that owns its components, each dwelling unit type is defined as a DwellUnitType, a hub object that holds references to separately defined equipment objects. This means one heat pump system specification is shared across all 88 units.

The diagram below shows how the DwellUnitType assembles its components. The left branch (blue) covers HVAC conditioning and is configured on the Dwelling Unit Type Data tab. The right branch (green) covers ventilation and is configured on the Indoor Air Quality Vent tab.

Key Modeling Points

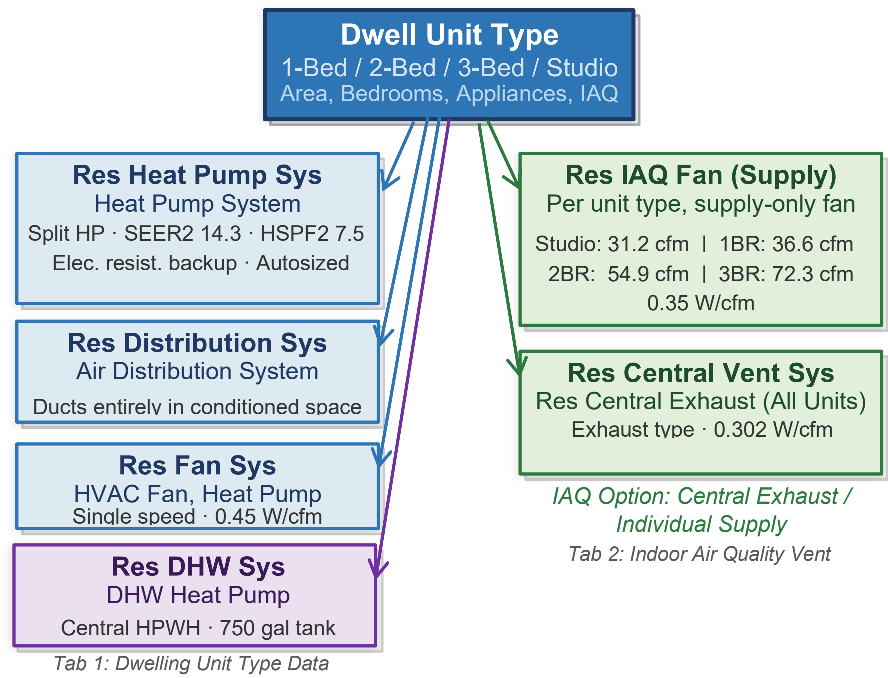
- **The DwellUnitType is a template;** it defines equipment assignments once. Individual DwellUnit instances (52 thermal zones) reference a type and inherit all assignments.

- **The Heat Pump System object** is shared across all unit types. SEER2, EER2, and HSPF2 are set once and apply to every unit; capacity is autosized per zone.

- **The IAQ approach** is set per unit type on Tab 2: Central Exhaust / Individual Supply. Each type references its own supply fan (sized by bedroom count) and a shared central exhaust system.

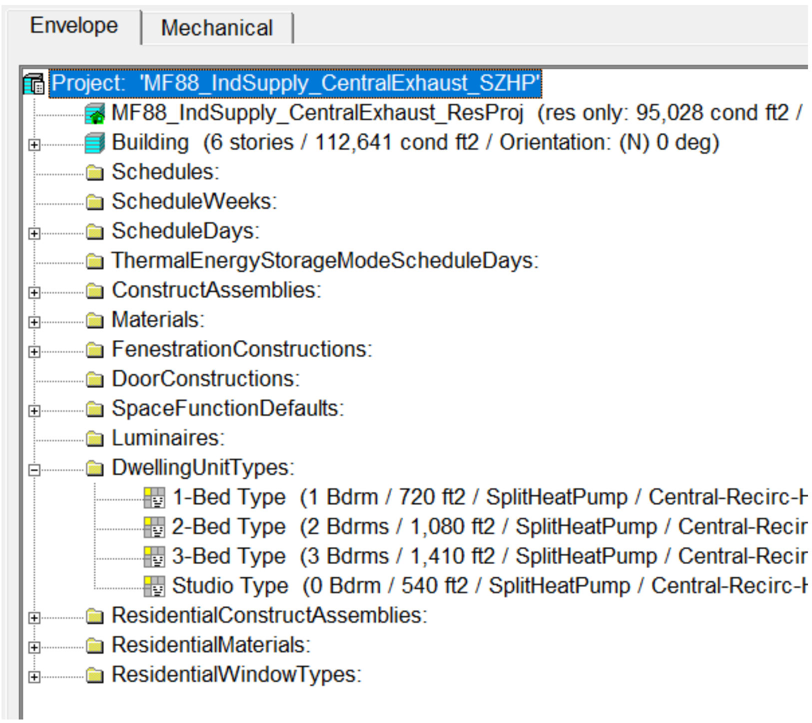
- **The supply IAQ fans** are set to IAQ Fan Type = Supply and do not have the option for heat recovery.

- **The central exhaust system** (Res Central Exhaust, All Units) is a single building-wide object referenced by every unit type - not duplicated per unit or floor.

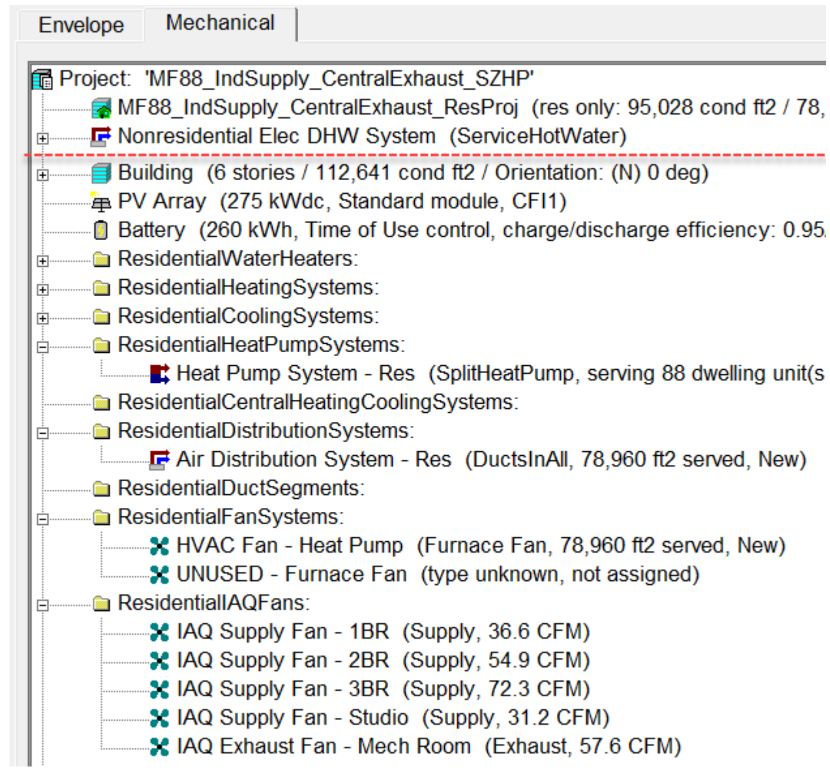


CBECC Object Locations

For multifamily buildings in CBECC, the key objects for configuring the HVAC are on the envelope and the mechanical tab. The envelope tab, as shown below, is where dwelling units live. These are the integration points for all multifamily dwellings where all the components for each dwelling type are defined and linked to mechanical systems.

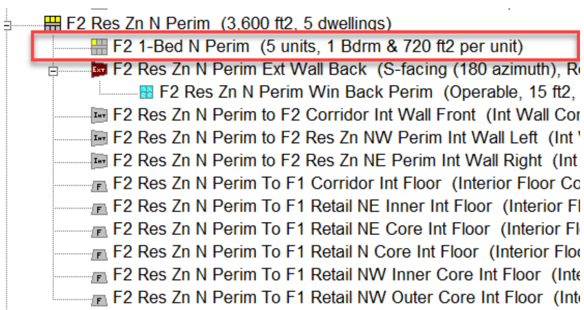


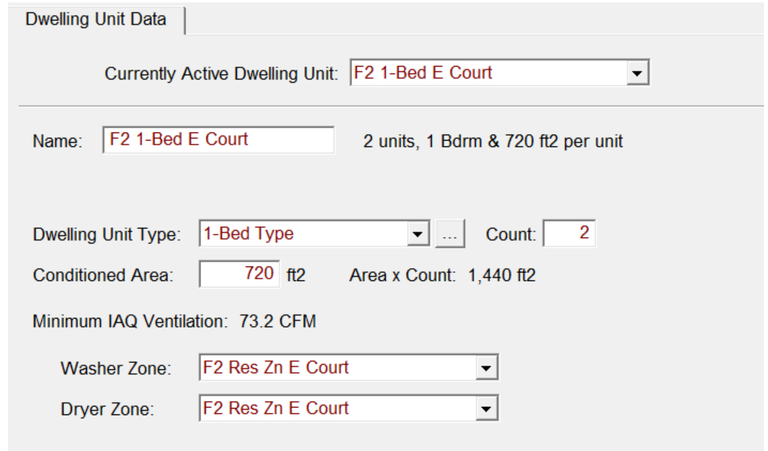
The mechanical tab is where those systems reside and where you can make multiple versions as needed of each system component. For example, this model uses a single heat pump system to represent the split heat pumps however you may end up with several of these, one for each capacity of heat pump on a project. Similarly, you can see in the residential AQ fans there are multiple fans at specific air flow rates for fresh air based on the different number of bedrooms in each typical dwelling unit.



Thermal Space Dwelling Unit Data

Each space in the model includes a Dwelling Unit Data object. This object holds how many instances of this type are included. In this example, the space has 2 1-Bed Type units included. It is also where the washer and dryer are defined.

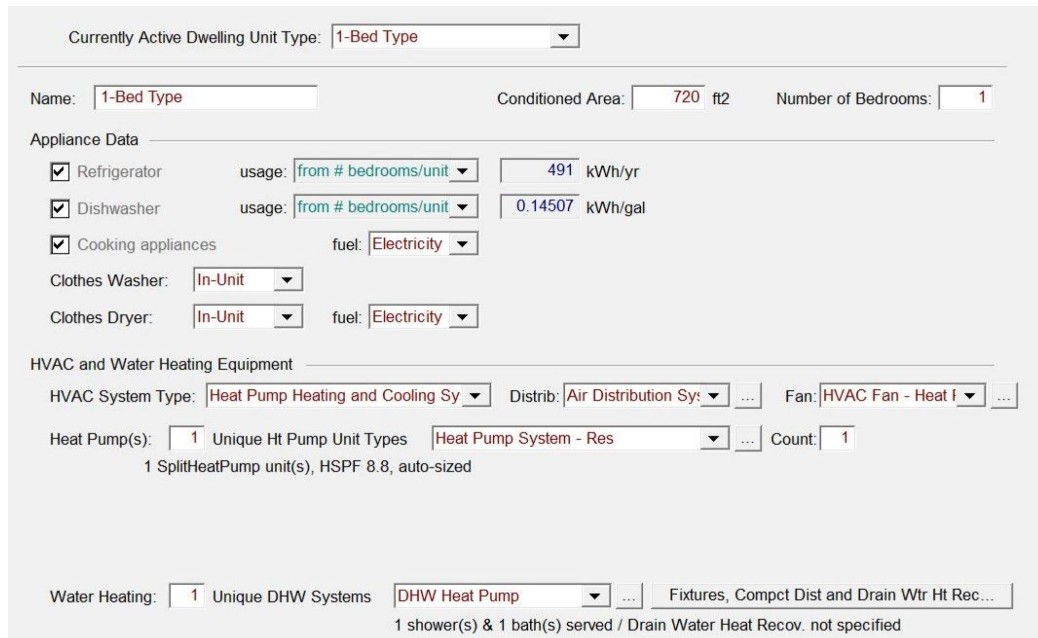




Dwelling Unit Type Data (1-Bed Type shown)

The DwellUnitType is a template; it defines equipment assignments once. Individual DwellUnit instances (52 thermal zones) reference a type and inherit all assignments.

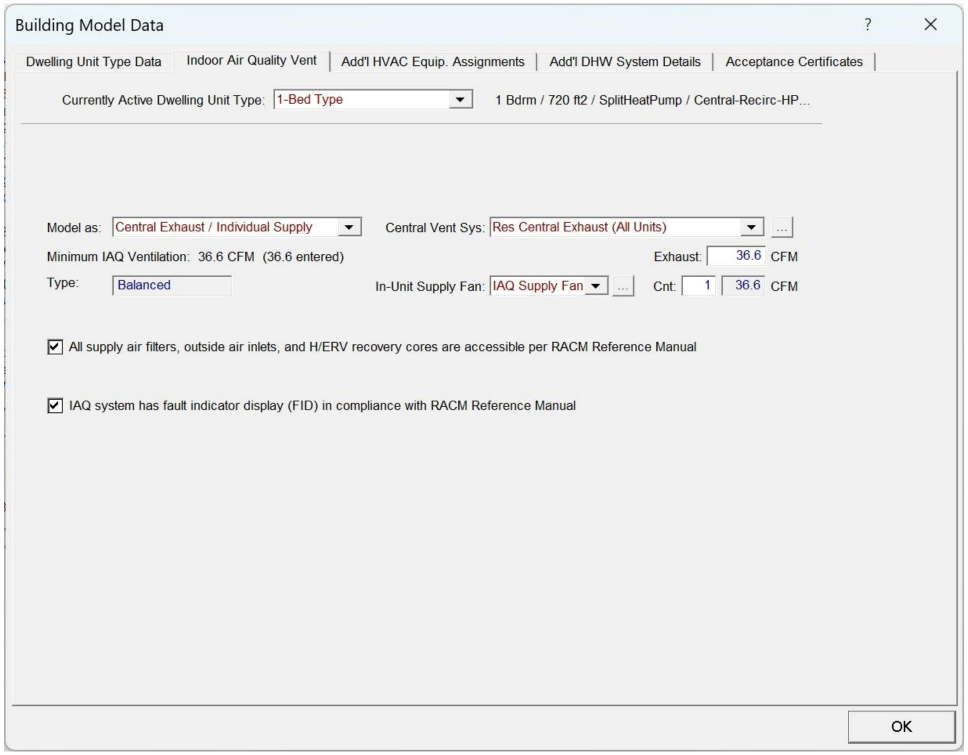
This screen sets the DwellUnit area, bedroom count, appliances, HVAC system type, heat pump object, fan, distribution, and DHW reference.



Indoor Air Quality Vent (1-Bed Type shown)

The IAQ approach is set per unit type on Tab 2: Central Exhaust / Individual Supply. Each type references its own supply fan (sized by bedroom count) and a shared central exhaust system.

Sets ventilation approach (Central Exhaust / Individual Supply), central vent exhaust system, in-unit supply fan, and accessibility/FID compliance checkboxes



Relevant Energy Code Citations

Restructured 2025 Title 24, Part 6 with section numbers shown with legacy cross-reference in brackets.

Ventilation & IAQ, Attached Dwelling Units

403.2.2.3 & 403.2.2.3.4 [160.2(b)2 & 160.2(b)2Aiv]:

The governing sections for MF dwelling unit ventilation. All attached dwelling units shall meet ASHRAE 62.2 as amended by the Code. ISUP/CEXH qualifies as balanced ventilation per item 2.1. Compartmentalization testing ≤ 0.30 cfm/sf at 50 Pa required per item 2.2.

Ducts in Conditioned Space

402.2.6.1.1, under 402.2.6.1 [150.0(m)1]:

When all ducts are located entirely within conditioned space, duct insulation is not required. Must be confirmed through HERS field verification per RA3.1.4.3.8. All dwelling unit ducts modeled as entirely in conditioned space. No duct loss penalty applied. HERS verification required at construction.

Single-Zone Ducted System Fan Efficacy

402.2.6.13.2 [150.0(m)13B]:

Single-zone ducted systems shall meet ≤ 0.58 W/cfm (non-gas AHU) at ≥ 350 cfm/ton airflow. Model inputs 0.45 W/cfm for all dwelling unit HVAC fans. HERS verification required.

HP Supplemental Heat Controls & Thermostat

402.2.2.7 & 402.2.4.2 [150.0(h)7 & 150.0(i)2]:

Heat pumps with electric resistance backup must lock out supplemental heat above 35°F OAT. Thermostats must display when backup is active, include OAT sensing, and meet setback requirements.

Electric Resistance Supplemental Heat Sizing

402.2.2.8 [150.0(h)8]:

The capacity of electric resistance supplemental heat shall not exceed the HP nominal cooling capacity (at 95°F) × 2.7 kW/ton, rounded up to nearest kW. CBECC autosizes the backup element. Model uses a 0.75× heating sizing factor for the HP compressor, with backup covering the remaining load.

Standard Design Mechanical Package, CZ9

403.3.1.1 [170.2(c)3A]:

For MF performance compliance in CZ9: HP SEER2 and HSPF2 at federal code minimum per 403.3.1.1; refrigerant charge verification required per 403.3.1.2.1; HRV/ERV not required for balanced ventilation. Individual supply fan efficacy for non-HRV supply systems: 0.40 W/cfm per 403.3.1.2.5 in CZ 5-10 and CZ 15.

Standard design uses same SZHP system type as proposed. Primary compliance margin comes from fan energy and lighting, not equipment efficiency.

Example 2: MF Central VRF Heat Pump

System Tag: MF-ISUP-CEXH-VRF-HPs

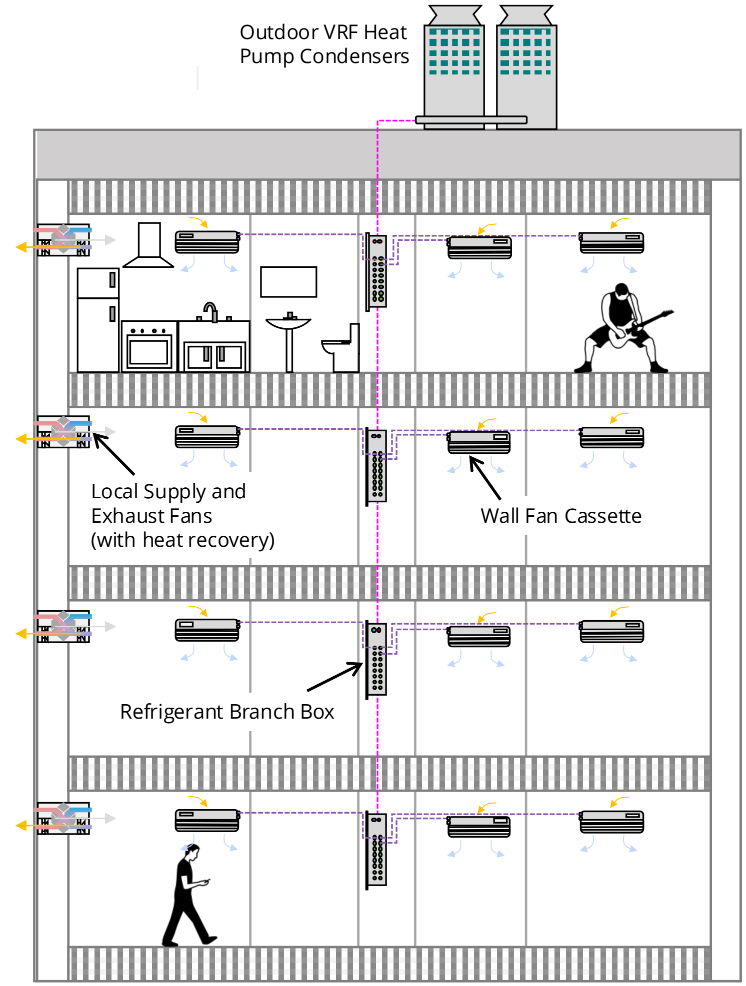
Mechanical Description

Each of the eight residential dwelling units in the 2-story MF08 prototype is conditioned by a central variable refrigerant flow (VRF) heat pump system. A single central outdoor unit serves all units through a refrigerant piping network, with indoor fan coils inside each dwelling. Each indoor unit modulates its refrigerant flow while the outdoor unit varies its speed to match the combined zone loads without reheat or mixing losses. All indoor units are in the same mode, heating or cooling, at any time.

Ventilation is handled separately from conditioning by balanced individual supply and exhaust fans with heat recovery. There is no central ventilation shaft, and the VRF system does not deliver outside air. Domestic hot water is provided by a central heat pump water heater plant.

Diagram

The diagram shows a sample of four residential floors, each with an individual supply and exhaust fan (left, grey and orange arrows) pushing outdoor air into the dwelling units and exhausting air back outside, and a ducted indoor fan coil per dwelling fed by refrigerant piping from the rooftop outdoor unit. A single VRF outdoor unit on the roof serves every dwelling in the building.



Mechanical Details

The central VRF system was applied to the MF08 prototype, with a single outdoor unit serving all eight dwelling units through a shared refrigerant distribution network and individual indoor fan coils in each unit.

Ventilation: Balanced ventilator per dwelling unit with heat recovery.

Ventilation control: Fixed flow, no DCV

Cooling: VRF heat pump, all-electric

Heating: VRF heat pump, all-electric, no supplemental electric resistance or gas

Capacity control: Variable refrigerant flow modulated at the outdoor unit, fixed supply temperature

Economizing: None

Mechanical Capacities and Sizing

Indoor fan coils and refrigerant capacity are autosized per zone by the simulation engine. The outdoor unit is hard-sized at the rated capacity. Both VRF methods use the same dwelling unit indoor fan, distribution, ventilator, and DHW objects.

Residential Ventilation Fans

Unit Type	Design OA (cfm)	Fan Power (W/cfm)	Fan Type	Heat Recovery
1-Bed	37.5	0.4	Balanced	HRV, 70% SRE
2-Bed	54.9	0.4	Balanced	HRV, 70% SRE

Residential Dwelling Unit Indoor Fan

Parameter	Value
Object	ResFanSys - HVAC Fan, VRF Indoor
Type	Single Speed Fan
W/cfm (Cooling)	0.45

Domestic Hot Water Plant

Parameter	Value
Object	ResDHWSys - DHWHeatpump
System Type	Standard (Single Pass Primary)
Compressor	Sanden GS3-45HPA-US (4 kW at 40 F)
Compressor Quantity	2
Primary Tank Volume (gal)	160
Loop Tank Volume (gal)	80
Loop Tank Type	Electric Resistance
Recirc Type	Non-Central
Source Air / Tank Location	Outside

Code Compliance Software Configuration

CBECC models VRF heat pump systems using one of two methods, determined by the outdoor unit's rated cooling capacity. The threshold is 65,000 Btu/h, which is where the AHRI test procedure changes: equipment below uses AHRI 210/240 (rated with SEER2 and HSPF2); equipment at or above uses AHRI 1230 (rated with EER, COP47, and IEER). CBECC requires the object type and efficiency metrics to match, so always verify the rated cooling capacity before selecting a method; using the wrong metrics produces inaccurate energy simulation results.

Both methods are demonstrated using the same prototype model. In each, the DwellUnitType object is the central organizing element: it holds references to all systems serving a unit type, and each DwellUnit instance inherits those references by pointing to a type. The diagram below shows how DwellUnitType assembles its components across three branches — HVAC conditioning (blue, Dwelling Unit Type Data tab), ventilation (green, Indoor Air Quality Vent tab), and DHW (purple). White boxes highlight where the Res Heat Pump System (ResHtPumpSys) configuration differs from the Res Central Heating and Cooling System (ResCentralHtgClgSys).

VRF Efficiency Rating Thresholds for CBECC Multi-Family Modeling

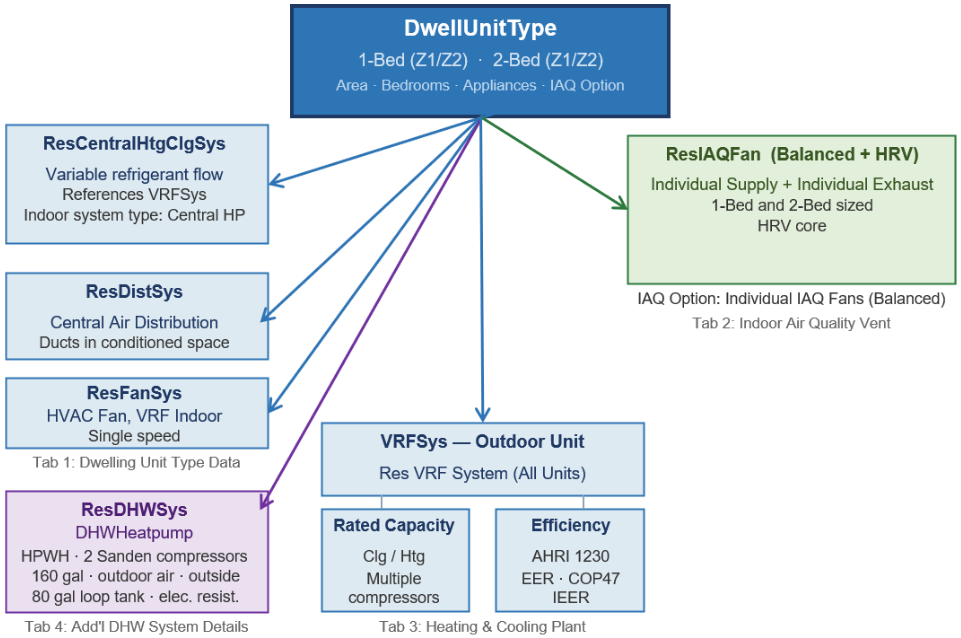
The appropriate efficiency metric for modeling VRF heat pump systems depends on the outdoor unit's rated cooling capacity, with 65,000 Btu/h serving as the dividing line.

- **Below 65,000 Btu/h:** Systems fall under the residential/light-commercial framework (AHRI 210/240-2023) and are rated using **HSPF2** for heating efficiency. These units should be modeled using HSPF2 input values consistent with the Appendix M1 test procedure.
- **At or above 65,000 Btu/h:** Systems fall under commercial equipment standards (AHRI 1230) and are rated using **COP** metrics — specifically **COP47** (coefficient of performance measured at 47°F) — along with IEER for cooling. These units should be modeled accordingly using COP-based inputs.

Figure 1: VRF central outdoor compressors

Method 1: Central VRF Above 65,000 Btu/h (AHRI 1230)

Applies when the outdoor unit's rated cooling capacity is at or above 65,000 Btu/h. The system is rated using EER, COP47, and IEER under AHRI 1230. In CBECC, the dwelling unit's HVAC system is set to Central Heating and Cooling System, and the ResCentralHtgClgSys object is set to variable refrigerant flow. That object references a separate VRFSys object that holds the outdoor unit's capacity, efficiency, compressor count, and refrigerant piping geometry.



VRF Outdoor Unit (Method 1)

Parameter	Value
Object	VRFSys - Res VRF System (All Units)
Rated Cooling Capacity (Btu/h)	216,000
Rated Heating Capacity (Btu/h)	250,000
EER	10
COP47	3.2
IEER	17
Compressor Quantity	3
Equivalent Pipe Length (ft)	150
Maximum Vertical Separation (ft)	50
Control Priority	Load Priority

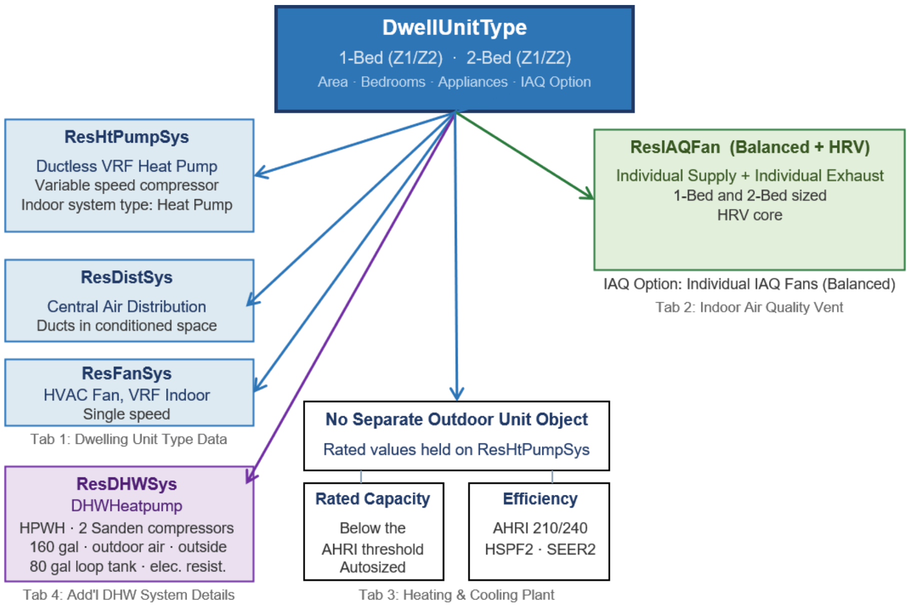
Method 2: Ductless VRF Below 65,000 Btu/h (AHRI 210/240)

Applies when the outdoor unit's rated cooling capacity is below 65,000 Btu/h. The system is rated using HSPF2 and SEER2 under AHRI 210/240-2023. In CBECC, the dwelling unit's HVAC system type is set to Heat Pump Heating and Cooling System, and a ResHtPumpSys object with the Ductless VRF Heat Pump type holds the rated efficiency values. There is no separate VRFSys outdoor unit object on this path.

This method is appropriate for smaller multifamily prototypes or for VRF systems sized to serve a single dwelling unit or a small group of units below the commercial capacity threshold.

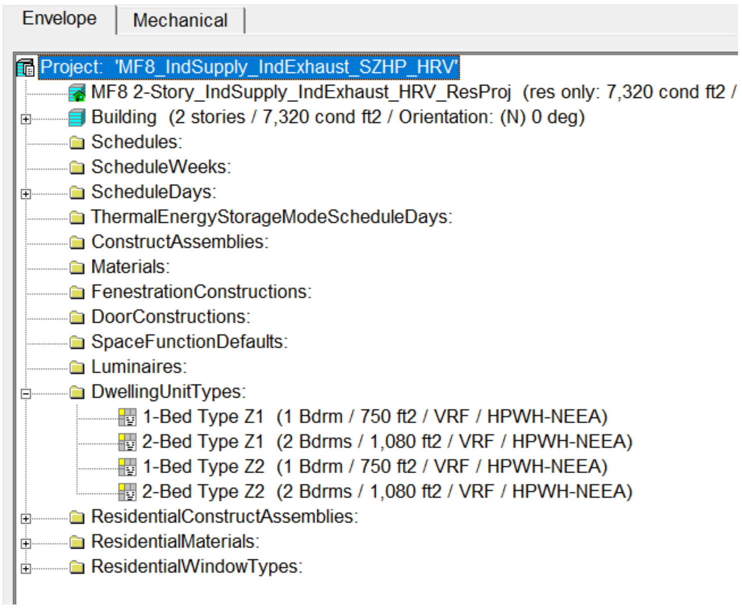
VRF Heat Pump (Method 2)

Parameter	Value
Object	ResHtPumpSys - VRF Type Heat Pump
Type	Ductless VRF Heat Pump
Compressor Speeds	Variable
HSPF2	7.0
SEER2	14
Backup	none
Capacity	Autosized

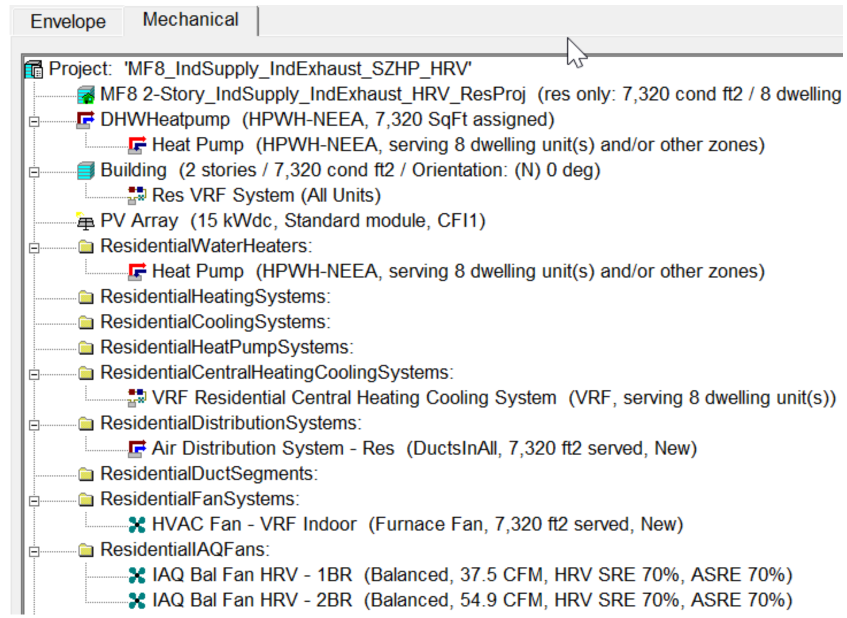


CBECC Object Locations

For multifamily buildings in CBECC, HVAC inputs live on two tabs: Envelope and Mechanical. Dwelling units and their type references are on the Envelope tab. System objects (the VRF outdoor unit or the Ductless VRF heat pump, the indoor fan, distribution, balanced ventilator, and DHW plant) are on the Mechanical tab.

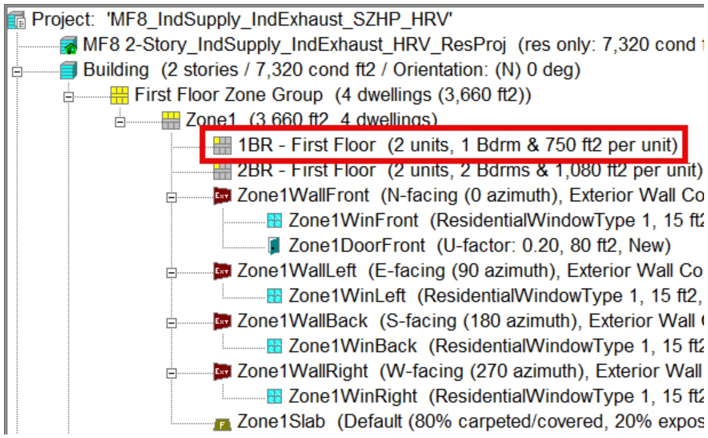


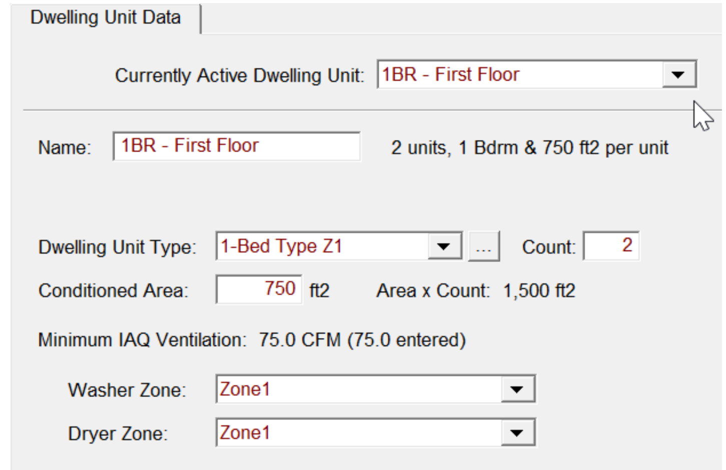
The Mechanical tab is where those systems reside and where you can make multiple versions as needed of each system component. For example, this model uses a single heat pump system to represent the split heat pumps however you may end up with several of these, one for each capacity of heat pump on a project. Similarly, you can see in the residential AQ fans there are multiple fans at specific air flow rates for fresh air based on the different number of bedrooms in each typical dwelling unit.



Thermal Space Dwelling Unit Data

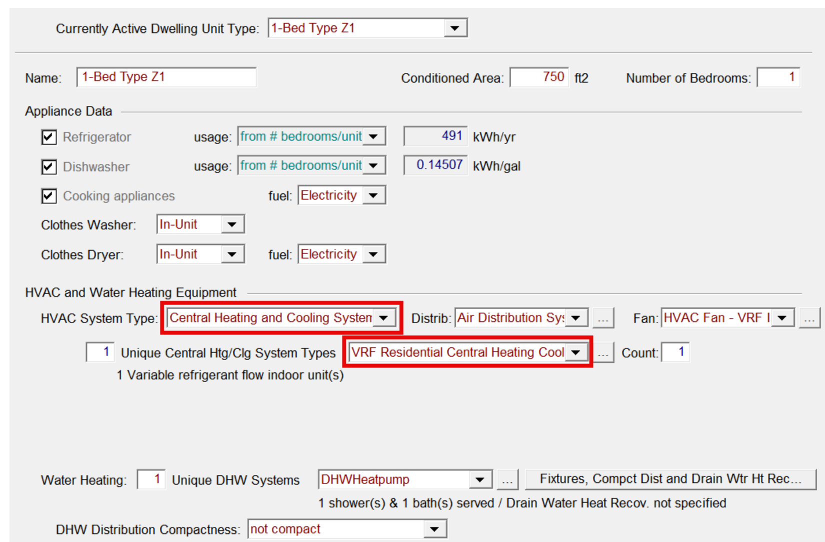
Each thermal space holds a Dwelling Unit Data object that records the count of unit instances of that type in the space and the in-unit appliances.





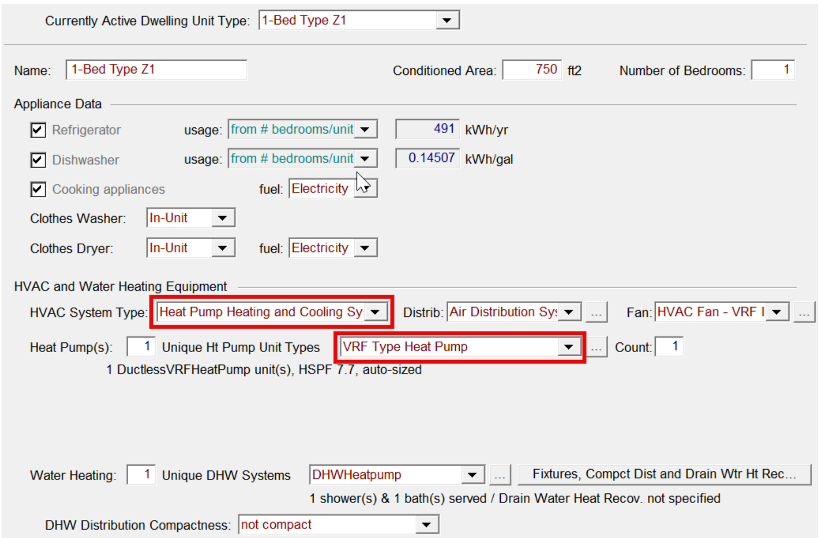
Dwelling Unit Type Data (Method 1, 1-Bed shown)

Sets unit area, bedrooms, appliances, HVAC system type to Central Heating and Cooling System, the ResCentralHtgClgSys reference, indoor fan, distribution, and DHW reference.



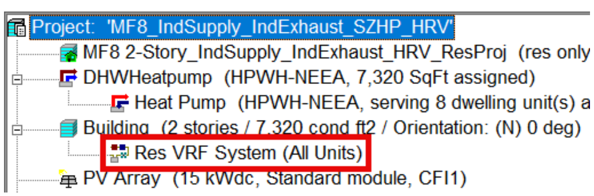
Dwelling Unit Type Data (Method 2, 1-Bed shown)

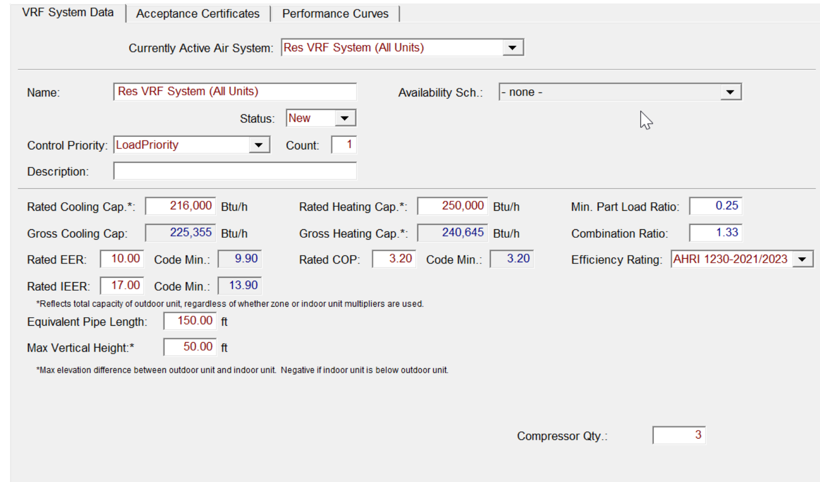
Sets unit area, bedrooms, appliances, HVAC system type to Heat Pump Heating and Cooling System, the ResHtPumpSys reference, indoor fan, distribution, and DHW reference.



VRF System Object (Method 1)

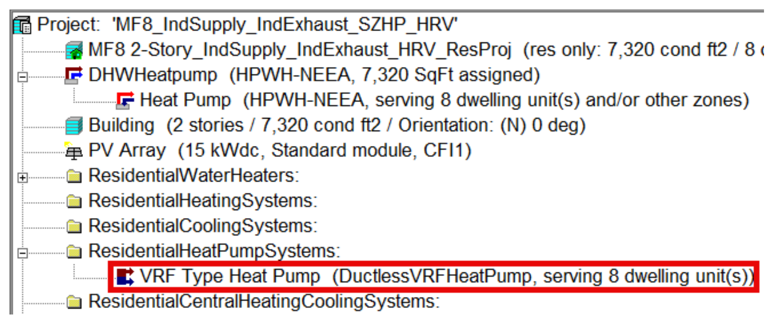
On the Mechanical tab. Sets the VRFSys rated capacity, AHRI 1230 metrics, compressor count, equivalent pipe length, and maximum vertical separation between indoor and outdoor units.

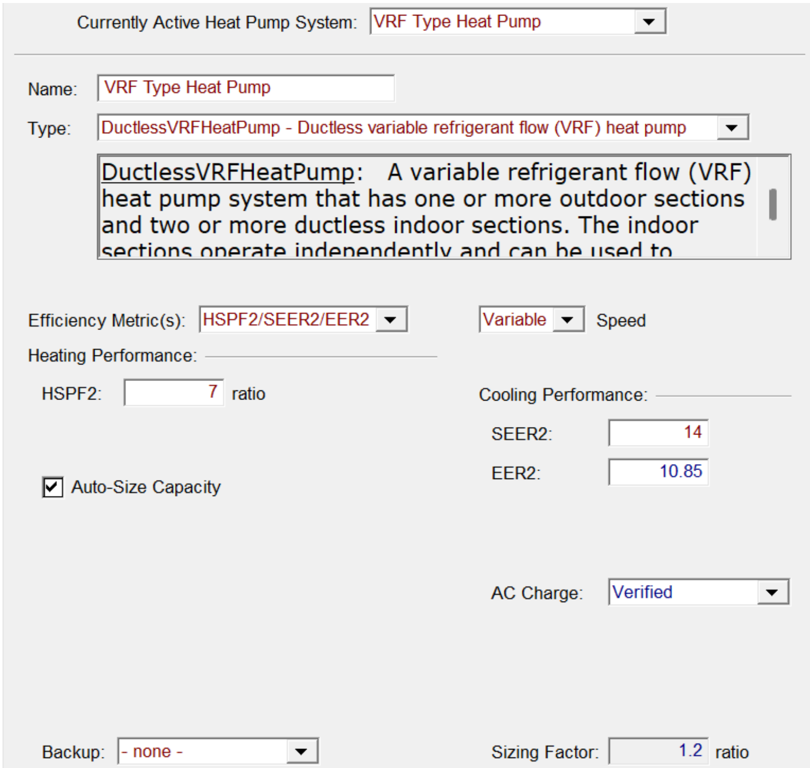


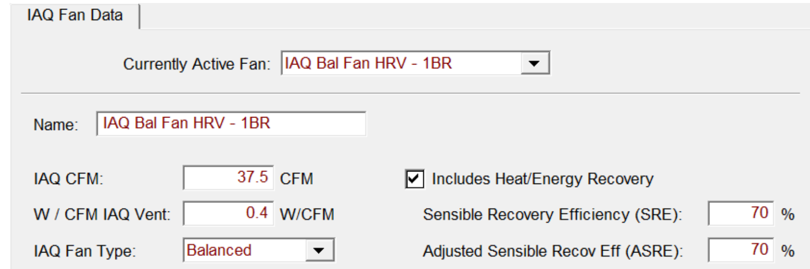


VRF Heat Pump Object (Method 2)

On the Mechanical tab. Sets the ResHtPumpSys type to Ductless VRF Heat Pump, with HSPF2, SEER2, and variable speed compressor.

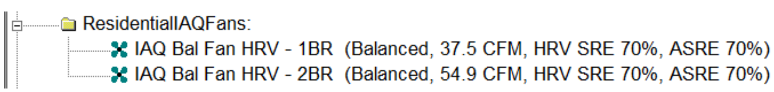






Indoor Air Quality Vent (1-Bed shown)

Sets the IAQ approach to Individual IAQ Fans, references the balanced HRV ventilator for the unit, and the FID accessibility checkboxes. Same configuration for both VRF modeling methods.



Relevant Energy Code Citations

Restructured 2025 Title 24, Part 6 with section numbers shown with legacy cross-reference in brackets.

Ventilation and IAQ, Attached Dwelling Units

403.2.2.3 & 403.2.2.3.4 [160.2(b)2 & 160.2(b)2Aiv]:

The governing sections for MF dwelling unit ventilation. All attached dwelling units shall meet ASHRAE 62.2 as amended by the Code. ISUP/IEXH qualifies as balanced ventilation per item 2.1. Compartmentalization testing ≤ 0.30 cfm/sf at 50 Pa required per item 2.2.

VRF Efficiency Metric by Capacity

Section 400.5 / Table 400.5-G [110.2 / Table 110.2-G]:

Sets the size-vs-metric split for VRF. < 65,000 Btu/h: AHRI 210/240, rated SEER2 and HSPF2; model as ResHtPumpSys (Ductless VRF). ≥ 65,000 Btu/h: AHRI 1230, rated EER, COP47, and IEER; model as VRFSys referenced by a ResCentralHtgClgSys set to Variable refrigerant flow. Wrong metric for the system size produces inaccurate results.

Balanced Ventilation with Heat Recovery

403.2.2.3.4 [160.2(b)2Aiv], item 2.1:

Balanced ventilation systems with HRV or ERV serving a single dwelling unit shall have fan efficacy ≤ 1.0 W/cfm. Recovery effectiveness is credited through the HVI listing entered for the IAQ fan object. See also 403.3.1.2.5 [170.2(c)3Bv]: ≤ 0.4 W/cfm for balanced ventilation without HRV/ERV in CZ 5-10 and CZ 15.

Ducts in Conditioned Space

402.2.6.1.1, under 402.2.6.1 [150.0(m)1]:

When all ducts are located entirely within conditioned space, duct insulation is not required. Must be confirmed through HERS field verification per RA3.1.4.3.8. All dwelling unit ducts modeled as entirely in conditioned space. HERS verification required at construction.

Single-Zone Ducted System Fan Efficacy

402.2.6.13.2 [150.0(m)13B]:

Single-zone ducted systems shall meet ≤ 0.58 W/cfm (non-gas AHU) at ≥ 350 cfm/ton airflow. VRF indoor fan coils are non-gas. Model inputs 0.45 W/cfm for all dwelling unit HVAC fans. HERS verification required.

Standard Design Mechanical Package, CZ9

403.3.1.1 [170.2(c)3A]:

For MF performance compliance in CZ9: HP SEER2 and HSPF2 at federal code minimum per 403.3.1.1; refrigerant charge verification required per 403.3.1.2.1. Individual supply fan efficacy for non-HRV balanced systems: ≤ 0.4 W/cfm per 403.3.1.2.5 in CZ 5-10 and CZ 15.

Standard design is a Split Heat Pump baseline. Proposed VRF gains compliance margin from part-load performance, no supplemental resistance heat, and the HRV ventilator credit.

Example 3: MF Water Source Heat Pumps with Cooling Tower and Boiler

System Tag: MF-ISUP-CEXH-Water-Source-HPs

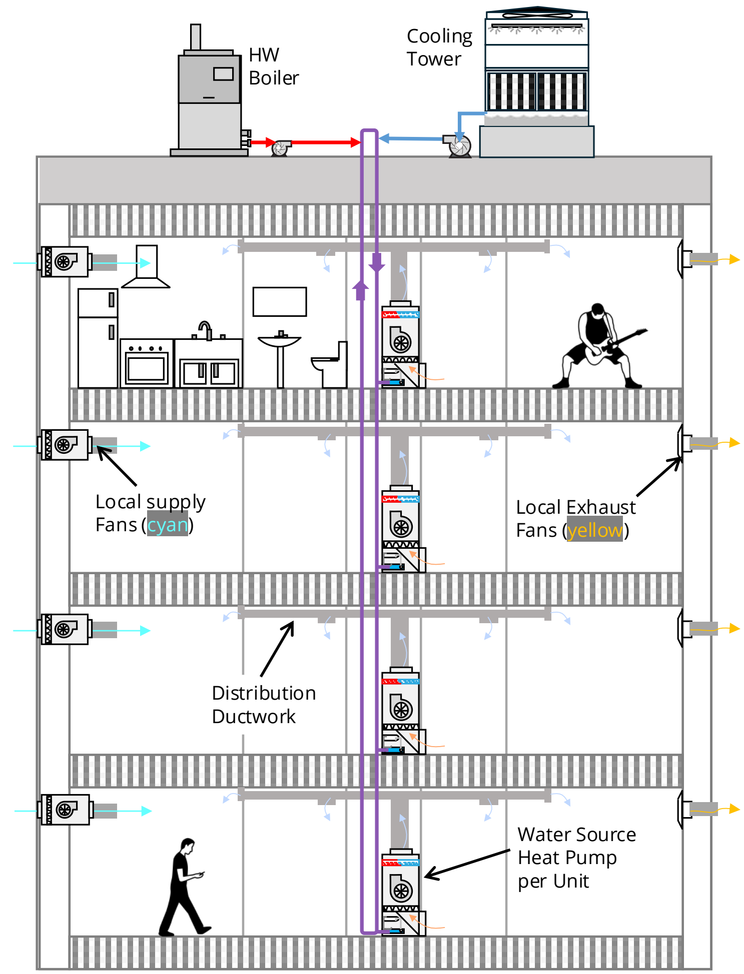
Mechanical Description

Each of the eight residential dwelling units in the 2-story MF08 prototype is conditioned by an in-unit water source heat pump (WSHP). Every WSHP exchanges heat with a shared condenser water loop held in a moderate temperature band year-round, so each compressor works against a smaller temperature lift than an air-source equivalent. A gas-fired condensing boiler adds heat only when the loop falls below its heating setpoint; a cooling tower rejects heat only when the loop rises above its cooling setpoint. Indoor fans are single-speed and ducted, with ducts located in conditioned space.

Ventilation is handled separately from conditioning by balanced individual supply and exhaust fans. Each dwelling has a dedicated balanced ventilator supplying outdoor air and exhaust at matched airflow sized by bedroom count for 1-bed and 2-bed unit types. Domestic hot water is provided by a central heat pump water heater plant.

Diagram

The diagram shows a sample of four residential floors, each with a balanced ventilator (individual supply and exhaust, cyan and yellow arrows) and a ducted WSHP with distribution ductwork per unit. A shared condenser water loop (purple) connects to the condensing gas boiler and cooling tower on the rooftop.



Mechanical Details

The water source heat pump system was applied to the MF08 prototype, with eight in-unit WSHPs sharing a common condenser water loop maintained by a central cooling tower and gas-fired condensing boiler.

Ventilation: Balanced ventilator per dwelling unit; no central vent shaft

Ventilation control: Fixed flow, no DCV

Cooling: WSHP at the unit; heat rejected to a shared condenser water loop with open cooling tower

Heating: WSHP at the unit; loop topped up by a gas-fired condensing boiler when needed

Capacity control: Constant volume, fixed supply air temperature

Economizing: None

All WSHP share the same rated cooling and heating efficiencies, found in the equipment table below. The condenser water loop boiler and cooling tower are sized for the loop served. The boiler is enabled only when the loop temperature drops below the heating setpoint; the tower's variable-speed fan modulates when the loop needs to reject heat.

Mechanical Capacities and Sizing

WSHP indoor units are autosized per zone by the simulation engine. The condenser water loop and its boiler and cooling tower are hard sized for the loop served.

Residential Ventilation Fans

Unit Type	OA (cfm)	Supply W/cfm
1-Bed	37.5	0.4
2-Bed	54.9	0.4

Water Source Heat Pump

Parameter	Value
Object	ResCentralHtgClgSys - WSHP System
Type	Water Source Heat Pump
Rated COP (heating)	4.8
Rated EER (cooling)	17
CW Loop Inlet Reference	CW Supply Segment
CW Loop Outlet Reference	CW Return Segment

Indoor Fan and Distribution

Parameter	Value
Indoor Fan Object	ResFanSys - HVAC Fan, WSHP Indoor
Fan Type	Single Speed
W/cfm (cooling)	0.45
Distribution Object	ResDistSys - Air Distribution System, Res
Duct Location	Entirely in conditioned space

Dwelling Unit Templates and Instances

Template	Bedrooms	Area (sf)	Instances Referencing	Total Units
1-Bed Type Z1	1	750	1BR First Floor, 1BR Second Floor	4
2-Bed Type Z1	2	1,080	2BR First Floor, 2BR Second Floor	4

Per-Zone Autosized Capacities

Zone	Floor Area (sf)	Clg Cap (kBtu/h)	Htg Cap (kBtu/h)	Rated EER	Rated COP @ 47 F
Zone1 (First Floor)	3,660	25.8	32.2	17	4.8
Zone2 (Second Floor)	3,660	39.1	48.9	17	4.8

Condenser Water Loop (Plant)

Parameter	Value
Object	FluidSys - CW Loop
Loop Type	Condenser Water
Design Supply Temperature (F)	79
Pump Object	CW Loop Pump (on Return Segment)

Cooling Tower

Parameter	Value
Object	HtRej - CW Loop Cooling Tower
Tower Type	Open Tower
Fan Type	Axial
Fan Control	Variable Speed Drive
Rated Capacity (Btu/h)	70,000
Total Fan Horsepower (hp)	0.334
Air Flow Capacity (cfm)	1,389
Water Flow Capacity (gpm)	14.1
Low Speed Air Flow Ratio	0.5
Minimum Speed Ratio	0.5

Boiler

Parameter	Value
Object	Blr - CW Loop Boiler
Boiler Type	Hot Water
Fuel	Gas
Draft Type	Condensing
Rated Capacity (Btu/h)	22,000
AFUE	0.91

Domestic Hot Water Plant

Parameter	Value
Object	ResDHWSys - DHWHeatpump
System Type	Standard (Single Pass Primary)
Compressor	Sanden GS3-45HPA-US (4 kW at 40 F)
Compressor Quantity	2
Primary Tank Volume (gal)	160
Loop Tank Volume (gal)	80
Loop Tank Type	Electric Resistance
Recirculation Type	Non-Central
Source Air / Tank Location	Outside

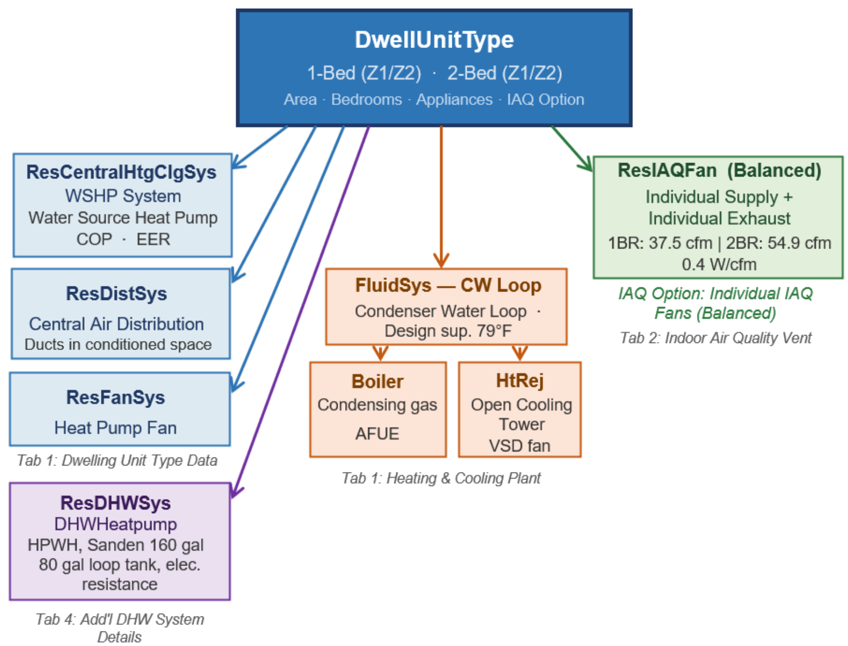
Code Compliance Software Configuration

In CBECC, the residential building is configured around the DwellUnitType object. Each unit type is an object that holds references to the HVAC system, indoor fan, distribution, balanced ventilator, and DHW plant. DwellUnit instances point at a type and inherit its references. The WSHP example adds a plant: a FluidSys object that defines the condenser water loop, with a boiler and cooling tower as loop equipment.

The diagram below shows how the DwellUnitType assembles its components and how the WSHP system in turn references the condenser water loop. The blue branch covers HVAC conditioning on the Dwelling Unit Type Data tab. The orange branch covers the plant on the Heating and Cooling Plant tab. The green branch covers ventilation on the Indoor Air Quality Vent tab. The purple branch covers DHW.

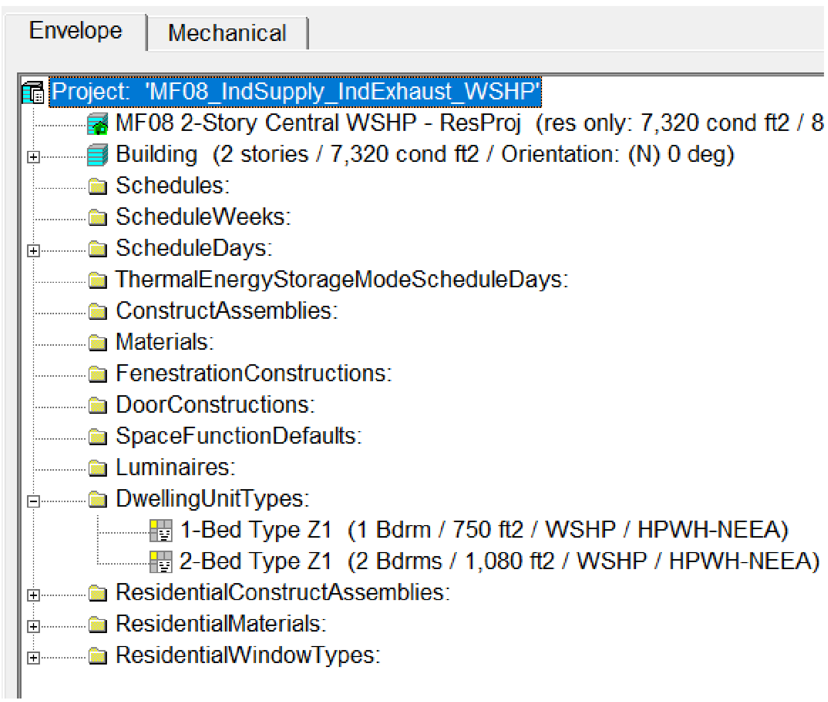
Key Modeling Points

- **The DwellUnitType is a template**; it defines equipment assignments once. Two templates are defined (1-Bed Type Z1 and 2-Bed Type Z1). Four DwellUnit instances each include a count of two, resulting in eight total dwelling units across the two floors.
- **The WSHP system object** is shared across all unit types. Rated COP and EER are set once and apply to every unit. Indoor capacity is autosized per zone. Each unit's ResCentralHtgClgSys references the CW loop supply and return segments so unit-level conditioning is tied to plant loads.
- **The condenser water plant** is configured once on the Heating and Cooling Plant tab as a single FluidSys CW Loop. The boiler and the open cooling tower are child equipment of the loop, referenced through the loop's inlet and outlet segments.
- **The IAQ approach** is set per unit type on Tab 2: Individual IAQ Fans (Balanced). Each type references its own balanced ventilator sized by bedroom count.
- **The balanced ventilators** are set to IAQ Fan Type = Balanced with no heat recovery in this example.

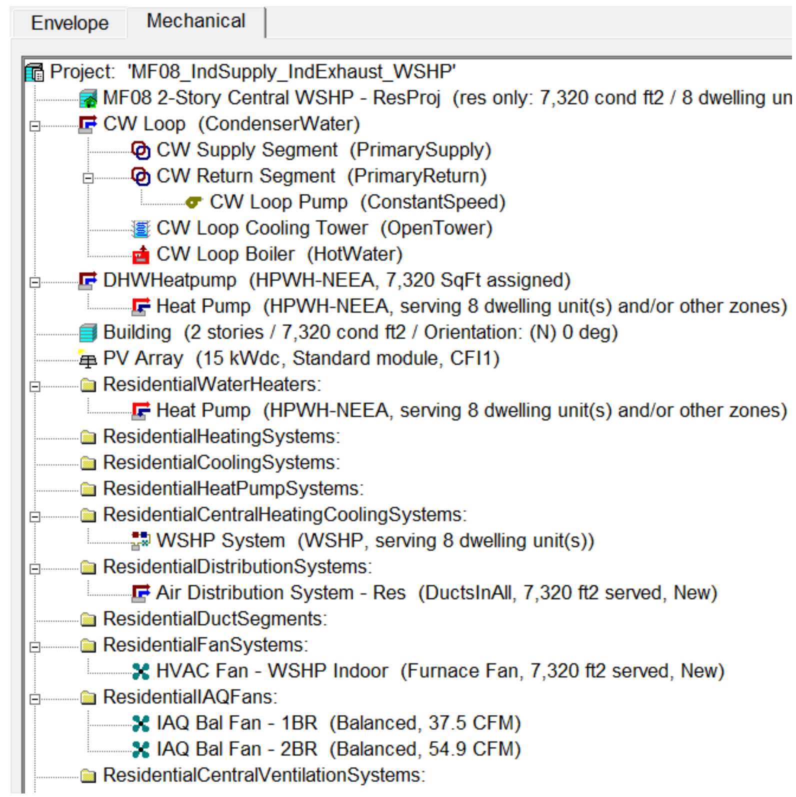


CBECC Object Locations

For multifamily buildings in CBECC, the key objects for configuring the HVAC are on the envelope and the mechanical tab. The envelope tab, as shown below, is where dwelling units live. These are the integration points for all multifamily dwellings where all the components for each dwelling type are defined and linked to mechanical systems.



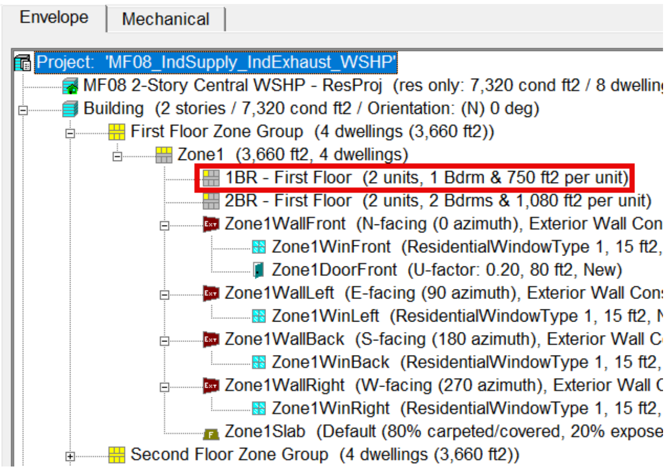
The mechanical tab is where those systems reside and where you can make multiple versions as needed of each system component. For example, this model uses a single WSHP System object to represent the water source heat pumps in every dwelling however you could use several WSHP objects, one for each capacity or configuration of WSHP, on a project. Similarly, you can see in the residential IAQ fans that there are two fans at specific air flow rates for fresh air based on the different number of bedrooms in each typical dwelling unit. The condenser water loop appears at the top of the Mechanical tab as a FluidSys object, with the CW Loop pump, open cooling tower, and gas-fired boiler configured as children of the loop.

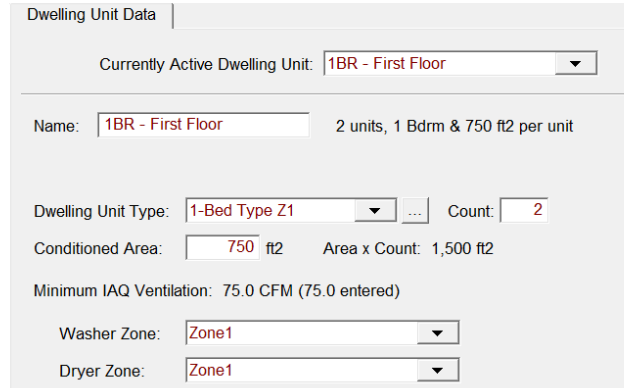


Screenshots

Thermal Space Dwelling Unit Data

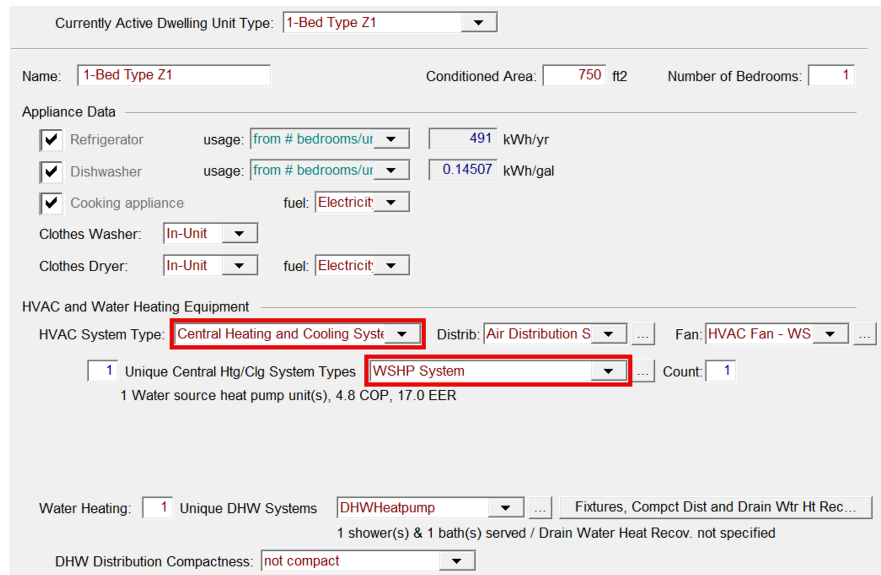
Each thermal space holds a Dwelling Unit Data object that records the count of unit instances of that type in the space and the in-unit appliances.





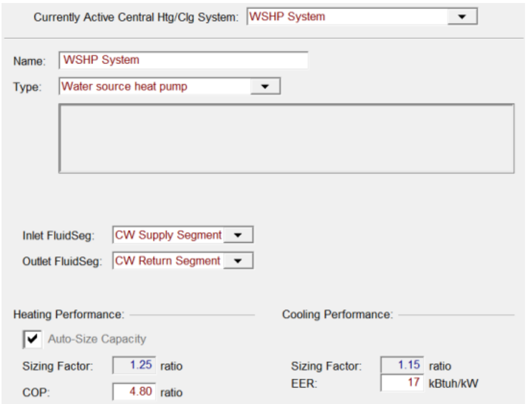
Dwelling Unit Type Data (1-Bed shown)

Sets unit area, bedrooms, appliances, HVAC System type set to Central Heating and Cooling System, the WSHP system reference, indoor fan, distribution, and DHW reference.



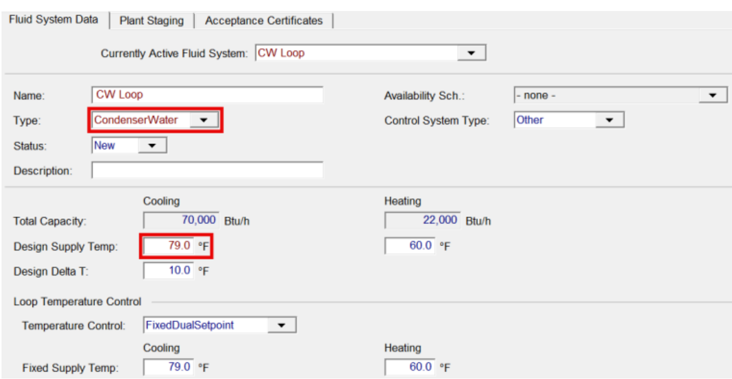
WSHP System Object

On the Mechanical tab. Sets the WSHP type, rated COP and EER, and the CW Loop supply and return segment references.



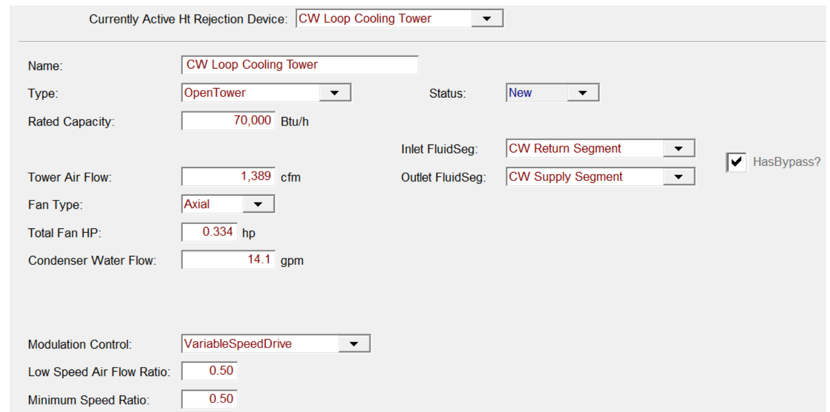
Condenser Water Loop (FluidSys)

On the Mechanical tab, the CW loop is defined for the WSHP systems. The CW loop defines the type as Condenser Water, the design supply temperature. With the loop pump as a child of the return segment and the boiler and cooling tower added as child equipment of the CW Loop.



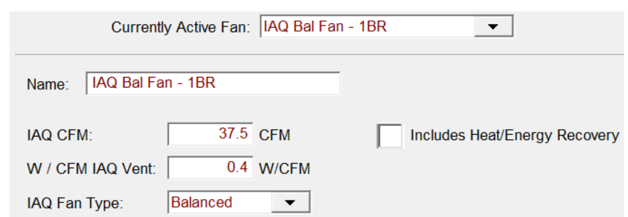
Cooling Tower (HtRej)

Opened from the CW Loop's heat rejection child on the Mechanical tab. Sets the tower type as Open Tower, the rated capacity, and links the tower to the loop through Inlet FluidSeg (CW Return Segment) and Outlet FluidSeg (CW Supply Segment). The axial fan and total fan horsepower set fan power; condenser water flow sets the design loop flow through the tower. Modulation Control is set to Variable Speed Drive, with low speed air flow ratio and minimum speed ratio capping the turndown range.



Indoor Air Quality (1-Bed shown)

Sets the IAQ approach to Individual IAQ Fans and references the unit's balanced ventilator. The heat recovery box is unchecked in this example.



Relevant Energy Code Citations

Restructured 2025 Title 24, Part 6 with section numbers shown with legacy cross-reference in brackets.

Ventilation & IAQ, Attached Dwelling Units

403.2.2.3 & 403.2.2.3.4 [160.2(b)2 & 160.2(b)2Aiv]:

The governing sections for MF dwelling unit ventilation. All attached dwelling units shall meet ASHRAE 62.2 as amended by the Code. ISUP/IEXH qualifies as balanced ventilation per item 2.1. Compartmentalization testing ≤ 0.30 cfm/sf at 50 Pa required per item 2.2.

Equipment Efficiency, WSHP and Boiler

400.5.1 [110.2(a)]:

Equipment shall meet the applicable federal minimum efficiency in Tables 400.5-A through 400.5-L. Water source heat pumps are covered by Table 400.5-B [110.2-B]. The boiler in this model is well below the 1 MMBtu/h system input that triggers Title 24's commercial boiler prescriptive requirements (401.3.13.8 [140.4(k)8] and related); federal minimum efficiency for residential-class gas hot water boilers applies via this section. Modeled WSHP COP and EER and boiler AFUE all exceed the federal minimum (see equipment tables).

Cooling Tower Mandatory Requirements

400.5.5 [110.2(e)]:

Open and closed-circuit cooling towers ≥ 150 tons shall meet conductivity-control and cycles-of-concentration requirements. The tower in this model is well below the 150-ton threshold and is exempt. NR prescriptive 401.3.10.1 [140.4(h)1] would require VSD fan control on motors ≥ 7.5 hp; the model tower fan is below that threshold. VSD control is used in the model to match design intent.

Ducts in Conditioned Space

402.2.6.1.1, under 402.2.6.1 [150.0(m)1]:

When all ducts are located entirely within conditioned space, duct insulation is not required. Must be confirmed through HERS field verification per RA3.1.4.3.8. All dwelling unit ducts modeled as entirely in conditioned space.

Single-Zone Ducted System Fan Efficacy

402.2.6.13.2 [150.0(m)13B]:

Single-zone ducted systems shall meet ≤ 0.58 W/cfm (non-gas AHU) at ≥ 350 cfm/ton airflow. WSHP indoor fans are non-gas. Modeled fan efficacy is below the code cap; see indoor fan table. HERS verification required.

Standard Design Mechanical Package, CZ9

403.3.1.1 [170.2(c)3A]:

For MF performance compliance in CZ9: HP SEER2 and HSPF2 at federal code minimum per 403.3.1.1; refrigerant charge verification required per 403.3.1.2.1. Individual supply fan efficacy for non-HRV balanced systems: ≤ 0.4 W/cfm per 403.3.1.2.5 in CZ 5-10 and CZ 15.

Standard design is a Split Heat Pump baseline. Proposed WSHP picks up compliance credit from the high WSHP COP and EER, offset by gas boiler heat input to the loop and the tower fan and loop pump energy that the Standard Design does not include.

Example 4: NR Small Office, Single Zone VAV, Dual Fuel Heat Pumps

System Tag: T24ACM-SZVAVDFHP
Title 24 2025 ACM: System c3

Mechanical Description

Each thermal zone is served by a dedicated packaged dual-fuel heat pump unit providing ventilation, heating, and cooling. The system uses a variable speed fan to modulate airflow while maintaining fixed supply air temperatures for heating and cooling modes.

Cooling is provided by the heat pump refrigerant circuit, with an economizer and multi-stage capacity control on larger units. Heating is staged between the heat pump and a secondary gas furnace, with two outdoor air temperature setpoints governing the transition: a supplemental heating coil limit, below which the furnace begins contributing, and a compressor lockout temperature, below which the heat pump is disabled and the furnace takes over entirely.

In CBECC, each unit is modeled as a separate SZ-VAV-DFHP air system object assigned to its corresponding thermal zone.

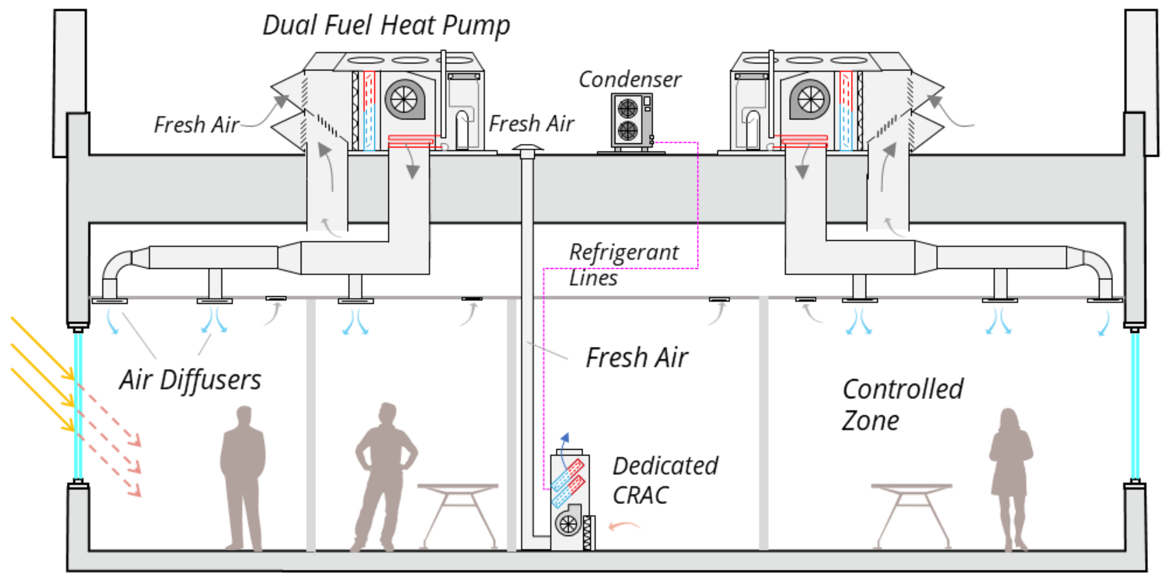


Figure 2: Non-Residential Small Office: SZ Variable Dual Fuel HPs

The diagram above shows dual fuel heat pump single zone rooftop packaged units serving the building. The left unit supplies two rooms via a shared duct run; in practice, each unit controls a single thermostat location.

Mechanical Details

The SZ-VAV-DFHP system was applied to the custom small office prototype, applying this to 7 thermal zones with an additional exhaust-only zone for the restroom and a computer room AC unit for the IT zone. For those 7 systems, the following components are detailed below:

Ventilation: Mixed Air at each unit

Ventilation control: CO2 controls in 3 zones based on people density and flow.

Cooling: DX cooling (reversing heat pump)

Heating: heat pump and supplemental gas furnace

Capacity control: variable air flow with fixed air temperatures

Economizing: Yes, in units above 3.5 tons

Mechanical Capacities and Sizing

Equipment is sized based on the peak loads for each thermal zone calculated by CBECC when simulation is set to autosize based on 55°F supply air for cooling and 95°F supply air for heating. EnergyPlus evaluates the zone peak cooling, heating, and airflow rates. The results of those loads were used to specifically size the model components.

Coil Name	Nom Total Cap (Btu/h)	Nom Sensible Cap (Btu/h)	Max Air Flow Rate (CFM)	Heating Cap (Btu/h)
Zn Sys 1 Reception	51,545	37,068	1,363	51,545
Zn Sys 2 Conference	59,153	41,116	1,449	51,229
Zn Sys 3 Break Room	46,008	36,290	1,473	43,444
Zn Sys 4 Open Office	202,499	148,667	5,602	201,797
Zn Sys 5 Conference-Office	22,535	16,497	621	22,564
Zn Sys 6 Conference-Support	47,990	38,248	1,567	70,005
Zn Sys 7 Restrooms	0	0	0	0
Zn Sys 8 It And Elec	31,183	31,183	1,010	0
Zn Sys 9 Library	72,924	55,424	2,173	54,000
Zn Sys 10 Elec	0	0	0	0

Code Compliance Software Configuration

This section documents the HVAC system configuration as modeled in CBECC for Title 24 compliance. A summary diagram of the system architecture is provided, followed by detailed screenshots of key input screens.

The compliance model is organized around individual air systems (AirSys), one per conditioned thermal zone. Each air system contains a supply segment and a return segment. The supply segment hosts the cooling coil, heating coil, supplemental furnace, and supply fan as sequential components, along with an air terminal unit connecting the system to its zone and an outdoor air controller.

The SZVAVDFHP systems are modeled, each serving one conditioned zone. The systems are configured as follows:

- **Cooling coils** are modeled as direct expansion (DX) coils
- **Heating coils** are modeled as heat pump coils, serving as the primary heating source
- **Supplemental heating coils** are modeled as gas furnaces, activating as secondary heat when outdoor temperatures fall below the heat pump compressor lockout threshold
- **Supply fans** are modeled as variable speed drive (VSD) fans, reducing speed during low-load conditions to match zone ventilation demand
- **Outdoor air control** uses a fixed dry-bulb economizer with the high-limit shutoff temperature except System 10, which has no economizer due to its small capacity.

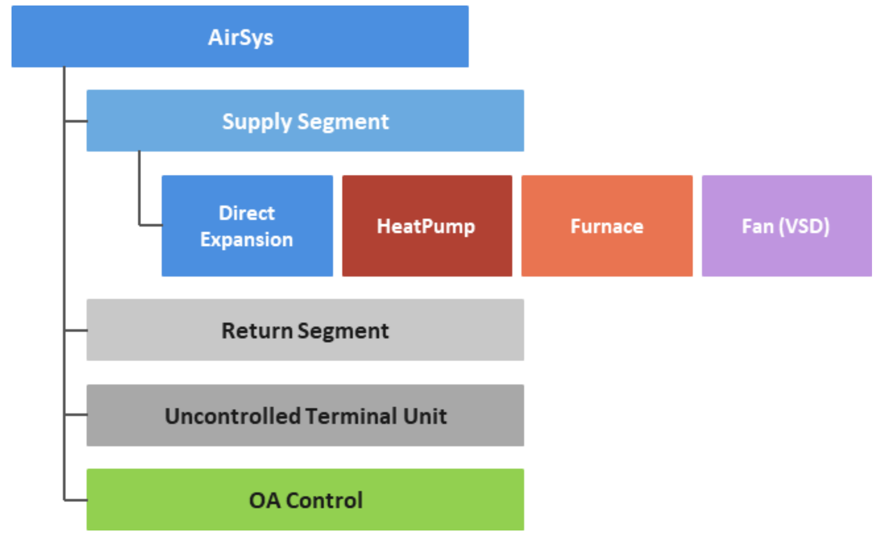


Figure 3: Component Diagram for SZVAVDFHP

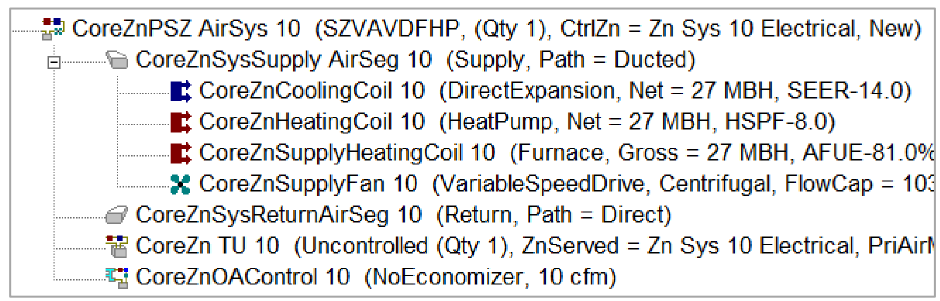


Figure 4: SZVAVDFHP Components in CBECC

CBECC Object Locations

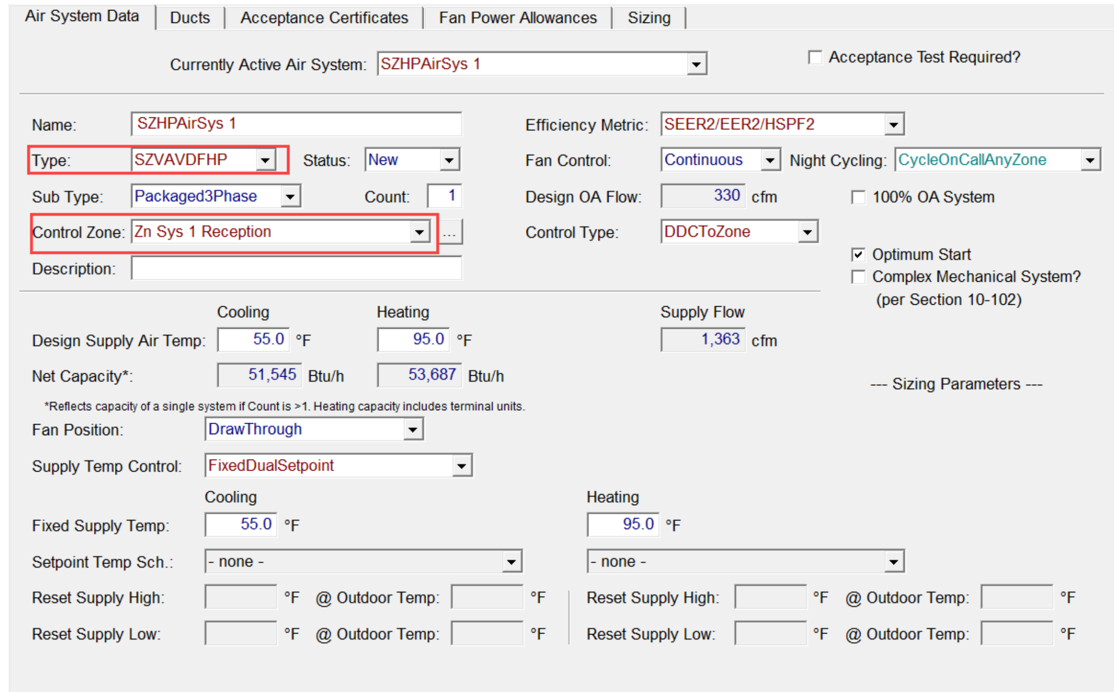
Included are screenshots of the air systems used to specify the SZVAVDFHP and the cooling coil elements for each.

Air Systems and Zone Systems

The primary HVAC system, SZVAVDFHP, is configured with 7 air systems in CBECC. The air system component enables variable speed fans as well as economizer controls which zone systems do not have configured.

Secondary systems, serving the restroom, the IT/Elec and computer rooms are configured with Zone Systems respectively.

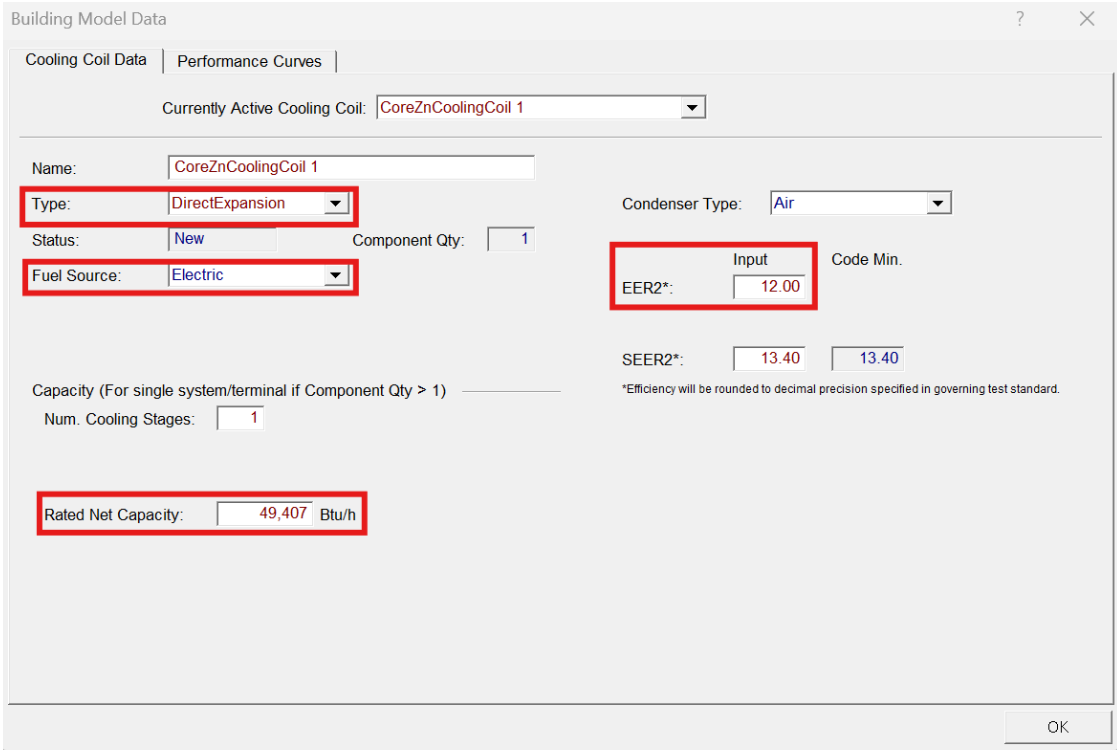
Zone Name	Sys Type	Floor Area (sf)
Zn Sys 1 Reception	SZVAVDFHP	1392.2
Zn Sys 2 Conference	SZVAVDFHP	928.9
Zn Sys 3 Break Room	SZVAVDFHP	1414.3
Zn Sys 4 Open Office	SZVAVDFHP	5962.3
Zn Sys 5 Conf-Office	SZVAVDFHP	578.3
Zn Sys 6 Conference-Support	SZVAVDFHP	1359.2
Zn Sys 7 Restrooms	Exhaust	245.5
Zn Sys 8 IT and Elec	SZAC	131.9
Zn Sys 9 Library	SZVAVDFHP	1818



DX Cooling Coils

The cooling coils are modelled as direct expansion with the fuel source being electric. The restroom zone type has no cooling coil modeled since it just consists of an exhaust fan.

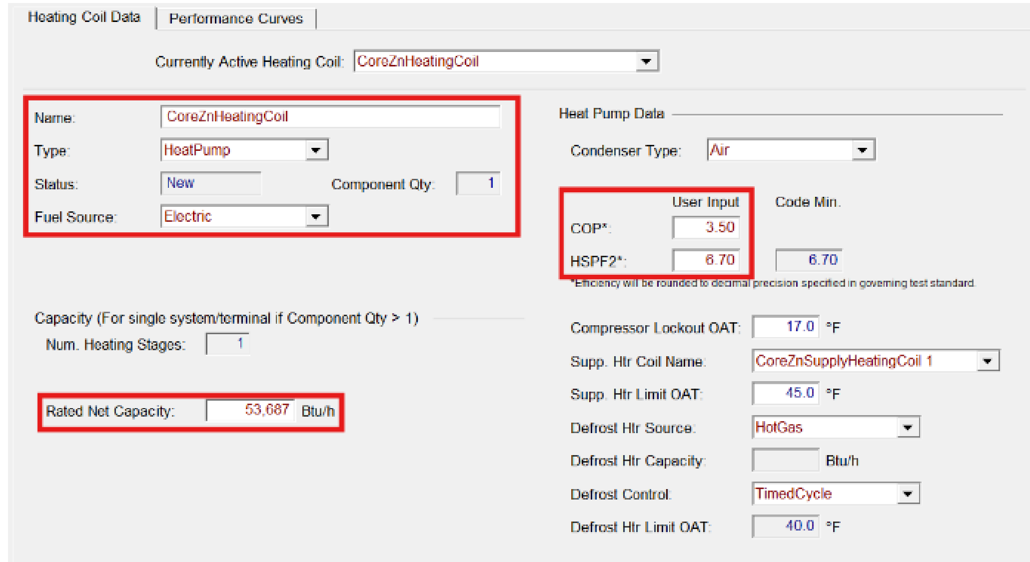
Zone Name	Clg Net	Clg
	(kBtu/hr)	EER2
Zn Sys 1 Reception	49.4	12
Zn Sys 2 Conference	56.7	12
Zn Sys 3 Break Room	44.1	12
Zn Sys 4 Open Office	194.1	10.4
Zn Sys 5 Conf-Office	21.6	12
Zn Sys 6 Conf-Support	46	12
Zn Sys 7 Restrooms	-	-
Zn Sys 8 IT and Elec	70	-
Zn Sys 9 Library	69.9	10.8

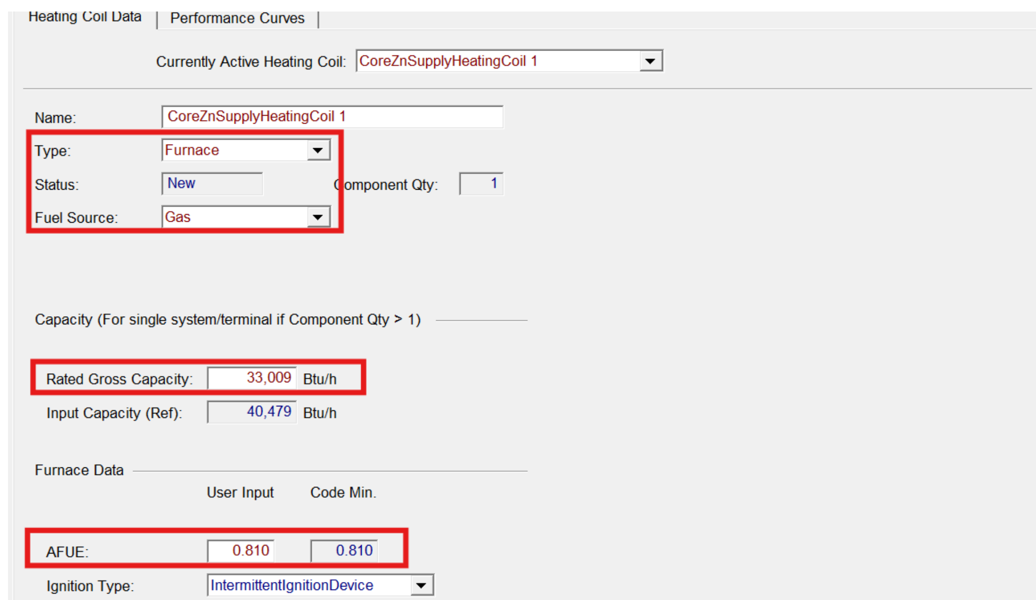


HP and Gas Backup Heating Coils

Two heating coil objects are modelled. The primary is the heat pump type and the secondary is the furnace type. Both the restroom and IT/Elec systems do not have heating. Heat pumps were designed at a COP of 3.5 and an HSPF2 of 6.7. Furnaces were designed at a minimum efficiency of 81%.

Zone Name	Htg HP (kBtu/hr)	Gas Furnace (kBtu/hr)
Zn Sys 1 Reception	53.7	33.0
Zn Sys 2 Conference	53.7	43.7
Zn Sys 3 Break Room	45.4	53.1
Zn Sys 4 Open Office	210.2	132.0
Zn Sys 5 Conf-Office	23.5	15.7
Zn Sys 6 Conf-Support	72.0	58.8
Zn Sys 9 Library	46.9	46.9

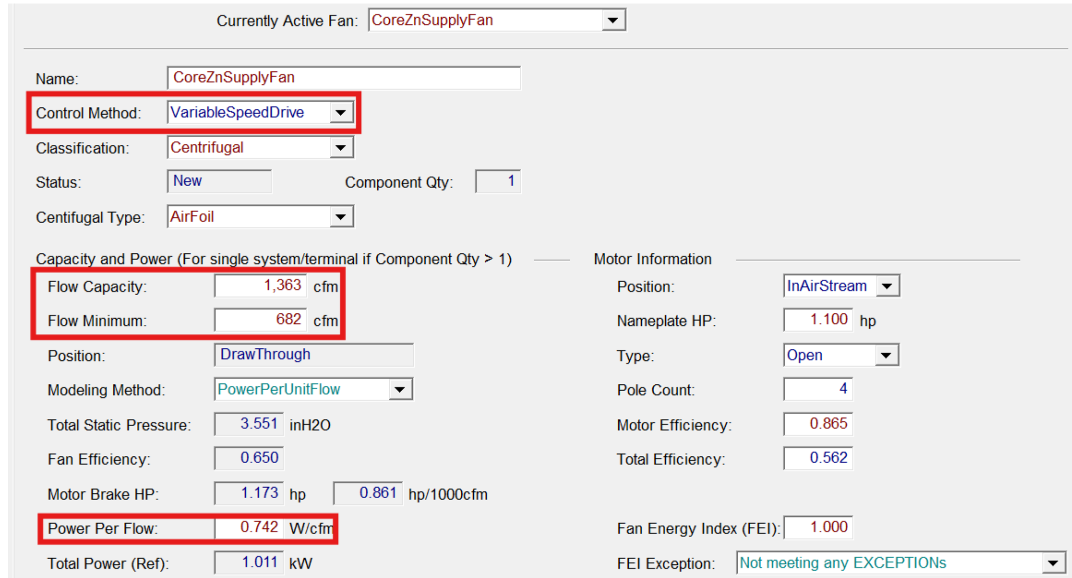


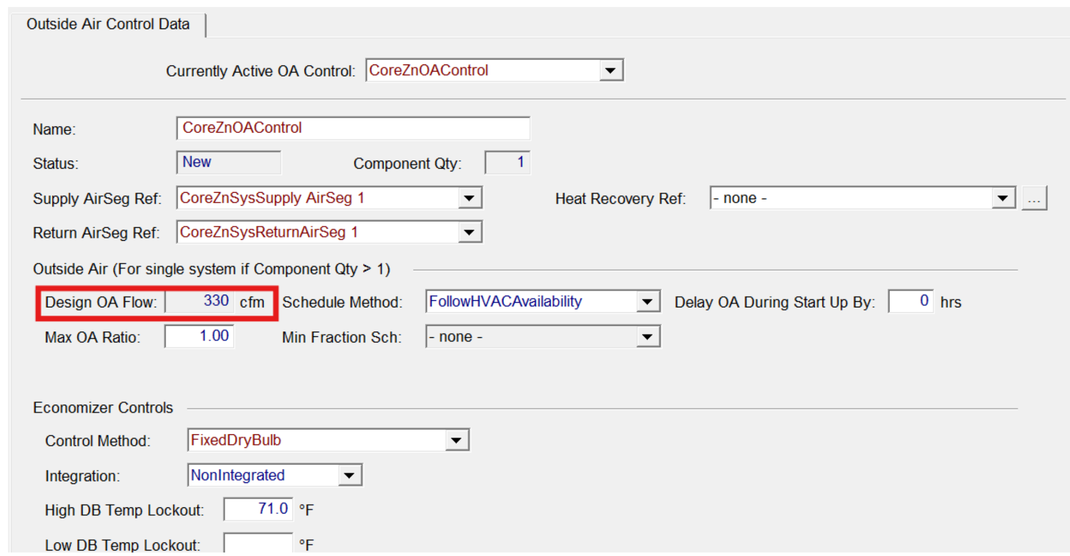


Fan Component

Each fan object includes maximum, minimum, fan power, motor horsepower, motor efficiency, and FEI. CBECC uses these inputs to calculate part-load fan power across the annual simulation. Zones are modelled with fan control as variable speed drive except for restrooms and Elec/IT rooms which are constant volume.

Zone	Supply (CFM)	Min (CFM) (50%)	Fan Eff (W/cfm)
Zn Sys 1 Reception	1363	682	0.742
Zn Sys 2 Conference	1449	725	0.742
Zn Sys 3 Break Room	1473	737	0.742
Zn Sys 4 Open Office	5603	2802	0.742
Zn Sys 5 Conf-Office	621	311	0.742
Zn Sys 6 Conf-Support	1567	784	0.742
Zn Sys 7 Restrooms	250	-	-
Zn Sys 8 IT and Elec	985	-	0.58
Zn Sys 9 Library	2173	1087	0.742





System Efficiency Tables

The table shows the system compared with the T24 2025 standard baseline system for this building and location.

SYSTEM ARCHITECTURE COMPARISON - Proposed (SZVAVDFHP) vs. Standard (SZHP / SZVAVHP / SZAC)		
Category	**Proposed (SZVAVDFHP)**	**Standard (SZHP / SZVAVHP / SZAC)**
System Type	SZVAVDFHP - Single-Zone VAV Dual-Fuel Heat Pump all zones	SZHP; SZVAVHP; SZAC: Single-Zone Heat Pump (CV); Single-Zone VAV Heat Pump; Single-Zone Air Conditioner
Cooling Efficiency	EER 10.4 / EER 10.8 / EER 12.5 / IEER 13.3 (large zones) / SEER 13.9	EER 10.6 / 11.4 (all zones)
Heating Primary	Air-source HP, COP 3.5 (all zones)	Air-source HP, COP 3.2 / 3.3 (all zones)
Heating Supp.	Natural Gas Furnace (AFUE 0.81) - inline supply air furnace - switches on at 35°F	Electric - switches on at 35°F
Fan Type	VSD, CV on ALL zones (0.8804 / 0.9646 / 1.0191 W/cfm)	CV, VSD on most zones (0.58 / 0.72 / 0.742 W/cfm)
VAV Terminal	VAVNoReheatBox - min 50% of design flow (all zones)	Uncontrolled (most zones); VAVNoReheatBox on large zones only
Economizer	Fixed DB 71°F Non Integ + mixed (7 of 8 zones)	Fixed DB 71°F Integ
Supp Lockout	Gas furnace takes over from HP at 35°F OAT	Electric resistance adds to HP at 35°F OAT

Relevant Energy Code Citations

Required Demand Control Ventilation

401.2.1.2.3 [Section 120.1(d)3]

Three zones exceeded the occupancy density limit and were equipped with an airside economizer based on cooling capacity requirements, therefore requiring a modulating airflow of ventilation based on CO2 control.

Fan Control

401.3.14 [Section 140.4(m)]

Fans are equipped to modulate their flow rate to 50% of airflow at 30% of power in each model.

Duct Insulation - Ducts in Directly Conditioned Space

401.2.4.1 [Section 120.4(a)]

Supply-air ducts routed within the return air plenum are considered enclosed in directly conditioned space and are therefore exempt from the minimum duct insulation requirement. No insulation is required for these duct segments.

Duct Sealing and Leakage Testing

401.2.4.7 [Section 120.4(g)]

Duct systems are required to be sealed per the applicable UL 181 standards. Formal leakage acceptance testing per NA7.5.3 is not required, as the duct system does not meet the triggering criteria for systems located predominantly in conditioned space.

Direct Digital Controls to Zone

401.2.2.10 [Section 120.2(j)] and Table 401.2-D [Table 120.2-A]

Each air-handling system and all zones served are required to have DDC to the zone level for new construction where the system supplies more than three zones with a design heating or cooling capacity of 300 kBtu/h or greater.

Optimum Start/Stop Controls

401.2.2.11 [Section 120.2(k)] Systems equipped with DDC to the zone level are required to have optimum start/stop controls that calculate pre-conditioning time based on space temperature, occupied setpoint, outdoor air temperature, and time to occupancy.

Supply Air Temperature Reset Controls

401.3.8 [Section 140.4(f)] A fixed dual setpoint range of 55°F to 95°F is applied as the cooling minimum and heating maximum for supply air temperature reset.

Required Air-Side Economizer

401.3.7 [Section 140.4(e)] All cooling systems exceed 33,000 Btu/hr and are required to include an air economizer. For Climate Zone 9, the fixed dry-bulb high-limit shutoff is set at 71°F per Table 401.3-G [Table 140.4-G].

Heat Pump Supplementary Heating Controls

400.5.2 [Section 110.2(b)] Supplementary heat is locked out when the heating load can be met by the heat pump alone. The outdoor air compressor cut-off is modeled at 17°F with secondary heat availability beginning at 45°F. Supplementary heat operation is permitted during defrost.

Example 5: NR Small Office, VAV-DOAS with Multi-Zone VRF Heat Pump

System Tag: T24STD-DOAS-VRF -HRV
Title 24 2025 STD: 140.4-Ai

Mechanical Description

The building is conditioned by two systems for HVAC: a dedicated outdoor air system (DOAS) with exhaust air heat recovery for ventilation, and a variable refrigerant flow (VRF) heat pump system with zone fan coil units for heating and cooling.

The DOAS handles all outdoor air delivery and latent load management continuously, while the VRF fan coils address sensible heating and cooling. Because ventilation is routed through a dedicated pathway, fan coils can cycle fully off at setpoint without interrupting code-required outdoor air rates, eliminating the primary control challenge of coupled systems and allowing the VRF to operate without ventilation constraints.

The IT room is served by a dedicated constant-volume, single-zone DX cooling unit sized for continuous precision cooling independent of occupancy. No heating is provided to this space. The DOAS supplies a small ventilation terminal to the room, and the unit otherwise operates independently of the VRF system.

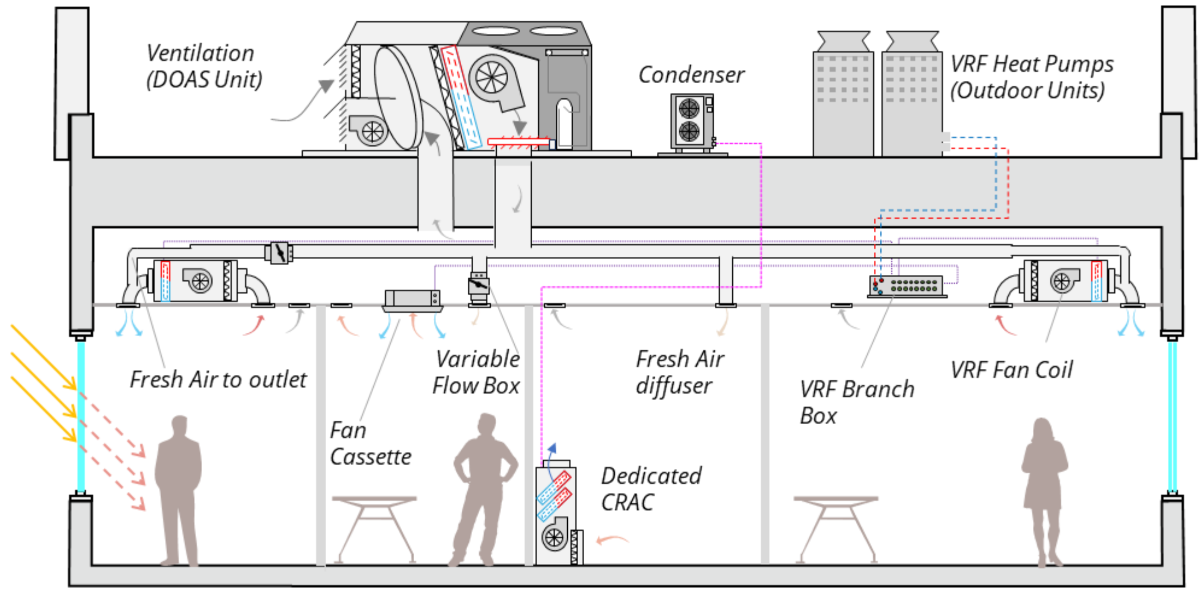


Figure 5: Non-Residential Small Office: DOAS with VRF

The diagram shows a central DOAS unit supplying tempered ventilation air to each zone, including the IT room. A separate VRF heat pump distributes refrigerant through a branch box to individual zone fan coils or cassettes. Zones requiring variable ventilation control are served by VAV boxes, as shown in the two left rooms.

Mechanical Details

The DOAS-HRV-VRF system was applied to the custom small office prototype, applying this to 7 thermal zones for conditioning and the IT zone for ventilation with a separate CRAC.

Ventilation: 100% outdoor air delivered to each zone via DOAS

Ventilation control: Constant volume DOAS with zone-level VAV terminals to distribute required outdoor air

Cooling: VRF system for space cooling with DOAS DX cooling coil for ventilation air

Heating: VRF heat recovery system for space heating with DOAS heat pump for ventilation air tempering

Capacity control: Variable refrigerant flow at terminal units with constant or variable fan operation; DOAS operates at near-constant ventilation airflow

Economizing: Yes, fixed dry bulb economizer on DOAS with high limit lockout of 71 F

Heat Recovery: Sensible and latent heat recovery through energy recovery ventilator serving the DOAS

Mechanical Capacities and Sizing

Systems were sized based on mapping autosized ventilation and zone loads to each component of the design. In the DOAS-VRF system, ventilation airflow was sized independently from space conditioning loads, with the DOAS matched to total outdoor air requirements and the VRF terminals matched one to one with each zone's peak heating and cooling loads. Airflow minimums for VRF fan coils were assumed to be 50% of peak flow where variable speed fans are modeled to represent a typical system. Efficiencies were specified for VRF equipment based on the nominal capacity and the minimum allowed efficiency requirements for heat recovery systems in Title 24 2025. DOAS heating and cooling components were also assigned efficiencies consistent with code minimums, and heat recovery effectiveness was assumed to reflect typical energy recovery ventilator performance.

Code Compliance Software Configuration

DOAS System

The DOAS system is modeled as a DOASVAV air system type, delivering 100% outside air to all occupied zones via terminal units.

- The system includes a furnace and DX cooling coil.
- The Supply fan is modeled as a VariableSpeedDrive centrifugal fan to modulate flow for zones with DCV.
- An exhaust fan is configured under the exhaust segment to balance flow.
- A HeatRecovery object is attached to the system to recover energy from the exhaust.
- Outside air control is handled by a dedicated object.

VAV Terminal Units

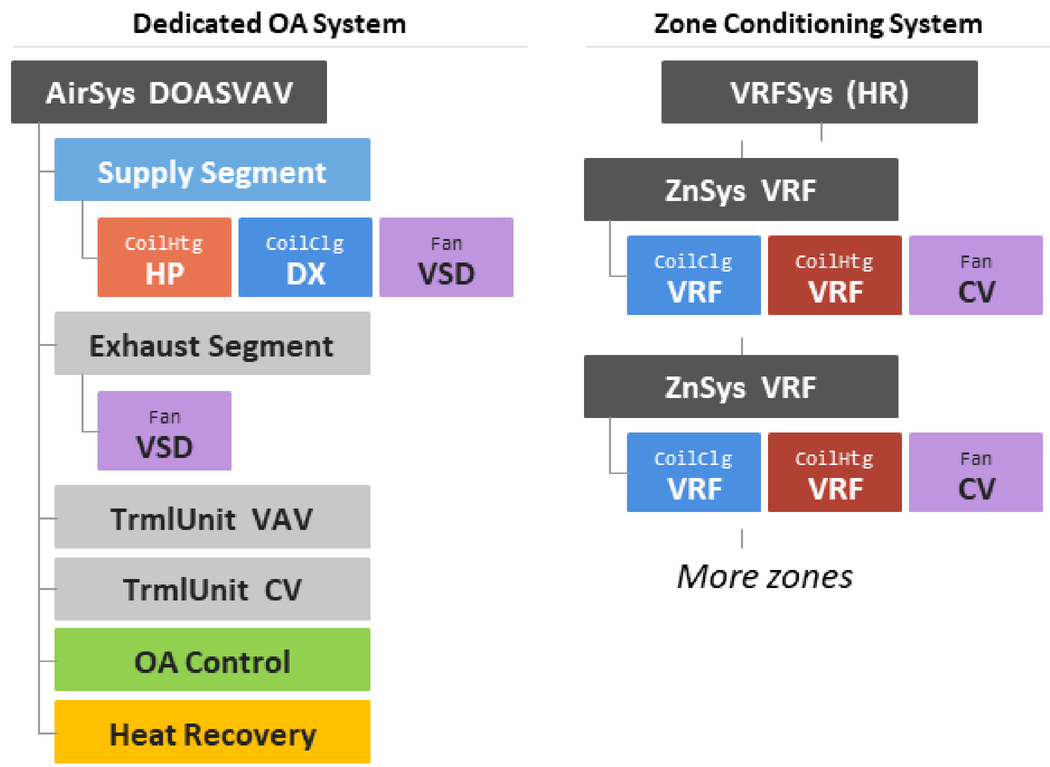
VAVNoReheatBox terminal units distribute DOAS air to zones with no zone-level reheat, each sized to zone ventilation flow.

VRF Heat Pump System

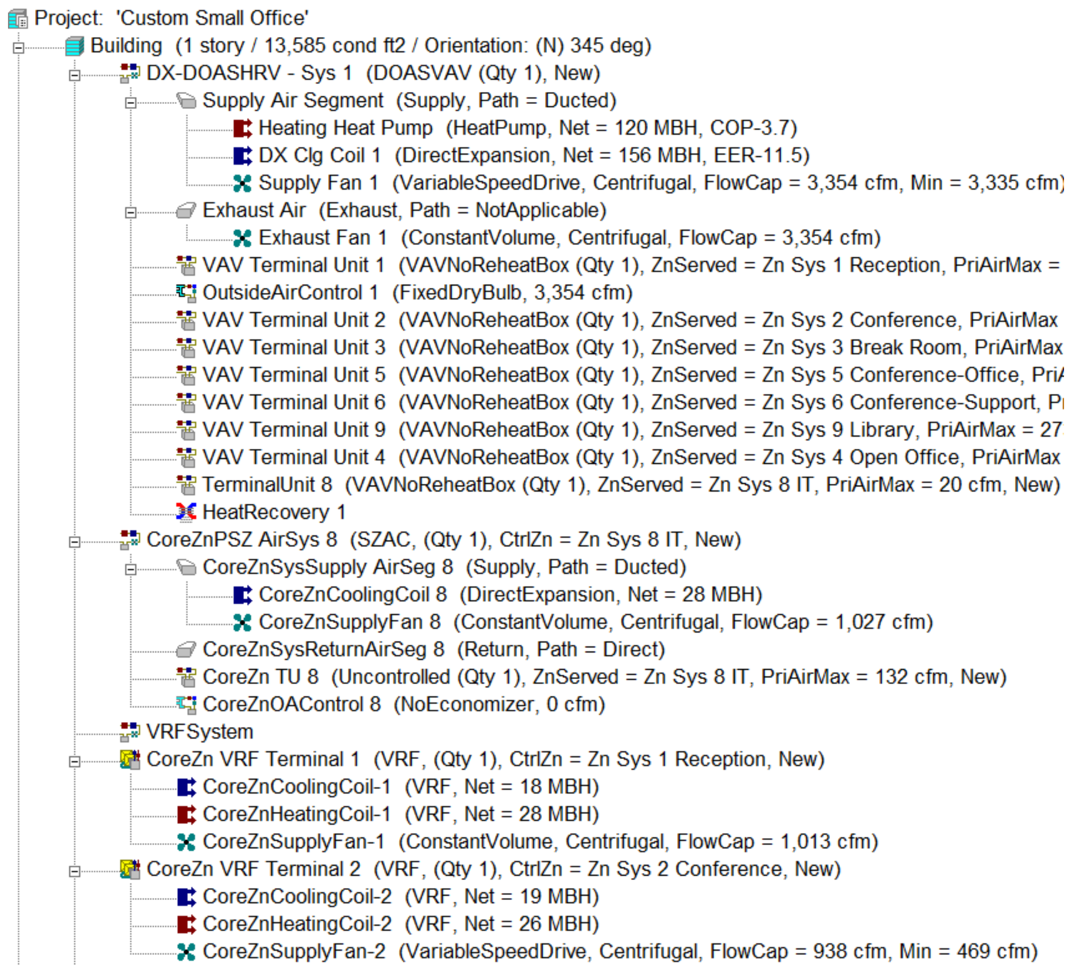
A central VRF system is built at the building level of the model tree structure and controls and distributes heat to each attached VRF zone system.

VRF Zone Systems

Zone Systems configured as VRF objects, with VRF cooling and heating coils configured for each thermal zone.



The system configuration is shown from CBECC 2025.2 for the DOAS -HRV-VRF system components.



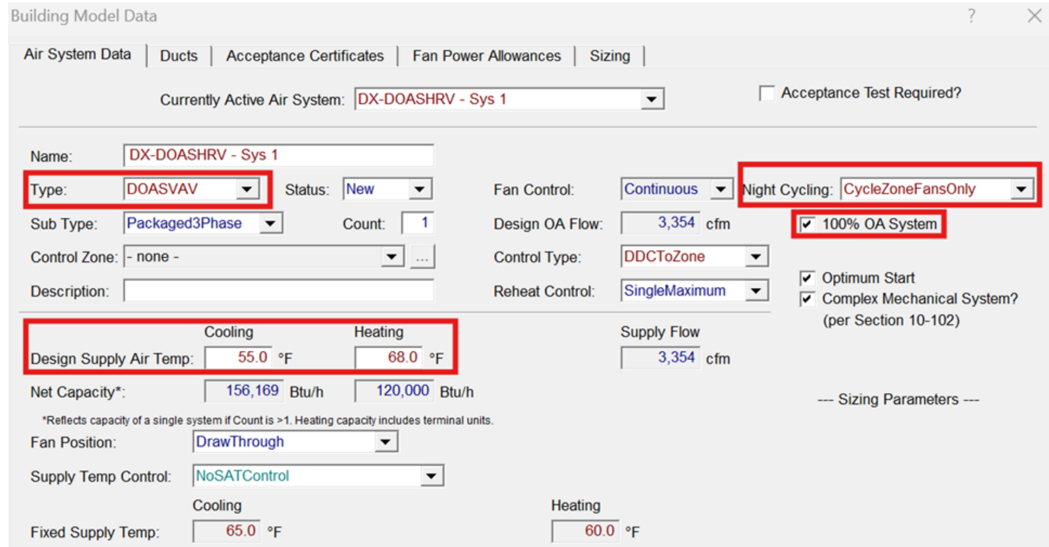
CBECC Object Locations

The model consists of seven VRF zones via VAV terminals, one zone with an SZHP system for the IT space and one unconditioned space for the restroom consisting of just an exhaust fan.

DOAS Ventilation System

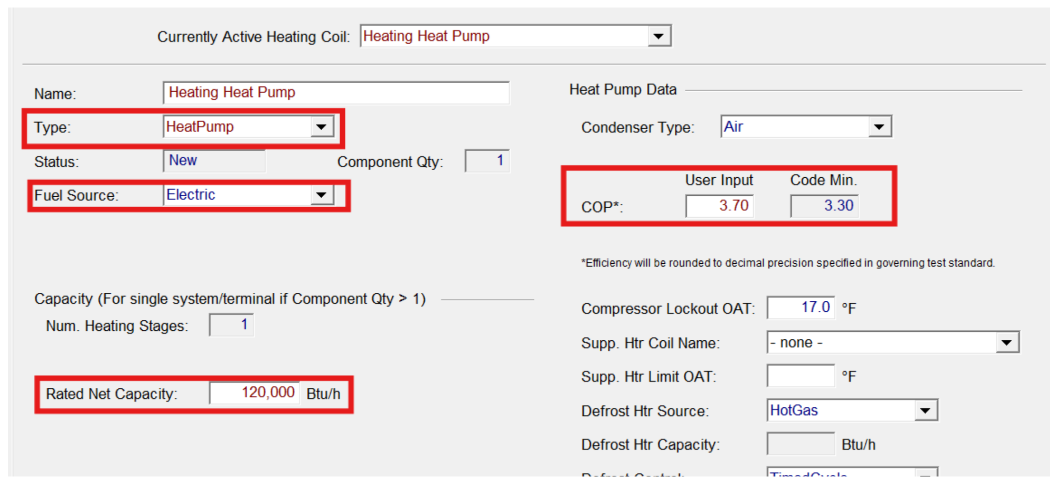
The DOAS is a 100% outdoor air system configured as a DOASVAV type, enabling ventilation airflow to modulate at the zone depending on the terminal unit types.
The air temperature is maintained at neutral conditions, which has design supply temperatures of 55 F and 68 F for cooling and heating.

To maintain temperature at night, the local zone fan coils are used, keeping the ventilation system off.



HP Heating Coil

The DOAS heating source consists of an electric air source heat pump.

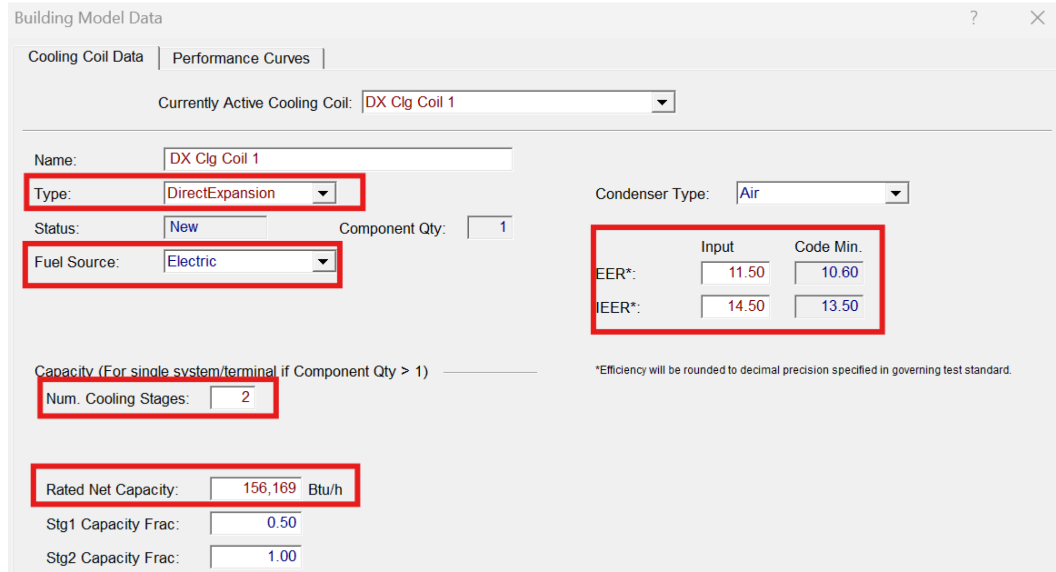


Coil Type	HeatPump (air-source)
Net Capacity	120,000 Btu/hr (10.0 tons eq.)
Capacity / Area	8.83 Btu/sf
COP	3.7 (heating)
HP Lockout	17°F

DX Cooling Coil

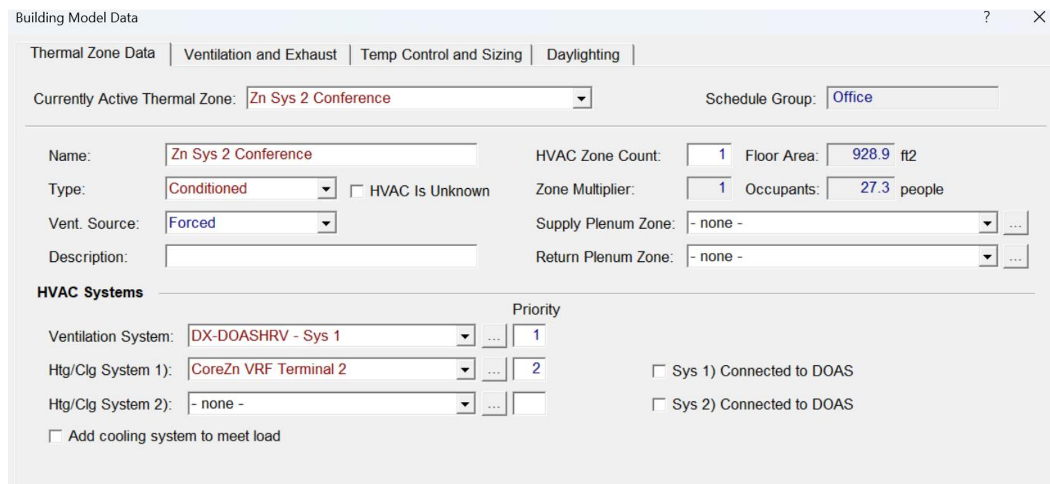
The DOAS cooling source consists of a direct expansion cooling coil

Coil Type	DirectExpansion (DX), 2-stage
Net Capacity	156,169 Btu/hr (13.0 tons)
Capacity / Area	11.50 Btu/sf
EER	11.5
IEER	14.5
Number of Stages	2
Design Supply T	55°F



Thermal Zones

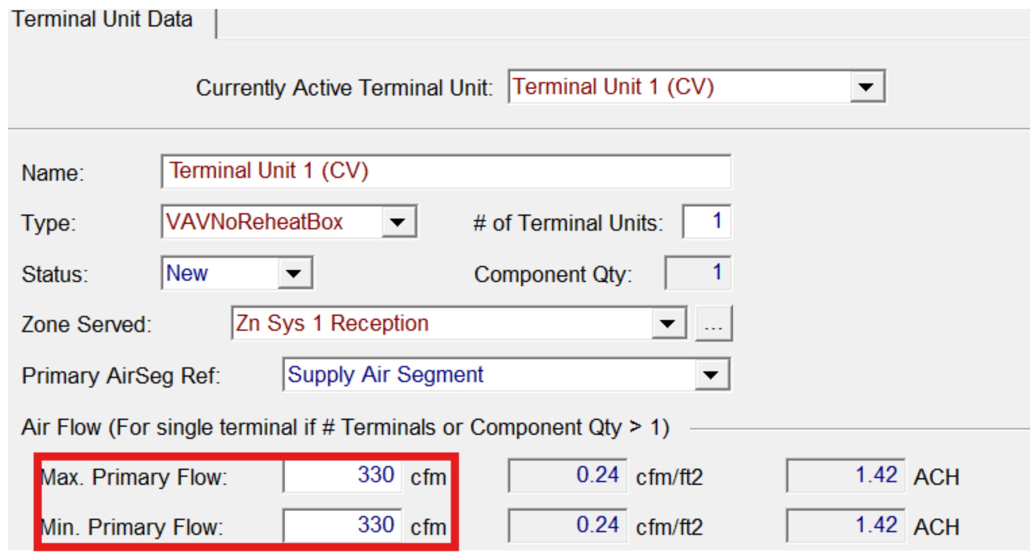
At each thermal zone, ventilation is configured from the DOAS unit and heating and cooling from the zones' designated VRF fan cassette. Because the ventilation is decoupled, delivered directly to the space or downstream of the fan in each VRF fan coil or cassette no box is checked in the software for DOAS.



Air Terminal Units

Air terminal units are created under the DOAS Air System for each thermal zone ventilation delivery. Three zones (Zn Sys 2, Zn Sys 3 and Zn Sys 6) have CO2 sensors based on occupant density and therefore also have minimum and maximum ventilation rates. All zones utilized a Variable Air Volume Terminal Unit for simplicity though only three were configured with a lower airflow limit.

Zone Name	Terminal Control	Floor Area (sf)	Max (cfm)	Min (cfm)
Zn Sys 1 Reception	Constant	1392.2	330	330
Zn Sys 2 Conference	Variable	928.9	419	139
Zn Sys 3 Break Room	Variable	1414.3	591	212
Zn Sys 4 Open Office	Constant	5962.3	928	928
Zn Sys 5 Conference-Office	Constant	578.3	121	121
Zn Sys 6 Conference-Support	Variable	1359.2	673	204
Zn Sys 7 Restrooms	Exhaust Fan	245.5	-	-
CoreZn TU 8 (uncontrolled)	Constant	131.9	1027	-
Zn Sys 9 Library	Constant	1818	273	273

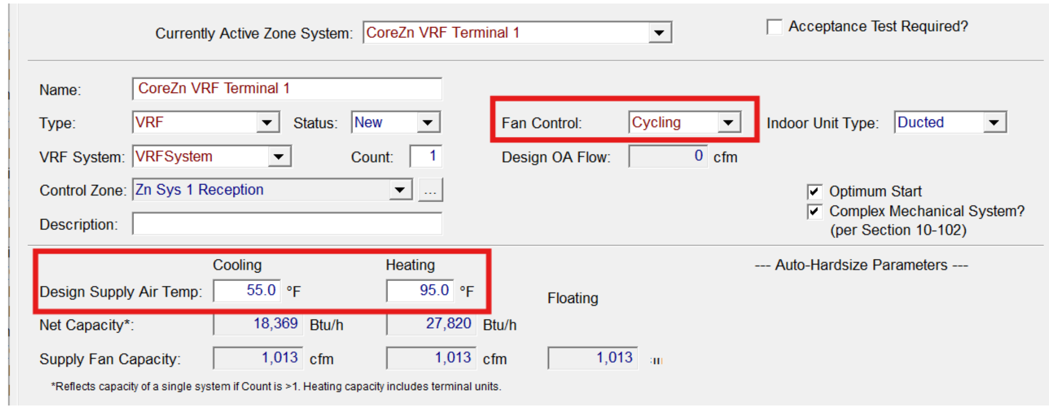


Zone System VRF Fan Coils

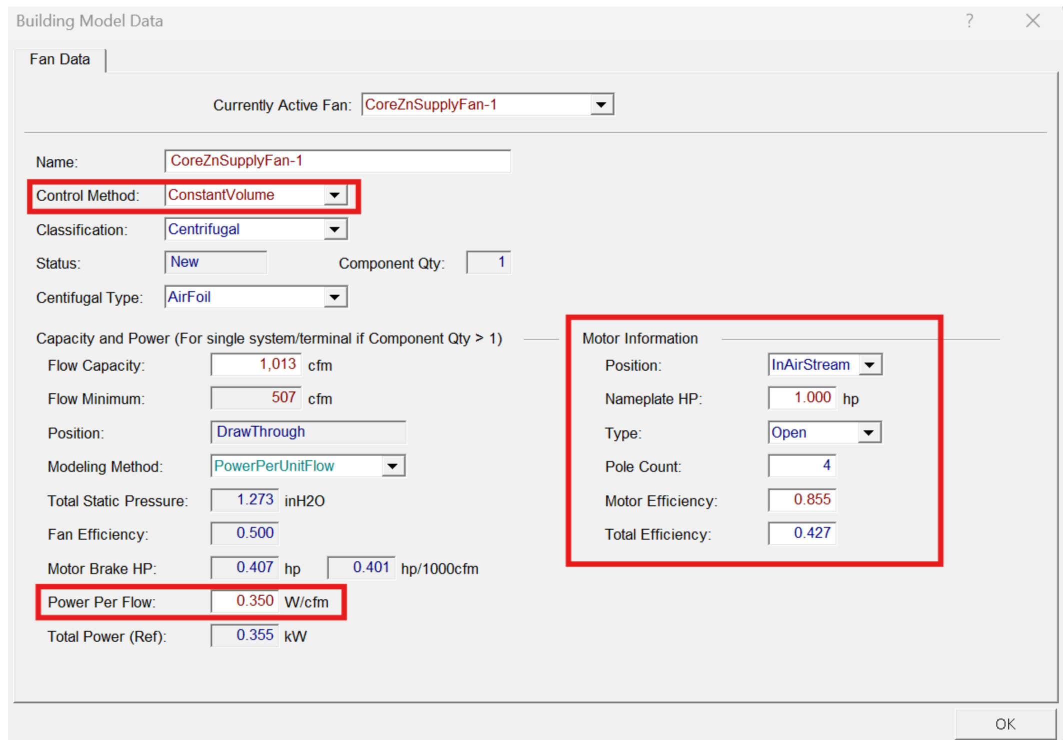
The model includes a VRF system with mixed fan configurations, with variable-speed terminals serving the Conference, Break Room, and Conference-Support zones, and constant-volume terminals serving all other zones.

Units were configured with cycling fans, which is the only modulating fan control allowed for these zone systems. Supply air temperature was left at default, supplying 55°F air in cooling, 95°F heating.

Aux. power was configured to represent a small amount of power used in the VRF system for the branch controller for the specific zone.

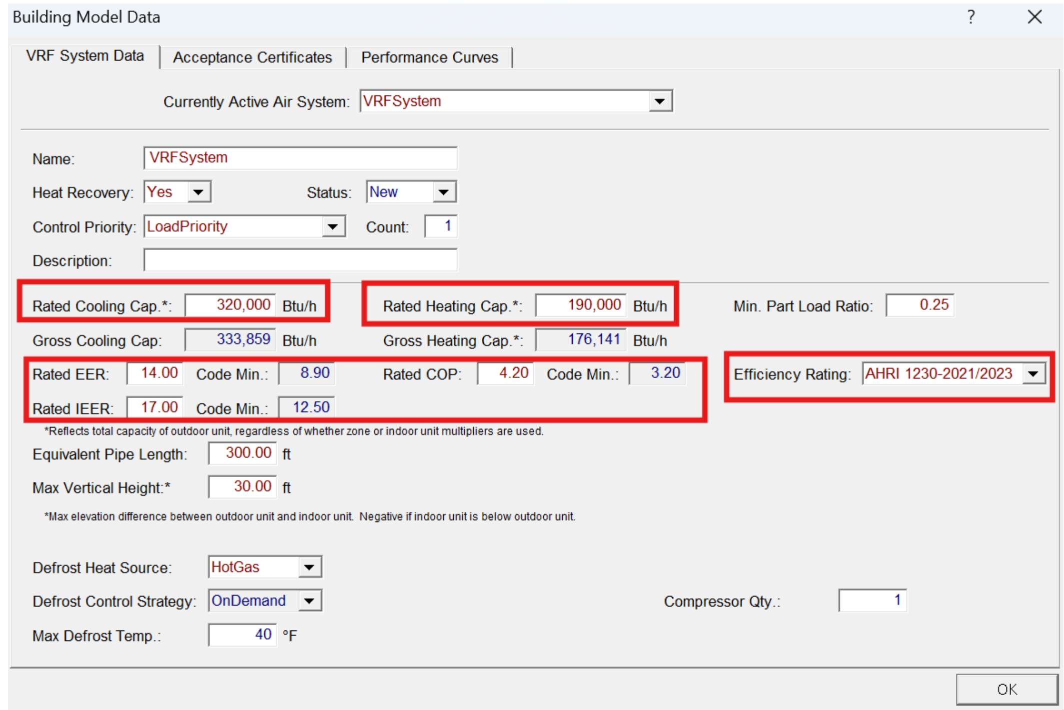


Fans are set to constant volume. Regardless of their assignment, in CBECC 2025 they are set to on off fans upon simulation and will cycle on and off as needed.



VRF Central HP System

The central heat pump is configured with refrigerant heat recovery, as well as control based on the aggregated zone fan coil load, Load Priority. This is the most common configuration for VRF heat pump systems with multiple zones.



System Efficiency Tables

Category	Proposed (DOAS -DC-VRF-HRV)	Standard (SZHP / SZVAVHP)
OA Strategy	100% dedicated OA via DOAS-HRV (CV supply); VRF handles zone conditioning	Per-zone OA via each SZHP unit intake
VRF Sizing	Full-load VRF (NOT decoupled/sensible-only); sized for full sensible+latent zone load	SZHP per-zone; sized for full load per zone
DOAS Cooling	DX coil 156.2 kBtu/hr (EER 11.5 / IEER 14.5), 2-stage, air-cooled	Per-zone DX HP coils (EER 10.6–11.4)
DOAS Heating	Air-source HP, COP 3.7, fully electric, no gas; lockout 17°F, no supplemental	Per-zone HP COP 3.2–3.3 + electric resistance supplemental at 35°F
DOAS Fan	Supply VSD (≈CV at 0.611 W/cfm); Exhaust CV (0.390 W/cfm)	N/A: no central DOAS
Zone Fan Mix	CV on Zones 1,4,5,9; VSD min 50% on Zones 2,3,6, W/cfm 0.35–0.66	CV on most zones (0.58–0.66 W/cfm); VSD min 50% on Zone 4 only
VAV Terminal Mins	Varies: min=max on Zones 1,4,5,8,9; partial mins on Zones 2 (45%), 3 (36%), 6 (58%)	Uncontrolled (most zones); VAVNoReheatBox on Zone 4 only
Economizer	DOAS Fixed DB 71°F NonIntegrated	Per-zone Fixed DB 71°F Integrated (6 of 7 zones)
Gas Use	Fully electric: no gas heating anywhere	Fully electric: no gas
Zone 8 IT	SZAC 28.0 kBtu/hr + 20 cfm DOAS OA via dedicated VAV terminal	SZAC 27.3 kBtu/hr + per-unit OA intake (19.8 cfm)

Relevant Energy Code Citations

Required Demand Control Ventilation

401.2.1.2.3 [Section 120.1(d)3]

Three zones exceeded the occupancy density limit, requiring CO2-based modulating ventilation airflow. Zone-level VAV terminals on the DOAS serve those zones.

Fan Power Budget - DOAS Unit

401.3.3.4 [Section 140.4(a)3E] and 401.3.17.1 [Section 140.4(p)]

The DOAS unit is required to comply with the prescriptive system requirements for a VRF heat pump system with DOAS per Section 401.3.3.1.1 [Section 140.4(a)3Ai], which designates the DOAS under Section 401.3.3.4 [Section 140.4(a)3E]. That section sets a maximum DOAS fan power of 0.77 W/cfm at design airflow. The modeled DOAS fan power is consistent with this prescriptive limit.

Fan Power Budget - VRF Indoor Fan Coil Units

401.3.3.3 [Section 140.4(a)3D]

VRF indoor fan coil units were aligned with prescriptive code for the multi-zone heat pump system to a fan power of 0.35 W/cfm and airflow down to 33% of peak flow.

Air-Side Economizer Exemption - DOAS Unit

401.3.7 [Section 140.4(e)]

The DOAS unit operates at 100% outdoor air and therefore has no return air damper to modulate. An air-side economizer is not applicable to this system configuration.

Air-Side Economizer - VRF Fan Coils

401.3.7 [Section 140.4(e)]

VRF fan coils with cooling capacity exceeding 33,000 Btu/hr would individually trigger the economizer requirement. No economizer is provided on the fan coil units. The VRF outdoor unit is rated at IEER 17.0, which exceeds the 30% efficiency improvement threshold above the mandatory minimum required to eliminate the economizer requirement for Climate Zone 9.

Exhaust Air Heat Recovery

401.3.18 [Section 140.4(q)]

Outdoor air systems delivering 3,000 CFM or more at 70% or greater outdoor air fraction are required to include exhaust air heat recovery. The DOAS delivers 100% outdoor air above this airflow threshold, requiring the modeled heat recovery ventilator.

Minimum DOAS Cooling and Heating Efficiency

Table 401.3-A [Table 140.4-A]

The DOAS DX cooling coil and heat pump heating coil are each required to meet minimum EER and COP thresholds for their capacity ranges. Both modeled coils exceed the applicable mandatory minimums.

Same Criteria as Example 1

- Duct Sealing and Leakage Testing
- Direct Digital Controls to Zone
- Optimum Start/Stop Controls

Example 6: NR Classroom Laboratory, VAV-DOAS with Four-Pipe Fan Coils and Air-to-Water Heat Pump

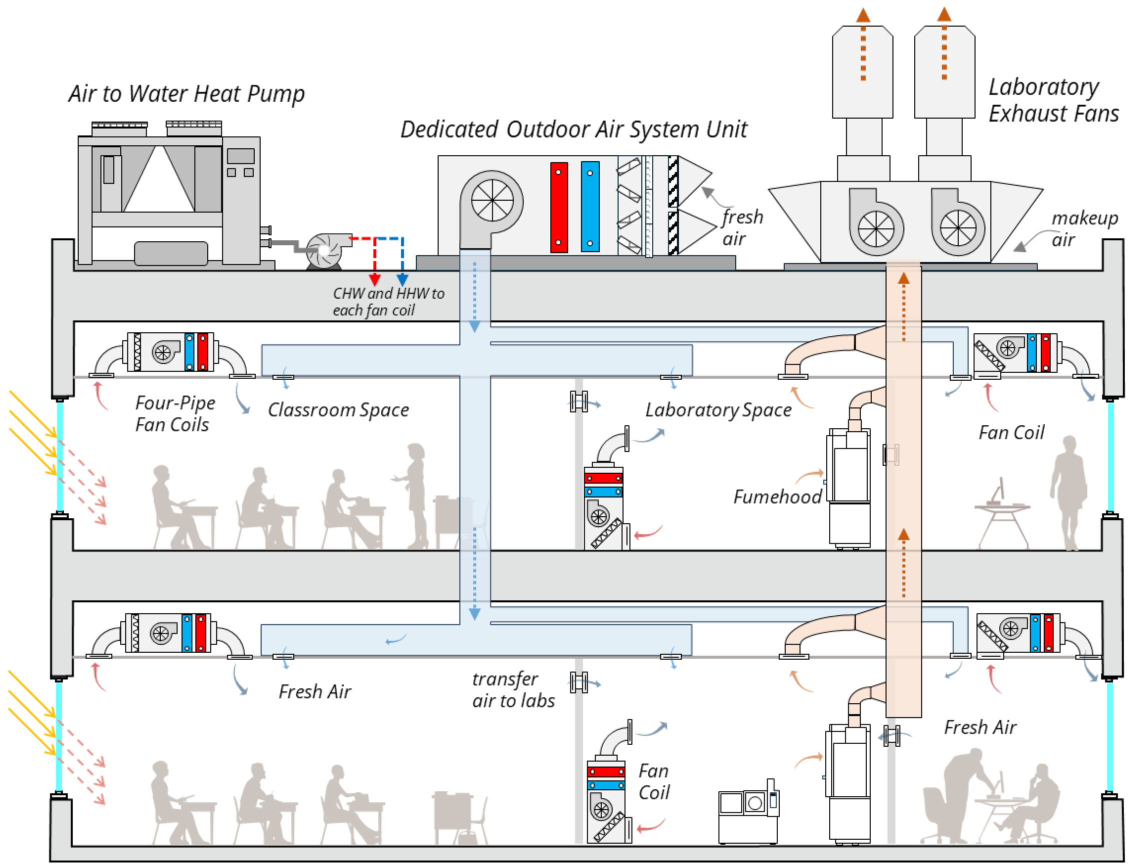
System Tag: T24STD-DOAS-FPFC-AWHP-HRV
Title 24 2025 STD:140.4-Aii

Mechanical Description

The building is conditioned by a dedicated outdoor air system (DOAS) with distributed four-pipe-fan coil units (FPFC), providing heating and cooling. A central plant, consisting of an air-to-water heat pump, produces hot and cold water conditioning the ventilation air and each thermal space.

Chilled water as well as hot water for heating and cooling are generated by an air-to-water heat pump. Fresh air is provided by a central DOAS unit, transferred from classrooms and offices to laboratory spaces, and exhausted through a central laboratory exhaust system. The laboratory spaces include fume hoods to demonstrate how exhaust-driven ventilation systems are balanced.

Laboratory exhaust is handled by a dedicated variable speed exhaust fan system capable of wide turndown to track actual exhaust demand across varying fume hood and general exhaust loads.



The diagram shows a central DOAS unit supplying tempered ventilation air to each zone. A separate fan coil is provided in each thermal zone, with ventilation air supplied to each zone and transferred to the laboratories for cascaded airflow.

Mechanical Details

The system was applied to the custom lab classroom prototype, with 25 thermal zones.

Ventilation: 100% outdoor air delivered to each zone via DOAS. Air is cascaded through the classrooms to the laboratories and exhausted with additional exhaust at the DOAS.

Ventilation control: Variable volume DOAS with zone-level VAV terminals in rooms where DCV is required and CV terminals in others.

Cooling: Four-pipe fan coil units for space cooling with chilled water from air-cooled screw chiller; DOAS chilled water coil for ventilation air pre-cooling.

Heating: Four-pipe fan coil units for space heating with hot water from air-to-water heat pump; DOAS hot water coil for ventilation air tempering.

Capacity control: Variable chilled and hot water flow at fan coil units with variable-speed fans; DOAS operates at variable ventilation airflow tracking zone demand

Economizing: No economizing

Heat Recovery: Sensible and latent heat recovery through energy recovery ventilator serving the DOAS.

Mechanical Capacities and Sizing

The following tables show the capacities for major components in this example model for the DOAS ventilation unit and central plant heating and cooling devices.

The ventilation system was sized to meet total outdoor air requirements across all zones, with heating and cooling coil capacities matched to peak ventilation loads.

An exhaust fan was included in the lab exhaust air system only. To enable the DOAS air system to function only a supply segment and fan were configured without any exhaust or return air segment.

Air Systems	Sys Type	Fan Ctrl	Supply CFM	Min CFM (VSD)	Supply Density (CFM/sf)
DOAS-AHU Supply	DOAS	VSD	15,879	10,177	0.59
DOAS-AHU Exhaust	DOAS	VSD	5,294	5,294	0.30
Lab Exhaust Fan	Exhaust	VSD	10,585	4,883	0.39

Equipment	Plant Type	Rated Capacity (Btu/h)	Capacity / Building Area (Btu/sf)	EER	IPLV	COP
Air Cooled Chiller	ChilledWater	989,261	36.6	15	21	n/a
Air-to-Water HP	HotWater	308,705	11.4	n/a	n/a	2.5

Four-pipe fan coil units were sized with each zone's heating and cooling loads, with independent chilled water and hot water coil capacities assigned separately to reflect the decoupled nature of the four-pipe configuration.

Central plant equipment: the air-cooled screw chiller and air-to-water heat pump were sized to the peak loads of the FCUs and DOAS coils. Chiller and heat pump efficiencies were specified based on capacity and minimum allowed efficiency requirements per Title 24 2025. DOAS heating and cooling coil components were assigned efficiencies consistent with code minimums, and heat recovery effectiveness was assumed to reflect typical energy recovery ventilator performance.

Code Compliance Software Configuration

DOAS System

The DOASVAV type delivers 100% outside air and includes:

- A chilled water cooling coil and hot water heating coil served by the central hydronic plant.
- A variable-speed drive centrifugal supply fan to modulate flow.
- An exhaust fan to balance flow.
- An outside air control for demand-based ventilation.
- A HeatRecovery object to recover energy from exhaust.

VAV Terminal Units

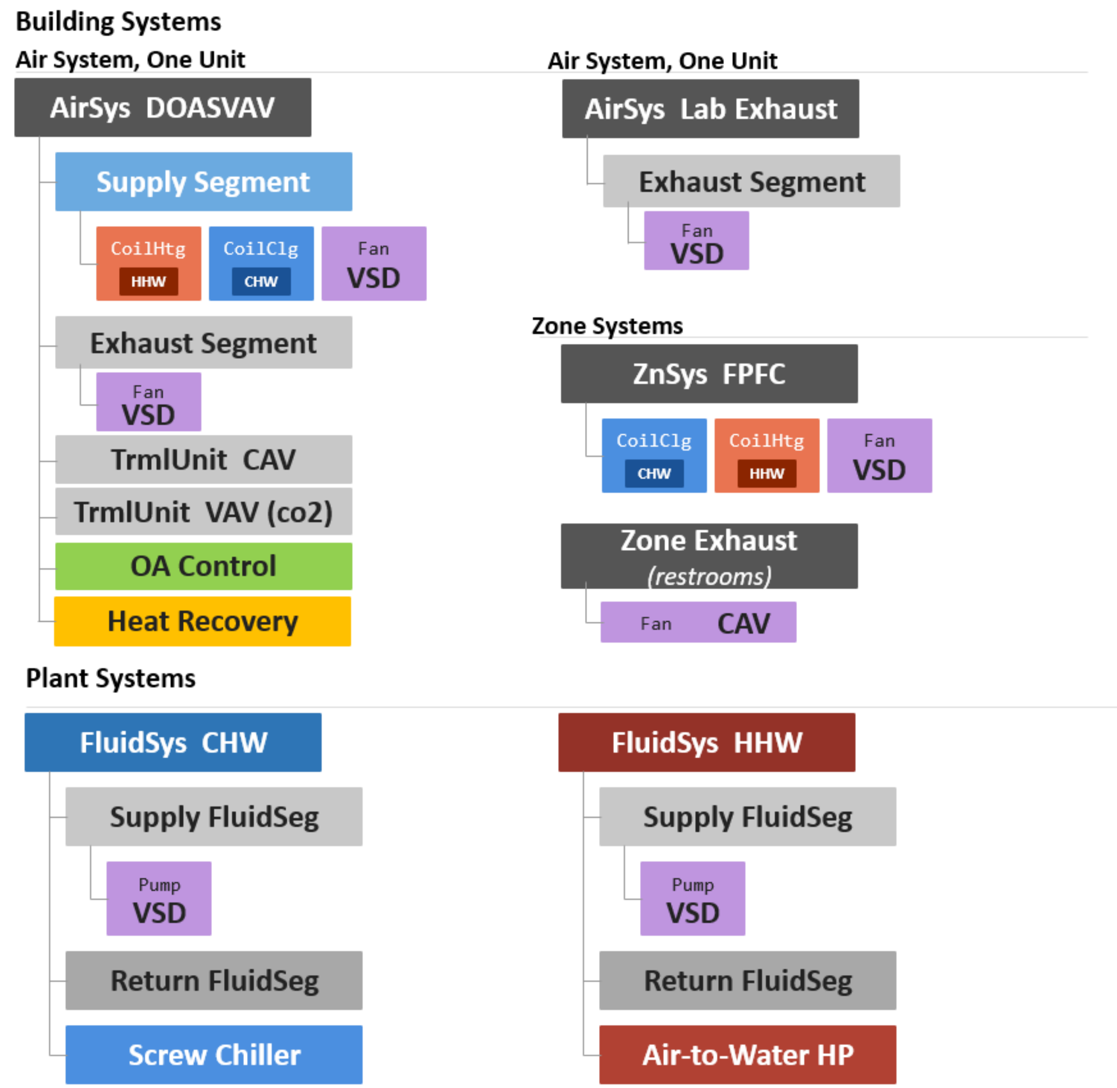
VAVNoReheatBox terminal units distribute ventilation air to zones. Zones with CO2-based control requirements have the lower limit configured to enable modular flow.

Central Hydronic Plant

The chilled water plant is modeled as an air-cooled screw chiller on a primary variable-flow loop. The hot water plant uses an air-to-water heat pump. Both loops serve DOAS coils and fan coil units.

Lab Exhaust System

The laboratory exhaust system uses a variable-speed exhaust fan sized to peak exhaust demand. Supplemental zone fans serve exhaust zones such as restrooms.



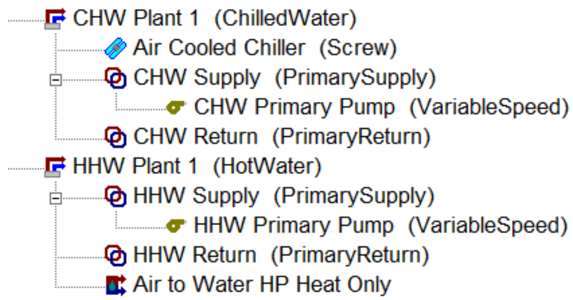
The system configuration is shown from CBECC 2025.2 for the DOAS -VAV-FPFC (CHW/HHW) system components.

The plant systems are depicted for the chilled water and hot water systems.

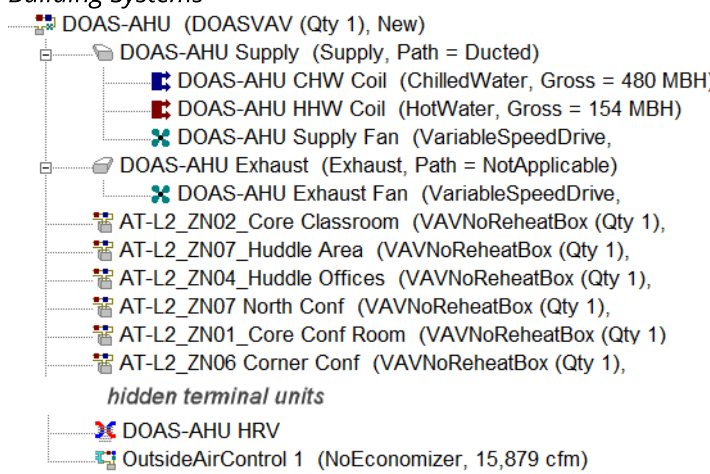
The DOAS air system is shown with each coil, fan, and terminal units, and finally the heat recovery device and outdoor air controller.

The laboratory exhaust system, an air system, is shown with the single exhaust fan type. The zone system exhaust fans and a sample zone fan coil system are also shown with their individual coils and fans.

Plant Systems



Building Systems



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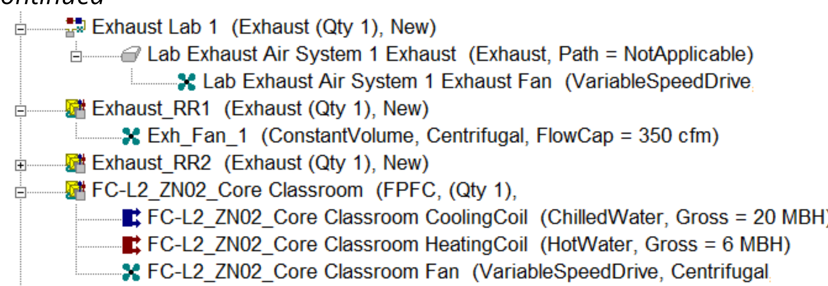


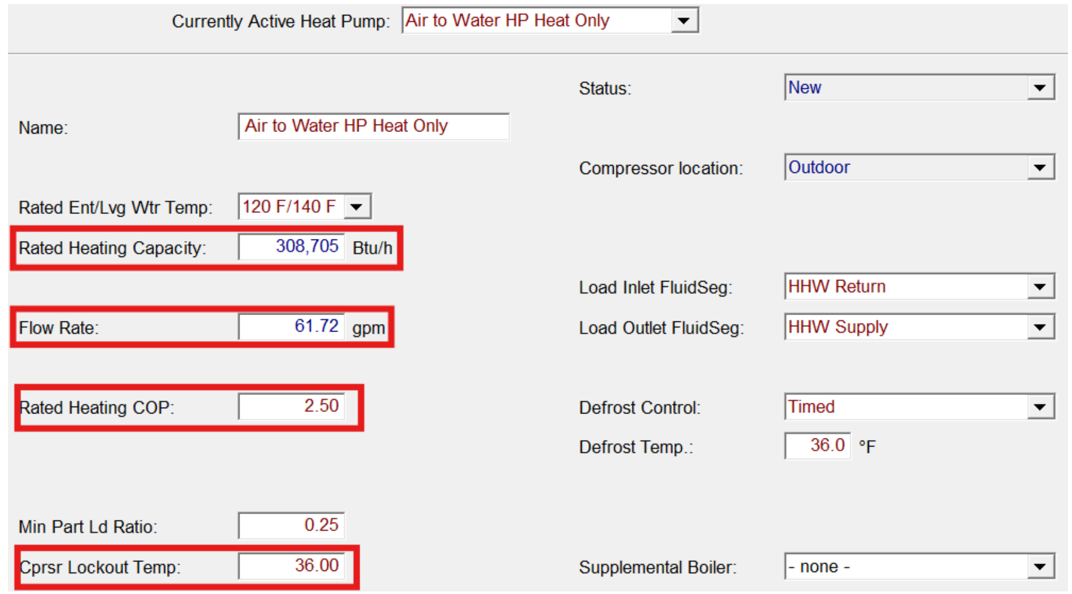
CBECC Object Locations

Key screenshots of the system for the ventilation unit, central plant components, and the laboratory exhaust are shown below.

Plant System

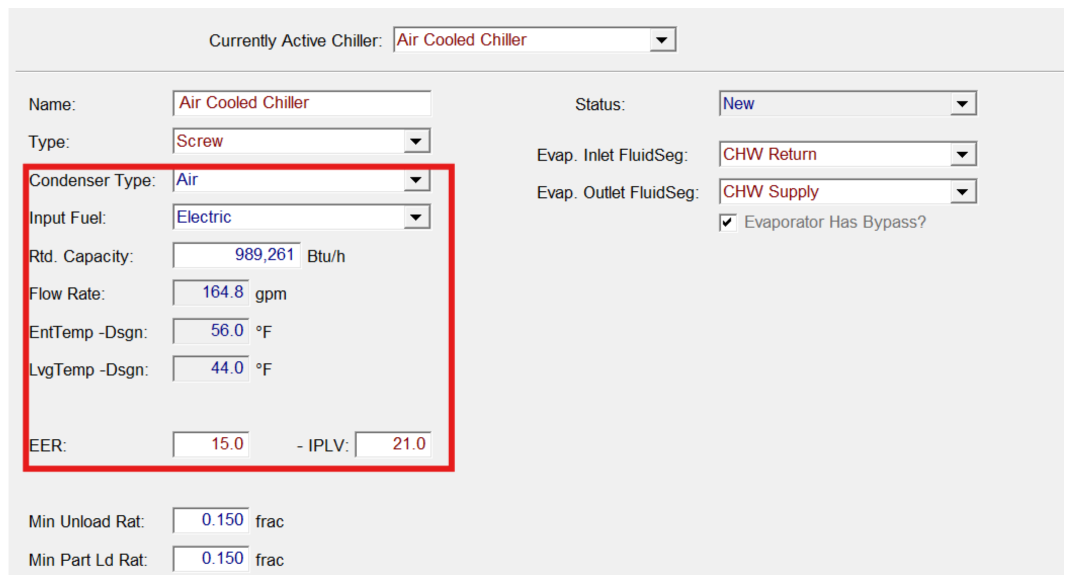
The heating plant consists of an air-to-water heat pump, supplying hot water at the fan coils and DOAS unit HW coil.

Coil Type	HeatPump (air-to-water)
Capacity	308,705 Btu/hr (25.7 tons)
Capacity / Area	11.42 Btu/sf
COP	2.5 (heating)
Flow Rate	61.72 gpm
HP Lockout	36°F



The cooling plant consists of an air cooled chiller serving the same fan coils and a DOAS CHW coil.

Coil Type	Air Cooled Chiller (Screw)
Net Capacity	989,261Btu/hr (82.5 tons)
Capacity / Area	36.56 Btu/sf
EER	15
IPLV	21
Flow Rate	164.8 gpm
Entering and Leaving Temp	56°F/44°F

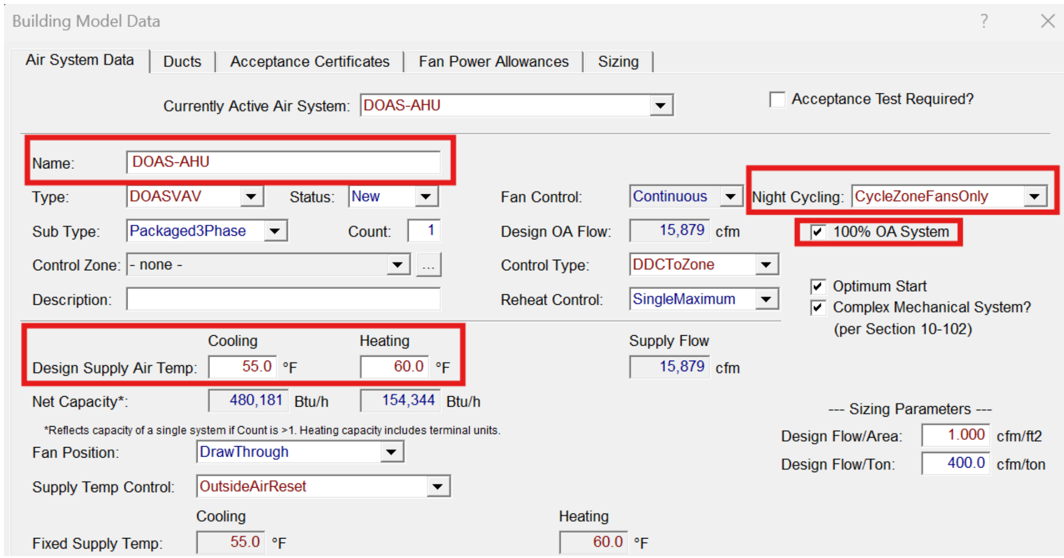


DOAS Air System

The DOAS is a 100% outdoor air system configured as a DOASVAV type, enabling ventilation airflow to modulate at the zone depending on the terminal unit types.

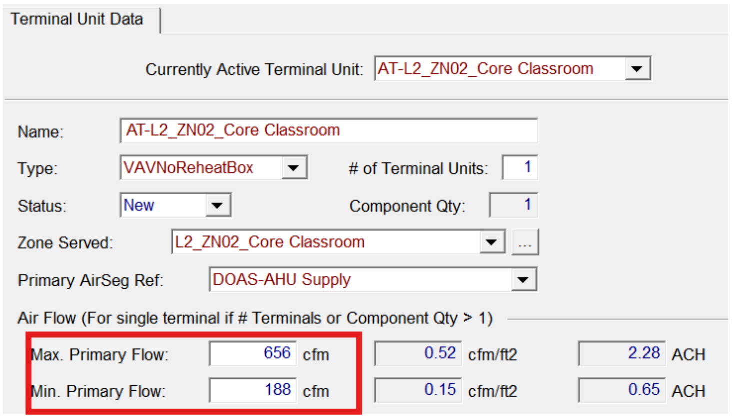
The air temperature is maintained at neutral conditions, which has design supply temperatures of 55 F and 60 F for cooling and heating.

To maintain temperature at night, the local zone fan coils are used, keeping the ventilation system off.



Air System Terminal Units

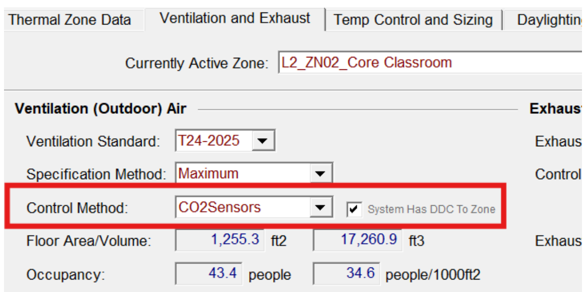
Air terminal units are created under the DOAS Air System for each thermal zone ventilation delivery. The terminal units are configured for ventilation only, providing peak flow for fully occupied and a lower level for minimum ventilation allowed based on CO2 sensors.

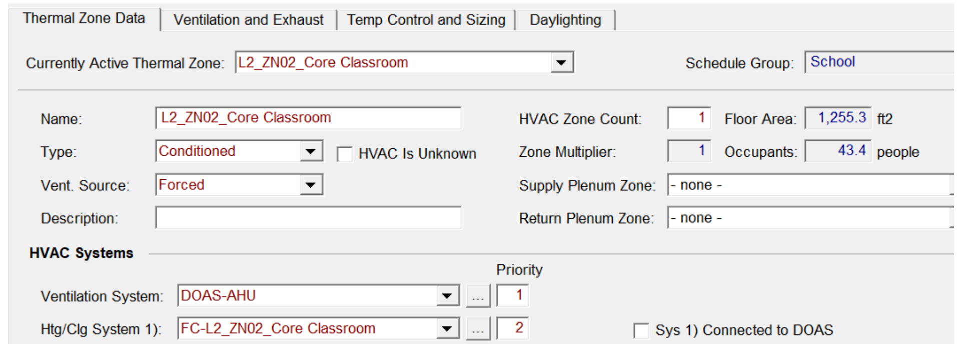


Thermal Zones

At each thermal zone, ventilation is configured from the DOAS unit and heating and cooling from the zones designated four pipe fan coil.

Nine zones have CO2 sensors based on occupant density and therefore also have minimum and maximum ventilation rates. All zones utilized a Variable Air Volume Terminal Unit for simplicity though only nine were configured with a lower airflow limit.





Thermal Zone Exhaust Ventilation Control

Air Terminal Units

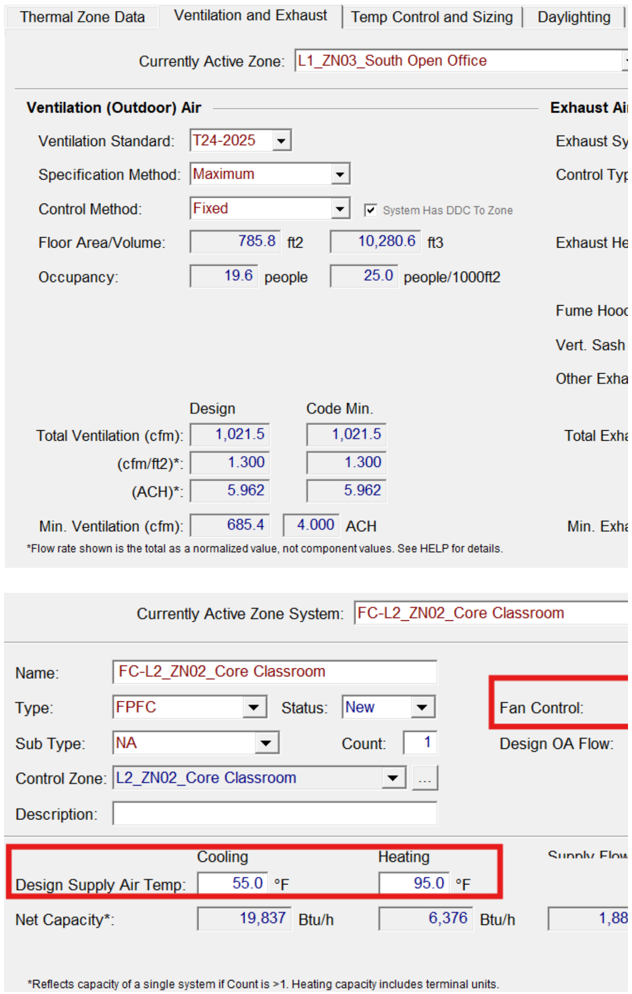
For classrooms with laboratory exhaust, the second tab of inputs in the Thermal Zone Data object is a key source for definition. This tab defines the exhaust system serving this building as well as links the exhaust system to an exhaust heat recovery device, located in the supply side air system.

Zone System Four Pipe Fan Coils

The zone systems consist of four pipe fan coils, serving each thermal zone. Additional air terminal units supply the fresh air from DOAS. Even with systems where fresh air is routed to a fan coil, the proper configuration is to enable two elements serving each zone in CBECC: a terminal unit and a zone system.

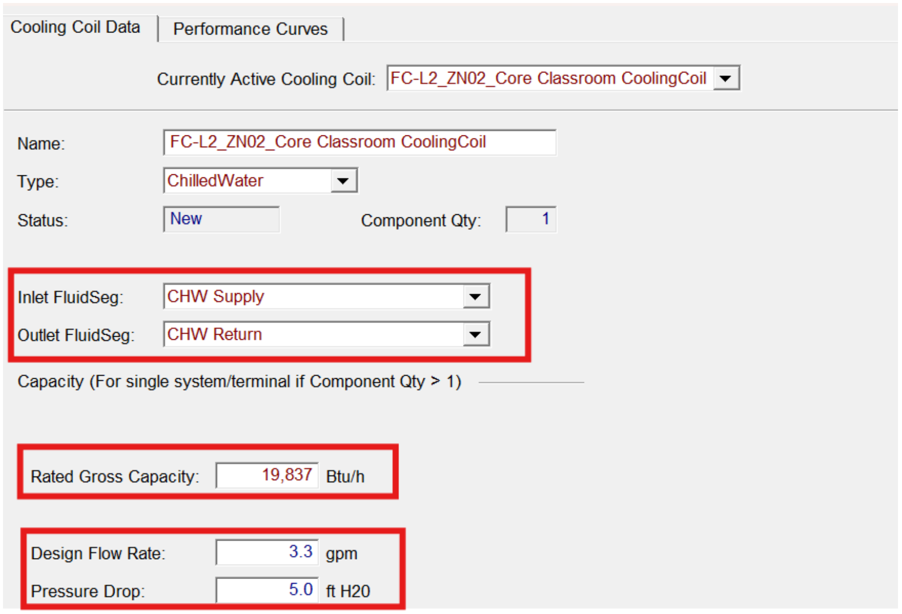
Units were configured with cycling fans, which is the only modulating fan control allowed for these zone systems. Supply air temperature was left at default, supplying 55°F air in cooling, 95°F heating.

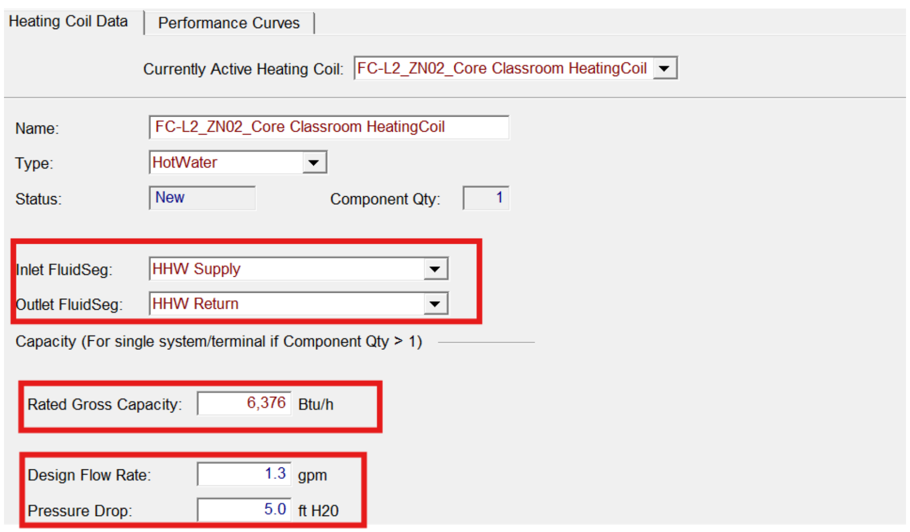
Fans are set to variable speed drive. Regardless of their assignment, in CBECC 2025 they are set to on off fans upon simulation and will cycle on and off as needed.



Four Pipe Fan Coil Heating and Cooling Coils

Each zone is served by a four-pipe fan coil unit with both a chilled water cooling coil and a hot water heating coil connected to their respective supply and return fluid segments. The unit operates with a variable speed drive centrifugal fan with a defined maximum and minimum flow capacity.


Cooling Coil Data
Performance Curves
Currently Active Cooling Coil: FC-L2_ZN02_Core Classroom CoolingCoil
Name: FC-L2_ZN02_Core Classroom CoolingCoil
Type: ChilledWater
Status: New
Component Qty: 1
Inlet FluidSeg: CHW Supply
Outlet FluidSeg: CHW Return
Capacity (For single system/terminal if Component Qty > 1)
Rated Gross Capacity: 19,837 Btu/h
Design Flow Rate: 3.3 gpm
Pressure Drop: 5.0 ft H20


Heating Coil Data
Performance Curves
Currently Active Heating Coil: FC-L2_ZN02_Core Classroom HeatingCoil
Name: FC-L2_ZN02_Core Classroom HeatingCoil
Type: HotWater
Status: New
Component Qty: 1
Inlet FluidSeg: HHW Supply
Outlet FluidSeg: HHW Return
Capacity (For single system/terminal if Component Qty > 1)
Rated Gross Capacity: 6,376 Btu/h
Design Flow Rate: 1.3 gpm
Pressure Drop: 5.0 ft H20

System Efficiency Tables

Category	Proposed (FPFC/DOAS+CHW/HHW)	Standard (SZHP / PVAV / SZAC)
System Type	FPFC/DOAS central plant all zones (IT: SZAC)	SZHP: small zones | PVAV: large open-office zones | SZAC: IT
Cooling Efficiency	Central air-cooled chiller EER=15.0 / COP=4.40	SZHP: EER=11.4 / SEER=14 | PVAV: EER=9.8
Heating Primary	Air-to-Water HP COP = 2.5 | HHW to FPFC coils and DOAS	SZHP: air-source HP COP=3.2 / PVAV: gas HHW boilers 82% AFUE
Heating Supp.	None	SZHP: electric resistance at 35°F OAT | PVAV: gas HHW reheat
Fan Type	VSD on ALL FPFC zones + VSD DOAS (0.35–2.29 W/cfm zone fans)	SZHP zones: CV (0.58–0.69 W/cfm) | PVAV: VSD (1.10–1.11 W/cfm)
Economizer	No Economizer at zone level (DOAS pre-conditions OA; no free-cool cycle)	SZHP: FixedDryBulb 71°F on 11 zones | PVAV: NoEconomizer
DCV	CO2Sensors on 11 zones | Fixed on 16 zones	CO2Sensors on fewer zones | Fixed on most
Supp Lockout	N/A, no supplemental heat, Defrost enabled at 36°F	SZHP: electric resistance adds at 35°F OAT | HP lockout at 17°F

Relevant Energy Code Citations

Required Demand Control Ventilation

401.2.1.2.3 [Section 120.1(d)3]

Nine zones exceeded the occupancy density limit, requiring CO2-based modulating ventilation airflow. Zone-level VAV terminals on the DOAS serve those zones.

Fan Power Budget - DOAS Unit

401.3.3.4 [Section 140.4(a)3E] and 401.3.17.1 [Section 140.4(p)]

The DOAS unit is required to comply with the prescriptive system requirements for a four-pipe fan coil system with DOAS. That section sets a maximum DOAS fan power of 0.77 W/cfm at design airflow. The modeled DOAS fan power is consistent with this prescriptive limit.

Fan Power Budget - Indoor Fan Coil Units

401.3.3.3 [Section 140.4(a)3D]

Indoor fan coil units were aligned with prescriptive code for the multi-zone heat pump system to a fan power of 0.35 W/cfm.

Air-Side Economizer Exemption - DOAS Unit

401.3.7 [Section 140.4(e)]

The DOAS unit operates at 100% outdoor air and therefore has no return air damper to modulate. An air-side economizer is not applicable to this system configuration.

Exhaust Air Heat Recovery

401.3.18 [Section 140.4(q)]

Outdoor air systems delivering 3,000 CFM or more at 70% or greater outdoor air fraction are required to include exhaust air heat recovery. The DOAS delivers 100% outdoor air above this airflow threshold, requiring the modeled heat recovery ventilator.

Minimum DOAS Cooling and Heating Efficiency

Section 140.4(a)3Aii, 140.4(a)3Aiii, or 140.4(a)3B

The DOAS cooling coil and heat pump heating coil are each required to meet minimum EER and COP thresholds for their capacity ranges. Both modeled coils exceed the applicable mandatory minimums.

Lab Hoods

The lab exhaust fans are required to meet thresholds per Table 120.1-C, Table 140.4-B, Section 140.9(c), Table 170.2-C. Lab exhaust fans are modelled according to the mandatory minimums.

Same Criteria as Example 1

- Duct Sealing and Leakage Testing
- Direct Digital Controls to Zone
- Optimum Start/Stop Controls

Example 7: NR Medium Office, Packaged VAV with Variable-Volume Reheat and Fan-Powered Boxes, Air-to-Water Heat Pump

System Tag: T24ACM-PVAVAWHP-PFPB
Title 24 2025 ACM: System 15d

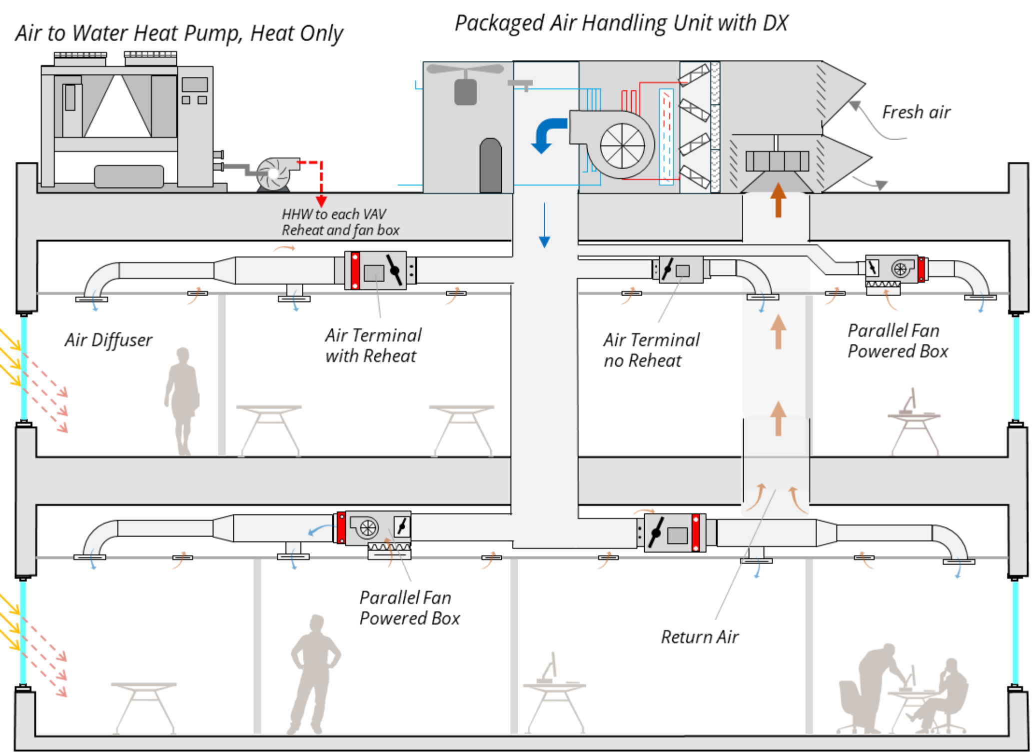
Mechanical Description

This system is a multi-zone heat pump system, with centrally located air handling units providing ventilation and conditioned air to thermal zones through terminal units - a mix of variable air volume reheat boxes and parallel fan-powered boxes. Zone-level terminal units include hot water heating coils supplied by a central air-to-water heat pump plant.

The central air handler systems are referred to as packaged variable air volume air handling units (PVAV), indicating that cooling is provided by a refrigerant system, a direct-expansion (DX) coil, an airside economizer, and modulating airflow and supply air temperature control. This configuration is classically referred to as a PVAV system, however in this setup a subset of thermal zones utilizes terminal units with zone fans, enabling an elevated level of efficiency and reduced level of reheat.

Diagram

The diagram depicts a version of this system with only a single packaged air handler serving two floors, a central air-to-water heat pump on the roof making hot water, and a mix of zone terminal unit types. In the model, packaged air handlers are utilized on each floor vs one for the whole building.



Mechanical Details

The system is designed with large floor-by-floor air handlers, each with a cooling coil, delivering fresh air and cold air to each thermal zone through terminal units. Terminal units are variable air volume and more efficient parallel fan powered boxes.

Ventilation: Mixed Air at each air handler, providing ventilation and airflow for cooling

Ventilation control: Fixed ventilation setpoints for all thermal zones (5 per floor)

Cooling: DX cooling delivered with air to variable airflow terminal units

Heating: central air-to-water heat pump and supplemental gas boiler serving hot water to terminal units

Capacity control: variable airflow with fixed air temperatures

Economizing: Yes, upper limit fixed dry bulb control

Ventilation and cooling are provided by the floor-by-floor PVAV air handling units and modulated at each thermal zone by the terminal units where ventilation controls reside. The system includes the ability to increase the flow of outside air with the airside economizer.

Cooling in the air handlers is produced by a direct-expansion (DX) refrigerant coil, extracting heat to the outside air. This cooling device is indicated in the title of this system by the term 'packaged' in PVAV to indicate this type of cooling element. Zone level variable air volume dampers adjust the airflow requested.

Heating is provided at each terminal unit through a hot water coil. Hot water is then generated by an air-to-water heat pump, extracting heat from the ambient air. In California, it is typically not common to have a heating coil or pre-heating coil in the air handling unit though in colder climates this can exist.

Mechanical Capacities and Sizing

Equipment is sized based on the peak loads for the building and for this example, sizing matches the compliance standard baseline capacities for the building. This includes the main components of the HVAC, with terminal unit capacity and airflow rates set to autosize. The air handling unit capacities are shown below.

Cooling is provided by three DX units with an integrated economizer. Capacities and efficiency assumptions shown below.

System Name	System Type	Clg Net (kBtu/hr)	Clg Cap (Btu/sf)	IEER	EER	Econo Lockout (°F DB)
Bottom VAV	PVAV	447.1	25	13	9.8	71
Mid VAV	PVAV	469.2	26	13	9.8	71
Top VAV	PVAV	487.7	27	13	9.8	71

Economizer: Fixed Dry Bulb

Each air handling unit is sized for full cooling and modulates air to the ventilation minimum. On average, the air handlers provide 0.68 cfm/sf at peak and 0.15 cfm/sf of ventilation at minimum.

System Name	System Type	Supply (CFM)	Ventilation Min (CFM)	Cooling Density (CFM/SF)	Ventilation Density (CFM/SF)
Bottom VAV	PVAV	11,478	2,681	0.64	0.15
Mid VAV	PVAV	12,116	2,681	0.68	0.15
Top VAV	PVAV	12,788	2,681	0.72	0.15

Fans in each unit are sized based on a prescriptive allowance of fan power in W/cfm. The equivalent static pressure and motor size are shown for reference.

System Name	System Type	Total Static (inH_2O)	Motor Size (BHP)	Fan Eff (W/cfm)
Bottom VAV	PVAV	4.84	13.5	0.946
Mid VAV	PVAV	4.84	14.2	0.946
Top VAV	PVAV	4.87	15.1	0.946

Fan Control: Variable Speed Drive

Code Compliance Software Configuration

The diagram on the right shows the configuration of the HVAC components based on CBECC architecture.

PVAV Air System

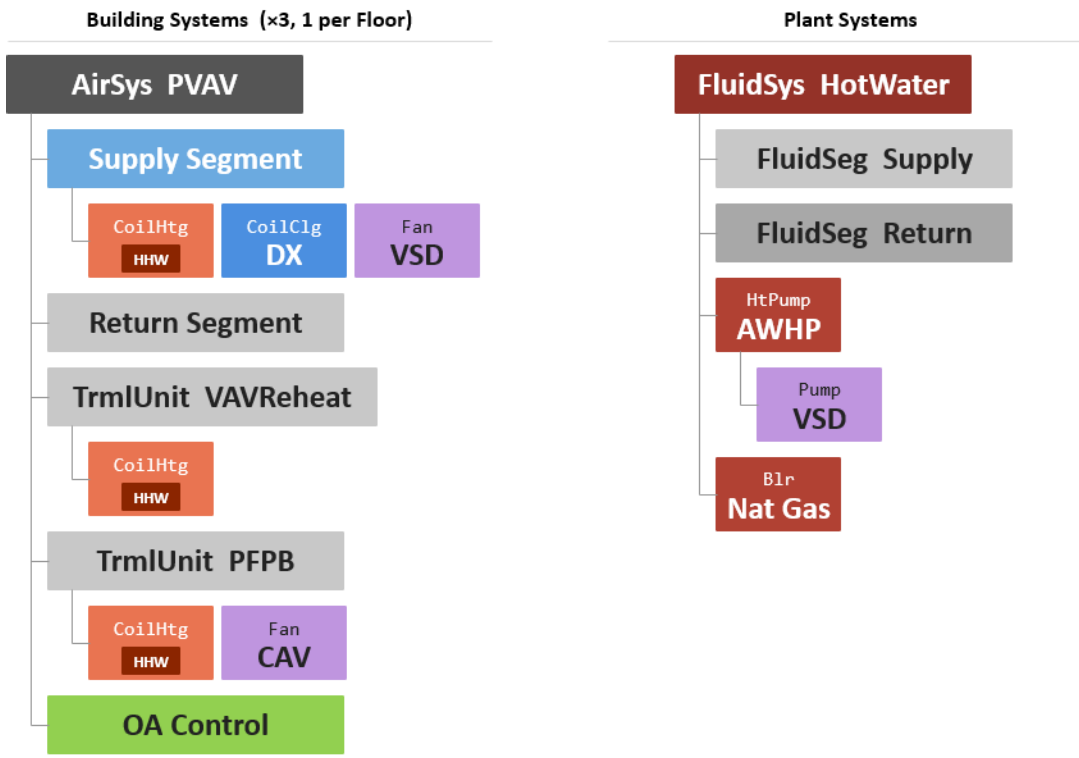
The floor-by-floor air systems are configured with a heating coil, DX cooling coil, outdoor air controller, and a supply fan.

Terminal Units

Two types of terminal units are included: variable air volume boxes with heating or reheat coils from the hot water plant and parallel-fan-powered boxes (PFPB) with heating coils and terminal-unit fans. The PFPB enables lower energy in those zones during reheat instances as well as heating instances by reducing the reliance on central fans to increase flow.

Central Hydronic Plant

The hot water plant is modeled with an air-to-water heat pump and backup natural gas boiler. The loop serves the zone terminal units as well as the air system heating coils.



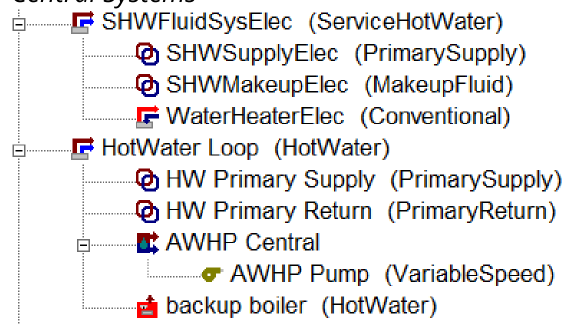
PVAV System

In CBECC, the same systems are depicted in the images shown for the central hot water plant, air handling units and terminal units.

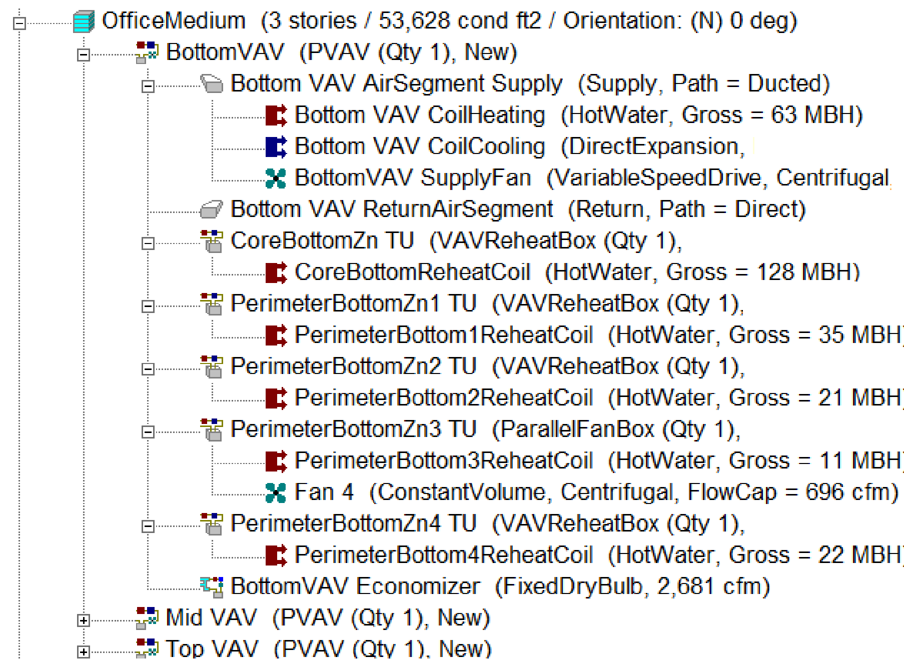
The central systems consist of the hot water loop for heating and the service hot water loop for domestic purposes. The central hot water plant was configured with an air-to-water heat pump and a backup natural gas boiler.

The building systems consist of air systems with terminal units serving each zone. Each air system maintains cooling and ventilation capabilities with heating provided at the terminal units. Two types of terminal units are used, primarily VAV reheat boxes controlling airflow and then PFPB units also controlling local airflow and variable flow from the air system.

Central Systems



Building Systems



CBECC Object Locations

The main component input screens are shown below for the system. Additional information is available by opening the model file.

HHW Plant Loop

The central plant for heating hot water is configured as a hot water loop supplying 130°F and returning 110°F.

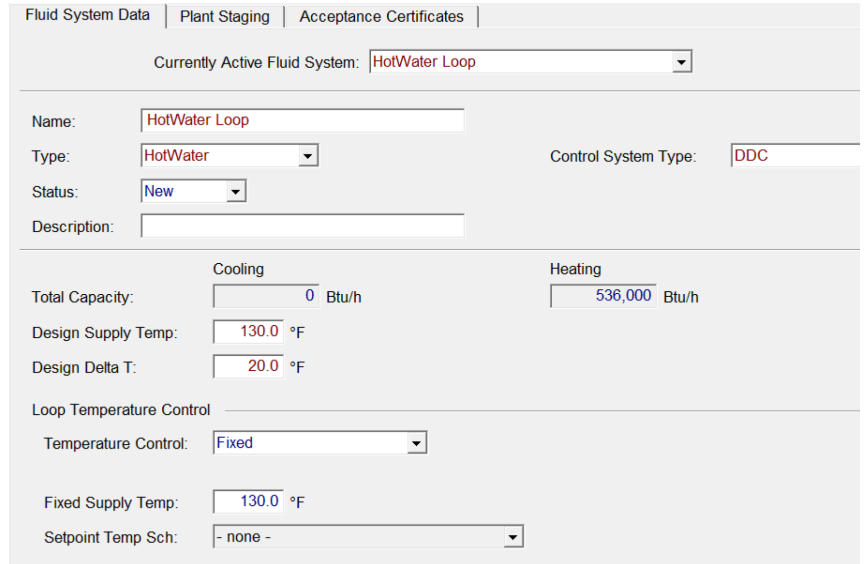
The air-to-water heat pump is configured to operate at the rated cop of 2.92 and a minimum part load ratio of 20%, along with a backup supplemental boiler.

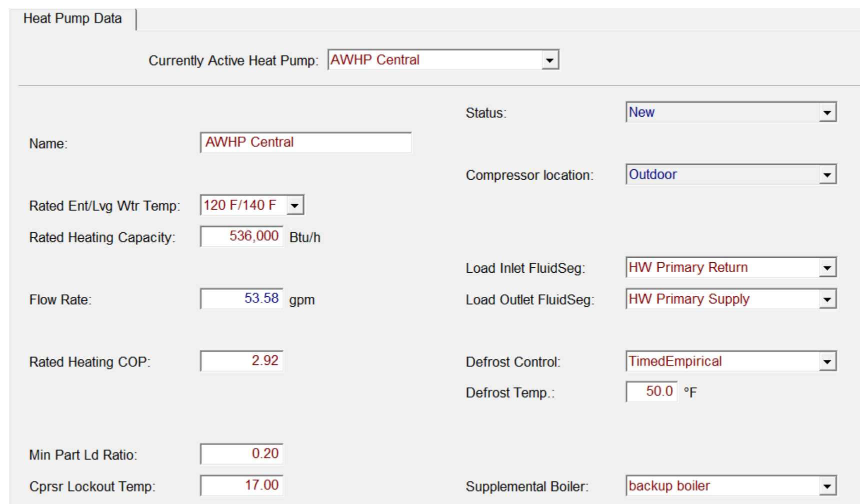
HHW Loop

Design Supply Temp	130°F
Design Delta-T	20°F
Control System	DDC

Air-to-Water HP

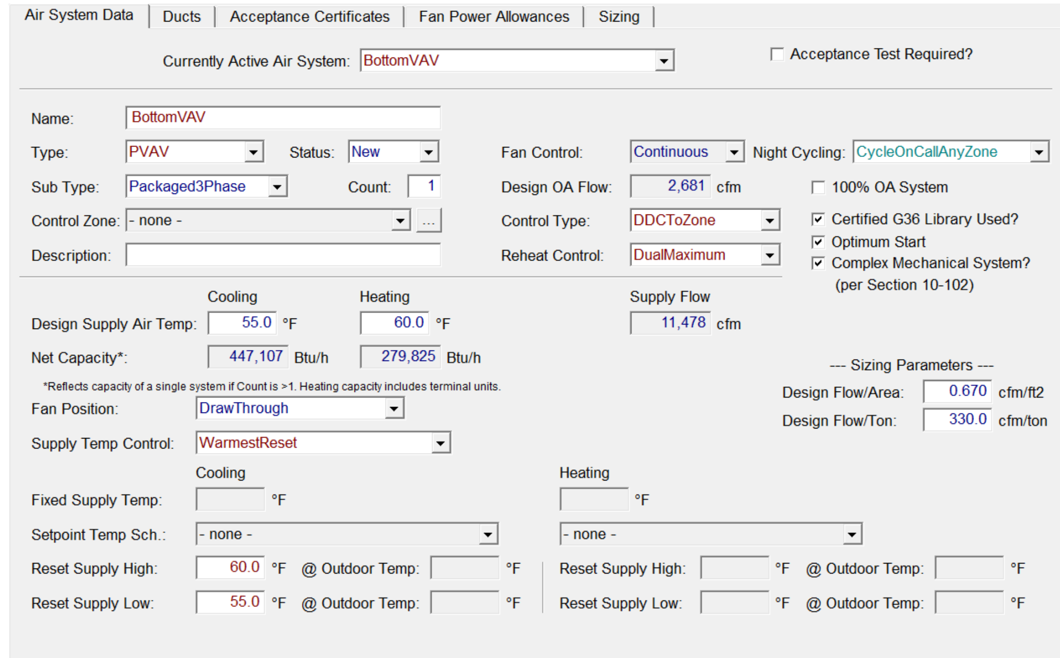
Rated Ent/Lvg	120°F/140°F
Capacity	536,000 Btu/hr (45 tons)
COP	2.92 (heating)
Flow Rate	53.6 gpm
Compressor Lockout	17°F
Backup Boiler	Natural Gas
Boiler Efficiency	84%





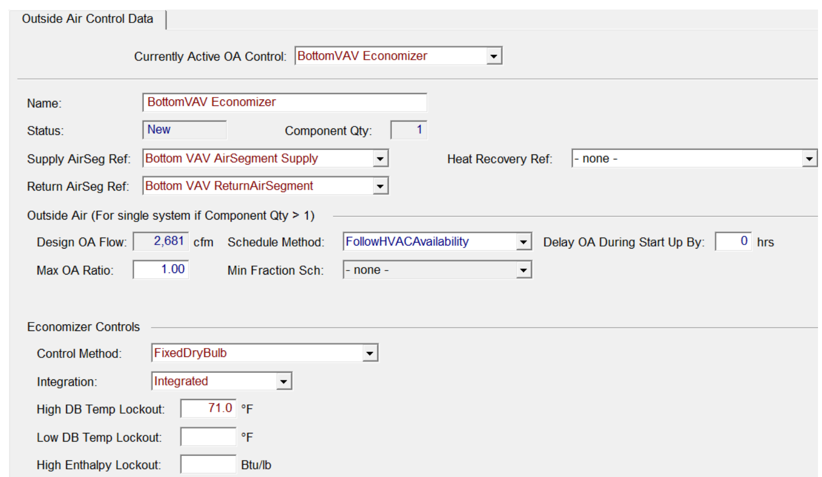
Air Systems

The packaged VAV air handlers are configured with digital controls to the zone (DDCtoZone), Dual Maximum controls, as utilized certified Guideline 36 Libraries. The supply temperature control is set to WarmestReset, which will decrease supply temperature based on the zone that needs the most cooling. Air temperature is able to adjust between 60°F down to 55°F.



Outdoor Air Controller

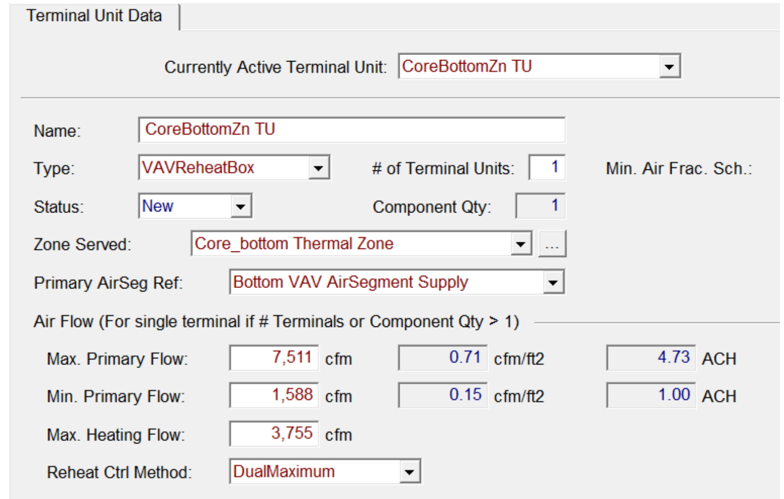
The last object in the air system is outdoor air control. This object controls the economizer if one is configured as shown here, controlled to Fixed Dry Bulb. The economizer is integrated, which is the most common configuration, meaning the unit will utilize outdoor air up to the return-air room setpoint providing the most energy benefit.



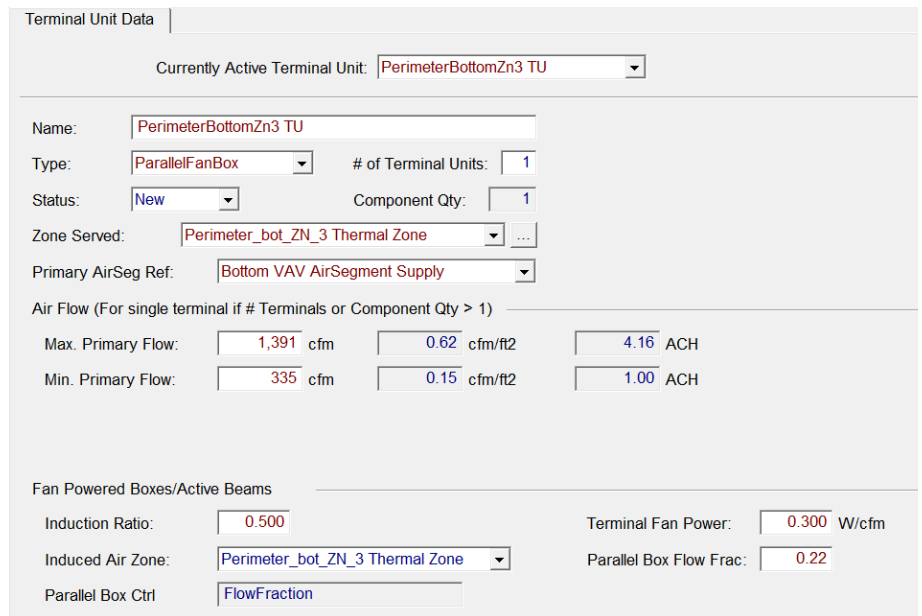
Terminal Units

Each zone is conditioned by a terminal unit, either a VAV Reheat Box or a PFPB.

The VAV reheat box here is shown with defined maximum flow, minimum flow for ventilation and heating maximum for each zone.



The PFPB is shown with both max and min flow. The terminal unit screen also defines the fan power efficiency and airflow induction ratio for the unit. The fan itself however is a separate child component to be defined.



System Efficiency Tables

Category	Proposed (PVAV with VAV, PFPB and AWHP + gas blr)	Standard (PVAV with VAV, PFPB and AWHP + elec blr)
System Type	PVAV | 3 air handlers	PVAV | 3 air handlers
Cooling Efficiency	EER=9.8	EER=9.8
Heating Primary (Central Plant)	Air-to-Water HP at COP 2.92, Backup Gas Boiler| 84% thrml eff	Air-to-Water HP at COP 2.92, Backup Electric | 98% thrml eff
Zone Heating (Reheat)	HW reheat coils at VAV boxes and PFPB units (from central plant)	HW reheat coils at VAV boxes and PFPB units (from central plant)
Fan Type & W/cfm (Supply Fans)	VariableSpeedDrive | (W/cfm), 0.946 W/cfm	VariableSpeedDrive | (W/cfm), 0.946 W/cfm
Economizer	FixedDryBulb (F), 71°F	FixedDryBulb (F), 71°F
DCV Control	Fixed OA	Fixed OA

Relevant Energy Code Citations

Fan Power Budget, Multi-Zone VAV Systems

401.3.3.1 [Section 140.4(a)3A]

Multi-zone VAV air systems shall comply with the prescriptive fan power allowance. The three PVAV supply fans are configured at 0.946 W/cfm with variable speed drive control, within the prescriptive allowance for the system capacity and configuration.

Parallel Fan-Powered Box Fan Power

401.3.3.2 [Section 140.4(a)3B]

Parallel fan-powered terminal units shall not exceed 0.3 W/cfm of unit design airflow. All PFPB terminal fans in this model are configured at 0.3 W/cfm.

Required Air-Side Economizer

401.3.7 [Section 140.4(e)]

All three PVAV cooling units exceed 33,000 Btu/hr and are required to include an air-side economizer. For CZ9, the fixed dry-bulb high-limit shutoff is 71°F per Table 401.3-G [Table 140.4-G]. Economizers are configured as integrated, permitting simultaneous economizer and mechanical cooling operation.

VAV Minimum Airflow Controls

401.3.14 [Section 140.4(m)]

VAV air systems shall include controls that reduce supply air volume to no more than 30% of design airflow at no more than 30% of design fan power. VAV and PFPB terminal units serving each zone include minimum flow setpoints to meet ventilation requirements at reduced load.

Supply Air Temperature Reset

401.3.8 [Section 140.4(f)]

Multi-zone VAV systems shall include supply air temperature reset controls. Supply air temperature resets from 60°F to 55°F based on zone cooling demand using WarmestReset control, reducing reheat energy when full cooling is not required.

Direct Digital Controls to Zone

401.2.2.10 [Section 120.2(j)] and Table 401.2-D [Table 120.2-A]

Each air-handling system and all zones served are required to have DDC to the zone level for new construction where the system supplies more than three zones with a design heating or cooling capacity of 300 kBtu/h or greater. All three PVAV units are configured with DDCtoZone controls and Dual Maximum terminal sequences per ASHRAE Guideline 36 libraries.

Optimum Start/Stop Controls

401.2.2.11 [Section 120.2(k)]

Systems equipped with DDC to the zone level are required to have optimum start/stop controls that calculate pre-conditioning time based on space temperature, occupied setpoint, outdoor air temperature, and time to occupancy.

Air-to-Water Heat Pump Heating Efficiency

Section 400.5 / Table 400.5-A [Section 110.2 / Table 110.2-A]

Air-to-water heat pumps supplying hot water for zone reheat must meet minimum COP requirements for their rated capacity and entering water temperature. The modeled unit is configured at COP 2.92 at rated conditions, meeting the applicable mandatory minimum.

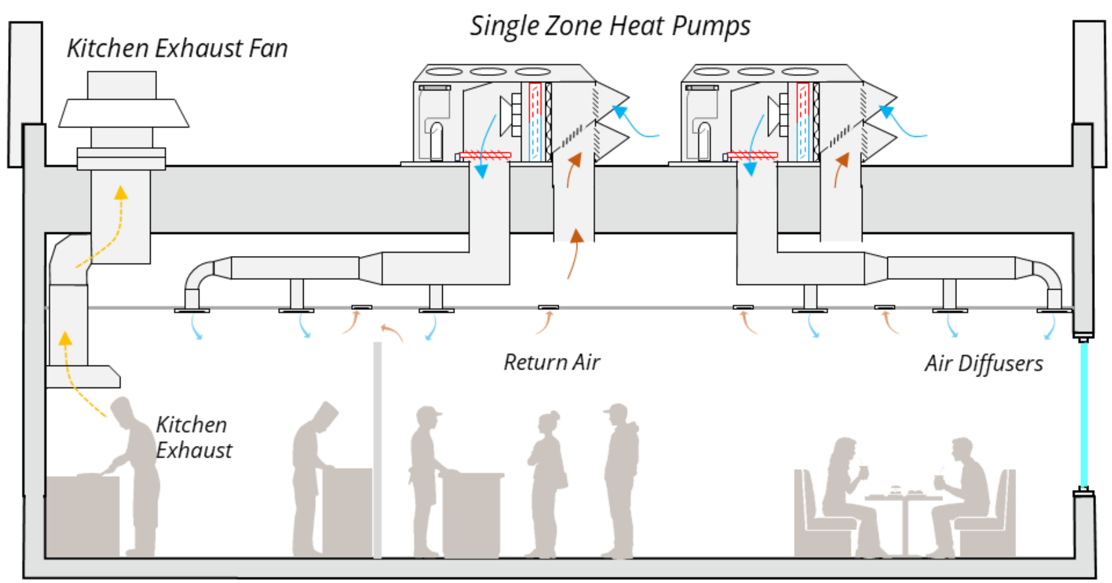
Example 8: NR Restaurant, Single Zone, DOAS Units Configured as Rooftop Unit

System Tag: T24ACM-SZVAVDFHP
Title 24 2025 ACM: System c3

Mechanical Description

The building is conditioned by two independently controlled packaged rooftop units, each serving a single occupied space; one the dining area, one the food preparation area. Both units are configured as mixed-air, rooftop units with AC and furnaces. A kitchen exhaust system maintains building pressure, relieving air through the hoods. The kitchen hood operates as a constant-volume commercial kitchen exhaust fan, ducted directly to outdoors. No heat recovery is provided on the exhaust air.

The primary rooftop equipment selected in this example can be configured as mixed-air rooftop units or as dedicated outdoor air systems, and was labeled by the manufacturer as 'DOAS units'. This example demonstrates how the configuration of a system should always reflect the architecture of the airflow and control, rather than the label of products specified by a manufacturer.



The diagram shows a standard fast-food restaurant, with one single zone unit serving the dining area, another serving the serving and cooking area. The exhaust fan runs to maintain indoor air quality with air transferring from the dining area as needed to maintain exhaust.

Mechanical Details

Two SZ VAV AC systems were applied to the fast-food restaurant prototype, with both thermal zones conditioned by their respective packaged rooftop unit. The Kitchen zone is also served by a continuous hood exhaust.

Ventilation: Outdoor air delivered through each RTU as a fraction of the total supply air to each zone.

Ventilation control: The Dining zone uses CO_2 based demand-controlled ventilation with a VAV terminal modulating supply between min and max airflow. The Kitchen zone ventilation is constant with VAV terminal modulating supply between min and max.

Cooling: Single-stage DX cooling on Dining RTU and 2-stage DX cooling on the Kitchen RTU.

Heating: Natural gas furnace at each rooftop unit, mixed fuel equipment matching real-world examples for this occupancy type.

Capacity control: VSD supply fan at each unit modulated to meet zone load through VAV no-reheat terminal box.

Economizing: Yes. Differential enthalpy economizer on both rooftop units, integrated with mechanical cooling.

Heat Recovery: None. Kitchen hood exhaust is exempt from heat recovery requirements.

Mechanical Capacities and Sizing

Systems were sized based on the as-built equipment selection documented in the source building's actual mechanical drawings given the proximity of the building size to the prototype for both zones. Outdoor air for the Dining zone was sized to the zone ventilation requirements, with CO_2-based DCV at the VAV terminal modulating supply between a minimum and maximum airflow. Outdoor air for the Kitchen zone was set to match both the zone ventilation requirement for kitchen/cooking occupancy and the makeup air requirement against the continuous hood exhaust. The Kitchen VAV terminal holds a constant minimum airflow floor with no CO_2 DCV applied. Cooling efficiencies were entered at the mandatory minimum efficiencies; both gas furnaces were entered with mandatory minimum AFUE matching drawing specs.

Kitchen Exhaust System

Exhaust (cfm)	Control	Hood Type	Air Path
2,400	Constant Volume	Wall Canopy, Heavy, 10 ft	Ducted to outdoors not in return air path

Zone Airflow Balance

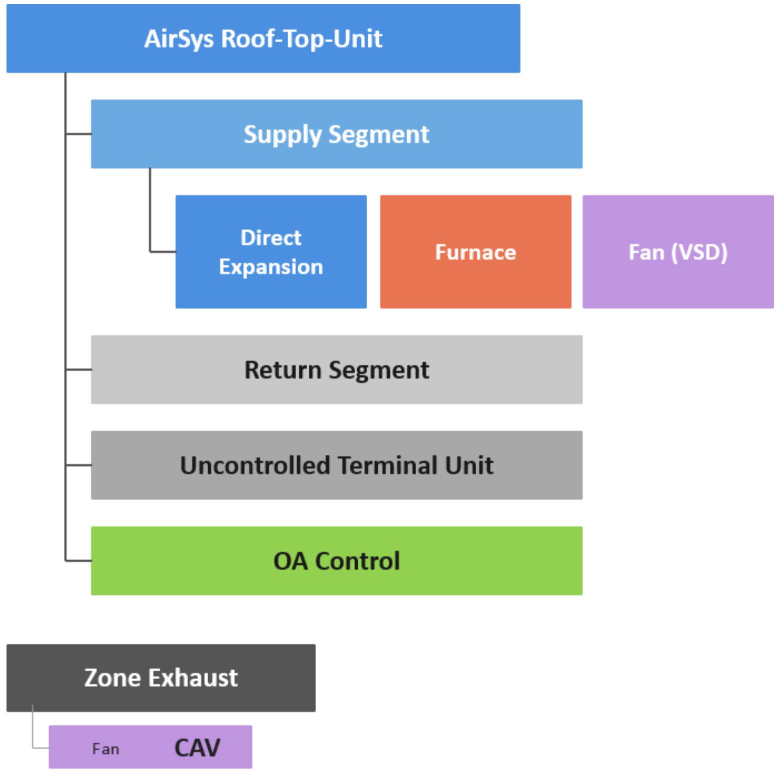
Zone	Sup. (cfm)	Min OA (cfm)	Return (cfm)	Exh. (cfm)	Net Pressurization
Dining	2,000	1,200	500 to 1300	—	Positive (700 cfm transfer air to Kitchen)
Kitchen	4,500	1,700	Up to 2,800	2,400	Balanced (pulling 700 cfm air from Dining)
Building Total	***6,500***	***2,900***		***2,400***	***Net +500 cfm OA***

Code Compliance Software Configuration

Each RTU was entered as a Package SZ VAV AC (SZVAVAC) air system serving a single thermal zone, with return air ductwork explicitly modeled (return air segment Path = Direct on each system). Outdoor air control was configured at the OA controller object for each system: DifferentialEnthalpy economizer, Integrated, with 71°F dry-bulb and 28 Btu/lb enthalpy high-limit lockouts. The Dining OA controller carries MaxOARat: 1.0 to allow full economizer modulation; the Kitchen OA controller has no MaxOARat set, fixing OA volume at the terminal minimum.

Cooling efficiencies were entered at code minimum (EER 11.0 on RTU-1, EER 10.8 on RTU-2) rather than the drawing-rated IEER values (14.6 and 14.0). This addresses the AHRI 920 (DOAS rating) vs AHRI 340/360 (RTU rating) standard mismatch when DOAS-rated equipment is installed in a coupled-RTU configuration. The compliance-eligible efficiency entry uses the AHRI 340/360 minimum for the equipment's installed function.

The Kitchen thermal zone was assigned the KitchenExhaust system reference (ExhSysRef = KitchenExhaust) and configured with FullyDuctedExhFlag = 0 on that exhaust system, instructing the simulation engine to permit transfer air from adjacent zones rather than treating the hood as a closed return loop. Hood inputs at the Kitchen space include KitExhHoodFlow (2,400 cfm), KitExhHoodLen (10 ft), KitExhHoodStyle (WallMountedCanopy), and KitExhHoodDuty (Heavy).



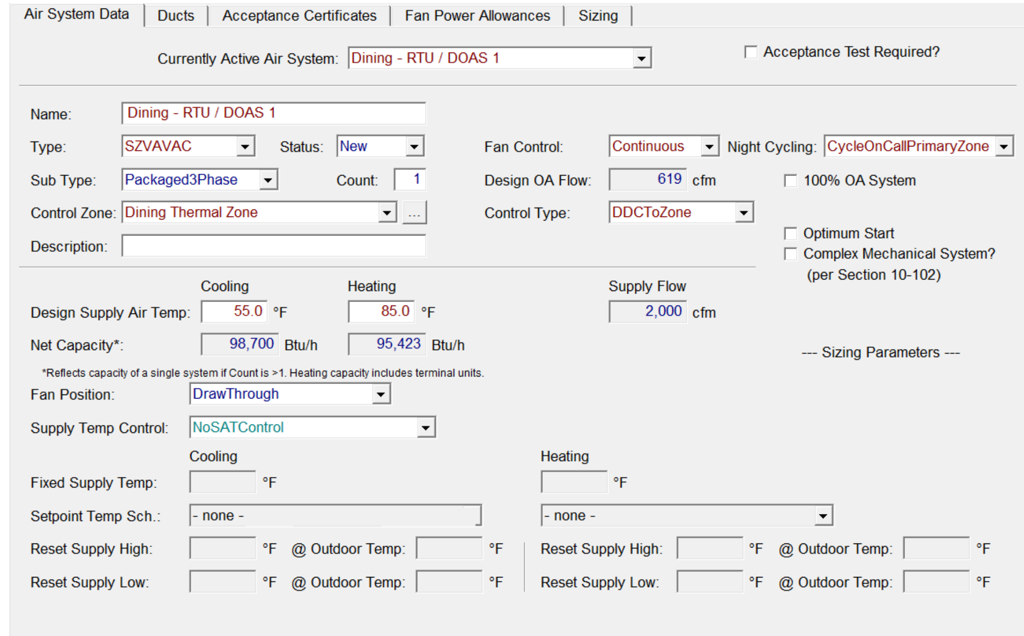
CBECC Object Locations

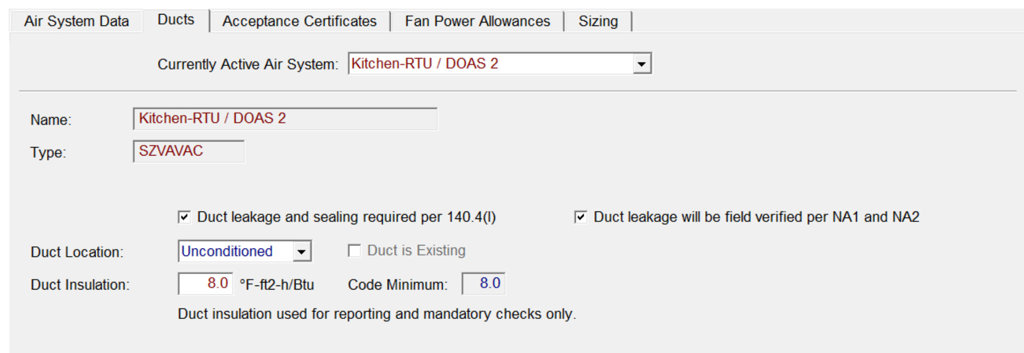
The model is made up of three systems: two air systems, one for dining, one for the kitchen, and a zone system for the kitchen exhaust.

Air Systems

The dining system is shown here for key inputs on the air-system input screen.

The unit was assumed to be ducted on the roof in an unconditioned space with duct insulation and duct leakage testing.

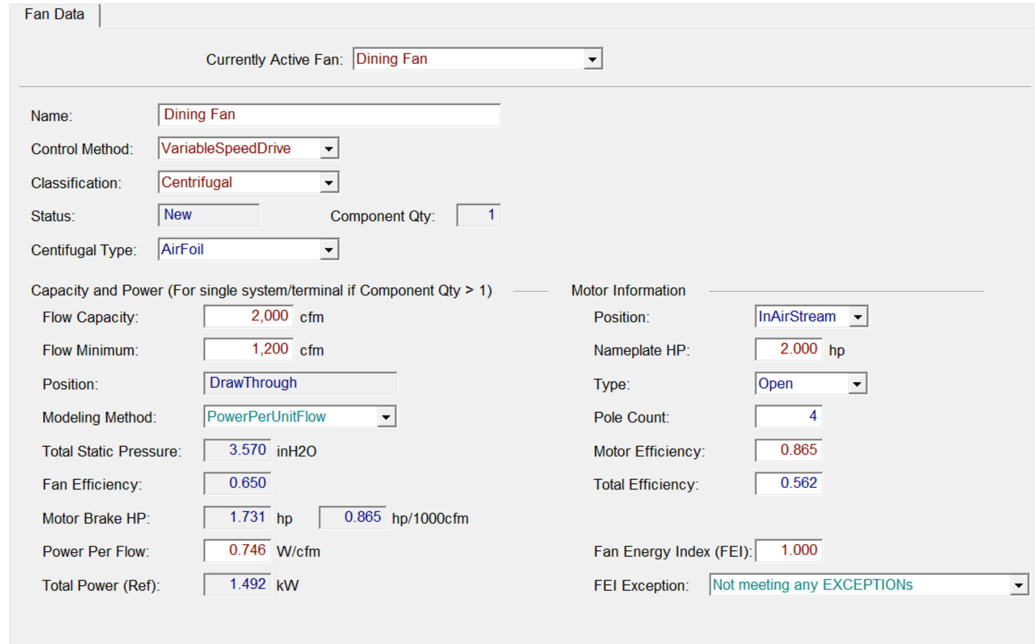




Air System Fan Component

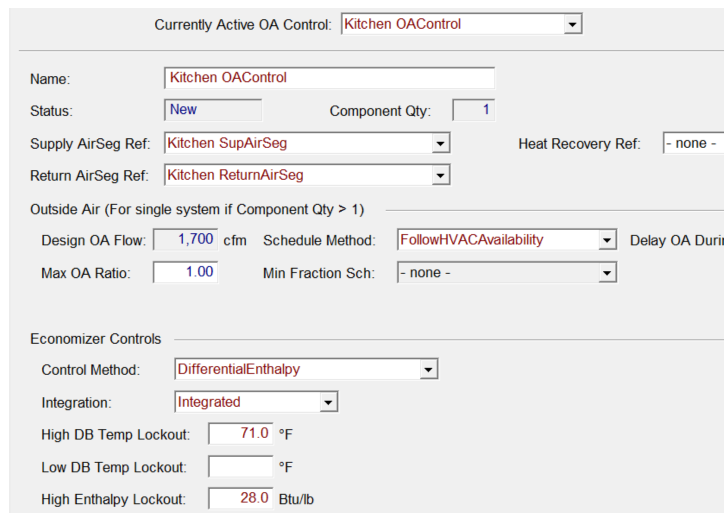
The fan airflow for each RTU was configured as a variable speed drive fan based on the design.

Zone	Supply Fan (cfm)	Outdoor Air (cfm)	Fan Eff. (W/cfm)	Economizer
Dining	2,000	1,200	0.746	Diff. Enthalpy
Kitchen	4,500	1,700	0.820	Diff. Enthalpy



Outdoor Air Controller

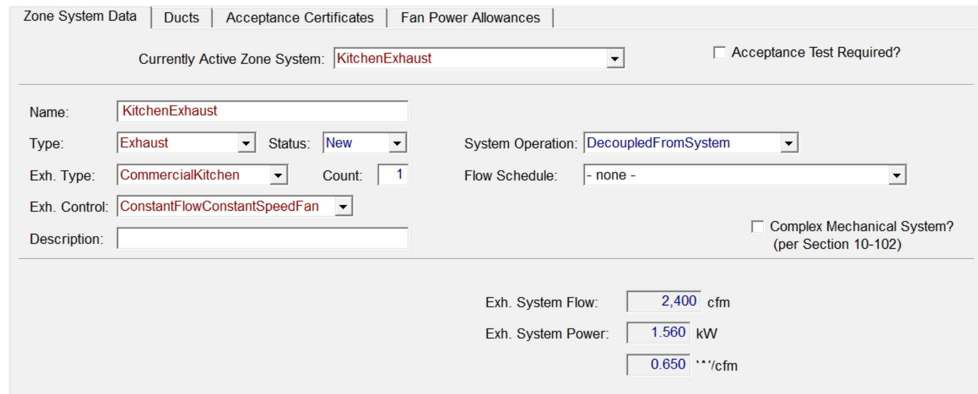
Each unit includes an economizer controlled based on enthalpy as shown below.



Zone System, Kitchen Exhaust

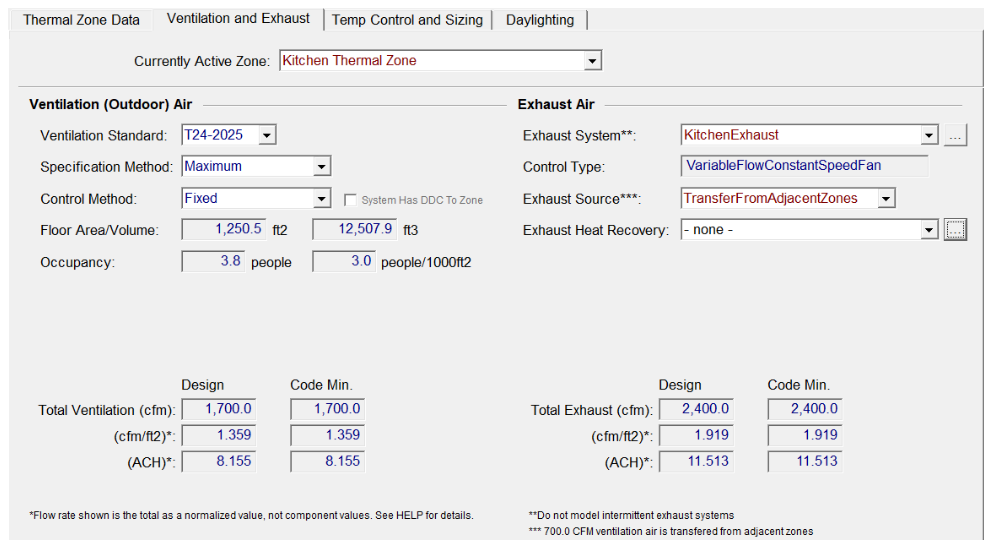
Zone kitchen exhaust was configured with a zone system set to CommercialKitchen as the fan type.

The control type was assumed to be a constant flow control with a constant speed fan.



Thermal Zone Exhaust Control

The thermal zone component for the kitchen sets the link to the kitchen exhaust fan, as well as defines the source of makeup air. In this configuration the makeup air is taken from the adjacent zones in the building, the dining area.



System Efficiency Tables

Category	Proposed Design	vs. Standard Baseline
System Type	Package SZVAVAC (both zones), VSD fan, partial-recirculation RTU configured with return air ductwork.	Standard assigns CV/SZ AC to Dining and SZ VAV AC to Kitchen; proposed uses VSD VAV on both zones.
Cooling	RTU-1 Dining: EER 11.0, single-stage DX. RTU-2 Kitchen: EER 10.8, two-stage DX.	Same DX equipment type per Table 140.4-A. Proposed entered at code-min EER rather than drawing-rated IEER.
Heating	Natural-gas furnace, AFUE 81%, at each RTU. No supplemental heat.	Same fuel and AFUE. NRCC C2 shows proposed losses 3.76 LSC on space heating vs. standard.
Supply Fan	VSD centrifugal: 0.75 W/cfm (Dining RTU), 0.82 W/cfm (Kitchen RTU).	Standard Dining: Constant volume fan. Kitchen: VSD. Proposed VSD on Dining saves 8.23 LSC on indoor fans.
VAV Terminal	VAVNoReheatBox at both zones. Dining modulates 1,200–2,000 cfm under CO_2 DCV. Kitchen fixed at 1,700 cfm.	Standard Dining: ConstantVolume, no DCV. Kitchen terminal type same in both designs.
Economizer	Differential enthalpy, integrated with mechanical cooling, on both RTUs.	Standard uses FixedDryBulb 71°F. Differential enthalpy performs better on cool, humid CZ9 coastal mornings.
Photovoltaics	24.3 kWdc rooftop PV array.	NRCC C2 shows proposed gains of 1.29 LSC vs. baseline.

Note: Heat recovery — neither RTU crosses the 70% outdoor air fraction threshold; kitchen hood exhaust (2,400 cfm Type I) is exempt from heat recovery requirements. Domestic hot water — 30-gallon natural-gas storage water heater, UEF 0.65; same equipment type and fuel in both proposed and standard designs.

Relevant Energy Code Citations

Required Demand Control Ventilation

401.2.1.2.3 [Section 120.1(d)3]

The Dining zone exceeds the occupancy density limit for cafeteria / fast-food dining, requiring CO_2-based modulating ventilation airflow. The VAV terminal on RTU-1 carries minimum and maximum airflow setpoints and is controlled by a zone CO_2 sensor. The Kitchen zone is not subject to DCV — kitchen ventilation rates are driven by the hood makeup-air requirement and held constant.

Fan Power Budget, Packaged VAV Units

401.3.3.3 [Section 140.4(a)3D]

Each Package SZ VAV AC supply fan must meet the prescriptive fan-power limit for VAV systems in its capacity range. The modeled supply fan power (0.75 W/cfm on RTU-1 and 0.82 W/cfm on RTU-2) is consistent with the prescriptive limit for packaged VAV systems at design airflow.

Air-Side Economizer, Packaged Units

401.3.7 [Section 140.4(e)]

Each rooftop unit exceeds the 33,000 Btu/hr cooling-capacity threshold that triggers the economizer requirement. Both units are configured with differential enthalpy economizers integrated with mechanical cooling, satisfying the prescriptive requirement in Climate Zone 9. Differential enthalpy was selected over fixed dry-bulb to improve free-cooling availability during the cool, humid morning hours typical of coastal Climate Zone 9 operation.

Exhaust Air Heat Recovery, Kitchen Hood Exemption

401.3.18 [Section 140.4(q)]

Outdoor air systems delivering 3,000 CFM or more at 70% or greater outdoor air fraction would typically require exhaust air heat recovery. Neither RTU exceeds the 70% outdoor air threshold (RTU-1 at 60%, RTU-2 at 38%), and the kitchen hood exhaust is independently exempt from heat recovery requirements as a Type I commercial kitchen hood exhaust stream. No heat recovery is required or provided.

Kitchen Hood Exhaust, Type I

Section 140.9(b)

The 2,400 cfm Wall-Mounted Canopy Type I hood is classified as heavy-duty. Hood airflow per linear foot meets the prescriptive maximum, and the hood is modeled with continuous occupied-hour operation. No demand-controlled kitchen ventilation is applied — the hood operates at constant volume.

Minimum DX Cooling and Furnace Efficiency

Table 401.3-A [Table 140.4-A]

The DX cooling coil and gas furnace heating coil at each rooftop unit must meet minimum EER, IEER, and AFUE thresholds for their capacity ranges. Both modeled units carry code-minimum cooling efficiency entries (see the modeling note above regarding the AHRI 920 vs. AHRI 340/360 rating-standard mismatch) and meet the 81% AFUE mandatory minimum on the gas furnace.

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Alternative System Examples

#	System	Base Example	Description
1b	**MF Central Supply, Local Exhaust**	MF Single-Zone Heat Pumps	A central fan delivers outdoor air to all units via a shared supply duct, with each unit exhausting independently through its own local fan.
1c	**MF Central Supply, Central Exhaust**	MF Single-Zone Heat Pumps	Central fans serve both supply and exhaust via shared ducts. Base conditioning system unchanged.
1d	**MF Local Supply, Local Exhaust, Facade-Mounted**	MF Single-Zone Heat Pumps	Each unit has independent supply and exhaust fans penetrating the exterior wall at separate locations with no shared ductwork. No heat recovery is possible. Base conditioning system unchanged.
1e	**MF Local Ventilator with Heat Recovery**	MF Single-Zone Heat Pumps	Each unit has a single through-wall device handling both supply and exhaust, with a heat exchanger core recovering energy from the exhaust stream. Base conditioning system unchanged.
5b	**NR DOAS with VRF, No Heat Recovery, Coupled Ventilation**	NR DOAS with VRF	Ventilation air is delivered directly through the VRF fan coil units rather than through a dedicated outdoor air system, and no heat recovery ventilator is present.
8b	**NR Restaurant Single Zone Variable Flow HP, Dual Fuel**	NR Single-Zone VAV Dual-Fuel Heat Pump	Each thermal zone contains a variable speed single zone heat pump with dual fuel heating sources,

Alternate MF Ventilation Options

Variations of the multi-family building for other configurations of ventilation were evaluated and included as files. These include:

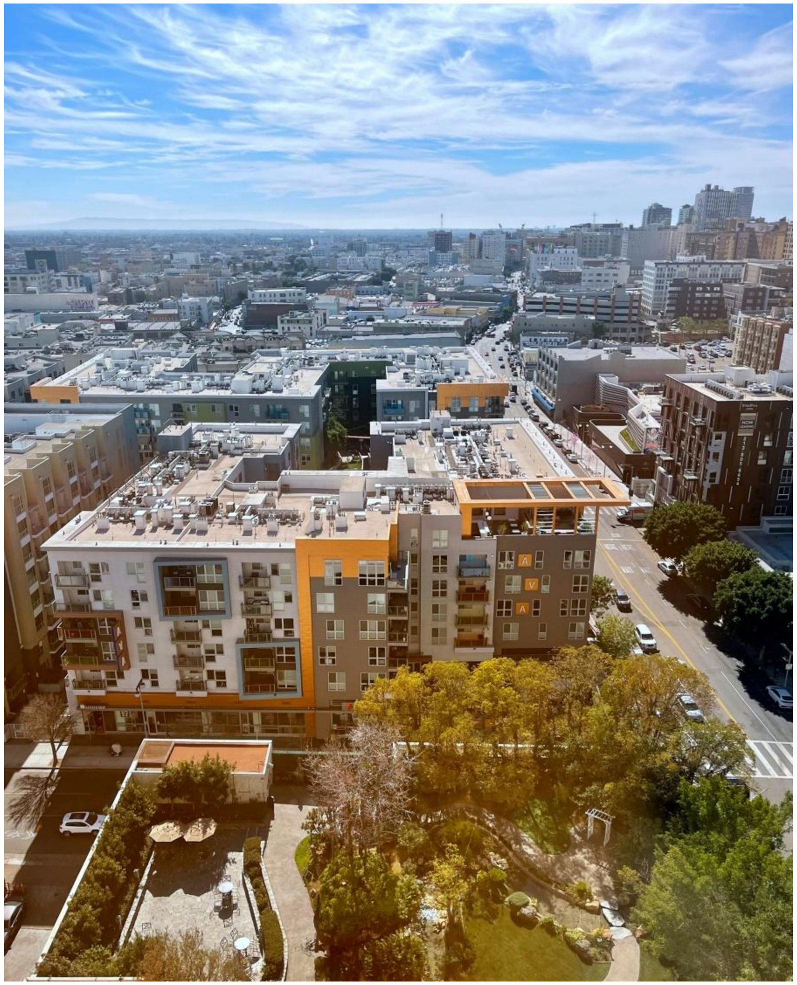
a) Local Supply Fans, Central Exhaust Fans (example 1)

b) Central Supply Fan, Local Exhaust Fans

c) Local Supply and Exhaust Fans, Façade-Mounted

d) Local Ventilator with Heat Recovery

e) Central Supply Fan, Central Exhaust Fan



Examples b through e are shown here with a brief description and system depiction. Assumptions are contained in the model input file examples.

For each configuration, the fan power of the Title 24 2025 standard system is noted alongside the description, as the baseline fan power varies depending on whether ventilation is centralized or distributed at the unit level.

The baseline heat recovery ventilator assignment is also noted where relevant; configurations d and e are assigned an HRV in the standard system at SRE 0.67 / ASRE 0.72 regardless of whether the proposed design includes heat recovery, meaning a design without HRV will carry a compliance penalty against that baseline.

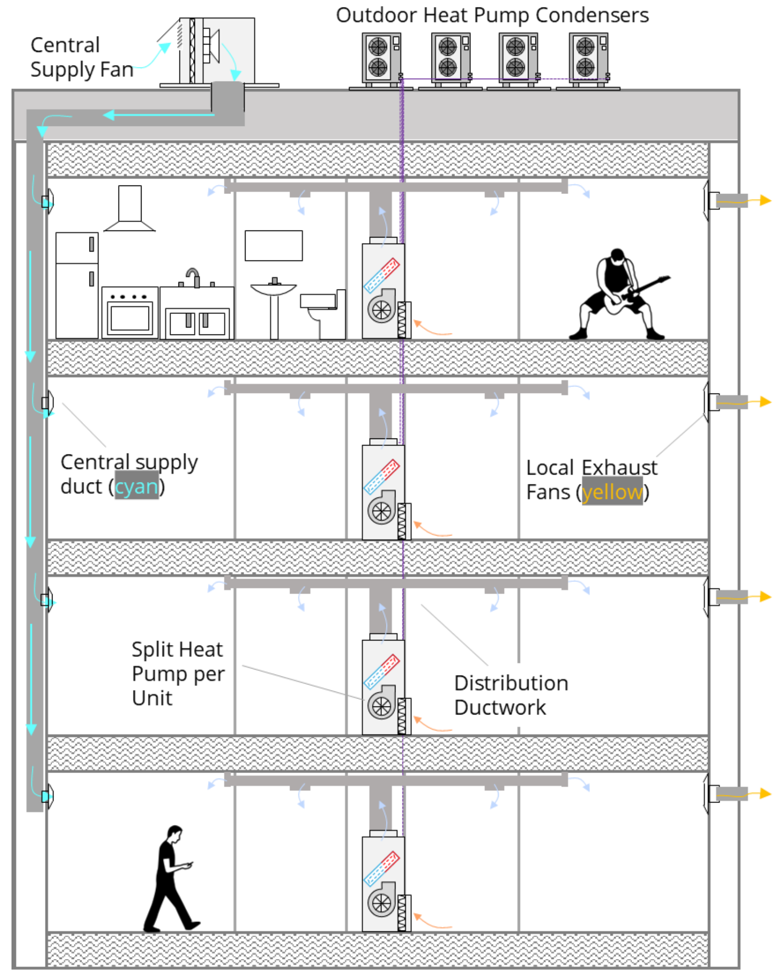
Alternate 1b: MF Ventilation Option: Central Supply, Local Exhaust

System Tag: MF-CSUP_IEXH-SZHP

Mechanical Description

A single central fan delivers conditioned outdoor air via a common duct to all units. Each dwelling has its own exhaust fan (typically in the bathroom or kitchen) that operates independently. Supply and exhaust are unbalanced at the unit level. This is the most common ventilation pattern in new heat-pump multifamily construction.

The Title 24 2025 standard system for this configuration uses a central supply fan at 0.441 W/cfm and individual exhaust fans at 0.350 W/cfm, with no heat recovery ventilator in the baseline.



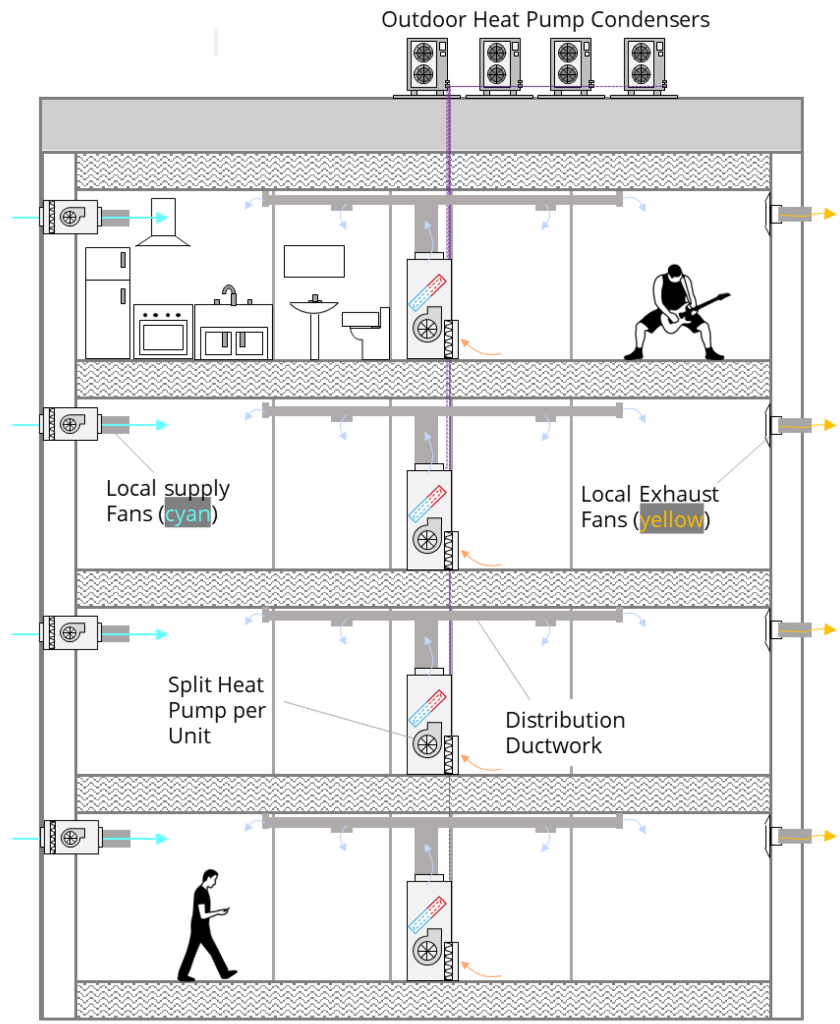
Alternate 1c: MF Ventilation Option: Local Supply and Exhaust

System Tag: MF-ISUP_IEXH-SZHP

Mechanical Description

Façade-Mounted (No Heat Recovery)
Each unit has its own supply and exhaust fan, each penetrating the exterior wall at a different location with no shared ductwork. Because the supply and exhaust streams never meet, heat recovery is not possible. This configuration is often implemented using a bathroom exhaust fan as the exhaust component, with a separate through-wall supply grille or fan serving the living area.

The Title 24 2025 standard system for this configuration is individual balanced ventilation with a combined fan power of 0.60 W/cfm and a heat recovery ventilator at SRE 0.67 / ASRE 0.72, regardless of whether the proposed design includes heat recovery. A proposed design without HRV will take a compliance penalty against this baseline.



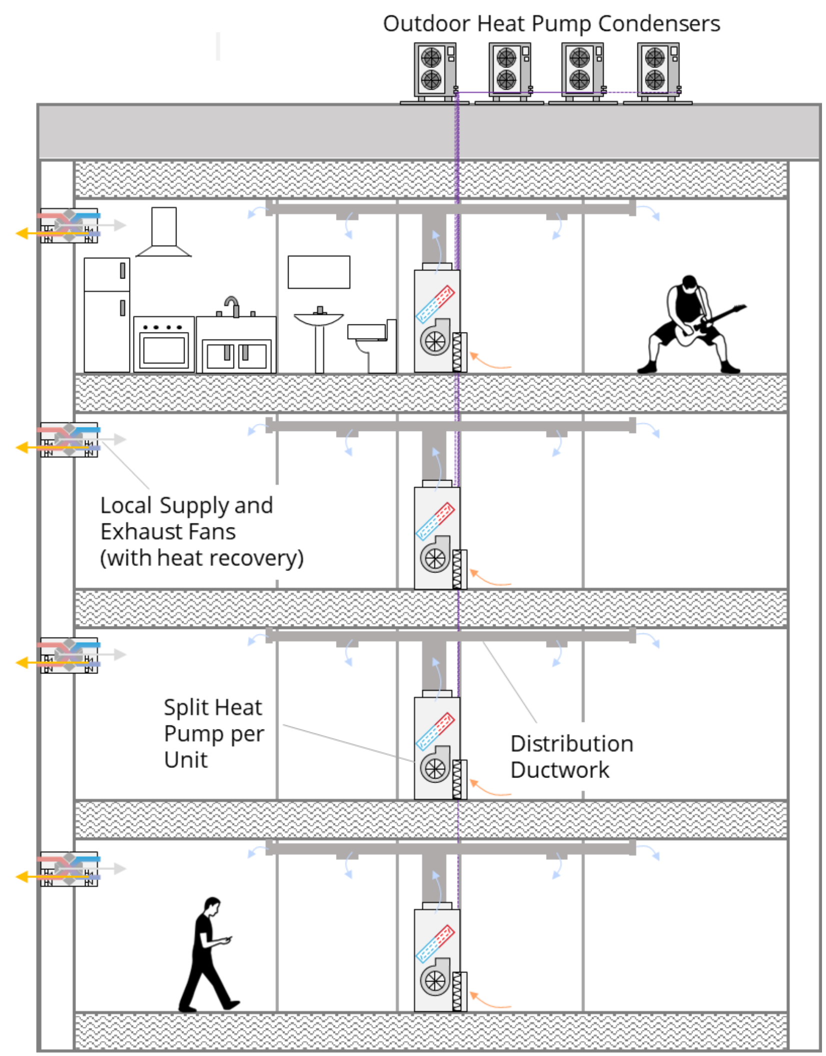
Alternate 1d: MF Ventilation Option: Local Ventilator with Heat Recovery

System Tag: MF-ISUP_IEXH-HRV-SZHP

Mechanical Description

A single through-wall device per unit handles both supply and exhaust within a single housing, passing the two airstreams through a heat exchanger core. The exhaust air pre-conditions incoming supply air before it enters the unit, recovering a significant fraction of heating or cooling energy. This configuration

The Title 24 2025 standard system for this configuration is also individual balanced ventilation with a combined fan power of 0.60 W/cfm and a fixed heat recovery ventilator at SRE 0.67 / ASRE 0.72; the baseline HRV efficiency is fixed and does not adjust to match the efficiency of the proposed unit.



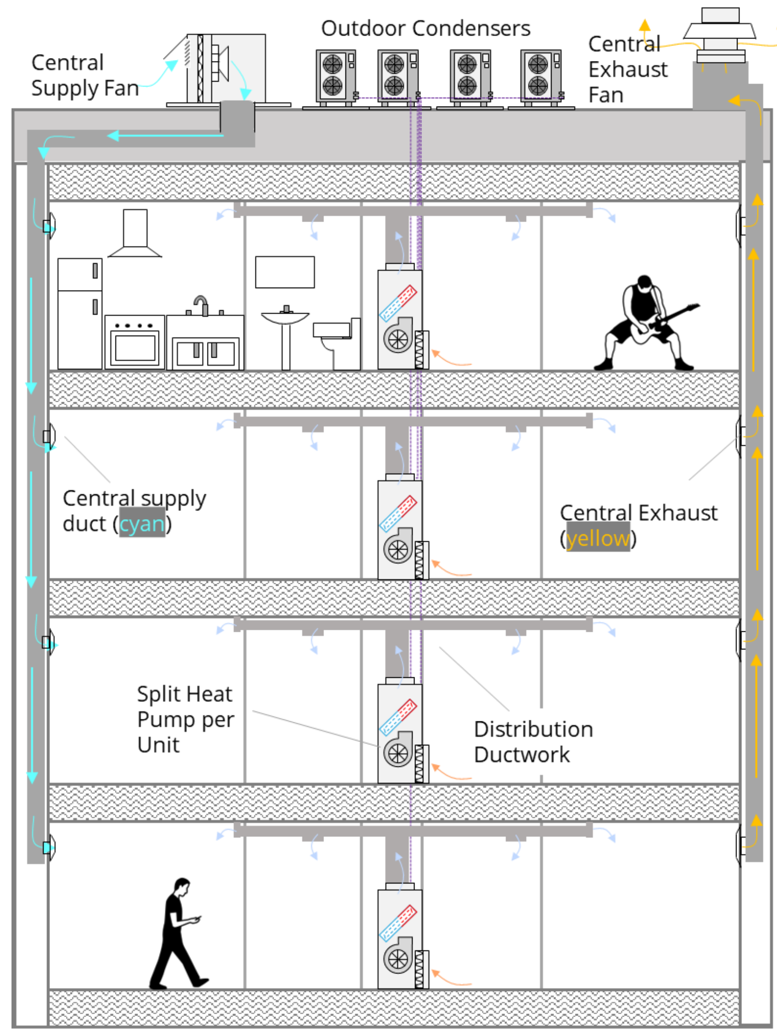
Alternate 1e: MF Ventilation Option: Central Supply, Central Exhaust

System Tag: MF-CSUP_CEXH-HRV-SZHP

Mechanical Description
(No Heat Recovery)

A single central fan delivers outdoor air to all units via a shared supply duct, and a separate central fan collects stale air from all units via a shared exhaust duct. Neither supply nor exhaust operates at the unit level. This configuration is more common in larger mid-rise buildings where centralizing both airstreams simplifies maintenance and allows for greater control over building pressurization.

The Title 24 2025 standard system for this configuration uses a central supply fan at 0.441 W/cfm and a central exhaust fan at 0.302 W/cfm, with no heat recovery ventilator in the baseline.



Alternate 5b: NR CV-DOAS with Multi-Zone VRF Heat Pump

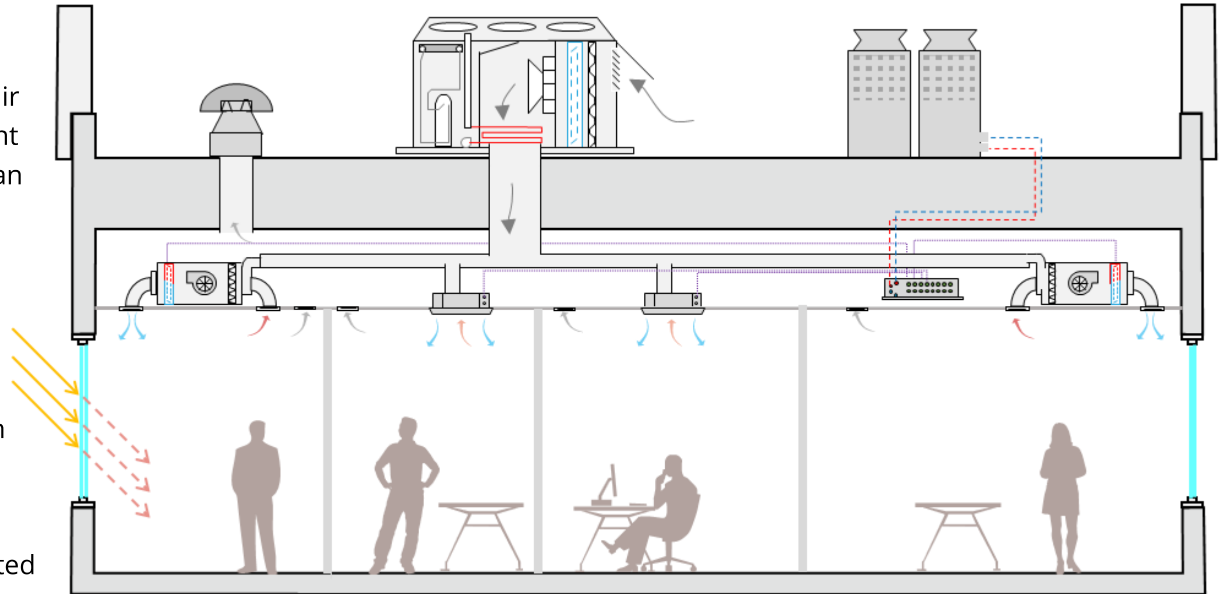
System Tag: CUSTOM-DOAS-VRF

Mechanical Description

This system is a dedicated outdoor air system (DOAS) with a variable refrigerant flow (VRF) heat pump system and zone fan coil units.

Ventilation is coupled with heating and cooling. The DOAS and the VRF fan coils address sensible and latent heating and cooling as well as ventilation simultaneously.

The IT room is served by a dedicated constant-volume, single-zone DX cooling unit sized for continuous precision cooling independent of occupancy. No heating is provided to this space. The DOAS supplies a small ventilation terminal to the room, and the unit otherwise operates independently of the VRF system.



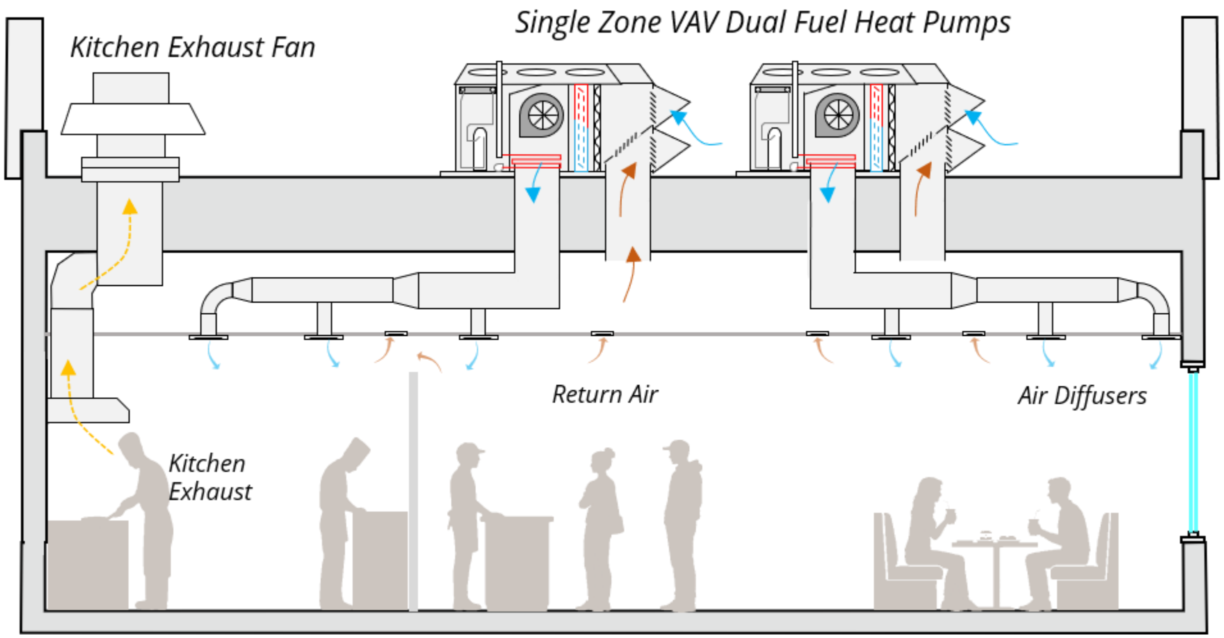
The diagram shows a central DOAS unit supplying tempered ventilation air to each zone, including the IT room. It is coupled with a VRF heat pump which distributes refrigerant through a branch box to individual zone fan coils or cassettes.

Alternate 8b: NR Restaurant, Single Zone Dual-Fuel Heat Pumps

System Tag: T24ACM-SZVAVDFHP
Title 24 2025 ACM: System 7c

Mechanical Description

This system is a single zone VAV airflow control dual-fuel heat pump configuration, with each of the two zones operating with their own unit. This configuration will consistently exceed the energy cost and source energy savings of an AC furnace configuration with the heat pump.



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Appendix: Terminology and Acronyms

ORGANIZATIONAL *full definitions*		
EOR	**Engineer of Record**	Licensed engineer who signs and seals the mechanical design documents. Their drawings serve as the primary source of design intent for the compliance model.
AHJ	**Authority Having Jurisdiction**	Governmental body or official responsible for enforcing the requirements of an energy code, including reviewing and approving compliance documentation.
CEC	**California Energy Commission**	State agency responsible for developing and adopting California's building energy efficiency standards, including Title 24 Part 6.
CalBEM	**CA Building Energy Modeling Symposium**	Annual industry forum that convenes compliance practitioners, software developers, and researchers to advance California building energy modeling practice.
—	**Design Team**	Architects, engineers, consultants, and specialists responsible for developing the building design documentation used as the basis for energy modeling.

BUILDING & CODE *full definitions*		
T24	**Title 24 Part 6**	California's mandatory energy efficiency standard for new and altered buildings, establishing minimum requirements for envelope, lighting, and mechanical systems.
ACM	**Alternate Calculation Method**	Performance-based compliance pathway allowing whole-building energy simulation in lieu of prescriptive requirements alone.

BUILDING & CODE *full definitions*

CBECC	**CA Building Energy Code Compliance**	CEC-developed software for Title 24 Part 6 compliance calculations covering nonresidential, multifamily, and single-family buildings. Uses EnergyPlus as the simulation engine for nonresidential buildings and CSE (California Simulation Engine) for residential and multifamily.
MF	**Multi-Family Buildings**	Residential buildings with three or more dwelling units, regulated under the residential provisions of Title 24 Part 6; modeled in CBECC using the CSE simulation engine.
NR	**Non-Residential Buildings**	Buildings other than single-family and low-rise multifamily, regulated under nonresidential provisions of Title 24 Part 6; modeled in CBECC using the EnergyPlus simulation engine.
HVAC	**Heating, Ventilation & Air Conditioning**	Mechanical systems providing thermal comfort, ventilation, and air quality control — the primary focus of energy compliance modeling under Title 24 Part 6.
—	**Proposed Design**	The energy model representing the building as designed, with systems entered as specified in construction documents. Compared against the Standard Design to determine compliance.
—	**Standard Design**	A code-defined baseline building model auto-generated by the compliance software using prescribed rules. The benchmark the Proposed Design must meet.
—	**Performance Compliance**	Pathway in which the proposed design is simulated and shown to use equal or less energy than the Standard Design, allowing flexibility across systems.
—	**Prescriptive Compliance**	Pathway in which each building system meets a defined minimum efficiency or configuration requirement, without requiring whole-building energy simulation.
—	**Thermal Zone**	Fundamental simulation unit in CBECC: a space or group of spaces with similar conditioning needs controlled by a single thermostat. Distinct from an HVAC zone.

BUILDING & CODE *full definitions*		
—	**Efficiency Metrics**	Standardized ratings used to compare equipment performance under Title 24: COP, EER, EER2, IEER, SEER, SEER2, HSPF, HSPF2, AFUE. See Appendix B for individual definitions.
COP	**Coefficient of Performance**	A dimensionless ratio of heating or cooling output to electrical input at a single rated condition. Higher is better. Used for heat pumps, chillers, and cooling towers in CBECC inputs; not annualized.
EER	**Energy Efficiency Ratio**	Cooling efficiency at a single ARI rated condition (95°F OAT), expressed as Btu/hr of cooling per watt of input. Legacy metric still used in some CBECC nonresidential fields.
EER2	**Energy Efficiency Ratio (2023 std.)**	Updated version of EER using revised AHRI 210/240 test conditions adopted in 2023. Values are generally slightly lower than legacy EER for the same equipment. Required for new residential and light commercial equipment compliance.
IEER	**Integrated Energy Efficiency Ratio**	A weighted average EER across four part-load operating conditions (100%, 75%, 50%, 25%), reflecting real-world performance better than single-point EER. Used for commercial cooling equipment and VRF systems in Title 24.
SEER	**Seasonal Energy Efficiency Ratio**	Annualized cooling efficiency metric for residential and light commercial equipment, calculated over a full cooling season. Legacy metric; superseded by SEER2 for new equipment as of 2023.
SEER2	**Seasonal Energy Efficiency Ratio (2023 std.)**	Updated SEER using revised external static pressure conditions that better reflect installed performance. Required for residential and light commercial equipment manufactured after January 2023. Typical values run 5–7% lower than legacy SEER for equivalent equipment.
HSPF	**Heating Seasonal Performance Factor**	Annualized heating efficiency metric for heat pumps, expressed as total heating output (Btu) per watt-hour of input over a heating season. Legacy metric; superseded by HSPF2.

BUILDING & CODE *full definitions*		
HSPF2	**Heating Seasonal Performance Factor (2023 std.)**	Updated HSPF using revised test conditions. Required for heat pumps manufactured after January 2023. Typical values run 10–15% lower than legacy HSPF for equivalent equipment due to higher external static pressure in testing.
AFUE	**Annual Fuel Utilization Efficiency**	The ratio of annual heat output to annual fuel energy consumed by a furnace or boiler, expressed as a percentage. An AFUE of 80% means 80% of fuel energy is converted to useful heat. Used in CBECC for gas furnace and boiler inputs.

MECHANICAL SYSTEMS *full definitions*		
AHU	**Air Handling Unit**	Central equipment that conditions and distributes air to multiple zones via a duct system. Typically includes supply fan, cooling/heating coils, filters, and outdoor-air mixing.
IAQ	**Indoor Air Quality**	Condition of indoor air with respect to health and comfort. Driven in part by minimum outdoor-air ventilation requirements that must be reflected in compliance models.
DCV	**Demand-Controlled Ventilation**	A ventilation control strategy that reduces outdoor airflow when occupancy is below design levels, typically using CO2 sensors to modulate flow in real time. Required by Title 24 in zones exceeding minimum occupancy density thresholds.
DHW	**Domestic Hot Water**	Potable hot water for occupant use (sinks, showers, kitchens), distinct from hot water used for space heating. DHW systems are modeled separately in CBECC and must meet Title 24 Part 6 efficiency requirements.
HPWH	**Heat Pump Water Heater**	A water heater that uses a refrigerant cycle to extract heat from surrounding air rather than generating heat directly, achieving significantly higher efficiency than electric resistance water heating.

MECHANICAL SYSTEMS *full definitions*		
VSD	**Variable Speed Drive**	An electrical control device that adjusts motor speed in response to load, used on supply fans, exhaust fans, and pumps to reduce energy use during part-load conditions. Also called a variable frequency drive (VFD).
CRAC	**Computer Room Air Conditioner**	A precision cooling unit for IT or electrical rooms, maintaining tight temperature and humidity tolerances. Modeled in CBECC as a single-zone air conditioner (SZAC) with a computer room subtype.
—	**Plant Systems**	Central heating and cooling equipment — chillers, boilers, cooling towers — producing chilled or hot water distributed to air handlers and zone equipment.
—	**Distribution Systems**	Duct and piping networks carrying conditioned air, chilled water, or hot water from central equipment to zone-level terminal devices.
—	**Zone Terminal Units**	Devices at the zone level (VAV boxes, fan-powered boxes) that control supply-air volume or temperature in a ducted air system.
—	**Zone Conditioning Systems**	Self-contained or hydronic units that condition individual zones directly, without a central air handler. Examples: fan coils, PTACs, water source heat pumps.
—	**Single Zone System**	An HVAC system serving one thermal zone, with a single thermostat controlling the entire system's heating and cooling output.
—	**Multi-Zone System**	An HVAC system serving multiple thermal zones simultaneously, with zone-level controls adjusting airflow or temperature to meet varying loads.
—	**Cooling Tower**	A heat rejection device that dissipates heat from a condenser water loop to the atmosphere through evaporative cooling. Serves as the heat sink for water source heat pump systems and chilled water plants.

MECHANICAL SYSTEMS *full definitions*		
—	**Boiler**	Central combustion or electric equipment that produces hot water for hydronic heating distribution. Defined as plant equipment connected to a hot water fluid loop in CBECC.
—	**Chiller**	Central refrigeration equipment that produces chilled water for distribution to air handlers and fan coils. Types include air-cooled and water-cooled; modeled in CBECC as plant equipment on the chilled water fluid loop.

SYSTEM TYPES *full definitions*		
VAV	**Variable Air Volume**	Air distribution strategy in which supply airflow to each zone varies in response to load, while supply air temperature is held relatively constant.
CAV	**Constant Air Volume**	Air distribution strategy in which supply airflow remains fixed; space temperature is controlled by varying supply air temperature.
PVAV	**Packaged VAV Air Handler**	Factory-assembled VAV air handler with integrated DX cooling coil and gas or electric heating. A common system type in California nonresidential buildings.
DOAS	**Dedicated Outdoor Air System**	Ventilation system that conditions and delivers 100% outdoor air separately from the primary space conditioning system, decoupling ventilation from load control.
VRF	**Variable Refrigerant Flow**	Multi-zone heat pump using variable-speed compressors and refrigerant piping to independently condition multiple zones. Heat recovery VRF can simultaneously heat and cool different zones.
DFHP	**Dual Fuel Heat Pump**	A heat pump paired with a gas furnace backup, switching to gas heating during very cold conditions when heat pump efficiency decreases.

SYSTEM TYPES *full definitions*		
HRV	**Heat Recovery Ventilator**	Ventilation device that transfers heat between exhaust and incoming outdoor air streams to reduce the energy cost of ventilation.
ERV	**Energy Recovery Ventilator**	Similar to HRV but transfers both heat and moisture between exhaust and supply air streams. Commonly used in California climate zones where humidity management is relevant.
AWHP	**Air-to-Water Heat Pump**	Heat pump that extracts heat from outdoor air to produce hot water for hydronic heating distribution systems.
WSHP	**Water Source Heat Pump**	Heat pump that exchanges heat with a condenser water loop rather than outdoor air, typically connected to a shared building loop with cooling tower and boiler.
FPFC	**Four-Pipe Fan Coil**	Zone-level hydronic conditioning unit with separate chilled water and hot water coils, allowing simultaneous heating and cooling capability.
PTHP	**Packaged Terminal Heat Pump**	Self-contained through-wall heat pump serving a single zone without ductwork. Commonly encountered in lodging and multifamily corridor applications.
SZHP	**Single-Zone Heat Pump**	An all-electric, single-zone packaged or split heat pump providing both heating and cooling to one thermal zone. A common baseline system type in Title 24 compliance modeling.
SZAC	**Single-Zone Air Conditioner**	A cooling-only packaged or split system serving a single thermal zone. Used in CBECC for spaces that require precision cooling without heating, such as IT and electrical rooms.
SZVAVDFHP	**Single-Zone VAV Dual Fuel Heat Pump**	A CBECC air system type combining a variable-speed single-zone heat pump with a gas furnace for supplemental heating. Maps to Title 24 2025 ACM System Type c3. The subject of Example 4 in this guide.

VENTILATION CONCEPTS *full definitions*		
ISUP/CEXH	**Individual Supply / Central Exhaust**	A multifamily ventilation configuration in which each dwelling unit has its own dedicated supply fan drawing outdoor air directly into the unit, while a single building-wide central exhaust fan collects stale air from all units via a shared riser.
HERS	**Home Energy Rating System**	A field verification and diagnostic testing program administered by California HERS raters. Required by Title 24 to confirm that installed systems match the compliance model assumptions for duct leakage, refrigerant charge, and fan efficacy.
CZ	**Climate Zone**	One of 16 geographic regions defined by the California Energy Commission, each with distinct weather data used to drive Title 24 energy simulations. All examples in this guide are modeled in Climate Zone 9.
—	**Autosize**	A CBECC modeling mode in which the simulation engine calculates and assigns equipment capacity based on peak zone loads rather than requiring the modeler to enter explicit values.
—	**HP Lockout / Compressor Lockout**	An outdoor air temperature threshold below which the heat pump compressor is disabled and heating load transfers entirely to supplemental heating. Required by Title 24 for heat pumps with backup heat.

CBECC SOFTWARE *full definitions*

—	**DwellUnitType**	In CBECC, a template object that defines the HVAC, ventilation, and DHW equipment assignments for a category of dwelling unit (e.g., 1-Bed, 2-Bed). Individual DwellUnit instances reference a type and inherit all assignments; equipment is specified once and applied to all units of that type.
—	**DOASVAV (Air System type)**	A CBECC Air System object type representing a dedicated outdoor air system with variable air volume terminal units. Used to model 100% outdoor air systems in Examples 5 and 6, where ventilation is fully decoupled from zone conditioning.

CBECC SOFTWARE *full definitions*

—	**Air Systems**	In CBECC, the object class representing multi-zone central air handling systems. Types include PVAV, VAV, DOAS, and HV. Expose the full range of multi-zone controls including variable volume operation, economizers, and outdoor air management.
—	**Zone Systems**	In CBECC, the object class representing single-zone conditioning equipment that serves individual thermal zones directly. Includes fan coils, PTACs, WSHPs, VRF indoor units, and radiant systems.
—	**Terminal Units**	In CBECC, zone-level devices attached to an Air System that modulate airflow or reheat. Includes VAV reheat boxes, fan-powered VAV boxes, and active chilled beams. Distinct from Zone Systems.
—	**Air Segment**	A CBECC object that defines a portion of an air system's duct network, specifying supply, return, or exhaust airflow paths and associated duct leakage and thermal properties.
—	**Outdoor Air Object**	A CBECC input object defining the outdoor air control strategy for an Air System, including economizer type, minimum outdoor air fractions, and demand-controlled ventilation settings.
—	**Fluid Loop**	In CBECC, the object connecting central plant equipment to air-side or zone-side coils via chilled water, hot water, or condenser water piping. The structural backbone of the Plant System hierarchy.
—	**Plant System**	In CBECC, the object hierarchy representing central hydronic equipment including fluid loops and connected plant equipment such as chillers, boilers, and cooling towers.
—	**Dwelling Unit**	In CBECC/CSE, the fundamental modeling unit for multifamily buildings representing a single apartment or unit, within which individual heating, cooling, and ventilation systems are defined.
—	**Heat Recovery (object)**	In CBECC, an input object within the Air System that defines the performance characteristics of air-to-air heat recovery equipment on the outdoor air stream.

Appendix: Base Building Energy Model Inputs

Custom Small Office

Base Building Assumptions

The following subsections describe the base building energy model inputs for the Custom Small Office (NR) prototype modeled in CBECC for this guide. This prototype is a single-story general office building with dedicated outdoor air supply (DOAS) with heat-recovery ventilator (HRV), variable refrigerant flow (VRF) zone equipment, on-site photovoltaic generation, and battery storage. Climate zone: CZ09 (San Bernardino).

Envelope

Assembly	Specification
Roof	Flat/low-slope, insulation above deck; U-0.028 (approx. R-35 ci)
Exterior Wall	Metal-framed; U-0.055 (R-21 cavity + R-8 continuous insulation)
Exterior Floor / Slab	Carpet over concrete slab; U-0.042 (R-20 ci)
Vertical Glazing	Fixed curtainwall; U-0.34, SHGC=0.22, VT=0.42
Skylights	Fixed skylight; U-0.58, SHGC=0.25, VT=0.49
Gross Wall Area	4,767 sf
Vertical Glazing Area	892 sf
Window-to-Wall Ratio (WWR)	18.7%
Roof Area	13,895 sf
Skylight Area	788 sf
Skylight-to-Roof Ratio (SRR)	5.7%

Lighting / All Gains

Space Function (T24 2025)	Floor Area (sf)	LPD (W/sf)
Office Area (>250 sf)	7,531	0.60
Convention, Conference, Multipurpose and Meeting	2,367	0.75
Lounge, Breakroom, or Waiting Area	1,098	0.55
Storage, General	1,070	0.40
Corridor Area	539	0.40
Lobby, Main Entry	351	0.70
Office Area (≤250 sf)	378	0.65
Restrooms	246	0.65
Electrical, Mechanical, Telephone Rooms	183	0.40
Computer Room	132	0.50
Total / Weighted Average	13,895	0.60

PV and Battery

Parameter	Value
PV System Size	46.1 kWdc
Array Type	Fixed (≤7:12 pitch), azimuth 150°–270°
Module Type	Standard
Inverter Efficiency	96%
Annual Solar Access	98%
Battery Capacity	68 kWh
Battery Charge Rate	17 kW
Battery Discharge Rate	17 kW
Round-trip Efficiency	90%
Battery Control Strategy	TOU — charge 00:00–11:00, discharge 11:00–19:00

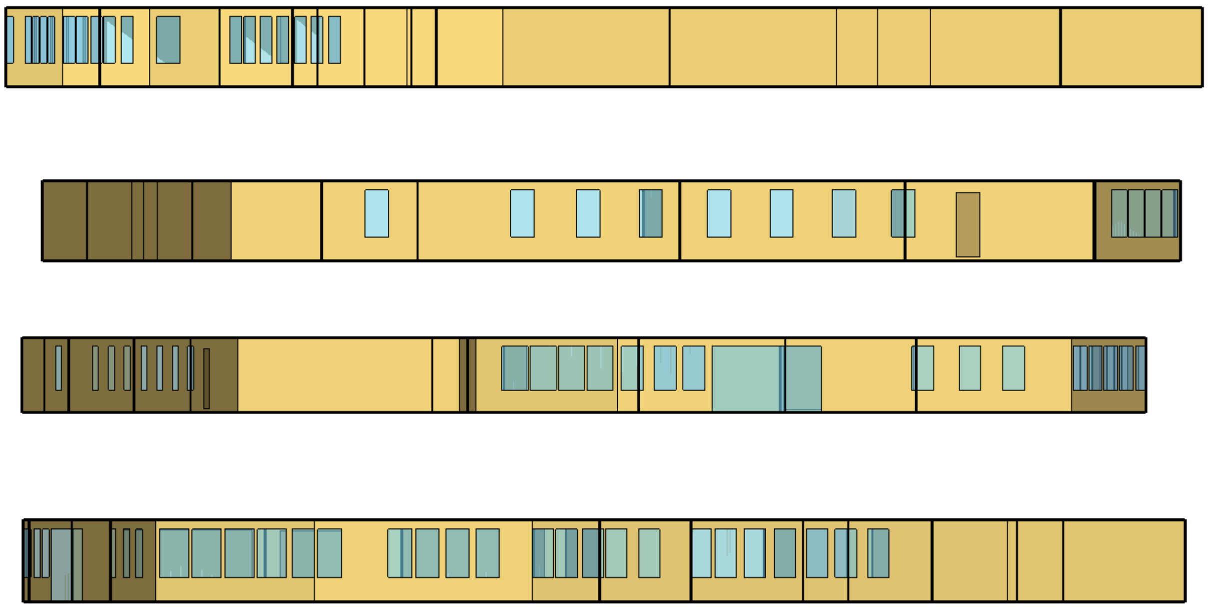
DHW

No domestic hot water system modeled. This prototype contains no service water heating loads. CBECC compliance was run under exceptional condition NoServiceWaterHeating per Section 140.5(c) Exception 1 — no SWH system present in the building.

Base Building Systems

Mechanical systems for the Custom Small Office prototype are described in the HVAC Narrative for Example 5 in this guide. In summary: a single central dedicated outdoor air system (DOAS) with heat-recovery ventilator (HRV) provides ventilation to all zones, and individual variable refrigerant flow (VRF) fan coil units provide zone heating and cooling. One server room zone is served by a separate packaged DX unit (CRAC).

Building Elevations



Midrise Apartment Building

The following subsections describe the base building energy model inputs for the Midrise Apartment Building (MF) prototype modeled in CBECC for this guide. This prototype is an 88-unit, 5-story mixed-occupancy building with individual supply (ISUP) and central exhaust (CEXH) ventilation, single-zone heat pumps (SZHP) for each zone, a central heat pump domestic hot water system, on-site photovoltaic generation, and battery storage. Climate zone: CZ09 (Los Angeles).

Dwelling Unit Mix

Unit Type	Count
Studio	8
1-Bedroom	40
2-Bedroom	32
3-Bedroom	8
Total	88

Envelope

Assembly	Specification
Residential Exterior Wall	Wood-framed; U-0.051 (Res Exterior Wall Cons)
NR Common Area Exterior Wall	Metal-framed; U-0.055 (MetalFrameWallU055); 6,590 sf
NR Non-Res Exterior Wall	Metal-framed; U-0.077; 1,870 sf
Roof / Top-Floor Ceiling	Cathedral ceiling assembly; U-0.029; cool roof (per FeatMF)
Below-Grade Wall	U-1.2; 16,920 sf (below-grade parking)
Residential Windows	Operable (MF); U-0.30, SHGC=0.23; bug screens included
NR Common Area Glazing	Fixed curtainwall; U-0.34, SHGC=0.22, VT=0.42; 659 sf

Lighting - Common Areas (NR)

NR Common Area Space Function	Floor Area (sf)	Total Power (W)	LPD (W/sf)
Retail / Amenity (Parking Level)	17,613	16,732	0.95
Corridor Area	10,824	4,330	0.40
Stairwell	1,800	1,080	0.60
Lobby, Main Entry	1,050	735	0.70
Exercise Center / Gymnasium	900	450	0.50
Lounge / Breakroom	720	396	0.55
Office Area (>250 sf)	414	248	0.60
Conference / Multipurpose	360	270	0.75
Total / Weighted Average	33,681	24,241	0.72

Note: Residential dwelling units are not subject to nonresidential LPD limits in Title 24 2025; only non-residential common areas are modeled for lighting compliance.

PV and Battery

Parameter	Value
PV System Size	274.5 kWdc
Array Type	Fixed (≤7:12 pitch), azimuth 150°–270°
Module Type	Standard
Inverter Efficiency	96%
Annual Solar Access	98%
Battery Capacity	260.2 kWh
Battery Charge Rate	65 kW
Battery Discharge Rate	65 kW
Round-trip Efficiency	90%
Battery Control Strategy	TOU — charge 00:00–11:00, discharge 11:00–19:00

DHW

System	Type	Distribution
DHW Heat Pump (Central)	Central heat pump water heater	MF recirculation loop
DHW Heat Pump Indiv	Individual unit heat pump water heater	Standard per-unit distribution

Base Building Systems

Mechanical systems (HVAC and ventilation) for the Midrise Apartment Building prototype are described in the HVAC Narrative for Example 1a in this guide. In summary: each residential and common-area zone is served by a single-zone heat pump (SZHP — ducted central split heat pump, SEER2=14.3, HSPF2=7.5). Ventilation uses individual supply (ISUP) air inlets per unit combined with a central exhaust (CEXH) fan system. The ground-floor amenity block is served by a PVAV air handler.

8-Unit Apartment Building

Base Building Assumptions

The following subsections describe the base building energy model inputs for the 8-Unit Apartment Building (MF) prototype modeled in CBECC for this guide. This prototype is an 8-unit, 2-story low-rise residential building with a central variable refrigerant flow (VRF) system serving all dwelling units, individual balanced heat-recovery ventilators (HRV) per unit, individual heat pump water heaters, and on-site photovoltaic generation. Climate zone: CZ09 (Los Angeles).

Dwelling Unit Mix

Unit Type	Count
1-Bedroom	4
2-Bedroom	4
Total	8

Envelope

Assembly	Specification
Exterior Wall	Wood-framed; U-0.051 (Exterior Wall Cons); 5,168 sf
Ceiling / Roof	Wood-framed ceiling below vented attic; U-0.025 (R-38 cavity); 3,660 sf
Attic	Vented attic with radiant barrier installed
Residential Windows	Operable (MF); U-0.30, SHGC=0.23; bug screens included

Lighting

No nonresidential common areas. This prototype is 100% residential; dwelling units are not subject to nonresidential LPD limits under Title 24 2025.

PV

Parameter	Value
PV System Size	15.4 kWdc
Array Type	Fixed (≤7:12 pitch), azimuth 150°–270°
Module Type	Standard
Inverter Efficiency	96%
Annual Solar Access	98%
Battery	None

DHW

Individual heat pump water heaters (NEEA-rated) per dwelling unit. No central DHW system or recirculation loop. Standard distribution within each unit.

Base Building Systems

Mechanical systems for the 8-Unit Apartment Building prototype are described in the HVAC Narrative for Example 2 in this guide. In summary: a single central VRF system (Type 1 — Central VRF, EER=10, COP=3.2) serves all 8 dwelling units via individual fan-coil units and a ducted distribution system. Each unit has an individual balanced heat-recovery ventilator (HRV, 70% SRE) for IAQ ventilation.

Custom Classroom / Lab

Base Building Assumptions

The following subsections describe the base building energy model inputs for the Custom Classroom/Lab (NR) prototype modeled in CBECC. This prototype is a single-story educational/laboratory building served by a Dedicated Outdoor Air System (DOAS) with Fan-Powered Fan Coils (FPFC) for zone heating and cooling. Climate zone: CZ09.

Envelope

Assembly	Specification
Roof	Flat/low-slope, insulation above deck; U-0.028; 14,818 sf
Exterior Wall	Metal-framed; U-0.055; 14,917 sf
Slab-on-Grade Floor	Slab-on-grade; F-0.073 (perimeter loss factor)
Vertical Glazing	Fixed window; U-0.34, SHGC=0.22, VT=0.42; 4,141 sf
Skylights	Fixed skylight; U-0.30, SHGC=0.25, VT=0.50; 141 sf
Window-to-Wall Ratio	27.8% (4,141 sf / 14,917 sf gross wall)
Skylight-to-Roof Ratio	0.95% (141 sf / 14,818 sf roof)

Lighting

Space Function (T24 2025)	Floor Area (sf)	LPD (W/sf)
Corridor Area	8,430	0.40
Laboratory, Scientific	8,143	0.90
Classroom, Lecture, Training, Vocational	5,290	0.60
Office Area (≤250 sf)	2,606	0.65
Restrooms	1,465	0.65
Storage, General	1,316	0.40
Lobby, Main Entry	504	0.70
Lounge / Breakroom	477	0.55
Computer Room	210	0.50
Electrical, Mechanical, Telephone Rooms	65	0.40
Total / Weighted Average	28,506	0.62

PV and Battery

Parameter	Value
PV System Size	64.8 kWdc
Array Type	Fixed (≤7:12 pitch), azimuth 150°–270°
Module Type	Standard
Inverter Efficiency	96%
Annual Solar Access	98%
Battery Capacity	119 kWh
Battery Charge Rate	29.75 kW
Battery Discharge Rate	29.75 kW
Round-trip Efficiency	90%
Battery Control Strategy	TOU — charge 00:00–11:00, discharge 11:00–19:00

DHW

No service hot water system. CBECC compliance run under exceptional condition NoServiceWaterHeating per Section 140.5(c) Exception 1 — no SWH system present in this building type.

Base Building Systems

Mechanical systems are described in the HVAC Narrative for Example 6. In summary: a central DOAS provides conditioned outdoor air to all zones; fan-powered fan coils (FPFC) at each zone provide supplemental heating and cooling using chilled and hot water.

NR Medium Office

Base Building Assumptions

The following subsections describe the base building energy model inputs for the NR Medium Office prototype modeled in CBECC. This prototype is a three-story office building served by packaged variable air volume (PVAV) air handlers with fan-powered parallel boxes (PFPB) at each zone. Climate zone: CZ09.

Envelope

Assembly	Specification
Roof	Flat/low-slope, insulation above deck; U-0.034; 17,876 sf
Exterior Wall	Metal-framed; U-0.055; 21,288 sf
Slab-on-Grade Floor	Slab-on-grade; F-0.073 (perimeter loss factor)
Vertical Glazing	Fixed window; U-0.34, SHGC=0.22, VT=0.42; 7,027 sf
Skylights	None
Window-to-Wall Ratio	33.0% (7,027 sf / 21,288 sf gross wall)

Lighting

Space Function (T24 2025)	Floor Area (sf)	LPD (W/sf)
Office Area (>250 sf)	53,628	0.60
Total / Weighted Average	53,628	0.60

PV and Battery

Parameter	Value
PV System Size	167.9 kWdc
Array Type	Fixed (≤7:12 pitch), azimuth 150°–270°
Module Type	Standard
Inverter Efficiency	96%
Annual Solar Access	98%
Battery Capacity	296.8 kWh
Battery Charge Rate	70.5 kW
Battery Discharge Rate	70.5 kW
Round-trip Efficiency	90%
Battery Control Strategy	Basic (non-TOU)

DHW

Parameter	Value
Fuel	Electric
Type	Storage tank
Capacity	30 gal
Input	8.74 kW
Efficiency (UEF)	0.94
First-Hour Rating	60 gal/hr

NR Restaurant

Base Building Assumptions

The following subsections describe the base building energy model inputs for the NR Restaurant prototype modeled in CBECC. This prototype is a single-story quick-service restaurant served by a single-zone VAV with DX cooling (SZ-VAV-AC) configured as a rooftop unit. Climate zone: CZ09.

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Assembly	Specification
Roof	Steep-slope, insulation above deck; U-0.028; 2,786 sf
Exterior Wall	Metal-framed; U-0.055; 2,001 sf
Slab-on-Grade Floor	Slab-on-grade; F-0.073 (perimeter loss factor)
Vertical Glazing	Fixed window; U-0.34, SHGC=0.22, VT=0.42; 280 sf
Skylights	None
Window-to-Wall Ratio	14.0% (280 sf / 2,001 sf gross wall)

Lighting

Space Function (T24 2025)	Floor Area (sf)	LPD (W/sf)
Fast Food / Dining	1,250	0.45
Kitchen, Commercial Food Preparation	1,250	0.95
Total / Weighted Average	2,500	0.70

PV

Parameter	Value
PV System Size	24.3 kWdc
Array Type	Fixed (≤7:12 pitch), azimuth 150°–270°
Module Type	Standard
Inverter Efficiency	96%
Annual Solar Access	98%
Battery	Reduced requirement exemption applied (Excpt3ReducedBattReq)

DHW

Parameter	Value
Fuel	Natural Gas
Type	Storage tank
Capacity	30 gal
Input	37.3 kBtu/hr
Efficiency (UEF)	0.65
First-Hour Rating	60 gal/hr

Base Building Systems

Mechanical systems are described in the HVAC Narrative for Example 8a. In summary: a single rooftop unit provides single-zone VAV supply with DX cooling and gas or heat-pump heating to the entire footprint. Dedicated exhaust is provided for the commercial kitchen.