| DOCKETED | |
|---|---|
| **Docket Number:** | 19-BSTD-02 |
| **Project Title:** | Residential Alternative Calculation Method Variable Capacity Heat Pump Modeling Approach |
| **TN #:** | 227124 |
| **Document Title:** | Presentation - Residential Alternative Calculation Method Avariable Capacity Heat Pump Modeling Approach - Public Workshop |
| **Description:** | VCHP Workshop Presentation Slides |
| **Filer:** | RJ Wichert |
| **Organization:** | California Energy Commission |
| **Submitter Role:** | Commission Staff |
| **Submission Date:** | 2/21/2019 6:49:38 AM |
| **Docketed Date:** | 2/21/2019 |

# Public Workshop

## Residential Alternative Calculation Method Variable Capacity Heat Pump Modeling Approach

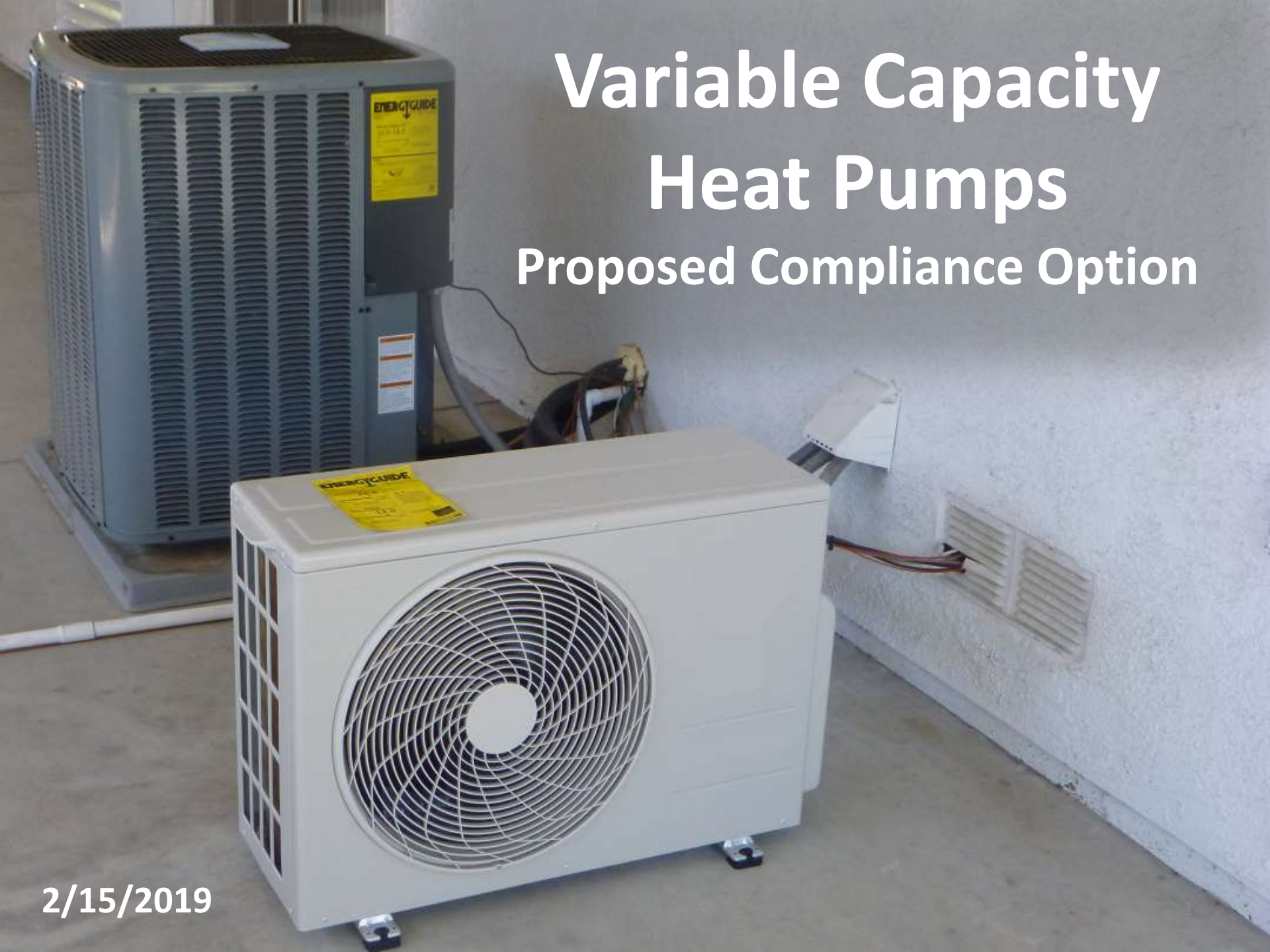
**February 15, 2019**
**California Energy Commission**

# General Workshop Information

- Broadcast using WebEx
  - The meeting is being recorded
  - In person participants: please sign in
- Online participants
  - Will remain muted unless they request to comment
  - Online comments will be taken after in person participants and in alphabetical order
- Comments
  - Provide business card and state name and affiliation before speaking
- Presentation
  - This presentation and transcript will be posted on our website in a few days

# General Workshop Information

- Moderator
  - Larry Froess, P.E. – California Energy Commission
- Presenters
  - Abram Conant - Proctor Engineering Group
  - Bruce A. Wilcox P.E.
- Question and Answers



# Variable Capacity Heat Pumps

## Proposed Compliance Option

2/15/2019

# Background

**Currently no credit for mini and multi split variable capacity heat pumps (VCHP)**

- High SEER and HSPF ratings not demonstrated to predict installed performance
- Issues with comfort, controls, installation

**Research Plan**

- Field based evaluation of multiple VCHP systems
- Determine appropriate credit and requirements

**Studies have been conducted each year since 2014**

- **http://www.etcc-ca.com/reports/variable-compressor-speed-heat-pumps**
- **https://www.etcc-ca.com/reports/central-valley-research-homes-evaluation-ducted-and-ductless-configurations-variable**

# Central Valley Research Homes (CVRH) Laboratory Houses




Houses received deep energy retrofits in 2013 and now approach the efficiency of modern CA building standards

# Extensively Instrumented

# Simulated Occupants



Title 24 internal gains schedule

# Reference HP System

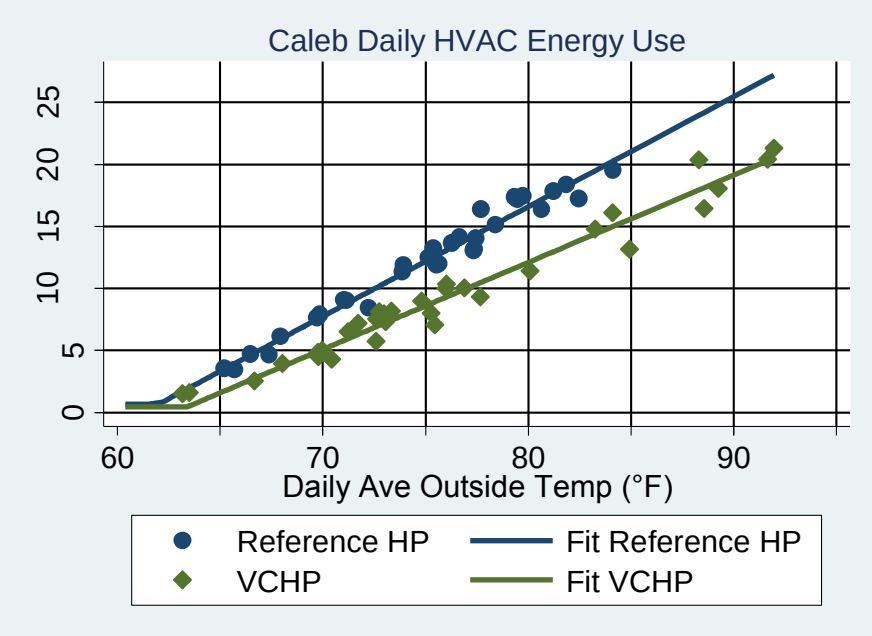
- Single speed, SEER 14, HSPF 8.2, in conditioned space
- VCHP and Reference HP alternate every few days
- Expected VCHP energy savings =
  - (VCHP SEER – Reference SEER)/VCHP SEER
  - (VCHP HSPF – Reference HSPF)/VCHP HSPF

# VCHP Systems

| | SEER | EER | HSPF | Type |
|---|---|---|---|---|
| Grange 2014 | 21.7 | 13.4 | 9.4 | Ductless multi split |
| Mayfair 2014 | 21.5 | 14.5 | 12.2 | Ducted mini split |
| Caleb 2015 | 20.9 | 12.7 | 10.5 | Ductless mini and multi split with transfer fans |
| Grange 2015 | 25.5 | 13.8 | 11.5 | Ductless mini split with transfer fans |
| Mayfair 2015 | 16 | 12.5 | 10 | Ducted mini split |
| Caleb 2016 Ducted | 19.0 | 12.8 | 10.6 | Ducted mini splits |
| Caleb 2016 Ductless | 21.0 | 13.2 | 10.4 | Ductless mini and multi split |
| Caleb 2016 Ductless + Fans | 21.0 | 13.2 | 10.4 | Ductless mini and multi split with transfer fans |
| Grange 2016 Ducted | 29.3 | 15.2 | 14 | Ducted mini split |
| Grange 2016 Ductless | 29.3 | 15.2 | 14 | Ductless mini split |
| Grange 2016 Ductless + Fans | 29.3 | 15.2 | 14 | Ductless mini split with transfer fans |
| Mayfair 2016 Ducted | 21 | 12.5 | 12 | Ducted mini split |
| Mayfair 2016 Ductless | 21 | 12.5 | 12 | Ductless mini split |
| Mayfair 2016 Ductless + Fans | 21 | 12.5 | 12 | Ductless mini split with transfer fans |
| Caleb 2017 Ducted | 14.6 | 9.3 | 9.1 | Ducted mini splits |
| Grange 2017 Ducted 1 Ton | 29.3 | 15.2 | 14 | Ducted mini split |
| Grange 2017 Ducted .75 Ton | 33 | 18 | 14.2 | Ducted mini split |
| Mayfair 2017 Ducted 1.5 Ton | 21 | 12.5 | 12 | Ducted mini split |
| Mayfair 2017 Ducted 1 Ton | 26.1 | 13.8 | 12.5 | Ducted mini split |

# Analysis Approach

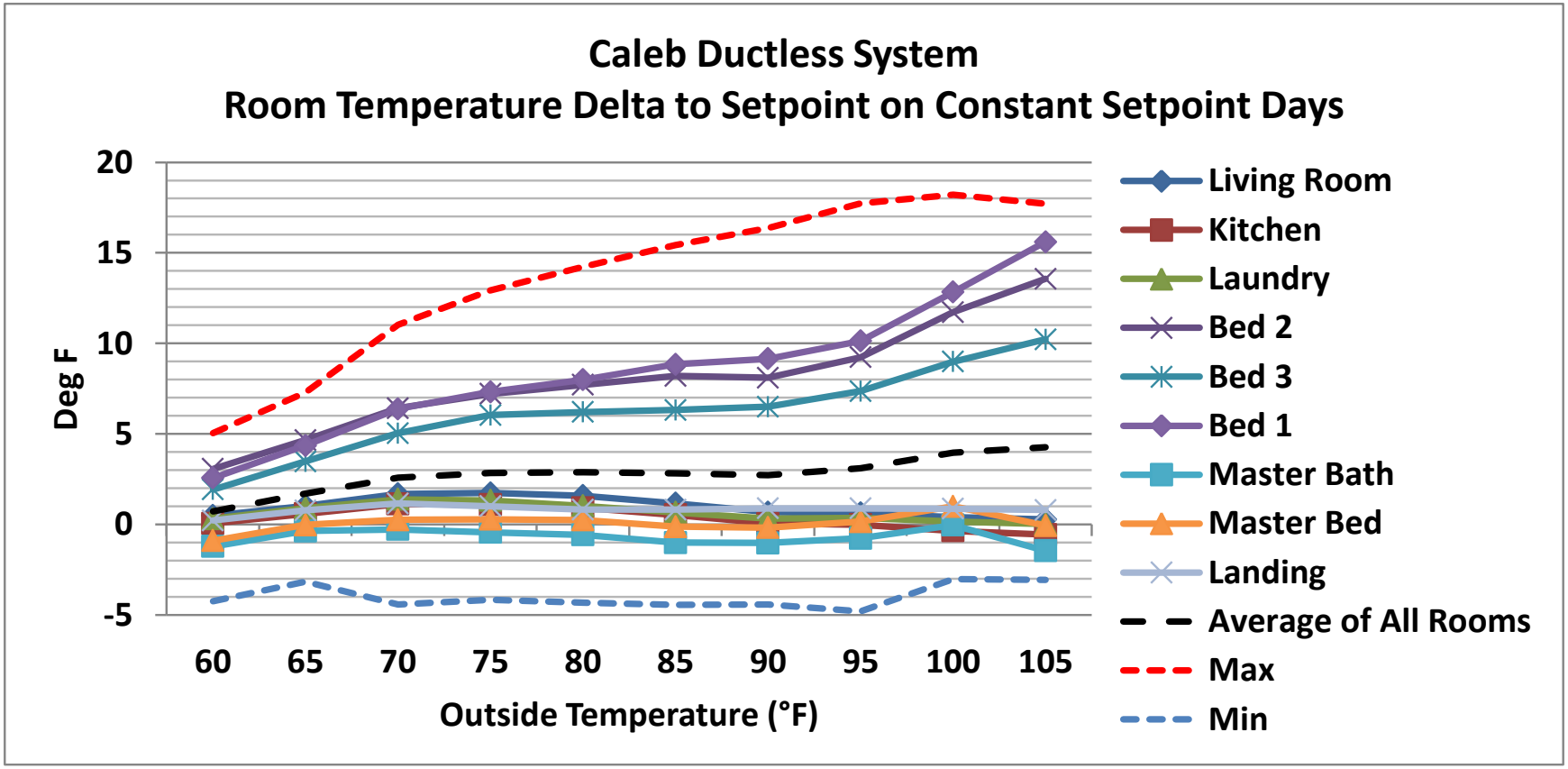
## Comparison of Normalized Annual Energy Use




- Linear regression of daily energy use vs. daily average outdoor temperature
- Applied to Title 24 weather file for Stockton, CA to calculate normalized annual energy use
- Expected energy savings =
  - (VCHP SEER – Reference SEER)/VCHP SEER
  - (VCHP HSPF – Reference HSPF)/VCHP HSPF

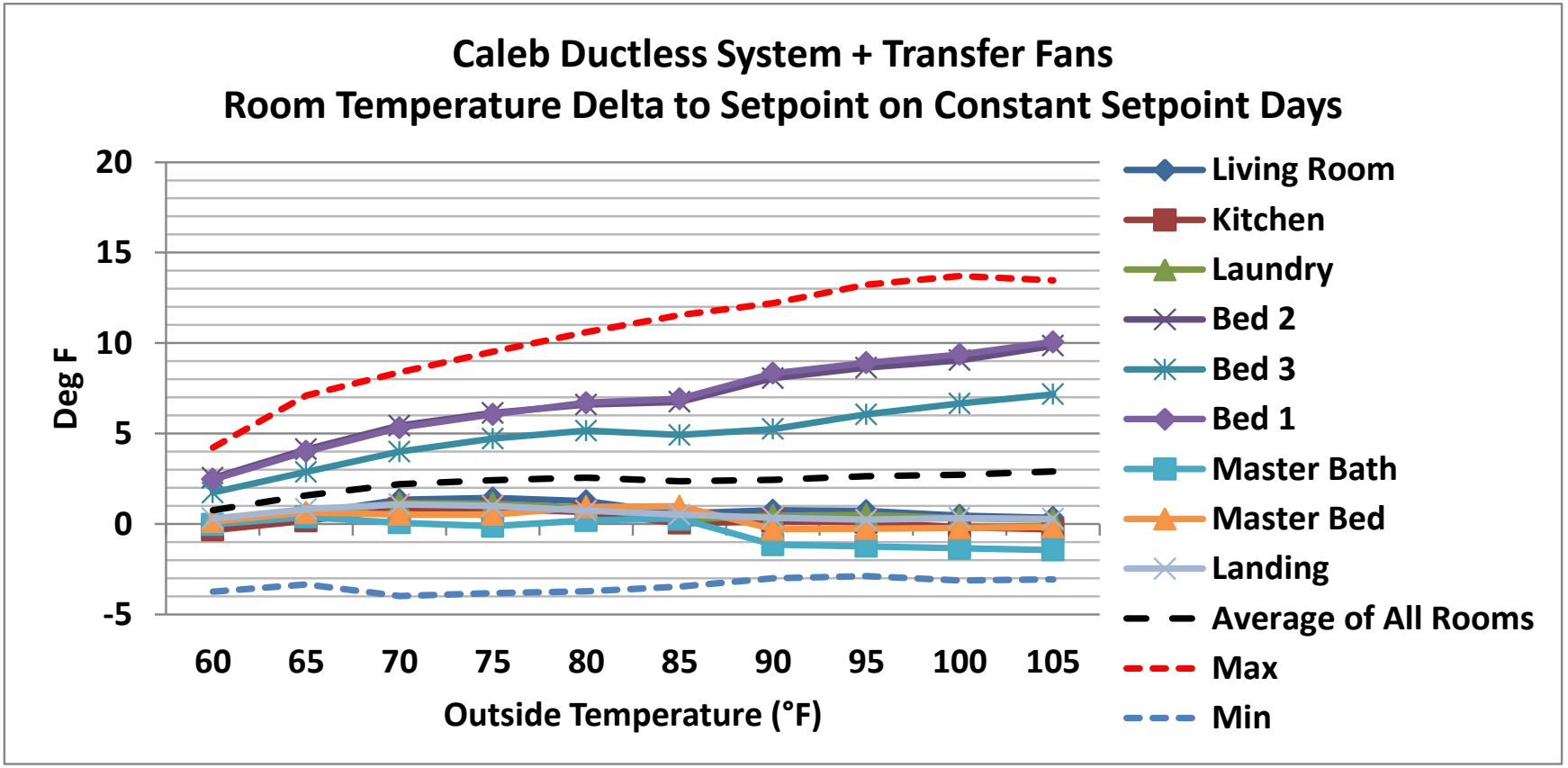
# Temperature Control Problems

## When All Rooms Are Not Directly Served by Ductless VCHP



# Temperature Control Problems

## When All Rooms Are Not Directly Served by Ductless VCHP

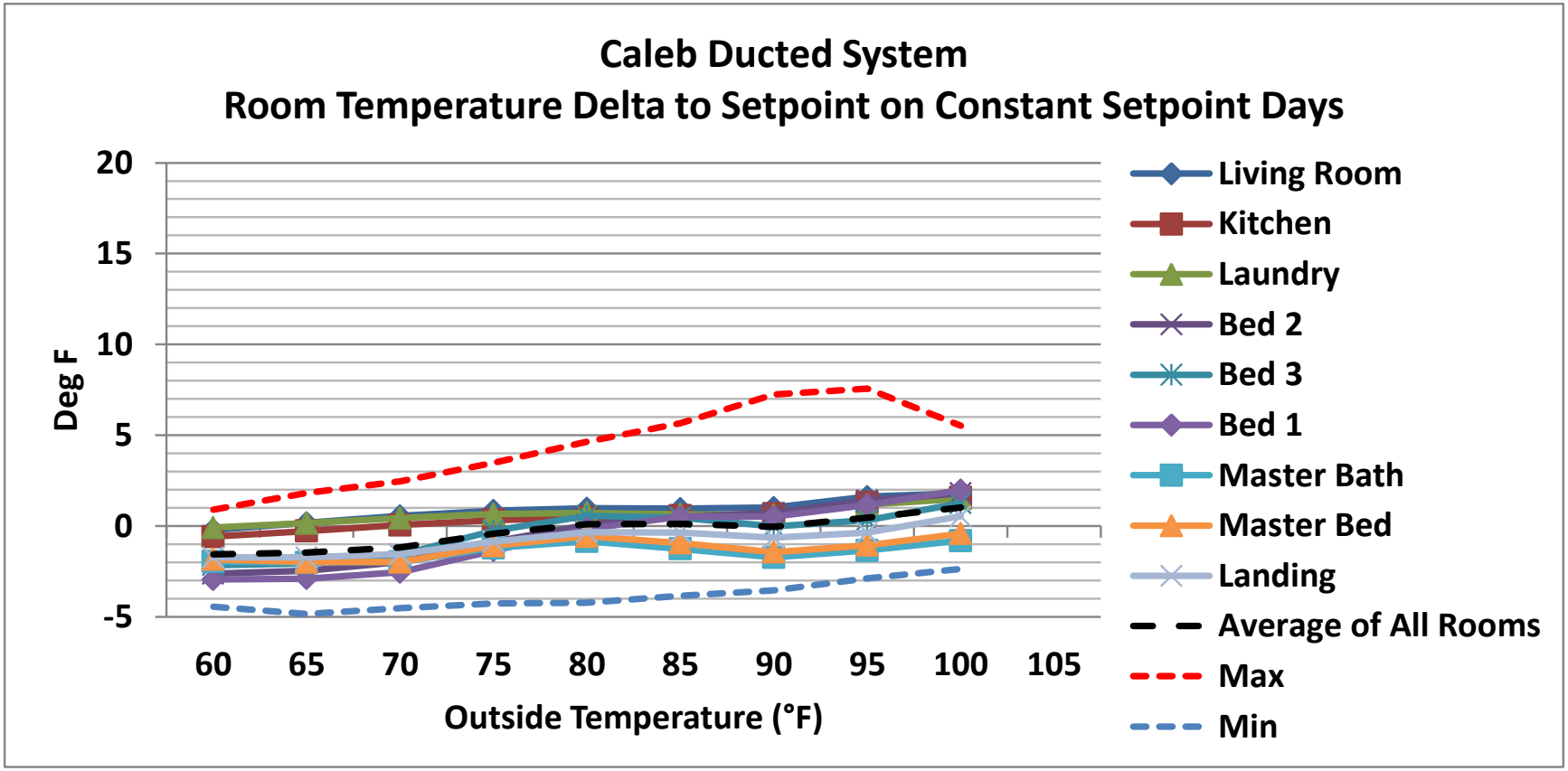



**Transfer fans are not an adequate solution**

- Comfort is not being provided
- Meaningful energy use comparison is not possible since the house isn't being fully cooled

# Temperature Control

## When All Rooms Are Directly Served by Ducted VCHP



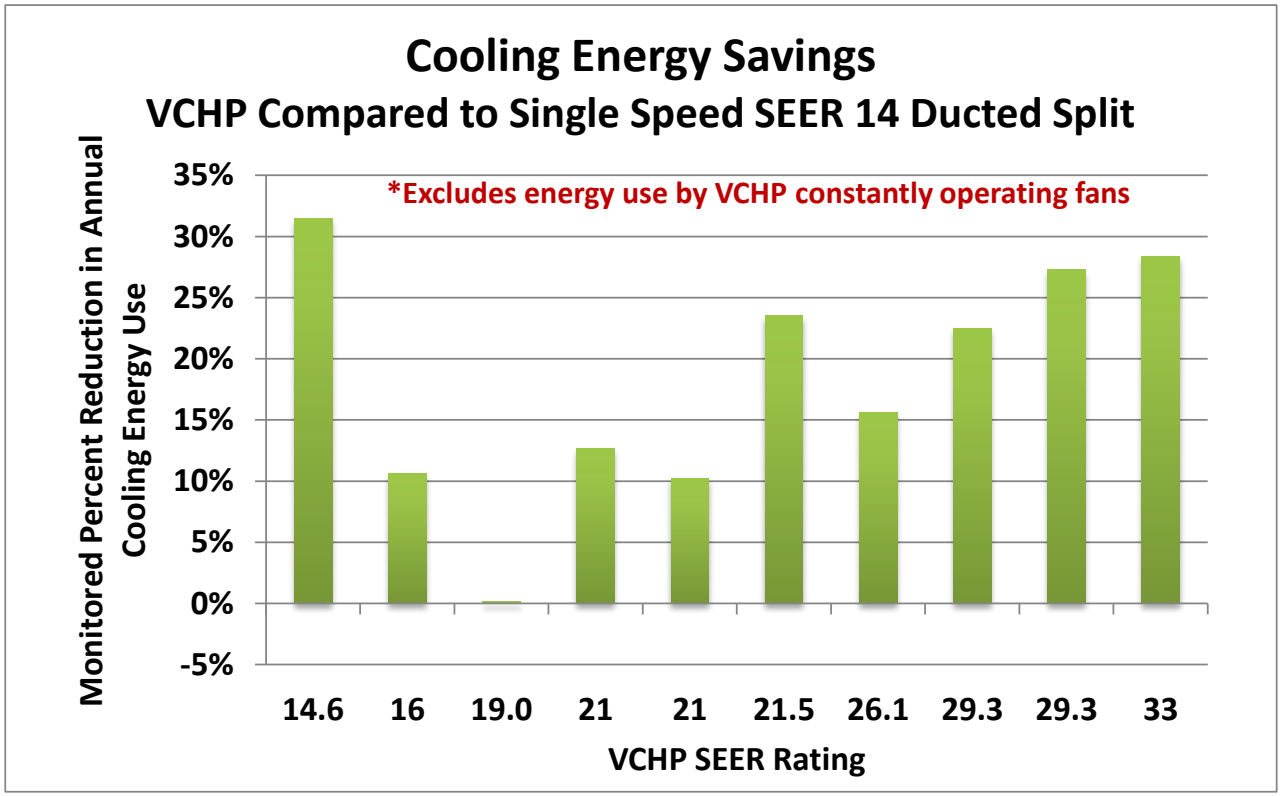

All habitable rooms must be directly served

# VCHP Systems Evaluated

| | Reference HP | | | VCHP | | | |
|---|---|---|---|---|---|---|---|
| | SEER | EER | HSPF | SEER | EER | HSPF | Notes |
| Grange 2014 | 15.5 | 11.9 | 3.412 | 21.7 | 13.4 | 9.4 | Found to be 29% undercharged |
| Mayfair 2014 | 16* | 13* | 3.412* | 21.5 | 14.5 | 12.2 | |
| Caleb 2015 | 14 | 12 | 8.2 | 20.9 | 12.7 | 10.5 | Not all habitable rooms were served |
| Grange 2015 | 14 | 11.5 | 8.2 | 25.5 | 13.8 | 11.5 | Not all habitable rooms were served |
| Mayfair 2015 | 14 | 11.5 | 8.2 | 16 | 12.5 | 10 | |
| Caleb 2016 Ducted | 14 | 12 | 8.2 | 19.0 | 12.8 | 10.6 | |
| Caleb 2016 Ductless | 14 | 12 | 8.2 | 21.0 | 13.2 | 10.4 | Not all habitable rooms were served |
| Caleb 2016 Ductless + Fans | 14 | 12 | 8.2 | 21.0 | 13.2 | 10.4 | Not all habitable rooms were served |
| Grange 2016 Ducted | 14 | 11.5 | 8.2 | 29.3 | 15.2 | 14 | |
| Grange 2016 Ductless | 14 | 11.5 | 8.2 | 29.3 | 15.2 | 14 | Not all habitable rooms were served |
| Grange 2016 Ductless + Fans | 14 | 11.5 | 8.2 | 29.3 | 15.2 | 14 | Not all habitable rooms were served |
| Mayfair 2016 Ducted | 14 | 11.5 | 8.2 | 21 | 12.5 | 12 | |
| Mayfair 2016 Ductless | 14 | 11.5 | 8.2 | 21 | 12.5 | 12 | Not all habitable rooms were served |
| Mayfair 2016 Ductless + Fans | 14 | 11.5 | 8.2 | 21 | 12.5 | 12 | Not all habitable rooms were served |
| Caleb 2017 Ducted | 14 | 12 | 8.2 | 14.6 | 9.3 | 9.1 | |
| Grange 2017 Ducted 1 Ton | 14 | 11.5 | 8.2 | 29.3 | 15.2 | 14 | |
| Grange 2017 Ducted .75 Ton | 14 | 11.5 | 8.2 | 33 | 18 | 14.2 | |
| Mayfair 2017 Ducted 1.5 Ton | 14 | 11.5 | 8.2 | 21 | 12.5 | 12 | |
| Mayfair 2017 Ducted 1 Ton | 14 | 11.5 | 8.2 | 26.1 | 13.8 | 12.5 | |

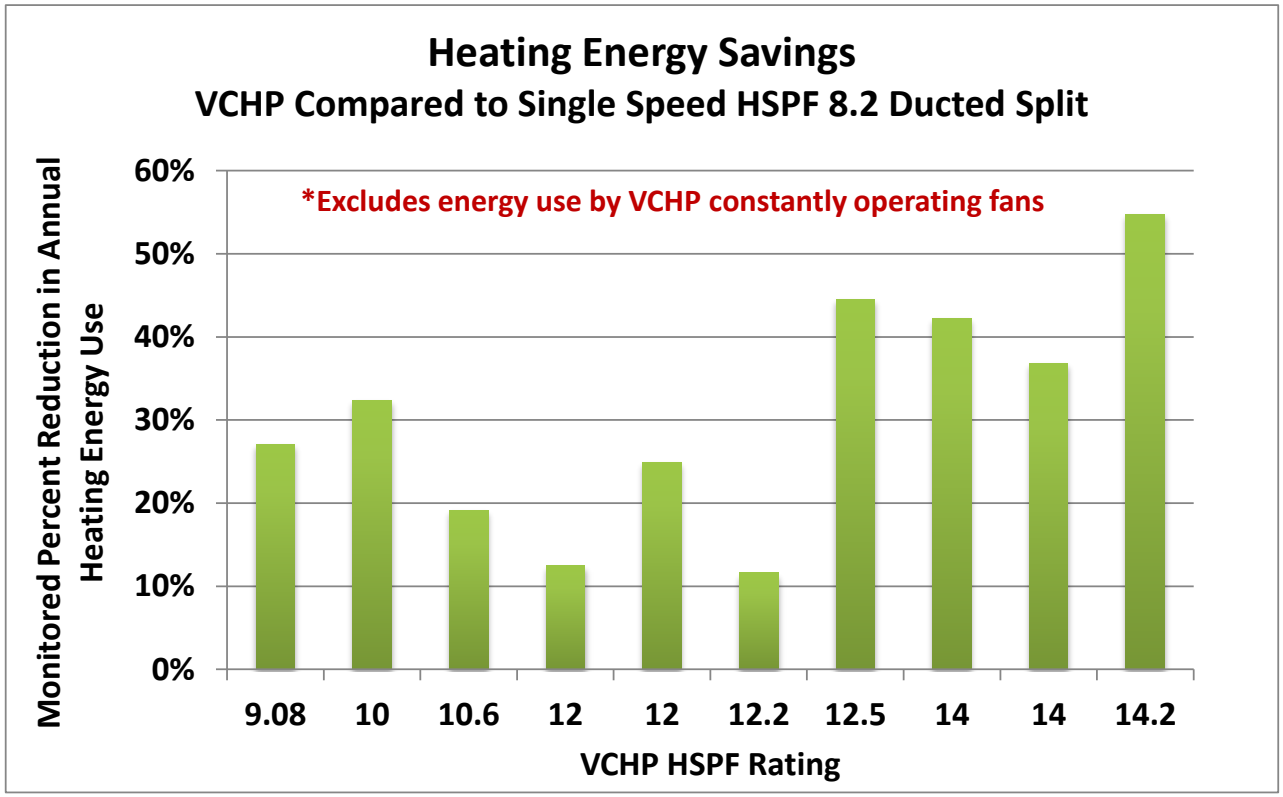
*Energy use adjusted to represent SEER 14 / HSPF 8.2 for consistency in the modeling analysis

# SEER Rating Is Not A Reliable Predictor of Cooling Energy Use




- The lowest SEER rated VCHP system had the best cooling energy performance relative to the single speed Reference heat pump
- A SEER 29 VCHP should use less than half as much energy as the SEER 14, but the actual energy savings are much smaller

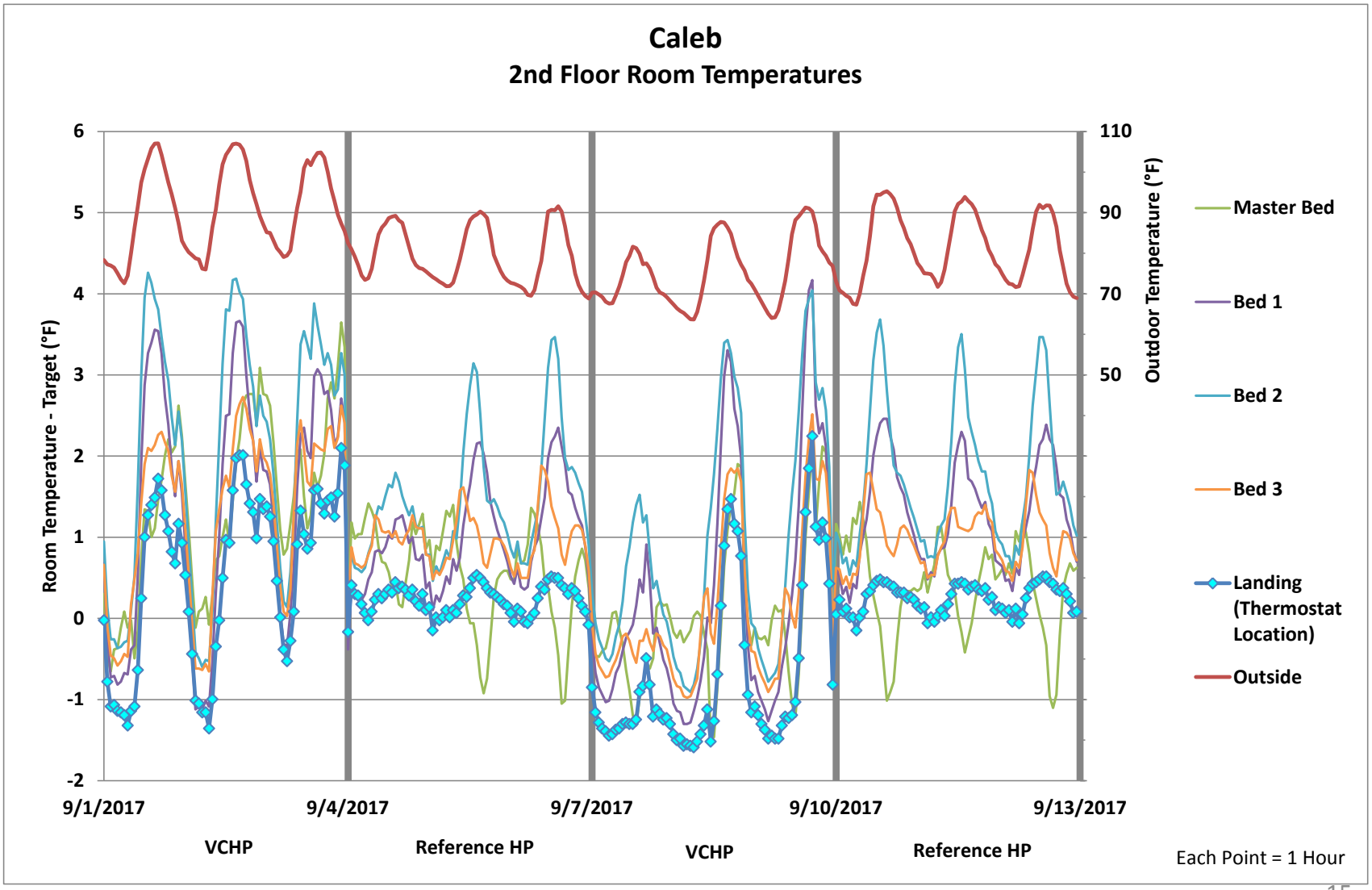
# HSPF Rating Is Not A Reliable Predictor of Heating Energy Use




- In general, heating savings were larger than cooling savings
- Some systems used significantly more energy than predicted by the relative HSPF rating

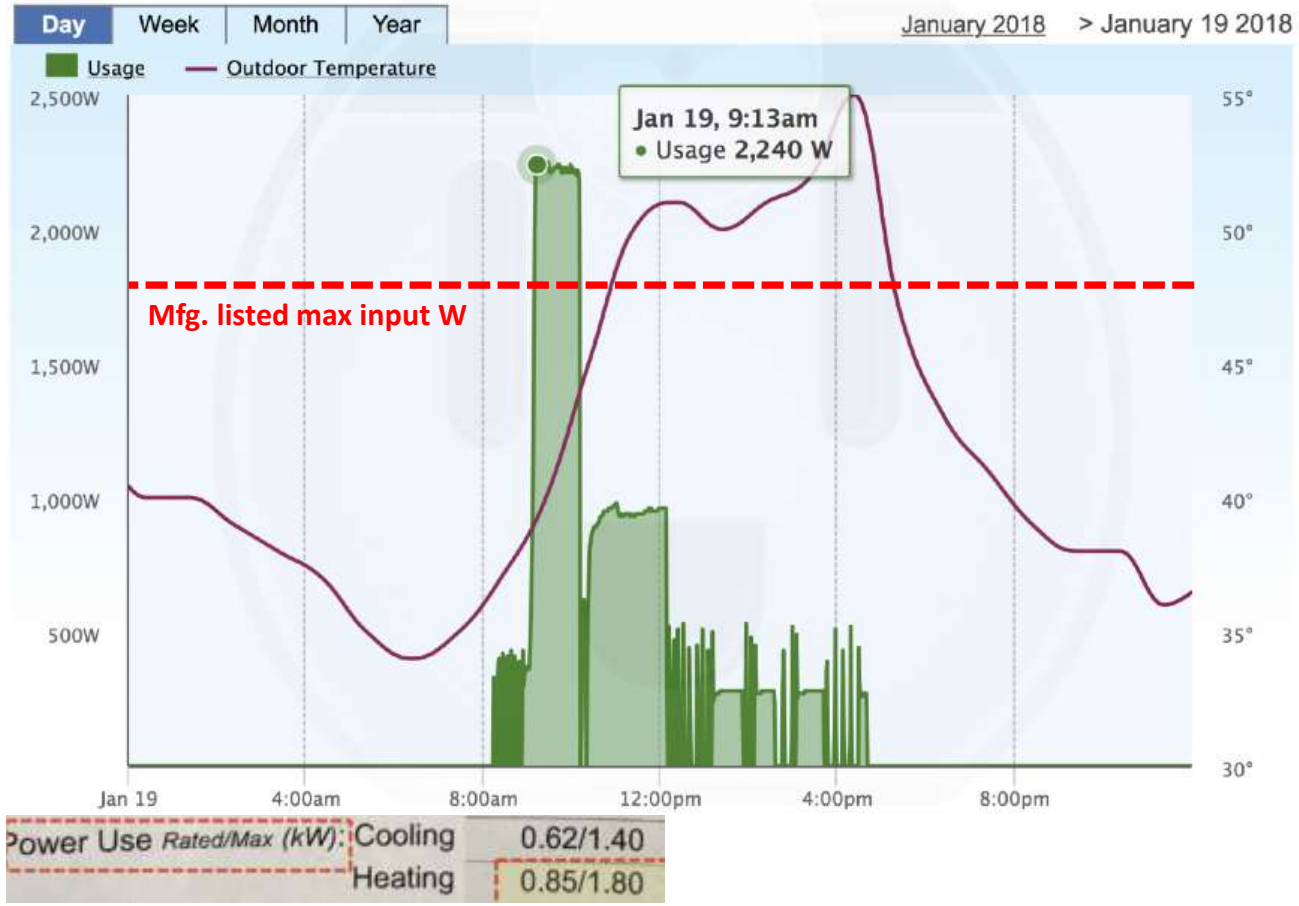
# Sources of Uncertainty

## Indoor Temperature Control Differences



# Sources of Uncertainty

## Occupant Behavior Not Accounted For




**Source: Mike MacFarland and Keith O'Hara**

# Sources of Uncertainty

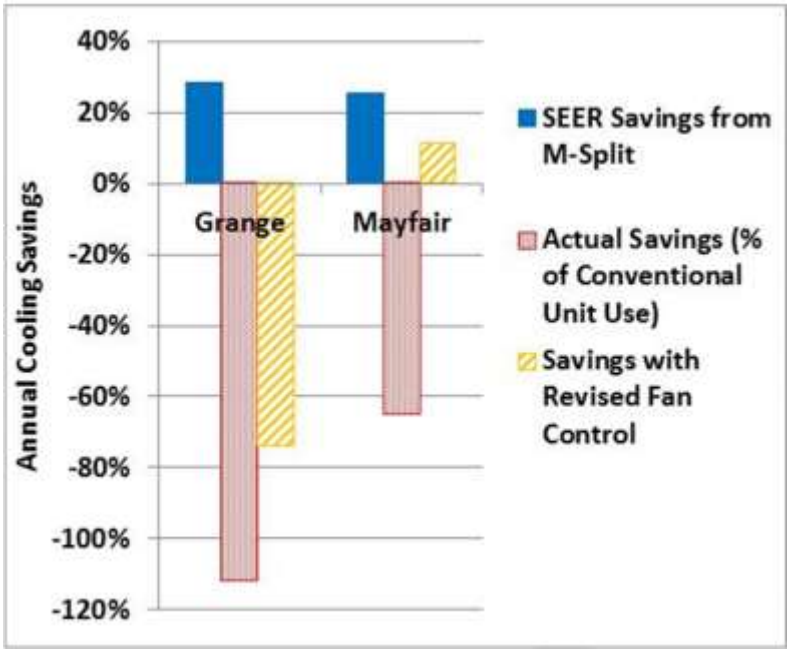
## VCHP System Design, Installation and Commissioning

Most VCHP systems were specified, installed, configured and commissioned by the research team or by the VCHP manufacturer.

- Probably optimistic relative to typical design and installation

The two systems that were installed by local HVAC contractors and are therefore the most representative of typical installation performed poorly.

- Low refrigerant charge (Grange)
- Constantly operating indoor fans



# Modeling Approach

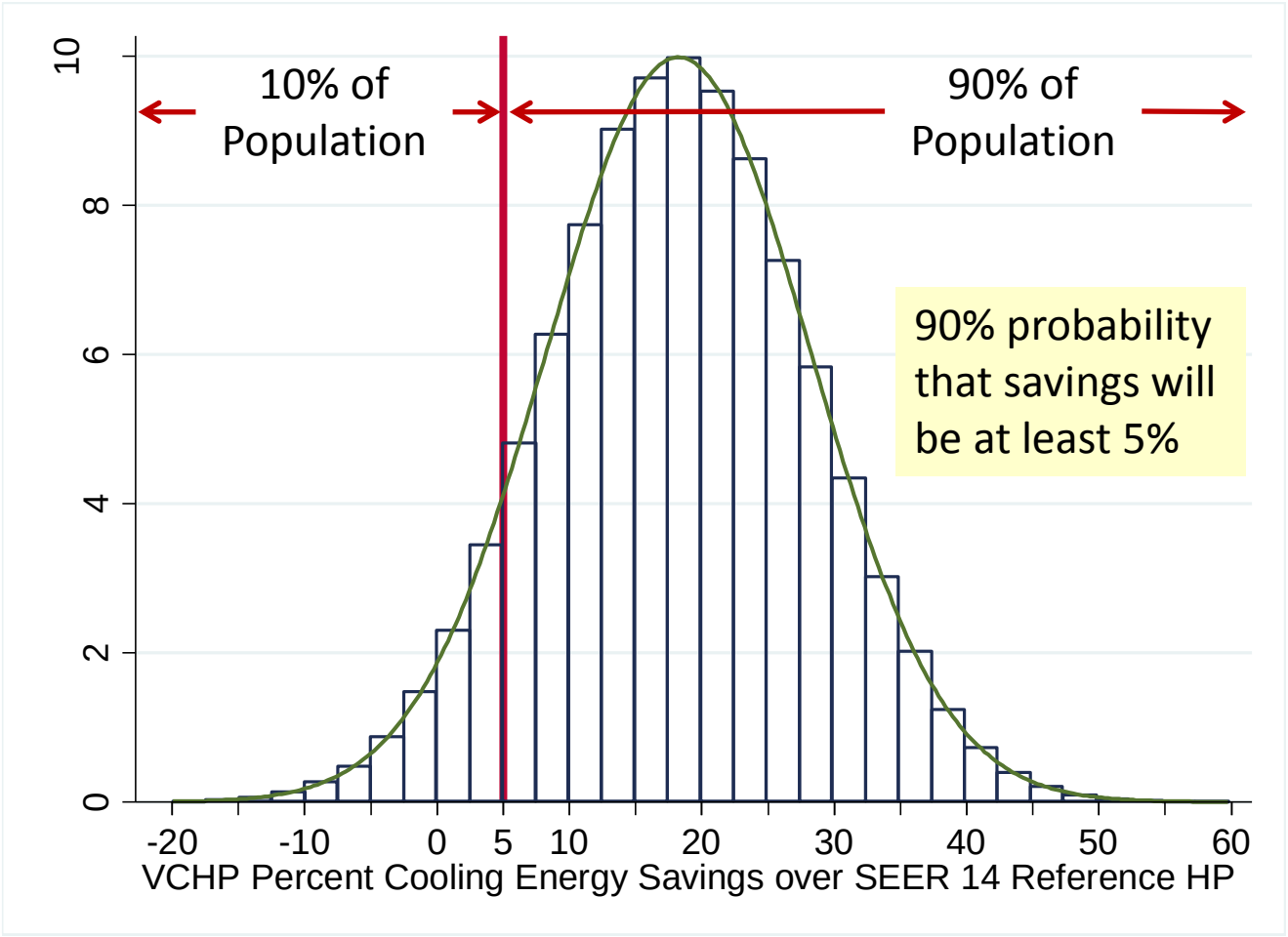
**Default VCHP model**

- Represents CVRH monitored seasonal energy savings over single speed SEER 14 / HSPF 8.2 HP, using current CBECC-Res model
- One model adopted for all VCHP systems, not a function of VCHP SEER, EER or HSPF ratings

**Specific VCHP model**

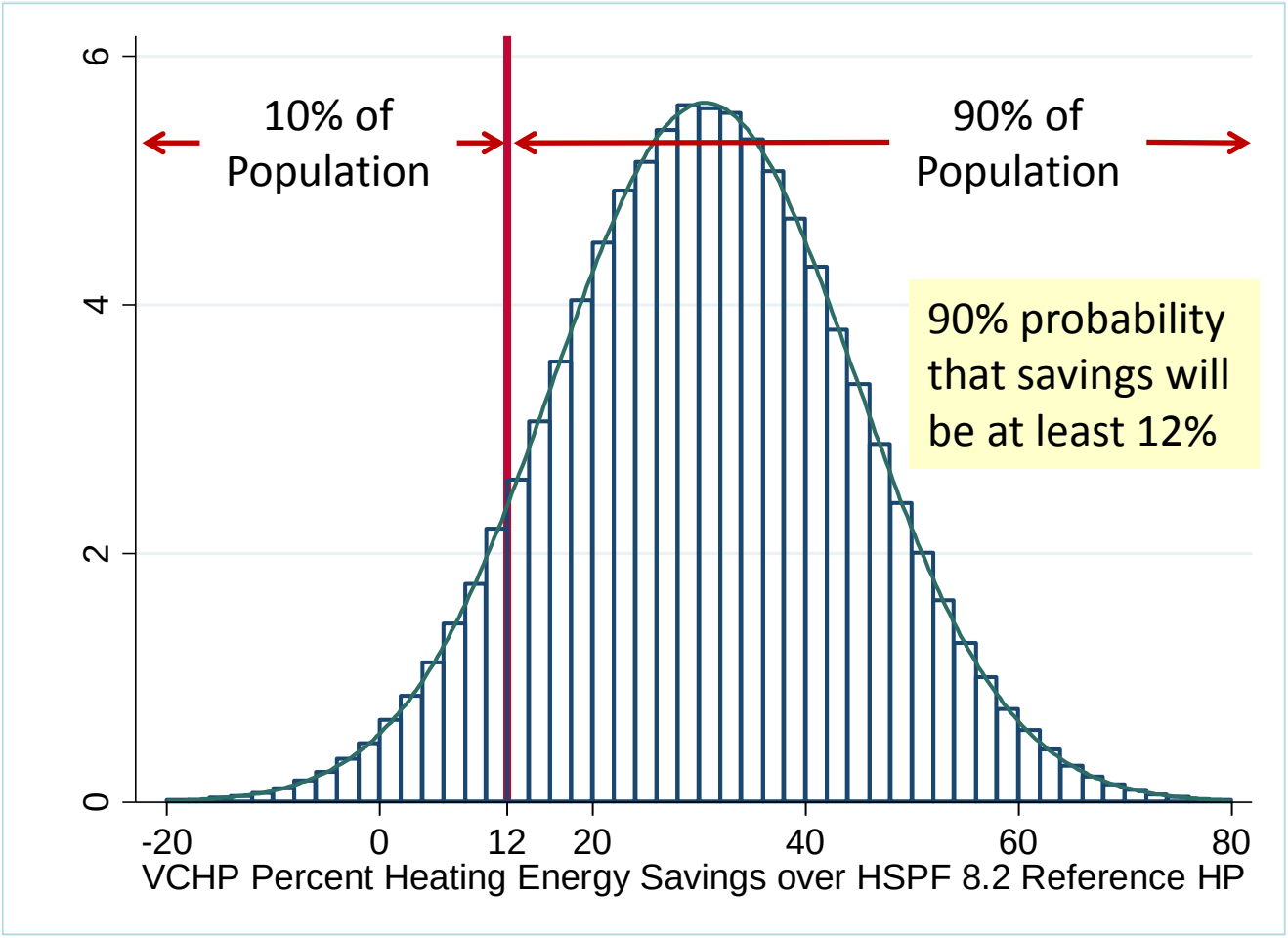
- Expected to become possible when reliable performance inputs become available (more information will be presented later)

# Cooling Energy Savings over SEER 14 HP Projected to a Normal Population




| | |
|---|---|
| **Number of Test Cases** | **10** |
| **Mean Annual Cooling Energy Savings over SEER 14 / EER 11.6 Reference HP** | **18%** |
| **Minimum** | **0%** |
| **Maximum** | **31%** |
| **Standard Deviation** | **10%** |

# Heating Energy Savings over HSPF 8.2 HP Projected to a Normal Population




| | |
|---|---|
| **Number of Test Cases** | **10** |
| **Mean Annual Heating Energy Savings over HSPF 8.2 Reference HP** | **31%** |
| **Minimum** | **12%** |
| **Maximum** | **55%** |
| **Standard Deviation** | **14%** |

# Proposed VCHP Performance Credit

- 5% cooling energy savings over minimum efficiency single speed SEER 14 / EER 11.6 Reference HP
- 12% heating energy savings over minimum efficiency single speed HSPF 8.2 Reference HP
- Reference HP fan efficacy = 0.35 W/cfm
  - This represents additional VCHP credit over the standard assumption
- Credit for ducts in conditioned space
- 50W/ton continuous fan energy assumed for ducted VCHP systems unless manufacturer certifies the fan does not operate continuously in the factory default control configuration (auto fan credit)

# Applicable System Types
## for Proposed VCHP Performance Credit

- Mini and multi-split VCHP systems with ductless indoor units
- Ducted mini and multi split VCHP systems with, low-static indoor units
  - Low-static:
    - Less than 0.35 IWC at cooling full load air volume
    - As defined by 10 CFR Parts 429 and 430, Docket No. EERE–2016–BT–TP–0029, Federal Register Vol. 82, No. 3, January 5, 2017

# Requirements
## for All VCHP Systems

- Each habitable room must be directly served by ducted air handler or ductless head
  - Transfer fans do not meet this requirement
- All ducts and indoor units (ducted or ductless) must be located entirely in conditioned space
- Wall mount thermostat required in each zone > 150 $ft^2$
- Indoor and outdoor unit make, model and serial numbers must be visible for field verification
- Field verification of installed system

# Requirements
## for Ducted VCHP Systems

- The manufacturer must certify to the Energy Commission that:
  - The VCHP system meets the DOE definition of a low-static system
  - If the auto fan credit is claimed, that in the factory default controls configuration the system does not operate the indoor unit fan when the compressor is off, except for a fan overrun (fan off delay) of less than 10 minutes at the end of the compressor on cycle
- VCHP system model numbers must be listed on the CEC website as a low-static system, and as eligible for the auto fan credit, if claimed
- Low Leakage Ducts in Conditioned Space per RA3.1.4.3.8
- Airflow ≥ 350 cfm/ton for each ducted indoor unit
- Air filters sized per 2019 Title 24 Part 6 Section 150.0(m)12B, and with a maximum clean filter pressure drop of 0.1 inch w.c. at the filter's design airflow rate, regardless of filter depth.

# Field Verification
## for All VCHP Systems

- Model number, nominal cooling capacity, and location of each indoor unit matches installer reported documentation
- Refrigerant charge

# Field Verification
## for Ducted VCHP Systems

- Verified Low Leakage Ducts in Conditioned Space per RA3.1.4.3.8
- Airflow ≥ 350 cfm/ton for each ducted indoor unit
- Air filters sized according to the requirements in 2019 Title 24 Part 6 Standards Section 150.0(m)12B, and all filters shall have a maximum clean filter pressure drop of 0.1 inch w.c. at the filter's design airflow rate, regardless of filter depth.
- Model numbers are listed on the CEC website as a low-static system
- If auto fan credit was claimed, model numbers are listed as eligible on CEC website and indoor fan of installed system does not operate continuously

# Field Verification

## New HERS Protocols for Multiple-Split Systems

**The new protocols will be used for all ducted multiple-split system types when applicable.**

- **Verified airflow for ducted indoor units**
  - Airflow target for each indoor unit will be based on the nominal cooling capacity (ton) from the nameplate of the indoor unit. This is a modification of the method used for conventional split systems that uses the nominal cooling capacity (ton) of the outdoor condensing unit.
  - Each ducted indoor unit required to verify compliance with the calculated minimum cfm/ton.
- **Duct leakage measurement for ducted indoor units**
  - Leakage target will be based on the nominal cooling capacity (ton) from the nameplate of the indoor unit. This is a modification of the RA3.1.4.2.2 nominal air handler airflow calculation.
  - Each ducted indoor unit required to comply individually with the applicable calculated maximum duct leakage (% of 400 cfm/ton)
- **Verified Low Leakage Ducts in Conditioned Space protocol for ducted indoor units**
  - No change to the protocol specified in RA3.1.4.3.8.
  - Each ducted indoor unit required to comply individually.

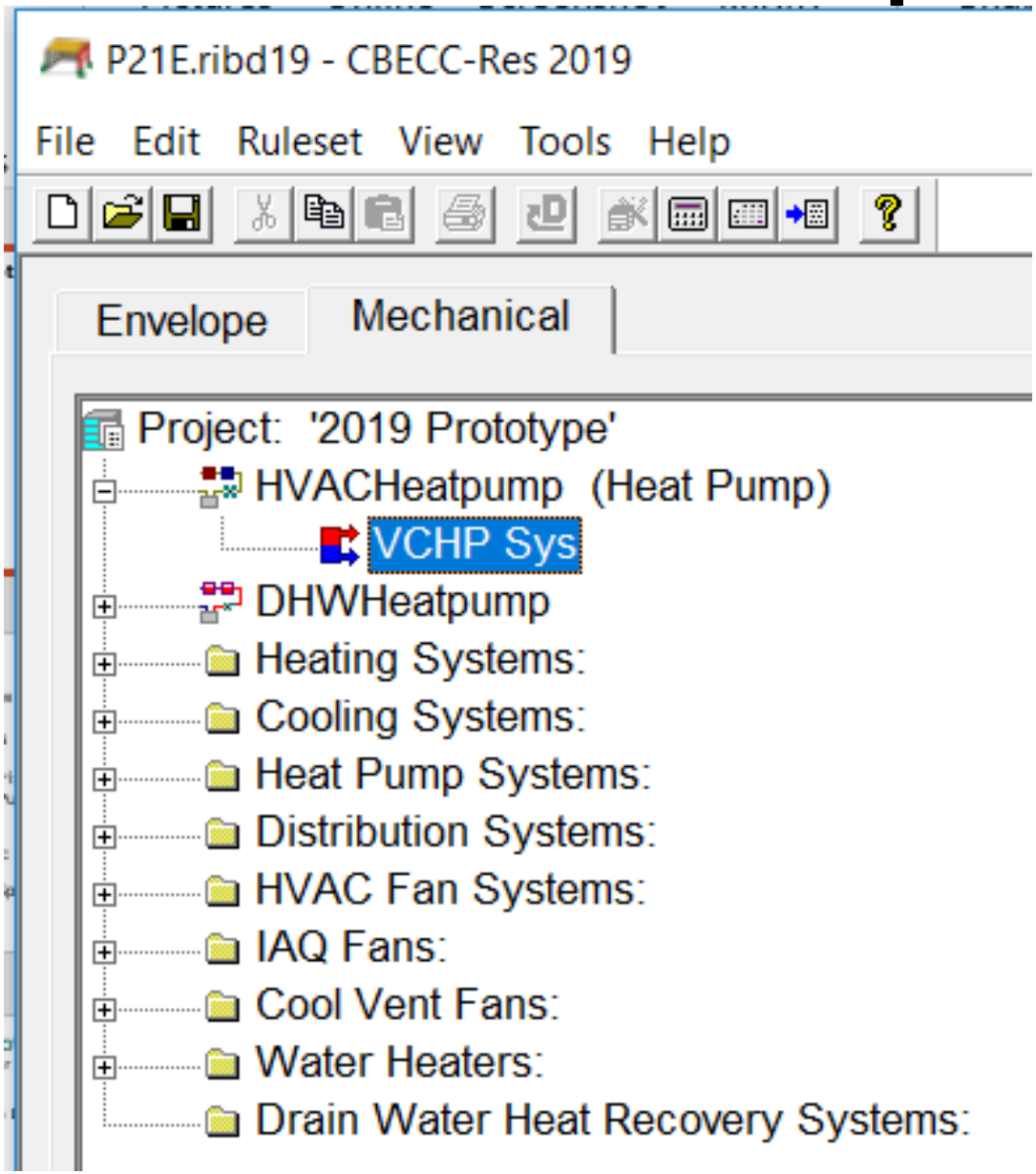
# Future Modeling Approach

**Optional voluntary pathway to credit a specific VCHP system**

- Manufacturer provides:
  - Data from CSA Exp-07 test
  - ASHRAE 205 performance map

CSA based model needs to be developed – this is beyond the scope of current modeling efforts

# CBECC-Res 2019 VCHP Option



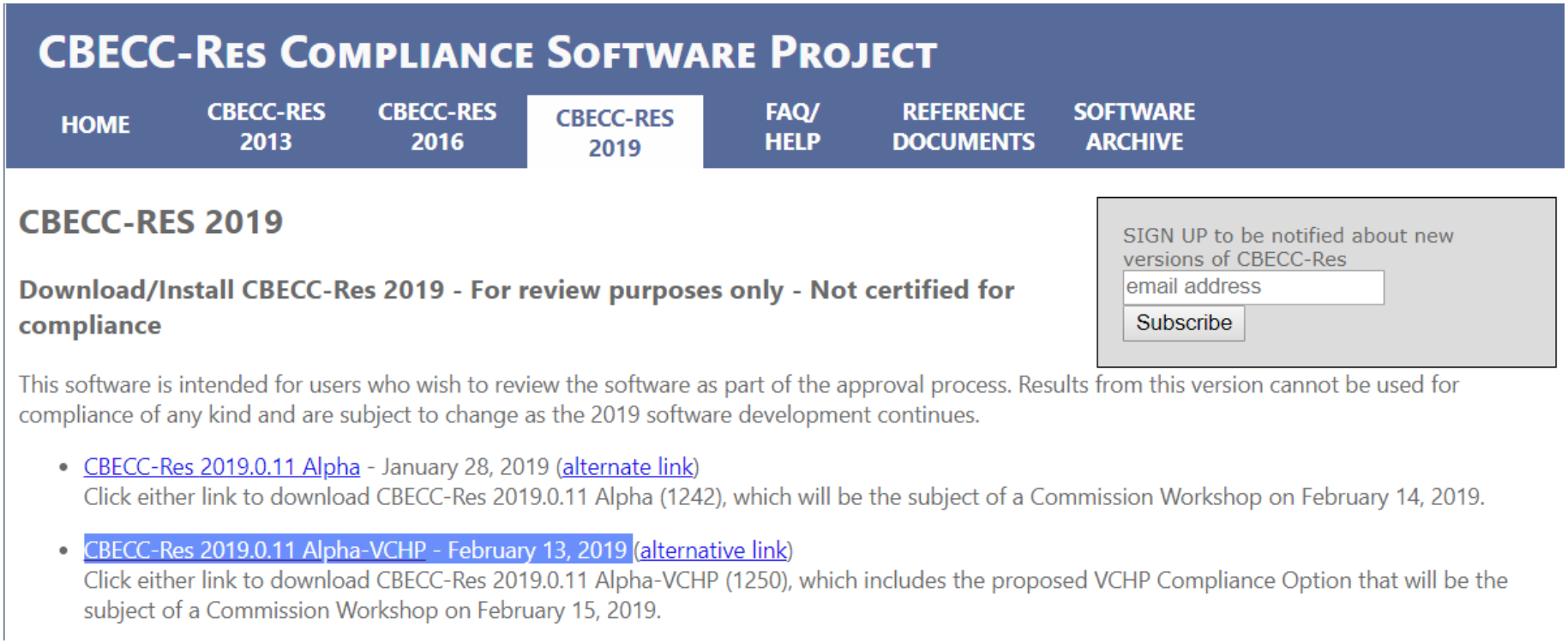
# Agenda

- CBECC-Res Compliance Software
- Proposed VCHP model Inputs
- Example Compliance Comparison with Standard Design Split Heat Pump having:
  - Ducts in 2019 Prescriptive Attic
  - Verified Ducts in Conditioned Space

# CBECC-Res Compliance Software

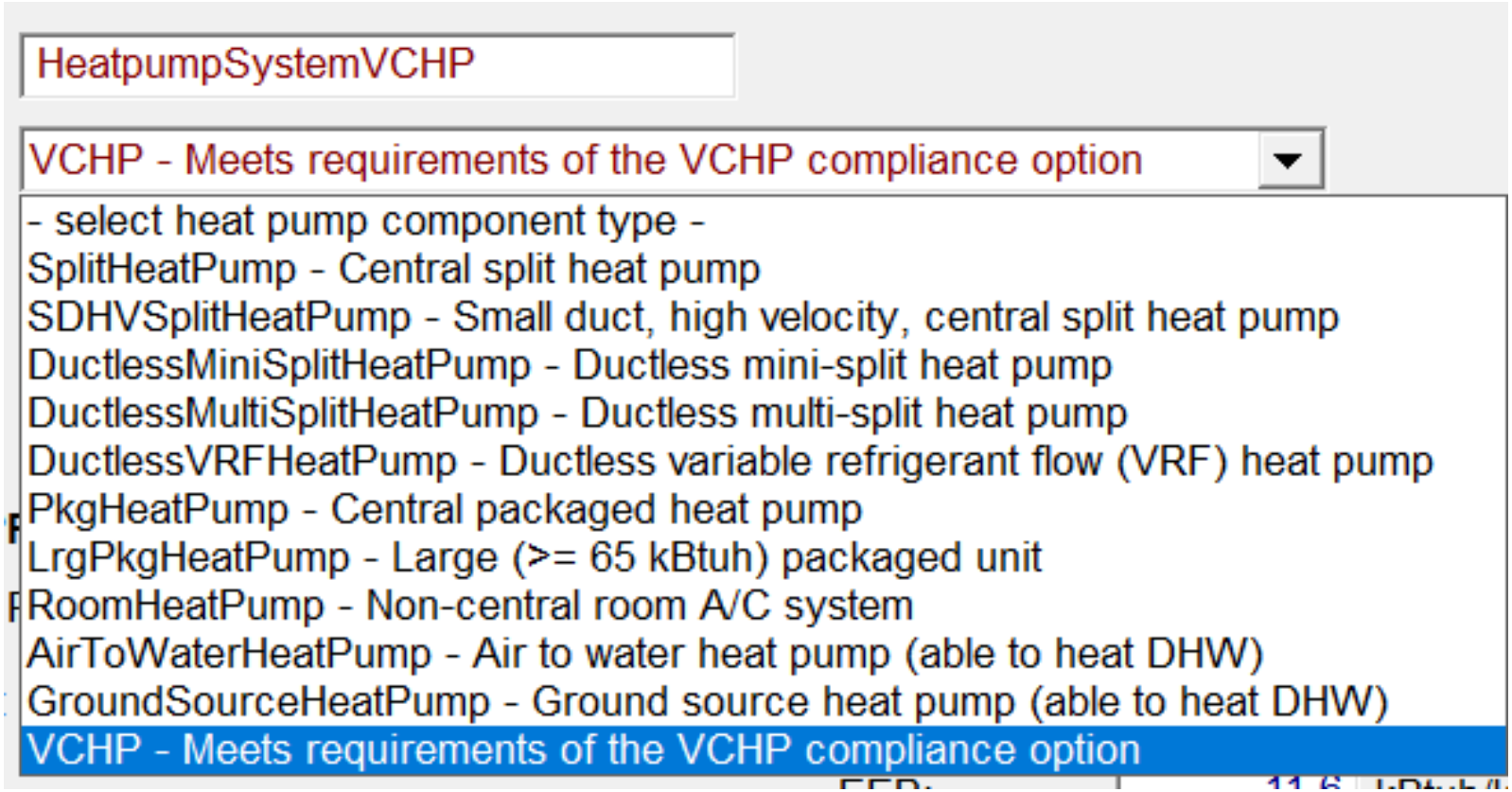
- Provides Performance compliance for Low Rise Residential building permits
- Compliance based on comparing the Energy Design Rating (EDR) of
  - Prescriptive Standard Design
  - Builders Proposed Design
- Both Efficiency and Total must comply
- Based on detailed hourly simulations using Time Dependent Valuation (TDV)
- Draft 2019 Standards version Public Workshop yesterday

# Draft VCHP version

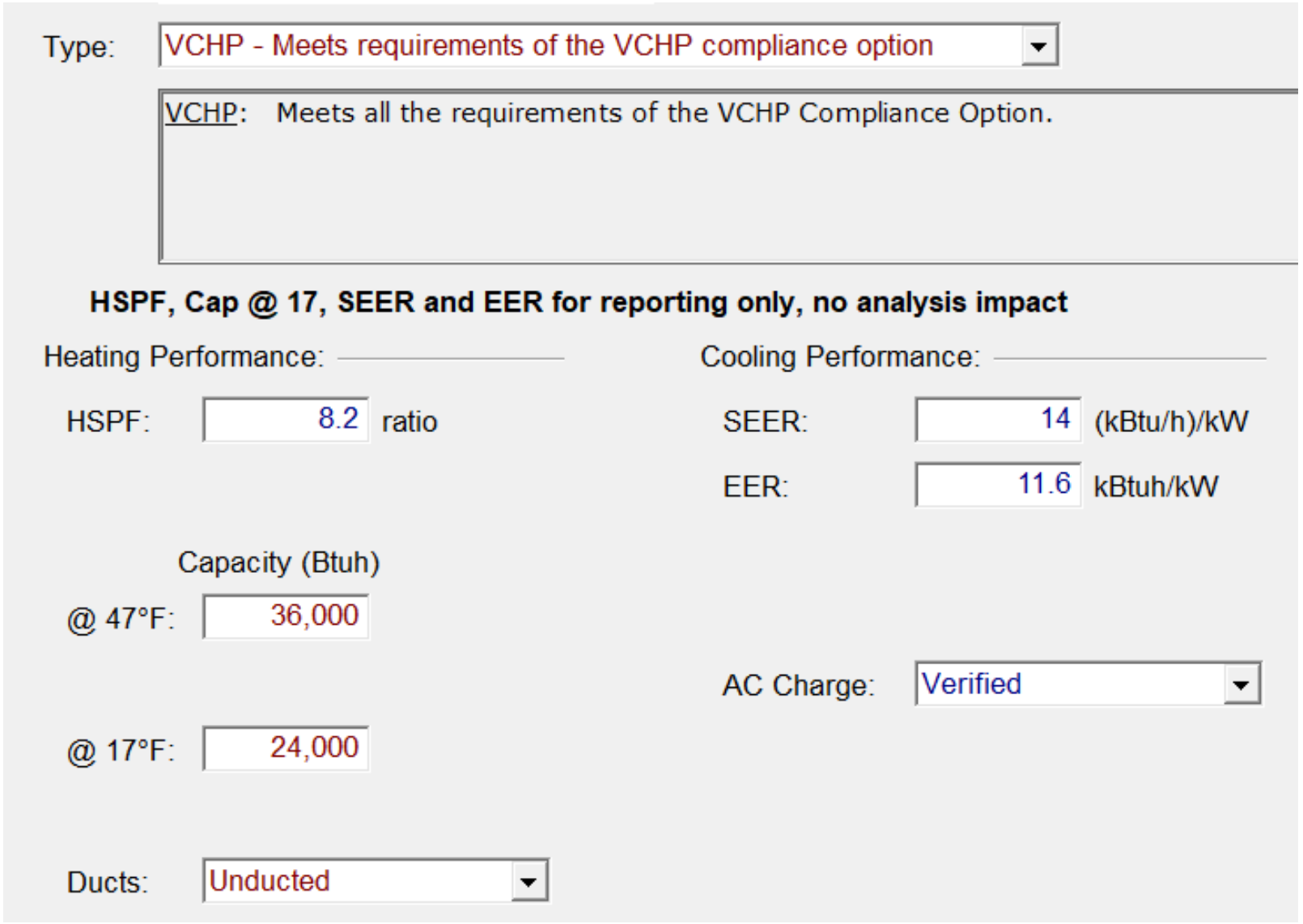



- CBECC-Res 2019.0.11 Alpha-VCHP
- http://www.bwilcox.com/BEES/cbecc2019.html

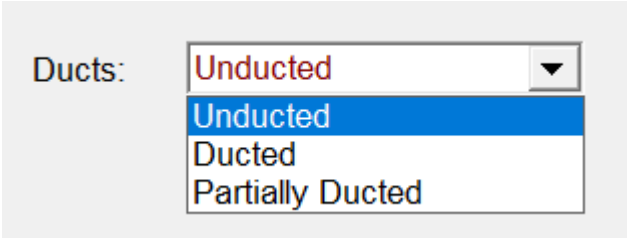
# VCHP Heat Pump System Type

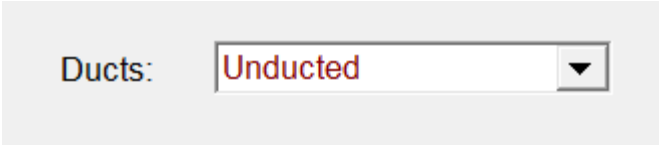


# VCHP Input Screen



# Unducted VCHP Input

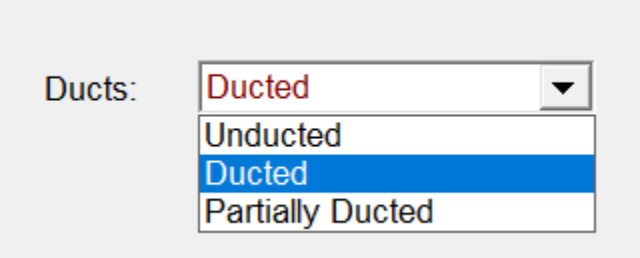


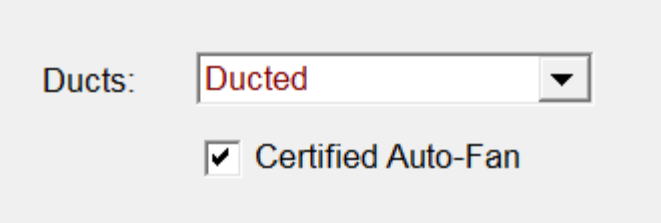




Done

# Unducted VCHP

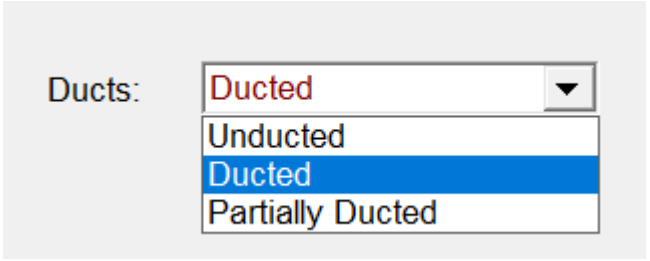
# If Ducted or Partly Ducted And Certified Auto-Fan

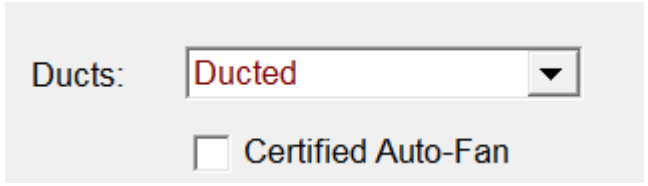



Done

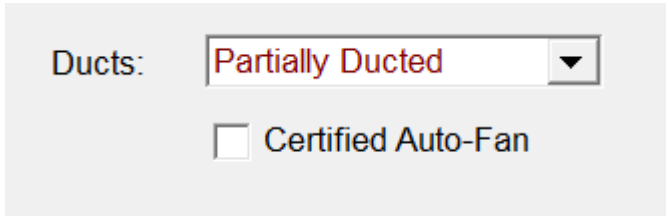
# Ducted or Partly Ducted and Not Certified




Done with 50 W/ton continuous fan

Or




Done with 25 W/ton continuous fan

# Ducted VCHP in Conditioned Space

# 12” furred space below the  ceiling

# Short, Low Pressure Ducts to Rooms

# VCHP Air Handler in Furred Space

# Return Grill and Access Hatch

# **2019 EDR** Compliance Comparison with Standard Design Split Heat Pump

| | EDR Efficiency | | | | EDR Flexibilty | | | | EDR Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Standard | VCHP | Diff | % Diff | Standard | VCHP | Diff | % Diff | Standard | VCHP | Diff | % Diff |
| CZ01 | 66.8 | 56.9 | 9.9 | 15% | 21.8 | 21.8 | 0.0 | 0% | 45.0 | 35.1 | 9.9 | 22% |
| CZ02 | 52.6 | 47.9 | 4.7 | 9% | 20.7 | 20.7 | 0.0 | 0% | 31.9 | 27.2 | 4.7 | 15% |
| CZ03 | 54.9 | 50.5 | 4.4 | 8% | 22.8 | 22.8 | 0.0 | 0% | 32.1 | 27.7 | 4.4 | 14% |
| CZ04 | 52.0 | 47.2 | 4.8 | 9% | 21.4 | 21.3 | 0.1 | 0% | 30.6 | 25.9 | 4.7 | 15% |
| CZ05 | 53.5 | 49.4 | 4.1 | 8% | 22.1 | 22.0 | 0.1 | 0% | 31.4 | 27.4 | 4.0 | 13% |
| CZ06 | 55.8 | 52.8 | 3.0 | 5% | 26.1 | 26.0 | 0.1 | 0% | 29.7 | 26.8 | 2.9 | 10% |
| CZ07 | 55.2 | 54.3 | 0.9 | 2% | 28.3 | 28.3 | 0.0 | 0% | 26.9 | 26.0 | 0.9 | 3% |
| CZ08 | 52.2 | 49.8 | 2.4 | 5% | 25.6 | 25.6 | 0.0 | 0% | 26.6 | 24.2 | 2.4 | 9% |
| CZ09 | 52.3 | 48.7 | 3.6 | 7% | 23.2 | 23.2 | 0.0 | 0% | 29.1 | 25.5 | 3.6 | 12% |
| CZ10 | 52.4 | 48.4 | 4.0 | 8% | 21.9 | 22.0 | -0.1 | 0% | 30.5 | 26.4 | 4.1 | 13% |
| CZ11 | 49.3 | 43.8 | 5.5 | 11% | 20.4 | 20.4 | 0.0 | 0% | 28.9 | 23.4 | 5.5 | 19% |
| CZ12 | 50.2 | 45.6 | 4.6 | 9% | 19.3 | 19.3 | 0.0 | 0% | 30.9 | 26.3 | 4.6 | 15% |
| CZ13 | 50.6 | 44.9 | 5.7 | 11% | 20.7 | 20.7 | 0.0 | 0% | 29.9 | 24.2 | 5.7 | 19% |
| CZ14 | 51.7 | 45.7 | 6.0 | 12% | 20.9 | 20.9 | 0.0 | 0% | 30.8 | 24.8 | 6.0 | 19% |
| CZ15 | 51.3 | 45.4 | 5.9 | 12% | 26.1 | 26.1 | 0.0 | 0% | 25.2 | 19.3 | 5.9 | 23% |
| CZ16 | 63.9 | 54.2 | 9.7 | 15% | 18.2 | 18.1 | 0.1 | 1% | 45.7 | 36.1 | 9.6 | 21% |
| **Average** | **54.04** | **49.09** | **4.95** | **9%** | **22.47** | **22.45** | **0.02** | **0%** | **31.58** | **26.64** | **4.93** | **15%** |

2700 ft2 prototype with 2019 prescriptive features & Standard Design PV Split HP Ducts in 2019 prescriptive attic, with max fan W/cfm

VCHP sized @ full load.  Split sized 75% w/ backup resistance heat

# **2019** TDV Comparison with Standard Design Split Heat Pump

| | Heating kTDV/ft2 | | | | Cooling kTDV/ft2 | | | | Total kTDV/ft2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Standard | VCHP | Diff | % Diff | Standard | VCHP | Diff | % Diff | Standard | VCHP | Diff | % Diff |
| CZ01 | 46.0 | 27.6 | 18.4 | 40% | 0.0 | 0.0 | 0.0 | | 83.7 | 65.4 | 18.4 | 22% |
| CZ02 | 25.7 | 17.4 | 8.3 | 32% | 2.8 | 1.9 | 1.0 | 34% | 62.8 | 53.6 | 9.2 | 15% |
| CZ03 | 18.8 | 11.2 | 7.6 | 40% | 0.0 | 0.0 | 0.0 | | 55.4 | 47.9 | 7.6 | 14% |
| CZ04 | 20.7 | 13.3 | 7.4 | 36% | 4.7 | 3.1 | 1.7 | 35% | 58.4 | 49.3 | 9.1 | 16% |
| CZ05 | 18.0 | 10.7 | 7.3 | 41% | 0.0 | 0.0 | 0.0 | | 56.1 | 48.8 | 7.3 | 13% |
| CZ06 | 8.6 | 5.7 | 2.9 | 34% | 3.8 | 2.3 | 1.5 | 40% | 44.5 | 40.1 | 4.4 | 10% |
| CZ07 | 3.0 | 2.1 | 1.0 | 32% | 0.6 | 0.3 | 0.3 | 43% | 36.8 | 35.5 | 1.2 | 3% |
| CZ08 | 4.6 | 3.4 | 1.2 | 26% | 12.3 | 9.6 | 2.8 | 22% | 43.7 | 39.8 | 3.9 | 9% |
| CZ09 | 7.0 | 5.1 | 1.9 | 27% | 22.6 | 17.6 | 5.0 | 22% | 54.9 | 48.1 | 6.8 | 12% |
| CZ10 | 8.4 | 6.1 | 2.3 | 28% | 26.1 | 20.3 | 5.8 | 22% | 60.7 | 52.5 | 8.1 | 13% |
| CZ11 | 23.8 | 16.7 | 7.2 | 30% | 37.7 | 30.0 | 7.7 | 20% | 78.3 | 63.4 | 14.9 | 19% |
| CZ12 | 22.7 | 16.3 | 6.4 | 28% | 22.1 | 17.7 | 4.4 | 20% | 72.5 | 61.7 | 10.8 | 15% |
| CZ13 | 20.7 | 14.9 | 5.9 | 28% | 42.6 | 33.1 | 9.5 | 22% | 80.1 | 64.8 | 15.3 | 19% |
| CZ14 | 23.6 | 16.4 | 7.2 | 31% | 36.1 | 28.0 | 8.1 | 23% | 77.8 | 62.5 | 15.3 | 20% |
| CZ15 | 1.9 | 1.4 | 0.5 | 25% | 87.2 | 69.7 | 17.5 | 20% | 76.7 | 58.8 | 18.0 | 23% |
| CZ16 | 61.7 | 41.1 | 20.6 | 33% | 4.6 | 3.2 | 1.4 | 31% | 104.6 | 82.6 | 22.0 | 21% |
| **Average** | **19.7** | **13.1** | **6.6** | **32%** | **19.0** | **14.8** | **4.2** | **27%** | **65.4** | **54.7** | **10.8** | **15%** |

2700 ft2 prototype with 2019 prescriptive features

Split HP Ducts in 2019 prescriptive attic, with max fan W/cfm

VCHP sized @ full load.  Split sized 75% w/ backup resistance heat

# Energy Use Comparison with Standard Design Split Heat Pump

| | Heating kWh | | | | Cooling kWh | | | |
|---|---|---|---|---|---|---|---|---|
| | Standard | VCHP | Diff | % Diff | Standard | VCHP | Diff | % Diff |
| CZ01 | 4565 | 2723 | 1843 | 40% | 0 | 0 | 0 | |
| CZ02 | 2739 | 1852 | 887 | 32% | 24 | 16 | 8 | 33% |
| CZ03 | 1933 | 1149 | 783 | 41% | 0 | 0 | 0 | |
| CZ04 | 2214 | 1421 | 793 | 36% | 38 | 25 | 13 | 35% |
| CZ05 | 1893 | 1121 | 772 | 41% | 0 | 0 | 0 | |
| CZ06 | 945 | 628 | 317 | 34% | 49 | 30 | 19 | 39% |
| CZ07 | 327 | 223 | 105 | 32% | 4 | 2 | 2 | 43% |
| CZ08 | 507 | 375 | 133 | 26% | 309 | 270 | 39 | 13% |
| CZ09 | 778 | 568 | 210 | 27% | 595 | 494 | 101 | 17% |
| CZ10 | 944 | 683 | 261 | 28% | 771 | 627 | 144 | 19% |
| CZ11 | 2553 | 1788 | 765 | 30% | 1614 | 1286 | 328 | 20% |
| CZ12 | 2423 | 1745 | 678 | 28% | 414 | 345 | 69 | 17% |
| CZ13 | 2201 | 1580 | 620 | 28% | 1801 | 1439 | 362 | 20% |
| CZ14 | 2608 | 1811 | 797 | 31% | 1581 | 1247 | 334 | 21% |
| CZ15 | 212 | 159 | 53 | 25% | 5377 | 4361 | 1016 | 19% |
| CZ16 | 5589 | 3687 | 1902 | 34% | 219 | 153 | 66 | 30% |
| **Average** | **2027** | **1344** | **682** | **32%** | **800** | **643** | **156** | **25%** |

2700 ft2 prototype with 2019 prescriptive features

Split HP Ducts in 2019 prescriptive attic, with max fan W/cfm

VCHP sized @ full load.  Split sized 75% w/ backup resistance heat

# **2019 EDR** Compliance Comparison with Split Heat Pump & DICS

| | EDR Efficiency | | | | EDR Flexibilty | | | | EDR Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VLLDCS | VCHP | Diff | % Diff | VLLDCS | VCHP | Diff | % Diff | VLLDCS | VCHP | Diff | % Diff |
| CZ01 | 60.5 | 56.9 | 3.6 | 6% | 21.8 | 21.8 | 0.0 | 0% | 38.7 | 35.1 | 3.6 | 9% |
| CZ02 | 50.3 | 47.9 | 2.4 | 5% | 20.8 | 20.7 | 0.1 | 0% | 29.5 | 27.2 | 2.3 | 8% |
| CZ03 | 51.8 | 50.5 | 1.3 | 3% | 22.8 | 22.8 | 0.0 | 0% | 29.0 | 27.7 | 1.3 | 4% |
| CZ04 | 49.7 | 47.2 | 2.5 | 5% | 21.3 | 21.3 | 0.0 | 0% | 28.4 | 25.9 | 2.5 | 9% |
| CZ05 | 50.8 | 49.4 | 1.4 | 3% | 22.0 | 22.0 | 0.0 | 0% | 28.8 | 27.4 | 1.4 | 5% |
| CZ06 | 54.1 | 52.8 | 1.3 | 2% | 26.1 | 26.0 | 0.1 | 0% | 28.0 | 26.8 | 1.2 | 4% |
| CZ07 | 54.6 | 54.3 | 0.3 | 1% | 28.3 | 28.3 | 0.0 | 0% | 26.3 | 26.0 | 0.3 | 1% |
| CZ08 | 51.0 | 49.8 | 1.2 | 2% | 25.5 | 25.6 | -0.1 | 0% | 25.5 | 24.2 | 1.3 | 5% |
| CZ09 | 50.7 | 48.7 | 2.0 | 4% | 23.2 | 23.2 | 0.0 | 0% | 27.5 | 25.5 | 2.0 | 7% |
| CZ10 | 50.6 | 48.4 | 2.2 | 4% | 22.0 | 22.0 | 0.0 | 0% | 28.6 | 26.4 | 2.2 | 8% |
| CZ11 | 47.1 | 43.8 | 3.3 | 7% | 20.4 | 20.4 | 0.0 | 0% | 26.7 | 23.4 | 3.3 | 12% |
| CZ12 | 48.4 | 45.6 | 2.8 | 6% | 19.3 | 19.3 | 0.0 | 0% | 29.1 | 26.3 | 2.8 | 10% |
| CZ13 | 48.3 | 44.9 | 3.4 | 7% | 20.7 | 20.7 | 0.0 | 0% | 27.6 | 24.2 | 3.4 | 12% |
| CZ14 | 49.1 | 45.7 | 3.4 | 7% | 20.9 | 20.9 | 0.0 | 0% | 28.2 | 24.8 | 3.4 | 12% |
| CZ15 | 49.3 | 45.4 | 3.9 | 8% | 26.1 | 26.1 | 0.0 | 0% | 23.2 | 19.3 | 3.9 | 17% |
| CZ16 | 59.7 | 54.2 | 5.5 | 9% | 18.1 | 18.1 | 0.0 | 0% | 41.6 | 36.1 | 5.5 | 13% |
| **Average** | **51.63** | **49.09** | **2.53** | **5%** | **22.46** | **22.45** | **0.01** | **0%** | **29.17** | **26.64** | **2.53** | **9%** |

2700 ft2 prototype with 2019 prescriptive features & Standard Design PV
Split HP w/ Verified Low Leakage Ducts in Conditioned Space, & max fan W/cfm
VCHP sized @ full load.  Split sized 75% w/ backup resistance heat

# TDV Comparison with Standard Design Split Heat Pump & DICS

| | Heating kTDV/ft2 | | | | Cooling kTDV/ft2 | | | | Total kTDV/ft2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VLLDCS | VCHP | Diff | % Diff | VLLDCS | VCHP | Diff | % Diff | VLLDCS | VCHP | Diff | % Diff |
| CZ01 | 34.2 | 27.6 | 6.6 | 19% | 0.0 | 0.0 | 0.0 | | 72.0 | 65.4 | 6.6 | 9% |
| CZ02 | 21.7 | 17.4 | 4.3 | 20% | 2.2 | 1.9 | 0.3 | 13% | 58.2 | 53.6 | 4.6 | 8% |
| CZ03 | 13.5 | 11.2 | 2.3 | 17% | 0.0 | 0.0 | 0.0 | | 50.1 | 47.9 | 2.3 | 4% |
| CZ04 | 17.4 | 13.3 | 4.1 | 24% | 3.8 | 3.1 | 0.8 | 20% | 54.1 | 49.3 | 4.9 | 9% |
| CZ05 | 13.2 | 10.7 | 2.5 | 19% | 0.0 | 0.0 | 0.0 | | 51.3 | 48.8 | 2.5 | 5% |
| CZ06 | 7.0 | 5.7 | 1.3 | 18% | 2.9 | 2.3 | 0.6 | 20% | 41.9 | 40.1 | 1.8 | 4% |
| CZ07 | 2.4 | 2.1 | 0.3 | 14% | 0.4 | 0.3 | 0.1 | 21% | 36.0 | 35.5 | 0.4 | 1% |
| CZ08 | 4.1 | 3.4 | 0.7 | 17% | 10.9 | 9.6 | 1.3 | 12% | 41.8 | 39.8 | 2.0 | 5% |
| CZ09 | 6.2 | 5.1 | 1.1 | 18% | 20.2 | 17.6 | 2.6 | 13% | 51.8 | 48.1 | 3.7 | 7% |
| CZ10 | 7.6 | 6.1 | 1.5 | 19% | 23.3 | 20.3 | 3.0 | 13% | 56.9 | 52.5 | 4.4 | 8% |
| CZ11 | 21.2 | 16.7 | 4.5 | 21% | 34.4 | 30.0 | 4.4 | 13% | 72.2 | 63.4 | 8.8 | 12% |
| CZ12 | 20.3 | 16.3 | 4.0 | 20% | 20.2 | 17.7 | 2.5 | 13% | 68.3 | 61.7 | 6.5 | 10% |
| CZ13 | 18.7 | 14.9 | 3.8 | 20% | 38.4 | 33.1 | 5.3 | 14% | 73.9 | 64.8 | 9.1 | 12% |
| CZ14 | 20.8 | 16.4 | 4.4 | 21% | 32.4 | 28.0 | 4.4 | 13% | 71.3 | 62.5 | 8.8 | 12% |
| CZ15 | 1.8 | 1.4 | 0.3 | 18% | 81.1 | 69.7 | 11.4 | 14% | 70.4 | 58.8 | 11.7 | 17% |
| CZ16 | 52.8 | 41.1 | 11.7 | 22% | 4.0 | 3.2 | 0.8 | 21% | 95.1 | 82.6 | 12.5 | 13% |
| **Average** | **16.4** | **13.1** | **3.3** | **19%** | **17.1** | **14.8** | **2.3** | **15%** | **60.3** | **54.7** | **5.7** | **9%** |

2700 ft2 prototype with 2019 prescriptive features

Split HP w/ Verified Low Leakage Ducts in Conditioned Space, & max fan W/cfm

VCHP sized @ full load.  Split sized 75% w/ backup resistance heat

# Energy Use Comparison with Standard Design Split Heat Pump and DICS

| | Heating kWh | | | | Cooling kWh | | | |
|---|---|---|---|---|---|---|---|---|
| | VLLDCS | VCHP | Diff | % Diff | VLLDCS | VCHP | Diff | % Diff |
| CZ01 | 3378 | 2723 | 655 | 19% | 0 | 0 | 0 | |
| CZ02 | 2314 | 1852 | 463 | 20% | 19 | 16 | 3 | 14% |
| CZ03 | 1382 | 1149 | 233 | 17% | 0 | 0 | 0 | |
| CZ04 | 1861 | 1421 | 440 | 24% | 31 | 25 | 6 | 20% |
| CZ05 | 1387 | 1121 | 266 | 19% | 0 | 0 | 0 | |
| CZ06 | 765 | 628 | 137 | 18% | 38 | 30 | 8 | 21% |
| CZ07 | 260 | 223 | 37 | 14% | 3 | 2 | 1 | 21% |
| CZ08 | 452 | 375 | 77 | 17% | 291 | 270 | 21 | 7% |
| CZ09 | 693 | 568 | 125 | 18% | 551 | 494 | 57 | 10% |
| CZ10 | 845 | 683 | 163 | 19% | 709 | 627 | 82 | 12% |
| CZ11 | 2266 | 1788 | 478 | 21% | 1479 | 1286 | 193 | 13% |
| CZ12 | 2171 | 1745 | 427 | 20% | 382 | 345 | 37 | 10% |
| CZ13 | 1987 | 1580 | 406 | 20% | 1657 | 1439 | 218 | 13% |
| CZ14 | 2302 | 1811 | 491 | 21% | 1438 | 1247 | 191 | 13% |
| CZ15 | 194 | 159 | 35 | 18% | 5055 | 4361 | 695 | 14% |
| CZ16 | 4772 | 3687 | 1085 | 23% | 194 | 153 | 40 | 21% |
| **Average** | **1689** | **1344** | **345** | **19%** | **740** | **643** | **97** | **14%** |

2700 ft2 prototype with 2019 prescriptive features

Split HP w/ Verified Low Leakage Ducts in Conditioned Space, & max fan W/cfm

VCHP sized @ full load.  Split sized 75% w/ backup resistance heat

# Continuous Fan for Ducted Systems

- 50 W/ton for fully ducted
- 25 W/ton for partly ducted
- Fully ducted example for CTZ1
  - Off cycle fan energy = 686 kWh
  - Total VCP kWh = 2550
  - Continuous fan adds 27%

# Questions?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- 510 528 4406
- bwilcox@lmi.net

# How to Submit Written Comments

**We strongly encourage submitting written comments via e-file by March 1, 2019.**

Comments on the Draft 2019 Alternative Calculation Method Reference Manuals and Compliance Software Tools can be submitted to:

https://efiling.energy.ca.gov/EComment/EComment.aspx?docketnumber=19-BSTD-02

Comments can also be submitted physically or by e-mail, here:

California Energy Commission
Dockets Office, MS-4
Re: Docket No. 19-BSTD-01
1516 Ninth Street
Sacramento, CA 95814-5512
Docket@energy.ca.gov

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