International Energy Conservation Code
Code Change Proposal Tracking Sheet

Proposal #	CEPI-076-21 HVAC Total System Performance
CDP ID #	121
Code	IECC CE
Code Section(s)	C403.1.3 New Section y
Location	base
Proponent	Jeremy Williams jeremy.williams@ee.doe.gov
Proposal Status	SC rev
Subcommittee	CE HVACR & WH
Subcommittee Notes	• Reid Hart (PNNL) presented on the TSPR concept. • Subcommittee discussion about how designers appreciate the flexibility in design that is allowed. • Discussion and concern that the software does not cover complex systems, with note that TSPR path is intended for simpler buildings. • This proposal encourages performance-based approaches. US DOE would like to see a move to performance paths and this proposal supports this direction. • Subcommittee discussion around whether EER is supported for part load and how work is being done on a way to allow the entry of IEER. Some concern that the software created by PNNL only accepts full-load EER as an input, using EER to calculate part-load performance can lead to errors. Subcommittee noted that this is actually an industry problem, since many manufacturers do not provide part-load performance data useful for modeling. • Comments that alternate path must allow minimum efficiency equipment and that the current performance paths allow the use of EER to determine part load performance. The IECC should not wait for industry to act. • Subcommittee questions on how this compares to the EPA software, with response that EPA applies to downstream on existing buildings, while this applies to buildings under design. • Proposal is closely aligned with 90.1. • Likely will help jurisdictions avoid the need to create their own rules or software. • Some question around who can develop the software to support this alternative, and concern that small manufacturers would be disadvantaged because they cannot make software. Response that two large manufacturers that offer software that supports the existing performance methods are already advantaged. They have spent much time and resources to create that software, and it is likely that independent software makers will offer to add smaller manufacturers' equipment to their programs for a fee.

	• Subcommittee made a friendly amendment to call out occupancy groups rather than example occupancies.
Recommendation	Approve as modified, refer to attached modification. Reason: Proposal provides an alternative compliance path with a focus on performance. Please also refer to the reason statement in the proposal.
Vote	Approve as modified 9-5-1
Recommendation Date	3/10/2022
Next Step	To Subcommittee_____ To Advisory Group_____ To Consensus Committee _X_____
Consensus Committee	
Committee Response	
Vote	Affirmative_____ Negative_____ Table_____ To Subcommittee_____
Date	

CEPI-76-21 AS MODIFIED

IECC®: SECTION 202 (New), C403.1, C403.1.3 (New), C403.1.3.1 (New), C403.1.3.2 (New), C403.1.3.3 (New), C406.13 (New), TABLE C406.1(1), TABLE C406.1(2), TABLE C406.1(3), TABLE C406.1(4), TABLE C406.1(5), SECTION C409 (New), C409.1 (New), C409.2 (New), C409.3 (New), C409.4 (New), Table C409.4 (New), C409.4.1 (New), C409.5 (New), C409.5.1 (New), C409.5.2 (New), C409.5.3 (New), C409.5.3.1 (New), C409.6 (New), C409.6.1 (New), C409.6.1.1 (New), C409.6.1.1.1 (New), C409.6.1.2 (New), C409.6.1.3 (New), C409.6.1.3.1 (New), C409.6.1.3.2 (New), C409.6.1.4 (New), C409.6.1.4.1 (New), C409.6.1.4.2 (New), C409.6.1.4.3 (New), C409.6.1.4.4 (New), C409.6.1.4.5 (New), C409.6.1.4.6 (New), C409.6.1.4.7 (New), C409.6.1.4.8 (New), C409.6.1.5 (New), C409.6.1.6 (New), C409.6.1.7 (New), C409.6.1.8 (New), C409.6.1.9 (New), C409.6.1.10 (New), C409.6.1.10.1 (New), TABLE C409.6.1.10.1 (New), C409.6.1.10.2 (New), TABLE C409.6.1.10.2(1) (New), TABLE C409.6.1.10.2(2) (New), C409.6.1.10.3 (New), C409.6.2 (New), C409.6.2.1 (New), C409.6.2.2 (New), C409.6.2.3 (New), C409.6.2.4 (New), C409.6.2.5 (New), C409.6.2.6 (New), C409.6.2.7 (New), C409.6.2.8 (New), C409.6.2.9 (New), C409.6.2.10 (New), C409.6.2.11 (New), Table C409.6.2.11(1) (New), Table C409.6.2.11(2) (New), Table C409.6.2.11(3) (New), C409.7 (New), Table C409.7(1) (New), TABLE C409.7(2) (New), TABLE C409.7(3) (New), Appendix CD (New), CD 101 (New), (New)

Proponents: Jeremy Williams, representing U.S. Department of Energy (jeremy.williams@ee.doe.gov)

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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.

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*.

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*.

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. **occupancy group B,**
2. **occupancy group M,**
3. **occupancy group A-3,**
4. **occupancy group E,**

5. occupancy group R-1,

6. 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 package vertical heat pump, or

   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 12,000 Btu/hr 5.(3500 kW)

   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 that HVAC system type.
5. 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.
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 surgical centers, or that are required by other applicable codes or standards to provide 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 C403.5.5 "Economizer fault detection and diagnostics."
2. Variable-air-volume system systems 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 C403.4.3.3.
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 operable openings interlock requirements of Section C402.5.11.10. 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:

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

Portions of table not shown remain unchanged.

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

Portions of table not shown remain unchanged.

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

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

Portions of table not shown remain unchanged.

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.

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

Portions of table not shown remain unchanged.

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.

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

Portions of table not shown remain unchanged.

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 text as follows:

SECTION C409
CALCULATION OF HVAC TOTAL SYSTEM PERFORMANCE RATIO

C409.1 Purpose. Section 409 establishes criteria for demonstrating compliance with the requirements of C403.1.1, *HVAC total system performance ratio (HVAC TSPR)*

C409.2 Scope. Section C409 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.

All applicable HVAC systems shall comply with Section C409.

C409.3 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.

C409.4 HVAC 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.

$$TSPRp > TSPRr / MPF \quad \text{(Equation 4-16)}$$

where:

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

TSPRr = *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

$$MPF = (A_1*MPF_1 + A_2* MPF_2+...+A_n*MPF_n)/(A_1+A_2+...+A_n) \quad \text{(Equation 4-17)}$$

where:

MPF_1, MPF_2 through MPF_n = Mechanical Performance Factors from Table C409.4 based on climate zone and *building* use types 1,2, through n

A_1, A_2 through A_n = Conditioned *floor* areas for *building* use types 1, 2, through n

Table C409.4 Mechanical Performance Factors

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	Climate Zone:	0A	0B	1A	1B	2A	2B	3A	3B	3C	4A	4B	4C	5A	5B	5C	6A	6B	7	8
Building type	Ocp. Group																			
Office (small and medium)[a]	B	0.72	0.715	0.7	0.705	0.685	0.65	0.71	0.68	0.645	0.805	0.7	0.78	0.845	0.765	0.805	0.865	0.835	0.875	0.895
Office (Large)[a]	B	0.83	0.83	0.84	0.84	0.79	0.82	0.72	0.81	0.77	0.67	0.76	0.63	0.71	0.72	0.63	0.73	0.71	0.71	0.71
Retail	M	0.6	0.57	0.5	0.55	0.46	0.46	0.43	0.51	0.4	0.45	0.57	0.68	0.46	0.68	0.67	0.5	0.45	0.44	0.38
Hotel/Motel	R-1	0.62	0.62	0.63	0.63	0.62	0.68	0.61	0.71	0.73	0.45	0.59	0.52	0.38	0.47	0.51	0.35	0.38	0.31	0.26
Multi-Family/ Dormitory	R-2	0.64	0.63	0.67	0.63	0.65	0.64	0.59	0.72	0.55	0.53	0.5	0.44	0.54	0.47	0.38	0.55	0.5	0.51	0.47
School/ Education and Libraries	E (A-3)	0.82	0.81	0.8	0.79	0.75	0.72	0.71	0.72	0.67	0.73	0.72	0.68	0.82	0.73	0.61	0.89	0.8	0.83	0.77

a. Large office (gross conditioned floor area >150,000 ft^2 (14,000 m^2) or > 5 floors); all other offices are small or medium

C409.4.1 HVAC 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

C409.5 General. Projects shall comply with the requirements of this Section when calculating compliance using *HVAC Total System Performance Ratio.*

C409.5.1 Simulation 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, except for Sections 7 and 8 of Standard 140, shall be permitted to be *approved.* The required tests shall include *building* thermal envelope and fabric load tests (Sections 5.2.1, 5.2.2, and 5.2.3), ground coupled slab-on-grade analytical verification tests (Section 5.2.4), space-cooling equipment performance tests (Section 5.3), space-heating equipment performance tests (Section 5.4), and air-side HVAC *equipment* analytical verification tests (Section 5.5), along with the associated reporting (Section 6). 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.
3. The test results and modeler reports shall be posted on a publicly available website and shall include the test results of the simulation program and input files used for generating the results along with the results of the other simulation programs included in ASHRAE Standard 140 Annexes B8 and B16. The modeler report in Standard 140 Annex A2 Attachment A2.7 shall be completed for results exceeding the maximum or falling below the minimum of the reference values and for omitted results.
4. The simulation program shall have the ability to explicitly model part-load performance curves or other part-load adjustment methods based on manufacturer's part-load performance data for mechanical equipment.

C409.5.2 Climatic 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://energycode.pnl.gov/HVACSystemPerformance/resources

C409.5.3 Documentation. Documentation conforming to the provisions of this section shall be provided to the *code official.*

C409.5.3.1 Compliance 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 Heat rejection equipment (open and closed circuit cooling towers; dry coolers)

2.10 Electric resistance coils

2.11 Condensing units

2.12 Motors for fans and pumps

2.13 Energy recovery devices

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

3.1 Equipment name or tag consistent with that found on the design documents.

3.2 Rated Efficiency level.

3.3 Rated Capacity.

3.4 Where not provided by the simulation program report in item a, documentation of the calculation of any weighted equipment efficiencies input into the program

3.5 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)

4. Floor plan of the building identifying:

4.1 How portions of the buildings are assigned to the simulated blocks

4.2 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. A more complex zoning of the building shall be allowed where all thermal zones in the reference and proposed model are the same and rules related to block geometry and HVAC system assignment to blocks are met with appropriate assignment to thermal zones.

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 or each floor shall be modeled as a core zone with no exterior walls.

C409.6.1.3 Occupancy. Building occupancies modeled in the *standard reference design* and the *proposed design* shall comply with the following requirements.

C409.6.1.3.1 Occupancy 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.

C409.6.1.3.2 Occupancy 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.

C409.6.1.4 Envelope Components. Building envelope components modeled in the *standard reference design* and the *proposed design* shall comply with the requirements of this Section.

C409.6.1.4.1 Roofs.. 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.

C409.6.1.4.2 Above 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.

C409.6.1.4.3 Below 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.

C409.6.1.4.4 Above 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.

C409.6.1.4.5 Slab 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.

C409.6.1.4.6 Vertical 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.

C409.6.1.4.7 Skylights.. 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

C409.6.1.4.8 Exterior 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.

$P_{avg} = (A_1 \times L_{o1} + A2 \times L_{o2}... + An \times L_{on}) / (Lw_1 + Lw_2... + L_{wn})$ (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 vertic

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/ft^2
2. Multifamily common areas shall have a miscellaneous load density of 0 W/ft^2

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

System No.	System
1	Packag
2	Packag
3	Packag systems
4	Packag electric
5	Variable
6	Four Pi
7	Water S System,

8	Ground Source Heat Pump	~~GSHP~~
9	Packaged Variable Air Volume (DX cooling)[a]	~~PVAV~~
10	Variable Air Volume (hydronic cooling) [a]	~~VAV~~
11	Variable Air Volume with Fan Powered Terminal Units	~~VAVFPTU~~
12	Dedicated Outdoor Air System (in conjunction with systems 1-8)	~~DOAS~~

a. * Reheat ~~and~~ or primary heat may be electric, hydronic, or gas furnace

b. Conde

ers or heat pumps

C409.6.1.10.2 Proposed building HVAC system simulation.. The HVAC systems shall be modeled as in the proposed design at design conditions unless otherwise stated 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.

Table C409.6.1.10.1 proposed building HVAC parameter requirements are based on input of full-load equipment efficiencies with adjustment using part-load curves integrated in the simulation program. Where other approaches to part-load adjustment are used, it is permitted for specific input parameters to vary.

The simulation program shall model part-load HVAC equipment performance using either:

1. **full-load efficiency adjusted for fan power input that is modeled separately and typical part-load performance adjustments for the proposed equipment,**
2. **part-load adjustments based on input of both full-load and part-load metrics, or**
3. **equipment-specific adjustments based on performance data provided by the equipment manufacturer for the proposed equipment.**

(Equation 4-24)

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

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
HVAC System Type	System Type	User Defined	Selected from Table C409.6.1.10.1	All
System Sizing	Design Day Information	Fixed	99.6% heating design and 1% dry-bulb and 1% wet-bulb cooling design	All
	Zone Coil Capacity	Fixed	Sizing factors used are 1.25 for heating equipment and 1.15 for cooling equipment	All
	Supply Airflow	Fixed	Based on a supply-air-to-room-air temperature *set-point* difference of 20°F or	1-11
		Fixed	Equal to required outdoor air ventilation	12
Outdoor Ventilation Air	Portion of supply air with proposed Filter ≥MERV 13	User-defined	Percentage of supply airflow subject to higher filtration (Adjusts baseline Fan Power higher. Prorated)	All
	Outdoor Ventilation Air Flow Rate	Fixed	As specified in ASHRAE Standard 90.1 Normative Appendix C, adjusted for proposed DCV control	All
	Outdoor *Ventilation* Supply Air Flow Rate Adjustments	Fixed	Based on ASHRAE Standard 62.1 Section 6.2.4.3 System Ventilation Efficiency (Evs) is 0.75	9-11
		Fixed	System Ventilation Efficiency (Evs) is 1.0	1-8, 12
		Fixed	Basis is 1.0 Zone Air Distribution Effectiveness	All
System Operation	Space temperature Set points	Fixed	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 • hotel/motel that shall be 70 deg. F (21 deg C) heating and 72 deg F (22 deg C) cooling	All
	Fan Operation – Occupied	User Defined	Runs continuously during occupied hours or cycles to meet load. Multispeed fans reduce airflow related to thermal loads.	1-11
	Fan Operation – Occupied	Fixed	Fan runs continuously during occupied hours	12
	Fan Operation – Night Cycle	Fixed	Fan cycles on to meet setback temperatures	1-11
Packaged Equipment Efficiency	DX Cooling Efficiency	User Defined	Cooling COP without fan energy calculated in accordance with Section C409.6.1.10.2	1, 2, 3, 4, 5,7, 8, 9, 11,12
	DX Coil Number of Stages	User-defined	Single Stage or Multistage	3, 4, 9, 10, 11, 12
	Heat Pump Efficiency	User Defined	Heating COP without fan energy calculated in accordance with Section C409.6.1.10.2	2, 4, 5, 7, 8, 12
	Furnace Efficiency	User Defined	Furnace thermal efficiency	3, 9, 11, 12
Heat Pump Supplemental Heat	Heat Source	User-defined	Electric resistance or gas furnace	2,4,7,8,12

	Control	**Fixed**	**Supplemental Electric resistance heat locked out above 40°F (4°C) OAT. Runs as needed in In conjunction with compressor between 40°F (4°C) and 0°F (-17.8°C). Gas heat operates in place of the heat pump when the heat pump cannot meet load.**	**2, 4, 7,8,12**
System Fan Power and Controls	**Part-load Fan Controls** • Constant volume • Two Speed or three speed, • *VAV*	**User-defined**	Static pressure reset included for *VAV*.	1-8 (CAV, two or three speed) 9,10,11 (VAV) 12 (CAV and VAV)

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
	Design Fan Power (W/cfm)	User Defined	Input electric power for all fans in required to operate at fan system design conditions divided by the supply airflow rate This is a "wire to air" value including all drive, motor *efficiency* and other losses.	All
	Low-speed and medium speed fan power	User Defined	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. Also provide medium speed values for three-speed fans.	1-8
Variable Air Volume Systems	Supply Air Temperature (SAT) Controls	User defined	If not SAT reset then constant at 55°F. - Options for reset based on outside air temperature (OAT) or warmest zone. If warmest zone, then the user can specify the minimum and maximum temperatures. 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.	9, 10, 11
	Minimum Terminal Unit airflow percentage	User Defined	Average minimum terminal unit airflow percentage for *block* weighted by cfm or minimum required for outdoor air ventilation, whichever is higher.	9, 10, 11
	Terminal Unit Heating Source	User Defined	Electric or hydronic	9, 10, 11
	Dual *set point* minimum *VAV* damper position	User-defined	Heating maximum airflow fraction	9,10.
	Fan Powered Terminal Unit (FPTU) Type	User Defined	Series or parallel FPTU	11
	Parallel FPTU Fan	Fixed	Sized for 50% peak primary air at 0.35 W/cfm	11
	Series FPTU Fan	Fixed	Sized for 50% peak primary air at 0.35 W/cfm	11
Economizer	Economizer Presence	User Defined	Yes or No	3, 4, 5, 6, 9, 10,11
	Economizer Control Type	Fixed	Lockout on Differential dry-bulb temperature (OAT > RAT) in 6A, 5A, All B & C climate zones; fixed enthalpy >28 Btu/lb (47 kJ/kg) or fixed drybulb OAT > 75°F (24°C) in 0A to 4A climate zones	3, 4, 5, 6, 9, 10,11
Energy Recovery	Sensible Effectiveness	User Defined	Heat exchanger sensible effectiveness at design heating and cooling conditions	3, 4, 9, 10, 11, 12
	Latent Effectiveness	User Defined	Heat exchanger latent effectiveness at design heating and cooling conditions	3, 4, 9, 10, 11, 12
	Economizer Bypass	User Defined	If ERV is bypassed or wheel rotation is slowed during economizer conditions (Yes/No)	3, 4, 9, 10, 11, 12

Economizer Bypass active	Fixed	IF there is a bypass, it will be active between 45°F (7°C) and 75°F (24°C) outside air temperature.	
Bypass SAT Setpoint	User Defined	If bypass, target supply air temperature	3, 4, 9, 10, 11, 12
Fan Power Reduction during Bypass (W/cfm)	User Defined	If ERV system include bypass, static pressure set point and variable speed fan, fan power can be reduced during economizer conditions	3, 4, 9, 10, 11, 12

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
Demand Controlled Ventilation	DCV Application on/off	User Defined	Percent of block floor area under occupied standby controls, ON/OFF only with occupancy sensor and no variable control	3, 4, 9, 10, 11, 12
	DCV Application CO_2	User Defined	Percentage of block floor area under variable DCV control (CO2); may include both variable and ON/OFF control	
DOAS	DOAS Fan Power W/cfm	User Defined	Fan electrical input power in W/cfm of supply airflow	12
	DOAS Supplemental Heating and Cooling	User Defined	Heating source, cooling source, energy recovery and respective efficiencies	12
	Maximum SAT Set point (Cooling)	User-defined	SAT set point if DOAS includes supplemental cooling	12
	Minimum SAT Set point (Heating)	User-defined	SAT set point if DOAS includes supplemental heating	12
	-	-	-	-
Heating Plant	Boiler Efficiency	User Defined	Boiler thermal efficiency	1, 6, 7, 9, 10, 11, 12
	Heating Water Loop Configuration	User-defined	Constant flow primary only; Variable flow primary only; Constant flow primary – variable flow secondary, Variable flow primary and secondary	1, 6, 7, 9, 10, 11, 12
	Heating Water Primary Pump Power (W/gpm)	User-defined	Heating water primary pump input W/gpm heating water flow	1, 6, 7, 9, 10, 11, 12
	Heating Water Secondary Pump Power (W/gpm)	User-defined	Heating water secondary pump input W/gpm heating water flow (if primary/secondary)	1, 6, 7, 9, 10, 11, 12
	Heating Water Loop Temperature	User-defined	Heating water supply and return temperatures, °F (°C)	1, 6, 9, 10,11
	Heating Water Loop Supply Temperature Reset Included	User-defined	Yes/No	1,6,7,9,10,11,12
	Heating Water Loop Supply Temperature Reset	Fixed	Reset HWS by 27.3% of design delta-T (HWS – 70°F (21.1°C) *Space* Heating temperature *set point*) between 20°F (-6.7°C) and 50°F (10°C) OAT	1,6,7,9,10,11,12
	Boiler Type	Fixed	Non-condensing boiler where input thermal efficiency is less than 86%; Condensing boiler otherwise	1, 6, 7, 9, 10, 11, 12
Chilled Water Plant	Chiller Compressor Type	User Defined	Screw/Scroll, Centrifugal or Reciprocating	6,1 0, 11, 12
	Chiller Condenser Type	User Defined	Air cooled or water cooled	6, 10, 11, 12
	Chiller Full Load Efficiency	User Defined	Chiller COP	6, 10, 11, 12

Chilled Water Loop Configuration	User Defined	Variable flow primary only, constant flow primary – variable flow secondary, variable flow primary and secondary	6, 10, 11,12
Chilled Water Primary Pump Power (W/gpm)	User-defined	Primary pump input W/gpm chilled water flow	6, 10, 11,12
Chilled Water Secondary Pump Power (W/gpm)	User-defined	Secondary Pump input W/gpm chilled water flow (if primary/secondary)	6, 10, 11,12
Chilled Water Temperature Reset Included	User Defined	Yes/No	6, 10, 11,12

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
Chilled Water Plant (cont.)	Chilled Water Temperature Reset Schedule (if included)	Fixed	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	6, 10, 11,12
	Condenser Water Pump Power (W/gpm)	User Defined	Pump input W/gpm condenser water flow	6, 7, 8, ,10, 11, 12
	Condenser Water Pump Control	User Defined	Constant speed or variable speed	6, 7, 8, 10, 11,12
	Heat Rejection Equipment Efficiency	User Defined	gpm/hp tower fan	6, 7, 10, 11,12
	Heat Rejection Fan Control	User Defined	Constant or variable speed	6, 7, 10, 11,12
	Heat Rejection Approach and Range	User Defined	Design cooling tower approach and range temperature	6, 7, 10, 11,12
Heat Pump Loop	Loop flow and Heat Pump Control Valve	Fixed	Two position Valve with VFD on Pump. Loop flow at 3 gpm/ton	7, 8
	[redacted] Control	User-defined	User input; restrict to minimum 20°F (11°C) and maximum 40°F (22°C) temperature difference	7
GLHP Well Field	-	Fixed	Bore depth = 250' (76 m) Bore length 200'/ton (1.5 m/kW) for the greater of cooling or heating load Bore spacing = 15' (4.6 m) Bore diameter = 5" (12.5 cm) ¾" (19 mm) diameter Polyethylene pipe Ground and grout conductivity =4.8 Btu-in/h-ft^2-°F (0.69 W/(m·K))	8

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

Equation Term	Fan Power Coefficients	Pump Power Coefficients	
-	VSD + SP reset	Ride Pump Curve	VSD + DP/valve reset
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 floor area of the building that is covered by DCV. The simplified method shall accommodate both variable DCV and on/off DCV, giving on/off DCV one third the effective floor control area of variable DCV. Outdoor air reduction coefficients shall be as stated in Table C409.6.1.10.3.**

Exception: On/off DCV shall receive full effective area adjustment for R-1 and R-2 occupancies.

Table C409.6.1.10.3
DCV Outdoor Air Reduction Curve Coefficients

Equation Term	*DCV* OSA reduction (y) as a function of effective *DCV* control floor area (x)			
	Office	School	Hotel; Motel; Multi-Family; Dormitory	Retail
b	0	0	0	0
x	0.4053	0.2676	0.5882	0.4623
x^2	-0.8489	0.7753	-1.0712	-0.848
x^3	1.0092	-1.5165	1.3565	1.1925
x^4	-0.4168	0.7136	-0.6379	-0.5895

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 design.***

C409.6.2.2 Blocks. **Same as *proposed design.***

C409.6.2.3 Thermal zoning. **Same as *proposed design.***

C409.6.2.4 Occupancy type, schedule, density, and heat gain. **Same as *proposed design.***

C409.6.2.5 Envelope components.. **Same as *proposed design.***

C409.6.2.6 Lighting. **Same as *proposed design.***

C409.6.2.7 Miscellaneous equipment. **Same as *proposed design.***

C409.6.2.8 Elevators. **Not modeled. Same as *proposed design.***

C409.6.2.9 Service water heating equipment. **Not modeled. Same as *proposed design.***

C409.6.2.10 On-site renewable energy systems. **Not modeled. Same as *proposed design.***

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 (Enthalpy Recovery Ratio) ERV bypass SAT *set point*	NA	NA	50% No Bypass	50% 60°F except 4A
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	Axial Fan Open Circuit 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 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)
Design chilled water supply temperature, °F (°C)	44 (6.7)	44 (6.7)	44 (6.7)	44 (6.7)

Chilled water supply temperature (CHWST) reset *set point* vs Outside Air Temperature (OAT), °F (°C)	**CHWST: 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)**	**CHWST: 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)**	**CHWST: 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)**	**CHWST: 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)**

Building Type Parameter	Large Office (warm)	Large Office (cold)	School (warm)	School (cold)
CHW cooling loop *pump*ing control	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD
Heating *pump* power (W/gpm (W·s/L))	16.1 (254)	16.1 (254)	19 (254)	19 (254)
Heating oil HW dT. °F (°C)	50 (10)	50 (10)	50 (10)	50 (10)
Design Hot Water Supply Temperature (HWST). °F (°C)	180 (82)	180 (82)	180 (82)	180 (82)
HWST reset *set point* vs OAT, °F (°C)	HWSTT: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)
Heat loop *pumping* control	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD	2-way Valves & *pump* VSD

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

Building Type Parameter	Medium Office (warm)	Medium Office (cold)	Small Office (warm)	Small Office (cold)	Retail (warm)	Retail (cold)
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	Constant Volume	Constant Volume
Main fan power (W/CFM (W·s/L)) proposed ≥ MERV13	1.285 (2.723)	1.285 (2.723)	0.916 (1.941)	0.916 (1.941)	0.899 (1.905)	0.899 (1.905)
Main fan power (W/CFM (W·s/L)) proposed < MERV13	1.176 (2.492)	1.176 (2.492)	0.850 (1.808)	0.850 (1.801)	0.835 (1.801)	0.835 (1.801)
Zonal fan power (W/CFM (W·s/L))	0.35 (0.75)	NA	NA	NA	NA	NA
Minimum zone airflow fraction	30%	30%	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	No	Yes except 4A	No	Yes except 4A	No	Yes except 4A
Occupied OSA source	Packaged unit, occupied damper, all *building* use types					
Energy recovery ventilator	No	No	No	No	No	No
DCV	No	No	No	No	No	No
Cooling source	DX, multi-stage	DX, multi-stage	DX, 1 stage (heat pump)	DX, single stage	DX, 1 stage (heat pump)	DX, single stage
Cooling *COP* (net of fan)	3.40	3.40	3.00	3.00	3.40	3.50
Heating source	*Electric resistance*	Gas *Boiler*	Heat Pump	Furnace	Heat Pump	Furnace
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	*PTHP*	*PTAC*	*PTHP*	*PTAC*
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	*PTHP*	(2) Hydronic *Boiler*	*PTHP*	(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: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	NA	HWST: 180-150 / OAT 20-50 (82-65.6/ -6.7-10)
Heat loop *pump*ing 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 (with SP Reset)	VSD (with SP Reset)	VSD (with SP Reset)	VSD (with SP Reset)
Main fan power (W/CFM (W·s/L) Proposed ≥ MERV13	1.127 (2.388)	1.127 (2.388)	1.127 (2.388)	1.127 (2.388)
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	*Yes except 0-1*	Yes	*Yes except 0-1*	Yes
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	Yes	Yes	Yes	Yes
% Area Variable Control	15%	15%	70%	70%
% Area On/Off Control	65%	65%	20%	20%
Cooling Source	(2) Water-cooled Centrif Chillers	(2) Water- cooled Centrif Chillers	(2) Water- Cooled Screw Chillers	(2) Water- Cooled Screw Chillers
Cooling *COP* (net of fan)	ASHRAE 90.1 Appendix G, Table G3.5.3	ASHRAE 90.1 Appendix G, Table G3.5.3	ASHRAE 90.1 Appendix G, Table G3.5.3	ASHRAE 90.1 Appendix G, Table G3.5.3
Heating source (reheat)	*Electric resistance*	Gas *Boiler*	*Electric resistance*	Gas *Boiler*
Furnace or *boiler efficiency*	1.0	90% Et	1.0	80% Et
Condenser heat rejection	Cooling Tower	Cooling Tower	Cooling Tower	Cooling Tower
Cooling tower *efficiency* (gpm/hp (L/s·*kW*))—See G3.1.3.11	40.2 (3.40)	40.2 (3.40)	40.2 (3.40)	40.2 (3.40)
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	ASHRAE 90.1 Appendix G, Section G3.1.3.11	ASHRAE 90.1 Appendix G, Section G3.1.3.11	ASHRAE 90.1 Appendix G, Section G3.1.3.11	ASHRAE 90.1 Appendix G, Section G3.1.3.11
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)	18 (10)	18 (10)	18 (10)	18 (10)

Design chilled water supply temperature, °F (°C)	42 (5.56)	42 (5.56)	42 (5.56)	42 (5.56)

Building Type Parameter	Large Office (warm)	Large Office (cold)	School (warm)	School (cold)
Chilled water supply temperature (CHWST) reset *set point* vs outside air temperature (OAT) range, °F (°C)	CHWS 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)	CHWS 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)	CHWS 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)	CHWS 44-54/ OAT 80-60 (6.7-12.2/ 26.7-15.6)
CHW cooling loop *pump*ing control	2-way Valves & *pump* VSD	2-way Valves & *pump*VSD	2-way Valves & *pump*VSD	2-way Valves & *pump* VSD
Heating *pump* 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)
Hot water supply temperature (HWST) range vs outside air temperature (OAT) range	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)
Heat loop *pumping* control	2-way Valves & *pump* VSD	2-way Valves & *pump*VSD	2-way Valves & *pump*VSD	2-way Valves & *pump* VSD

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

Building Type / Parameter	Medium Office (warm)	Medium Office (cold)	Small Office (warm)	Small Office (cold)	Retail (warm)	Retail (cold)
System type	Package VAV - Electric Reheat	Package VAV - Hydronic Reheat	PSZ-HP	PSZ-AC	PSZ-HP	PSZ-AC
Fan control	VSD (with SP Reset)	VSD (with SP Reset)	Constant Volume	Constant Volume	2-speed	2-speed
Main fan power (W/CFM (W·s/L)) proposed ≥ MERV13	0.634 (1.343)	0.634 (1.343)	0.486 (1.03)	0.486 (1.03)	0.585 (1.245)	0.585 (1.245)
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 vs OAT, °F (°C)	NA	HWST: 180-150/ OAT 20-50 (82-65.6/ -6.7-10)	NA	NA	NA	NA
Heat loop pumping control	NA	2-way Valves & ride pump curve	NA	NA	NA	NA
Heating pump power (W/gpm (W·s/L))	NA	16.1	NA	NA	NA	NA

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

Building Type / Parameter	Hotel (warm)	Hotel (cold)	Multifamily (warm)	Multifamily (cold)
System type	*PTHP*	*PTAC with Hydronic Boiler*	*Split HP*	*Split AC*
Fan control	Cycling	Cycling	Cycling	Cycling
Main fan power (W/CFM (W·s/L))	0.300 (0.638)	0.300 (0.638)	0.246 (0.523)	0.271 (0.576)
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	Only CZ 2, 3	No	No	No
Occupied OSA source	DOAS	DOAS	DOAS	DOAS except 3C
Energy recovery ventilator	NA	NA	Yes	Yes except 3C
ERR	NA	NA	60%	60%
DCV	Yes	Yes	No	No
% Area Variable Control	70%	70%		
% Area On/Off Control	0%	0%		
Cooling source	DX, 1stage (heat pump)	DX, 1 stage	DX, 1 stage (heat pump)	DX, 1 stage
Cooling *COP* (net of fan)	3.83	3.83	3.823	3.6504
Heating source	*Heat Pump*	(2) Hydronic *Boiler*	*Heat Pump*	Furnace
Heating *COP* (net of fan) / furnace or *boiler efficiency*	3.44	81% E_t	3.86	80% AFUE
Heating *pump* power (W/gpm (W·s/L))	NA	16.1	NA	NA
Heating coil heating water delta-T, °F (°C)	NA	20 (11.11)	NA	NA
Design HWST, °F (°C)	NA	140 (60)	NA	NA
HWST reset *set point* vs OAT, °F (°C)	NA	HWST: 180-150/ OAT20-50 (82-65.6/ -6.7-10)	NA	NA
Heat loop *pump*ing control	NA	2-way Valves & ride *pump* curve	NA	NA

Appendix CD
REQUIRED HVAC TSPR

CD 101 Required HVAC TSPR. For jurisdictions who wish to adopt a stretch code or HVAC incentive system, make the following changes to Section C403.

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 *HVACTSPR* of the *standard reference design* divided by the applicable mechanical performance factor (MPF) from Table C409.4. *HVACTSPR* 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.

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
Building type	Ocp. Group																		
Office (small and medium)[a]	B	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
Office (Large)[a]	B	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
Retail	M	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
Hotel/Motel	R-1	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
Multi-Family/ Dormitory	R-2	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
School/ Education and Libraries E (A-3)		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 ft^2 (14,000 m^2) 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.

Additional Commentary for Section 409.3

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

Coordination with Proposal CEPI-193-21

Proposal CEPI-193-21 includes the following coordinating language that adds the HVAC TSPR approach as an HVAC energy credit.

1. Section 406.2.2 numbered list items 1 and 7.

2. Section C406.2.2.1,

3. the base energy credits for H01 in Tables C406.1.4(1) through C406.1.4(9).

If this Proposal CEPI-76-21 is not approved for publication in the 2024 IECC then the coordinating language for energy credit H01 in CEPI-193-21 needs to be removed prior to publication.

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.

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.