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

SYSTEM TAG: T24STD-DOAS-VRF-HRV

PROJECT VISION

California Title 24 compliance modeling requires translating mechanical system designs into CBECC 2025 software objects, a process for which little practical guidance exists. Developed as part of the *Addressing Complex HVAC Systems in Code Compliance* project, funded by Southern California Edison through the CalBEM working group, each example walks through how a recognizable HVAC system type translates into CBECC objects, what Title 24 2025 Part 6 requires, and what assumptions were made.

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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.

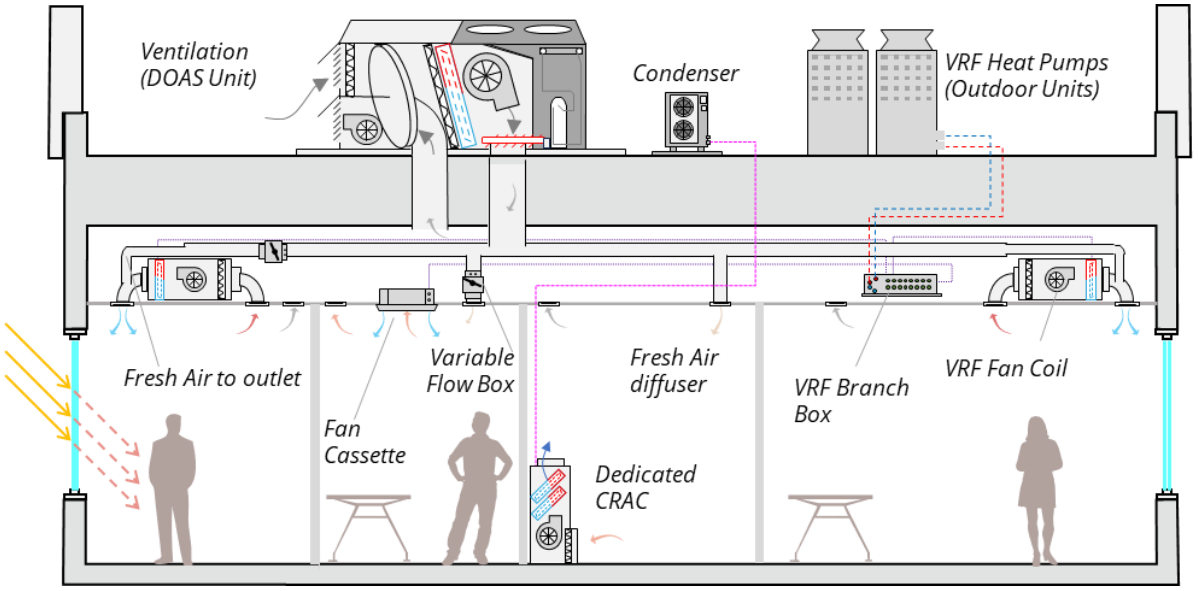


Figure 5: Non-Residential Small Office: DOAS with VRF

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

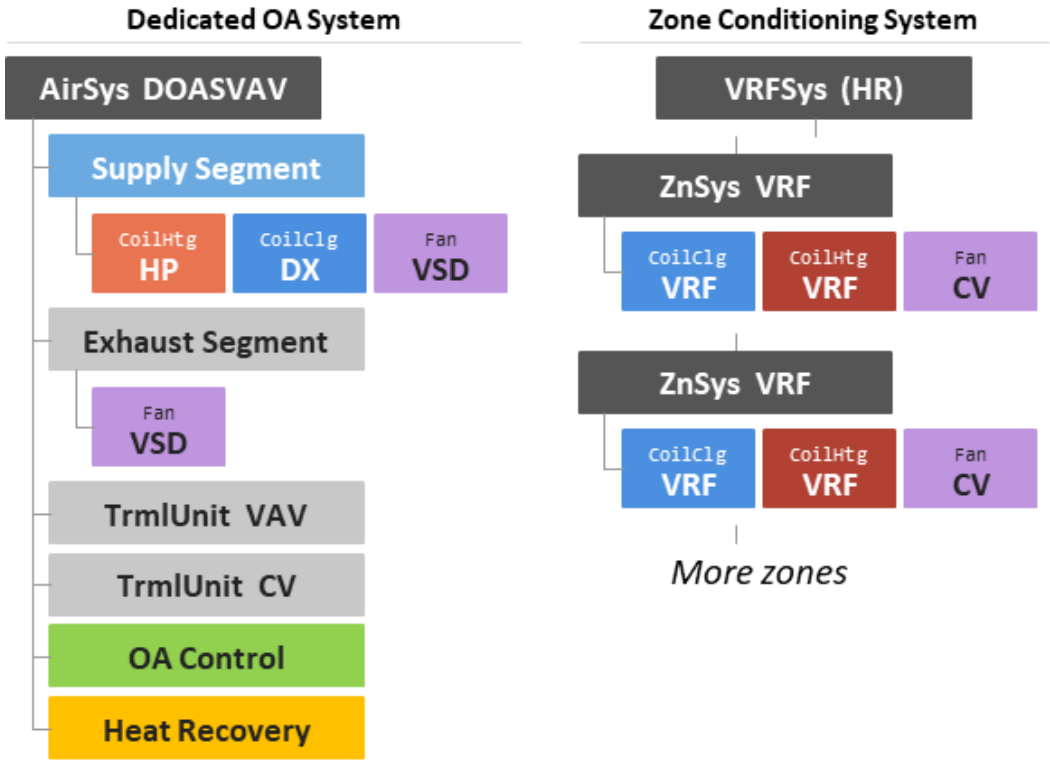
VAVNoReheatBox terminal units distribute DOAS air to zones with no zone-level reheat, each sized to zone ventilation flow.

VRF Heat Pump System

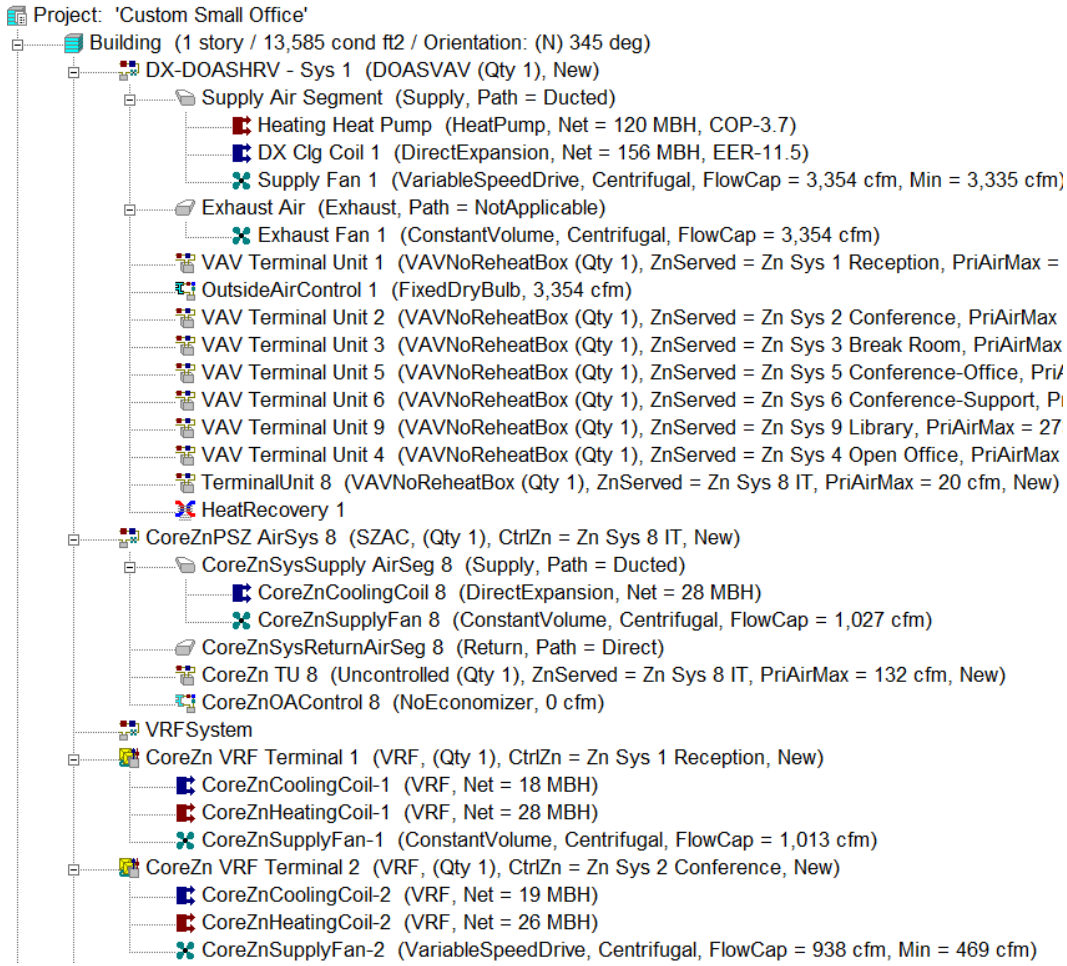
A central VRF system is built at the building level of the model tree structure and controls and distributes heat to each attached VRF zone system.

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 a SZHP system for the IT space and one unconditioned space for the restroom consisting of just an exhaust fan.

DOAS Ventilation System

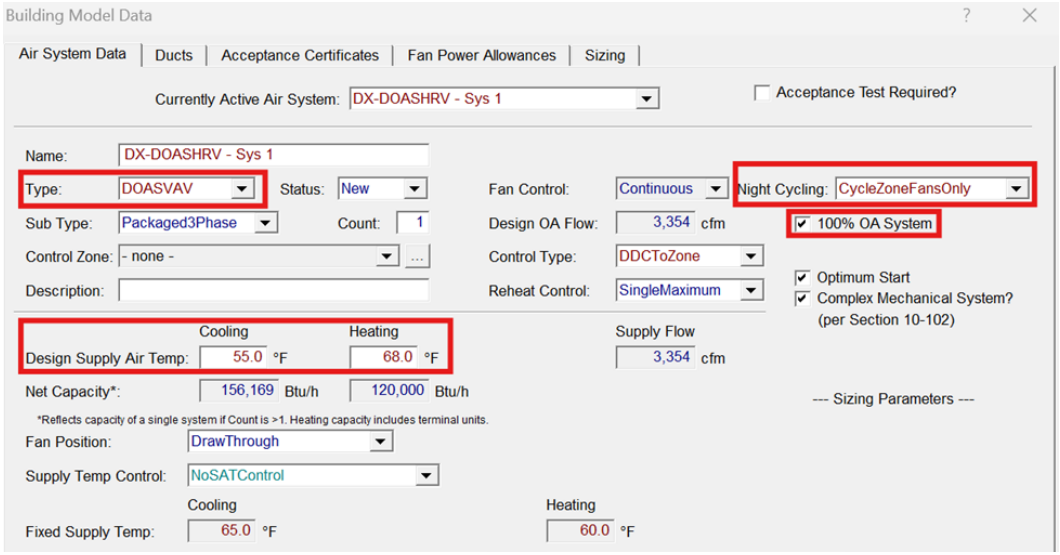
The DOAS is a 100% outdoor air system configured as a DOASVAV type, enabling ventilation airflow to modulate at the zone depending on the terminal unit types.
The air temperature is maintained at neutral conditions, which has design supply temperatures of 55 F and 68 F for cooling and heating.

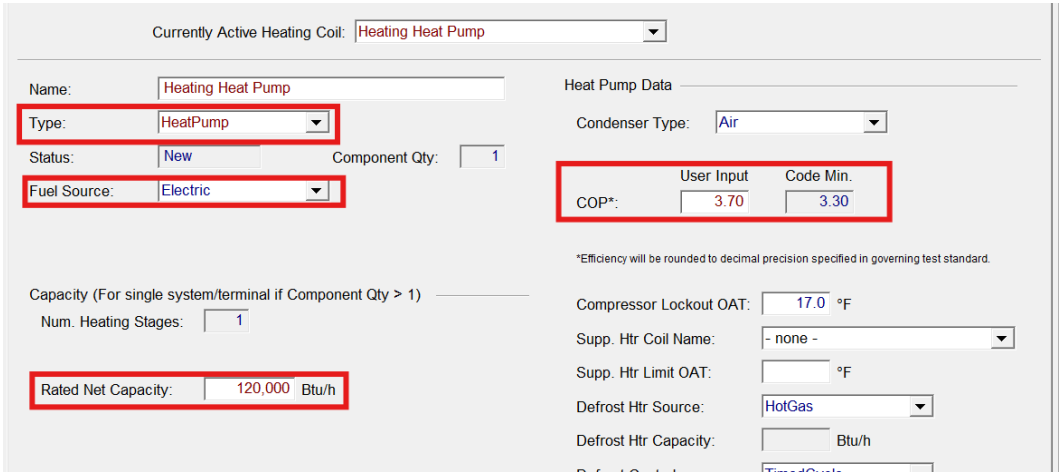
To maintain temperature at night, the local zone fan coils are used, keeping the ventilation system off.

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

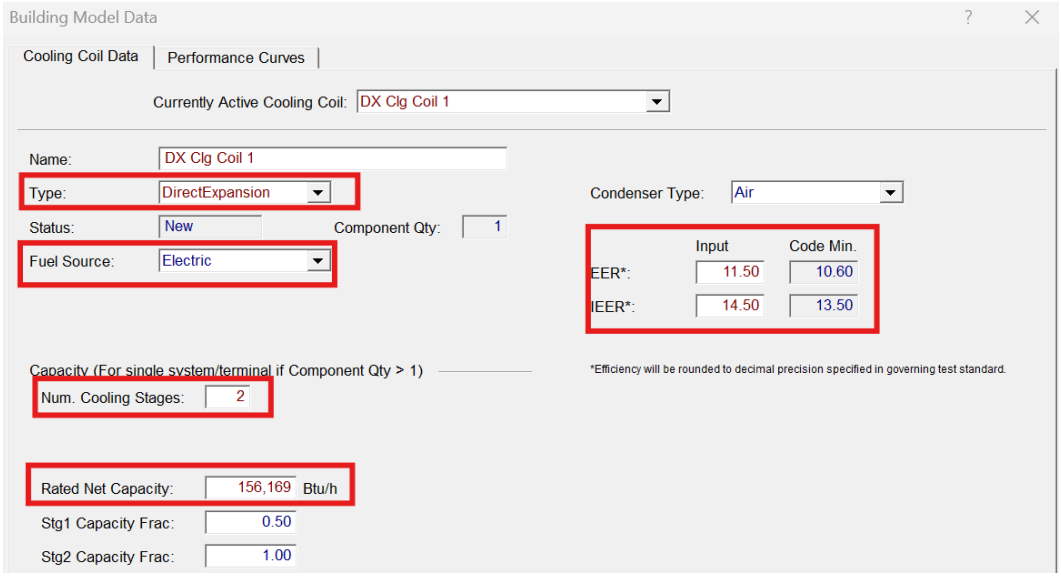




DX Cooling Coil

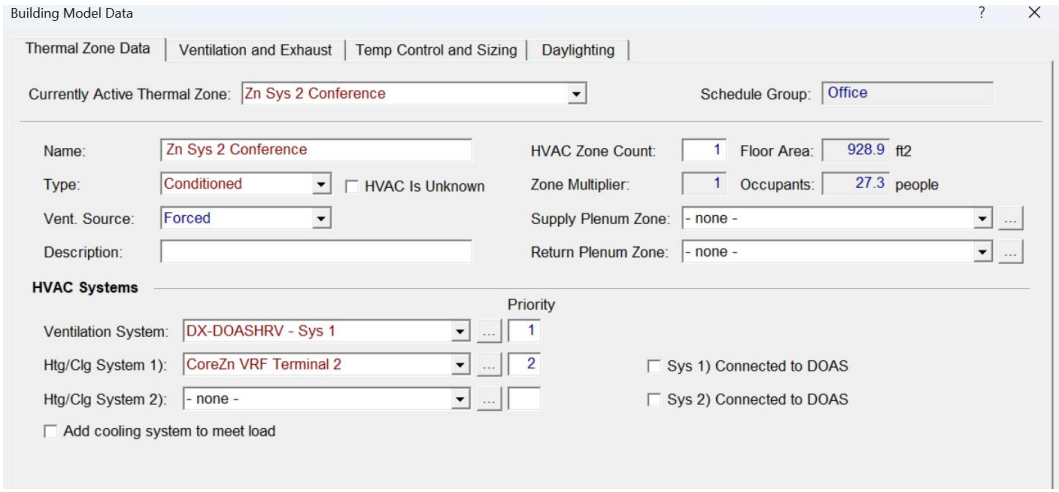
The DOAS cooling source consists of a direct expansion cooling coil

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

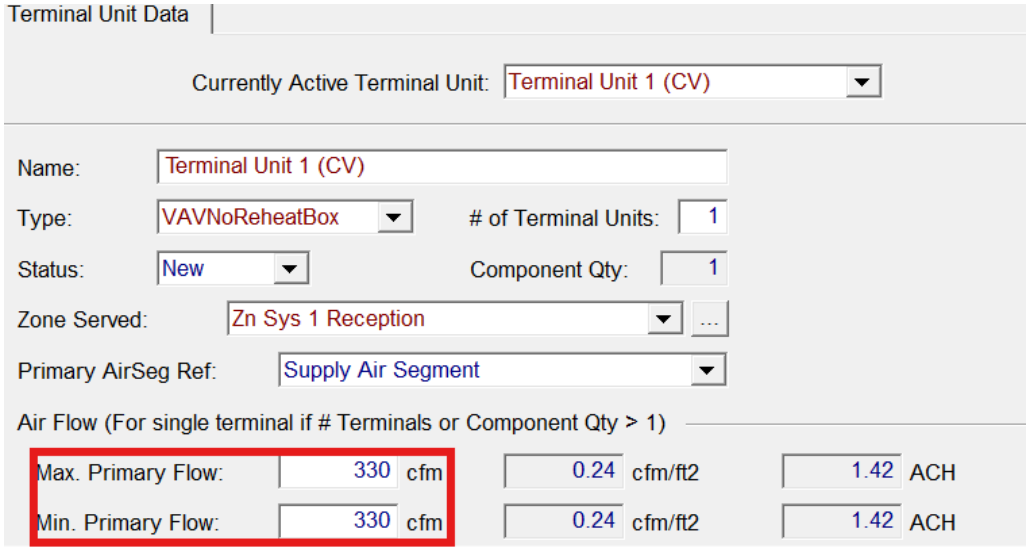
At each thermal zone, ventilation is configured from the DOAS unit and heating and cooling from the zones designated VRF fan cassette. Because the ventilation is decoupled, delivered directly to the space or downstream of the fan in each VRF fan coil or cassette no box is checked in the software for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



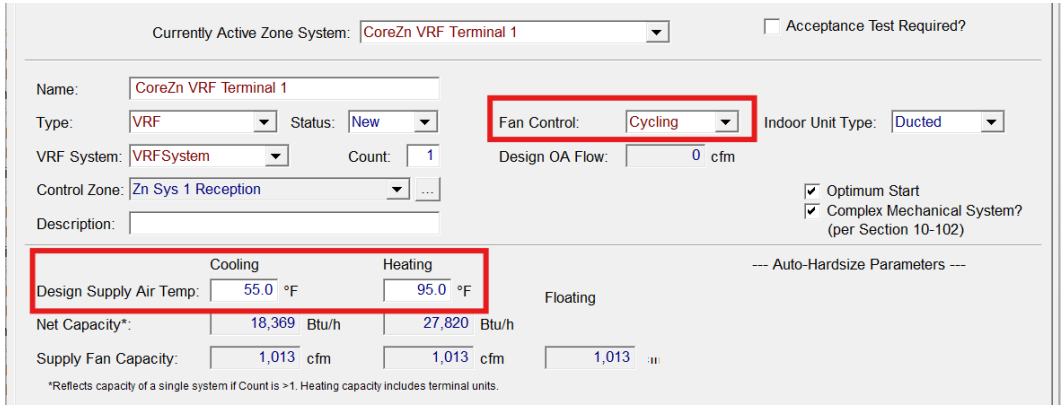
Zone System VRF Fan Coils

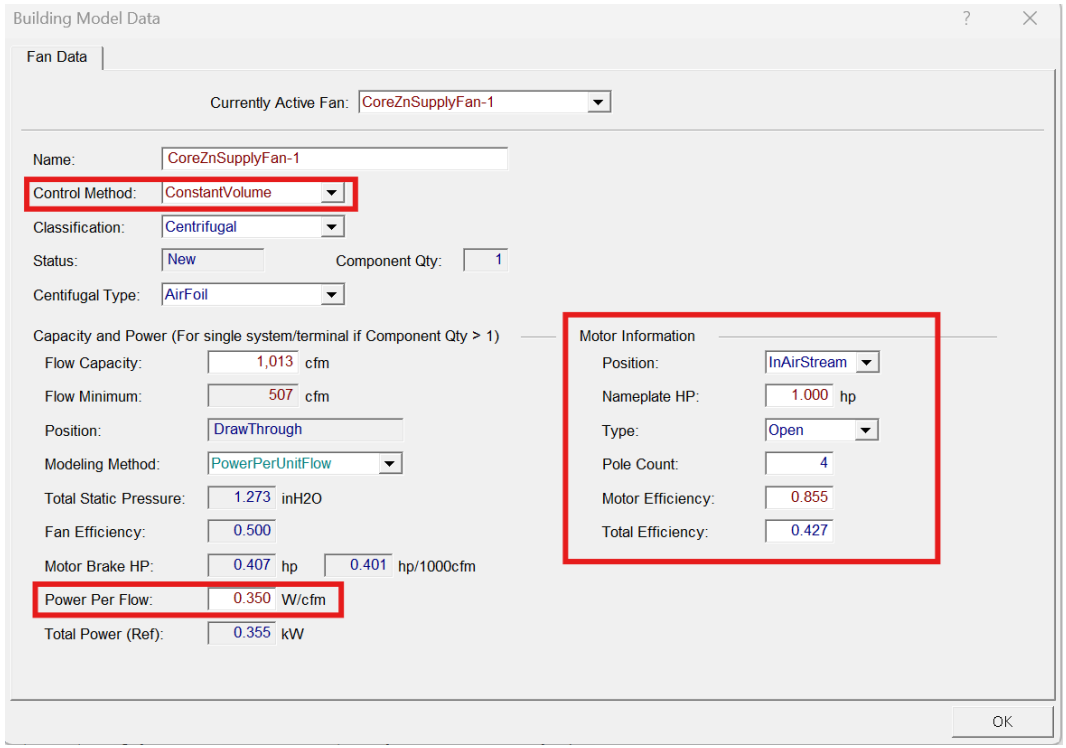
The model includes a VRF system with mixed fan configurations, with variable-speed terminals serving the Conference, Break Room, and Conference-Support zones, and constant-volume terminals serving all other zones.

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.

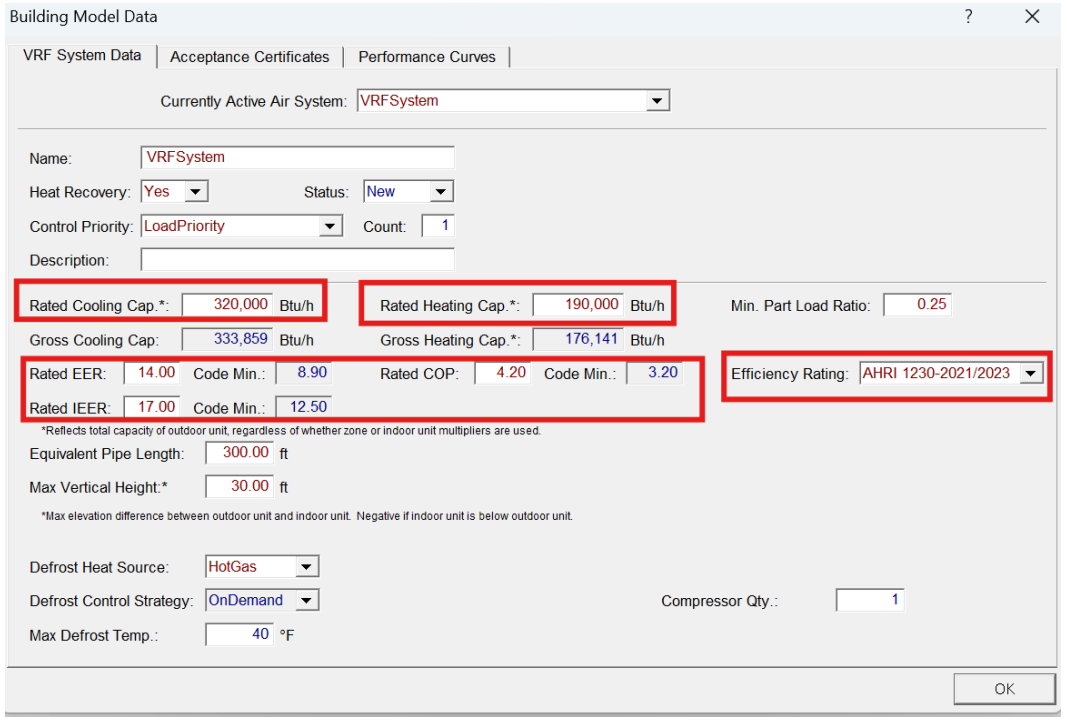
Fans are set to constant volume. Regardless of their assignment, in CBECC 2025 they are set to on off fans upon simulation and will cycle on and off as needed.





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

This example is one of eight developed as part of the *Addressing Complex HVAC Systems in Code Compliance* project. The full guide includes additional HVAC system types, alternative configurations, and working CBECC model files. All resources are available through the CalBEM working group and EnergyCodeAce platform.