DOCKETED	
Docket Number:	24-BSTD-01
Project Title:	2025 Energy Code Rulemaking
TN #:	256191
Document Title:	Taylor Engineers Comments - Comments on Nonresidential HVAC Heat Pump Baseline Proposal
Description:	N/A
Filer:	System
Organization:	Taylor Engineers
Submitter Role:	Public
Submission Date:	5/6/2024 9:51:12 AM
Docketed Date:	5/6/2024

Comment Received From: Taylor Engineers
Submitted On: 5/6/2024
Docket Number: 24-BSTD-01

Comments on Nonresidential HVAC Heat Pump Baseline Proposal

Additional submitted attachment is included below.

To:	California Energy Commission
From:	Taylor Engineers
Subject:	Docket Number: 24-BSTD-01 45-Day Language
Date:	May 6, 2024

We support the judicious use of heat pumps in Title 24 Part 6 to help address California's need for decarbonization in the built environment, where it can be demonstrated to be cost effective, reduce energy use, and provide designers with effective compliance pathways. However, we are deeply concerned with the proposed heat pump baselines in 140.4(a)3 as written. The proposed changes significantly and unduly restrict prescriptive compliance options for HVAC systems in offices and schools. The narrowly defined baselines effectively exclude most multi-zone HVAC systems that are used in practice today and many all-electric systems that may provide better efficiency and lifecycle cost. The CEC's workshop presentations on July 27, 2023 and August 24, 2023 did not provide sufficient detail and justification for a measure that would have profound impacts to typical design practice for office and school HVAC systems. The Nonresidential HVAC Heat Pump Baseline Measures Report that was posted to the docket on March 28, 2024 along with the 45-day language was provided extremely late in the process. This significantly limits the opportunity for affected stakeholders to adequately participate in the public review process, and does not provide sufficient time to address serious flaws in the supporting analysis and proposal. The proposal as written will have significant negative impacts to designers; contractors; building owners, occupants, and operators; and equipment manufacturers. Below we describe some of the issues and concerns with the current proposal and the analysis described in the Heat Pump Baseline Report.

First Costs and Maintenance Costs

There are clear and significant errors in the first cost and maintenance cost analyses that were used to evaluate the cost effectiveness of the proposed requirements. With these concerns taken into consideration, along with issues with the energy analysis, we believe that the heat pump baselines in 140.4(a)3 will not be cost effective to justify the proposed changes:

- FPFC + DOAS + AWHP is a very uncommon HVAC system type and extremely unlikely to have lower first costs than the baseline system types for large offices and schools. Can you reference a single instance where such a system has ever been designed and built – we have not ever seen one. It is astounding that the CEC would propose requiring an HVAC system type that the industry itself has not identified and built. The Heat Pump Baseline Report ostensibly shows higher first costs for most of the reported components of the FPFC system in Table 41, and higher maintenance costs in Table 42, but yet the cost effectiveness summary for large offices in Table 44 reports the proposed system type to have lower overall first costs and maintenance costs than the VAV baseline. That conclusion defies common sense and indicates major errors in the analysis and assumptions for justifying this measure. The baseline and proposed HP systems are comparable between the large office and large school prototypes, but yet the proposed HP systems for large schools have significantly higher first costs and maintenance costs in Table 45. Some examples of why the FPFC systems have unquestionably higher first costs:
    - An AWHP is roughly 5 times more expensive than a boiler, plus the cost of the supplemental electric boiler. The incremental electrical infrastructure costs associated with the heat pump and electric boiler would also be significant but do not appear to be included in the analysis.
    - The FPFC terminals are listed as 3 times more expensive than VAV boxes.
    - The FPFC requires an extra chilled water pipe distribution loop that may have been inadvertently omitted as it is not listed in Table 41, and which isn't needed for VAV.
    - FPFCs will require condensate pumps throughout.
    - It is also not clear whether the analysis includes costs in the proposed case for heat recovery and VAV boxes at each zone for the DOAS system to meet mandatory occupied-standby and DCV requirements, as well as oversizing the DOAS system to 0.3 cfm/ft2 per exception 6 to 140.4(e)1.

Table 41 also does not provide costs for gas boilers and PVAVs to be able to judge whether the costs assumed are reasonable. Overall, without further detail on quantities we cannot specifically identify errors in the first cost analysis, but the finding is very clearly erroneous based on simple inspection and engineering judgment.

- For small and medium office buildings, VRF + DOAS is a viable all-electric HVAC system type, however, the first cost assumptions also appear to be flawed. For example, the VRF costs are assumed at $0.50/ft2 in Table 41. For a realistic average of 800 ft2/zone, this assumption sets VRF installed costs at $400 per fan coil, which is impossibly low. Further, the cost of VRF systems is expected to increase as new refrigerant restrictions go into effect on January 1, 2026, which is the same effective date as the 2025 version of the building energy standard. The cost analysis must consider the increased VRF system costs associated with the mildly flammable A2L refrigerants.
- For schools, DCV is a mandatory requirement in densely occupied spaces like classrooms. DCV requires that VAV terminals are provided to each zone, even for DOAS, in order to effectively maintain CO2 concentrations. Designers often overlook this detail and it is unclear whether the added cost is included in the schools analysis.
- The Heat Pump Baseline Report acknowledges the increased maintenance costs with FPFC compared to VAV reheat terminals but the difference in annual maintenance cost per unit is severely underestimated. MERV 13 air filters in 1" or 2" depths would require changeout 3 or 4 times per year to maintain filtration efficiency with electret filters and to prevent excessive pressure drop as filters become loaded. See this typical 1" MERV 13 filter, for example, which "lasts up to 3 months." Even at a very fast pace of 5 minutes per changeout, 4 times per year, and labor at $100/hour, the labor cost for filter changeouts alone would be $2000/yr. Adding on the additional cost of the filters, old filter disposal, and maintenance for terminal fans, extra control valves, and condensate pumps, the estimate in the analysis is low by at least an order of magnitude.

Energy Analysis

There are clear and significant errors in the energy analyses that were used to evaluate the cost effectiveness of the proposed requirements. With these concerns taken into consideration, along with issues with the cost analyses, we believe that the heat pump baselines in 140.4(a)3 will not be cost effective to justify the proposed changes:

- Demand Controlled Ventilation: The proposed option in Section 140.4(a)3.A.iii requires DCV in all zones. DCV is already a mandatory requirement in densely occupied spaces, where it has been repeatedly demonstrated in past code cycles to provide cost effective energy savings. Expanding this requirement to all other spaces (i.e. spaces with lower occupant densities) will add costs without any associated energy savings. DCV allows ventilation rates to be lowered to the area-based ventilation rate of 0.15 cfm/ft2 when CO2 concentrations are low, but that is typically also the maximum design ventilation rate for low density spaces like offices. In other words, there is no opportunity to reduce ventilation rates with DCV. We understand that this requirement was added based on a misunderstanding of DCV requirements. This requirement must be deleted.
- Airside heat recovery: The proposed option in Section 140.4(a)3.A.iii seems to require airside heat recovery everywhere. The existing prescriptive requirements in 140.4(q) already require heat recovery in all climates and system configurations where it could be shown to be cost effective. It is very unlikely that airside heat recovery is cost effective in the milder climates and at lower outdoor air fractions. Nevertheless, if the new analyses show heat recovery to be effective in all climates and all outdoor air fractions, those changes should be made to 140.4(q), not just to this one baseline system. Regardless, the language in the requirement is unclear and needs to be fixed if it is maintained.
- VRF efficiency ratings are unrealistically high: Third party testing of VRF equipment have shown that AHRI-rated efficiencies are overstated, up to a factor of 2 higher than measured EER values in lab testing. The VRF system efficiency in heat recovery was also found to be significantly worse than commonly understood. Even in real life installations, the measured energy performance of actual VRF systems has been well below expected performance based on AHRI ratings (for example: the ASHRAE Headquarters).

- Unrealistic Title 24 modeling rules. The prescribed modeling rules in the ACM Manual are unrealistic and are not representative of typical building operations, where the differences will show biases against certain system configurations.
  - The CBECC internal load profiles are unrealistically high and monolithic. This favors fixed fan speed systems like VRF/DOAS and does not accurately reflect the energy efficiency potential of VAV systems. With realistic load profiles, VAV reheat has much lower total fan energy than DOAS, as illustrated in this analysis. ASHRAE RP-1515 was a long term study of many office buildings with thousands of zones. When the VAV zone minimums were reduced from 30% to 10-15% almost all of the zones spent almost all their time at the new zone minimums, meaning that real zone loads are rarely more than 10-15% of their design values. It is also not clear whether the energy analysis correctly defined VAV zone minimums according to prescriptive requirements.
  - CBECC does not model DCV or occupied-standby (OS) controls because the prescribed occupancy schedules are almost always at near design occupancy. Both of these are major energy saving measures, particularly with low office occupancies that are typical today and both are commonly installed in VAV systems. By contrast, VRF/DOAS systems are not typically installed with mandatory OS controls because of the need for VAV terminals throughout.
  - Not only does VRF/DOAS have higher annual cooling energy in most CA climates (due to the lack of an air economizer), it also has higher peak cooling energy because every zone is provided with its maximum ventilation every hour. With VAVR there will generally always be some ventilation diversity, DCV zones and OS zones that are not fully occupied, that allows for lower peak ventilation rates.
  - Most energy models of VAV systems do not accurately model zone minimum flow rates, which are now required to be no higher than minimum ventilation (typically about 10% of zone maximums). Most models use minimums of 20% (per the out-of-date 2019 version of Title 24) or higher.

Reduced Indoor Air Quality with DOAS
In coastal California climates, the mild weather conditions are ideal for air economizing. Accordingly, decades of Title 24 updates have increasingly made economizer requirements more stringent. Yet, the main prescriptive baselines mandate that ventilation is provided via DOAS, which effectively eliminates air economizers and reduces the overall outdoor air provided to occupied zones. This change will reduce indoor air quality compared to systems with economizers. This detailed analysis showed that air economizer systems average about 0.4 cfm/ft2 of outdoor air, which is far more than the 0.15 cfm/ft2 typically provided by DOAS. Most air economizer systems have the ability to provide at least 4 to 6 times as much outside air as DOAS. During the COVID pandemic, HVAC systems with economizers were able to provide additional outdoor air to reduce the risk of disease transmission, whereas DOAS systems could only provide minimum rates. Air economizer systems will have much greater flexibility to deal with future pandemics and to comply with ASHRAE Standard 241.

Other Concerns:
- Infeasible AWHP Efficiencies. The requirement for an AWHP with COP of 3.29 in 140.4(a)3.C effectively requires design hot water supply temperatures of close to 105F. There are no AWHPs available that can achieve that COP at the defined ambient and 130F supply temperatures.
- Contradictory Electric Resistance Requirements. The AWHP requirement in 140.4(a)3.C requires that 50% of the design heating capacity be provided by an electric resistance heater. This is directly incompatible with the existing prohibition of electric resistance heating in 140.4(g). Exception 2 to Section 140.4(g) allows electric resistance heating as a supplement where the heat pump provides a minimum of 75% of the design heating load. If the cost effectiveness analysis correctly evaluates a code-compliant system, the increase in AWHP capacity from 50 to 75% will significantly increase first costs. Please ensure that the analysis is updated accordingly.
- Required DOAS Oversizing. Each DOAS system in the baselines must be oversized to 0.3 cfm/ft2 as required by Exception 6 to 140.4(e)1. It is not clear if this was considered in energy or cost analysis.
- VRF Refrigerant Issues. Most VRF systems today use refrigerant R-410A which has a global warming potential (GWP) of around 2000. New EPA regulations will limit VRF systems installed after January 1, 2026 to use refrigerants with a GWP<700. These regulations will generally require manufacturers to shift VRF

products to use A2L refrigerants like R-32 and R-454B, which in turn will effectively reduce the size of VRF systems because of more stringent volume restrictions for mildly flammable refrigerants. Manufacturers are still racing to develop new product lines that can comply with the new restrictions, but this shift is expected to increase costs for VRF systems based on the new products and the smaller system sizes. The cost effectiveness analysis for VRF systems must consider the expected increases in first costs given that the effective date for the refrigerant restrictions directly coincide with the effective date of Title 24-2025.

- Refrigerant leaks with VRF. VRF systems generally require long, field-constructed refrigerant piping runs that are notoriously prone to slow leaks, despite passing pressure testing during start up. Because of the long piping runs, many of which are concealed, it is very difficult to find and repair these leaks so many owners are forced to simply recharge their systems periodically. It does not appear that the analysis has considered the cost and emissions impacts of these leaks.
- VRF Expected Useful Life. Table 42 shows VRF with an expected EUL of 20 years, which is very unrealistic. The EUL of VRF is very widely listed at 10 to 15 years through dozens of online sources. Our experiences match the shorter end of that time frame.
- The indoor fans section in 140.4(a)3.D requires that indoor fans turn off when there is no demand for heating or cooling in the space. For ducted fan coils, most designers integrate ventilation air with the fan coils, so that the fan coils can handle tempering of the outdoor air and the downstream ductwork and diffusers can support both temperature control and ventilation. This requirement would add cost by requiring tempering within the DOAS unit and additional duct distribution and diffusers that are dedicated to the DOAS system. It is also not clear that fan coils can meet the 0.35 W/cfm fan power limit and overcome the pressure drop associated with mandatory MERV-13 air filters. As the energy analysis appears to have assumed costs based on simplified $/cfm rules-of-thumb, rather than actual equipment selections, it does not appear that these cost impacts have been considered.
- The DOAS section in 140.4(a)3.E requires that hydronic coils in the DOAS unit be connected to the AWHP heating loop. Though this may be desirable in some cases, there are certainly cases where it would be preferable to provide DX heating in the DOAS unit instead. It will make the DOAS system more expensive in most cases, and it could very well be less efficient depending on the amount of heat recovery you are getting out of the AWHP. Hydronic heat pumps are less efficient than DX heat pump RTUs even without accounting for distribution losses and pump energy, so forcing hydronic is not only unnecessary, it is likely more energy intensive in many applications. There are also situations where you may have a DOAS unit far away from the rest of your hydronic system, so running piping a long distance would be worse than simply using a packaged heat pump. As the energy analysis appears to have assumed costs based on simplified $/cfm rules-of-thumb, rather than actual equipment selections, it does not appear that these cost impacts have been considered.
- Energy Equivalence Among Prescriptive Options. A key issue with the proposal is the expectation that each option within a prescriptive requirement must be energy equivalent. This expectation appears to have driven the development of the option 140.4(a)3.A.iii with extra requirements in an attempt to provide energy equivalence, that achieve additional stringency above the current code. That is not a statutory requirement in the Warren-Alquist Act and, in fact, there are precedents from recent code cycles where a single prescriptive option was evaluated to be cost effective, and other options were added for flexibility without any further energy analysis or modeling. For example, consider the lab exhaust requirements in 140.9(c)3 that were added in the 2019 cycle. The fan power limit in 140.9(c)3B was demonstrated to be cost effective, but no energy analysis or cost effectiveness evaluations were done for option 140.9(c)3D. Neither of the alternative options in 140.9(c)3C and 140.9(c)3D were capable of being modeled in CBECC. The HP Baseline Report states on page 44 that “alternative compliance option models need to perform at least as well as the heat pump baseline systems”, but yet Tables 31 and 32 show that the alternative options are not merely energy equivalent but significantly exceed the performance of the heat pump baseline. Though we aspire to continually advance the code and increase stringency, the proposed baselines are too constraining and should be refocused to allow for a wider range of heat pump solutions.
- Though the performance approach remains an alternative compliance pathway that provides greater flexibility than the proposed heat pump baselines, that adds cost and schedule impacts for many projects that could otherwise comply prescriptively. There are widespread concerns among the design community about limitations and bugs within the CBECC compliance software, and acknowledgment that the compliance

results are not a good indicator of proposed system energy performance. Other promising heat pump solutions for large multizone systems, like dual fan dual duct (DFDD) served by air-to-air heat pumps, and variable volume and variable temperature (VVT) with air-to-air heat pumps cannot be modeled in CBECC, and perhaps not even in EnergyPlus. We are concerned that narrowly defining prescriptive baselines that are not used in current practice, and that are likely to be less efficient and more expensive to build and operate, will simply force most projects to use the performance approach. It is unlikely that such a shift will actually deliver better energy efficiency results.

- Schools vs. Offices. There is no reason to have separate requirements for School and Office buildings as many HVAC system types are often appropriate for both building types. VRF has historically been a viable solution for some School requirements.
- Other Cleanup. Delete hydronic recirculating statement from 140.4(a)3iii due to invalid reference to 140.4(a)3F. There is no 140.4(a)3F. Reword simultaneous cooling and heating clause: As written, this clause appears to only allow AWHPs to provide cooling if there is also a heating load present.

If the heat pump baselines in 140.4(a)3 are found to be cost effective despite the many concerns noted above, we respectfully request that the CEC consider revising the language to allow more design flexibility while still encouraging the use of heat pumps. There are many heat pump solutions that can provide superior cost effectiveness and energy efficiency compared to the proposed VRF and FPFC systems.

Below is one suggested revision:

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 utilize heating supplied by an air source heat pump. Ventilation systems shall include DCV in all zones with design occupant density greater than or equal to 25 people per 1,000 square feet (40 square feet or less per person). All air systems designed to operate to the criteria listed in either Table 140.4-J or Table 140.4-K shall include an exhaust air heat recovery 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.
   A. If VRF is included, the indoor unit fans shall have an energy consumption at design airflow of not greater than 0.35 W/cfm and shall have not less than three speeds.
   B. If DOAS is included, it 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.

Below is another suggested revision that addresses many of our primary concerns and minimizes the amount of change from the current proposal:

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. Use a space conditioning system 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.
      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.
      iii. The space conditioning system shall utilize heating supplied by an air source heat pump.

B. Ventilation systems shall include DCV in all zones with design occupant density greater than or equal to 25 people per 1,000 square feet (40 square feet or less per person). All air systems designed to operate to the criteria listed in either Table 140.4-J or Table 140.4-K shall include an exhaust air heat recovery 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.

C. If VRF is included, VRF indoor unit fans shall have an energy consumption at design airflow of not greater than 0.35 W/cfm and shall have not less than three speeds.

D. If DOAS is included, it 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.