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MEMORANDUM

To: California Energy Commission
From: NORESCO
Date: June 7, 2024

Subject: Supplemental Justification for CEC-proposed Revisions to 45-day Language of the 2025 Energy Code, Section 140.4(a)3 on AWHP Rated COP

INTRODUCTION

During the 45-day language public comment period for the 2025 Building Energy Efficiency Standards (Energy Code), stakeholders expressed concern that requiring a coefficient of performance (COP) of 3.29 for air-to-water heat pumps (AWHPs) was overly prescriptive and limited the number of available products on the market that could comply with the standard. An analysis was performed to determine if lower COPs could meet the Long-term System Cost (LSC) and Source Energy compliance budgets and conditions required for a revision to the prescriptive requirements under Section 140.4(a)3 in order to ensure flexibility for products that could comply with the requirement.

DISCUSSION

Table 110.2-J in the Energy Code lists minimum rated COPs for AWHPs at three rating conditions that are applicable to the proposed code language.[1] These are summarized in Table 1.

Table 1: Table 110.2-J AWHP Minimum Rated COPs and Rating Points

COP	AWHP Entering Water Temperature [°F]	AWHP Leaving Water Temperature [°F]
3.29	95	105
2.77	105	120
2.31	120	140

[1] The entering air temperature for the evaporator is 47°F dry-bulb.

The Large Office and Large School prototypes were modeled with four-pipe fan coil systems (FPFC) using these three COPs and their corresponding entering and leaving water temperatures, with one exception. The 2.31 COP was modeled with a 130° F leaving water temperature since this is the proposed maximum hot water supply temperature for space heating for nonresidential and hotel/motel buildings in the 2025 Energy Code, see Section 120.2(l). The savings versus the 2022 prescriptive baseline system[2] are presented in Figure 1 through Figure 4 along with the total system incremental cost[3].

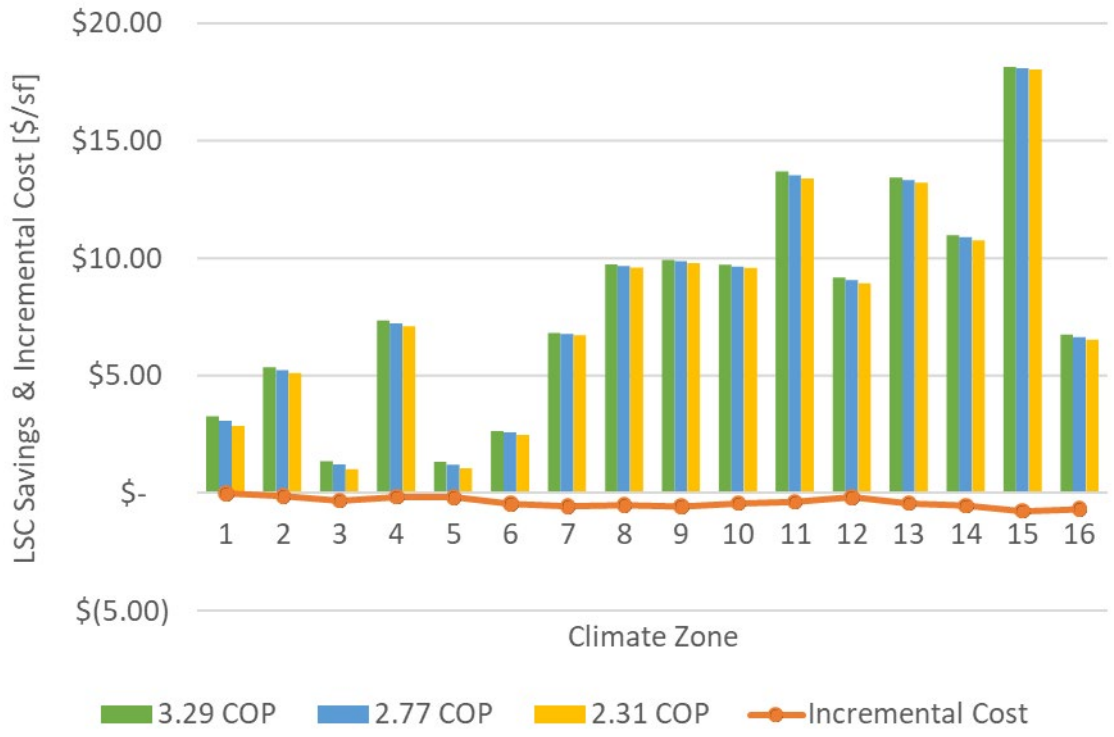

Figure 1: Large Office LSC Savings and Incremental Cost versus the 2022 Prescriptive Baseline

[2] A description of the 2022 prescriptive baseline systems can be found in Section 3.3.1 of the 2025 Nonresidential HVAC Heat Pump Baseline Report. TN#255318-3. Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=255318-3&DocumentContentId=91006.
[3] The total incremental cost was found to not change with variations in COP.

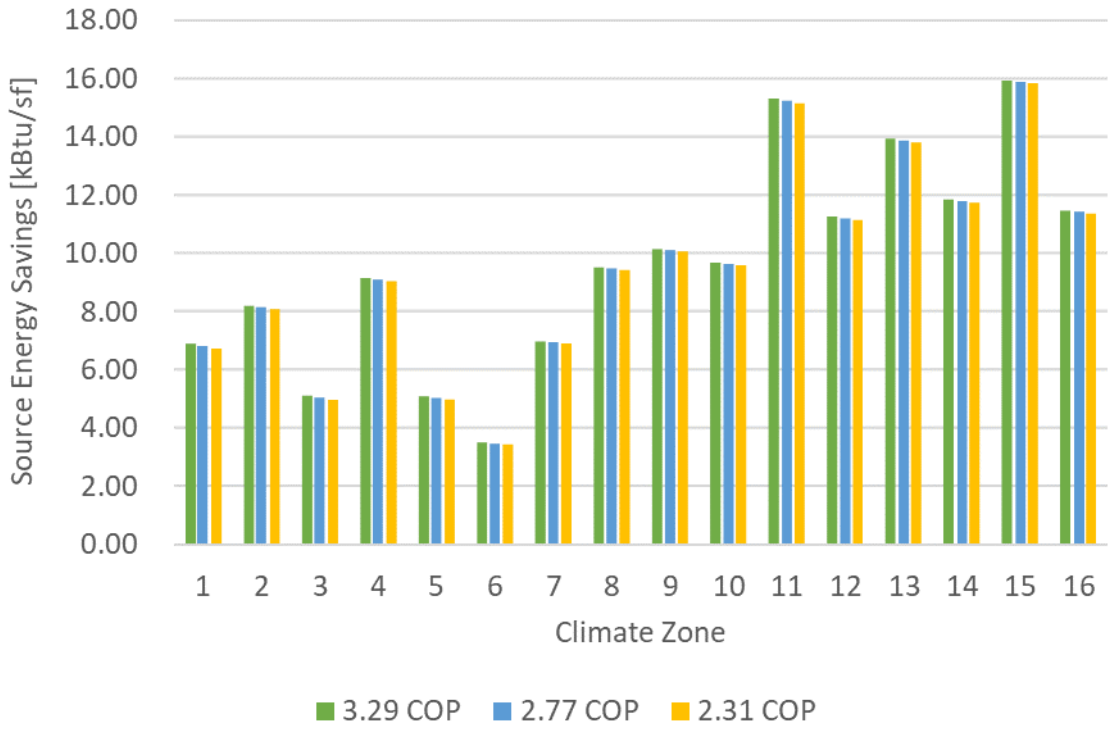

Figure 2: Large Office Source Energy Savings versus the 2022 Prescriptive Baseline

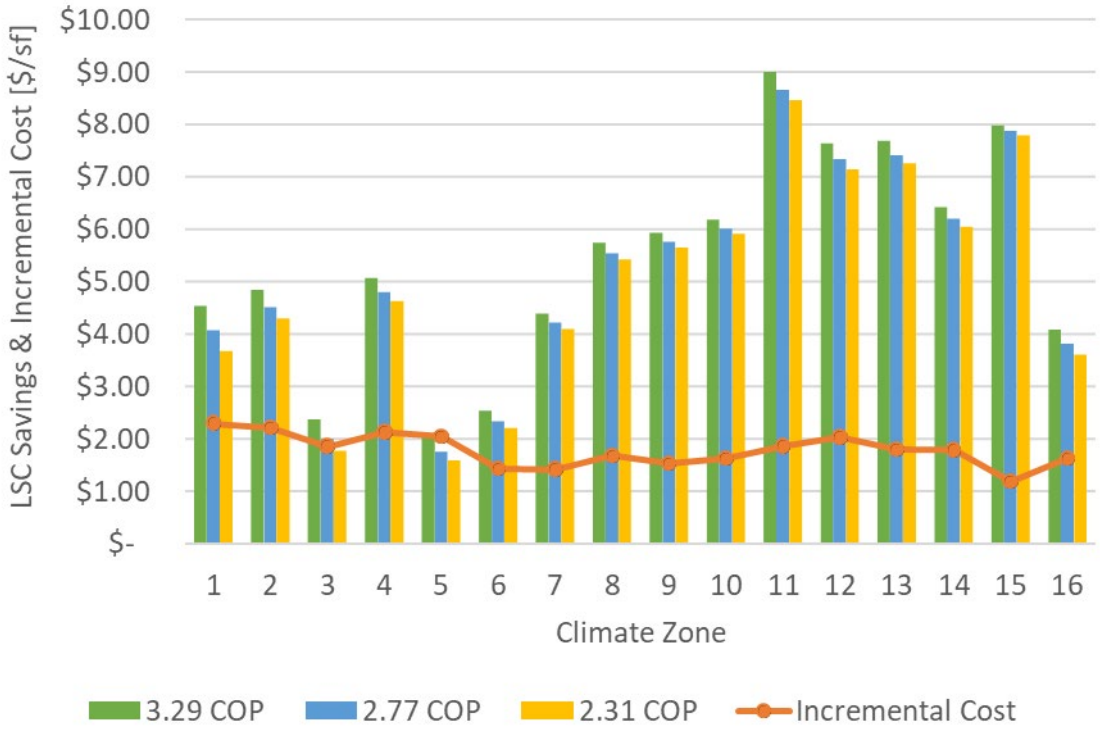

Figure 3: Large School LSC Savings and Incremental Cost versus the 2022 Prescriptive Baseline

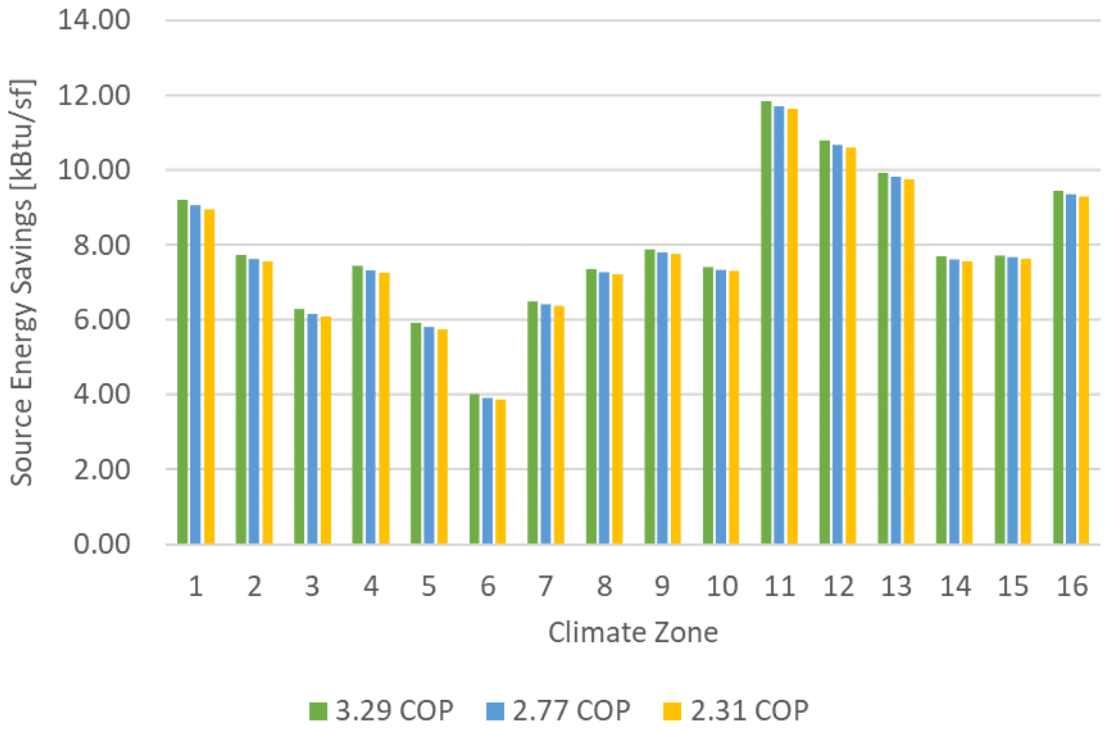

Figure 4: Large School Source Energy Savings versus the 2022 Prescriptive Baseline

The analysis showed that at 2.31 COP, the FPFC systems had LSC and Source Energy savings in excess of the LSC and Source Energy savings for the 2022 prescriptive baseline in all climate zones for both prototypes. AWHPs complying with any leaving water temperature specified in Table 110.2-J of the 45-day language are cost-effective, except for large schools in climate zones 3 and 5. For large schools in climate zone 3, AWHPs are cost-effective at the medium heating temperature rating point. For large schools in climate zone 5, AWHPs are cost-effective at the low heating temperature rating point.

CONCLUSION

A review of comments related to AWHP COPs resulted in further analysis of the 3.29 COP specification for AWHPs in Section 140.4(a)3 of the 45-day language. The analysis showed that AWHPs complying with any leaving water temperature specified in Table 110.2-J of the 45-day language are cost-effective, except for large schools in climate zones 3 and 5. For large schools in climate zone 3, AWHPs are cost effective at the medium leaving water temperature rating point, and for large schools in climate zone 5, AWHPs are cost effective at the low leaving water temperature rating point. Appendix A of this memo provides proposed code language replacing the COP of 3.29 requirement with a reference to Table 110.2-J of the 45-day language, which provides the applicable COP depending on the leaving temperature. This language is recommended as a revision to the 45-day language and addresses stakeholder concerns about flexible compliance options.

APPENDIX A

45-Day Language for Section 140.4(a)3

3. **Multizone zone space-conditioning system types.** Multizone space conditioning systems in office buildings and school buildings not covered by Section 140.4(a)2 shall meet the following requirements.:
   A. **Offices**. Office buildings shall use space conditioning systems complying with one of the following requirements:
      i. The space conditioning system shall be a variable refrigerant flow (VRF) heat pump system with a dedicated outdoor air system (DOAS) providing ventilation. Indoor fans shall meet the requirements of Section 140.4(a)3D. The DOAS shall comply with Section 140.4(a)3E; or
      ii. The space conditioning system shall be a four-pipe fan coil (FPFC) system with a DOAS providing ventilation. The FPFC hot water coils shall be supplied by an air-to-water heat pump (AWHP) space-heating hot water loop which complies with Section 140.4(a)3C. The DOAS shall comply with Section 140.4(a)3E; or
      iii. The space conditioning system shall utilize heating supplied through a hot water loop served by an AWHP which complies with Section 140.4(a)3C. Ventilation systems shall include DCV in all zones. All air systems shall be equipped with a heat recovery system in compliance with Section 140.4(q). A hydronic recirculated-air heating system complying with Section 140.4(a)3F shall be used in climate zone 16.
   B. **School buildings**. The space conditioning system shall be four-pipe fan coil (FPFC) terminal units with a DOAS providing ventilation. The FPFC hot water coils shall be supplied by an air-to-water heat pump (AWHP) space heating hot water loop which complies with Section 140.4(a)3C. The DOAS shall comply with Section 140.4(a)3E.
   C. **AWHP space-heating hot water loop**. Air-source heat pumps used for space-heating hot water shall have a rated heating COP of not less than 3.29 when the outdoor air temperature is 47°F dry-bulb and 43°F wet--bulb at a leaving water temperature not less than the design supply water temperature of the hot water loop. If chilled water produced by an AWHP is used for space-cooling it shall only be used when the AWHP is simultaneously supplying space-heating hot water equal to the AWHP's space-heating hot water demand. The loop fluid volume shall not be less than 8 gallons per nominal ton of heating capacity of the loop. Supplemental heating shall be an electric resistance boiler with a capacity of not greater than 50% of the design hot water loop heating capacity.
   D. **Indoor fans**. Indoor fans shall have an energy consumption at design airflow of not greater than 0.35 W/cfm, shall have not less than three speeds, and shall turn off when there is no demand for heating or cooling in the space.
   E. **DOAS**. DOAS shall comply with Section 140.4(p), shall be equipped with a heat recovery system in compliance with Section 140.4(q), and shall have a maximum fan energy consumption at design airflow of 0.77 W/cfm. If heating coils on the DOAS are included, they shall be hydronic heating coils utilizing the AWHP space-heating hot water loop. If cooling coils are included on the DOAS, they shall be hydronic cooling coils utilizing space-cooling chilled water.

      EXCEPTION to Section 140.4(a)3E: If an AWHP space-heating hot water loop is not included in the design, or space-cooling chilled water is not included in the design, DOAS heating and cooling shall be supplied by heat pump coils.

Proposed 15-Day Language

The following is the recommended revised code language for Section 140.4(a)3.

Section 140.4(a)3C

C. **AWHP space-heating hot water loop**. AWHPs used to comply with the requirements of Section 140.4(a)3ii, 140.4(a)3Aiii, or 140.4(a)3B, when used for space-heating hot water shall meet the following requirements:

   i. The minimum efficiency requirements specified in Table 110.2-J,

   ii. The design water temperature leaving the AWHP shall not be greater than the leaving water temperature at which the installed product is rated. If chilled water produced by an AWHP is used for space cooling, then the heat recovery system shall comply with Section 140.4(s).

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MEMORANDUM

To: California Energy Commission
From: NORESCO
Date: June 7, 2024

Subject: Supplemental Justification for CEC-proposed Revisions to 45-day Language of the 2025 Energy Code, Section 140.4(a)3Aiii on the Flexible Air System Option

INTRODUCTION

The 45-day language for the 2025 Building Energy Efficiency Standards (Energy Code) included proposed prescriptive requirements and options for nonresidential multizone heat pump baselines [1]. This proposal was documented in the technical measures report, Nonresidential HVAC Heat Pump Baseline Measures[2], developed by the California Energy Commission (CEC). NORESCO provided technical support for that report. The 45-day language proposed adding prescriptive requirements for multizone space conditioning systems for offices and schools.

In the nonresidential Heat Pump Baselines measure for offices, Section 140.4(a)3Aiii, one of the options included demand-controlled ventilation (DCV). This option in 140.4(a)3Aiii is called the "Flexible Air System Option" for the purposes of this memo. The proposed revisions in the 45-day language to the minimum ventilation requirements in Table 120.1-A clarified that demand control ventilation does not result in energy savings for offices. As a result, DCV was replaced with other measures to attain sufficient Long-term System Cost (LSC) and Source Energy savings. This memo provides a description of the analysis performed, justifying the proposed 15-day revisions to the 45-day language, to enable the Flexible Air System Option to continue to be available to designers and practitioners for compliance using the prescriptive path.

DISCUSSION

Flexible Air System Option

The 45-day language of the 2025 Energy Code introduced the original version of the prescriptive Flexible Air System Option. This option was originally based on an air-to-water heat pump (AWHP) in combination with variable air volume (VAV) and packaged variable air volume (PVAV) systems in the Large and Medium Office prototypes, respectively. These systems were then combined with three additional energy efficiency measures to attain the Long-term System Cost (LSC) and Source Energy equivalency for the Flexible Air System Option relative to the savings achieved by the options described in Section 140.4(a)3Ai (VRF) and Section 140.4(a)3Aii (AWHP + four-pipe fan coil (FPFC)) systems. The three additional energy efficiency measures that were assessed in combination with the Flexible Air System Option were:

[1] See Appendix A of this memo for regulatory language.
[2] https://efiling.energy.ca.gov/GetDocument.aspx?tn=255318-3&DocumentContentId=91006

- A minimum of 3.29 COP for the AWHP used for space-heating hot water when the outdoor air temperature is 47F dry-bulb and 43F wet-bulb at a leaving temperature not less than the design supply water temperature of the hot water loop, as specified in Section 140.4(a)3C,
- A sensible energy recovery ratio (ERR) of at least 60 percent for the heat recovery ventilator (HRV), as specified in Section 140.4(q), and
- DCV in all zones, as specified in Section 140.4(a)3Aiii.

The proposed 45-day language revisions to the 2025 Energy Code's minimum ventilation requirements in Table 120.1-A clarified that demand control ventilation does not result in energy savings for offices. As a result, other measures were required to replace the savings from DCV and demonstrate LSC and Source Energy equivalency for the Flexible Air System Option.

Revised Flexible Air System Option

To achieve the necessary LSC and Source Energy savings, the following combination of measures was proposed in the 15-day language:

- Maintaining the 3.29 COP by requiring a design water temperature leaving the AWHP that is no greater than 105F, and the 60 percent ERR HRV
- Replacing DCV with an increased AWHP capacity
- Adding parallel fan-powered box (PFPB) terminal units for selected climate zones (CZs) , see proposed regulatory language in Appendix A

Table 1 lists the prototype results for the minimum capacity of AWHP by terminal type and CZ that met the LSC and Source Energy targets. The capacity is expressed as a percentage of design capacity.

Table 1: Minimum AWHP Capacity as a Percent of Design Capacity

Prototype	Terminal Unit Type	CZ 1	CZ 2	CZ 3	CZ 4	CZ 5	CZ 6	CZ 7	CZ 8	CZ 9	CZ 10	CZ 11	CZ 12	CZ 13	CZ 14	CZ 15	CZ 16
Medium Office	VAV	85	85	55	80	80	50	55	50	50	50	95	75	50	95	50	NC
Medium Office	PFPB	90	80	75	75	100	50	50	50	50	50	90	70	50	85	50	95
Large Office	VAV	80	90	90	90	80	NC	NC	NC	NC	100	95	95	100	95	NC	NC
Large Office	PFPB	80	85	55	85	70	NC	50	50	50	50	85	85	70	85	50	95

* NC = Non-Compliant. The combination of increased AWHP capacity (up to 100%) and terminal unit could not meet the required LSC and Source Energy savings.

To address the variation in the results, the following procedure was used to select the capacity and type of terminal unit:

i. For a given CZ, compare the AWHP capacity of the VAV terminal units for the Medium and Large Office prototypes.
ii. Select the largest of these AWHP capacities since this is the capacity that would meet or exceed the LSC and Source Energy compliance budgets for both prototypes.

iii. Repeat steps 1 and 2 for the PFPB terminal units.
iv. If the AWHP capacity from the PFPB terminal unit selection is less than the AWHP capacity from the VAV terminal unit selection, then use that combination of PFPB and AWHP capacity. Otherwise, use the AWHP capacity from the VAV terminal unit case and do not require PFPB.

For example, in CZ 1, the Medium Office with VAV terminal units required 85 percent of design capacity; the Large Office, 80 percent. 85 percent of design capacity would meet the required LSC and Source Energy compliance budgets for the Medium Office and exceed the compliance budgets for the Large Office. So, 85 percent of design capacity is selected for the VAV case. This process, repeated for the PFPB case, results in a selected AWHP capacity of 90 percent.[3] Since the PFPB case results in a larger AWHP, the VAV case's AWHP capacity is selected for complying prescriptively with the proposed 2025 Energy Code 15-day language.

In CZ 3, the Medium Office with VAV terminal units required 55 percent of design capacity, the Large Office, 90 percent. 90 percent of capacity would meet the required LSC and Source Energy compliance budgets for the Large Office and exceed the compliance budgets for the Medium Office. So, 90 percent of design capacity is selected for the VAV case. This process, repeated for the PFPB case, results in a selected AWHP capacity of 75 percent. Since the PFPB case results in a smaller AWHP, the PFPB case's AWHP capacity is selected for complying prescriptively with the proposed 2025 Energy Code 15-day language.

The results of this selection procedure for every CZ are presented in Table 2.

Table 2: Capacity and Terminal Unit Specification for the AWHP Flexible Option

Category	CZ1	CZ2	CZ3	CZ4	CZ5	CZ6	CZ7	CZ8	CZ9	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
AWHP Capacity	85	85	75	85	80	50	50	50	50	50	90	85	70	85	50	95
Required Terminal Unit Type	VAV	PFPB	PFPB	PFPB	VAV	PFPB	PFPB	PFPB	PFPB	PFPB	PFPB	PFPB	PFPB	PFPB	PFPB	PFPB

CONCLUSION

As a result of the analysis described in this memo, the regulatory language in Appendix A identified as "Proposed 15-day Language" was determined to be the most appropriate and is recommended for use in the proposed 15-day language for the 2025 Energy Code.

[3] The additional fan operation in PFPB terminal units over VAV terminal units may outweigh energy savings from heating and fan static pressure. As a result, the overall model may require larger AWHPs to make up for this loss in savings.

APPENDIX A

45-Day Language for Section 140.4(a)3

3. **Multizone zone space-conditioning system types.** Multizone space conditioning systems in office buildings and school buildings not covered by Section 140.4(a)2 shall meet the following requirements.:
   A. **Offices**. Office buildings shall use space conditioning systems complying with one of the following requirements:
      i. The space conditioning system shall be a variable refrigerant flow (VRF) heat pump system with a dedicated outdoor air system (DOAS) providing ventilation. Indoor fans shall meet the requirements of Section 140.4(a)3D. The DOAS shall comply with Section 140.4(a)3E; or
      ii. The space conditioning system shall be a four-pipe fan coil (FPFC) system with a DOAS providing ventilation. The FPFC hot water coils shall be supplied by an air-to-water heat pump (AWHP) space-heating hot water loop which complies with Section 140.4(a)3C. The DOAS shall comply with Section 140.4(a)3E; or
      iii. The space conditioning system shall utilize heating supplied through a hot water loop served by an AWHP which complies with Section 140.4(a)3C. Ventilation systems shall include DCV in all zones. All air systems shall be equipped with a heat recovery system in compliance with Section 140.4(q). A hydronic recirculated-air heating system complying with Section 140.4(a)3F shall be used in climate zone 16.
   B. **School buildings**. The space conditioning system shall be four-pipe fan coil (FPFC) terminal units with a DOAS providing ventilation. The FPFC hot water coils shall be supplied by an air-to-water heat pump (AWHP) space heating hot water loop which complies with Section 140.4(a)3C. The DOAS shall comply with Section 140.4(a)3E.
   C. **AWHP space-heating hot water loop**. Air-source heat pumps used for space-heating hot water shall have a rated heating COP of not less than 3.29 when the outdoor air temperature is 47°F dry-bulb and 43°F wet-bulb at a leaving water temperature not less than the design supply water temperature of the hot water loop. If chilled water produced by an AWHP is used for space-cooling it shall only be used when the AWHP is simultaneously supplying space-heating hot water equal to the AWHP's space-heating hot water demand. The loop fluid volume shall not be less than 8 gallons per nominal ton of heating capacity of the loop. Supplemental heating shall be an electric resistance boiler with a capacity of not greater than 50% of the design hot water loop heating capacity.
   D. **Indoor fans**. Indoor fans shall have an energy consumption at design airflow of not greater than 0.35 W/cfm, shall have not less than three speeds, and shall turn off when there is no demand for heating or cooling in the space.
   E. **DOAS**. DOAS shall comply with Section 140.4(p), shall be equipped with a heat recovery system in compliance with Section 140.4(q), and shall have a maximum fan energy consumption at design airflow of 0.77 W/cfm. If heating coils on the DOAS are included, they shall be hydronic heating coils utilizing the AWHP space-heating hot water loop. If cooling coils are included on the DOAS, they shall be hydronic cooling coils utilizing space-cooling chilled water.

      EXCEPTION to Section 140.4(a)3E: If an AWHP space-heating hot water loop is not included in the design, or space-cooling chilled water is not included in the design, DOAS heating and cooling shall be supplied by heat pump coils.

Proposed 15-Day Language

The following is the recommended revised code language for Section 140.4(a)3.

Section 140.4(a)3Aiii

iii. The space conditioning system shall utilize heating supplied through a hot water loop served by an AWHP that complies with Section 140.4(a)3C with a design leaving water temperature no greater than 105ºF. Ventilation systems serving zones served by the space conditioning system shall be equipped with a heat recovery system in compliance with Section 140.4(q). A hydronic recirculated-air heating system complying with Section 140.4(a)3F shall be used in climate zones 2 through 4 and 6 through 16.

Section 140.4(a)3C

C. **AWHP space-heating hot water loop.** AWHPs used to comply with the requirements of Section 140.4(a)3Aii, 140.4(a)3Aiii, or 140.4(a)3B, when used for space-heating hot water shall meet the following requirements:

   i. The minimum efficiency requirements specified in Table 110.2-J,

   ii. The design water temperature leaving the AWHP shall not be greater than the leaving water temperature at which the installed product is rated. If chilled water produced by an AWHP is used for space-cooling, then it shall comply with Section 140.4(s),

   iii. The loop fluid volume shall not be less than 8 gallons per nominal ton of heating capacity of the loop, and

   iv. Supplemental heating shall be provided by an electric resistance boiler with a capacity of not greater than the following percentage of the design space-heating hot water loop heating capacity:

      a. For systems complying with Section 140.4(a)3Aii and 140.4(a)3B shall not be greater than 50%.

      b. For systems complying with Section 140.4(a)3Aiii:

         i. In climate zone 16, shall not be greater than 5%,

         ii. In climate zone 11, shall not be greater than 10%,

         iii. In climate zones 1, 2, 4, 12, and 14, shall not be greater than 15%,

         iv. In climate zone 5, shall not be greater than 20%,

         v. In climate zone 3, shall not be greater than 25%,

         vi. In climate zone 13, shall not be greater than 30%,

         vii. In climate zones 6 through 10 and 15, not be greater than 50%.