Welcome to the California Statewide Codes and Standards Enhancement (CASE) Team's Stakeholder Meeting on

Single Family HVAC Proposals!

We'll get started shortly.

In the meantime, please fill out the polls below.

CALIFORNIA ENERGY CODES & STANDARDS
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To view options, click on the  icon on the top ribbon, then select *Connect My Audio.*

1. **Dial-out:** receive a call from the meeting. *Please note this feature **requires a direct line.***
2. **Dial-in:** dial-in to the conference via phone. Conference phone number and room number code provided. *Please then **identify your line** by entering your unique user ID on your phone.*
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***Above**: audio conference settings pop-up box*

2022 TITLE 24 CODE CYCLE, PART 6

First Utility-Sponsored Stakeholder Meeting

Single Family HVAC

Statewide CASE Team

October 10, 2019

CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

Meeting Guidelines

Muting Guidelines

Once you turn on your preferred audio connection please **MUTE** your microphone.

- Please keep yourself **MUTED.**
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Phone users – please mute your phone line.

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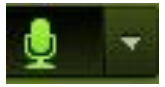


NOT MUTED

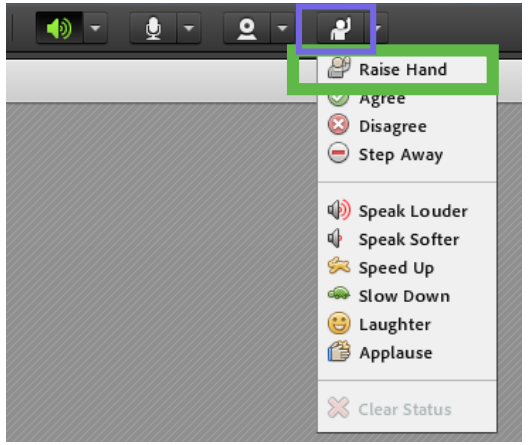
MUTED

Meeting Guidelines

Participation Guidelines

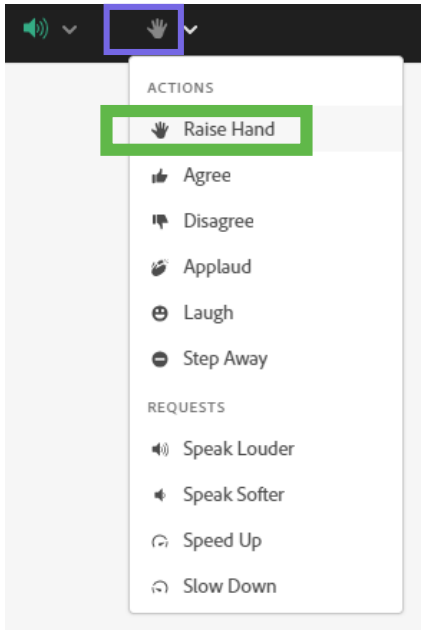
- **Questions & Comments**
  - Click **"*Raise Hand*"** if you would like to speak. Those with a hand raised will be called on by the speaker.
  - All questions and comments are also welcome via the chat window.

- **Other Meeting Feedback**
  - Provide live meeting feedback from the **top toolbar drop-down**.



Above: *feedback view for Adobe Connect app users.*

Below: *feedback view for HTML users.*



Meeting Ground Rules

- **We want to hear your thoughts**
  - Supporting and opposing viewpoints are welcome
- **When making comments**
  - Unmute yourself
  - Clearly state your name and affiliation prior to speaking
  - Speak loudly for phone audio
  - Place yourself back on mute
- **Calls are recorded** for note development, recordings will not be publicized
- Notes and presentation material will be posted on Title24Stakeholders.com

Agenda

1	**Meeting Guidelines**	*8:30 am*
2	**Opening Remarks** from the California Energy Commission	*8:35 am*
3	**Overview & Welcome** from the Statewide Utility Team	*8:40 am*
4	**Presentation I:** Air-to-Water Heat Pump Compliance Options	*8:45 am*
5	**Presentation II:** Fault Detection Diagnostics	*9:45 am*
6	*5 Minute Break*	*10:45 am*
7	**Presentation III:** Variable Capacity HVAC Software Revisions	*10:50 am*
8	**Closing**	*12:20 pm*

Opening Remarks: California Energy Commission

Policy Drivers: Building Standards

The following policy documents establish the goal for new building standards:

- **2008 CPUC/CEC Energy Action Plan** – ZNE for Residential buildings by 2020 and nonresidential buildings by 2030
- **SB 100** – Clean electricity by 2045
- **B-55-18** – Governor Jerry Brown's Executive Order to achieve carbon neutrality
- **AB 3232** – Assess the potential for the state to reduce the emissions of greenhouse gases from the state's residential and commercial building stock by at least 40% below 1990 levels by January 1, 2030

2022 Standards Schedule

ESTIMATED DATE	ACTIVITY OR MILESTONE
November 2018 - April 2019	Updated Weather Data Files
November 2018 - July 2019	Measures Identified and Approved (Internal at the Energy Commission)
November 2018 - July 2019	Compliance Metrics Development
April 24, 2019	Efficiency Measure Proposal Template for public to submit measures
October 17, 2019	Compliance Metrics and Climate Data workshop
November, 2019	Final Metrics Workshop
November, 2019	Research Version of CBECC Available with new weather data files and updated Metrics
July 2019 - March 2020	Utility-Sponsored Stakeholder Workshops
March, 2020	All Initial CASE/PUBLIC Reports Submitted to Commission
March - August 2020	Commission-Sponsored Workshops
July, 2020	All Final CASE/PUBLIC Reports Submitted to the Commission
July - September 2020	Express Terms Developed
January, 2021	45-Day Language posted and set to list serve, Start of 45-Day review/comment period
January, 2021	Lead Commissioner Hearing
April, 2021	Adoption of 2022 Standards at Business Meeting
May - November 2021	Staff work on Software, Compliance Manuals, Electronic Documents
May - November 2021	Final Statement of Reasons Drafted and Approved
October, 2021	Adoption CalGREEN (energy provisions) - Business Meeting
December, 2021	CBSC Approval Hearing
January, 2022	Software, Compliance Manuals, Electronic Documents Available to Industry
January - December 2022	Standards Training (provided by 3rd parties)
June 1, 2022	6 Month Statutory Wait Period Deadline
January 1, 2023	Effective Date

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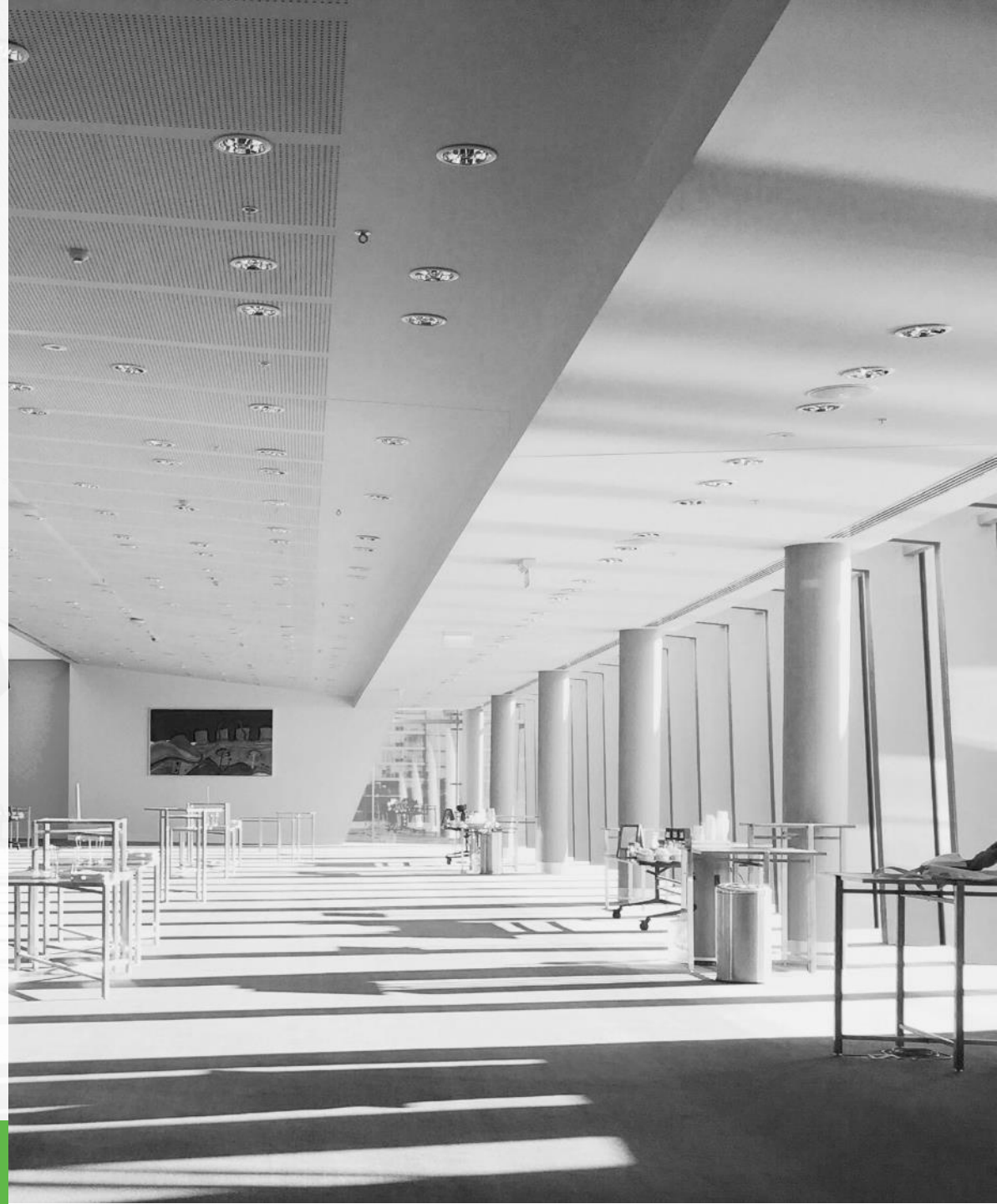
More information on pre-rulemaking for the 2022 Energy Code at:
https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency

Title 24, Part 6 Overview

Kelly Cunningham
Codes and Standards
Pacific Gas & Electric



Statewide Utility Codes and Standards Team

- **Actively supporting the California Energy Commission** in developing proposed changes to the California Energy Code (Title 24, Part 6)
- Achieve significant energy savings through the development of **feasible**, **enforceable**, **cost-effective, and non-proprietary** code change proposals for the 2022 code update, and beyond

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Requirements for a Successful Code Change Proposal

The utilities support the California Energy Commission by proposing changes to the Energy Code that are:

Feasible | Cost effective | Enforceable | Non-proprietary

Utility-Sponsored Stakeholder Meetings

- All meetings can be attended **remotely**
- Check Title24Stakeholders.com/events for information about meetings and topic updates
- Sign up to receive email notifications

First Round Utility-Sponsored Stakeholder Meetings

Meeting Topic	Building Type	Date
Multifamily & Nonresidential Water Heating	MF/NR	Thursday, October 3, 2019
Single Family HVAC	SF	Thursday, October 10, 2019
Nonresidential HVAC Part 1: Data Centers, Boilers, & Controls	NR	Tuesday, October 15, 2019
Nonresidential Envelope	NR	Thursday, October 24, 2019
Covered Processes Part 2: Compressed Air, Steam Traps, & Refrigeration	NR	Tuesday, November 5, 2019
Nonresidential HVAC Part 2: Air Distribution, & Controls	NR	Thursday, November 7, 2019
Single Family Whole Building	SF	Tuesday, November 12, 2019
Nonresidential Software Improvements	NR	Tuesday, November 12, 2019

Sign up for all meetings at title24stakeholders.com/events/

2022 Code Cycle – Key Milestones

CEC Milestone

Utility Team Milestone

Oct. 2018 – Feb. 2019:
Stakeholder outreach to request input on scope 2022 code cycle

Oct. 2018 – Feb. 2019:
Select 2022 Measures

April. 2019:
Work plans completed; Begin work on CASE Reports

August – Nov. 2019:
First round of utility-sponsored stakeholder meetings

Jan. 2020 – Feb. 2020:
Second round of utility-sponsored stakeholder meetings

Mar. – Apr. 2020:
Draft CASE Reports posted for public review

July 2020:
Final CASE Reports completed

June – Dec. 2020:
CEC Pre-rulemaking

Dec. 2020 - May 2021:
CEC Rulemaking

May 2021:
2022 Standards Adopted

The **Codes and Standards Reach Codes Program** provides technical support to local jurisdictions considering adopting a local energy and efficiency ordinance

www.LocalEnergyCodes.com

This program is funded by California utility customers under the auspices of the California Public Utilities Commission and in support of the California Energy Commission.

Thank You

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CALIFORNIA ENERGY CODES & STANDARDS
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2022 CALIFORNIA ENERGY CODE (TITLE 24, PART 6)

Air to Water Heat Pump(AWHP) Compliance Option

Codes and Standards Enhancement (CASE) Proposal

Residential | HVAC

Marc Hoeschele & James Haile, Frontier Energy, Inc.

October 10, 2019

CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

Agenda

1	Background	*5 min*
2	Market Overview and Analysis	*10 min*
3	Technical Feasibility	*10 min*
4	Cost and Energy Methodology	*10 min*
5	Compliance and Enforcement	*5 min*
6	Proposed Code Changes	*5 min*
7	Discussion and Next Steps	*15 min*

Background

- Context and History
- 2019 Code Requirements
- Code Change Proposal

Code Change Proposal – Summary

Building Types	System Type	Type of Change	Software Updates Required
Single and lowrise multi-family residential	HVAC	Compliance Option	Yes

- Existing implementation in CBECC-Res was designed as an interim approach
- Plan is to enhance AWHP and three function HP modeling, and add radiant ceiling panel delivery option
- 2022 proposal is that this will remain a compliance option (not a requirement!)
- Compliance option does not cover central AWHPs

Context and History

- Why are we proposing this measure?
  - CBECC-Res has included interim AWHP modeling for several years but uses methods that may not reflect true performance
  - AWHPs meet a need for all-electric solutions that are gaining traction in California and elsewhere
  - PG&E/SCE sponsored research underway for four years in a Central Valley Research House (CVRH) project lab house in Stockton, CA provides data on multiple AWHP products, as well as radiant panel delivery (two published reports[1])

[1] https://www.etcc-ca.com/reports/field-assessment-residential-radiant-ceiling-panel-space-conditioning-systems

https://www.etcc-ca.com/reports/central-valley-research-homes-phase-2-assessment-residential-radiant-ceiling-panel-space

Context and History

- AWHPs provide several advantages over air-to-air heat pumps
  - Do not require electric resistance backup heat for defrost cycle
  - Do not require charge verification or site-installed refrigerant piping (factory charged)
  - Can provide domestic hot water (DHW) at higher capacity than HPWHs, eliminating the need for supplemental electric resistance heat
  - Capable of distributing heating and cooling using multiple modes – radiant ceiling panels, radiant floors, and central or distributed fan coils with minimal ducting
  - Easily zoned, enhancing comfort in multi-story homes
  - Can accommodate thermal storage for fully off-peak cooling

2019 Code Requirements

- 2019 Requirements in Title 24, Part 6:
  - Compliance option, manufacturer certification required
  - CBECC Inputs: EER, capacity and COP at 47°F and 17°F determined using ANSI/AHRI 550-590, *Performance Rating of Water-chilling and Heat Pump Water-heating Packages Using the Vapor Compression Cycle*
- Other regulatory considerations:
  - Manufacturer certification required but no energy efficiency standard under Title 20 (listings instituted July 2016)
  - No federal regulations, no other known state regulations
  - ASHRAE 90.1 minimum efficiency (17 – 65 MBH): 13 EER using ISO 13256-1
  - ASHRAE 90.2 only recognizes water source

2019 Title 20 Listing Requirements (Section 1606, Table X)

	Heat pump water-chilling packages	Voltage*	
		Phase*	1, 3
		Refrigerant Type	Ozone-depleting, non-ozone-depleting
		Compressor Motor Design*	Single-speed, dual-speed, multiple-speed, variable speed
		OD Fan Motor Design*	Single-speed, dual-speed, multiple-speed, variable speed
		Model number includes all components?	Yes, no
		Is the model designed for space cooling?	Yes, no
		Cooling Capacity (BTU per hour) if applicable	
		Cooing power input (watts) if applicable	
		Energy Efficiency Ratio (EER) if applicable	
		Integrated part load value (IPLV)	
		Heating Capacity (BTU per hour) at 47° F	
		Heating power input (watts) at 47° F	
		Coefficient of Performance (COP) at 47° F	
		Heating Capacity (BTU per hour) at 17° F	
		Heating power input (watts) at 17° F	
		Coefficient of Performance (COP) at 17° F	
		Heat Capacity (BTU per hour) of heat reclaim[2]	
		COPR of heat reclaim[2]	

* "Identifier" information as described in Section 1602(a).

1 = Voluntary for federally-regulated appliances

2 = Voluntary for state-regulated appliances

Proposed Code Change Overview

- **Modify current compliance approach**
  - Considering a two-tiered credit approach similar in concept to 2019 Variable Capacity Heat Pump proposal currently in process (5% cooling savings, 12% heating savings proposed)[1]
  - Different heating and cooling credits would apply to fixed and variable speed AWHPs
- **Improve CBECC-Res AWHP water heating performance characterization** which is based on stand-alone heat pump water heaters with electric resistance backup
- **Incorporate radiant ceiling panels** as an alternative distribution option
  - Eliminates duct leakage and long-term duct longevity as an issue
- **Develop eligibility criteria** and potential HERS verification procedures

[1] https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-BSTD-02 (TN227124)

Market Overview

- Current Market Conditions
- Market Trends
- Potential Market Barriers and Solutions

Market Overview and Analysis

- **Current California Market**
  - Emerging AWHP market with small current penetration (primarily custom homes)
  - No utility incentive programs to date
  - Hydronic systems less common in the residential market and AWHPs are new to most California HVAC contractors
- **Market Trends and Barriers**
  - Push for electrification will increase interest in AWHPs and alternative delivery options
  - AWHPs offer an integrated approach for gas-to-electric conversions that can eliminate the need for additional electrical panel capacity required for heat pump water heaters
  - TDV penalties resulting from current modeling assumptions are a strong disincentive that the proposed measure will address

Technical Considerations

- Technical Considerations
- Potential Barriers and Solutions

Technical Considerations

- **Design Considerations**
  - Can serve heating, cooling, and DHW loads from one outdoor unit and facilitates potentially cost-effective alternative to ducts in conditioned space
  - Requires basic hydronic design skills (pumps and pipe sizing, controls design, etc.)
- **Barriers and Potential Solutions**
  - Design requires expertise in hydronic systems not common in California; design support is and can be provided by manufacturers and distributors until the market matures
  - Limited supply chain and product choices; likely to improve if demand and volume increase
  - HVAC contractors not familiar with hydronic systems and proper installation requires specialty contractors with plumbing as well as HVAC skills; with increasing demand workforce limitations will improve

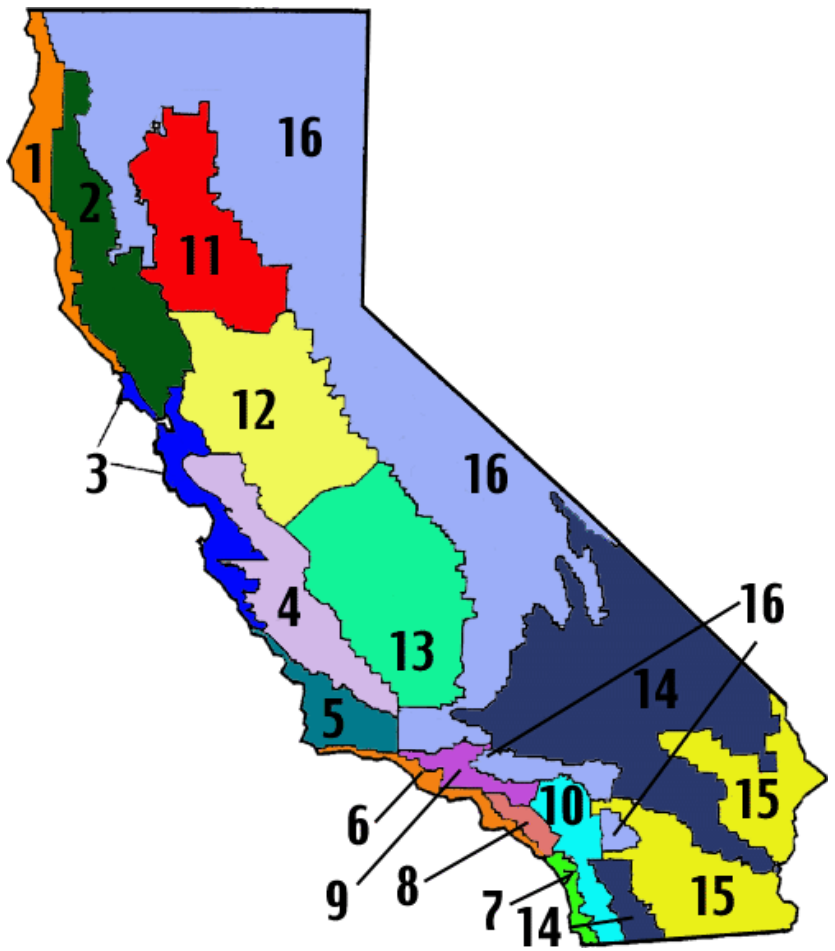
Energy and Cost Impacts

Methodology and Assumptions

- Energy Impacts Methodology
- Cost Impacts Methodology
  - Incremental costs
  - Energy cost savings

Methodology and Assumptions for Energy Impacts Analysis

- Utilize CBECC-Res to develop rated efficiency adjustment factors that reflect CVRH lab house test results
- Reference case – prescriptive requirements and minimum standard efficiency air-to-air heat pump
- Evaluate using 2,100 and 2,700 ft^2 prototype homes in all 16 Climate Zones



https://www.researchgate.net/profile/Maximilian_Auffhammer/publication/242224522/figure/fig1/AS:298686706929664@1448223868163/California-Energy-Commission-building-climate-zones.png

2023 Construction Forecast

- Key AWHP supplier interview results suggest California residential AWHP sales have been < 500 units per year but are softening due to market uncertainty and compliance issues, which makes forecasts of construction volume challenging
- Most applications are radiant floor systems in new very high-end homes and in heating dominated climates, though a small percentage are used with fan coils and radiant ceiling panels

Definition of Baseline and Proposed Conditions

Baseline Conditions

- Minimally compliant with 2019 Code
- Prescriptive all-electric package with minimum efficiency forced air heat pump and heat pump water heater

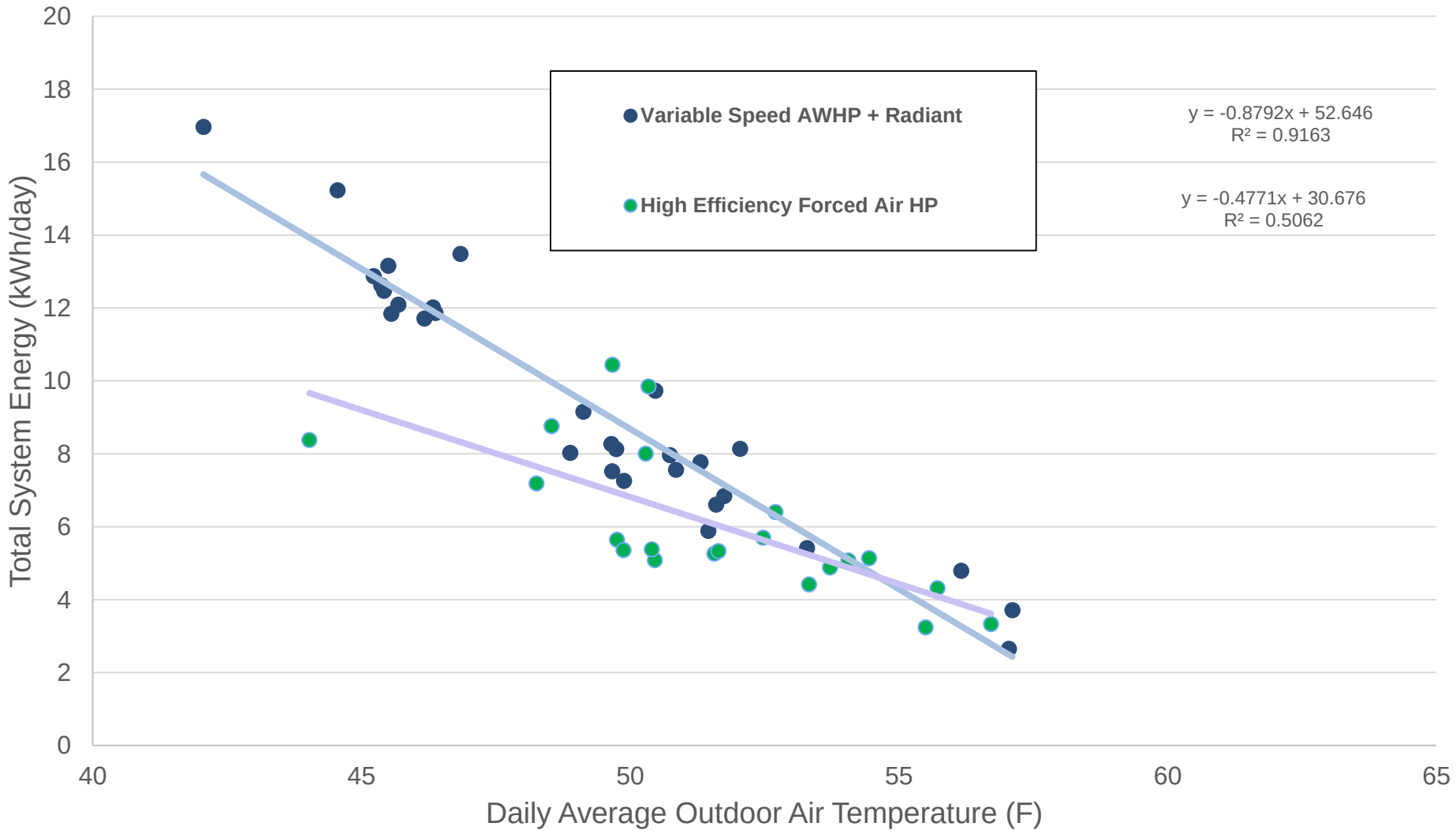
Proposed Conditions

- Same prescriptive envelope package with heating and cooling performance adjusted to match CVRH comparative monitoring results (AWHP vs. high performance reference HP)

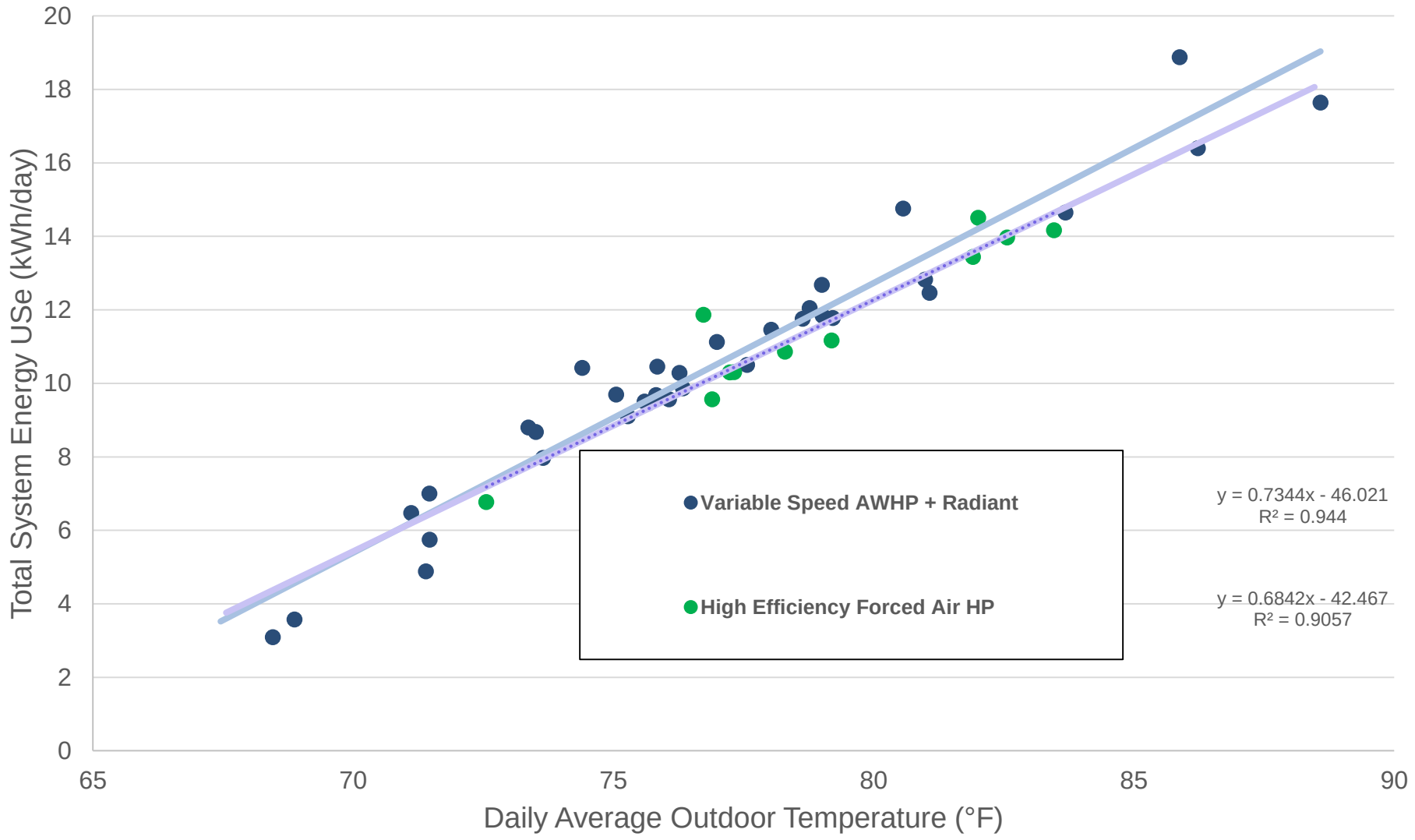
Initial Data and Findings

- Ongoing research at the Stockton lab house testing various AWHPs and configurations (work underway since 2015)
  - Energy and comfort comparison relative to a high performance ducted forced air heat pump with all ducts located in conditioned space
  - High performance reference HP specifications far exceed minimum prescriptive requirements:
    - 2-ton, two-stage split system heat pump (16 SEER, 12.5 EER, 9.5 HSPF)
    - 759 cfm (542 cfm/ton, operated only at low stage)
    - 0.15 Watts/cfm
  - Energy use results conservative since AWHP is maintaining equivalent indoor temperatures as the reference HP (no mean radiant temperature benefit)

Initial Data and Findings: Heating Performance



Initial Data and Findings: Cooling Performance



Preliminary Energy Savings Estimates

Preliminary Energy Savings Estimate				
Annual per Unit Electricity Savings* (kWh/___-yr)	Annual per Unit Natural Gas Savings* (Therms/___-yr)	First Year Statewide Electricity Savings (GWh/yr)	First Year Statewide Natural Gas Savings (Million Therms/yr)	Confidence Level (high, medium, low)

As a compliance option, statewide savings impacts **are not expected** since the assumption is that they will be traded off.

Sample Incremental Cost Information

- Cost and cost-effectiveness not needed for compliance option
- As an example, this table compares costs for a standard split system HP with ducts in conditioned space to an AWHP with radiant ceiling panels

	Forced Air	Radiant
Standard forced air system installation*	$16,263	
Chases for ducts (at $1.00 per ft^2)	$1,800	
Radiant panel installed cost**		$13,140
Heat pump (Chiltrix)		$3,600
Piping, valves, controls at $1.00/$ft^2$		$1,800
Totals	$18,063	$18,540

*2014 RS Means estimate for 1,200 ft^2 house, scaled to 1,800 ft^2

**$8 per ft^2 for one vendors panels at 60% ceiling area coverage, $1.50/$ft^2$ installation cost (net of drywall installation cost)

Incremental Per Unit Cost

Over 15/30 Year Period of Analysis

Not needed for compliance option

Incremental First Cost		Incremental Maintenance Cost	
Equipment	n/a	Equipment Replacement	n/a
Installation	n/a	Annual Maintenance	n/a
Commissioning	n/a		
Other	n/a		
Total		**Total**	

Compliance and Enforcement

- Design
- Permit Application
- Construction
- Inspection

Compliance Verification Process

1. Design Phase

- Select AWHP configuration and delivery option
- Specify equipment and develop installation details
- Evaluate Title 24, Part 6 compliance
- For radiant panels, provide manufacturer capacity data on plans

2. Permit Application Phase

- Verify AWHP equipment is Title 20 listed
- For radiant panels, verify panel sizing relative to Manual J load

Compliance Verification Process

3. Construction phase

- Coordinate installation timeline with the trades (panels…)
- Install specified equipment and controls as per design
- Commission AWHP (controls setup, hydronic system)

4. Inspection Phase

- Verify specified equipment is installed
- Pipe insulation inspection for hydronic piping (HERS)
- If radiant panels, potential HERS inspection for panel sizing, Quality Insulation Installation, and verification of prescriptive attic insulation levels.

Poll

Which AWHP installation elements should have required HERS verifications? *Select all that apply.*

A. Hydronic piping properly insulated
B. For radiant panel installations: quality insulation installation inspection required to verify attic insulation quality
C. For radiant panel installations: installed attic insulation R-values equal or greater than the prescriptive requirement
D. For radiant panel installation, installed panel area is sufficient to meet Manual J design load (based on panel manufacturer reported performance data)
E. None of the above

Market Actors

Market actors involved in implementing this measure include:

- Builder/Owner, Architect, Designers (Mechanical/Plumbing)
- Manufacturers, distributors, HVAC/plumbing/specialty hydronic contractors
- Energy Consultants, Plans Examiners, Building Inspectors, HERS Raters

Proposed Code Changes

- Draft Code Change Language
- Proposed Software Updates

Draft Code Change Language

- Code language changes are limited to addition of possible HERS inspection measures:
  - Proper pipe insulation
  - For radiant panels:
    - Prescriptive ceiling insulation or greater for radiant panel systems (also QII)
    - Installed panel area meets Manual J design load (based on manufacturer performance specifications)
- A Residential Appendix section that includes eligibility criteria for different system configurations will be proposed

Software Updates

- **Current modeling capabilities**
  - Interim AWHP and three function heat pump algorithms currently implemented in 2019 software
  - No capability for recognizing radiant panels
- **Proposed modeling capabilities**
  - Enhance AWHP and three function heat pump modeling in CBECC-Res
  - Anticipating two-tiered credit approach (fixed and variable speed equipment)
  - Enhance DHW modeling for three function heat pumps
  - Develop a simplified approach for recognizing radiant panel space conditioning delivery

Discussion and Next Steps

Thank You

Questions?

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2022 CALIFORNIA ENERGY CODE (TITLE 24, PART 6)

Residential HVAC Fault Detection and Diagnostics

Codes and Standards Enhancement (CASE) Proposal

Single Family | HVAC

Kristin Heinemeier, Frontier Energy, Inc.

October 10, 2019

CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

Agenda

Background

- Context and History
- 2019 Code Requirements
- Code Change Proposal

Context and History

- Why are we proposing this measure?
  - HVAC system performance degrades due to installation deficiencies, as well as things that happen over time.
  - Provide credit for use of advanced technologies that detect when residential HVAC systems are installed and operated optimally.
  - FDD devices can identify over time when an HVAC system's performance is not optimal (due to installation faults or faults that emerge over time), and alert the owners or service providers.
  - FDD tools can be embedded in OEM HVAC systems, or can be added as an option or as a retrofit.

Typical Residential HVAC Faults

- Low Refrigerant Charge
- High Refrigerant Charge
- Non-Condensables in Refrigeration System
- Restriction in Liquid Line
- Evaporator Airflow Restriction
- Condenser Airflow Restriction
- Slipping Belt
- Damaged or Poorly Installed TXV

2019 Code Requirements

- 2019 Requirements in Title 24, Part 6
  - There is a requirement for *initial* verification of performance:
    - Section 2.4 of the 2016 Title 24 Part 6 Residential ACM Reference Manual establishes a "compressor efficiency multiplier," used in calculations to degrade the SEER of an Air Conditioner by a factor of:
      - 10% when charge is not verified as correct
      - Only 4% when it is verified as correct
- No requirements or credits for installing devices that will ensure *ongoing* performance.

Code Change Proposal

- Use a modified Compressor Efficiency Multiplier when a certified FDD tool is installed and verified.
  - Current:

Initial Refrigerant Charge	
Verified	Not Verified
96%	90%

  - Proposed:

		Initial Refrigerant Charge	
		Verified	Not Verified
Ongoing FDD	Not Installed	96%	90%
	Installed	TBD (100%?)	TBD (96%?)

Poll

If you had to guess, what do you think would be an accurate Compressor Efficiency Multiplier when there is no initial refrigerant charge verification and no FDD?

(by definition, Compressor Efficiency Multiplier is 100% if performance perfectly matches rated performance.)

Short Answer: enter a number between 0% and 100%

Code Change Proposal

- Use a modified Compressor Efficiency Multiplier when a certified FDD tool is installed and verified.
  - Current:

Initial Refrigerant Charge	
Verified	Not Verified
96%	90%

  - Proposed:

		Initial Refrigerant Charge	
		Verified	Not Verified
Ongoing FDD	Not Installed	96%	90%
	Installed	TBD (100%?)	TBD (96%?)

Research into FDD Requirements

- Field test to establish appropriate compressor efficiency multipliers
- Lab test to verify FDD capabilities and provide intelligence for manufacturers' verification requirements

Field Test of Residential HVAC Performance

- Collect data on performance degradation in residential AC systems.

Age of System	Qty in No Cal	Qty in So Cal	TOTAL NUMBER
< 1 Year	6	6	12
1-5 Years	6	6	12
6-10 Years	6	6	12
>11 Years	6	6	12
TOTAL	24	24	48

- Monitor for up to 2 weeks, as-is
- Commission the system: conventional measurements, inspections, and tests to diagnose problems
- Calculate performance degradation; correlate with age and faults.
- Establish baseline and potential for savings from FDD
- Calculate degradation rate and Compressor Efficiency Multiplier

Lab Test of FDD Performance

- Testing Planned:
  - Single-Speed Split System with 24-V thermostat
  - Impose 3 or 4 faults: Non-Condensables, Low Charge, Liquid Line Restrictions, Low Evaporator Airflow
  - Fault Test: ≥20% Impact on Efficiency (arbitrary: performance degradation that clearly requires a “truck roll”)
  - False Alarm Test: ≤5% Impact on Efficiency (arbitrary: performance degradation that clearly DOES NOT require a “truck roll”)

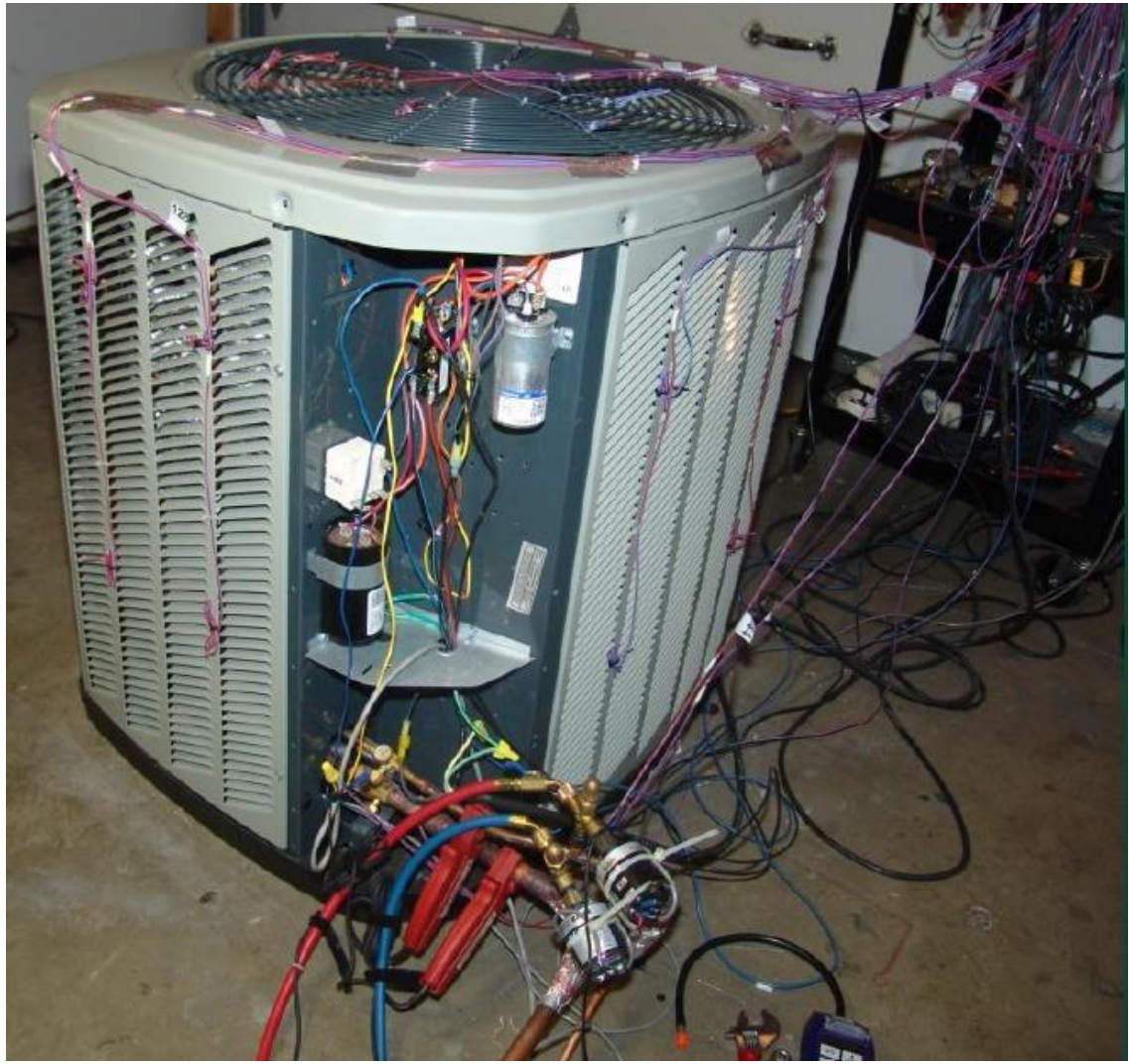


Photo: from SCE Report on Laboratory Testing of Residential HVAC Faults

Poll

What is the smallest level of efficiency degradation that you think justifies a “truck roll”?

(by definition, 0% = no faults/energy use is as expected; 100% = maximum possible fault/maximum possible degradation)

Short Answer: enter a number between 0% and 100%

Lab Testing

- Test one FDD tool in laboratory, in order to:
  - Verify that faults can be detected
  - Verify impacts of faults
  - Provide intelligence on mechanisms for manufacturer certifications
  - Certify one FDD tool (potentially)
- Test FDD Tool: Emerson Sensi Predict

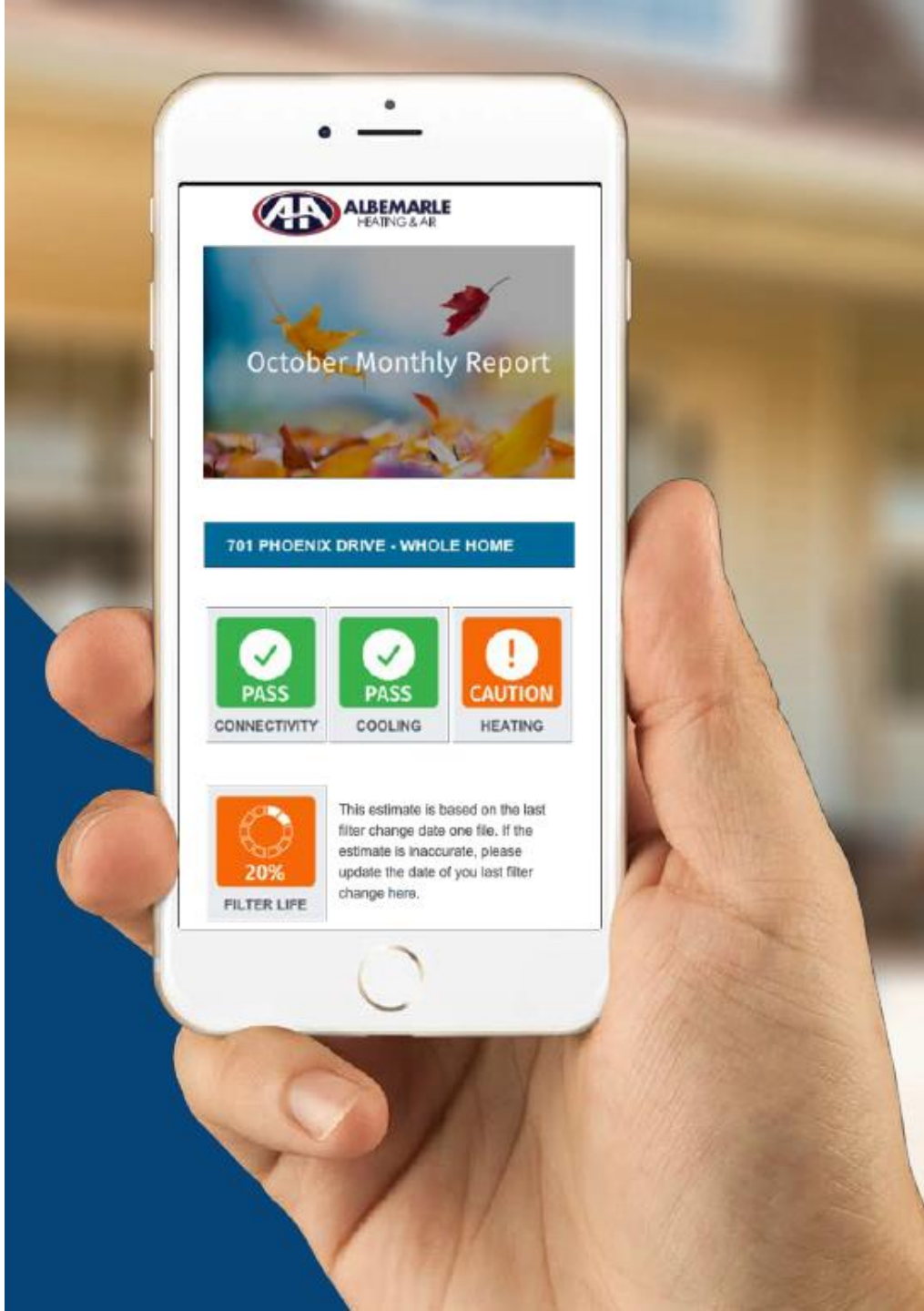


Photo source: Emerson

Manufacturer Certification

- Minimum eligibility criteria:
  - Annunciation of faults to occupant or contractor (how?)
  - Conditions detected: alarms for any faults that cause Fault Impact (EER or capacity) >20%
  - Minimal false alarms: no alarms for any faults that cause Fault Impact <5%
- Performance testing:
  - Lab testing by manufacturer: TBD Performance Specification
- Directory of certified products:
  - CEC-maintained, on CEC website

Discussion Item: What kind of testing do you think manufacturers should be required to do to certify that their FDD tool meets minimal eligibility criteria?

Field Verification

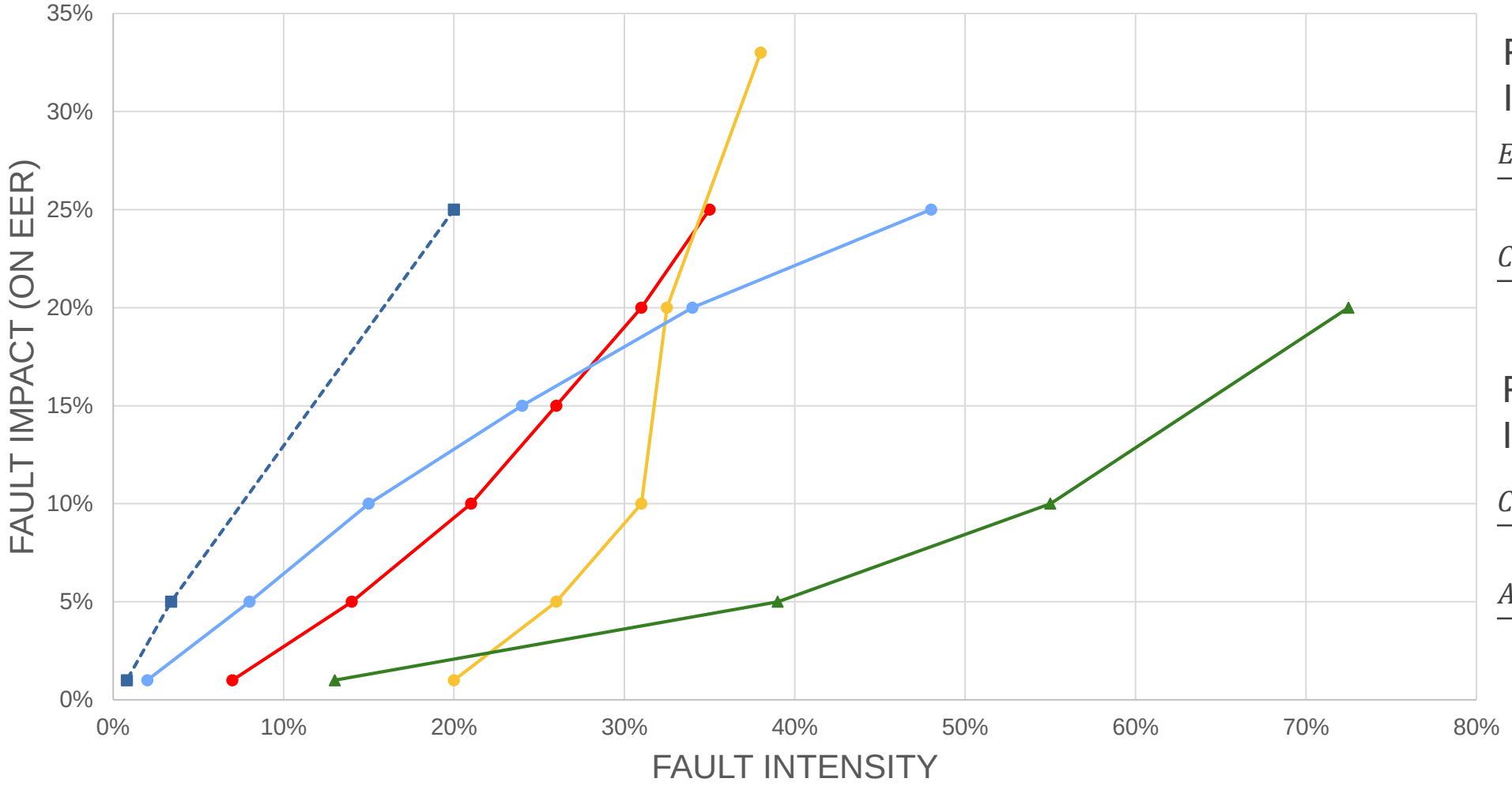
- HERS verification:
  - Verify model is certified
  - Confirm that it is hooked up
  - Confirm that it is configured to alert owner or send an alarm to contractor
  - Confirm sensor installation correct?

Discussion Item: What kind of testing do you think contractors should be required to do in the field to verify that the FDD tool is installed and configured correctly?

Technical Considerations

- Introduce terms:
  - Fault Impact
  - Fault Intensity
  - Fault Prevalence

Fault Impact – from the Literature (lab)



FAULT IMPACT:

$$\frac{EER_{no\ fault} - EER_{fault}}{EER_{no\ fault}}$$

$$\frac{Capacity_{no\ fault} - Capacity_{fault}}{Capacity_{no\ fault}}$$

FAULT INTENSITY:

$$\frac{Charge_{nominal} - Charge_{actual}}{Charge_{nominal}}$$

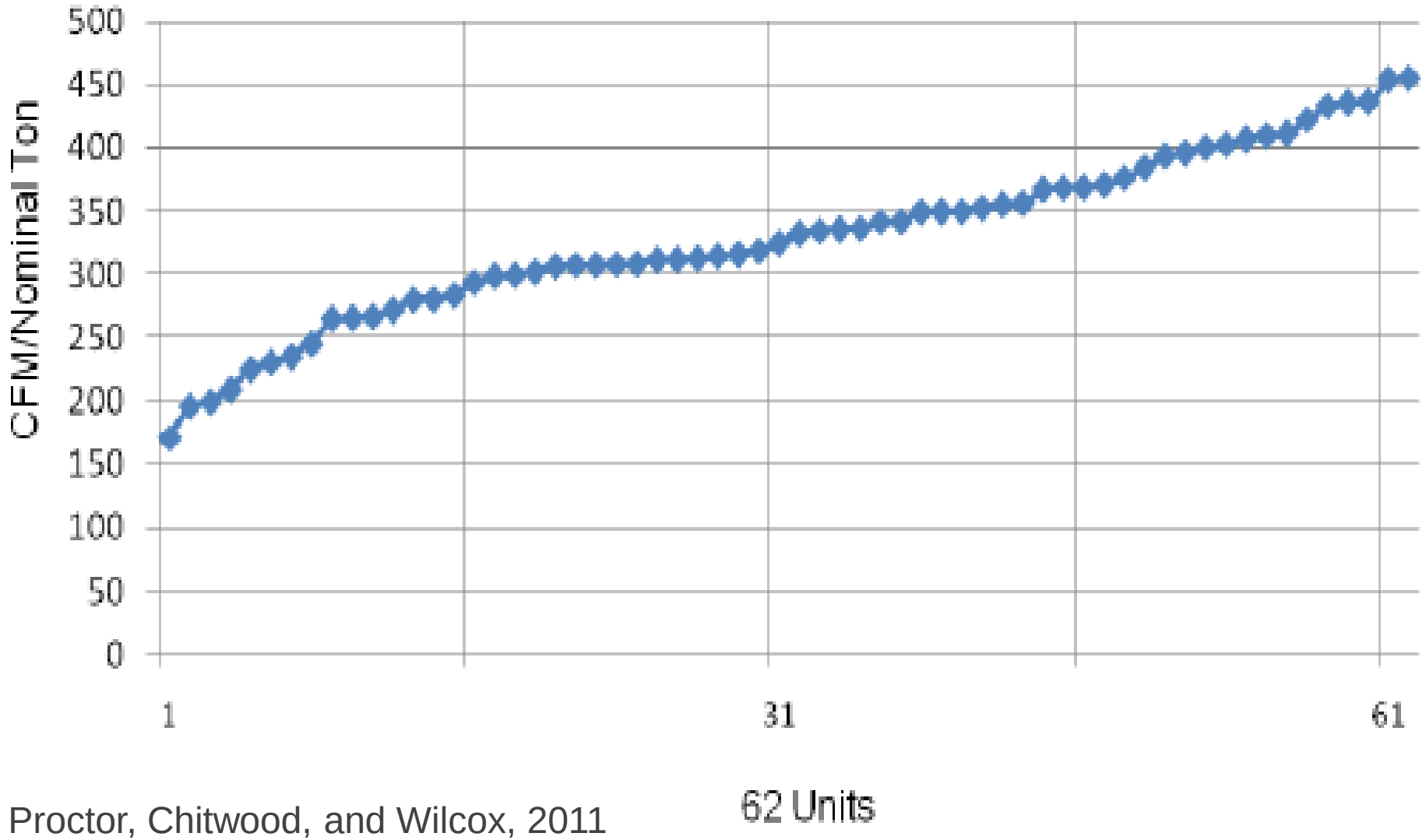
$$\frac{Airflow_{no\ fault} - Airflow_{fault}}{Airflow_{no\ fault}}$$

LOW CHG — LL RESTRICT — NON-COND x 20 — EVAP AIRFLOW — COND AIRFLOW

From "Generalized effects of refrigerant charge on normalized performance variables of air conditioners and heat pumps", Mehrabi and Yuill, 2017.

From "Generalized effects of faults on normalized performance variables of air conditioners and heat pumps." Mehrabi and Yuill, 2018.

Fault Intensity – from the Literature



Proctor, Chitwood, and Wilcox, 2011

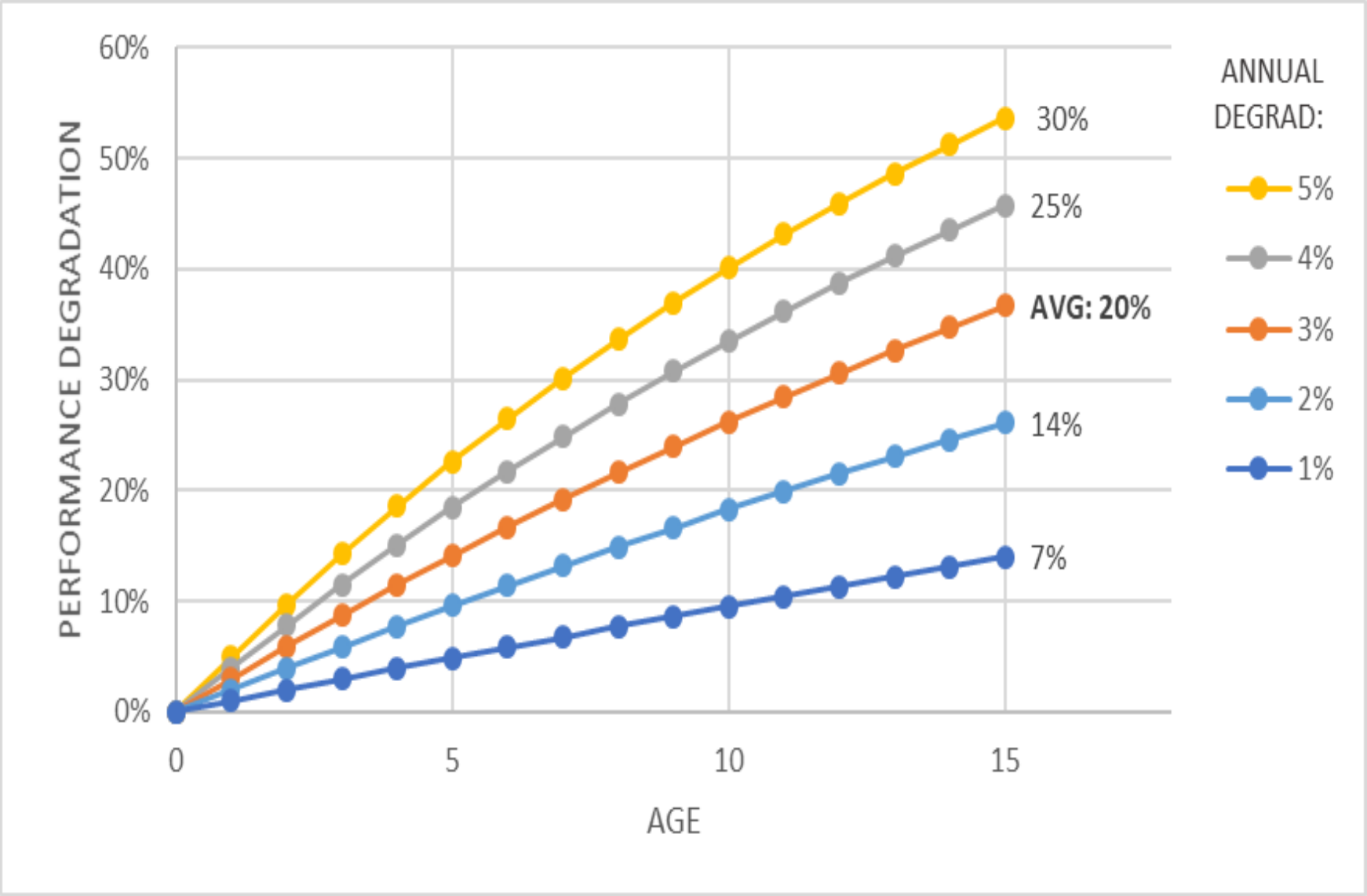
Fault Prevalence – from the Literature

- Refrigerant charge.
  - Incorrect charge found in more than 50% of examined field installations (California and the Southwest: Proctor 1997)
  - Low charge found in 78% of evaluated systems (the Phoenix area: Blasnik et al. 1996)
  - Incorrect charge in 77% of audited systems (Field study of 4,168 air conditioners: Mowris et al. 2004)

- Low coil air flow and coil fouling.
  - Median measured coil air flow was 333 cfm/ton—compared with 400 cfm/ton recommended. (California: Proctor 1990).
  - Coil air flow was consistently deficient, average = 317 cfm/ton. (Florida: Parker et al. 1998).
  - Improper airflow found in 44% of evaluated systems (Field study of 4,168 air conditioners: Mowris et al. 2004)
  - Significant fouling typically occurred in most systems, often by about 7.5 years of use. (Siegel et al. 2002).

Savings Depends on Expected Annual Efficiency Degradation

- Annual efficiency degradation
  - Example: 3% annual leads to 20% *average* degradation over 15 year life
  - Evidence of up to 5% annual[1]
  - Field test will provide evidence of annual degradation



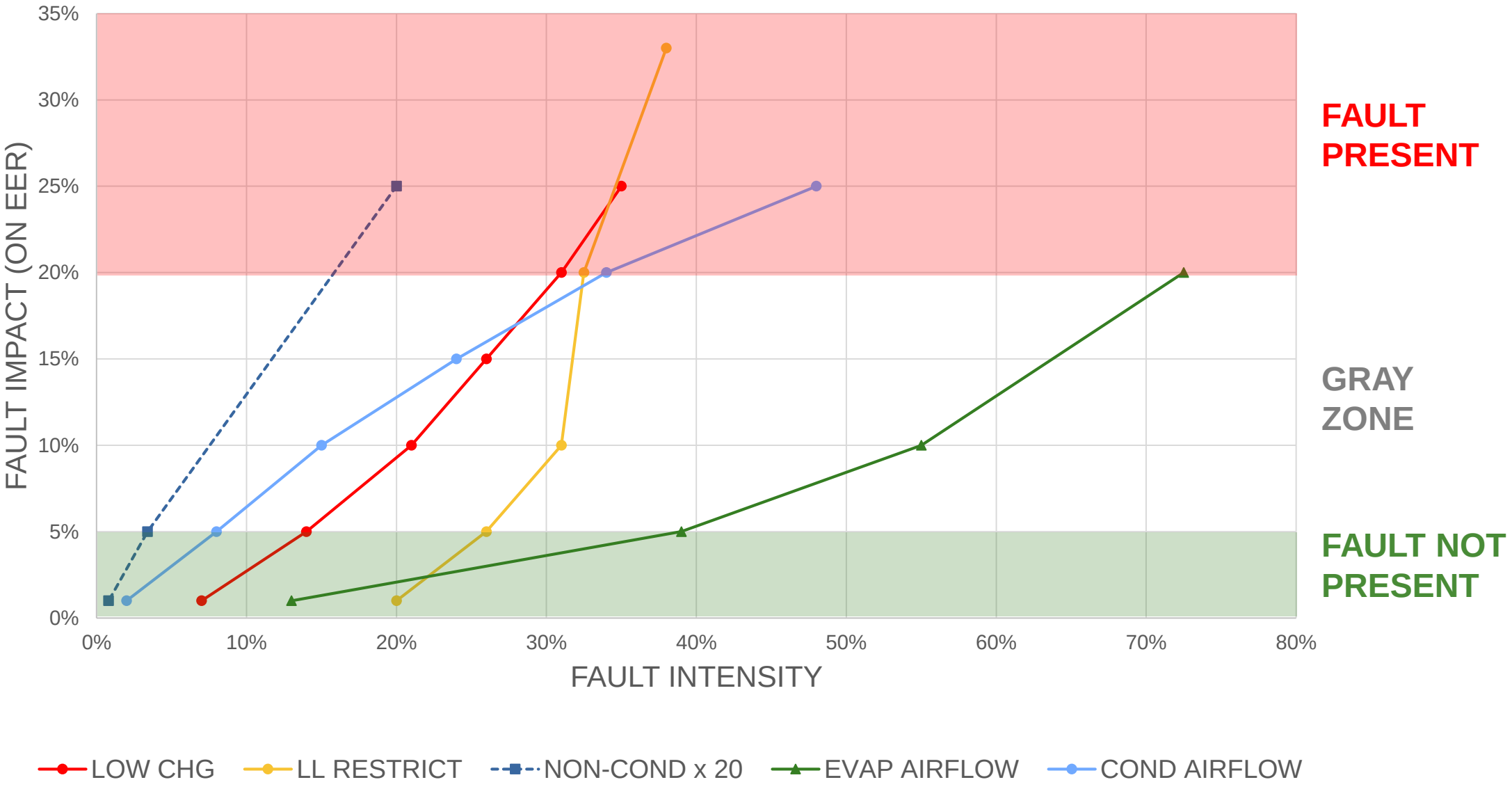
[1]Fenaughty, K., and D. Parker, 2018. "Evaluation of Air Conditioning Performance Degradation: Opportunities from Diagnostic Methods." Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings.

Energy and Cost Impacts

Methodology and Assumptions

- Energy Impacts Methodology
- Cost Impacts Methodology
  - Incremental costs – Not Required for Compliance Option
  - Energy cost savings

Fault Impact is the Key Metric



From "Generalized effects of refrigerant charge on normalized performance variables of air conditioners and heat pumps", Mehrabi and Yuill, 2017.

From "Generalized effects of faults on normalized performance variables of air conditioners and heat pumps." Mehrabi and Yuill, 2018.

Sample Savings Analysis

- Savings is based on analysis of fault impacts and probabilities of faults occurring and being fixed.
- Input: Annual Degradation Rate (field and literature)
- Assumptions: Probabilities of detecting and fixing
- Output: EER Benefit (Efficiency Multiplier)

Factor	Value
Annual Degradation Rate	3%
Fault Impact, avg 15 year	20%
Probability of detecting with FDD	*90%*
Probability of detecting without FDD	*10%*
Probability of fixing, if detected	*75%*
Probability of fixing a detected fault	60%
Overall EER Benefit (Impact x Probability)	**12%**

EXAMPLE

Initial Statewide Savings Estimates Per Year

Assumptions:

- 1055 kWh/dwelling unit—base case
- 12% savings

Gross Savings:

- 127 kWh/dwelling unit
- $300 15 year Present Value per dwelling unit (@ $0.20/kWh)
- Much of the savings is on-peak

Net Savings:

- Net savings is zero: tradeoff vs. other efficiency measures

Proposed Analysis:

- Model with compressor efficiency multiplier, Valuation per TDV

Compliance and Enforcement

- Design
- Permit Application
- Construction
- Inspection

Compliance Verification Process

1. Design Phase

- **FDD/Equipment Mfg** Certify product complies (lab testing, modeling). Certify w/ CEC.
- **CEC** Verify compliance and maintain directory of certified products
- **Energy Consultant/Modeler**: Specify FDD credit.
- **Designer/ Responsible Person** Indicate FDD on the plans and CF1R.

2. Permit Application Phase

- **Plans Examiner** Verify what's indicated on CF1R is also documented on plans.

Compliance Verification Process

3. Construction phase

- **HVAC Supplier** Review CEC certified list and supply certified products.
- **HVAC Contractor/ Maintenance Technician** Put make & model on CF2R. Purchase compliant equipment. Configure alarms. Educate homeowner. Possibly monitor alarms.

4. Inspection Phase

- **HERS Rater** Verify make and model are certified. Verify connected and configured to annunciate or send alarms. Complete CF2R.
- **Building Inspector** Verify HERS Rater has completed CF2R.

Market Actors

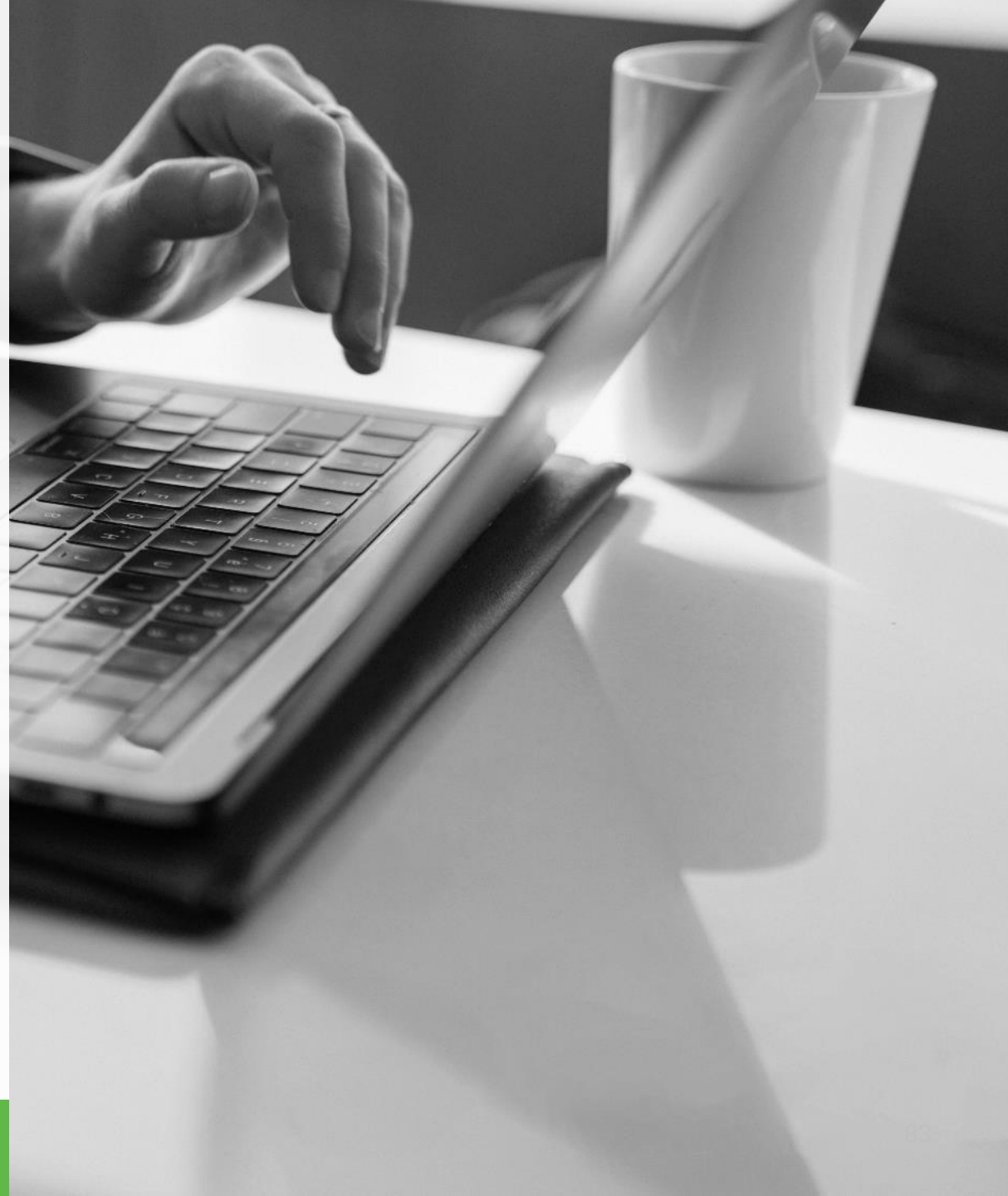
- Energy consultant/modeler
- HVAC contractor/maintenance technician
- HERS rater
- HVAC supplier
- HVAC / FDD manufacturers

- Energy consultant/modeler
- Designer/responsible person
- Plans examiner
- Builder/responsible person

- Engaging FDD manufacturers and researchers individually and via industry alliances

Proposed Code Changes

- Draft Code Change Language
- Proposed Software Updates



Draft Code Change Language and Software Update

ACM 2.4.5.1 VERIFIED REFRIGERANT CHARGE OR FAULT INDICATOR DISPLAY

Proper refrigerant charge is necessary for electrically driven compressor air-conditioning systems to operate at full capacity and efficiency, and ongoing verification is needed to keep it operating at full capacity and efficiency. Software calculations set the **compressor efficiency multiplier** to ~~0.90 to account for the effect of improper refrigerant charge or 0.96 for proper charge.~~:

- 0.90 when there is no initial verification and no ongoing FDD; or
- 0.96 when there is initial verification but no ongoing FDD; or
- XXX when there is ongoing FDD but no initial verification; or
- XXX when there is both initial verification and ongoing FDD.

RA3.4.5 RESIDENTIAL HVAC FDD VERIFICATION PROCEDURES (new content)

RA3.4.5.1 Construction Inspection (new content)

RA3.4.5.2 Functional Testing (new content)

JA6.4 RESIDENTIAL HVAC FDD CERTIFICATION SUBMITTAL REQUIREMENTS (new content)

Discussion and Next Steps

Thank You

Questions?

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CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

5 MINUTE BREAK

Reminder to download and review materials in the '*Resources*' box

CALIFORNIA ENERGY CODES & STANDARDS

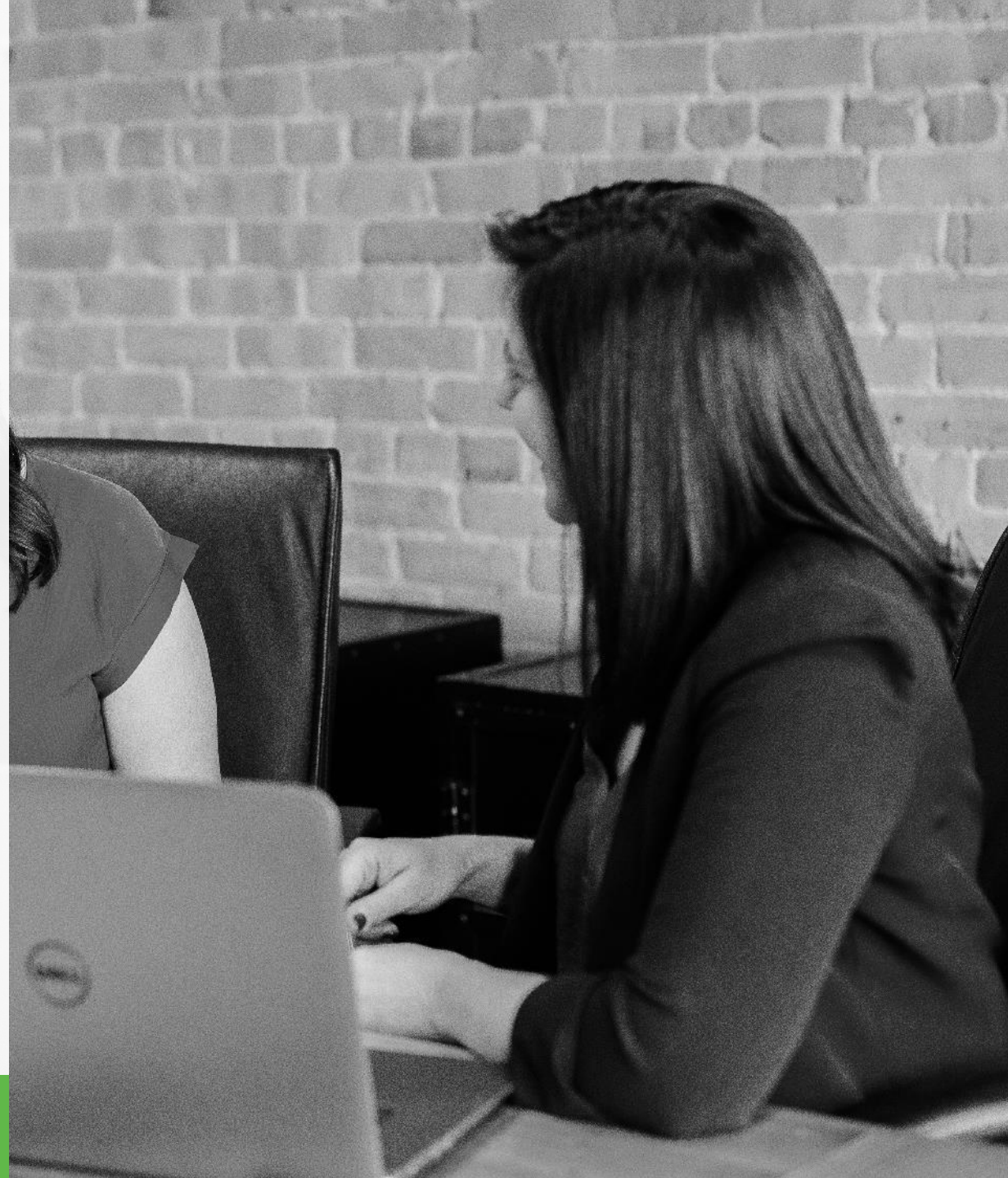
A STATEWIDE UTILITY PROGRAM

Stakeholder Survey for Single Family Topics

The CASE Team for *Energy Savings and Process Improvements for Additions and Alterations* is developing a survey to better understand your experience with additions, alterations, and the energy code.

We would love your feedback when this survey is live this fall.

May we contact you?



2022 CALIFORNIA ENERGY CODE (TITLE 24, PART 6)

Variable Capacity HVAC

Codes and Standards Enhancement (CASE) Proposal

Residential | HVAC

David Springer, Frontier Energy

Curtis Harrington, UCD Western Cooling Efficiency Center

October 10, 2019

CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

Agenda

Background

- Context and History
- 2019 Code Requirements
- Code Change Proposal

Code Change Proposal – Summary

Building Types	System Type	Type of Change	Software Updates Required
New single-family homes	Variable capacity = multi-speed and variable speed air conditioners and heat pumps*	Compliance Option	Yes

*Does not apply to mini-splits (VCHPs)

- Prescriptive Path:
  - Currently requires ducts to be in conditioned space or a high-performance attic
  - Builders not likely to use the prescriptive path if installing more expensive variable capacity systems
- Proposed Performance Path:
  - The ACM will account for reduced airflow and decreased distribution effectiveness for two-speed and variable speed split systems if ducts are located in the attic
  - The ACM may treat qualified systems that integrate zone control and system capacity the same as single-speed systems.

Context and History

- **Why are we proposing this measure?**
  - Variable capacity split systems may be increasingly used as a trade-off against high performance walls and attics and other required measures
  - WCEC lab test results clearly show distribution effectiveness is significantly reduced when airflow through ducts in a hot attic is lowered, offsetting efficiency improvements of variable capacity equipment
  - WCEC lab test results also show distribution effectiveness is preserved when zoning is linked to equipment airflow and capacity
  - Updating the duct model in the compliance software will improve accuracy of energy use predictions for variable capacity systems

Context and History

- Compliance software simulates duct performance the same way for single-speed and variable-speed systems, using entered SEER and EER
- In hotter climate zones the current ACM results show greater TDV reductions for variable speed equipment with attic ducts than for single speed equipment with ducts in conditioned space (DCS)

2100 ft^2 Prototype, Climate Zone 13, east front			
	Cooling kWh	Cooling KTDV/ft^2	TDV % Improvement
Single speed, SEER 14, EER 12.2, attic ducts*	1281	41.3	-
Single speed, SEER 14, EER 12.2, DCS**	1189	37.8	8.5%
Var. Speed, SEER 21, EER 13.5, attic ducts*	1104	36.8	10.9%
Var. speed, SEER 21, EER 13.5, DCS**	1023	33.5	18.9%

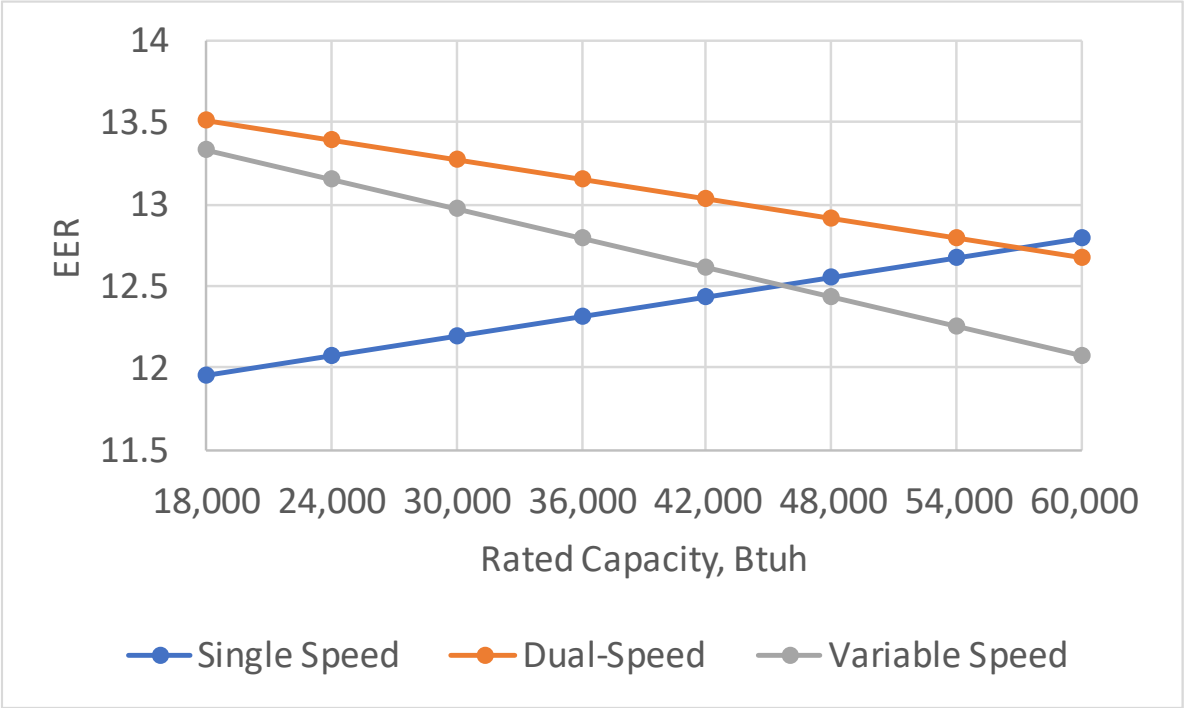
*Vented attic with no deck insulation

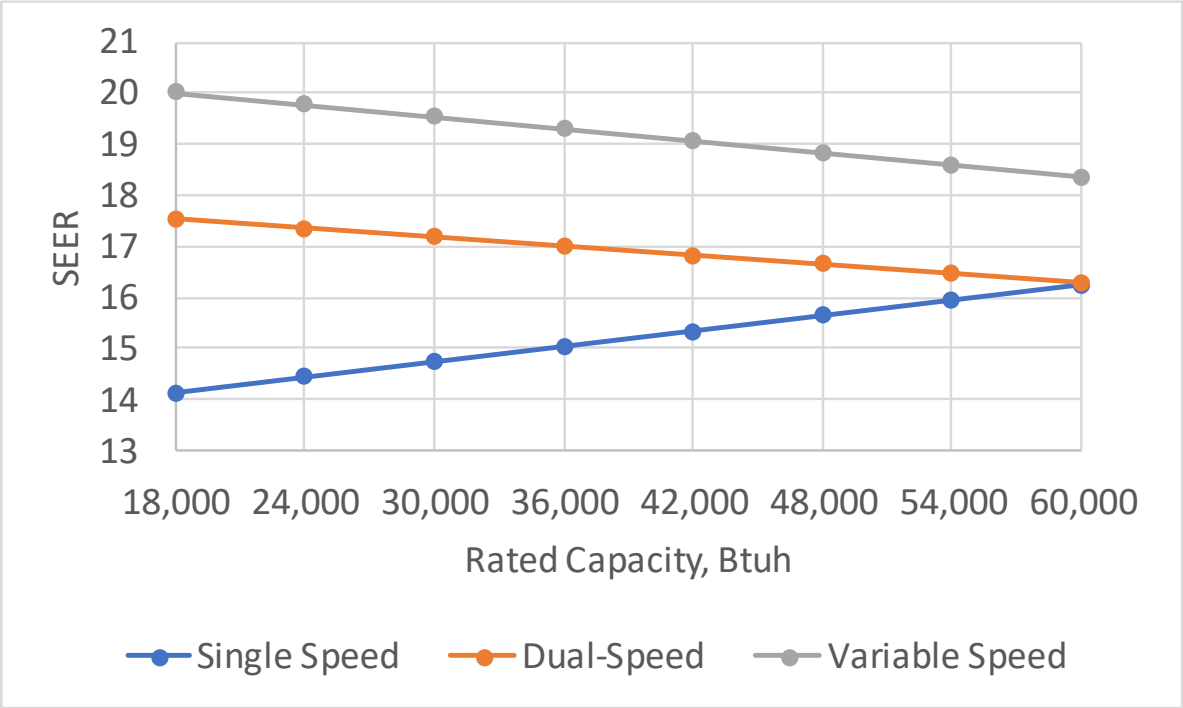
** Ducts in conditioned space, equipment in attic with up to 12 feet of attic duct

Efficiency of Variable Capacity Air Conditioners

- Linear regressions of split system air conditioner records from MAEDBS:

250 single speed - 2112 dual speed - 897 variable speed



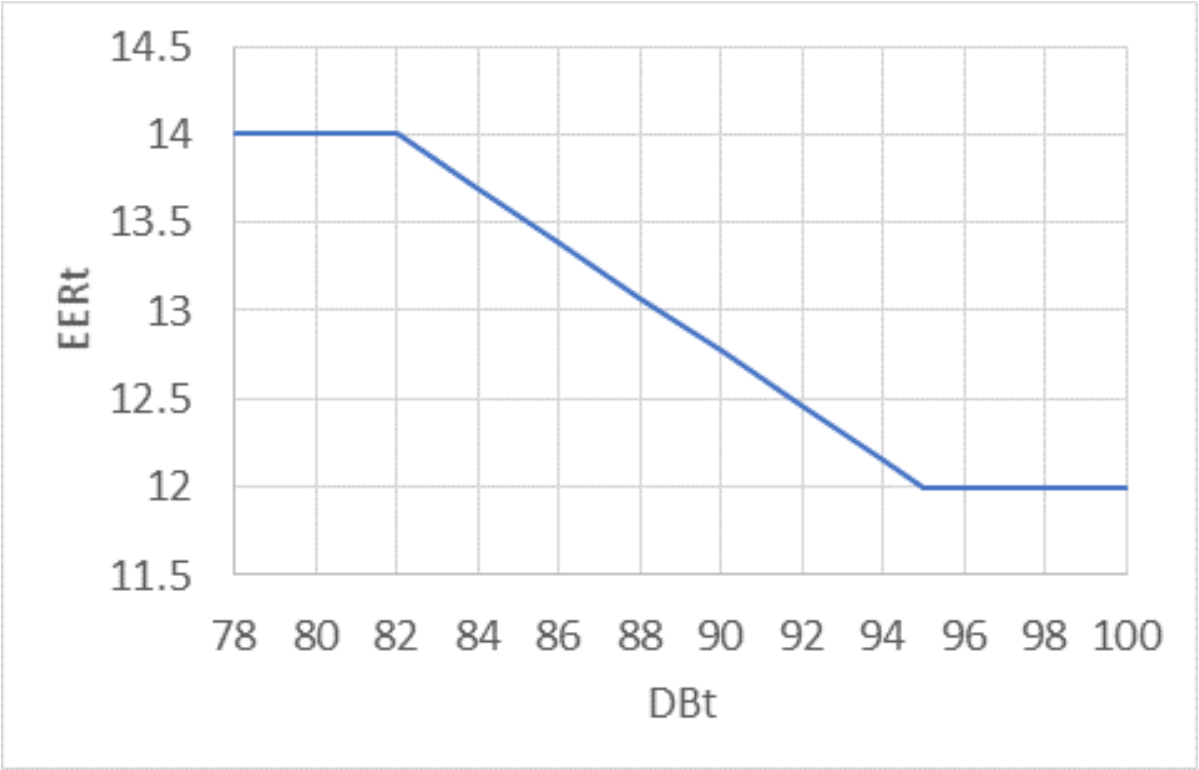


How the ACM calculates hourly air conditioner performance

$DB_t \leq 82°F$: $EER_t = SEER_{nf}$

$82 < DB_t < 95°F$: $EER_t = SEER_{nf} + ((DB_t - 82)*(EER_{nf} – SEER_{nf}) / 13)$

$DBt \geq 95°F$ $EER_t = EER_{nf}$



DB_t = outdoor dry bulb temperature, nf = not including indoor fan, EER_t = EER at time step

2019 Code Requirements

- 2019 Requirements in Title 24, Part 6
  - No constraints on the use of variable capacity split systems – treated the same as single speed except:
  - When multispeed or variable speed compressor systems are used, compliance with airflow and fan efficacy requirements are demonstrated with all zones calling for conditioning instead of in all control modes (as for single speed systems) – Section 150.0(m)13C, Exception 1.
  - Variable speed *mini-split* heat pumps:
    - 2016: Required to be modeled as minimum efficiency heat pumps with ducts in conditioned space
    - 2019 Proposal: 5% performance improvement over the SEER 14 / EER 11.7 federal minimum cooling efficiency, and a 12% improvement over the HSPF 8.2 federal minimum heating efficiency, and ducts must be in conditioned space

2019 Code Requirements

- Other Codes & Standards:
  - ASHRAE Standard 152-2014: *Method Of Test For Determining The Design And Seasonal Efficiencies Of Residential Thermal Distribution Systems*
  - Combined efficiency of equipment and distribution systems not recognized in other codes
- Other regulatory considerations
  - Proposed handling of mini-split performance sets precedent for requiring ducts in conditioned space (not subject to preemption)
  - This proposed measure does not increase stringency but corrects an energy accounting oversight and produces energy savings

Proposed Code Change Overview

- Draft code language for this submeasure is available in the **resources tab**
- Description of proposed changes for variable capacity systems
  - Prescriptive: No change
  - Performance:
    - Performance model to account for reduced air velocity in calculating distribution effectiveness and overall cooling system energy use
    - When specified, zoned systems assumed to have same duct airflow as un-zoned when controls are integrated with zoning – requires HERS verification

Market Overview

- Current Market Conditions
- Market Trends
- Potential Market Barriers and Solutions

Market Overview and Analysis

- Current Market
  - Could be as high as 20% of market share (under investigation)
  - All major HVAC manufacturers offer variable capacity equipment
  - Utility incentives
    - California Advanced Home Program
    - High performance HVAC yields larger delta EDRs

the NEWS

Variable Speed's Impact on HVAC *February 6, 2017*

Variable-speed options have become the industry standard

GIVE ME A REASON: Efficiency and comfort are two of the most popular reasons for switching to variable speed.

Market Overview and Analysis

- **Market Trends**
  - Use of high-performance HVAC may increase as standards become more rigorous
  - Results from a survey of HVAC contractors specializing in new home construction are pending
- **Market Barriers**
  - Cost of ducts in conditioned space or high-performance attic
  - Limited availability and high cost of systems that integrate zone control with variable capacity

Poll

Approximately what proportion of air conditioners and heat pumps installed in new homes are two-speed or variable speed?

A: Less than 5%

B: Up to 25%

C: Up to 50%

D: Over 50%

What is the key reason variable capacity systems are installed?

A. To pass Title 24

B. To improve comfort

C. To provide better comfort

D. To make zoning work better

Technical Considerations

- Technical Considerations
- Potential Barriers and Solutions

Technical Considerations

- **Technical Considerations**
  - Placing ducts in conditioned space (DCS) eliminates duct losses but increases construction complexity and cost
  - Locating ducts in a high-performance attic (HPA) reduces duct loss penalties resulting from low airflow; duct loss depends on duct environment temperature
  - Zoning only improves distribution effectiveness if zone controls are linked to compressor & fan speed
- **Potential Solutions**
  - DCS is the only solution that in practice will preserve all variable capacity efficiency gains
  - HPAs may preserve much of the efficiency gains from variable capacity systems
  - Zoning systems should be configured as close as possible to utilize the same fraction of ductwork as capacity being delivered (i.e. 50% capacity should be delivered to ~50% of the ductwork)

Energy and Cost Impacts

Methodology and Assumptions

- Energy Impacts Methodology
- Cost Impacts Methodology
  - Incremental costs
  - Energy cost savings

Methodology for Energy Impacts Analysis

- Proposed Methodology (under development)
  - Utilize one and two-story single-family residential prototypes
  - Make “under-the-hood” changes to CBECC to allow duct air velocities to be varied, for example based on daily average load conditions
  - Calibrate CBECC duct losses using WCEC laboratory data
  - Use modified and calibrated CBECC model and typical variable capacity system ratings to compute energy use for ducts in vented attics, high performance attics, and for ducts in conditioned space in all climate zones

Preliminary Assumptions for Energy Impacts Analysis

- **From WCEC research:**
  - Test results based on R6 duct
  - Assumed mean attic temperature during cooling cycles of 106˚F:
  - *System* COP falls from 2.4 at full airflow to 1.7 at 40% of full airflow (71%)
- **Other assumptions and methodology**
  - Variable speed system EER = 13.5, SEER = 21
  - Applied 71% multiplier to develop alternate inputs (9.6 EER, 14.9 SEER)
  - Used CBECC 2019 to model difference in energy use using 2100 ft^2 single story prototype

Definition of Baseline and Proposed Conditions

Baseline Conditions

- Prescriptive except for HVAC system
- Variable speed compressor and fan
- EER & SEER reduced to account for attic duct losses and impact on overall system COP

Proposed Conditions

- Prescriptive except for HVAC system
- Variable speed compressor and fan
- EER & SEER as rated
- Ducts in conditioned space

2023 Construction Forecast

- Assumed that 5% of newly constructed single-family homes will be impacted by the proposed requirement (this estimate will be updated following completion of an HVAC contractor survey)
- Based on this percentage and using 2019 housing start estimates, the total number of homes that will be impacted annually by the proposed requirement is estimated to be 46,569.

Preliminary Energy Savings Estimates

- *Preliminary* results for dwelling unit and statewide savings presented in table (based on system COPs from WCEC tests)
- Need accounting for airflow in CBECC to more accurately estimate energy use and savings

Climate Zone	EER/SEER 13/18	EER/SEER* 9.2/12.8	Savings kWh/yr	Housing Starts	Statewide Savings, MWh/yr**
11	927	1272	345	5970	103.0
12	204	252	48	19465	46.7
13	1051	1442	391	13912	272.0
14	875	1200	325	3338	54.2
15	3551	4982	1431	3885	278.0
				Total	753.9

*Estimated 29% decrease in performance based on lab results

**Assume 5% of new homes have variable capacity systems with attic ducts

Initial Data and Findings

- Laboratory test results (in following slides)
  - Duct delivery effectiveness (R-6 ducts)
  - Equipment COP and duct efficiency vs. compressor and fan-speed
  - System COP
  - Zoning impacts
- Cost-effectiveness:
  - Not evaluated for compliance options
  - Zero incremental cost assumed

Lab Test Results

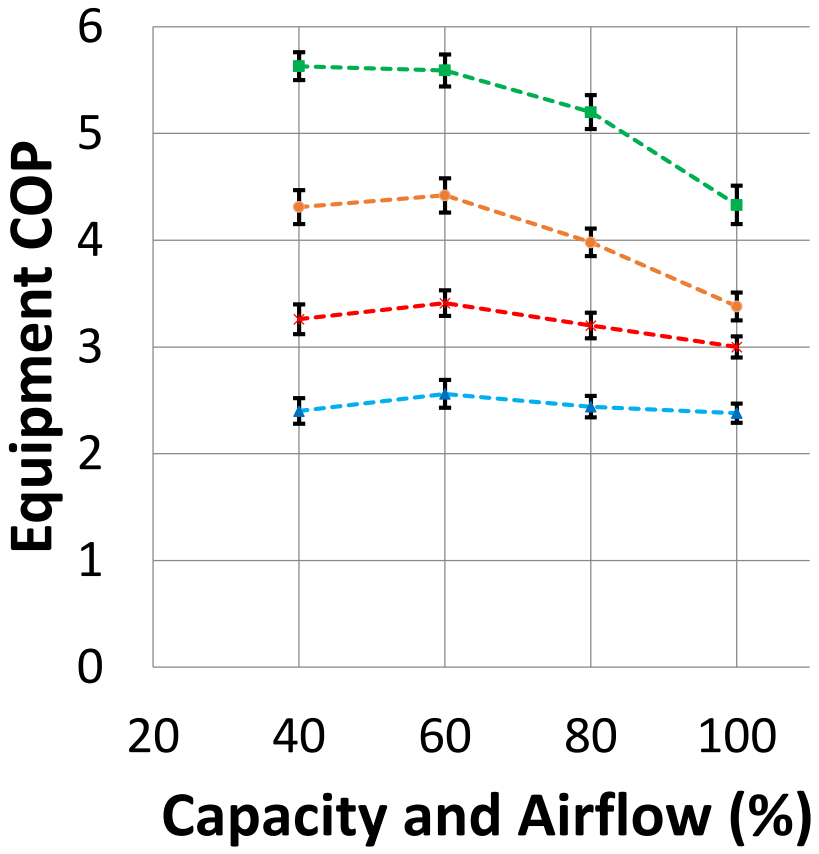
Duct Delivery Effectiveness

How well ducts deliver the conditioned air to ducted space

- Duct loss assessment with variable capacity heat pump
  - Actual duct design for a 2-ton single-family system
  - Ducts located in unconditioned space (same temp as outdoor)
  - Standard new-construction duct insulation – R-6
  - No duct leakage

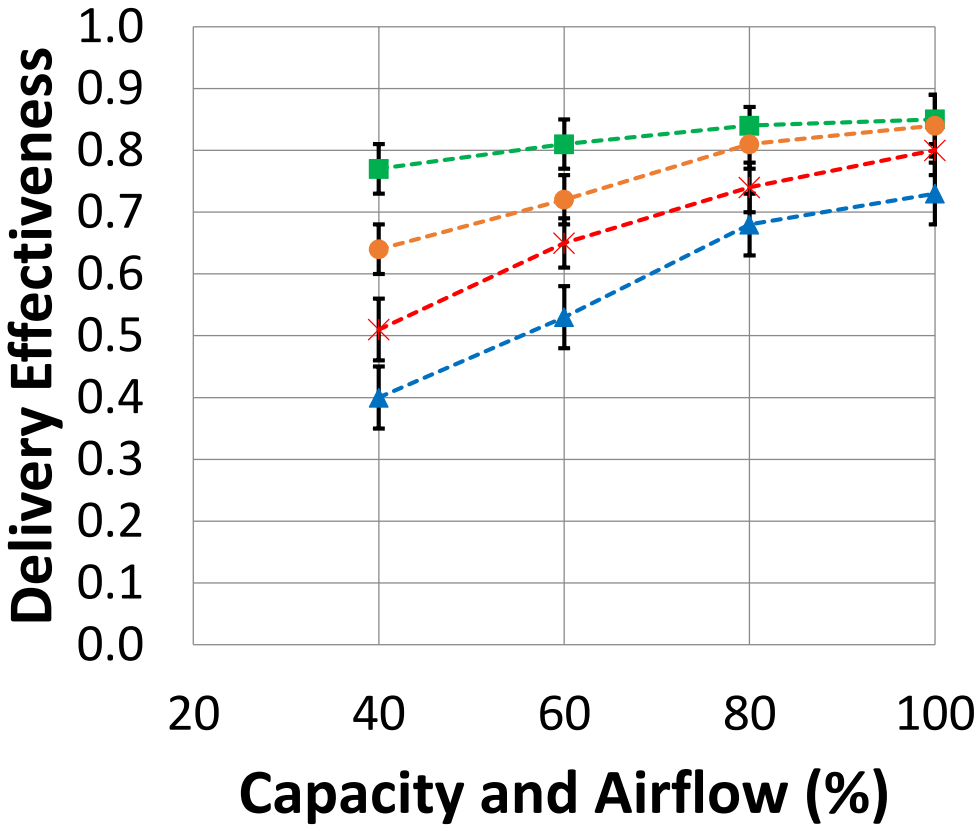
Maximum System COP depends on outdoor/attic temp

Equipment COP and Duct Efficiency vs. Compressor and Fan-Speed



Duct-zone temperatures:

- 85°F
- 95°F
- 105°F
- 115°F



Equipment performance increases as speed is reduced

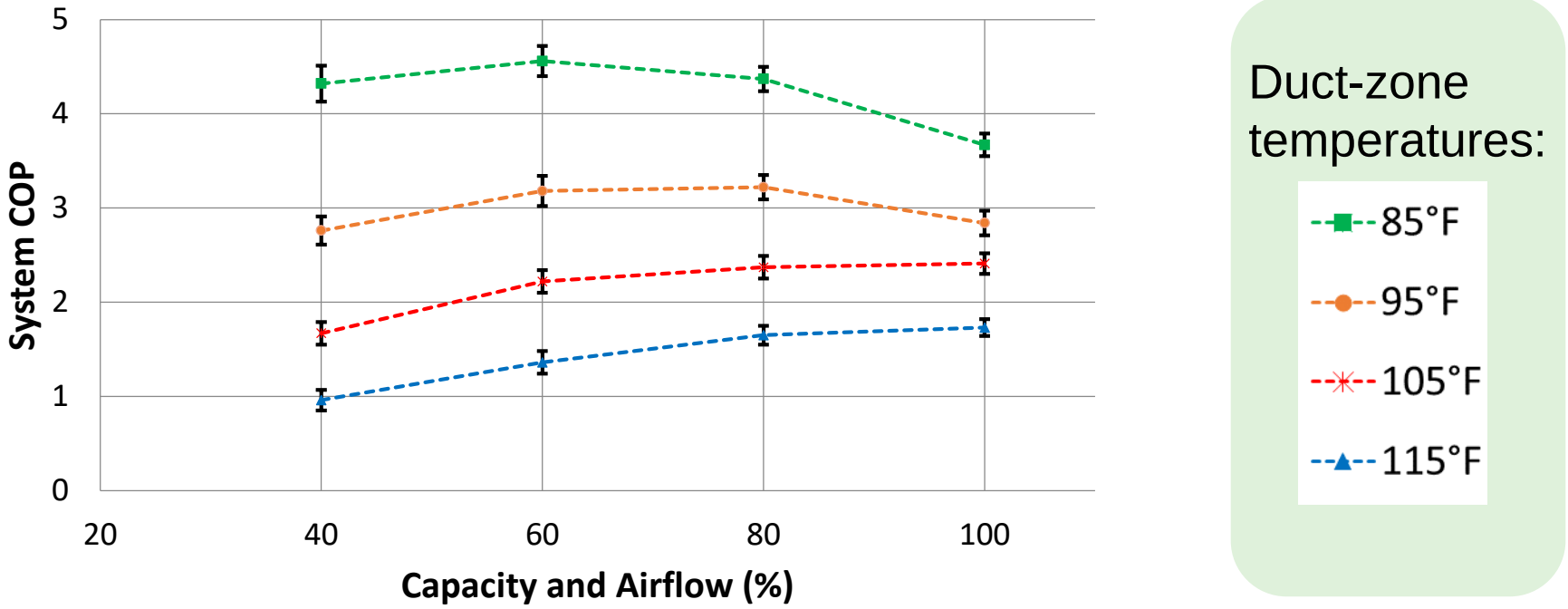
Delivery effectiveness decreases as speed is reduced

System COP

System COP = Equipment COP x Delivery Effectiveness

- *System COP describes overall efficiency including equipment and ducts*

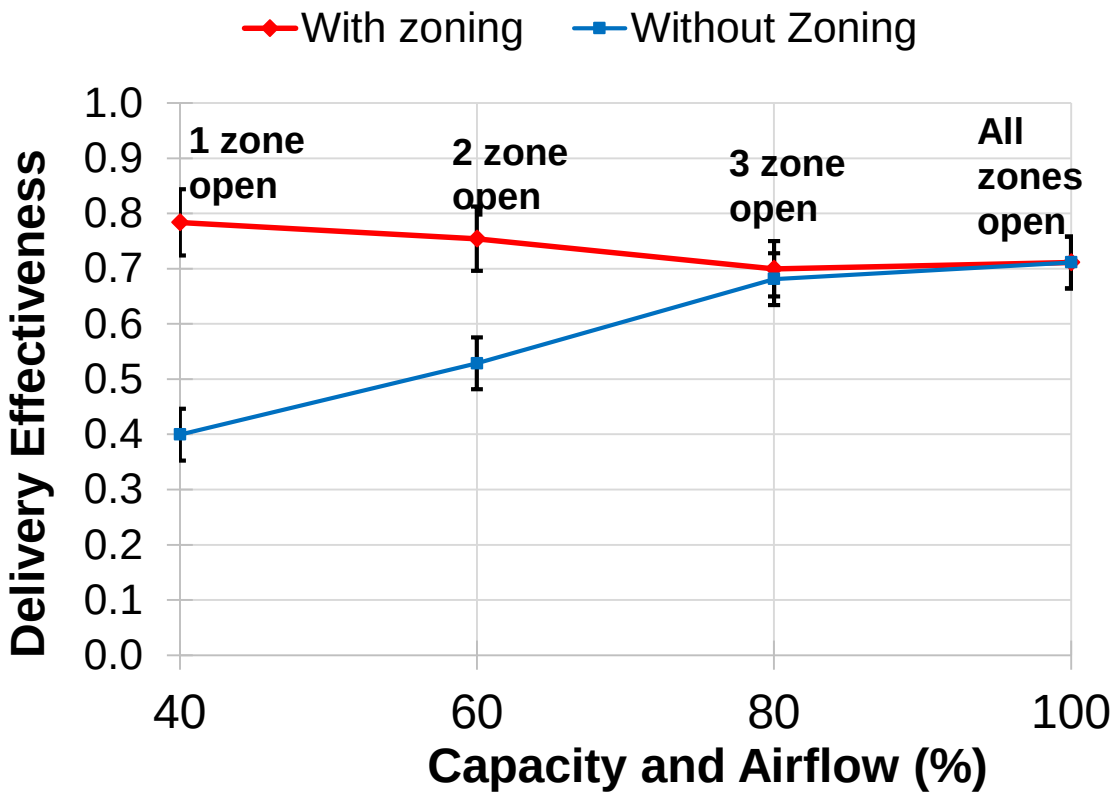
Maximum System COP depends on outdoor/attic temperature

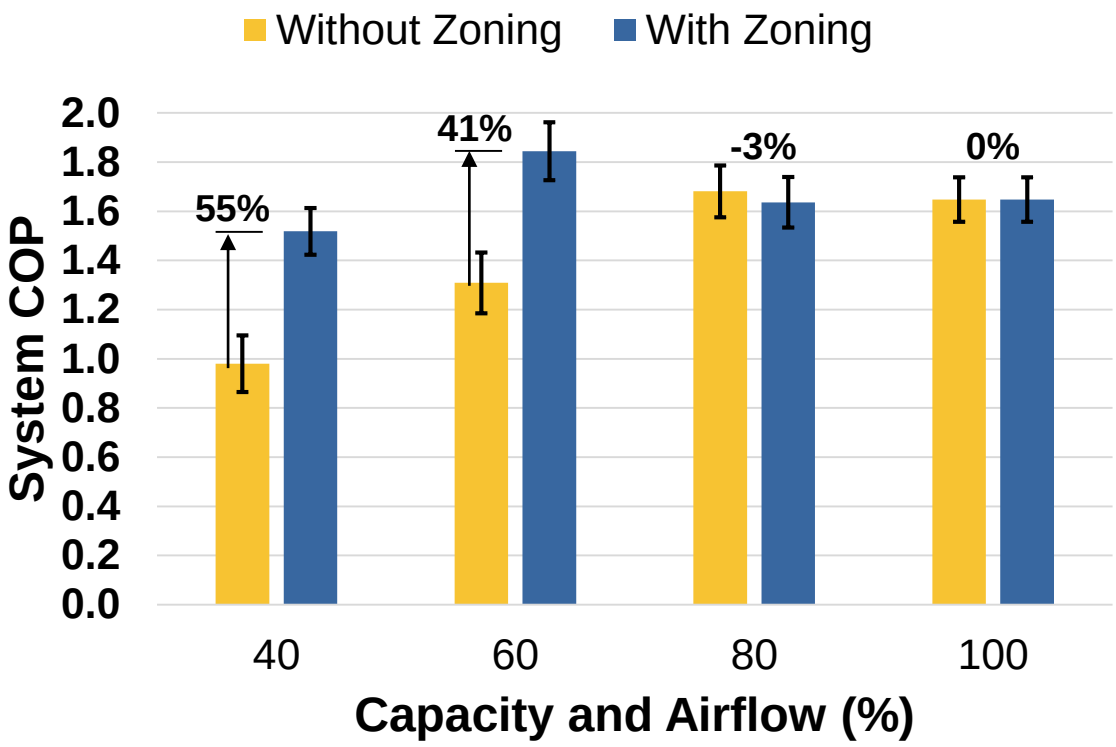


Optimal speed at high temperatures is 100%

Impact of Adding Zoning: (Attic: 115°F, Indoor: 75°F)

- 95% more cooling delivered when zoned at low speed
- 40-55% better system efficiency at low speed





Zoning can significantly reduce duct losses at low speed

Incremental Cost Information

- Scenarios - High performance HVAC is required for compliance
  1. Ducts in conditioned space – no incremental cost since included in the standard model (Component Package Option C), get full credit for overall system performance
  2. Ducts in high-performance attic – no incremental cost since included in the standard model (Component Package Option B), get reduced credit for overall system performance
  3. Ducts in unconditioned attic with zone controls integrated with system speed – negative incremental cost for attic duct location but added cost for zone controls, get full credit for equipment performance and same assumed distribution effectiveness as for single speed
  4. Ducts in standard vented attic w/o zoning – negative incremental cost for attic duct location; may yield a lower compliance margin than for a single speed system with ducts in a high-performance attic or conditioned space (Option B or C).
- Incremental cost assumed to be zero

Incremental Per Unit Cost

Over 15/30 Year Period of Analysis

Incremental First Cost		Incremental Maintenance Cost	
Equipment	$0	Equipment Replacement	$0
Installation	$0	Annual Maintenance	$0
Commissioning	$0		$0
Other	$0		$0
Total	**$0**	**Total**	**$0**

- Variable capacity HVAC systems are an alternative compliance option used to improve the compliance margin and therefore have no incremental first cost.
- Maintenance costs are likely to be equivalent to those of single speed systems, and perhaps lower due to reduced short-cycling and refrigerant pressures.

Poll

When assessing the incremental cost of the proposed change, is it reasonable to assume the cost of DCS or HPA is zero given that they are prescriptively required?

A. Yes, it seems reasonable

B. No, incremental costs should be included since DCS and HPA are typically avoided using trade-offs

C. No, the cost of an integrated zone system should be accounted for

D. I don’t know

Compliance and Enforcement

- Design
- Permit Application
- Construction
- Inspection

Compliance Verification Process

1. Design Phase

- Energy analyst selects variable capacity system and distribution design
- Design consultant specifies HVAC system and zone controls (if applicable) and details duct location (attic, HPA, DCS) in construction documents

2. Permit Application Phase

- Equipment efficiency, duct location, cooling system type* and zoning** designated on CF1R-NCB for plan check.

*A cooling new cooling system category must be added for variable capacity systems

**CF1R does not currently include zoning in distribution system type

Compliance Verification Process

3. Construction phase

- HVAC contractor installs equipment and duct system as specified
- HERS rater verifies installed equipment is the same as listed in the CF2R, and verifies duct location
- HERS rater verifies that integrated zoning/variable capacity system is listed (if used)

4. Inspection Phase

- HERS rater verifies HVAC systems and completes testing, submits CF3R-MCH-21-H and CF3R-MCH-26-H to the registry

Market Actors

Market actors involved in implementing this measure include:

- Roles of market actors:
  - Energy consultant: Selects high performance HVAC system and duct location as needed for compliance, coordinates with builder and HVAC contractor to ensure feasibility, completes compliance documentation
  - Mechanical consultant: Completes plans for permit submittal specifying equipment and duct location
  - HVAC contractor: Procures, installs, and commissions HVAC system
  - HERS rater confirms compliance
- Additional information may be obtained through an HVAC contractor survey

Proposed Code Changes

- Draft Code Change Language
- Proposed Software Updates

Draft Code Change Language

- Draft code language is available in the resources tab
- Allows either ducts in conditioned space or integrated zoning to be used to preserve *system* performance

Poll

Do you expect this measure to make compliance and verification more challenging?

A: Yes

B: No

Are you aware of systems that integrate zone controls with compressor & fan speed?

A: Yes

B: No

Software Updates

- **Current modeling capabilities**
  - System performance as a function of outdoor temperature and a fixed airflow rate
  - Distribution effectiveness using fixed airflow rates and duct environment (attic, HPA, DCS)
- **Key proposed modeling needs**
  - Reduction of assumed air velocity in ducts when variable capacity equipment is specified
  - Different assumptions for two-speed and variable speed systems?
- **Ideal modeling capabilities**
  - Velocity a function of hourly load
  - Addition of zones for occupied spaces and integration with variable speed, zoned systems

Discussion and Next Steps

Thank You

Questions?

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We want to hear from you!

- Provide **any last comments or feedback** on this presentation now verbally or over the chat
- More information on pre-rulemaking for the 2022 Energy Code at https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency
- **Comments on this measure** are due by October 24, please send to info@title24stakeholders.com and copy CASE Authors (see contact info on following slide).

Thank you for your participation today

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Please complete the closing polls below

Upcoming Meetings

Meeting Topic	Building Type	Date
Single Family HVAC	SF	Thursday, October 10, 2019
Nonresidential HVAC Part 1: Data Centers, Boilers, & Controls	NR	Tuesday, October 15, 2019
Nonresidential Envelope Part 1	NR	Thursday, October 24, 2019
Nonresidential HVAC and Envelope Part 2: Air Distribution, & Controls	NR	Tuesday, November 5, 2019
Covered Processes Part 2: Compressed Air, Steam Traps, & Refrigeration	NR	Thursday, November 7, 2019
Single Family Whole Building	SF	Tuesday, November 12, 2019
Nonresidential Software Improvements	NR	Tuesday, November 12, 2019