

HVAC Total System Performance Ratio (TSPR)

Modify the 2021 International Energy Conservation Code as follows:

Revise as follows:

C403.1 General.

Mechanical systems and equipment serving the building heating, cooling, ventilating or refrigerating needs shall comply with ~~this section~~ one of the following:

1. Sections C403.1.1 and C403.2 through C403.14
2. Data Centers shall comply with C403.1.1, C403.1.2 and C403.6 through C403.14
3. Section C403.1.3 and Sections within Section C403 that are listed in Table C407.2

Exception: ~~Data center systems are exempt from the requirements of Sections C403.4 and C403.5.~~

Add new text as follows:

C403.1.3 HVAC total system performance ratio (HVAC TSPR).

HVAC systems serving buildings or portions of buildings listed in C403.1.3.1 that are not served by systems listed in C403.1.3.2 shall have an HVAC total system performance ratio (HVAC TSPR) of the proposed design HVAC systems that is greater than or equal to the HVAC TSPR of the standard reference design divided by the applicable mechanical performance factor (MPF) from Table C409.3.1. HVAC TSPR shall be calculated in accordance with Section C409, Calculation of HVAC Total System Performance Ratio. Systems using the HVAC TSPR method shall also meet requirements in C403.1.3.3.

C403.1.3.1 Included Building Types.

HVAC systems that serve the following building use types are allowed to use the TSPR Method:

1. office (including medical office) (occupancy group B),
2. retail (occupancy group M), library (occupancy group A-3),
3. education (occupancy group E),
4. hotel/motel occupancies (occupancy group R-1),
5. the dwelling units and common areas within occupancy group R-2 multifamily buildings.

C403.1.3.2 Excluded Systems.

The following HVAC systems are excluded from using the TSPR Method:

1. HVAC Systems using
 - 1.1 district heating water, chilled water or steam
 - 1.2. small duct high velocity air cooled, space constrained air cooled, single package vertical air conditioner, single p
 - 1.3 double-duct air conditioner or double-duct heat pump as defined in subpart F to 10CFR part 431
 - 1.4. packaged terminal air conditioners and packaged terminal heat pumps that have cooling capacity greater than 1
 - 1.5. a common heating source serving both HVAC and service water heating equipment, or
2. HVAC systems that provide recovered heat for service water heating
3. HVAC systems not included in Table C409.5.2.10.1
4. HVAC systems included in table C409.5.2.10.1 with parameters in Table C409.5.2.10.2, not identified as applicable to

5. HVAC systems with chilled water supplied by absorption chillers, heat recovery chillers, water to water heat pumps, and the same chilled water loop.
6. HVAC systems served by heating water plants that include air to water or water to water heat pumps.
7. Underfloor air distribution and displacement ventilation HVAC systems.
8. Space conditioning systems that do not include mechanical cooling.
9. HVAC systems serving laundry rooms, elevator rooms, mechanical rooms, electrical rooms, data centers, and computer rooms.
10. Buildings or areas of medical office buildings that comply fully with ASHRAE Standard 170, including but not limited to providing 24/7 air handling unit operation
11. HVAC systems serving laboratories with fume hoods
12. Locker rooms with more than 2 showers
13. Natatoriums and rooms with saunas
14. Restaurants and commercial kitchens with total cooking capacity greater than 100,000 Btu/h
15. Areas of buildings with commercial refrigeration equipment exceeding 100 kW of power input.
16. Cafeterias and dining rooms

C403.1.3.3 TSPR Method Partial Prescriptive Requirements.

HVAC systems using the HVAC Performance Rating Method shall meet relevant prescriptive requirements in Section C403 as follows:

1. Air economizers shall meet the requirements of Section C403.5.3.4 "relief of excess outdoor air" and Section C403.5.3.5.
2. Variable-air-volume system shall meet requirements of Sections C403.6.5, C403.6.6, and C403.6.9.
3. Hydronic systems shall meet the requirements of C403.4.4.
4. Plants with multiple chillers or boilers shall meet the requirements of Section C403.4.5.
5. Hydronic (Water Loop) Heat Pumps and Water-Cooled Unitary Air Conditioners shall meet the requirements of Section C403.4.6.
6. Cooling tower turndown shall meet requirements of Section C403.10.4.
7. Heating of unenclosed spaces shall meet the requirements of Section C403.13.1.
8. Hot-gas bypass shall meet the requirements of Section C403.3.3.
9. Systems shall meet the door switch control requirements of Section 6.5.10.
10. Refrigeration systems shall meet the requirements of Section C403.11.

C406.13 HVAC Performance (TSPR).

For systems allowed to use Section C403.1.3, the HVAC TSPR shall exceed the minimum requirement by 5 percent. If improvement is greater, credits in Tables C406.1(1) through C406.1(5) are permitted to be prorated up to a 20 percent improvement using Equation 4-16. Energy credits for C406.13 may not be combined with energy credits from any of the HVAC measures described in Section C406.2.

HVAC TSPR energy credit = base energy credit from Table 406.1 x (TSPR % / 5%)

(Equation 4-14)

where:

TSPR% = Percentage by which TSPR of proposed design exceeds minimum TSPR requirement. The value of TSPR% cannot exceed 20% for purposes of calculating H01 energy credits.

Revise as follows:

Portions of table not shown remain unchanged.

TABLE C406.1(1) ADDITIONAL ENERGY EFFICIENCY CREDITS FOR GROUP B OCCUPANCIES

SECTION	CLIMATE ZONE																
	0A & 1A	0B & 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
C406.13: HVAC TSPR	8	8	7	7	6	6	4	6	6	4	6	6	4	6	6	6	6

TABLE C406.1(2) ADDITIONAL ENERGY EFFICIENCY CREDITS FOR GROUP R AND I OCCUPANCIES

SECTION	CLIMATE ZONE																
	0A & 1A	0B & 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
C406.13: HVAC TSPR	8	8	8	7	6	6	5	6	6	4	6	5	4	6	6	6	7

Portions of table not shown remain unchanged.

TABLE C406.1(3) ADDITIONAL ENERGY EFFICIENCY CREDITS FOR GROUP E OCCUPANCIES

SECTION	CLIMATE ZONE																
	0A & 1A	0B & 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
C406.13: HVAC TSPR	11	11	10	9	8	8	6	8	7	6	7	7	6	8	7	8	8

NA = Not Applicable.

a. For schools with showers or full-service kitchens.

Portions of table not shown remain unchanged.

TABLE C406.1(4) ADDITIONAL ENERGY EFFICIENCY CREDITS FOR GROUP M OCCUPANCIES

SECTION	CLIMATE ZONE																
	0A & 1A	0B & 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
C406.13 HVAC TSPR	11	11	10	9	8	8	6	8	8	7	8	8	6	9	8	9	10

NA = Not Applicable.

Portions of table not shown remain unchanged.

TABLE C406.1(5) ADDITIONAL ENERGY EFFICIENCY CREDITS FOR OTHER^a OCCUPANCIES

SECTION	CLIMATE ZONE																
	0A & 1A	0B & 1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
C406.13: HVAC TSPR	7	8	7	6	6	5	3	6	5	4	7	6	4	8	7	8	8

Add new Section C409 text as follows:

Section C409 Calculation of HVAC Total System Performance Ratio

C409.1 Purpose.

This appendix establishes criteria for demonstrating compliance with the requirements of C403.1.1, HVAC total system performance ratio (HVAC TSPR)

C409.2 Scope.

This appendix applies to new HVAC systems that serve buildings in Section C403.1.3.1 and are not excluded from using HVAC TSPR by Section C403.1.3, and

1. serve office (including medical office), retail, library, hotel/motel, and education occupancies, or.
2. serve dwelling units and common areas within multifamily buildings.

All applicable HVAC systems shall comply with Section C409.

C409.2.1 Core & Shell / Initial Build-Out, and Future System Construction Analysis.

Where the building permit applies to only a portion of the HVAC system in a building and the remaining components will be designed under a future building permit or were previously installed, the future or previously installed components shall be modeled as follows:

1. Where the HVAC zones that do not include HVAC systems in the current permit will be or are served by independent systems, then the block including those zones shall not be included in the model.
2. Where the HVAC zones that do not include complete HVAC systems in the permit are intended to receive HVAC services from systems in the permit, their proposed zonal systems shall be modeled with equipment that meets, but does not exceed, the requirements of C403.
3. Where the zone equipment in the permit receives HVAC services from previously installed systems that are not in the permit, the previously installed systems shall be modeled with equipment matching the certified value of what is installed or equipment that meets the requirements of C403.
4. Where the central plant heating and cooling equipment is completely replaced and HVAC zones with existing systems receive HVAC services from systems in the permit, their proposed zonal systems shall be modeled with equipment that meets, but does not exceed, the requirements of Section C403.

Informative Note:

1. Examples of HVAC systems that are intended to receive HVAC services from systems in the permit include future zonal water source heat pumps that will receive loop water that is heated by a boiler or cooled by a cooling tower included in the permit, any system that will receive outdoor ventilation air from a dedicated outdoor air system included in the permit, and future zone terminal units that will be connected to a central VAV system included in the permit.
2. An initial build-out with heating coils served from a previously installed system with a high-efficiency condensing boiler would use the installed efficiency if it exceeded the current requirements. If the installed boiler had a lower efficiency than the current requirements, the current requirement would be used.
3. A partial central plant upgrade (e.g. chiller, but not boiler replacement) cannot use this method

C409.3Definitions.

The definitions contained in this section supplement or modify the definitions in Section C202 of the International Energy Conservation Code.

Add new definition as follows:

BLOCK. A generic concept used in energy simulation. It can include one or more thermal zones. It represents a whole building or portion of a building with the same use type served by the same HVAC system type.

HVAC TOTAL SYSTEM PERFORMANCE RATIO (HVAC TSPR). The ratio of the sum of a building's annual heating and cooling load in thousands of Btus to the sum of annual site energy consumption of the building HVAC systems in BTU.

PROPOSED DESIGN.

A description of the proposed building used to estimate annual energy use for determining compliance based on total building performance and HVAC total system performance ratio.

STANDARD REFERENCE DESIGN.

A version of the proposed design that meets the minimum requirements of this code and is used to determine the maximum annual energy use requirement for compliance based on total building performance and HVAC total system performance ratio.

Add new text as follows:

C409.4HVAC TSPR Compliance.

Systems allowed to use HVAC TSPR in accordance with C403.1.3 shall comply with all of the following:

1. Systems shall meet the applicable provisions of Section C403.1.3.3 and Sections within Section C403 that are listed in Table C407.2
2. The HVAC TSPR of the proposed design shall be greater than or equal to the HVAC TSPR of the standard reference design divided by the mechanical performance factor (MPF) using Equation 4-16.

$$TSPR_p > TSPR_r / MPF$$

(Equation 4-16)

where:

TSPR_p = HVAC TSPR of the proposed design calculated in accordance with Sections C409.4, C409.5 and C409.6.

TSPR_r = HVAC TSPR of the reference building design calculated in accordance with Sections C409.4, C409.5 and C409.6.

MPF = Mechanical Performance Factor from Table C409.4 based on climate zone and building use type

Where a building has multiple building use types, MPF shall be area weighted using Equation 4-17

$$MPF = (A_1 * MPF_1 + A_2 * MPF_2 + \dots + A_n * MPF_n) / (A_1 + A_2 + \dots + A_n)$$

(Equation 4-17)

where:

MPF₁, MPF₂ through MPF_n = Mechanical Performance Factors from Table C409.4 based on climate zone and building use types 1, 2, through n

A₁, A₂ through A_n = Conditioned floor areas for building use types 1, 2, through n

Table C409.4 Mechanical Performance Factors

Climate Zone:	Ocp. Group	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
<i>Building type</i>																				
Office (small and medium) ^a	B	0.75	0.75	0.74	0.74	0.72	0.69	0.75	0.70	0.69	0.73	0.70	0.71	0.76	0.72	0.72	0.78	0.75	0.79	0.81
Office (Large) ^a	B	0.91	0.93	0.94	0.93	0.88	0.94	0.80	0.88	0.95	0.77	0.95	0.82	0.82	0.89	0.82	0.81	0.84	0.79	0.77
Retail	M	0.61	0.59	0.52	0.56	0.48	0.47	0.43	0.46	0.62	0.53	0.60	0.73	0.57	0.68	0.75	0.60	0.60	0.57	0.52
Hotel/Motel	R-1	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.69	0.73	0.59	0.66	0.65	0.55	0.59	0.68	0.51	0.54	0.47	0.40
Multi-Family/Dormitory	R-2	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.60	0.54	0.59	0.57	0.52	0.58	0.53	0.48	0.57	0.53	0.55	0.52
School/Education and Libraries	E (A-3)	0.89	0.89	0.89	0.87	0.83	0.82	0.79	0.80	0.80	0.75	0.85	0.77	0.84	0.83	0.73	0.86	0.82	0.83	0.78

^a large office (gross conditioned floor area >150,000 ft² (14,000 m²) or > 5 floors); all other offices are small or medium

C409.4.1HVAC TSPR.

HVAC TSPR is calculated according to Equation 4-18 .

HVAC TSPR = heating and cooling load / building HVAC system energy

(Equation 4-18)

where:

building HVAC system energy = sum of the annual site energy consumption for heating, cooling, fans, energy recovery, pumps, and heat rejection in thousands of Btus

heating and cooling load = sum of the annual heating and cooling loads met by the building HVAC system in thousands of Btus

C409.5General

C409.5.1Simulation Program.

Simulation tools used to calculate HVAC TSPR of the *Standard Reference Design* shall comply with the following:

1. The simulation program shall calculate the *HVAC TSPR* based only on the input for the *proposed design* and the requirements of Section 409. The calculation procedure shall not allow the user to directly modify the building component characteristics of the *standard reference design*.
2. Performance analysis tools meeting the applicable subsections of Section 409 and tested according to ASHRAE Standard 140 shall be permitted to be *approved*. Tools are permitted to be *approved* based on meeting a specified threshold for a jurisdiction. The *code official* shall be permitted to approve tools for a specified application or limited scope.

C409.5.2Climatic Data.

The simulation program shall perform the simulation using hourly values of climatic data, such as temperature and humidity, using TMY3 data for the site as specified here:
<https://buildingenergyscore.energy.gov/resources>

C409.5.3Documentation.

Documentation conforming to the provisions of this section shall be provided to the *code official*.

C409.5.3.1Compliance Report.

Building permit submittals shall include:

- 1 A report produced by the simulation software that includes the following:
 - 1.1 Address of the building.
 - 1.2 Name of individual completing the compliance report.
 - 1.3 Name and version of the compliance software tool.
 - 1.4 The dimensions, floor heights and number of floors for each *block*.
 - 1.5 By *block*, the U-factor, C-factor, or F-factor for each simulated opaque envelope component and the U-factor and SHGC for each fenestration component.
 - 1.6 By *block* or by surface for each block, the fenestration area.

- 1.7 By block, a list of the HVAC equipment simulated in the *proposed design* including the equipment type, fuel type, equipment efficiencies and system controls.
- 1.8 Annual site HVAC energy use by end use for the proposed and baseline building
- 1.9 Annual sum of heating and cooling loads for the baseline building.
- 1.10 The HVAC total system performance ratio for both the *standard reference design* and the *proposed design*.

2 A mapping of the actual building HVAC component characteristics and those simulated in the *proposed design* showing how individual pieces of HVAC equipment identified above have been combined into average inputs as required by Section C409.6.1.10 including:

- 2.1 Fans
- 2.2 Hydronic pumps
- 2.3 Air handlers
- 2.4 Packaged cooling equipment
- 2.5 Furnaces
- 2.6 Heat pumps
- 2.7 Boilers
- 2.8 Chillers
- 2.9 Cooling towers
- 2.10 Electric resistance coils
- 2.11 Condensing units
- 2.12 Motors for fans and pumps
- 2.13 Energy recovery devices

For each piece of equipment identified above include the following as applicable:

1. Equipment name or tag consistent with that found on the design documents.
2. Rated Efficiency level.
3. Rated Capacity.
4. Electrical input power for fans and pumps (before any speed or frequency control device) at design condition and calculation of input value (W/cfm or W/gpm)

3 Floor plan of the building identifying:

- 3.1 How portions of the buildings are assigned to the simulated blocks
- 3.2 Areas of the building that are not covered under the requirements of Section C403.1.1.

C409.6 Calculation Procedures.

Except as specified by this Section, the *standard reference design* and *proposed design* shall be configured and analyzed using identical methods and techniques

C409.6.1 Simulation of the proposed building design.

The proposed design shall be configured and analyzed as specified in this section.

C409.6.1.1 Block Geometry.

The geometry of buildings shall be configured using one or more *blocks*. Each *block* shall define attributes including *block* dimensions, number of floors, floor to floor height and floor to ceiling height. Simulation software may allow the use of simplified shapes (such as rectangle, L shape, H Shape, U shape or T shape) to represent *blocks*. Where actual building shape does not match these pre-defined shapes, simplifications are permitted providing the following requirements are met:

1. The *conditioned floor area* and volume of each *block* shall match the proposed design within 10 percent.
2. The area of each exterior envelope component from Table C402.1.4 is accounted for within 10 percent of the actual design.
3. The area of vertical fenestration and skylights is accounted for within 10 percent of the actual design.
4. The orientation of each component in 2 and 3 above is accounted for within 45 degrees of the actual design.

The creation of additional *blocks* may be necessary to meet these requirements.

Exception: Portions of the building that are unconditioned or served by systems not covered by the requirements of Section C403.1.1 shall be omitted.

C409.6.1.1.1 Number of Blocks.

One or more *blocks* may be required per building based on the following restrictions:

1. Each *block* can have only one occupancy type (multifamily *dwelling unit*, multifamily common area, office, library, education, hotel/motel or retail). Therefore, at least one single *block* shall be created for each unique use type.
2. Each *block* can be served by only one type of HVAC system. Therefore, a single *block* shall be created for each unique HVAC system and use type combination. Multiple HVAC units of the same type may be represented in one *block*. Table D601.10.2 provides directions for combining multiple HVAC units or components of the same type into a single *block*.
3. Each *block* can have a single definition of floor to floor or floor to ceiling heights. Where floor heights differ by more than two feet, unique *blocks* should be created for the floors with varying heights.
4. Each *block* can include either above grade or below grade floors. For buildings with both above grade and below grade floors, separate *blocks* should be created for each. For buildings with floors partially above grade and partially below grade, if the total wall area of the floor(s) in consideration is greater than or equal to 50 percent above grade, then it should be simulated as a completely above grade *block*, otherwise it should be simulated as a below grade *block*.
5. Each wall on a façade of a *block* shall have similar vertical fenestration. The product of the proposed design U-factor times the area of windows (UA) on each façade of a given floor cannot differ by more than 15 percent of the average UA for that façade in each *block*. The product of the proposed design SHGC times the area of windows (SHGCA) on each façade of a given floor cannot differ by more than 15 percent of the average SHGCA for that façade in each *block*. If either of these conditions are not met, additional *blocks* shall be created consisting of floors with similar fenestration.
6. For a building model with multiple *blocks*, the *blocks* should be configured together to have the same adjacencies as the actual building design.

C409.6.1.2 Thermal Zoning.

Each floor in a *block* shall be modeled as a single thermal zone or as five thermal zones consisting of four perimeter zones and a core zone. Below grade floors shall be modeled as a single thermal *block*. If any

façade in the *block* is less than 45 feet in length, there shall only be a single thermal zone per floor. Otherwise each floor shall be modeled with five thermal zones. A perimeter zone shall be created extending from each façade to a depth of 15 feet. Where facades intersect, the zone boundary shall be formed by a 45 degree angle with the two facades. The remaining area of each floor shall be modeled as a core zone with no exterior walls.

C409.6.1.3Occupancy

C409.6.1.3.1Occupancy Type.

The occupancy type for each *block* shall be consistent with the building area type as determined in accordance with C405.4.2.1. Portions of the building that are building area types other than multifamily *dwelling unit*, multifamily common area, office, school (education), library, or retail shall not be included in the simulation. Surfaces adjacent to such building portions shall be modeled as adiabatic in the simulation program.

C409.6.1.3.2Occupancy schedule, density, and heat gain.

The occupant density, heat gain, and schedule shall be for multifamily, office, retail, library, hotel/motel or school as specified by ASHRAE Standard 90.1 Normative Appendix C.

C409.6.1.4Envelope Components

C409.6.1.4.1Roofs.

Roofs will be modeled with insulation above a steel roof deck. The roof U-factor and area shall be modeled as in the proposed design. If different roof thermal properties are present in a single *block*, an area weighted U-factor shall be used. Roof solar absorptance shall be modeled at 0.70 and emittance at 0.90.

C409.6.1.4.2Above grade walls.

Walls will be modeled as steel frame construction. The U-factor and area of above grade walls shall be modeled as in the proposed design. If different wall constructions exist on the façade of a *block* an area-weighted U-factor shall be used.

C409.6.1.4.3Below grade walls.

The C-factor and area of below grade walls shall be modeled as in the proposed design. If different slab on grade floor constructions exist in a *block*, an area-weighted C- factor shall be used.

C409.6.1.4.4Above grade exterior floors.

Exterior floors shall be modeled as steel frame. The U-factor and area of floors shall be modeled as in the proposed design. If different wall constructions exist in the *block* an area-weighted U-factor shall be used.

C409.6.1.4.5Slab on grade floors.

The F-factor and area of slab on grade floors shall be modeled as in the proposed design. If different below grade wall constructions exist in a *block*, an area-weighted F- factor shall be used.

C409.6.1.4.6Vertical Fenestration.

The window area and area weighted U-factor and SHGC shall be modeled for each façade based the proposed design. Each exterior surface in a *block* must comply with Section C409.6.1.1.1 item 5. Windows will be combined into a single window centered on each façade based on the area and sill height input by the user. When different U values, SHGC or sill heights exist on a single facade, area weighted average for each shall be input by the user.

C409.6.1.4.7Skylights.

The skylight area and area weighted U-factor and SHGC shall be modeled for each floor based the proposed design. Skylights will be combined into a single skylight centered on the roof of each zone based on the area input by the user

C409.6.1.4.8Exterior Shading.

Permanent window overhangs shall be modeled. When windows with and without overhangs or windows with different overhang projection factors exist on a façade, window width weighted projection factors shall be input by the user as follows.

$$P_{avg} = (A_1 \times L_{o1} + A_2 \times L_{o2} \dots + A_n \times L_{on}) / (L_{w1} + L_{w2} \dots + L_{wn})$$

(Equation 4-19)

where:

P_{avg} = Average overhang projection modeled in the simulation tool

A = Distance measured horizontally from the furthest continuous extremity of any overhang, eave, or permanently attached shading device to the vertical surface of the glazing.

L_o = Length off the overhang

L_w = Length of the window

C409.6.1.5 Lighting.

Interior lighting power density shall be equal to the allowance in Table C405.4.2(1) for multifamily, office, retail, library, or school. The lighting schedule shall be for multifamily, office, retail, library, or school as specified by ASHRAE Standard 90.1 Normative Appendix C. The impact of lighting controls is assumed to be captured by the lighting schedule and no explicit controls shall be modeled. Exterior lighting shall not be modeled.

C409.6.1.6 Miscellaneous equipment.

The miscellaneous equipment schedule and power shall be for multifamily, office, retail, library, or school as specified by ASHRAE Standard 90.1 Normative Appendix C. The impact of miscellaneous equipment controls is assumed to be captured by the equipment schedule and no explicit controls shall be modeled.

Exceptions:

1. Multifamily dwelling units shall have a miscellaneous load density of 0.42 W/ft²
2. Multifamily common areas shall have a miscellaneous load density of 0 W/ft²

C409.6.1.7 Elevators.

Elevators shall not be modeled.

C409.6.1.8 Service water heating equipment.

Service water heating shall not be modeled.

C409.6.1.9 On-site renewable energy systems.

On-site Renewable Energy Systems shall not be modeled.

C409.6.1.10 HVAC equipment.

HVAC systems shall meet the requirements of Section C403 Mechanical Systems.

C409.6.1.10.1 Supported HVAC systems.

At a minimum, the HVAC systems shown in Table CD105.2.10.1 shall be supported by the simulation program.

TABLE C409.6.1.10.1 PROPOSED BUILDING HVAC SYSTEMS SUPPORTED BY HVAC TSPR SIMULATION SOFTWARE

<u>System No.</u>	<u>System Name</u>	<u>System Abbreviation</u>
<u>1</u>	<u>Packaged Terminal Air Conditioner</u>	<u>PTAC</u>
<u>2</u>	<u>Packaged Terminal Air Heat Pump</u>	<u>PTHP</u>
<u>3</u>	<u>Packaged Single Zone Gas Furnace</u>	<u>PSZGF</u>
<u>4</u>	<u>Packaged Single Zone Heat Pump (air to air only)</u>	<u>PSZHP</u>

<u>5</u>	<u>Variable Refrigerant Flow (air cooled only)</u>	<u>VRF</u>
<u>6</u>	<u>Four Pipe Fan Coil</u>	<u>FPFC</u>
<u>7</u>	<u>Water Source Heat Pump</u>	<u>WSHP</u>
<u>8</u>	<u>Ground Source Heat Pump</u>	<u>GSHP</u>
<u>9</u>	<u>Packaged Variable Air Volume (DX cooling)</u>	<u>PVAV</u>
<u>10</u>	<u>Variable Air Volume (hydronic cooling)</u>	<u>VAV</u>
<u>11</u>	<u>Variable Air Volume with Fan Powered Terminal Units</u>	<u>VAVFPTU</u>
<u>12</u>	<u>Dedicated Outdoor Air System (in conjunction with systems 1-8)</u>	<u>DOAS</u>

C409.6.1.10.2 Proposed building HVAC system simulation.

The HVAC systems shall be modeled as in the proposed design with clarifications and simplifications as described in Tables C409.6.1.10.2(1) and C409.6.1.10.2(2). System parameters not described in the following sections shall be simulated to meet the minimum requirements of Section C403. All zones within a block shall be served by the same HVAC system type as described in Section C409.6.1.1.1 item 2. Heat loss from ducts and pipes shall not be modeled.

For packaged single-zone air conditioners (cooling only), water-loop heat pumps, ground-source heat pumps and packaged rooftop heat pumps, heating COP and cooling COP, exclusive of fan power, shall be determined using the following equations:

For Table C409.6.1.10.1 Systems 4, 7, and 8 heating efficiency

$$\text{COP}_{\text{nfheating}} = 1.48\text{E-}7 \times \text{COP}_{47} \times Q + 1.062 \times \text{COP}_{47}$$

(Equation 4-20)

where:

COP shall be at AHRI full load test conditions

Q = AHRI rated cooling capacity in BTU/h. If Q > 760,000BTU/h use 760,000 in the calculation

For Table C409.6.1.10.1 System 3 heating efficiency

$$\text{COP}_{\text{nfheating}} = -0.0296 \times \text{HSPF}^2 + 0.7134 \times \text{HSPF}$$

(Equation 4-21)

where:

COP and HSPF shall be at AHRI full load test conditions

For Table C409.6.1.10.1 System 4, 7, 8, and 9 cooling efficiency

$$\text{COP}_{\text{nfcooling}} = 7.84\text{E-}8 \times \text{EER} \times Q + 0.338 \times \text{EER}$$

(Equation 4-22)

where:

EER, and COP shall be at AHRI full load test conditions

Q = AHRI rated cooling capacity in BTU/h. If Q > 760,000BTU/h use 760,000 in the calculation

For Table C409.6.1.10.1 System 1 and 2 cooling efficiency

$$\text{COP}_{\text{nfcooling}} = -0.0076 \times \text{SEER}^2 + 0.3796 \times \text{SEER}$$

(Equation 4-23)

where:

SEER and COP and HSPF shall be at AHRI full load test conditions.

For Table C409.6.1.10.1 System 1 and 2 cooling efficiency

$$\text{COP}_{\text{nfcooling}} = 0.3322 \times \text{EER} - 0.2145$$

(Equation 4-24)

where:

EER and COP shall be at AHRI full load test conditions

For Table C409.6.1.10.1 System 2 heating efficiency

$$\text{COP}_{\text{nfheating}} = 1.1329 \times \text{COP} - 0.214$$

(Equation 4-25)

where:

COP shall be at AHRI full load test conditions

Note to adopting authority: *The following equations (in italics) are the SI version of Equations 4-20 through 4-25 and shall be used when adopting an SI version of the IECC.*

$$\text{(COP}_{\text{nfheating}} = 5.05\text{E-}4 \times \text{COP}_{\text{H8.3}} \times \text{Q} + 1.062 \times \text{COP}_{\text{H8.3}}\text{)} \quad \text{Equation 4-20 (SI)}$$

$$\text{(COP}_{\text{nfheating}} = -0.3446 \times \text{SCOP}_{\text{H}}^2 + 2.434 \times \text{SCOP}_{\text{H}}\text{)} \quad \text{Equation 4-21(SI)}$$

$$\text{(COP}_{\text{nfcooling}} = 9.13\text{E-}4 \times \text{COP}_{\text{C}} \times \text{Q} + 1.15 \times \text{COP}_{\text{C}}\text{)} \quad \text{Equation 4-22(SI)}$$

$$\text{(COP}_{\text{nfcooling}} = -0.0885 \times \text{SCOP}_{\text{C}}^2 + 1.295 \times \text{SCOP}_{\text{C}}\text{)} \quad \text{Equation 4-23(SI)}$$

$$\text{(COP}_{\text{nfcooling}} = 9.13\text{E-}4 \times \text{COP}_{\text{C}} \times \text{Q} + 1.15 \times \text{COP}_{\text{C}}\text{)} \quad \text{Equation 4-24(SI)}$$

$$\text{(COP}_{\text{nfheating}} = 1.1329 \times \text{COP} - 0.214\text{)} \quad \text{Equation 4-25(SI)}$$

Where: EER, SEER, COP and HSPF shall be at AHRI full load test conditions Q = AHRI rated cooling capacity in BTU/h. If Q > 760,000 BTU/h use 760,000 in the calculation.

Where multiple system components serve a block, average values weighed by the appropriate metric as described in this section shall be used.

1. Where multiple fan systems serve a single block, fan power shall be based on weighted average using the design supply air cfm

2. Where multiple cooling systems serve a single block, COP shall be based on a weighted average using cooling capacity. DX coils shall be entered as multi-stage if more than 50% of coil capacity serving the block is multi-stage with staged controls.
3. Where multiple heating systems serve a single block, thermal efficiency or heating COP shall be based on a weighted average using heating capacity.
4. Where multiple boilers or chillers serve a heating water or chilled water loop, efficiency shall be based on a weighted average for using heating or cooling capacity.
5. When multiple cooling towers serving a condenser water loop are combined, the cooling tower efficiency, cooling tower design approach and design range are based on a weighted average of the design water flow rate through each cooling tower.
6. Where multiple pumps serve a heating water, chilled water or condenser water loop, pump power shall be based on a weighted average for using design water flow rate.
7. When multiple system types with and without economizers are combined, the economizer maximum outside air fraction of the combined system shall be based on weighted average of 100% supply air for systems with economizers and design outdoor air for systems without economizers.
8. Multiple systems with and without ERVs cannot be combined.
9. Systems with and without supply air temperature reset cannot be combined.
10. Systems with different fan control (constant volume, multi-speed or VAV) for supply fans cannot be combined.

TABLE C409.6.1.10.2(1) PROPOSED BUILDING SYSTEM PARAMETERS

<u>Category</u>	<u>Parameter</u>	<u>Fixed or User Defined</u>	<u>Required</u>	<u>Applicable Systems</u>
<u>HVAC System Type</u>	<u>System Type</u>	<u>User Defined</u>	<u>Selected from Table C409.6.1.10.1</u>	<u>All</u>
<u>System Sizing</u>	<u>Design Day Information</u>	<u>Fixed</u>	<u>99.6% heating design and 1% dry-bulb and 1% wet-bulb cooling design</u>	<u>All</u>
	<u>Zone Coil Capacity</u>	<u>Fixed</u>	<u>Sizing factors used are 1.25 for heating equipment and 1.15 for cooling equipment</u>	<u>All</u>
	<u>Supply Airflow</u>	<u>Fixed</u>	<u>Based on a supply-air-to-room-air temperature <i>set-point</i> difference of 20°F or</u>	<u>1-11</u>
		<u>Fixed</u>	<u>Equal to required outdoor air ventilation</u>	<u>12</u>
<u>Outdoor Ventilation Air</u>	<u>Portion of supply air with proposed Filter ≥MERV 13</u>	<u>User-defined</u>	<u>Percentage of supply air flow subject to higher filtration (Adjusts baseline Fan Power higher, Prorated)</u>	<u>All</u>
	<u>Outdoor Ventilation Air Flow Rate</u>	<u>Fixed</u>	<u>As specified in ASHRAE Standard 90.1 Normative Appendix C, adjusted for proposed DCV control</u>	<u>All</u>
	<u>Outdoor Ventilation Supply Air Flow Rate Adjustments</u>	<u>Fixed</u>	<u>Based on ASHRAE Standard 62.1 Section 6.2.4.3 System Ventilation Efficiency (Evs) is 0.75</u>	<u>9-11</u>
	-	<u>Fixed</u>	<u>System Ventilation Efficiency (Evs) is 1.0</u>	<u>1-8, 12</u>
		<u>Fixed</u>	<u>Basis is 1.0 Zone Air Distribution Effectiveness</u>	<u>All</u>
<u>System Operation</u>	<u>Space temperature Set points</u>	<u>Fixed</u>	<u>As specified in ASHRAE Standard 90.1 Normative Appendix C, except multifamily which shall use 68 deg. F heating and 76 deg. F cooling setpoints</u>	<u>1-11</u>
	<u>Fan Operation – Occupied</u>	<u>User Defined</u>	<u>Runs continuously during occupied hours or cycles to meet load.</u>	<u>1-11</u>
	-	-	<u>Multispeed fans reduce airflow related to thermal loads.</u>	

<u>Category</u>	<u>Parameter</u>	<u>Fixed or User Defined</u>	<u>Required</u>	<u>Applicable Systems</u>
	<u>Fan Operation – Occupied</u>	<u>Fixed</u>	<u>Fan runs continuously during occupied hours</u>	<u>12</u>
	-		-	
	<u>Fan Operation – Night Cycle</u>	<u>Fixed</u>	<u>Fan cycles on to meet setback temperatures</u>	<u>1-11</u>
<u>Packaged Equipment Efficiency</u>	<u>DX Cooling Efficiency</u>	<u>User Defined</u>	<u>Cooling COP without fan energy calculated in accordance with Section C409.6.1.10.2</u>	<u>1, 2, 3, 4, 5, 7, 8, 9, 11, 12</u>
	<u>DX Coil Number of Stages</u>	<u>User-defined</u>	<u>Single Stage or Multistage</u>	<u>3, 4, 9</u>
	-		-	
	<u>Heat Pump Efficiency</u>	<u>User Defined</u>	<u>Heating COP without fan energy calculated in accordance with Section C409.6.1.10.2</u>	<u>2, 4, 5, 7, 8</u>
	<u>Furnace Efficiency</u>	<u>User Defined</u>	<u>Furnace thermal efficiency</u>	<u>3, 11</u>
<u>Heat Pump Supplemental Heat</u>	<u>Control</u>	<u>Fixed</u>	<u>Supplemental electric heat locked out above 40°F. Runs In conjunction with compressor between 40°F and 0°F.</u>	<u>2, 4</u>
<u>System Fan Power and Controls</u>	<u>Part-load Fan Controls</u>	<u>User-defined</u>	<u>Constant volume or two speed</u>	<u>1-8</u>
	<u>Part-load Fan Controls^a</u>	<u>User-defined</u>	<u>Constant volume or variable air volume</u>	<u>12</u>
	<u>Part-load Fan Controls^a</u>	<u>Fixed</u>	<u>Variable air volume. VFD with static pressure reset</u>	<u>9-11</u>
	<u>Design Fan Power (W/cfm)</u>	<u>User Defined</u>	<u>Input electric power for all fans in required to operate at fan system design conditions divided by the supply airflow rate</u>	<u>All</u>
			<u>This is a “wire to air” value including all drive, motor efficiency and other losses.</u>	
	<u>Low-speed fan power</u>	<u>User Defined</u>	<u>Low speed input electric power for all fans required to operate at low speed conditions divided by the low speed supply airflow rate. This is a “wire to air” value including all drive, motor efficiency and other losses.</u>	<u>1-8</u>
<u>Variable Air Volume Systems</u>	<u>Supply Air Temperature (SAT) Controls</u>	<u>User defined</u>	<u>If not SAT reset then constant at 55°F.</u>	<u>9, 10, 11</u>
	-		-	
			<u>Options for reset based on outside air temperature (OAT) or warmest zone.</u>	
			<u>If warmest zone, then the user can specify the minimum and maximum temperatures.</u>	
			<u>If OAT reset, SAT is reset higher to 60°F at outdoor low of 50°F. SAT is 55°F at outdoor high of 70°F.</u>	
	<u>Minimum Terminal Unit airflow percentage</u>	<u>User Defined</u>	<u>Average minimum terminal unit airflow percentage for block weighted by cfm or minimum required for outdoor air ventilation, whichever is higher.</u>	<u>9, 10, 11</u>
	<u>Terminal Unit Heating Source</u>	<u>User Defined</u>	<u>Electric or hydronic</u>	<u>9, 10, 11</u>

<u>Category</u>	<u>Parameter</u>	<u>Fixed or User Defined</u>	<u>Required</u>	<u>Applicable Systems</u>
	<u>Dual set point minimum VAV damper position</u>	<u>User-defined</u>	<u>Heating maximum airflow fraction</u>	<u>9, 10.</u>
	<u>Fan Powered Terminal Unit (FPTU) Type</u>	<u>User Defined</u>	<u>Series or parallel FPTU</u>	<u>11</u>
	<u>Parallel FPTU Fan</u>	<u>Fixed</u>	<u>Sized for 50% peak primary air at 0.35 W/cfm</u>	<u>11</u>
	<u>Series FPTU Fan</u>	<u>Fixed</u>	<u>Sized for 50% peak primary air at 0.35 W/cfm</u>	<u>11</u>
<u>Economizer</u>	<u>Economizer Presence</u>	<u>User Defined</u>	<u>Yes or No</u>	<u>3, 4, 9, 10, 11</u>
	<u>Economizer Control Type</u>	<u>Fixed</u>	<u>Differential dry-bulb</u>	<u>3, 4, 9, 10, 11</u>
<u>Energy Recovery</u>	<u>Sensible Effectiveness</u>	<u>User Defined</u>	<u>Heat exchanger sensible effectiveness at design heating and cooling conditions</u>	<u>3, 4, 9, 10, 11, 12</u>
	<u>Latent Effectiveness</u>	<u>User Defined</u>	<u>Heat exchanger latent effectiveness at design heating and cooling conditions</u>	<u>3, 4, 9, 10, 11, 12</u>
	<u>Economizer Bypass</u>	<u>User Defined</u>	<u>If ERV is bypassed during economizer conditions</u>	<u>3, 4, 9, 10, 11, 12</u>
	<u>Bypass SAT Setpoint</u>	<u>User Defined</u>	<u>If bypass, target supply air temperature</u>	<u>3, 4, 9, 10, 11, 12</u>
	<u>Fan Power Reduction during Bypass (W/cfm)</u>	<u>User Defined</u>	<u>If ERV system include bypass, static pressure set point and variable speed fan, fan power can be reduced during economizer conditions</u>	<u>3, 4, 9, 10, 11, 12</u>
<u>Demand Controlled Ventilation</u>	<u>DCV Application</u>	<u>User Defined</u>	<u>Percent of block floor area under DCV control</u>	<u>3, 4, 9, 10, 11, 12</u>
<u>DOAS</u>	<u>DOAS Fan Power W/cfm</u>	<u>User Defined</u>	<u>Fan electrical input power in W/cfm of supply airflowa</u>	<u>12</u>
	<u>DOAS Supplemental Heating and Cooling</u>	<u>User Defined</u>	<u>Heating source, cooling source</u>	<u>12</u>
	<u>Maximum SAT Set point (Cooling)</u>	<u>User-defined</u>	<u>SAT set point if DOAS includes supplemental cooling</u>	<u>12</u>
	<u>Minimum SAT Set point (Heating)</u>	<u>User-defined</u>	<u>SAT set point if DOAS includes supplemental heating</u>	<u>12</u>
	-	-	-	-
<u>Heating Plant</u>	<u>Boiler Efficiency</u>	<u>User Defined</u>	<u>Boiler thermal efficiency</u>	<u>1, 6, 7, 9, 10, 11, 12</u>
	<u>Heating Water Loop Configuration</u>	<u>User-defined</u>	<u>Constant flow primary only; Variable flow primary only; Constant flow primary – variable flow secondary</u>	<u>1, 6, 7, 9, 10, 11, 12</u>
	<u>Heating Water Primary Pump Power (W/gpm)</u>	<u>User-defined</u>	<u>Heating water primary pump input W/gpm heating water flow</u>	<u>1, 6, 7, 9, 10, 11, 12</u>

<u>Category</u>	<u>Parameter</u>	<u>Fixed or User Defined</u>	<u>Required</u>	<u>Applicable Systems</u>
	<u>Heating Water Secondary Pump Power (W/gpm)</u>	<u>User-defined</u>	<u>Heating water secondary pump input W/gpm heating water flow (if primary/secondary)</u>	<u>1, 6, 7, 9, 10, 11, 12</u>
	<u>Heating Water Loop Temperature</u>	<u>Fixed</u>	<u>180°F supply, 130°F return</u>	<u>1, 6, 9, 10, 11</u>
	<u>Boiler Type</u>	<u>Fixed</u>	<u>Non-condensing boiler where input thermal efficiency is less than 86%; Condensing boiler otherwise</u>	<u>1, 6, 7, 9, 10, 11, 12</u>
<u>Chilled Water Plant</u>	<u>Chiller Compressor Type</u>	<u>User Defined</u>	<u>Screw/Scroll, Centrifugal or Reciprocating</u>	<u>6, 10, 11, 12</u>
	<u>Chiller Condenser Type</u>	<u>User Defined</u>	<u>Air cooled or water cooled</u>	<u>6, 10, 11, 12</u>
	<u>Chiller Full Load Efficiency</u>	<u>User Defined</u>	<u>Chiller COP</u>	<u>6, 10, 11, 12</u>
	<u>Chilled Water Loop Configuration</u>	<u>User Defined</u>	<u>Variable flow primary only, constant flow primary – variable flow secondary</u>	<u>6, 10, 11, 12</u>
	<u>Chilled Water Primary Pump Power (W/gpm)</u>	<u>User-defined</u>	<u>Primary pump input W/gpm chilled water flow</u>	<u>6, 10, 11, 12</u>
	<u>Chilled Water Secondary Pump Power (W/gpm)</u>	<u>User-defined</u>	<u>Secondary Pump input W/gpm chilled water flow (if primary/secondary)</u>	<u>6, 10, 11, 12</u>
	<u>Chilled Water Temperature Reset Included</u>	<u>User Defined</u>	<u>Yes/No</u>	<u>6, 10, 11, 12</u>
<u>Chilled Water Plant (cont.)</u>	<u>Chilled Water Temperature Reset Schedule (if included)</u>	<u>Fixed</u>	<u>Outdoor air reset: CHW supply temperature of 44°F at 80°F outdoor air dry bulb and above, CHW supply temperature of 54°F at 60°F outdoor air dry bulb temperature and below, ramped linearly between</u>	<u>6, 10, 11, 12</u>
	<u>Condenser Water Pump Power (W/gpm)</u>	<u>User Defined</u>	<u>Pump input W/gpm condenser water flow</u>	<u>6, 7, 8, 10, 11, 12</u>
	<u>Condenser Water Pump Control</u>	<u>User Defined</u>	<u>Constant speed or variable speed</u>	<u>6, 7, 8, 10, 11, 12</u>
	<u>Cooling Tower Efficiency</u>	<u>User Defined</u>	<u>gpm/hp tower fan</u>	<u>6, 7, 10, 11, 12</u>
	<u>Cooling Tower Fan Control</u>	<u>User Defined</u>	<u>Constant or variable speed</u>	<u>6, 7, 10, 11, 12</u>
	<u>Cooling Tower Approach and Range</u>	<u>User Defined</u>	<u>Design cooling tower approach and range temperature</u>	<u>6, 7, 10, 11, 12</u>
<u>Heat Pump Loop Flow Control</u>	<u>Loop flow and Heat Pump Control Valve</u>	<u>Fixed</u>	<u>Two position Valve with VFD on Pump. Loop flow at 3 gpm/ton</u>	<u>7, 8</u>
<u>Heat Pump Loop Temperature Control</u>	<u>-</u>	<u>Fixed</u>	<u>Set to maintain temperature between 50°F and 70°F</u>	<u>7</u>
<u>GLHP Well Field</u>	<u>-</u>	<u>Fixed</u>	<u>Bore depth = 250'</u> <u>Bore length 200'/ton for greater of cooling or heating load</u>	<u>8</u>

<u>Category</u>	<u>Parameter</u>	<u>Fixed or User Defined</u>	<u>Required</u>	<u>Applicable Systems</u>
			Bore spacing = 15' Bore diameter = 5"	
			¾" Polyethylene pipe	
			Ground and grout conductivity =	
			4.8 Btu-in/h-ft ² -0F	

a. Part load fan power and pump power modified in accordance with Table C409.6.1.10.2(2)

TABLE C409.6.1.10.2(2) FAN AND PUMP Power CURVE COEFFICIENTS

<u>Equation Term</u>	<u>Fan Power Coefficients</u>		<u>Pump Power Coefficients</u>	
	<u>VSD + SP reset</u>		<u>Ride Pump Curve</u>	<u>VSD + DP/valve reset</u>
-				
b	0.0408	0	0	
x	0.088	3.2485	0.0205	
x ²	-0.0729	-4.7443	0.4101	
x ³	0.9437	2.5295	0.5753	

C409.6.1.10.3 Demand Control Ventilation..

Demand Controlled Ventilation (DCV) shall be modeled using a simplified approach that adjusts the design outdoor supply air flow rate based on the area of the building that is covered by DCV.

C409.6.2 Simulation of the standard reference design.

The standard reference design shall be configured and analyzed as specified in this section.

C409.6.2.1 Utility Rates.

Same as proposed.

C409.6.2.2 Blocks.

Same as proposed.

C409.6.2.3 Thermal zoning.

Same as proposed.

C409.6.2.4 Occupancy type, schedule, density, and heat gain.

Same as proposed

C409.6.2.5 Envelope components..

Same as proposed.

C409.6.2.6 Lighting.

Same as proposed.

C409.6.2.7 Miscellaneous equipment.

Same as proposed.

C409.6.2.8 Elevators.

Not modeled. Same as proposed.

C409.6.2.9 Service water heating equipment.

Not modeled. Same as proposed.

C409.6.2.10 On-site renewable energy systems.

Not modeled. Same as proposed.

C409.6.2.11 HVAC equipment.

The *reference building design* HVAC equipment consists of separate space conditioning systems as described in Table C409.6.2.11(1) through Table C409.6.2.11(3) for the appropriate building use types. In these tables, 'Warm' refers to climate zones 0 to 2 and 3A and 'Cold' refers to climate zones 3B, 3C, and 4 to 8.

Table C409.6.2.11(1) Reference Building Design HVAC Complex Systems

Building Type Parameter	Large Office (warm)	Large Office (cold)	School (warm)	School (cold)
System Type	VAV/ RH Water-cooled Chiller/ Electric Reheat (PIU)	VAV/ RH Water-cooled Chiller/ Gas Boiler	VAV/ RH Water-cooled Chiller/ Electric Reheat (PIU)	VAV/ RH Water-cooled Chiller/ Gas Boiler
Fan control	VSD (No SP Reset)	VSD (No SP Reset)	VSD (No SP Reset)	VSD (No SP Reset)
Main fan power (W/CFM (W·s/L) Proposed ≥ MERV13	1.165 (2.468)	1.165 (2.468)	1.165 (2.468)	1.165 (2.468)
Main fan power (W/CFM (W·s/L) proposed < MERV13	1.066 (2.259)	1.066 (2.259)	1.066 (2.259)	1.066 (2.259)
Zonal fan power (W/CFM (W·s/L))	0.35 (0.75)	NA	0.35 (0.75)	NA
Minimum zone airflow fraction	1.5* Voz	1.5* Voz	1.2* Voz	1.2 * Voz
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Outdoor air economizer	No	Yes except 4A	No	Yes except 4A
Occupied OSA (= proposed)	Sum(Voz)/0.75	Sum(Voz)/0.75	Sum(Voz)/0.65	Sum(Voz)/0.65
Energy recovery ventilator efficiency ERR	NA	NA	50%	50%
(Enthalpy Recovery Ratio)			No Bypass	60°F except 4A
ERV bypass SAT set point				
DCV	No	No	No	No
Cooling Source	(2) Water-cooled Centrifugal Chillers	(2) Water- cooled Centrifugal Chillers	(2) Water- Cooled Screw Chillers	(2) Water- Cooled Screw Chillers
Cooling COP (net of fan)	Path B for profile	Path B for profile	Path B for profile	Path B for profile
Heating source (reheat)	Electric resistance	Gas Boiler	Electric resistance	Gas Boiler
Furnace or boiler efficiency	1.0	75% Et	1.0	80% Et
Condenser heat rejection	Cooling Tower	Cooling Tower	Cooling Tower	Cooling Tower
Cooling tower efficiency (gpm/fan-hp (L/s-fan-kW))	38.2 (3.23)	38.2 (3.23)	38.2 (3.23)	38.2 (3.23)
Tower turndown (> 300 ton (1060 kW))	50%	50%	50%	50%
Pump (constant flow/variable flow)	Constant Flow; 10°F (5.6°C) range	Constant Flow; 10°F (5.6°C) range	Constant Flow; 10°F (5.6°C) range	Constant Flow; 10°F (5.6°C) range
Tower approach	25.72 – (0.24 x WB), where WB is the 0.4% evaporation design wet-bulb temperature (°F)			
Cooling condenser pump power (W/gpm (W·s/L))	19 (300)	19 (300)	19 (300)	19 (300)
Cooling primary pump power (W/gpm (W·s/L))	9 (142)	9 (142)	9 (142)	9 (142)
Cooling secondary pump power (W/gpm (W·s/L))	13 (205)	13 (205)	13 (205)	13 (205)
Cooling coil chilled water delta- T, °F (°C)	12 (6.7)	12 (6.7)	12 (6.7)	12 (6.7)

<u>Building Type Parameter</u>	<u>Large Office (warm)</u>	<u>Large Office (cold)</u>	<u>School (warm)</u>	<u>School (cold)</u>
<u>Design chilled water supply temperature, °F (°C)</u>	<u>44 (6.7)</u>	<u>44 (6.7)</u>	<u>44 (6.7)</u>	<u>44 (6.7)</u>
<u>Chilled water supply temperature (CHWST)</u>	<u>CHWST/OAT: 44-54/ 80-60</u>	<u>CHWST/OAT: 44-54/ 80-60 (6.7-12.2/ 26.7-15.6)</u>	<u>CHWST/OAT: 44-54/ 80-60 (6.7-12.2/ 26.7-15.6)</u>	<u>CHWST/OAT: 44-54/ 80-60 (6.7-12.2/ 26.7-15.6)</u>
<u>reset set point vs OAT, °F (°C)</u>	<u>(6.7-12.2/ 26.7-15.6)</u>			
<u>CHW cooling loop pumping control</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>
<u>Heating pump power (W/gpm (W·s/L))</u>	<u>16.1 (254)</u>	<u>16.1 (254)</u>	<u>19 (254)</u>	<u>19 (254)</u>
<u>Heating oil HW dT, °F (°C)</u>	<u>50 (10)</u>	<u>50 (10)</u>	<u>50 (10)</u>	<u>50 (10)</u>
<u>Design HWST, °F (°C)</u>	<u>180 (82)</u>	<u>180 (82)</u>	<u>180 (82)</u>	<u>180 (82)</u>
<u>HWST reset set point vs OAT, °F (°C)</u>	<u>HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)</u>	<u>HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)</u>	<u>HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)</u>	<u>HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)</u>
<u>Heat loop pumping control</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>

Table C409.6.2.11(2) TSPR Reference Building Design HVAC Simple Systems

<u>Building Type Parameter</u>	<u>Medium Office (warm)</u>	<u>Medium Office (cold)</u>	<u>Small Office (warm)</u>	<u>Small Office (cold)</u>	<u>Retail (warm)</u>	<u>Retail (cold)</u>
<u>System type</u>	<u>Package VAV - Electric Reheat</u>	<u>Package VAV - Hydronic Reheat</u>	<u>PSZ-HP</u>	<u>PSZ-AC</u>	<u>PSZ-HP</u>	<u>PSZ-AC</u>
<u>Fan control</u>	<u>VSD (No SP Reset)</u>	<u>VSD (No SP Reset)</u>	<u>Constant Volume</u>	<u>Constant Volume</u>	<u>Constant Volume</u>	<u>Constant Volume</u>
<u>Main fan power (W/CFM (W·s/L))</u>	<u>1.285 (2.723)</u>	<u>1.285 (2.723)</u>	<u>0.916 (1.941)</u>	<u>0.916 (1.941)</u>	<u>0.899 (1.905)</u>	<u>0.899 (1.905)</u>
<u>proposed ≥ MERV13</u>						
<u>Main fan power (W/CFM (W·s/L))</u>	<u>1.176 (2.492)</u>	<u>1.176 (2.492)</u>	<u>0.850 (1.808)</u>	<u>0.850 (1.801)</u>	<u>0.835 (1.801)</u>	<u>0.835 (1.801)</u>
<u>proposed < MERV13</u>						
<u>Zonal fan power (W/CFM (W·s/L))</u>	<u>0.35 (0.75)</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>
<u>Minimum zone airflow fraction</u>	<u>30%</u>	<u>30%</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>
<u>Heat/cool sizing factor</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>
<u>Supplemental heating availability</u>	<u>NA</u>	<u>NA</u>	<u><40°F (<4.4°C) OAT</u>	<u>NA</u>	<u><40°F (<4.4°C) OAT</u>	<u>NA</u>
<u>Outdoor air economizer</u>	<u>No</u>	<u>Yes except 4A</u>	<u>No</u>	<u>Yes except 4A</u>	<u>No</u>	<u>Yes except 4A</u>
<u>Occupied OSA source</u>	<u>Packaged unit, occupied damper, all building use types</u>					
<u>Energy recovery ventilator</u>	<u>No</u>	<u>No</u>	<u>No</u>	<u>No</u>	<u>No</u>	<u>No</u>
<u>DCV</u>	<u>No</u>	<u>No</u>	<u>No</u>	<u>No</u>	<u>No</u>	<u>No</u>
<u>Cooling source</u>	<u>DX, multi-stage</u>	<u>DX, multi-stage</u>	<u>DX, 1 stage (heat pump)</u>	<u>DX, single stage</u>	<u>DX, 1 stage (heat pump)</u>	<u>DX, single stage</u>
<u>Cooling COP (net of fan)</u>	<u>3.40</u>	<u>3.40</u>	<u>3.00</u>	<u>3.00</u>	<u>3.40</u>	<u>3.50</u>
<u>Heating source</u>	<u>Electric resistance</u>	<u>Gas Boiler</u>	<u>Heat Pump</u>	<u>Furnace</u>	<u>Heat Pump</u>	<u>Furnace</u>

Building Type Parameter	Medium Office (warm)	Medium Office (cold)	Small Office (warm)	Small Office (cold)	Retail (warm)	Retail (cold)
Heating COP (net of fan) / furnace or boiler efficiency	1.0	75% E _t	3.40	80% E _t	3.40	80% E _t

Table C409.6.2.11(3) TSPR Reference Building Design HVAC Simple Systems

Building Type Parameter	Hotel (warm)	Hotel (cold)	Multifamily (warm)	Multifamily (cold)
System type	<i>PTHP</i>	<i>PTAC</i>	<i>PTHP</i>	<i>PTAC</i>
Fan control	Constant Volume	Constant Volume	Constant Volume	Constant Volume
Main fan power (W/CFM (W-s/L))	0.300 (0.636)	0.300 (0.636)	0.300 (0.636)	0.300 (0.636)
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental heating availability	<40°F (<4.4°C)	NA	<40°F (<4.4°C)	NA
Outdoor air economizer	No	No	No	No
Occupied OSA source	Packaged unit, occupied damper	Packaged unit, occupied damper	Packaged unit, occupied damper	Packaged unit, occupied damper
Energy recovery ventilator	No	No	No	No
DCV	No	No	No	No
Cooling source	DX, 1stage (heat pump)	DX, 1 stage	DX, 1 stage (heat pump)	DX, 1 stage
Cooling COP (net of fan)	3.10	3.20	3.10	3.20
Heating source	<i>PTHP</i>	(2) Hydronic Boiler	<i>PTHP</i>	(2) Hydronic Boiler
Heating COP (net of fan) / furnace or boiler efficiency	3.10	75% E _t	3.10	75% E _t
Heating pump power (W/gpm (W-s/L))	NA	19 (300)	NA	19 (300)
Heating coil heating water delta-T, °F (°C)	NA	50 (27.8)	NA	50 (27.8)
Design HWST, °F (°C)	NA	180 (82.2)	NA	180 (82.2)
HWST reset set point vs OAT, °F (°C)	NA	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)	NA	HWST/OAT: 180/150 20/50 (82-65.6/ -6.7-10)
Heat loop pumping control	NA	2-way Valves & ride pump curve	NA	2-way Valves & ride pump curve

C409.7 Target Design HVAC Systems.

Target system descriptions described in Tables C409.7(1) through C409.7(3) are provided as reference for Section C403.1.1 Exception 10. The target systems are used for developing MPF values and do not need to be programmed into TSPR software.

Table C409.7(1) Target Building Design Criteria HVAC Complex Systems

Building Type Parameter	Large Office (warm)	Large Office (cold)	School (warm)	School (cold)
System Type	VAV/ RH	VAV/ RH	VAV/ RH	VAV/ RH
	Water-cooled Chiller/	Water-cooled Chiller/	Water-cooled Chiller/	Water-cooled Chiller/
	Electric Reheat (PIU)	Gas Boiler	Electric Reheat (PIU)	Gas Boiler
Fan control	VSD (No SP Reset)	VSD (No SP Reset)	VSD (No SP Reset)	VSD (No SP Reset)

<u>Building Type Parameter</u>	<u>Large Office</u>	<u>Large Office</u>	<u>School</u>	<u>School</u>
	<u>(warm)</u>	<u>(cold)</u>	<u>(warm)</u>	<u>(cold)</u>
<u>Main fan power (W/CFM (W·s/L) Proposed ≥ MERV13)</u>	1.127 (2.388)	1.127 (2.388)	1.127 (2.388)	1.127 (2.388)
<u>Zonal fan power (W/CFM (W·s/L))</u>	0.35 (0.75)	NA	0.35 (0.75)	NA
<u>Minimum zone airflow fraction</u>	1.5* <u>Voz</u>	1.5* <u>Voz</u>	1.2* <u>Voz</u>	1.2 * <u>Voz</u>
<u>Heat/cool sizing factor</u>	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
<u>Outdoor air economizer</u>	<u>Yes except 0-1</u>	<u>Yes</u>	<u>Yes except 0-1</u>	<u>Yes</u>
<u>Occupied OSA (= proposed)</u>	<u>Sum(Voz)/0.75</u>	<u>Sum(Voz)/0.75</u>	<u>Sum(Voz)/0.65</u>	<u>Sum(Voz)/0.65</u>
<u>Energy recovery ventilator efficiency ERR</u>	NA	NA	50%	50%
<u>(Enthalpy Recovery Ratio)</u>			<u>No Bypass</u>	<u>60°F except 4A</u>
<u>ERV bypass SAT set point</u>			-	-
<u>DCV</u>	<u>Yes</u>	<u>Yes</u>	<u>Yes</u>	<u>Yes</u>
<u>% Area Variable Control</u>	15%	15%	70%	70%
<u>% Area On/Off Control</u>	65%	65%	20%	20%
<u>Cooling Source</u>	<u>(2) Water-cooled Centrif Chillers</u>	<u>(2) Water- cooled Centrif Chillers</u>	<u>(2) Water- Cooled Screw Chillers</u>	<u>(2) Water- Cooled Screw Chillers</u>
<u>Cooling COP (net of fan)</u>	<u>Path B for profile</u>	<u>Path B for profile</u>	<u>Path B for profile</u>	<u>Path B for profile</u>
<u>Heating source (reheat)</u>	<u>Electric resistance</u>	<u>Gas Boiler</u>	<u>Electric resistance</u>	<u>Gas Boiler</u>
<u>Furnace or boiler efficiency</u>	1.0	90% Et	1.0	80% Et
<u>Condenser heat rejection</u>	<u>Cooling Tower</u>	<u>Cooling Tower</u>	<u>Cooling Tower</u>	<u>Cooling Tower</u>
<u>Cooling tower efficiency (gpm/hp (L/s·kW))—See G3.1.3.11</u>	40.2 (3.40)	40.2 (3.40)	40.2 (3.40)	40.2 (3.40)
<u>Tower turndown (> 300 ton (1060 kW))</u>	50%	50%	50%	50%
<u>Pump (constant flow/variable flow)</u>	<u>Constant Flow; 10°F (5.6°C) range</u>	<u>Constant Flow; 10°F (5.6°C) range</u>	<u>Constant Flow; 10°F (5.6°C) range</u>	<u>Constant Flow; 10°F (5.6°C) range</u>
<u>Tower approach</u>	<u>G3.1.3.11</u>	<u>G3.1.3.11</u>	<u>G3.1.3.11</u>	<u>G3.1.3.11</u>
<u>Cooling condenser pump power (W/gpm (W·s/L))</u>	19 (300)	19 (300)	19 (300)	19 (300)
<u>Cooling primary pump power (W/gpm (W·s/L))</u>	9 (142)	9 (142)	9 (142)	9 (142)
<u>Cooling secondary pump power (W/gpm (W·s/L))</u>	13 (205)	13 (205)	13 (205)	13 (205)
<u>Cooling coil chilled water delta-T, °F (°C)</u>	18 (10)	18 (10)	18 (10)	18 (10)
<u>Design chilled water supply temperature, °F (°C)</u>	42 (5.56)	42 (5.56)	42 (5.56)	42 (5.56)
<u>Chilled water supply temperature (CHWST)</u>	<u>CHWST/OAT:</u>	<u>CHWST/OAT:</u>	<u>CHWST/OAT:</u>	<u>CHWST/OAT:</u>
<u>reset set point vs OAT, °F (°C)</u>	44-54/ 80-60	44-54/ 80-60 (6.7-12.2/ 26.7-15.6) (see Apx G)	44-54/ 80-60 (6.7-12.2/ 26.7-15.6) (see Apx G)	44-54/ 80-60 (6.7-12.2/ 26.7-15.6) (see Apx G)
-	(6.7-12.2/ 26.7-15.6) (see Apx G)	-	-	-
<u>CHW cooling loop pumping control</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>	<u>2-way Valves & pump VSD</u>

<u>Building Type Parameter</u>	<u>Large Office</u> <u>(warm)</u>	<u>Large Office</u> <u>(cold)</u>	<u>School</u> <u>(warm)</u>	<u>School</u> <u>(cold)</u>
Heating <i>pump</i> power (W/gpm (W·s/L))	16.1 (254)	16.1 (254)	19 (254)	19 (254)
Heating HW dT. °F (°C)	50 (27.78)	20 (11.11)	50 (27.78)	20 (11.11)
Design HWST. °F (°C)	180 (82)	140 (60)	180 (82)	140 (60)
HWST reset <i>set point</i> vs OAT. °F (°C)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7- 10)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7- 10)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7- 10)	HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7- 10)
Heat loop <i>pumping</i> control	2-way Valves & <i>pump</i> VSD	2-way Valves & <i>pump</i> VSD	2-way Valves & <i>pump</i> VSD	2-way Valves & <i>pump</i> VSD

Table C409.7(2) Target Building Design Criteria HVAC Simple Systems

<u>Building Type</u> <u>Parameter</u>	<u>Medium Office</u> <u>(warm)</u>	<u>Medium Office (cold)</u>	<u>Small Office</u> <u>(warm)</u>	<u>Small</u> <u>Office</u> <u>(cold)</u>	<u>Retail (warm)</u>	<u>Retail</u> <u>(cold)</u>
System type	Package VAV - Electric Reheat	Package VAV - Hydronic Reheat	PSZ-HP	PSZ-AC	PSZ-HP	PSZ-AC
Fan control	VSD (No SP Reset)	VSD (No SP Reset)	Constant Volume	Constant Volume	2-speed	2-speed
Main fan power (W/CFM (W·s/L))	0.634 (1.343)	0.634 (1.343)	0.486 (1.03)	0.486 (1.03)	0.585 (1.245)	0.585 (1.245)
proposed ≥ MERV13						
Zonal fan power (W/CFM (W·s/L))	0.35 (5.53)	NA	NA	NA	NA	NA
Minimum zone airflow fraction	1.5* Voz	1.5* Voz	NA	NA	NA	NA
Heat/cool sizing factor	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental heating availability	NA	NA	<40°F (<4.4°C) OAT	NA	<40°F (<4.4°C) OAT	NA
Outdoor air economizer	Yes except 0-1	Yes	Yes except 0- 1	Yes	Yes except 0- 1	Yes
Occupied OSA source	Packaged unit, occupied damper, all building use types					
Energy recovery ventilator	No	No	No	No	Yes, in 0A, 1A, 2A, 3A	Yes all A, 6,7,8 CZ
ERR					50%	50%
DCV	Yes	Yes	No	No	Yes	Yes
% Area Variable Control	15%	15%			80%	80%
% Area On/Off Control	65%	65%			0%	0%
Cooling source	DX, multi-stage	DX, multi-stage	DX, 1 stage (heat pump)	DX, single stage	DX, 2 stage (heat pump)	DX, 2 stage
Cooling COP (net of fan)	3.83	3.83	3.82	3.8248	3.765	3.765
Heating source	Electric resistance	Gas Boiler	Heat Pump	Furnace	Heat Pump	Furnace
Heating COP (net of fan) / furnace or boiler efficiency	100%	81% E _t	3.81	81% E _t	3.536	81% E _t
Heating coil HW dT. °F (°C)	NA	20 (11.11)	NA	NA	NA	NA
Design HWST. °F (°C)	NA	140 (60)	NA	NA	NA	NA
HWST reset set point	NA		NA	NA	NA	NA

<u>Building Type</u>	<u>Medium Office (warm)</u>	<u>Medium Office (cold)</u>	<u>Small Office (warm)</u>	<u>Small Office (cold)</u>	<u>Retail (warm)</u>	<u>Retail (cold)</u>
<u>Parameter</u>						
<u>vs OAT, °F (°C)</u>		<u>HWST/OAT: 180-150/20-50 (82-65.6/ -6.7-10)</u>				
<u>Heat loop pumping control</u>	<u>NA</u>	<u>2-way Valves & ride pump curve</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>
<u>Heating pump power (W/gpm (W-s/L))</u>	<u>NA</u>	<u>16.1</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>

Table C409.7(3) Target Building Design Criteria HVAC Simple Systems

<u>Building Type</u>	<u>Hotel (warm)</u>	<u>Hotel (cold)</u>	<u>Multifamily (warm)</u>	<u>Multifamily (cold)</u>
<u>Parameter</u>				
<u>System type</u>	<u>PTHP</u>	<u>PTAC with Hydronic Boiler</u>	<u>Split HP</u>	<u>Split AC</u>
<u>Fan control</u>	<u>Cycling</u>	<u>Cycling</u>	<u>Cycling</u>	<u>Cycling</u>
<u>Main fan power (W/CFM (W-s/L))</u>	<u>0.300 (0.638)</u>	<u>0.300 (0.638)</u>	<u>0.246 (0.523)</u>	<u>0.271 (0.576)</u>
<u>Heat/cool sizing factor</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>	<u>1.25/1.15</u>
<u>Supplemental heating availability</u>	<u><40°F (<4.4°C)</u>	<u>NA</u>	<u><40°F (<4.4°C)</u>	<u>NA</u>
<u>Outdoor air economizer</u>	<u>Only CZ 2, 3</u>	<u>No</u>	<u>No</u>	<u>No</u>
<u>Occupied OSA source</u>	<u>DOAS</u>	<u>DOAS</u>	<u>DOAS</u>	<u>DOAS except 3C</u>
<u>Energy recovery ventilator</u>	<u>NA</u>	<u>NA</u>	<u>Yes</u>	<u>Yes except 3C</u>
<u>DCV</u>	<u>Yes</u>	<u>Yes</u>	<u>No</u>	<u>No</u>
<u>% Area Variable Control</u>	<u>70%</u>	<u>70%</u>		
<u>% Area On/Off Control</u>	<u>0%</u>	<u>0%</u>		
<u>Cooling source</u>	<u>DX, 1stage (heat pump)</u>	<u>DX, 1 stage</u>	<u>DX, 1 stage (heat pump)</u>	<u>DX, 1 stage</u>
<u>Cooling COP (net of fan)</u>	<u>3.83</u>	<u>3.83</u>	<u>3.823</u>	<u>3.6504</u>
<u>Heating source</u>	<u>Heat Pump</u>	<u>(2) Hydronic Boiler</u>	<u>Heat Pump</u>	<u>Furnace</u>
<u>Heating COP (net of fan) / furnace or boiler efficiency</u>	<u>3.44</u>	<u>81% E_r</u>	<u>3.86</u>	<u>80% AFUE</u>
<u>Heating pump power (W/gpm (W-s/L))</u>	<u>NA</u>	<u>16.1</u>	<u>NA</u>	<u>NA</u>
<u>Heating coil heating water delta-T, °F (°C)</u>	<u>NA</u>	<u>20 (11.11)</u>	<u>NA</u>	<u>NA</u>
<u>Design HWST, °F (°C)</u>	<u>NA</u>	<u>140 (60)</u>	<u>NA</u>	<u>NA</u>
<u>HWST reset set point vs OAT, °F (°C)</u>	<u>NA</u>	<u>HWST/OAT: 180-150/ 20-50 (82-65.6/ -6.7-10)</u>	<u>NA</u>	<u>NA</u>
<u>Heat loop pumping control</u>	<u>NA</u>	<u>2-way Valves & ride pump curve</u>	<u>NA</u>	<u>NA</u>

Add new Appendix CD as follows:

Appendix CD REQUIRED HVAC TSPR

CD 101Required HVAC TSPR.

For jurisdictions who wish to adopt a stretch code or HVAC incentive system, make the following changes to Section C403.

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Replace Section C403.1 with the following:

C403.1 General. Mechanical systems and equipment serving the building heating, cooling, ventilating, or refrigerating needs shall comply with one of the following:

1. Sections C403.1.1 and C403.2 through C403.14 and also comply with Section C403.1.3
2. Data Centers shall comply with C403.1.1, C403.1.2 and C403.6 through C403.14

Replace Section C403.1.3 with the following.

C403.1.3 HVAC total system performance ratio (HVAC TSPR). For systems serving buildings or portions of buildings of the following types:

1. office (including medical office) (occupancy group B),
2. retail (occupancy group M), library (occupancy group A-3),
3. education (occupancy group E), and
4. hotel/motel occupancies (occupancy group R-1) and
5. the dwelling units and common areas within occupancy group R-2 multifamily buildings,

The HVAC total system performance ratio (HVACTSPR) of the proposed design HVAC systems shall be greater than or equal to the HVAC TSPR of the standard reference design divided by the applicable mechanical performance factor (MPF) from Table C409.3.1. HVAC TSPR shall be calculated in accordance with Section C409, Calculation of HVAC Total System Performance Ratio.

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Exceptions to C403.1.3

1. Buildings with conditioned floor area less than 5,000 square feet.
2. Alterations to existing buildings that do not substantially replace the entire HVAC system and are not serving initial build-out construction
3. HVAC systems using district heating water, chilled water or steam.
4. Portions of buildings served by systems using:
 - 4.1. small duct high velocity air cooled, space constrained air cooled, single package vertical air conditioner, single package vertical heat pump, or
 - 4.2. double-duct air conditioner or double-duct heat pump as defined in subpart F to 10CFR part 431
 - 4.3. packaged terminal air conditioners and packaged terminal heat pumps that have cooling capacity greater than 12,000 Btu/hr (3500 kW)
 - 4.4. a common heating source serving both HVAC and service water heating equipment
 - 4.5. HVAC systems not included in Table C409.5.2.10.1
 - 4.6. HVAC systems included in table C409.5.2.10.1 with parameters in Table C409.5.2.10.2, not identified as applicable to that HVAC system type.
 - 4.7. Underfloor air distribution and displacement ventilation HVAC systems.

- 4.8. Space conditioning systems that do not include mechanical cooling.
- 4.9. HVAC systems that provide recovered heat for service water heating
- 4.10. HVAC systems with chilled water supplied by absorption chillers, heat recovery chillers, water to water heat pumps, air to water heat pumps, or a combination of air and water cooled chillers on the same chilled water loop.
- 4.11. HVAC system served by heating water plants that include air to water or water to water heat pumps.
- 4.12. HVAC systems meeting or exceeding all the requirements of the applicable Target Design HVAC System described in Tables C409.5.4(1) through C409.5.4(3),
- 4.13. HVAC systems serving laundry rooms, elevator rooms, mechanical rooms, electrical rooms, data centers, and computer rooms.
- 4.14. Buildings or areas of medical office buildings that comply fully with ASHRAE Standard 170, including but not limited to surgical centers, or that are required by other applicable codes or standards to provide 24/7 air handling unit operation
- 4.15. HVAC systems serving laboratories with fume hoods
- 4.16. Locker rooms with more than 2 showers
- 4.17. Natatoriums and rooms with saunas
- 4.18. Restaurants and commercial kitchens with total cooking capacity greater than 100,000 Btu/h
- 4.19. Cafeterias and dining rooms
- 4.20. Areas of buildings with commercial refrigeration equipment exceeding 100 kW of power input.

Add new text as follows:

Replace Table C409.4 with the following, this provides a 5% reduction in HVAC energy:

Climate Zone:		0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
<u>Building type</u>	<u>Ocp. Group</u>																			
<u>Office (small and medium)^{a1}</u>	<u>B</u>	0.68	0.68	0.67	0.67	0.65	0.62	0.67	0.65	0.61	0.76	0.67	0.74	0.8	0.73	0.76	0.82	0.79	0.83	0.85
<u>Office (Large)^a</u>	<u>B</u>	0.79	0.79	0.8	0.8	0.75	0.78	0.68	0.77	0.73	0.64	0.72	0.6	0.67	0.68	0.6	0.69	0.67	0.67	0.67
<u>Retail</u>	<u>M</u>	0.57	0.54	0.48	0.52	0.44	0.44	0.41	0.48	0.38	0.43	0.54	0.65	0.44	0.65	0.64	0.48	0.43	0.42	0.36
<u>Hotel/Motel</u>	<u>R-1</u>	0.59	0.59	0.6	0.6	0.59	0.65	0.58	0.67	0.69	0.43	0.56	0.49	0.36	0.45	0.48	0.33	0.36	0.29	0.25
<u>Multi-Family/ Dormitory</u>	<u>R-2</u>	0.61	0.6	0.64	0.6	0.62	0.61	0.56	0.68	0.52	0.5	0.48	0.42	0.51	0.45	0.36	0.52	0.48	0.48	0.45
<u>School/ Education and Libraries</u>	<u>E (A-3)</u>	0.78	0.77	0.76	0.75	0.71	0.68	0.67	0.68	0.64	0.69	0.68	0.65	0.78	0.69	0.58	0.85	0.76	0.79	0.73

a. large office (gross conditioned floor area >150,000 ft² (14,000 m²) or > 5 floors); all other offices are small or medium

Reason:

The prescriptive path is traditionally the most widely used approach for commercial code compliance in the United States. Though easy to implement, the prescriptive approach does not discriminate between high-performing and poorly performing heating, ventilation, air conditioning (HVAC) system configurations that are both minimally compliant. For example, a high capacity PTAC is less efficient than a packaged rooftop air conditioner, but either one can be used in the prescriptive path. The packaged rooftop unit is a better design choice, both for energy savings and reduced noise in the space. To meet aggressive energy and carbon reduction goals, energy codes will need to transition from prescriptive to performance-based approaches, a transition that has several challenges.

This proposal includes 3 features:

- An alternative path in Section C403 that can be used optionally for tradeoffs, such as a more efficient system that does not have outside air economizers. This performance path uses minimum efficiency HVAC equipment for all the target systems with a selection of a reasonable and typical system type and related fan and pumping parameters. In this case, mandatory requirements and certain prescriptive requirements are maintained, while most prescriptive requirements can be traded off for improved efficiency in other parts of the system.
- An addition to the energy credits section (C406) of the code that accounts for the total HVAC system performance, not just heating and cooling efficiency.
- An optional appendix that can be adopted for stretch codes and utility incentive certification that requires TSPR analysis where it is applicable and requires a higher level of performance, saving 5% vs. minimum efficiency systems.

HVAC System Performance is a discipline performance path and provides a simpler solution to HVAC system evaluation compared to whole building performance, while keeping tradeoffs limited to specific building systems. The Total System Performance Ratio (TSPR) is a metric for evaluation of overall system efficiency instead of individual component efficiency, a solution that could also eventually facilitate the transition to a 100% performance-based code structure. TSPR is a ratio that compares the annual heating and cooling load of a building to the annual energy consumed by the building's HVAC system.

A web-based calculation tool has been developed for determining a building's TSPR. Already incorporated into the 2018 Washington State Energy Code, this approach has also been evaluated by the ASHRAE Standard 90.1 Project Committee and has the potential to provide a comprehensive performance-based approach for HVAC system evaluation and analysis

For the stretch code option, implementing a base TSPR minimum requirement for HVAC systems in relevant buildings will result in savings when the least efficient systems allowed under the prescriptive path are required to make some change to improve efficiency in line with a reasonably good prescriptive system. Such changes might include efficiency improvements, better duct design that reduces fan power, or the inclusion of options like economizers, demand controlled ventilation, improvement in energy recovery effectiveness or addition of energy recovery that might be excepted for the particular situation. The HVAC System performance path looks at the performance of all the systems in the building, so smaller systems do not necessarily need to meet higher requirements.

Cost Impact:

The code change proposal will neither increase nor decrease the cost of construction.

For the base proposal, there is no cost impact, as TSPR is an optional path that is not required under the prescriptive path.

For the energy credits addition, this is one of many options, and the energy credits show cost effectiveness through one cost effective path that may not include this option. Adding TSPR to energy credits just increases efficiency.

For the stretch code appendix, there may be a cost increase; however, this option is a jurisdictional adoption choice where the jurisdiction may choose to require improved efficiency performance as a matter of policy, rather than focusing on individual building cost savings, including consideration for environmental externalities and societal costs.

Bibliography:

Goel S., R Hart, M Tillou, M Rosenberg, J Gonzalez, K Devaprasad, and J Lerond. 2021. HVAC System Performance for Energy Codes. PNNL-31571. Richland, WA: Pacific Northwest National Laboratory.