TITLE 24, PART 6 | 2025 CODE CYCLE

Residential HVAC Performance

Codes and Standards Enhancement (CASE) Proposal

SF and MF HVAC Performance

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CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

Speaker Introduction

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…among others!

Agenda

Background, Market Overview and Analysis, Technical Feasibility	*20 min*
Design (Load Calc, System Selection) and Supplementary Heating	*20 min*
Discussion	*15 min*
Defrost and Crankcase Heating	*20 min*
Discussion	*15 min*
Break	*15 min*
Refrigerant Charge Verification and Variable Speed/Zoned Systems	*20 min*
Discussion	*15 min*
Cost / Energy Impacts and Compliance / Enforcement	*20 min*
Discussion	*15 min*
General Discussion and Next Steps	*20 min*

Residential HVAC Performance Measures

- Design (Load Calculation and System Selection)
- Supplementary Heating
- Defrost
- Crankcase Heating
- Refrigerant Charge Verification
- Variable Capacity / Zoned Systems

Including HVAC systems for both Single Family and Multi-Family Residences, and not including Heat Pump Baseline—i.e. not “Should I put in a heat pump?” but **“How can I make sure my heat pump performs?”**

i.e. not “Should I put in a heat pump?” but **“How can I make sure my heat pump performs *well?*”**

Design
(Load Calculation and System Selection)

- Background
- Market Overview
- Technical Considerations

Design: Background

Sizing is important for performance, particularly for heat pumps which require a careful **balance** between:

- **Oversizing**
  inefficient, uncomfortable
  and
- **Undersizing**
  excessive operation of strip heating, insufficient airflow to achieve whole dwelling comfort, lack of humidity control

Proposed Code Changes Would…

- Require sizing of systems according to ACCA Manuals J and S, with modifications
- Use Manual J design temperatures
- Allow for simplified inputs in some cases
- Encourage infiltration measurement when installing a new system in an existing dwelling
- Make system selection more specific to CA climates and address sizing of heat pumps for both cooling and heating loads.
- Avoid “cascading” safety factors by removing some redundancies that lead to oversizing.
- Require more attention to design of ducts and diffusers to avoid drafts.

- Add more strength to current requirements, by requiring sizing of systems according to ACCA Manuals J and S, with modifications
- Use Manual J design temperatures for load calculations
- Make it easier to calculate loads, by allowing for simplified inputs in some cases
- Make it more accurate, by encouraging infiltration measurement when installing a new system in an existing dwelling
- Make system selection more specific to California climates and address sizing of heat pumps for both cooling and heating loads.
- Avoid “cascading” safety factors by removing some redundancies that lead to oversizing.
- Require more attention to design of ducts and diffusers to avoid drafts.

Impacts of Sizing

Research by NIST suggests:

In heating dominated climates:

- Capacity can be slightly under- or significantly oversized without much of a penalty.

In cooling dominated climates:

- Cooling capacity can be undersized without much of a penalty (especially if the ducts are oversized for the capacity, where there is actually a 7.5% benefit).
- Capacity can be oversized only if the ducts are correspondingly oversized (avoiding what would be a penalty of about 2.5% for every 10% the capacity is oversized).

Analysis of data from "Sensitivity Analysis of Installation Faults on Heat Pump Performance", Domanski, Henderson, and Payne, 2014. NIST Technical Note 1848.

Design: Current Code Requirements

- Manual J or similar is required, but not verified
- Climate Data in JA2.2 to be used:
  - 1% for cooling
  - Winter Median of Extremes for heating
- Manual S is required in Title 24, Part 11, but not verified

Load Calculation: Proposed Requirements

Mandatory: Manual J load calculation would be required.

- Design temperatures based on the ASHRAE 2021 Reference Standard data, provided in a new JA2.2: California Design Location Data.
- Load calcs would use:
  - Heating design temperatures no lower than the 99% DB
  - Cooling design temperatures no higher than 1% DB and MCWB.
- Simplifying Assumptions would be allowed for:
  - Like-for-like system replacements
  - Existing systems serving an addition that is less than 144 ft^2.
- Simplifying Assumptions not allowed for heat pumps with strip heating.

ASHRAE - American Society of Heating Airconditioning and Air Conditioning Engineers California Design Location Data

Load Calculation: Proposed Requirements

In existing homes, measurement of infiltration rates recommended.

Mandatory requirements when measured infiltration is not used:

- The Manual J infiltration value used in the calculations no worse than “Average”.
- Would require disclosure that the system could be undersized and future infiltration reduction measures are recommended to improve comfort.

Mandatory requirements when measured infiltration is used:

- Manual J infiltration value no greater than measured infiltration.
- Infiltration test per RESNET protocols for existing homes.
- If measured CFM50 is greater than conditioned floor area, would require disclosure that the system size could have been reduced with very cost-effective infiltration reduction measures.

System Selection: Proposed Requirements

Mandatory: For heat pumps, installed equipment sized based on ACCA Manual S-2023, substituting the limits to the right.

Mandatory: Heating-only systems use Manual S-2023 Table N2.5.

Mandatory: Cooling-only systems subject to the Cooling limits to the right.

Exception: The single speed Max limits are waived if duct size is verified, per Verified Duct Design protocol.
Note this means that in some highly cooling-dominated climate zones, Verified Duct Design will be mandatory.

Exception: The heating capacity can be lower if there is no available equipment that has a capacity that will meet the Manual J load.

Minimum Capacity:

- Heating Capacity ≥ Heating Load

Maximum Capacity:

Only where Total Cooling Load > Heating Load:

Single Speed:

- Cooling Capacity ≤ Cooling Load + 6,000 Btuh AND
- Heating Capacity ≤ Heating Load + 12,000 Btuh*

Minimum Load (Multi- or Variable-Speed):

- Cooling Capacity ≤ Cooling Load * 0.80 AND
- Heating Capacity ≤ Heating Load * 0.80

Comparison of System Selection Limits

Manual S-2014:

Cooling Dominated CZs (6-15)	Sensible Cooling		Latent Cooling		Total Cooling		Heating	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1 Speed					C/L ≥ 0.9	C/L ≤ 1.15		
2 Speed					C/L ≥ 0.9	C/L ≤ 1.2		
Variable					C/L ≥ 0.9	C/L ≤ 1.3		
Heating Dominated CZs (1-5, 16)	Sensible Cooling		Latent Cooling		Total Cooling		Heating	
	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
1 Speed					C/L ≥ 0.9	C ≤ L+15,000		
2 Speed					C/L ≥ 0.9	C ≤ L+15,000		
Variable					C/L ≥ 0.9	C ≤ L+15,000		

Manual S-2023 (proposed):

		Sensible Cooling		Latent Cooling		Total Cooling		Heating	
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
HIGH SPEED	1 Speed	C/L ≥ 0.90		C/L ≥ 1.00		C/L ≥ 0.90	C ≤ L + 6,000		
	2 Speed								C/L ≤ 1.20
	Variable							C/L ≥ 1.00	
LOW SPEED	1 Speed						n/a		n/a
	2 Speed						C/L ≤ 0.77		C/L ≤ 0.80
	Variable						C/L ≤ 0.80		C/L ≤ 0.80

Title 24-2025 (proposed):

Design Cooling Load > Design Heating Load:		Total Cooling		Heating	
		MIN	MAX	MIN	MAX
HIGH SPEED	1 Speed		C ≤ L + 6,000†	C/L ≥ 1.00	C ≤ L + 12,000†
	2 Speed			C/L ≥ 1.00	
	Variable			C/L ≥ 1.00	
LOW SPEED	1 Speed		n/a		n/a
	2 Speed		C/L ≤ 0.77		C/L ≤ 0.80
	Variable		C/L ≤ 0.80		C/L ≤ 0.80
Design Heating Load > Design Cooling Load:		Total Cooling		Heating	
		MIN	MAX	MIN	MAX
HIGH SPEED	1 Speed			C/L ≥ 1.00	
	2 Speed			C/L ≥ 1.00	
	Variable			C/L ≥ 1.00	
LOW SPEED	1 Speed				
	2 Speed				
	Variable				

C = Selected Total Cooling or Heating Capacity at the local design temperature.
L = Manual J Total Cooling or Heating Load at the local design temperature.

Design Verification: Proposed Requirements

Mandatory: Propose requiring that designer submit on a CF1R to the local jurisdiction for plan review:

- Manual J and S Calculations
- A duct layout or room-by-room list of ducts and diffusers meeting [TBD] requirements of (based on ACCA Manuals D and T)
- A self-certification that air distribution design meets best practices, described in ACCA Manual T.

Supply

Room	CFM	Make	Model	Size	Room Throw	Manuf Throw at ___ FPM	Noise Cr.
Dining	95	Shoemaker	FC-CB10C	6x6	12′	13′ at 50 FPM	<20
Great Rm 1	165	Titus	904	10x6	16′	15′ at 50 FPM	25
Etc.							

Total airflow: 1,000 CFM

Return

Room	CFM	Make	Model	Size	Depth	Net Free Area SF	Velocity	MERV
Hallway	750	Shoemaker	920FG2	20x30	2″	3.0	250 FPM	13
Master	250	Shoemaker	920FG2	20x20	2″	2.0	125 FPM	13

Total airflow: 1,000 CFM

Air Distribution Minimum Best Practice Guidelines Draft

- ◊ Designer performed an accurate Manual J total load calculation and room by room calculation
  Bonus: Blower door maximum CFM50 used and specified for verification
- ◊ Designer evaluated heating and cooling loads and selected equipment capable of meeting dry climate airflow targets of equal to or greater than 450 CFM/Ton
- ◊ Designer established a total heating and cooling airflow amount (# tons x 450 CFM/Ton)
- ◊ Designer divided total airflow above (manually or program) into each habitable space
- ◊ Designer selected supply terminal device locations to
  (1) minimize the overall size of the distribution system
  (2) provide uniformity in duct resistance by centrally locating equipment
  (3) provide adequate room air mixing
  (4) eliminate occupant drafts
  (5) reduce objectionable noise by location (for example, none over pillows)
  (6) reduce objectionable noise by type (for example sidewall vs curved blade)
- ◊ Designer used terminal device information supplied by the manufacturer to design the supply and return system.
- ◊ Designer listed all terminal device performance as follows:

Design: Market Overview and Analysis

Current Market

- Systems in all sizes are available
- Many contractors do not carry out sizing calculations

Market Trends

- Sizing calculations are probably done more consistently for new construction and production homes than for system replacement

Market Barriers

- Many contractors are not well prepared to do accurate sizing calcs (despite current requirement)
- Many contractors do not own Blower Doors and do not know how to do a test

Design: Technical Considerations

Technical Considerations

- Builders and contractors believe that undersizing can create comfort problems but overlook the comfort problems created by oversizing.
- When heat pumps are undersized, strip heating energy use can be excessive.
- As the market switches from furnaces to heat pumps, it is critical to do proper air distribution design to avoid drafts and improve comfort.

Technical Barriers and Potential Solutions

- Collecting inputs for load calculation is time consuming.
  - Could reduce this time by allowing simplification where outputs are not sensitive to input accuracy.
  - Time may be better spent measuring infiltration rates.
- More training will be needed

More training will be needed for designers (proper load calculation, system selection, air distribution design), and installers (infiltration rate measurement).

Supplementary Heating

- Background
- Market Overview
- Technical Considerations

Supplementary Heating: Background

- Moving towards full electrification, electric resistance strip heating will become an unacceptable waste of energy.
- It can also be a major contributor to winter morning peak demand.
- With good design, most systems in California do not need supplementary heating.
- If systems do use supplementary heating, it needs to be carefully controlled.

Proposed Code Changes Would…

- Ensure that electric resistance strip heaters do not use an excessive amount of energy:
  - More attention paid to proper sizing when strip heating is used.
  - Controls to ensure strip heating does not run at milder temperatures, while still allowing operation during defrost (but see Defrost Measure about minimizing this).
  - Limit the size of strip heating
  - Similarly, ensure that dual-fuel systems use as little fossil fuels as possible.

Proposed Code Changes Would…

Ensure that electric resistance strip heaters do not use an excessive amount of energy:

- Make sure that more attention is paid to proper sizing when strip heating is used.
- Add controls to ensure that strip heating does not run at milder temperatures, while still allowing operation during defrost (but see Defrost Measure about minimizing this).
- Limit the size of strip heating so that if they run too often, the waste will be minimized.

Similarly, ensure that dual-fuel systems use as little fossil fuels as possible.

Supplementary Heating: Current Code Requirements

110.2 MANDATORY REQUIREMENTS FOR SPACE-CONDITIONING EQUIPMENT

(b). Controls for Heat Pumps with Supplementary Electric Resistance Heaters

Heat pumps with supplementary electric resistance heaters shall have controls:

1. That prevent supplementary heater operation when the heating load can be met by the heat pump alone; and
2. In which the cut-on temperature for compression heating is higher than the cut-on temperature for supplementary heating, and the cut-off temperature for compression heating is higher than the cut-off temperature for supplementary heating.

Exception 1 to Section 110.2(b): The controls may allow supplementary heater operation during:

A. Defrost; and

B. Transient periods such as start-ups and following room thermostat setpoint advance, if the controls provide preferential rate control, intelligent recovery, staging, ramping or another control mechanism designed to preclude the unnecessary operation of supplementary heating.

Supplementary Heating: Proposed Requirements

Mandatory; If Electric Resistance Strip Heat is used, would require:

- Simplifying assumptions not allowed in Manual J inputs.
- For existing dwellings, infiltration testing required and the measurement used for Manual J inputs.
- Controls required that use either an outdoor air temperature sensor or an internet weather feed to lock out strip heating whenever the outdoor temperature exceeds 35°. Controls verified.

  Exceptions: Supplementary heating can operate during defrost mode or emergency operation.
- Strip heating capacity limited to the maximum of:
  - The difference between the heat pump capacity and design load.
  - [TBD] kw per ton (for defrost).

Mandatory; If Dual Fuel is used, would require:

Controls that lock out fossil fuel use whenever the outdoor temperature exceeds 35°F. Controls verified.

Exceptions: Supplementary heating can operate during defrost mode or emergency operation.

Supplementary Heating: Market Overview and Analysis

Current Market

- Heat pumps in all sizes and cold-climate heat pumps that can provide sufficient heating without supplementary heating are readily available.

Market Trends

- Many contractors in California find that they do not need to install supplementary heating. (Currently estimating fraction through surveys).

Market Barriers

- It is much easier to install a small heat pump and assume that supplementary heating will make up any shortfalls, than to design the system optimally from the start.

Supplementary Heating: Technical Considerations

Technical Considerations

- A well-designed heat pump can provide sufficient heating in all but the most severe climate zones, in which case cold-climate heat pumps can be used.
- Avoiding supplementary heating would make the other performance measures proposed here even more important (eg sizing and air-distribution design).
- If a contractor or builder chooses to add supplementary heating, they would be required to ensure that the controls preclude wasteful operation and would be required to install compensatory measures to make up for performance shortfalls.

Technical Barriers and Potential Solutions

Training would be necessary for designing (sizing and air-distribution design) and for configuring controls.

Discussion: Sizing and Supplementary Heat

- What do we have wrong?
- What do we have right?
- How could we improve this?
- Do you have information or data that would help us?

Submit questions and comments using the Menti link.
We will attempt to discuss these today. If we don't get to your question, we will respond after the meeting.

Raise your hand to ask a question.
We will call on you and invite you to unmute yourself. If we don't get to your question, please submit it using the link, and we will attempt to respond after the meeting.

Or feel free to follow up with kheinemeier@frontierenergy.com with a cc to **info@title24stakeholders.com**

Defrost Control

- Background
- Market Overview
- Technical Considerations

Defrost Efficiency: Background

- Defrost cycles prevent outdoor coils of a heat pump or air conditioner from icing up.
- Defrost modes run the system backwards—on a heat pump, this is essentially air conditioning the space—to warm up the outside coils, then reheat the space by running supplementary heating.
- Many systems use a delay timer to start the defrost cycle and a temperature measurement or timer to end the cycle.

Defrost Efficiency: Background

Defrost cycles increase energy use and contribute to discomfort.

Some controls engage defrost even when it isn't needed.

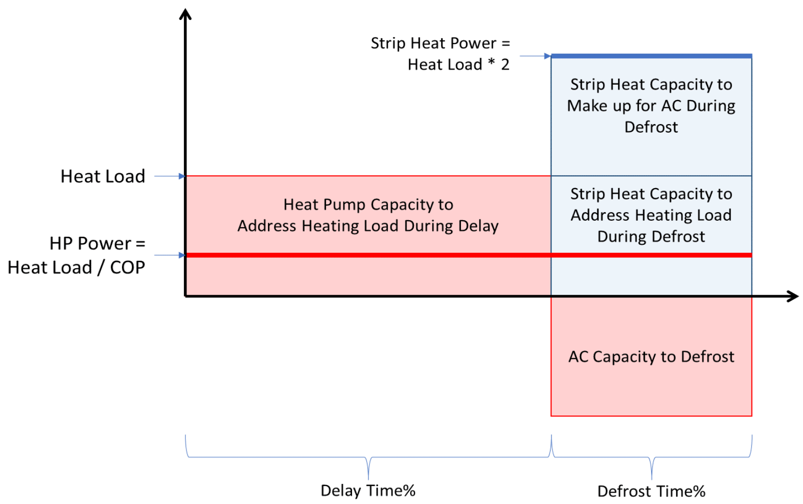
- Delay timers are typically not set optimally.
- Most systems do not sense when defrost is actually needed.

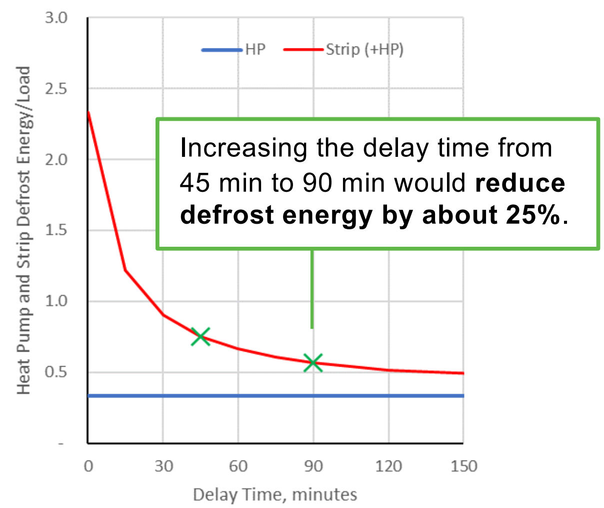
Defrost modes can create uncomfortable cool drafts if
design of the air-distribution system is not optimal (see "Design" measures).

The Proposed Code Changes Would…

- Require setting delay timers optimally.
- Give credit for systems that provide advanced control.

Impacts of Defrost Delay Time





Defrost Efficiency:
Current Code Requirements

- Current code does not address **how** or **when** Defrost is done.
- It explicitly allows supplementary heating when in Defrost mode.

Defrost Efficiency: Proposed Requirements

Mandatory: Proposed requirement that **if it has a defrost delay timer, it must be set and verified to be ≥ 90 minutes**

Compliance Option: Proposed to be eligible for Defrost Smart Control Compliance Credit, [TBD] for:

- Embedded controls:
  - Demand Control Defrost
  - Detection of excessive differential air pressure across coils
  - Measurement of coil temperature
- Thermostat-based controls:
  - Turn blower motor off

For this credit, would require that options be configured properly and possibly HERS-verified.

Defrost Efficiency: Market Overview and Analysis

Current Market

- Most products have a delay timer that can be set at ≥90 minutes “ (jumper or dip switch).
- Some products have advanced controls to sense when defrost is needed.

Market Trends

- Advanced controls are typically available in only the highest end systems.

Market Barriers

- This is seldom a feature that is advertised or considered a differentiator. Code requirements would overcome this barrier.

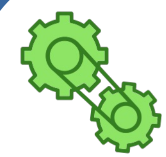
Defrost Efficiency: Technical Considerations

Technical Considerations

- Setting delay timer properly is a simple task.

Technical Barriers and Potential Solutions

- Training might be required to convince contractors to use optimal configuration.



Crankcase Heating

- Background
- Market Overview
- Technical Considerations

Crankcase Heating: Background

- Crankcase heating (CCH) keeps the compressor of a heat pump or air conditioner warmer than the outdoor coils and casing. This prevents the migration of liquid refrigerant into the compressor, which could cause severe damage.
- CCH only needs to run when the compressor is off.
- A variety of superior technologies exist, including compressors that do not require CCH, and controls that operate CCH only as needed.

Crankcase Heating: Background

- Field monitoring studies have found that CCH can consume surprising amounts of energy, particularly in low load buildings or other applications where the compressor is off frequently.
- Poorly controlled crankcase heating is particularly a problem in Air Conditioners, where the CCH can run all winter long.

The Proposed Code Changes would…

- Avoid CCH that unnecessarily run when the compressor is ON.
- Encourage CCH that only run when temperatures are low.
- Reward systems that do not require CCH.

Field Research

- For one monitored project, CCH in apartments consumed 900-2300 kWh/year, or almost half of the total annual HVAC load.[1]
- CCH in each apartment at a complex in California was a fixed load of about 100 watts, consuming about 900 kWh/year or half of the average systems' energy use.[2]
- A research house in central California found CCH was roughly half the total energy for the system's cooling energy use.[3]

1. "Heat Pump Controls: Decarbonizing Buildings While Avoiding Electric Resistance Heating and Higher Net Peak Demand," ACEEE Summer Study 2022, McHugh, German, Dryden, Larson, Feng, Bade, and Alatorre, August 2022.
2. "Getting to All-Electric Multifamily ZNE Construction. Draft Final Project Report." EPC-15-097. Dryden, Pfotenhauer, Stone, Armstrong et al. March 2021.
3. PGE Central Valley Research Homes, Variable Capacity Heat Pumps, Evaluation of Ducted and Ductless Configurations 2016-2017. Wilcox, Conant, and Chitwood. 2018

Crankcase Heating: Current Code Requirements

DOE regulates OFF mode power*, including CCH, for residential air conditioners and heat pumps.

- The DOE standard is $P_{w,off} \leq 30W$ for air conditioners and $\leq 33W$ for heat pumps, as determined by the AHRI 210/240 test method and calculations.

DOE does **not** regulate the ON mode power of CCH

*Code of Federal Regulation 10 CFR §430.32(c).

There are no current Title 24 requirements, although CCH is included in energy calculations.

Crankcase Heating: Proposed Requirements

Mandatory: Propose to disallow, for heat pumps or air conditioners, CCH that runs continuously, even when the compressor is ON.

- Installer would be required to provide manufacturer certification that CCH does not run when the compressor is ON, or that there is no CCH.

Prescriptive: In addition, one of these options would be required:

1. Install [TBD] additional energy savings measure, saving approximately 200 kWh/yr.
2. Provide manufacturer certification of CCH performance:
   - "P2" measurement from AHRI 210/240 testing, which would be required to be less than [TBD]
   - Type of control, which would be required to include either:
     - *Thermostatic Control (off above [TBD] degrees), or*
     - *Positive Temperature Coefficient Control (wattage varies with temperature).*
3. Provide manufacturer certification that the equipment does not have CCH.

Crankcase Heating: Market Overview and Analysis

Current Market

- HVAC OEMs provide little or no information on CCH wattage and controls in the published performance data and manuals
- Of the 32 different unit models (over 11 different manufacturers), 16 included CCH as a standard factory installed component. That equates to 50% of the units surveyed.
- Almost all manufacturers stated the recommendation and/or need for CCH if the heat pump is to operate in low ambient conditions, in “extreme cold operation” in northern parts of the US and Canada, in Climatic Zones 1,2, and 3 (includes most of California), in ambient conditions < 55 deg F.
- CCH Power: of the models of resistance heaters reviewed, the total power input ranged from 70 W – 150 W.

Source: “UPDATE #2: Residential Heat Pump Crankcase Heater, Product Review.” Red Car Analytics Memorandum. Stober and Bulger. 2022

Crankcase Heating: Market Overview and Analysis

Market Trends

- There are no known factors driving market change. There is almost no visibility to market actors.

Market Barriers

- In most cases the $P_{w,off}$ value listed with DOE is equal to the DOE maximum allowed value. OEMs are only required to certify that they meet the DOE standard, not publish measured power or other detailed information.
- Provide a pathway for OEMs to voluntarily report more detailed information for use in the compliance calculations. The information reported could be aligned with the DOE $P_{w,off}$ test method to facilitate OEM participation

Source: "UPDATE #2: Residential Heat Pump Crankcase Heater, Product Review." Red Car Analytics Memorandum. Stober and Bulger. 2022

Crankcase Heating: Technical Considerations

Technical Considerations

- OEMs would voluntarily provide applicable test measurements
- The reported values would be input into CBECC-Res
- Compliance calculations would use these inputs instead of default assumptions

Technical Barriers and Potential Solutions

- No technical barriers. The main barrier would be a market barrier: Would OEMs provide the information?

Discussion: Defrost and Crankcase Heating

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- What do we have right?
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15 Minute Break

Refrigerant Charge Verification

- Background
- Market Overview
- Technical Considerations

Refrigerant Charge Verification: Background

- Proper charge is necessary for air conditioners and heat pumps and in all Climate Zones to operate at peak performance.
- Modern systems are more complicated, and manufacturers know the best amount of charge, making weigh-in preferred.
- Using refrigerant gauges provides opportunities for leaks (GHG emissions and reduced performance).
- The accuracy of Standard Charge Verification Protocols has been questioned.
- Weigh-in still requires some verification of proper installation, such as capacity.

Refrigerant Charge Verification: Background

- Verification of weigh-in of manufacturer recommended amounts of refrigerant can be done less expensively than Standard Charge Verification.
- New systems and variable-capacity systems are more complex, and manufacturer weigh-in recommendations should be relied upon.
- Less expensive remote verification is warranted, with simple weigh-in methods and new documentation technologies.

The Proposed Code Changes would…

- Shift focus from charge testing (subcooling and superheat) to verified weigh-in and supplementary performance tests (capacity).
- Provide an option for HERS Raters to verify weigh-in REMOTELY, with electronic documentation and remote HERS validation.

Effectiveness of Current Requirements

"FDD A" is Current T24 Charge Verification Procedure

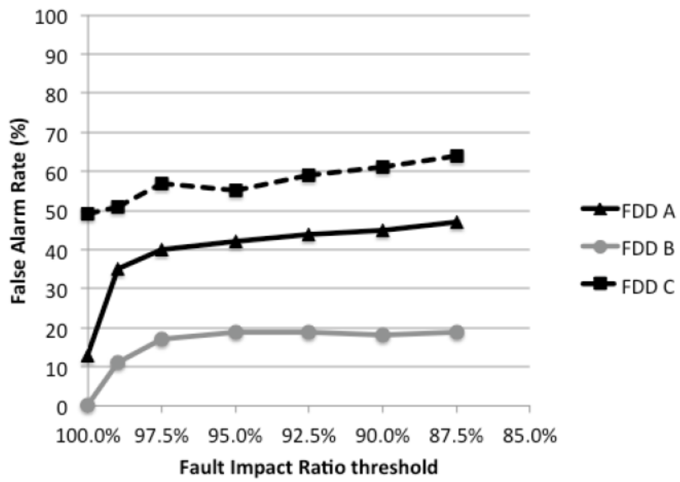


Figure 3: False Alarm rates from measurement data

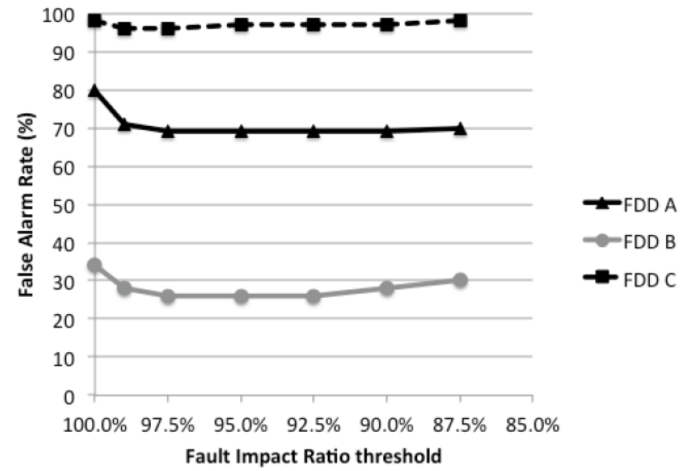


Figure 4: False Alarm rates from simulation data

Source: "Evaluation of Fault Detection and Diagnostics Tools by Simulation Results of Multiple Vapor Compression Systems," International Refrigeration and Air Conditioning Conference at Purdue. Yuill, Cheung, and Braun. 2014

Refrigerant Charge Verification: Current Requirements

- Refrigerant charge must be verified for air conditioners and heat pumps in CZs 2 and 8-15.
- Standard Charge Verification Procedures:
  - Fixed Metering Device: Superheat
  - Variable Metering Device: Subcooling
- Weigh-in Observation
- Winter Installation: Weigh-in, condenser outlet air restrictor, or return visit
- Efficiency is derated by 10% without verification, 4% with verification

Refrigerant Charge Verification: Proposed Requirements

Mandatory: In all Climate Zones where verification is found to be cost effective, heat pumps and air conditioners would be **required to have refrigerant charge verified**.

Mandatory: When charge verification is required, there would be **three options available**:

1. **Current Standard Charge Verification Procedure**
   - Including winter setup and tentative approval with return visit.
   - Only allowed for Single Speed systems, or when following manufacturer recommendations.
2. **Weigh-In Charging Procedure, with ONSITE Verification**
   - Current Weigh-In procedure, including ONSITE HERS observation. ***Exception**: Pre-charged systems with line length less than [TBD].*
   - Capacity test, including ONSITE HERS verification.
3. **Weigh-In Charging Procedure, with REMOTE Verification**
   - Current Weigh-In procedure, including REMOTE HERS observation. ***Exception**: Pre-charged systems with line length less than [TBD].*
   - Capacity test, including REMOTE HERS verification.

Sampling allowed only for Standard Charge Verification and Capacity Tests for ONSITE Weigh-In.

Refrigerant Charge Verification: Market Overview and Analysis

Current Market

- All manufacturers provide required weight of refrigerant
- Past refrigerant charge programs focused on testing with gauges, which is less accurate and prone to refrigerant releases, and not suitable for variable capacity systems.

Market Trends

- Anecdotal evidence suggests verification is not always of high quality.

Market Barriers

- The cost for HERS verification may be a big contributor to non-compliance rates, so reducing the cost may improve compliance rates.

Refrigerant Charge Verification: Technical Considerations

Technical Considerations

- Researchers have suggested that current methods may have a 50% chance of misreporting appropriateness of charge.
- Modern systems are more complicated, and manufacturers know the best amount of charge, making weigh-in preferred.
- Still important to verify that contractors are using due diligence.

Technical Barriers and Potential Solutions

- HERS capability to receive electronic documentation and verify that proper adjustments were made must be developed, and both HERS Raters and contractors would need to be trained on how to utilize it.
- Capacity test procedures would need to be developed and training provided.
- Other solutions such as FDD can also be considered.

Variable Capacity / Zoned Systems

- Background
- Market Overview
- Technical Considerations

Variable Capacity / Zoned Systems: Background

Variable Capacity and Multi Speed (VCMS) systems can provide much improved system efficiency, accounted for in high SEER ratings.

However, when the airflow rate is reduced, the distribution efficiency is reduced, and attic duct losses climb. This is not reflected in standard modeling of VCMS systems.

- Compliance software currently provides a VCHP-Detailed system type, which:
  - Calculates energy savings from low-speed performance
  - Calculates the penalty of reduced distribution efficiency at reduced airflow rates
  - Is limited to use with NEEP-listed cold climate heat pumps only.

  This system type is voluntary, so the energy penalty is not required to be modeled.
- Currently, airflow and fan efficacy (W/cfm) testing of zonally controlled VCMS systems can be done at maximum speed with all dampers open—this overlooks the efficacy penalty if a zone is calling for high speed fan and not all dampers are open.
- All zoned systems are currently required to deliver 350 cfm per ton of nominal cooling capacity, neglecting systems—such as multi-splits—that zone using multiple air handlers instead of dampers.

Variable Capacity / Zoned Systems: Proposed Requirements

Mandatory for all Variable Capacity/Zoned Systems:

- VCMS/Zoned systems must do airflow and efficacy testing in every zonal control mode.

  Exception: Systems with integrated compressor/fan speed and zone controls may be tested with all zones calling.

- For systems with multiple air handlers, the sum of airflows measured at all air handlers must be at least 350 cfm per ton of <u>compressor</u> capacity, not per ton of each <u>air handler</u> capacity.

Proposed CBECC-Res Modeling of Variable Capacity Systems:

- For non-zonally controlled VCMS systems with attic ducts, performance (airflow, distribution efficiency, and duct loss) will be calculated as a function of instantaneous load.
- The VCHP-Detailed option will be retained.

Variable Capacity / Zoned Systems: Market Overview & Analysis

Current Market and Market Trends

- Compliance challenges and incentive programs are increasing the adoption of VCMS
- Zonal control appears to be a more popular means of providing uniform temperatures than multiple systems
- Of the cold climate heat pumps in the NEEP database, 25,584 out of 38,641 units are variable capacity

Market Barriers

- The primary market barrier to improving airflow and efficacy of zonally controlled systems is the higher cost of systems that integrate zonal control and compressor/fan speed
- Building departments may not be enforcing efficacy testing, particularly measurement of fan watts

Variable Capacity / Zoned Systems: Technical Considerations

Technical Considerations

- Would represent only a minor modification to the way that airflow and efficacy tests are done for these systems
- CBECC-Res contains and applies algorithms that calculate duct loss as a function of airflow rate; VCMS systems can be identified using the existing Multi-speed Compressor check box

Technical Barriers and Potential Solutions

- To implement CBECC-Res modifications, a relationship between load, capacity, and airflow must be established that is representative of commonly used HVAC systems
- Data from available expanded performance tables is being reviewed for this purpose; additional data would improve accuracy

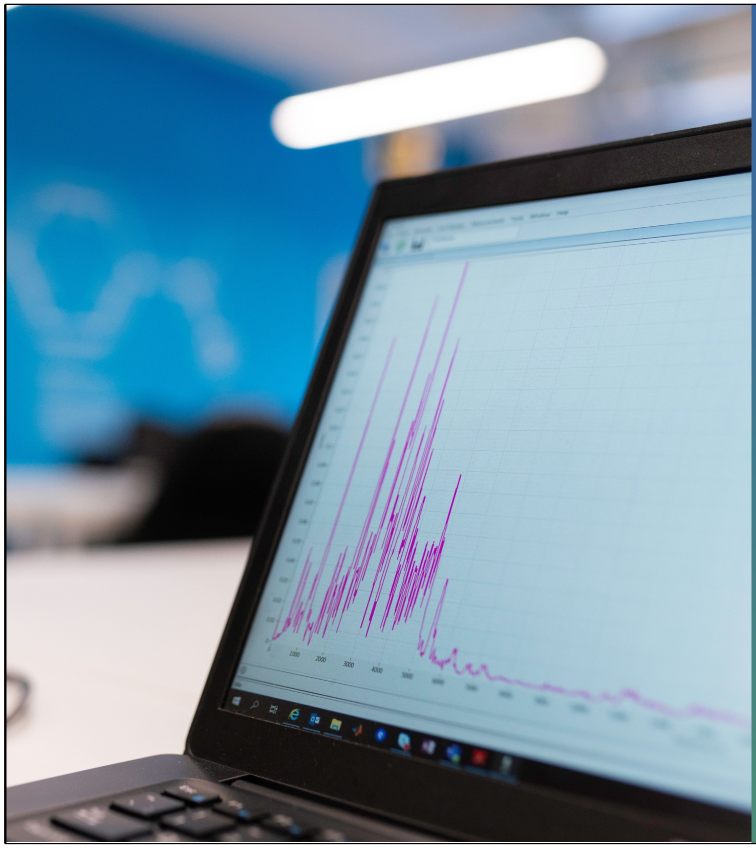
Discussion: Charge Verification and VC/Zoning

- What do we have wrong?
- What do we have right?
- How could we improve this?
- Do you have information or data that would help us?

Submit questions and comments using the Menti link.
We will attempt to discuss these today. If we don't get to your question, we will respond after the meeting.

Raise your hand to ask a question.
We will call on you and invite you to unmute yourself. If we don't get to your question, please submit it using the link, and we will attempt to respond after the meeting.

Or feel free to follow up with kheinemeier@frontierenergy.com with a cc to **info@title24stakeholders.com**



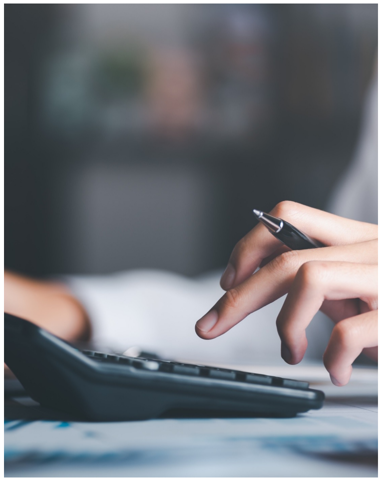
Energy and Cost Impacts Per Home/Dwelling Unit

- Energy Savings Methodology
- Cost Impacts Methodology and Results
  - – Incremental costs
  - – Energy cost savings

Methodology for Energy Impacts Analysis

Overall methodology for per-home energy and demand impacts:

- Model prototypes [Single-Family (2100 sqft, 2700 sqft, 500 sqft) and Multi-Family (Low-rise Garden, Loaded Corridor, Mid-rise, High-rise Mixed Use, and High-rise Apartment)] in all CZ
- For each measure, standard design is a Single Speed Heat Pump.
- For each measure, the proposed design is improved per the measure description.
- Will report first-year energy savings (kWh, therms, kW, source energy) and life-cycle cost-benefit and annual statewide savings



Assumptions for Standard and Proposed Designs

Measure		Standard Assumptions	Baseline Assumptions
Sizing		Use Man S sizing rules	Use T24 rules
Supplementary Heat		CBECC-RES strip heating assumptions	Strip heating does not run at OAT > 35°F, except during defrost
Defrost	Set Time Delay	CBECC-RES defrost assumptions	Standard with defrost energy reduced by 25%
	Smart Control		[TBD]
Crankcase Heating	OFF when comp ON	33W or 11W/ton 8760 hours of operation	33W or 11W/ton OFF when compressor ON
	OFF above OAT		33W or 11W/ton OFF above [TBD] OAT
Charge Verification	Heat Pumps	CEM = 0.90 in CZ 1,3-7,16 CEM = 0.96 in CZ 2,8-15	CEM = 0.96 in all CZs
	Air Conditioners		CEM = 0.96 in all CZs

Energy Savings Estimates Per Home or Dwelling Unit

		Annual Electricity Savings (kWh/yr)	Annual Natural Gas Savings (Therms/yr)	Peak Demand Reduction (W)	Annual Life Cycle Energy Cost Savings (kBTU/yr)	Annual Source Energy Savings (kBTU/yr)
Sizing	By Prototype and CZ					
Supplementary Heat	By Prototype and CZ					
Defrost	By Prototype and CZ					
Crankcase Heating	By Prototype and CZ					
Charge Verification	By Prototype and CZ					

Work is Ongoing

Preliminary Energy Savings Estimates: Refrigerant Charge Verification for Heat Pumps

Climate Zone	2,100 sq. ft.			2,700 sq. ft.		
	Annual Electricity Savings (kWh)	SLCC Savings	Annual Source Energy Savings (kBtu)	Annual Electricity Savings (kWh)	SLCC Savings	Annual Source Energy Savings (kBtu)
1	205	$1,533	546	197	$1,485	540
3	74	$651	252	75	$675	270
4	110	$861	315	142	$1,080	432
5	67	$546	231	61	$513	216
6	23	$189	84	31	$270	81
7	23	$168	63	33	$216	54
16	205	$1,596	546	238	$1,809	648

Notes:
- Verifying charge for HPs in CZs 2, 8-15 will have the same costs and higher savings than for AC, and the cost effectiveness for AC in those CZs has already been established, so no analysis will be done.
- There will be a separate analysis for verifying charge for AC in these CZs.

Preliminary Energy Savings Estimates: Crankcase Heating

	2,100 sq. ft.			2,700 sq. ft.		
Climate Zone	Annual Electricity Savings (kWh)	SLCC Savings	Annual Source Energy Savings (kBtu)	Annual Electricity Savings (kWh)	SLCC Savings	Annual Source Energy Savings (kBtu)
1	171	$3,927	357	174	$3,996	351
2	207	$5,040	441	208	$4,887	459
3	244	$6,216	546	245	$6,210	540
4	240	$5,523	546	239	$5,454	540
5	237	$5,985	525	238	$5,994	513
6	271	$6,762	672	270	$6,723	648
7	279	$7,119	693	278	$7,101	675
8	262	$6,195	630	261	$6,129	621
9	256	$5,985	609	255	$5,886	594
10	238	$5,544	546	237	$5,481	540
11	201	$4,557	420	202	$4,563	405
12	219	$5,061	483	218	$4,968	459
13	204	$4,536	441	204	$4,536	432
14	198	$4,410	420	197	$4,401	432
15	248	$5,838	630	334	$7,884	837
16	155	$3,591	336	170	$3,915	351

Incremental Per Home / Dwelling Unit Cost

Incremental First Cost	
Equipment	$x,xxx.xx
Installation	$x,xxx.xx
Design / Permitting	$x,xxx.xx
HERS Verification	$x,xxx.xx
Other?	$x,xxx.xx
Total	**$x,xxx.xx**

Incremental Maintenance Cost	
Equipment Replacement	$x,xxx.xx
Annual Maintenance	($x,xxx.xx)
Other?	$x,xxx.xx
Total	**$x,xxx.xx**

Work is Ongoing

Incremental Cost Information

How we are collecting costs of base case technology and proposed technology:

- Base case is Single Speed Heat Pump with electric strip heating, with crankcase heating, no extra controls, charge verification per 2022, a range of sizes.
- Interviews and surveys with manufacturers, distributors and contractors

Work is Ongoing

M=materials, L=design/installation labor, H=HERS labor

DESIGN (LOAD CALC, SYSTEM SELECTION)
Manual J Load Calc:
· Full cost avoided by not doing Man J Calc (L)
· Incremental cost avoided by using simplifications in Man J Calc (L)
Blower Door Test:
· Full cost of contractor doing Blower Door test (L)
· Full cost of HERS Rater doing Blower Door test (L)
System Selection:
· Incremental cost per ton avoided by avoiding oversized system (M)
Duct/Diffuser Design:
· Full cost to document duct/diffuser design (L)
· Full cost for designer to self-certify (L)
SUPPLEMENTARY HEATING
Strip Heating Efficiency:
· Incremental cost for controls for recovery lockout and OAT lockout (M,L)
· Incremental cost for HERS Verification of controls (H)
Dual Fuel Efficiency:
· Incremental cost for controls for OAT lockout (M,L)
· Incremental cost for HERS Verification of controls (H)
DEFROST EFFICIENCY
· Incremental cost to set delay timer (L)
· Incremental cost for Smart Defrost Control (M,L)
· Incremental cost for HERS Verification of controls (H)
CRANKCASE HEATING EFFICIENCY
· Incremental cost avoided by avoiding CCH (HP) (M)
· Incremental cost avoided by avoiding CCH (AC) (M)
REFRIGERANT CHARGE VERIFICATION
· Full cost for weigh-in with onsite HERS Verification (L,H) · Incremental cost for SC/SH testing (vs. weigh-in) (L,H) · Full cost for Capacity Tests (L,H) · Incremental cost avoided by using remote verification (vs. onsite) (L,H)
VARIABLE CAPACITY / ZONED SYSTEMS
· Incremental cost for fan efficacy test with only smallest zone calling (L,H)
· Full cost for SP test (L,H)

Incremental Cost Poll Coming Up…

In a minute, we'll open up polls to help us gauge the costs of some of the options.

Please provide a quick ballpark estimate of the ***incremental*** cost for the items to the right, including labor, materials, design, installation, permitting…

Or feel free to follow up with **kheinemeier@frontierenergy.com**

cc. info@title24stakeholders.com to share information confidentially.

Approximately what would be the typical added cost for the following upgrades to a central ducted furnace and air conditioner system?
Assuming new construction, production builder, 3-ton, single-speed, no strip heat, and code minimum efficiency.

From that central furnace/AC to a heat pump

a. From the central furnace/AC to a DUAL FUEL heat pump
b. From the 3-ton standard heat pump to a 4-ton heat pump
c. From that single-speed heat pump to a variable capacity heat pump
d. Adding strip heating to that heat pump
e. Adding a thermostat with an OAT sensor to that heat pump

Poll Request (Incremental Costs: HP Upgrade)

- **Measure Name:** Incremental Costs: HP Upgrade
- **Type of Poll:** Word Cloud
- **Question:** Approximately what would be the typical added cost to upgrade from a central furnace/AC to a heat pump?

- **Placement:** After poll on "Incremental Cost Poll Coming Up…" (slide 62?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)

Poll Request (Incremental Costs: Dual Fuel HP)

- **Measure Name:** Incremental Costs: Dual Fuel Upgrade
- **Type of Poll:** Word Cloud
- **Question:** Approximately what would be the typical added cost to upgrade from a central furnace/AC to a Dual Fuel heat pump?

- **Placement:** After poll on "Est Costs – Baseline" (slide 63?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)

Poll Request (Incremental Costs: Increase by 1 Ton)

- **Measure Name:** Estimated costs: Increase by 1 Ton
- **Type of Poll:** Word Cloud
- **Question:** Approximately what would be the typical added cost to upgrade from the 3-ton standard heat pump to a 4-ton heat pump?

- **Placement:** After poll on “Inc. Costs: Dual Fuel Upgrade” (slide 64?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)

Poll Request (Incremental Costs: Single to Variable)

- **Measure Name:** Incremental Costs: Single to Variable
- **Type of Poll:** Word Cloud
- **Question:** Approximately what would be the typical added cost to upgrade from that single-speed heat pump to a variable capacity heat pump?

- **Placement:** After poll on "Inc Costs – Increase by 1 Ton" (slide 65?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)

Poll Request (Incremental Costs: Strip Heating)

- **Measure Name:** Incremental Costs: Strip Heating
- **Type of Poll:** Word Cloud
- **Question:** Approximately what would be the typical added cost to add strip heating to that heat pump?

- **Placement:** After poll on “Inc Costs – Single to Variable” (slide 66?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)

Poll Request (Incremental Costs: Tstat with OAT Sensor

- **Measure Name:** Incremental Costs: Tstat with OAT Sensor
- **Type of Poll:** Word Cloud
- **Question:** Approximately what would be the typical added cost to add a thermostat with an OAT sensor to that heat pump?

- **Placement:** After poll on “Inc Costs – Strip Heating” (slide 67?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)

Cost Effectiveness

	Design	Supp Heating	Defrost	CCH	Charge Verif	VC / Zoned
Metric:	By Prototype By CZ	By Prototype By CZ	By Prototype By CZ	By Prototype By CZ	By Prototype By CZ	By Prototype By CZ
Benefits: Life Cycle Energy Cost Savings + Other PV Savings (2026 PV$)						
Costs: Total Incremental PV Costs (2026 PV$)						
Benefit-to-Cost Ratio						

Work is Ongoing

Statewide Energy Impacts Methodology

The Statewide CASE Team estimates annual statewide impacts by multiplying **A x B x C**:

A. per-home/dwelling unit energy impacts (discussed in previous section)

B. number of homes/dwelling units of new construction/additions/alterations of each applicable building type

C. portion of affected homes/dwelling units in each climate zone

Example:

Work is Ongoing

Per Unit Impacts

Savings type	Savings per sq ft
Electricity	[X] kWh
Peak demand	[X] Watts
Natural gas	[X] Therms
GHG emissions	[X] Tons CO_2e

×

Affected New Construction

Climate Zone	SF2100 sq ft	SF2700 sq ft…
1	50,000	70,000
2	75,000	90,000
…		
16	8,000	15,000

=

Statewide Energy Impacts

Climate Zone	Elec Savings (GWh)	…	GHG savings (MT CO_2e)
1	20		1,500
2	50		3,000
…			
16	100		2,000

Compliance and Enforcement

- Design
- Permit Application
- Construction
- Inspection
- Revisions to Compliance Software

Proposed Compliance and Verification Process

1. **Design Phase**
   - Specify a system that meets mandatory and selected prescriptive requirements.
   - Carry out sizing calculations per requirements, prepare a duct layout or room-by-room list air distribution system meeting the requirements of the local jurisdiction, and self-certification that air distribution design meets best practices.
2. **Permit Application Phase**
   - Submit permit application package with CF1R including worksheet with ACCA Manual J, S and D calculations and air distribution layout or list, and self-certification of design.
3. **Construction Phase**
   - Install the correct equipment according to manufacturer's instruction (including Refrigerant Charge weigh-in target).
   - Acquire necessary manufacturer certifications on Crankcase Heating.
   - Conduct testing (infiltration, refrigerant charge, efficacy for variable capacity/zoned system).
   - Prepare CF2Rs, including results of testing.
   - Submit electronic documentation of testing for remote HERS verification or obtain onsite verification; receive CF3Rs.
4. **Inspection Phase**
   - Building inspector may verify correct equipment installed.
   - Building inspector verifies that all required CF3Rs are completed.

Compliance and Verification

Many measures are interactive and will require more attention to design, and design information on CF1R.

- **HERS Verifications:**
  - Blower Door tests in some circumstances, in existing buildings.
  - Strip heating and Dual Fuel lockout controls.
  - Defrost delay timer setting and advanced controls configuration.
  - Refrigerant Charge Verification in more systems, with modified methods (remote methods added).
- **Proposed modifications to HERS process:**
  - Define bundles of verifications rather than individual verifications: individual measures may not trigger a verification, but when verification is done, it should include a full set of measures.
  - Process to be developed by HERS Providers to carry out remote verification after documentation submitted electronically.
- More emphasis on disclosures and self-certifications
- After adoption, EnergyCodeAce will be a resource to assist in compliance and verification.

Market Actors

Market actors involved in implementing these measures include: HVAC Designer, HVAC Installer, Builder, HERS Rater, HERS Provider, Code Official/Plans Checker, Original Equipment Manufacturer, Homeowner.

CASE report will include a discussion of:

- Related tasks in the current compliance process
- How the proposed CASE measure will impact current processes or workflow
- How the proposed code change would impact compliance and enforcement
- Opportunities to minimize negative impacts of requirements while maximizing positive impacts

We are in the process of surveying and interviewing stakeholders (except homeowners).

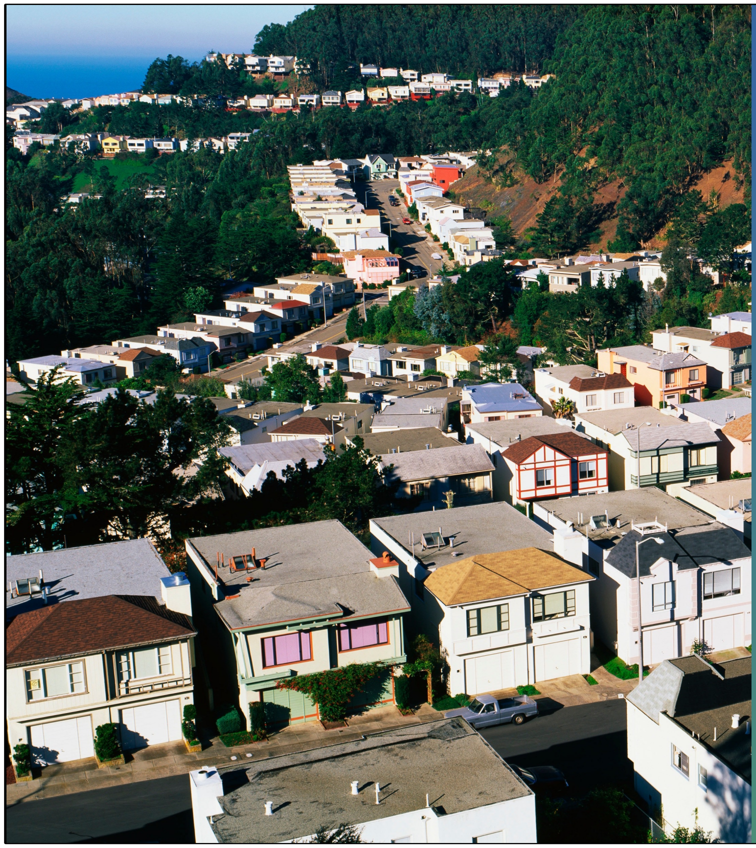
Software Updates

Appendix C of the CASE Report will discuss software updates.

- Changes to how Crankcase Heating and Defrost are modeled
- Possibly modify auto-sizing methodology?

Draft Code Change Language

Draft code language available for review in the handouts and downloadable.



General Discussion and Next Steps

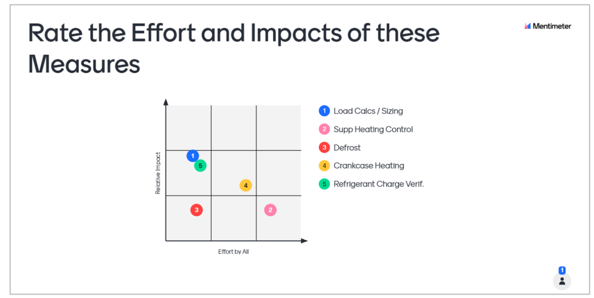
Poll Request (How would you describe proposals?)

- **Measure Name:** How Would You Describe these Proposals?
- **Type of Poll:** Word Cloud
- **Question:** What one or two words would you use to describe these proposals?

- **Placement:** After “General Discussion and Next Steps” slide (Slide 78?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)

Poll Request (Rate Measures by Effort and Impact)

- **Measure Name:** Rate Measures by Effort and Impact
- **Type of Poll:** 2x2 Grid
- **Question:** Please rate each of the proposed measures according to how much effort it will take by all parties, and by relative energy impact.
- **Answers:** Load Calcs / Sizing; Supp Heating; Defrost; Crankcase Heating; Refrigerant Charge Verification
- **Placement:** After poll on "How would you describe Proposals?" slide (Slide 79?)
- **Broadcast results to attendees as they respond:** (Y)
- **Make poll public during presentation:** (Y)



Next Steps: We want to hear from you!

- Provide **any last comments or feedback** on this presentation now verbally or using the Menti link
- More information on pre-rulemaking for the 2025 Energy Code at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-building-energy-efficiency

Comments on these measures are due by February 7, 2023.
Please send comments to info@title24stakeholders.com and copy CASE Author (see contact info on following slide).

Thank You

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CALIFORNIA ENERGY CODES & STANDARDS
A STATEWIDE UTILITY PROGRAM