
EER & SEER AS PREDICTORS OF SEASONAL COOLING PERFORMANCE

REPORT SUMMARY

Developed by:

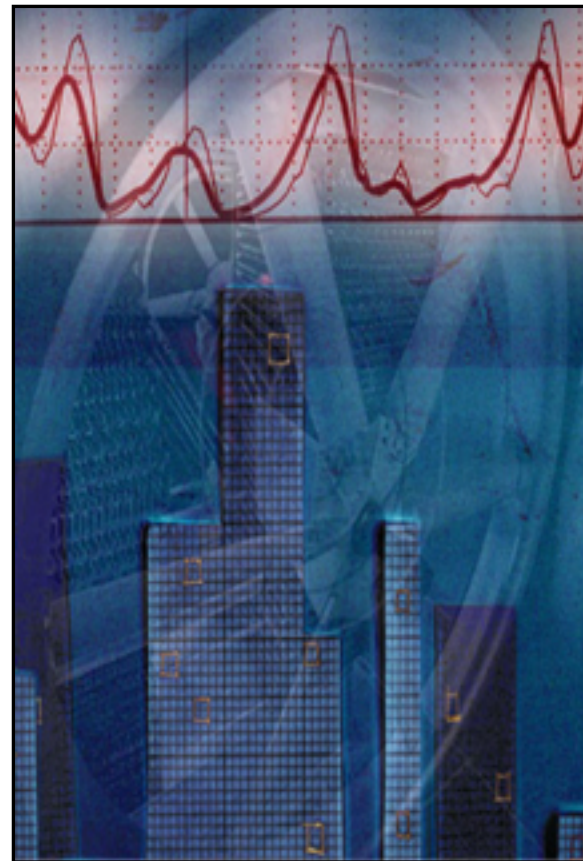
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THE ORIGINAL MOTIVATION FOR THE STUDY

BACKGROUND: KEY ASSUMPTIONS IN THE SEER RATING METHODOLOGY

ANALYSIS METHODOLOGY: UNDERSTANDING WHAT IMPACTS SEER

ANALYSIS METHODOLOGY: SIMULATION ANALYSIS PROCESS

FINDINGS REGARDING KEY ASSUMPTIONS OF THE SEER RATING PROCEDURE

FINDINGS THAT ADDRESS THE QUESTIONS THAT GUIDED THE RESEARCH

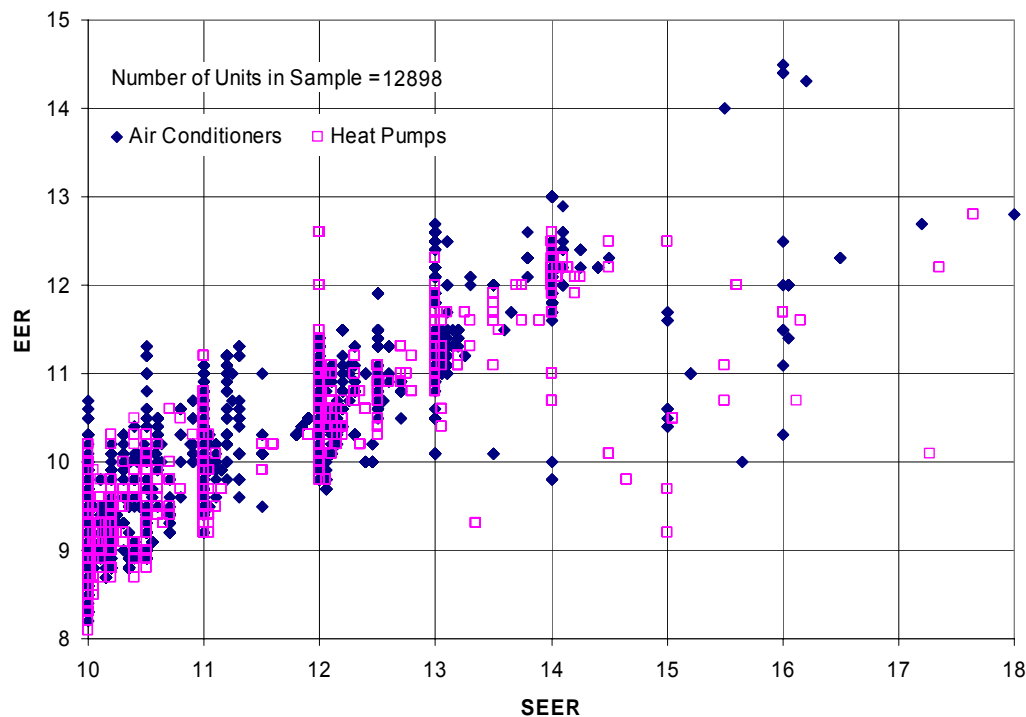
SUMMARY OF FINDINGS

NEXT STEPS

The Original Motivation for the Study

It was expected that the EER and SEER alternative ratings would correlate with one another. The data in Figure 1 (approximately 13,000 HVAC systems) show this not to be true.

Figure 1: Performance Characteristics of SEER-rated Cooling Systems
Rated SEER (at 82°F) versus Rated EER (at 95°F)



The questions That Guided This Study

QUESTION 1: How effective is SEER as a predictor of expected annual cooling *energy use*?

QUESTION 2: How effective is SEER in estimating cooling energy *savings*?

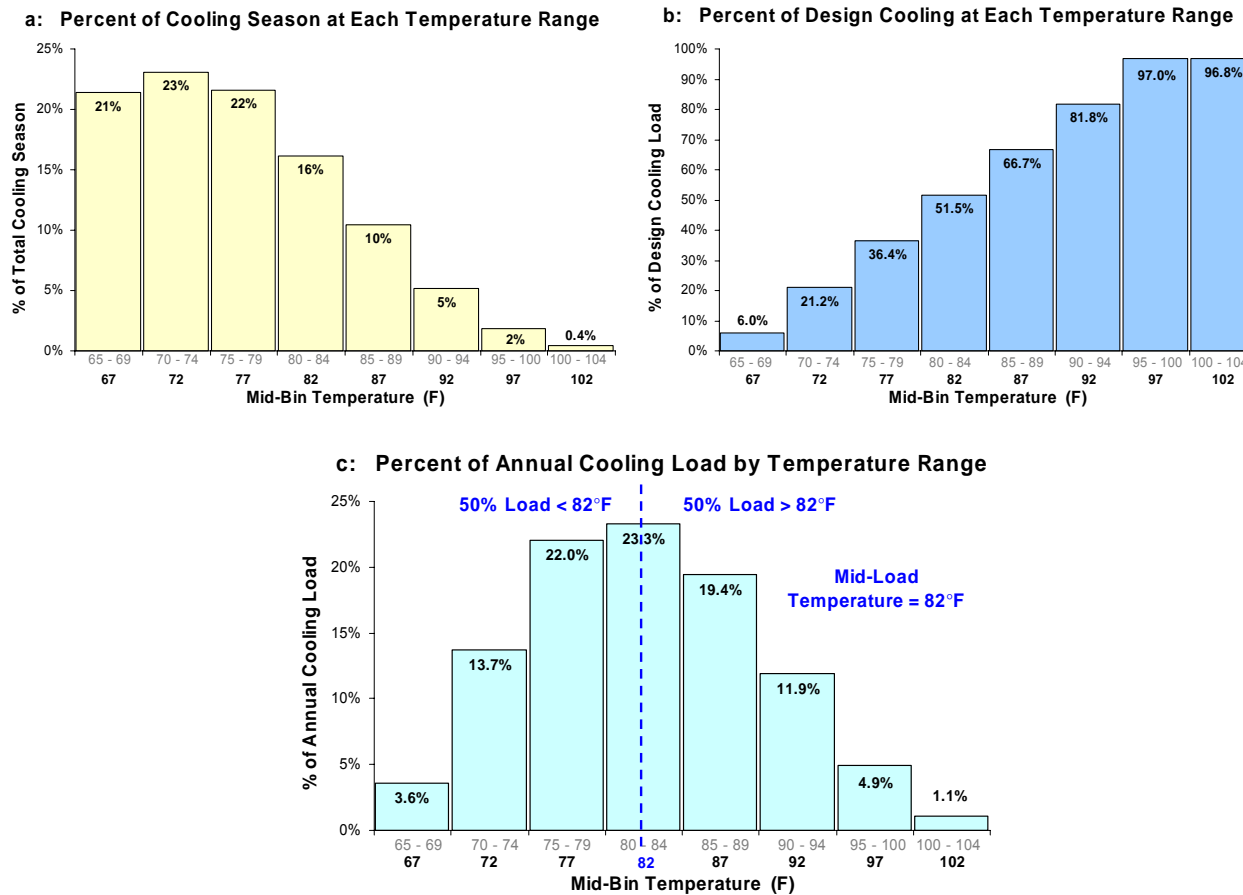
QUESTION 3: How effective is SEER in estimating the *relative* seasonal cooling efficiency of different units, i.e., *rank ordering* seasonal performance?

QUESTION 4: How effective is SEER as a predictor of cooling *peak demand* and demand savings?

Background: Key Assumptions in the SEER Rating Methodology

- 1) Distribution of outdoor temperatures illustrated in Figure 2a (median value of approximately 76°F).
- 2) Building thermal characteristics yield a 65°F balance point for the building (Figure 2b).
- 3) All cooling coil load is a linear function of outdoor temperature only (Figure 2b).
- 4) Assumptions (1) through (3) results in load distribution illustrated in Figure 2c and a *mid-load* temperature of 82°F.

Figure 2: Key Assumptions Implicit in the SEER Rating Procedure Derivation of the 82°F “Mid-Load” Temperature



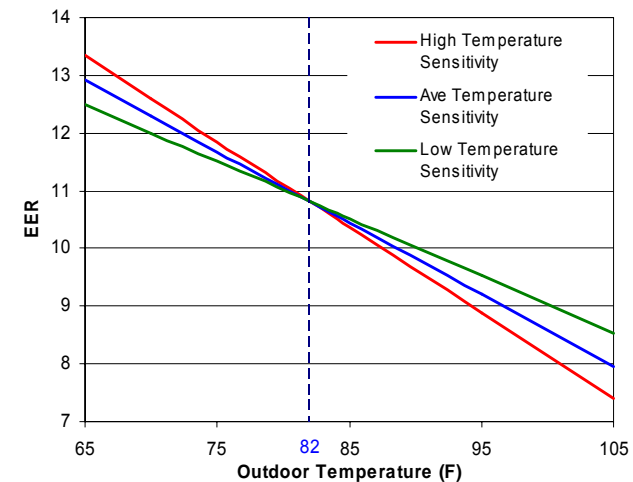
Background: Key Assumptions in the SEER Rating Methodology

- 5) The sensitivity of capacity and efficiency to outdoor temperature for individual HVAC units assumed to be linear with outdoor temperature.
- Units with equal SEER but differing EER at other temperatures have equal annual cooling energy consumption.
 - Hour-by-hour performance for DX units will vary with outdoor temperature: less efficient in warmer outdoor temperatures; more efficient in cooler temperatures.

Example: two units with equal SEER but differing sensitivity to outdoor temperature

- Unit with higher temperature sensitivity will be less efficient at hotter outdoor temperatures than the other unit.
- Temperature sensitivity is linear (Figure 3)
- This will balance out over an entire cooling season,

Figure 3
Unit Performance-Related Assumptions
Implicit in the SEER Rating Procedure
Efficiency (EER) Sensitivity to Temperature



- 6) The assumption (5) involves two added assumptions:
- Energy from both fans is a small and constant portion of the total energy requirement.
 - Indoor and condenser fans are assumed to cycle with the compressor

Analysis Methodology: Understanding What Impacts SEER

Climate characteristics

California climate cooling season median temperature is not 82°F.

- Initial analysis was run using five climate zones: Oakland, Long Beach, San Diego, Sacramento, and Palm Springs, to capture the typical range of California cooling climates.
- Final analysis was run using all sixteen climate zones.

Building characteristics

Building thermal characteristics will help determine the *mid-load* temperature

- Zone balance point
- Zone operating schedule
- Linearity of the relationship between cooling coil load and outdoor temperature

Building types (characteristics determined from state-wide surveys)

- Single-family Residential
- Small office
- Small Retail
- Conventional School Classrooms
- Portable School Classrooms

HVAC system characteristics

Approximately 90 HVAC systems to reflect the range of currently available systems varying sensitivity to:

- Outdoor temperature
- Cycling effects (i.e., C_D)
- Coil entering conditions

Analysis Methodology: Simulation Analysis Process

Analysis Tool

- DOE-2.2 was used
- Prior experience gives industry confidence DOE-2 is capable of predicating actual system performance.

All systems were simulated using manufacturers' extended ratings data.

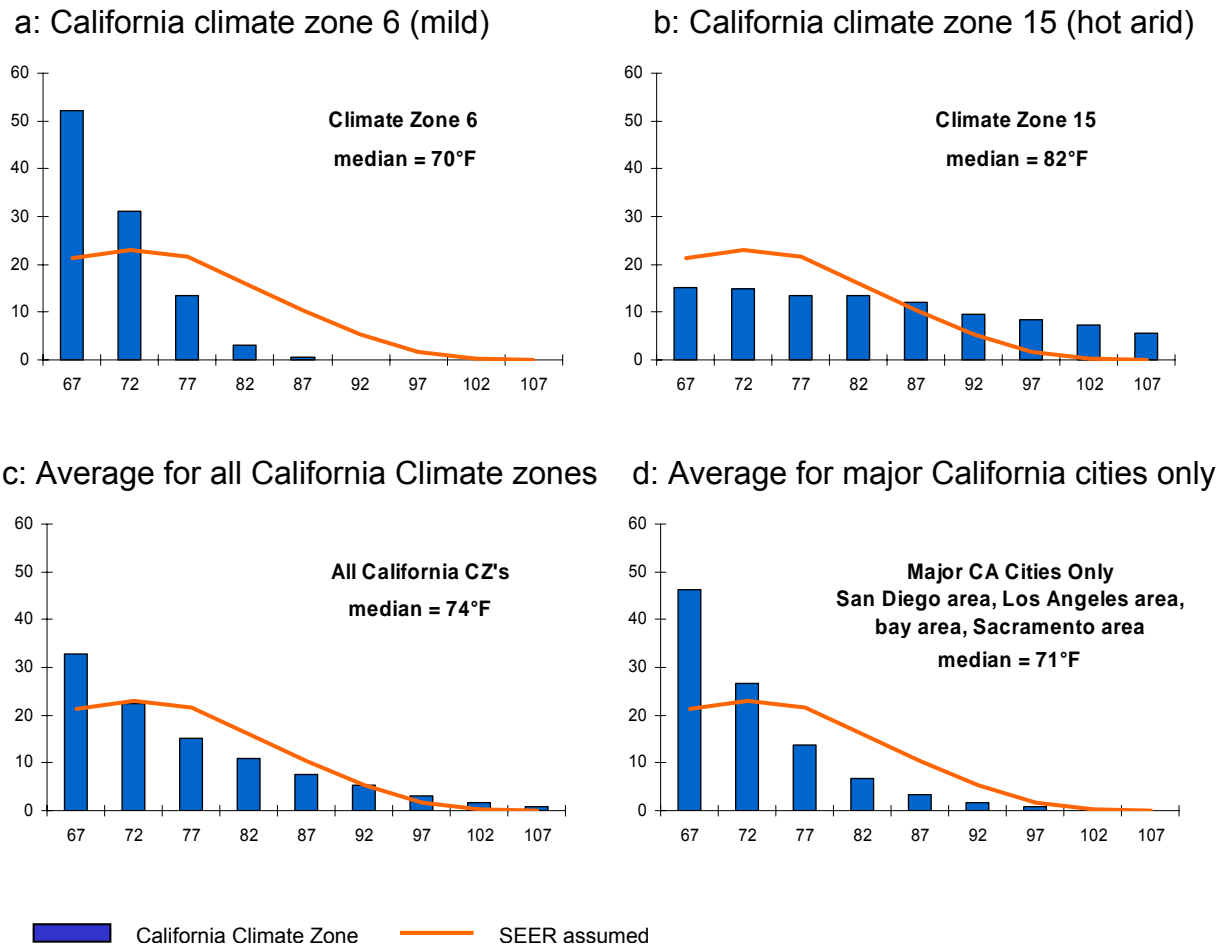
Simulation Steps

- Average effect of climate on SEER
 - Median building and median HVAC characteristics in CTZ's
- Effect of building characteristics on SEER
 - Min/median/max buildings with median HVAC system characteristics in CTZ's.
 - Identify those combinations of building characteristics that yield min and max SEER.
 - Use these cases to characterize the impact of building on SEER.
- Effect of HVAC system characteristics on SEER
 - Median buildings with min/median/max HVAC system characteristics in all climate zones.

Findings Regarding Key Assumptions of the SEER Rating Procedure

1) How similar are California climates to the U.S. average SEER climate? **They are not.**

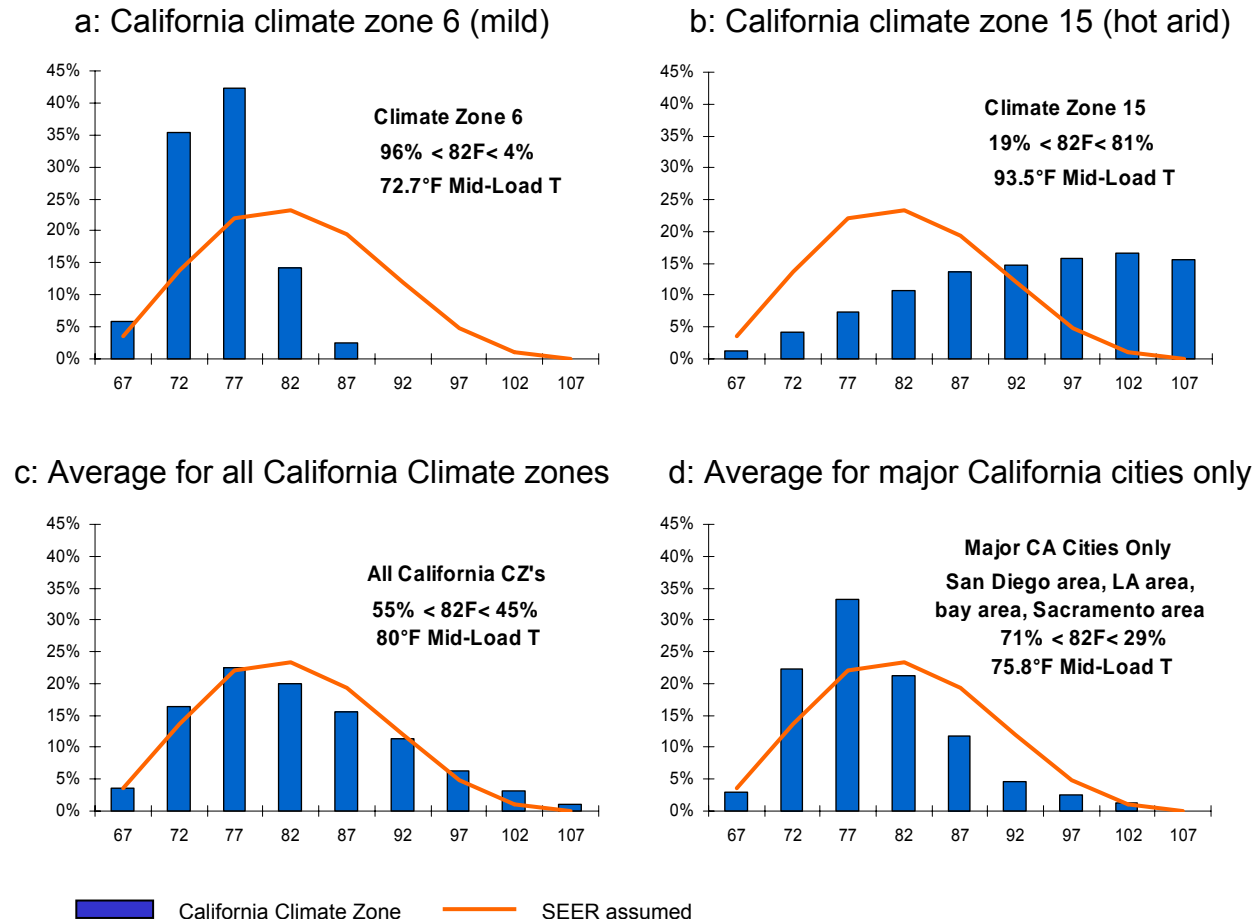
Figure 4: Distribution of Cooling Season Outdoor Temperature California Climate Zones vs. SEER rating assumption



Findings Regarding Key Assumptions of the SEER Rating Procedure

2) How valid is the SEER-assumed distribution of annual cooling coil loads for typical single-family homes in California climates? **It is not valid.**

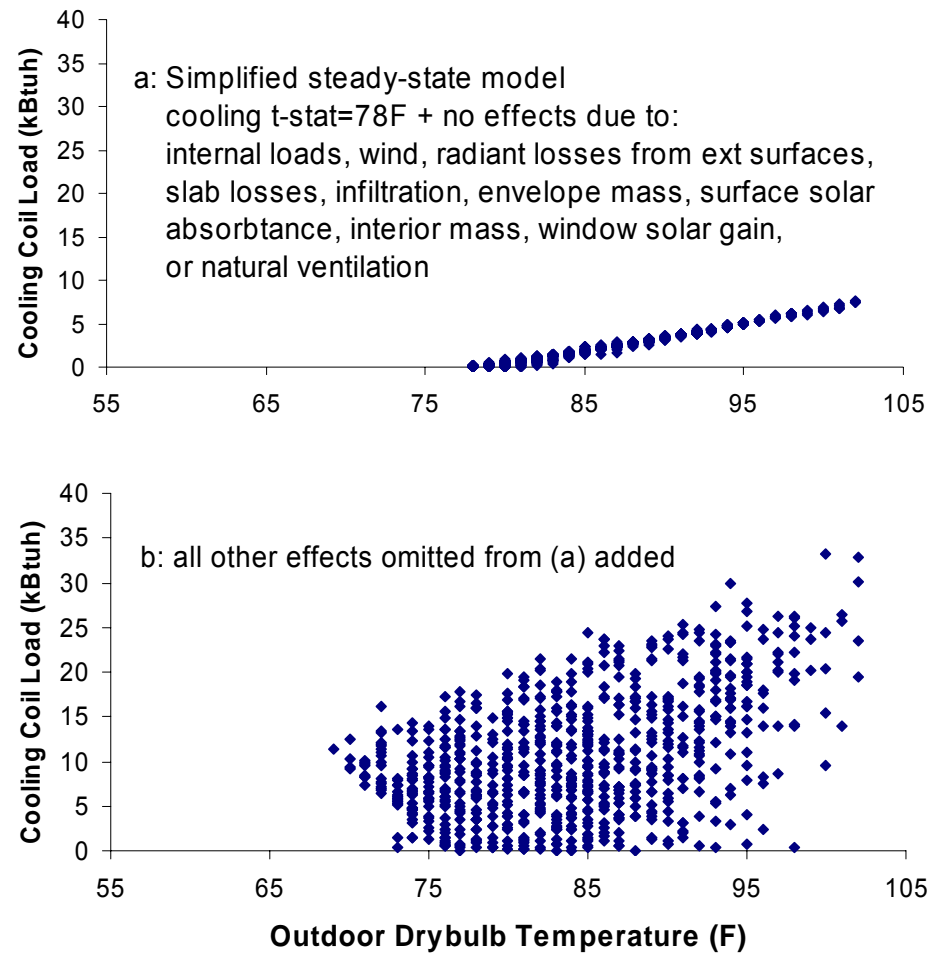
Figure 5: Distribution of Cooling Coil Load by California Climate Zones
DOE-2 cooling loads, Median Single Family Residence



Findings Regarding Key Assumptions of the SEER Rating Procedure

3) Is the linear relationship between cooling load and outdoor temperature assumed by SEER rating process valid for typical (median) California single-family houses? **It is not.**

Figure 6: Cooling Coil Load as a Function of Outdoor Temperature (median single family residence, DOE-2 cooling loads, CZ09)

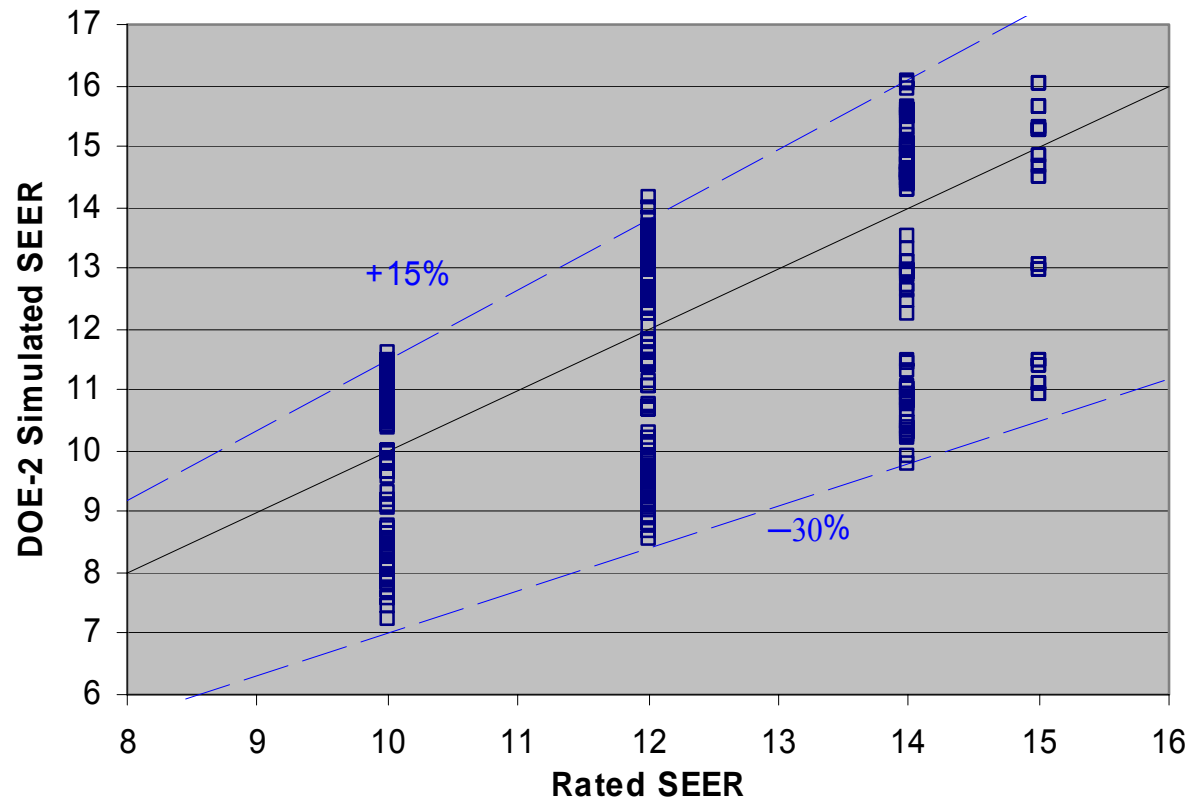


Findings That Address the Questions That Guided the Study

QUESTION 1: How effective is SEER as a predictor of expected annual cooling energy use?

Not very effective, results in +15% to -30% accuracy.

Figure 7: Rated SEER as a Predictor of Annual Cooling Efficiency Single Family Residential Prototype, Representative California Climate Zones Min/Median/Max Building Characteristics, Min/Median/Max System Characteristics



What causes this variation?

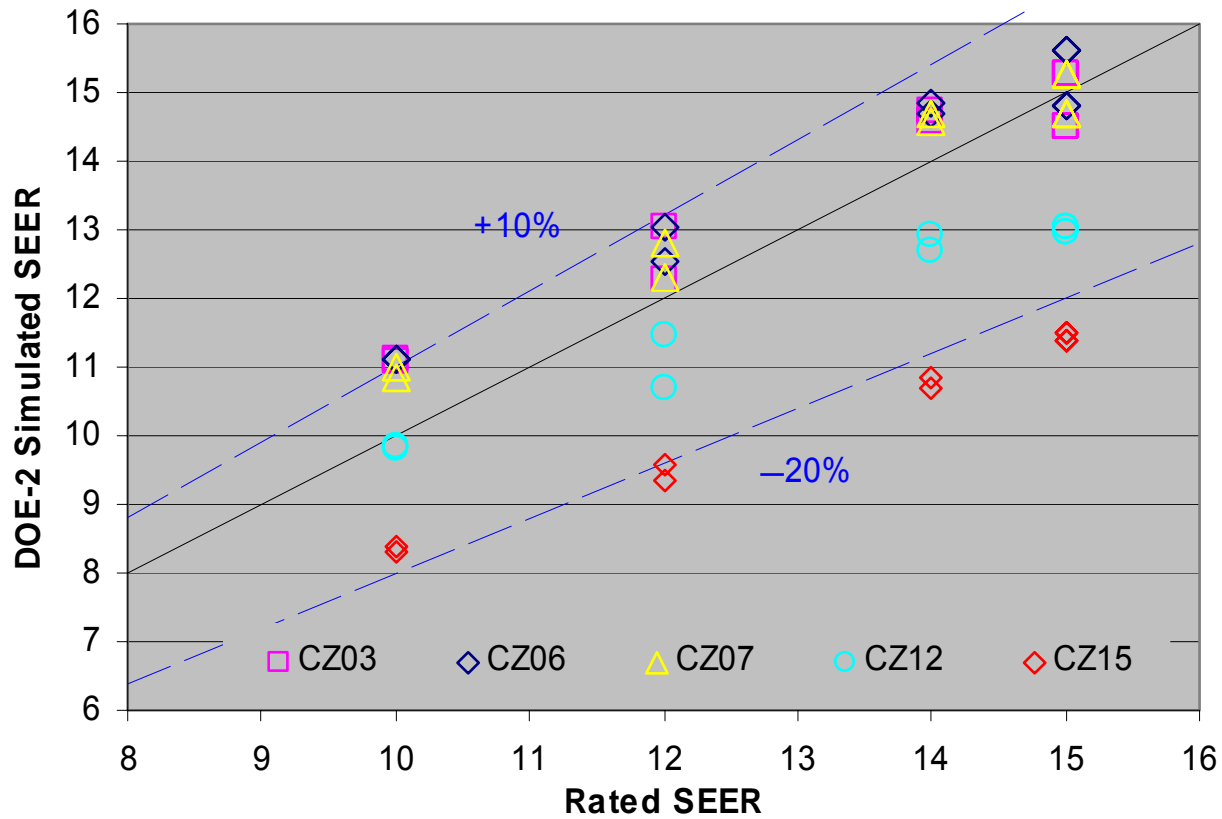
Three areas of shortcomings were found:

- Climate effects
- Building effects
- System effects

Findings That Address the Questions That Guided the Study

How much of the total variation due to climate zone effects? **Half to two thirds (from +10% to -20%)**

Figure 8: Effect of Climate on Simulation-Estimated SEER
Median Building Characteristics, Median System Characteristics

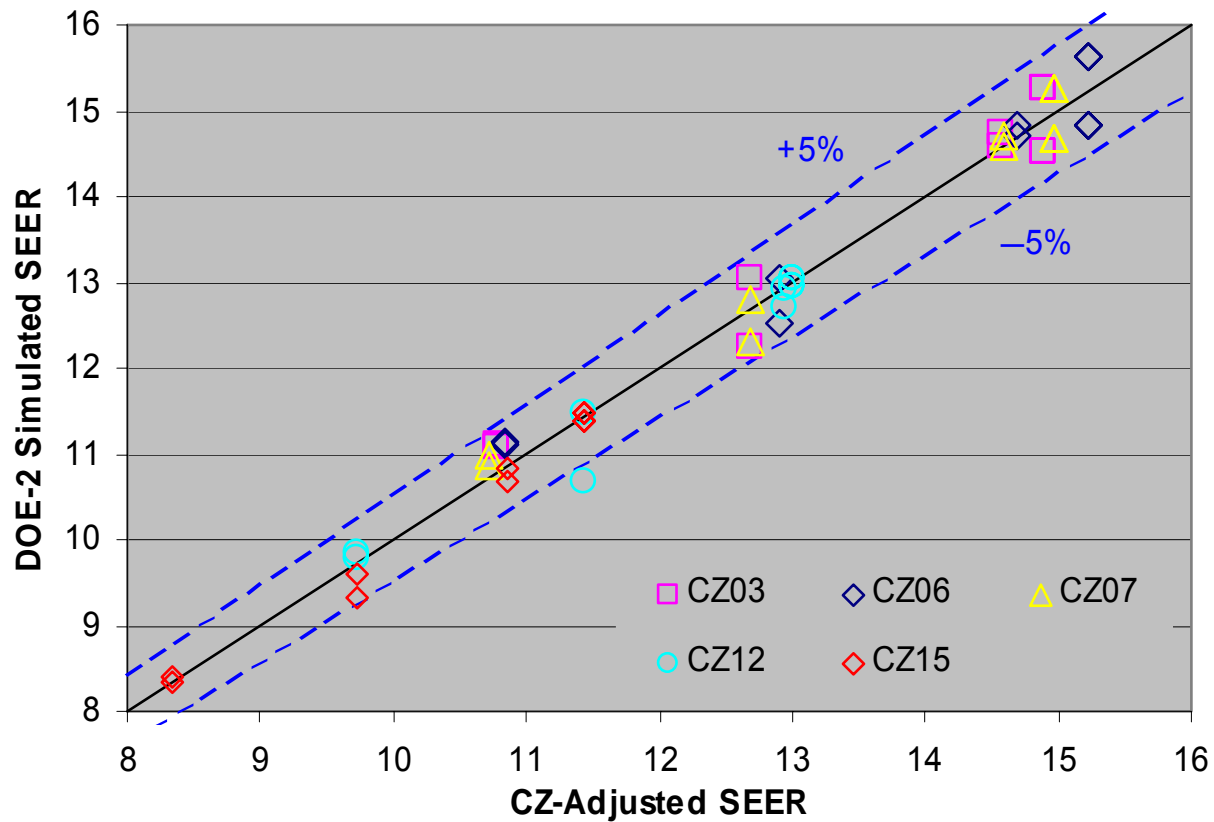


Findings That Address the Questions That Guided the Study

Can this much variation be reduced using a simple correction factor for each climate zone?

Yes, from +10% and -20% to $\pm 5\%$.

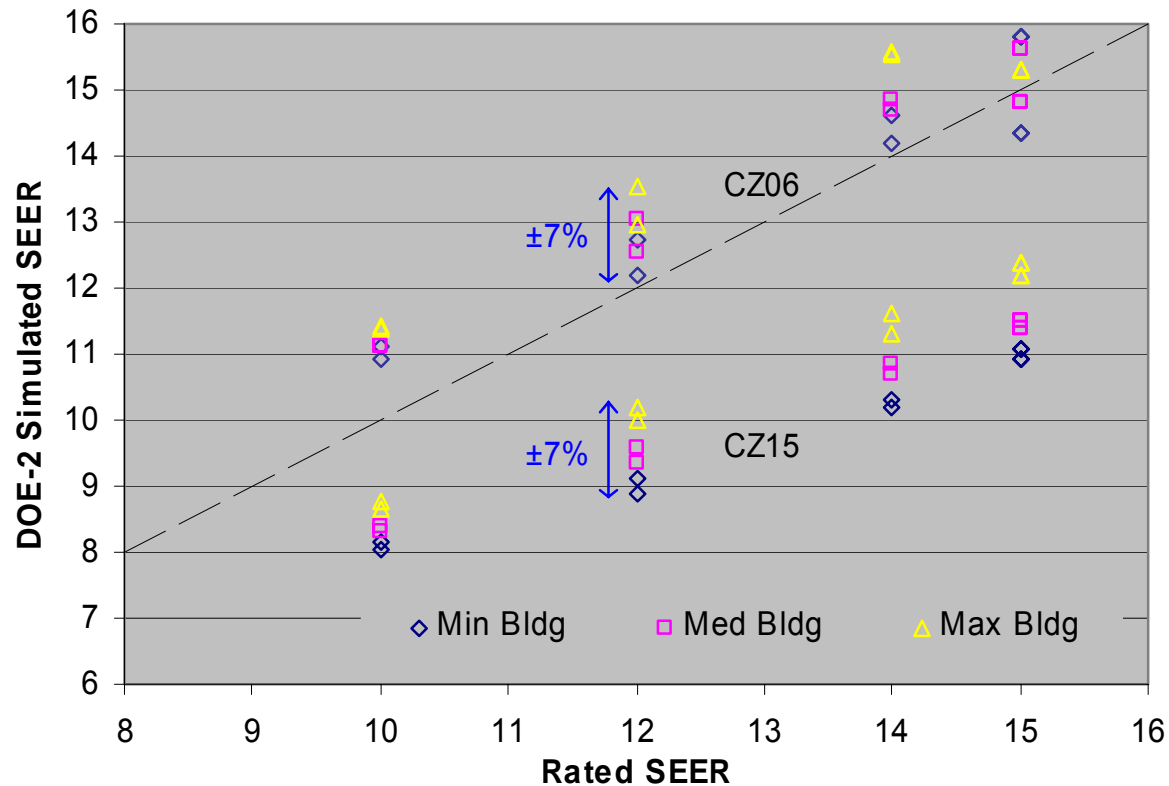
Figure 9: Climate Zone-Adjusted SEER as a Predictor of Annual Cooling Efficiency
Median Building Characteristics, Median System Characteristics



Findings That Address the Questions That Guided the Study

How much of the total variation is due to variation in building characteristics? **About ±7%.**

Figure 10: Effect of Building Characteristics on Simulation-Estimated SEER
 Single Family Residential Prototype, Climate Zones 6 (mild) and 15 (hot arid)
 Min/Median/Max Building Characteristics, Median System Characteristics

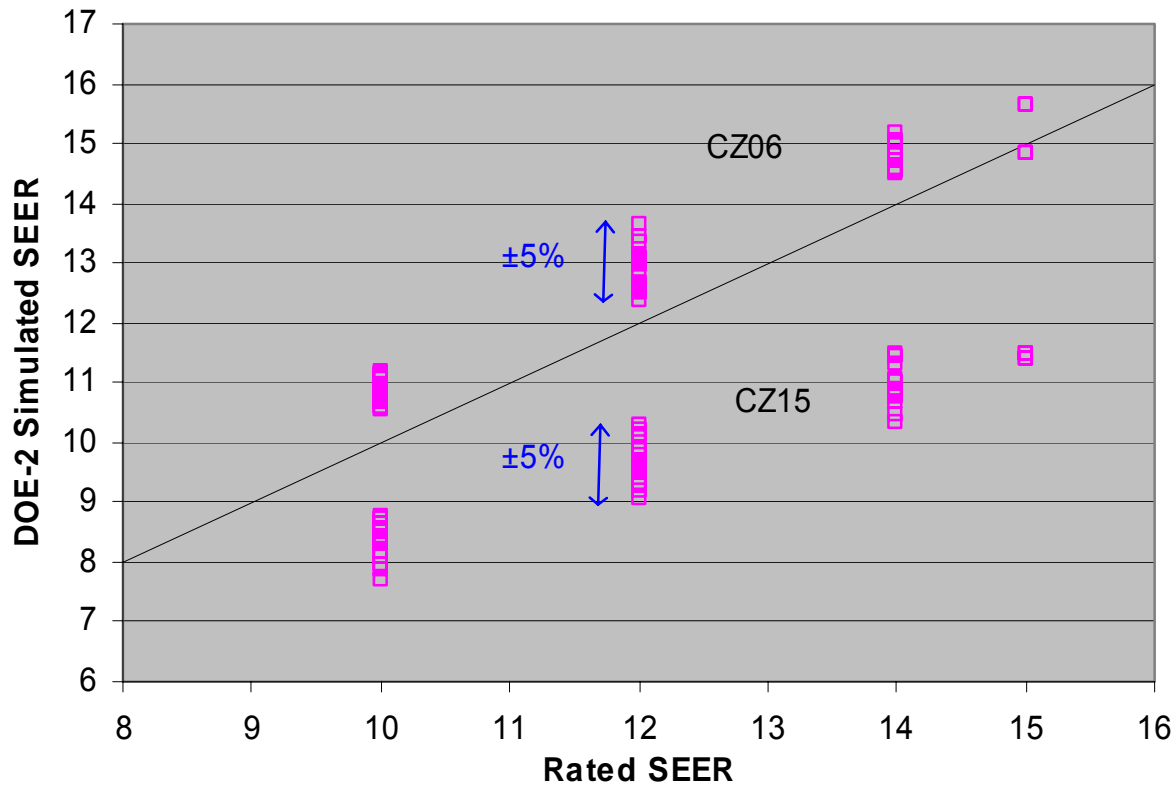


For a discussion of corrections for building effects, see the full report.

Findings That Address the Questions That Guided the Study

How much of the total variation is due to variation in HVAC system characteristics? **Approximately $\pm 5\%$**

Figure 11: Effect of HVAC System Characteristics on Simulation-Estimated SEER
 Single Family Residential Prototype, Climate Zones 6 (mild) and 15 (hot arid)
 Median Building Characteristics, All System Characteristics

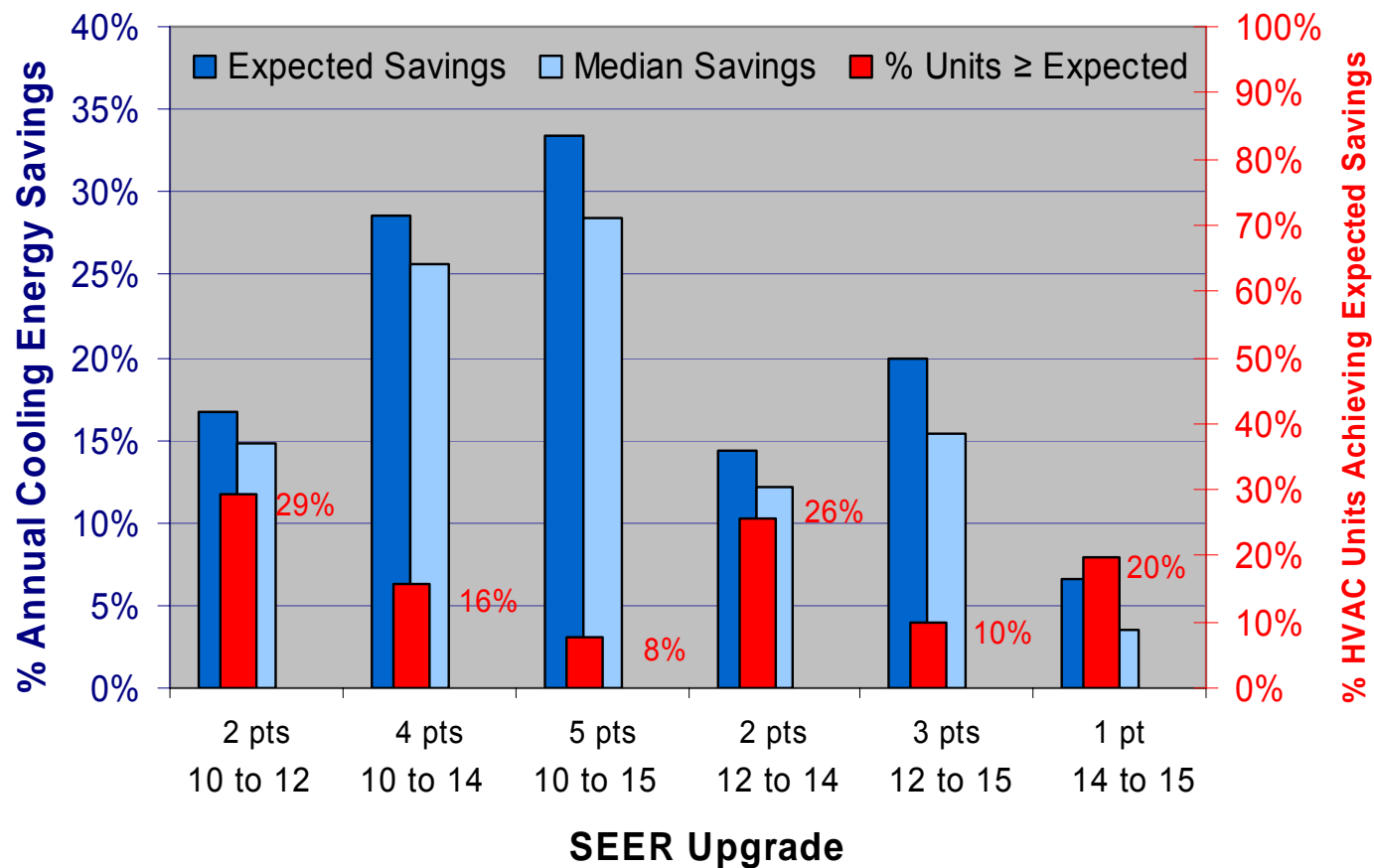


For a discussion of corrections for system effects, see the full report.

Findings That Address the Questions That Guided the Study

QUESTION 2: How effective is SEER in estimating cooling energy savings? Not very effective.

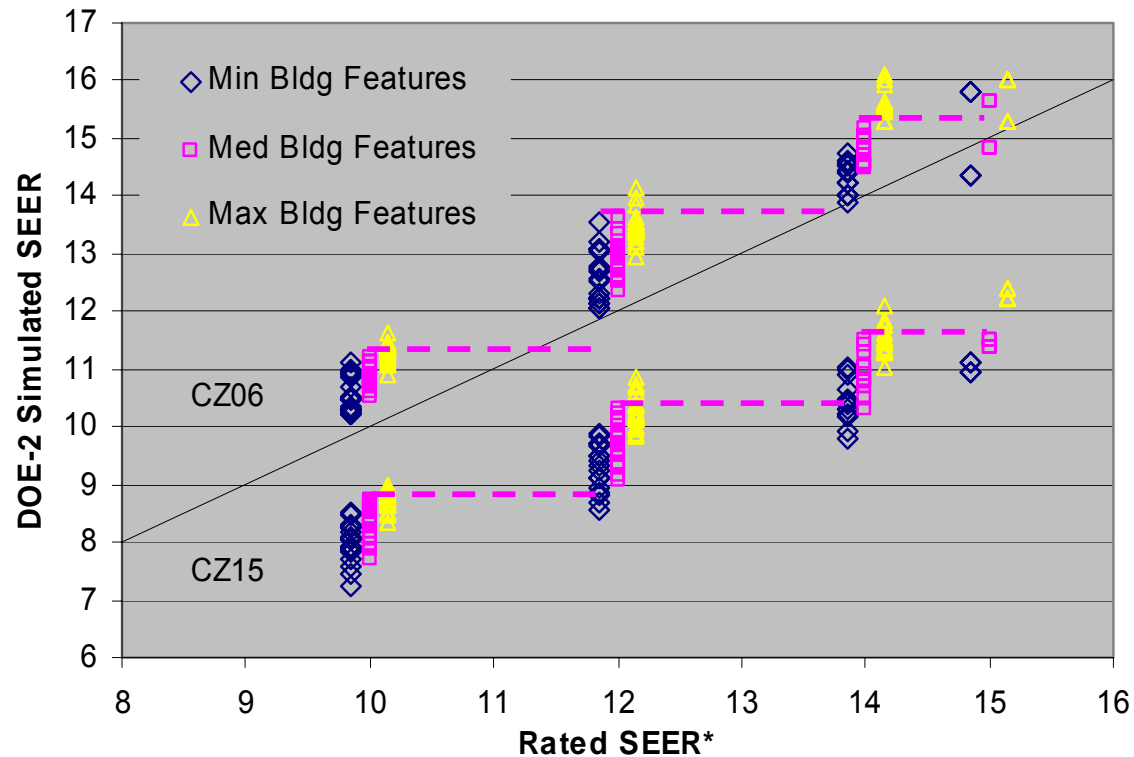
Figure 12: Percentage Savings Achieved by SEER Upgrade (Upgrading from a Lower SEER System to a Higher SEER System)
Single Family Residential Prototype, All California Climate Zones Min/Median/Max Buildings, Min/Median/Max Systems



Findings That Address the Questions That Guided the Study

QUESTION 3: How effective is SEER in estimating the relative seasonal cooling efficiency of different units, i.e., rank ordering seasonal performance? **Not very effective unless at least a 2 to 3 point SEER rating increase is adopted, but then demand can be unfavorably effected.**

Figure 13: Reliability of SEER* in Ranking the Relative Savings of HVAC Systems Single Family Residential Prototype, Climate Zones 6 (mild) and 15 (hot arid) Min/Median/Max Building Characteristics, Min/Median/Max System Characteristics

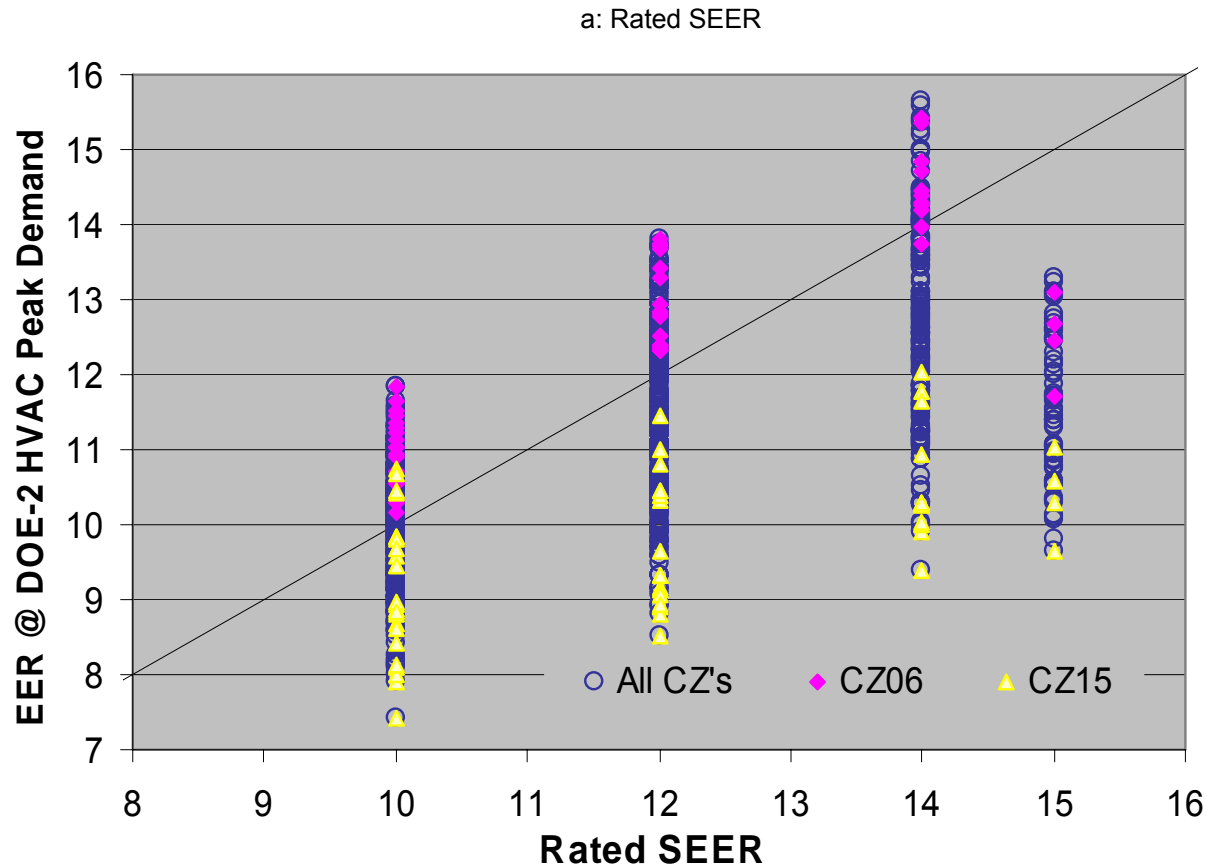


* rated SEER values in Figure 13 have been slightly juxtaposed to improve legibility. Actual rated SEER values are integer values.

Findings That Address the Questions That Guided the Study

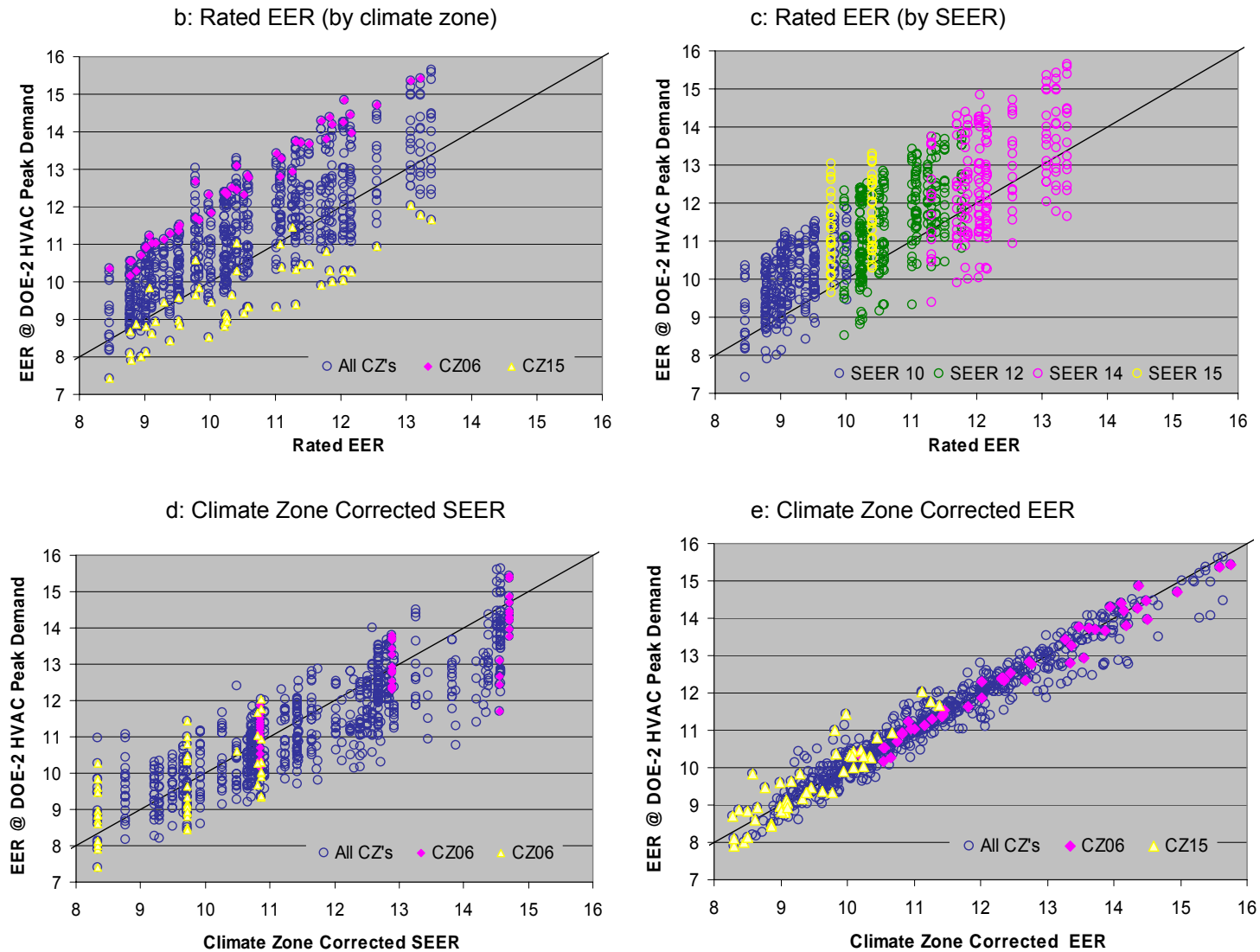
QUESTION 4: How effective is SEER as a predictor of cooling peak demand and demand savings? **Poor.**

Figure 14: SEER and EER as Predictors of EER at HVAC Peak Demand Single Family Residential Prototype, All California Climate Zones Median Building Characteristics, Median System Characteristics



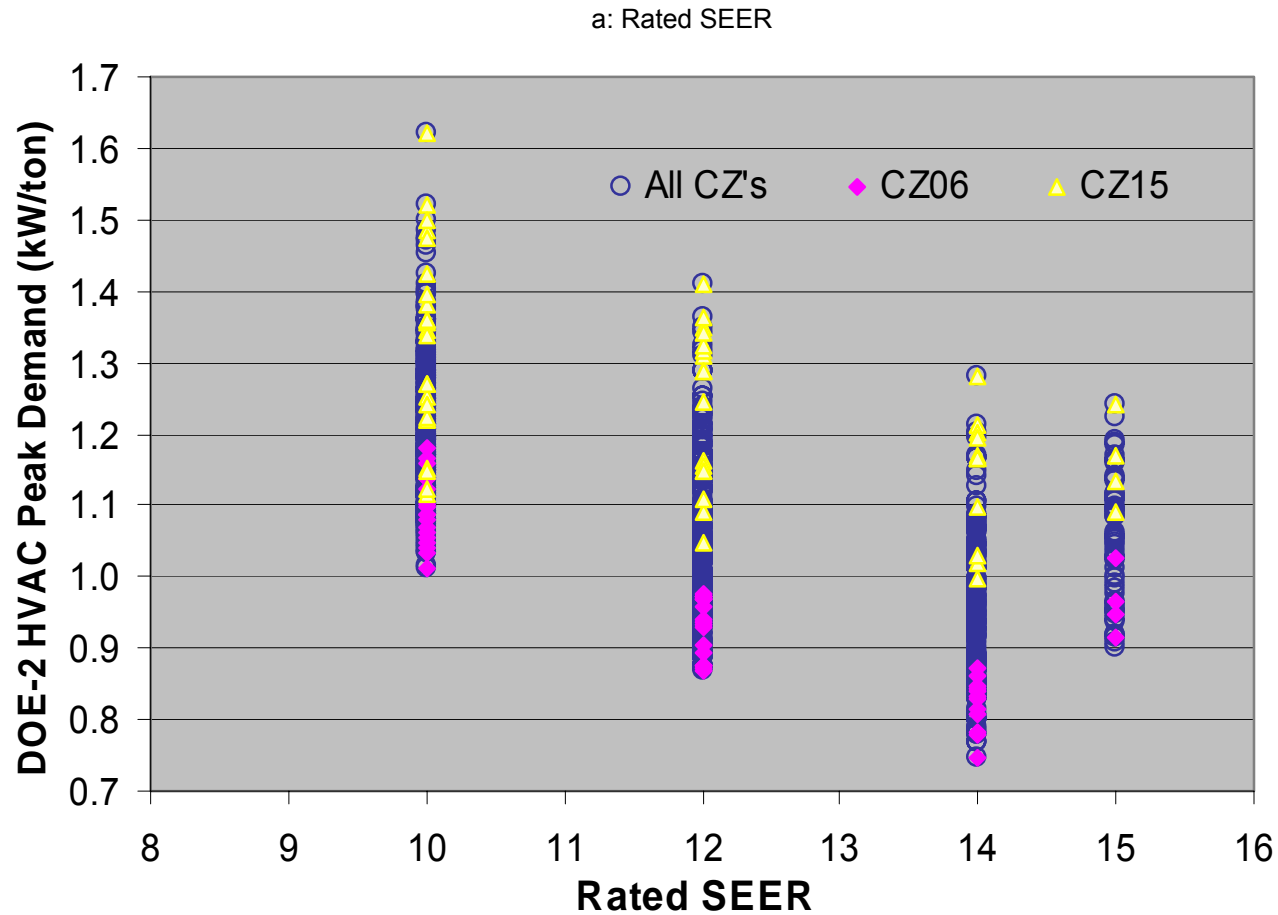
Findings That Address the Questions That Guided the Study

Figure 14 (cont'd): SEER and EER as Predictors of EER at HVAC Peak Demand Single Family Residential Prototype, All California Climate Zones Median Building Characteristics, Median System Characteristics



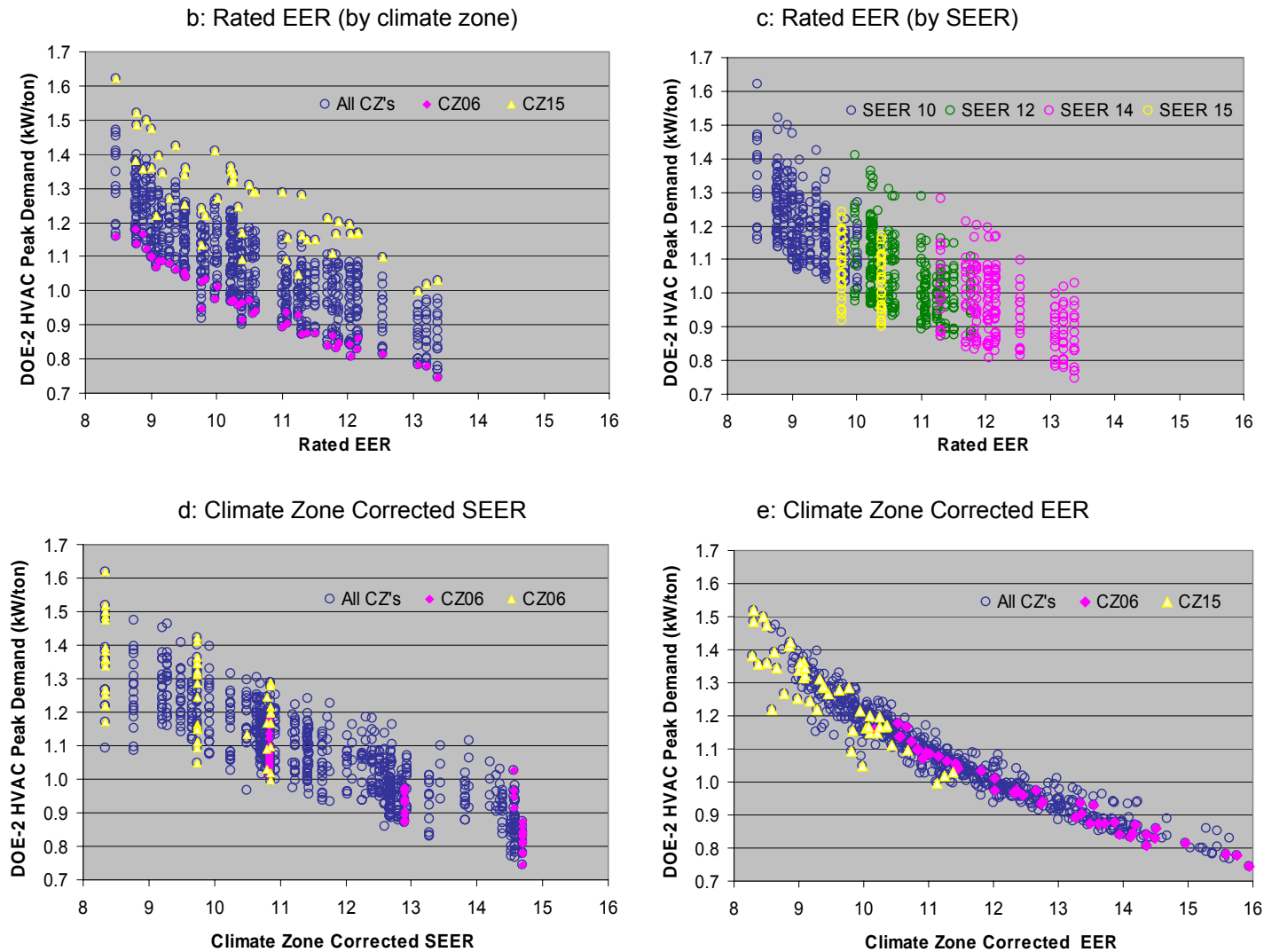
Findings That Address the Questions That Guided the Study

Figure 15: SEER and EER as Predictors of HVAC Peak Demand Single Family Residential Prototype, All California Climate Zones Median Building Characteristics, Median System Characteristics



Findings That Address the Questions That Guided the Study

Figure 15 (cont'd): SEER and EER as Predictors of HVAC Peak Demand Single Family Residential Prototype, All California Climate Zones Median Building Characteristics, Median System Characteristics



Findings That Address the Questions That Guided the Study

QUESTION 1-4: What about non-residential applications?

QUESTION 1: How effective is SEER as a predictor of expected annual cooling energy consumption in non-residential applications? **Not very Effective.**

The analysis revealed VERY different findings for non-residential applications.

The most significant violation of SEER rating process assumptions in non-residential applications was related to the operation of the indoor fan:

- In non-residential applications, the indoor fan operated continuously during occupied hours, to provide code-mandated ventilation air.

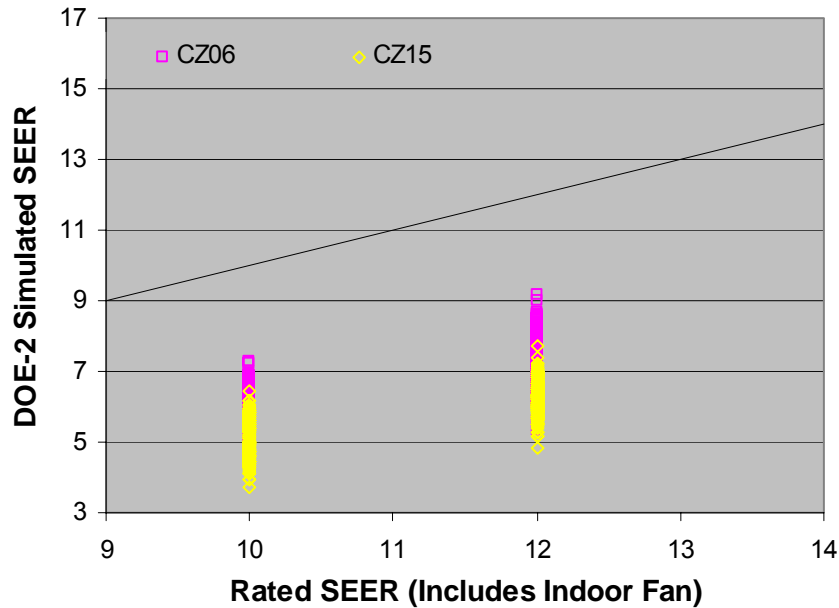
Once indoor fan energy was excluded, the non-residential results more nearly resembled residential results, however, significant remaining differences included:

- Influence of ventilation air,
- The greater range in non-residential building balance point due to the potential for much greater solar gain and internal load, and
- Use of core versus perimeter zoning.

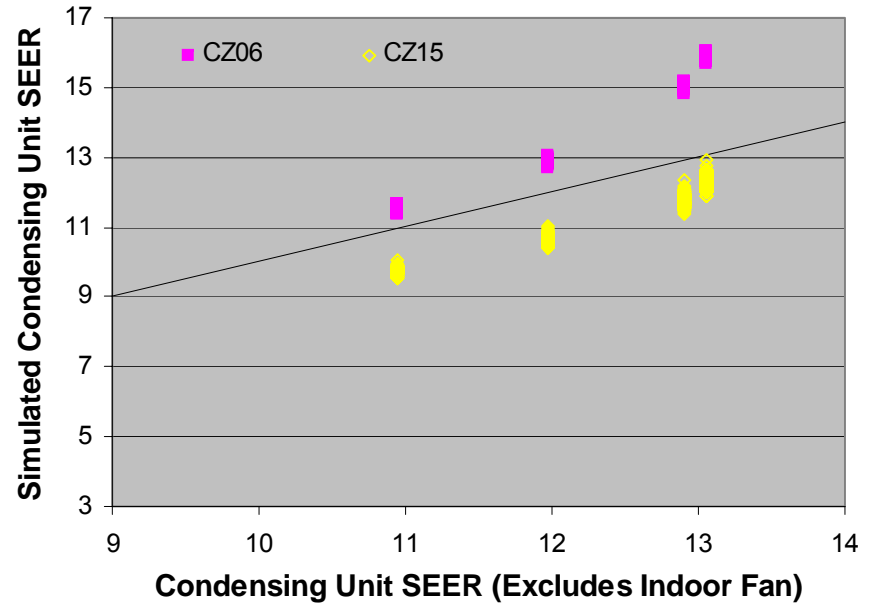
Findings That Address the Questions That Guided the Study

Figure 16: Rated SEER as a Predictor of Annual Cooling Efficiency Small Office Prototype, Climate Zones 6 (mild) and 15 (hot arid) Median Building Characteristics, All Zones, Min/Median/Max System Characteristics

a: Indoor Fan Energy Included



b: Indoor Fan Energy Excluded



Summary of Findings

- Neither SEER nor EER is a sufficiently reliable indicator of cooling energy performance (consumption or demand) for California. In residential applications – savings fall short 75% to 90% of the time. Non-residential applications are more complex and require substantial additional Study, but indications are that a similar fraction will fall short.
- Three of the basic assumptions implicit in the SEER rating process were found not to hold true for California. Use of these rating methodologies in the California market will require correction factors for each of those assumptions.
 - Climate effects: the assumed climate variation is a poor match for California CTZ's.
 - Building effects: the assumed load distribution is a poor match for California buildings.
 - System effects: the assumed equipment off-temperature and load performance is a poor match for actual equipment on the market in California.
- For residential applications in California, climate effects account for the greatest inaccuracy of the SEER and EER ratings
 - Climate effects: correction factors were developed that were effective in reducing error in both SEER and EER.
- Significant sources of error in using SEER or EER in non-residential applications require additional investigation:
 - Building effects: non-residential buildings tend to have much greater variation in internal load and solar load, greatly compromising the implicit relation SEER assumes between cooling load and outdoor temperature
 - System effects: in non-residential buildings, code requires indoor fans to run continuously to provide needed ventilation during occupancy periods; thus, indoor fan energy becomes a significant portion of the total HVAC system energy but the SEER rating assumes the fan cycles with the condensing unit compressor and fan.
- In 2002, ARI decided to no longer include EER in its equipment performance listings of SEER-rated equipment. Having at least two ratings points, i.e., SEER and EER, is critical to the energy efficiency industry in California.

Next Steps

- Extend this work to include:
 - Systems rated as SEER 13 (the minimum efficiency for the 2005 standards);
 - Include additional high efficiency two-speed systems (SEER 15 and 18 ratings);
 - Add HVAC equipment penetration rates and apply statistical methods to more accurately characterize the California state-wide impacts of performance variability on expected savings and demand.
- Explore how the inherent performance variability of SEER-rated HVAC systems, as characterized by this Study, can be applied to:
 - Future development of the California energy efficiency standards to better ensure resultant savings;
 - Utility incentive programs to improve efficiency realization rates.
- In residential applications, additional Study is required to more effectively correct for:
 - Building effects, e.g., varying mid-load temperatures;
 - System effects, e.g., including off-rated coil entering conditions.
- In non-residential applications, additional Study is required to better understand and characterize:
 - Building effects due to
 - increased internal loads
 - core/perimeter HVAC zoning
 - occupancy ventilation
 - System effects due to
 - indoor fan energy and operation
 - off-rated coil entering conditions