Energy Savings and Peak Demand Reduction of a SEER 21 Heat Pump vs. a SEER 13 Heat Pump with Attic and Indoor Duct Systems

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Research Concept

- Very high efficiency heat pumps have been developed using variable capacity controls.
  - As load declines, the equipment modulates capacity so the system runtime is greatly extended.
- The dwell time of air within the air distribution system (ADS) is substantially increased.
- Conductive losses of the system may therefore be considerably increased.
- Research has been performed to evaluate the impacts of ADS conductive losses

Research Concept (cont'd)

- Phase 1 experiments have compared the performance of a Nordyne iQ drive 3-ton variable capacity 21 SEER heat pump to a standard 3-ton 13 SEER unit using an attic duct system and an indoor duct system.
- The results of those experiments are presented here today.
- The research plan for Phase 2 experiments is summarized.

MH Lab

- Experiments are in a double-wide manufactured home, fabricated in 2000
  - With a HERS rating of 86
  - With medium-tan asphalt shingles
  - With original R6attic ductwork
  - With an indoor duct system; installed later.

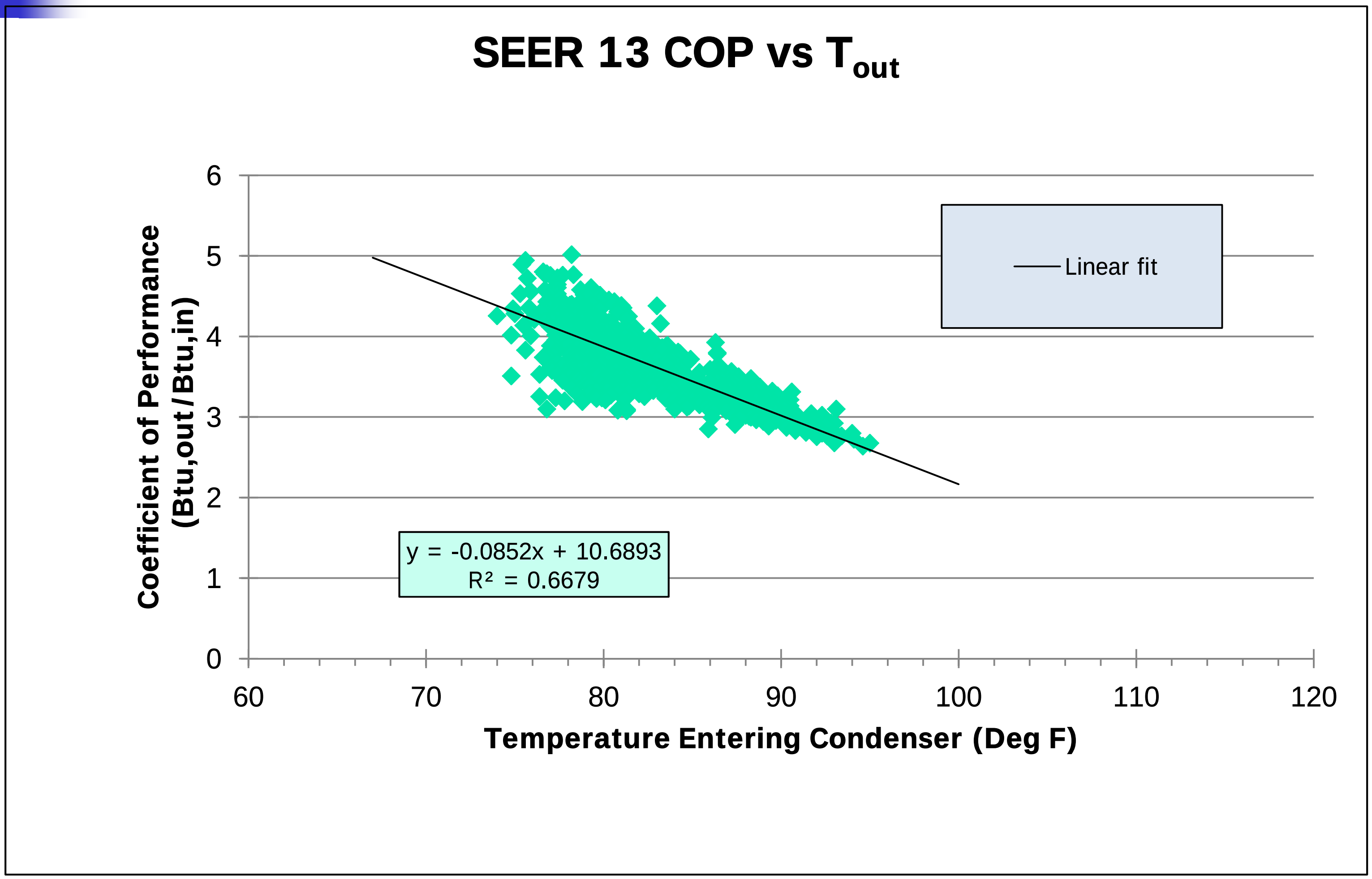
Variable capacity heat pump

- Nordyne Corp. has introduced a line of variable capacity AC and heat pump systems, in sizes of 2, 3, and 4 tons, with SEER ratings from 21 to 24.5.
  - Capacity varies from 40% to 118% of nominal capacity, and 34% to 100% of maximum capacity.
  - The compressor, AHU fan, and condenser fan all operate independently, with control signal from 15 to 60 hertz.
- Testing has found that system performance matches and in some cases considerably exceeds its ratings.

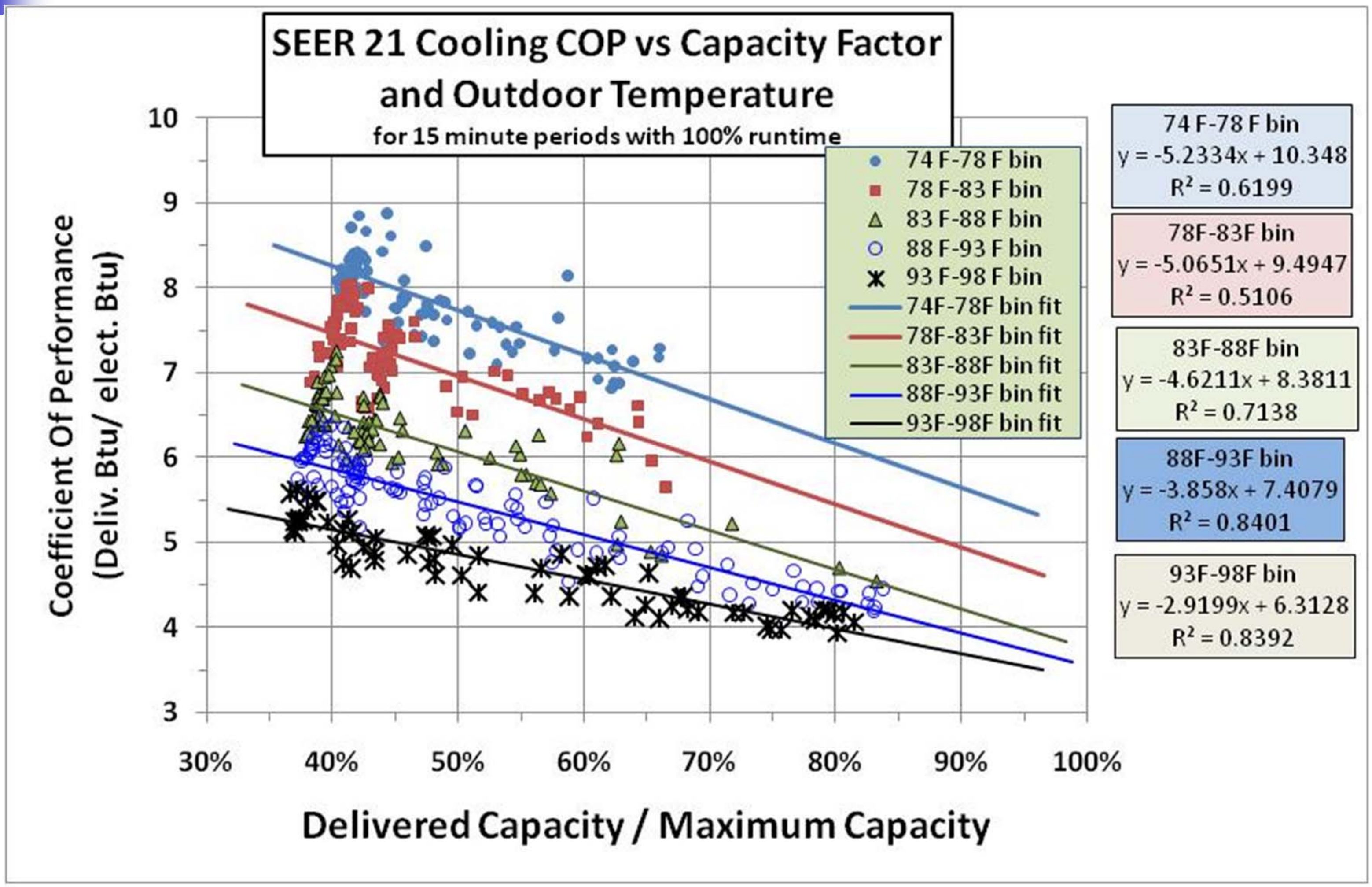
Air handlers installed side by side

- Instrumentation:
  - Conditional measurement of T/RH/cfm in return and T/RH in the supply
    - These measurement occur only when AHU fan is operating
  - Redundant measurement of condensate
  - Static pressure in return and supply plenums
  - Power for heat pump components and internal load sources
  - 145 channels of 15-minute data

SEER 13 cooling efficiency versus outdoor temperature – hourly data



SEER 21 cooling efficiency versus outdoor temperature and capacity factor



Cooling energy; affect of duct location

- An attic duct system with R6 flex ducts came with this manufactured home
  - The attic duct system is essentially leak free (~ 1% supply leak, 0~ return leak)
- An indoor duct system was constructed
  - Cooling system runtime
    - 37.5% for SEER 13 system
    - 72.0% for SEER 21 system
- Conductive duct losses of the attic duct system produced
  - 11% reduction in SEER 13 cooling efficiency
  - 17% reduction in SEER 21 cooling efficiency

Cooling energy; effect of duct location

- Based on SEER ratings alone, one would expect 38.1% cooling energy savings for the SEER 21 unit compared to the SEER 13 unit. For a typical summer day (82ºF average outdoor temperature), measured data finds that
  - the SEER 21 system saves 37.8% compared to the SEER 13 system when using the <u>indoor duct system</u>
  - the SEER 21 system saves 33.7% compared to the SEER 13 system when using the <u>attic duct system</u>
  - <u>Conclusion:</u> the variable capacity system experiences considerably greater conductive duct losses versus the fixed capacity system

Latent cooling and RH control

- The SEER 21 unit produced moderately higher indoor RH
  - The SEER 13 unit produced 48.6% and 48.9% average indoor RH with attic and indoor ductwork, respectively.
  - The SEER 21 unit produced 52.2% and 55.1% average indoor RH with attic and indoor ductwork, respectively.
  - Indoor RH is about 5 percentage points higher with the SEER 21 system vs. the SEER 13 system. Higher cfm/ton for the SEER 21 unit yields a warmer coil and reduced water vapor removal.

SEER 21 RH control mode

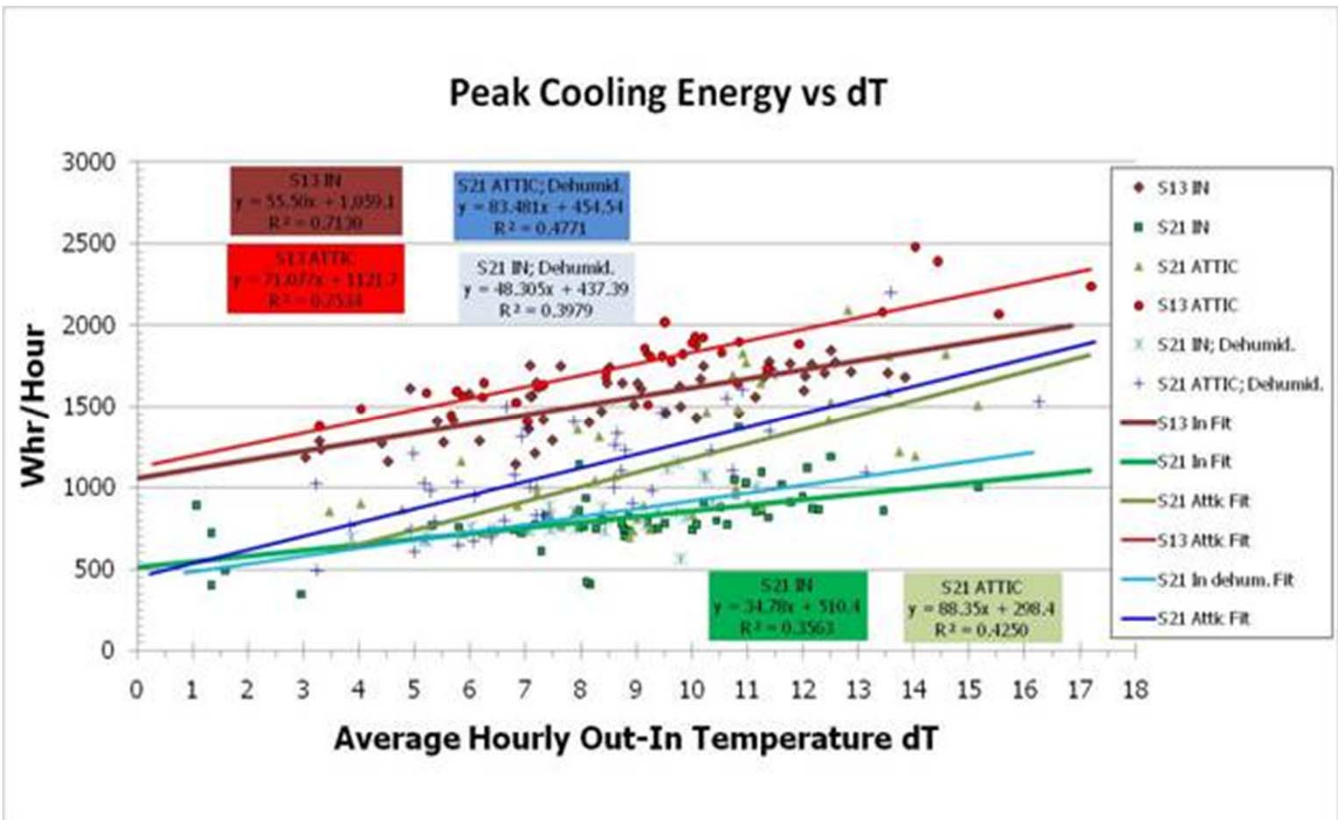
- The SEER 21 unit also has an RH control option
  - Where it reduces the AHU air flow rate to produce a colder coil and lower SHR.
  - When the indoor RH setting was 45%, the indoor RH level was about 2 percentage points lower (51% vs. 53%).
    - By contrast, the SEER 13 system produced 49% indoor RH.
  - This causes a 3.0% reduction in efficiency compared to standard control when using the <u>indoor duct system</u> and 3.6% reduction when using the <u>attic duct system</u>.
  - A portion of the apparent improvement in efficiency (SEER 21 vs. SEER 13) occurs because the latent cooling load is larger for the SEER 13 unit.

Fan power

- The SEER 13 AHU consumers 400 W (at 1290 cfm) when operating
- The SEER 21 AHU power varies with speed
  - It consumes 390 W (at 1270 cfm) when at full speed
  - It consumes 101 W (at 770 cfm) when at minimum capacity
  - In RH control mode, fan speed and fan power decline progressively to as low as 230 cfm and 4 watts
  - A significant portion of the SEER 21 efficiency, therefore, originates from the high efficiency ECM.

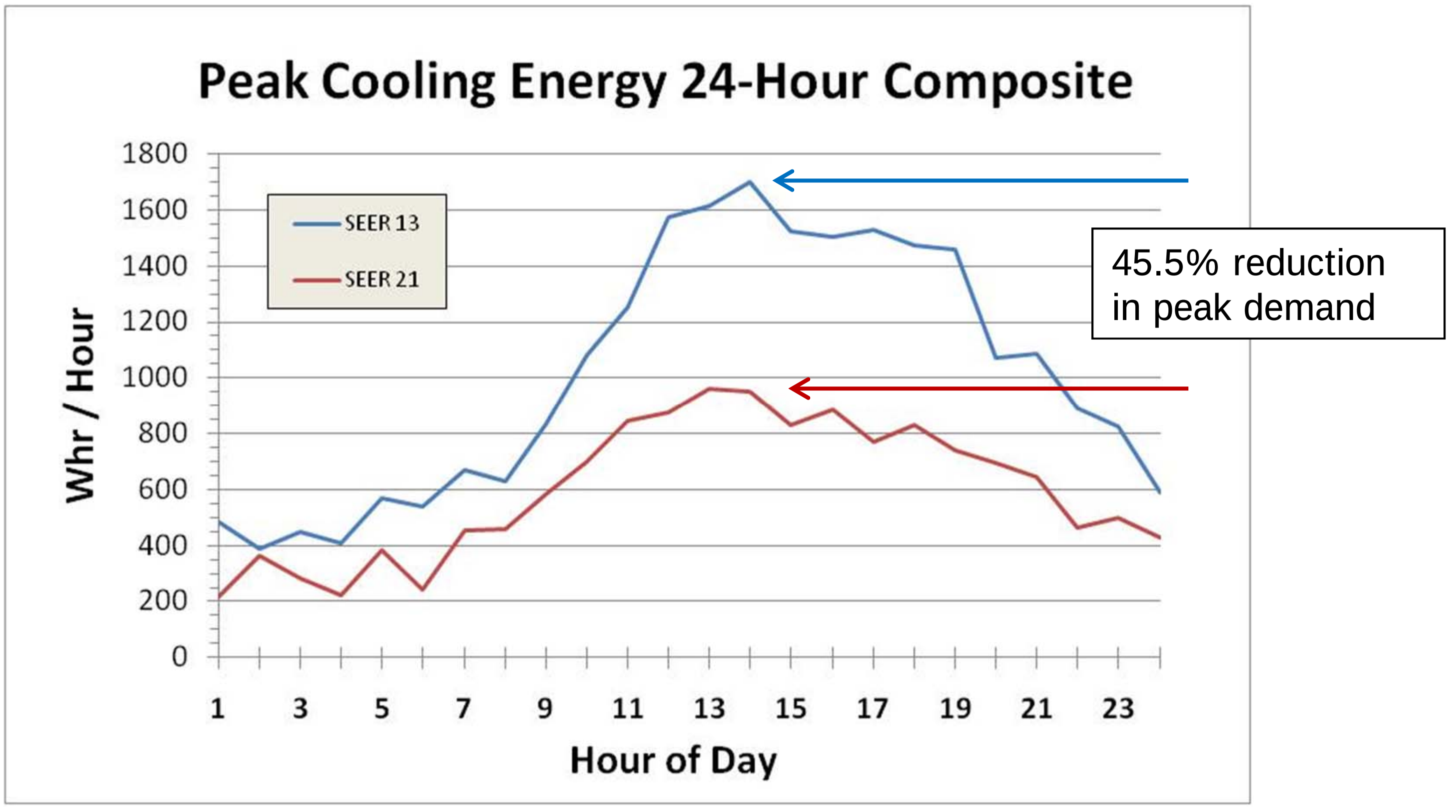
Cooling peak demand – regression analysis

Least-squares best-fit regression analysis was performed for the hours of 2 to 7 PM from a number of hot summer days using hourly data for each test configuration



Cooling peak demand – 24-hour composite

- 24-hour composite developed from two groups of equally hot summer days, one group for the SEER 13 experiments and one group for the SEER 21 experiments



Cooling peak demand analysis

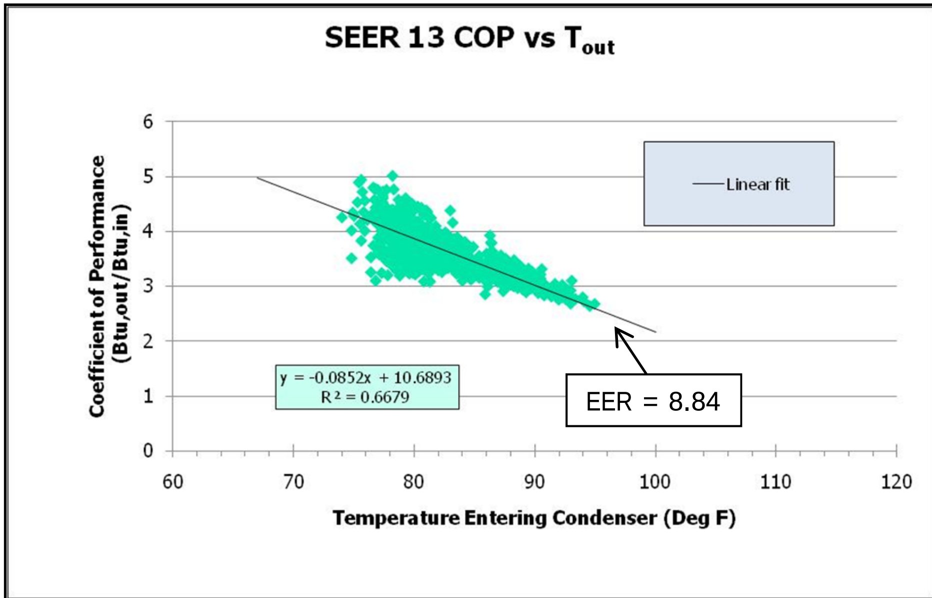
- There is good agreement between the two methods
  - 45.0% peak demand reduction from the regression method
  - 45.5% peak demand reduction from the composite method

Cooling peak demand – rated vs. measured

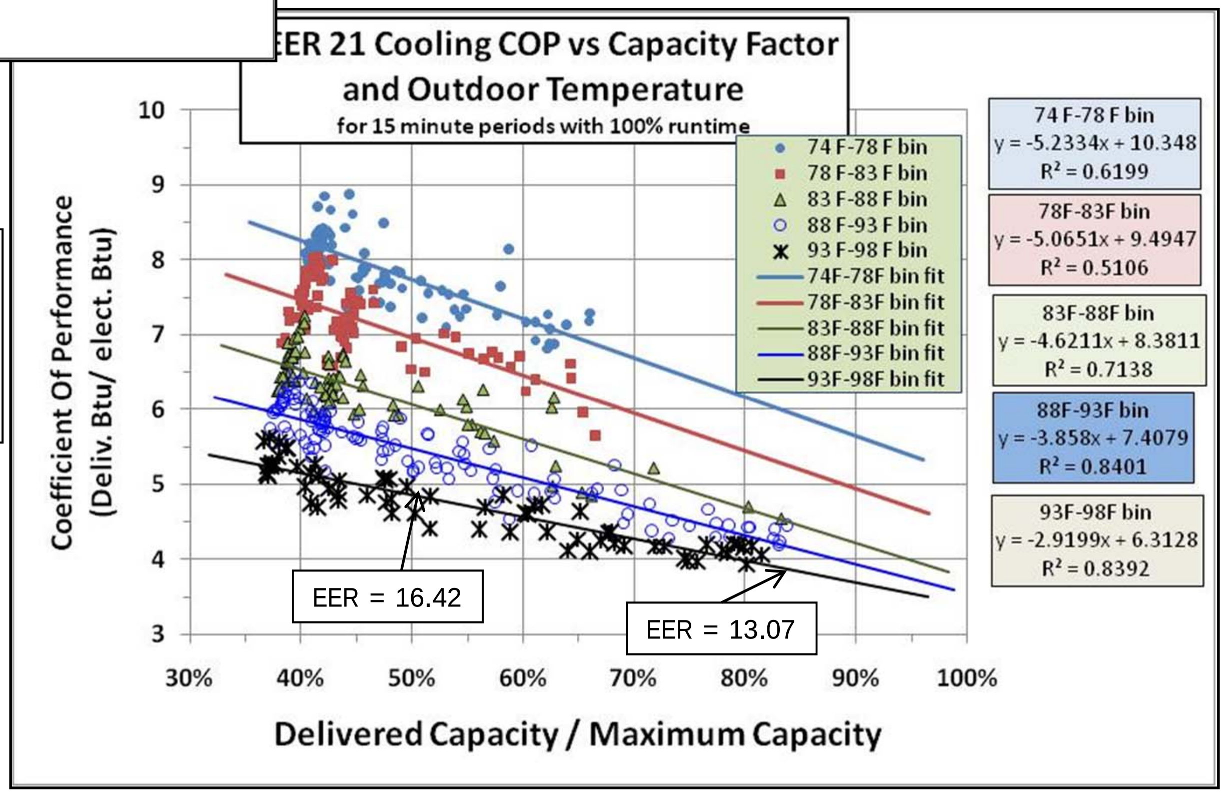
- The SEER 13 and SEER 21 units have EER ratings of 11.8 and 13.0, respectively.
  - From this, one would expect 9.2% peak demand reduction.
  - In actual fact, the SEER 21 unit produces a 45% reduction in peak demand, <u>when using the indoor duct system</u>.
    - Peak demand savings is <u>five times greater</u> than what would be expected based on EER ratings alone.
  - However, <u>when using the attic duct system</u>, the SEER 21 unit produces a 22.7% reduction in peak demand.
    - While the demand savings is reduced by a factor of two, it is still <u>2.5 times greater</u> than what would be expected based on EER ratings alone.

Cooling peak demand

- Why is the peak demand reduction produced by the SEER 21 unit so much better than expected?
  - There are two answers:
    - 1) the SEER 13 unit underperforms it EER rating by a significant margin while the SEER 21 unit matches its rating.
    - 2) the SEER 21 unit is operating at only about 51% of its nominal capacity (44% of maximum capacity) on the hottest hours of the year, because the system capacity is sized at 100% greater than the design load.

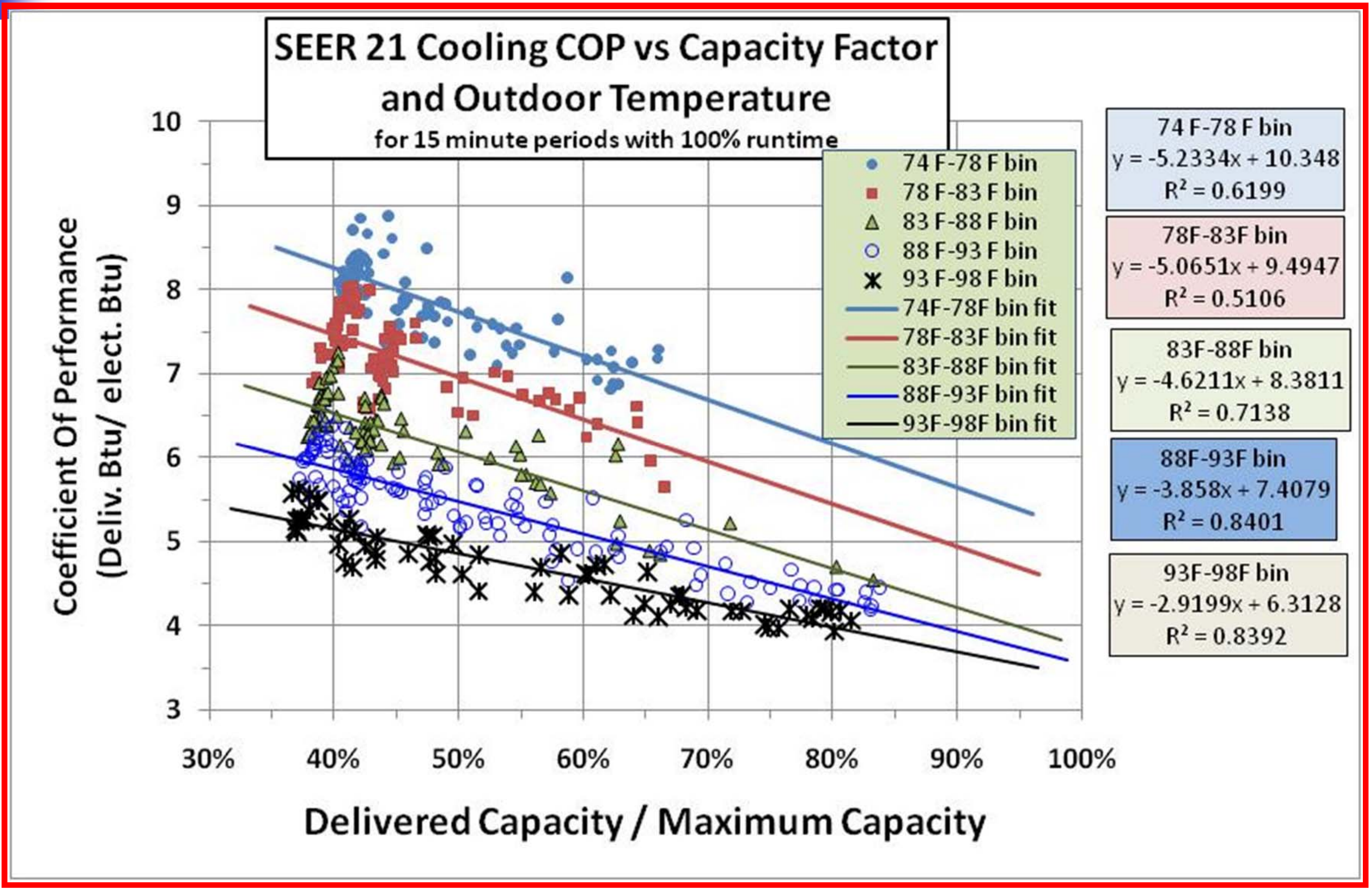


Measured SEER 13 performance falls 25% short of 11.8 EER rating

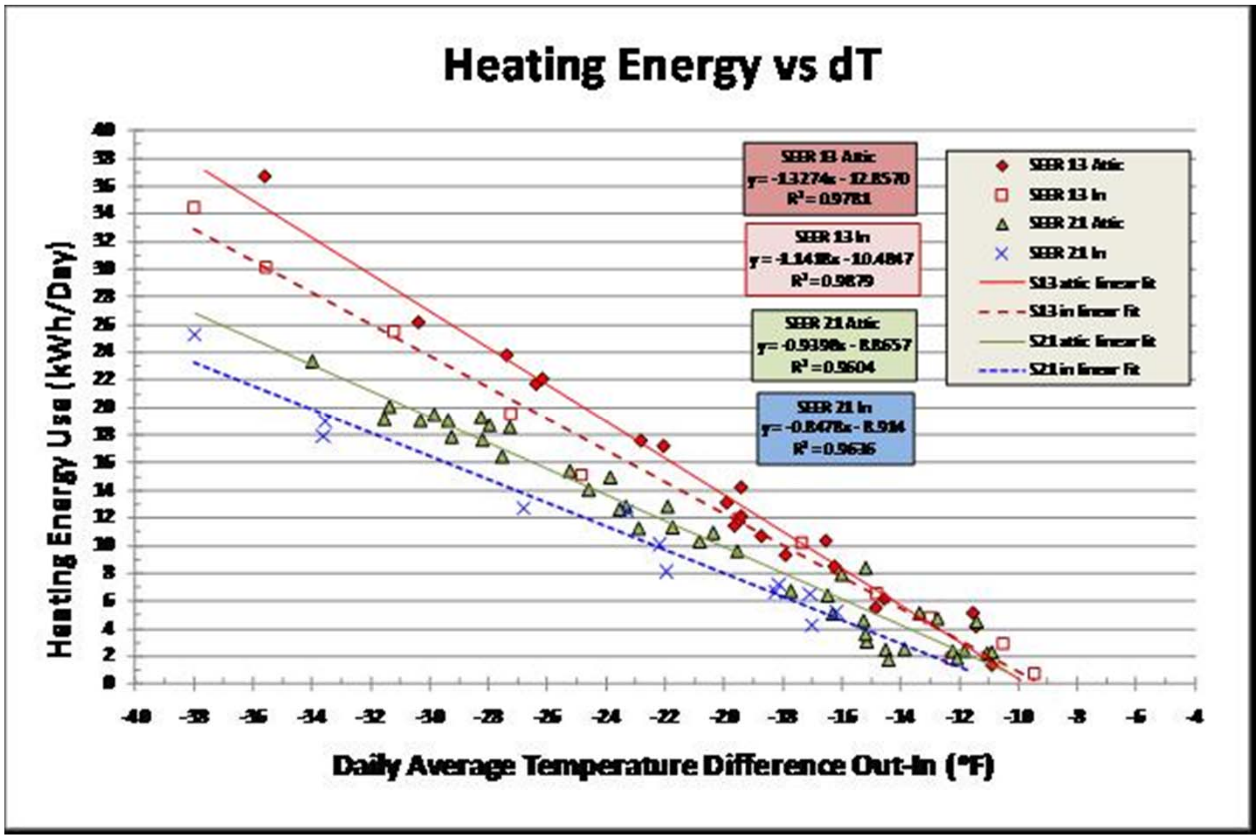


Measured SEER 21 unit EER rating matches 13.0 EER rating

Cooling peak demand



Heating energy savings

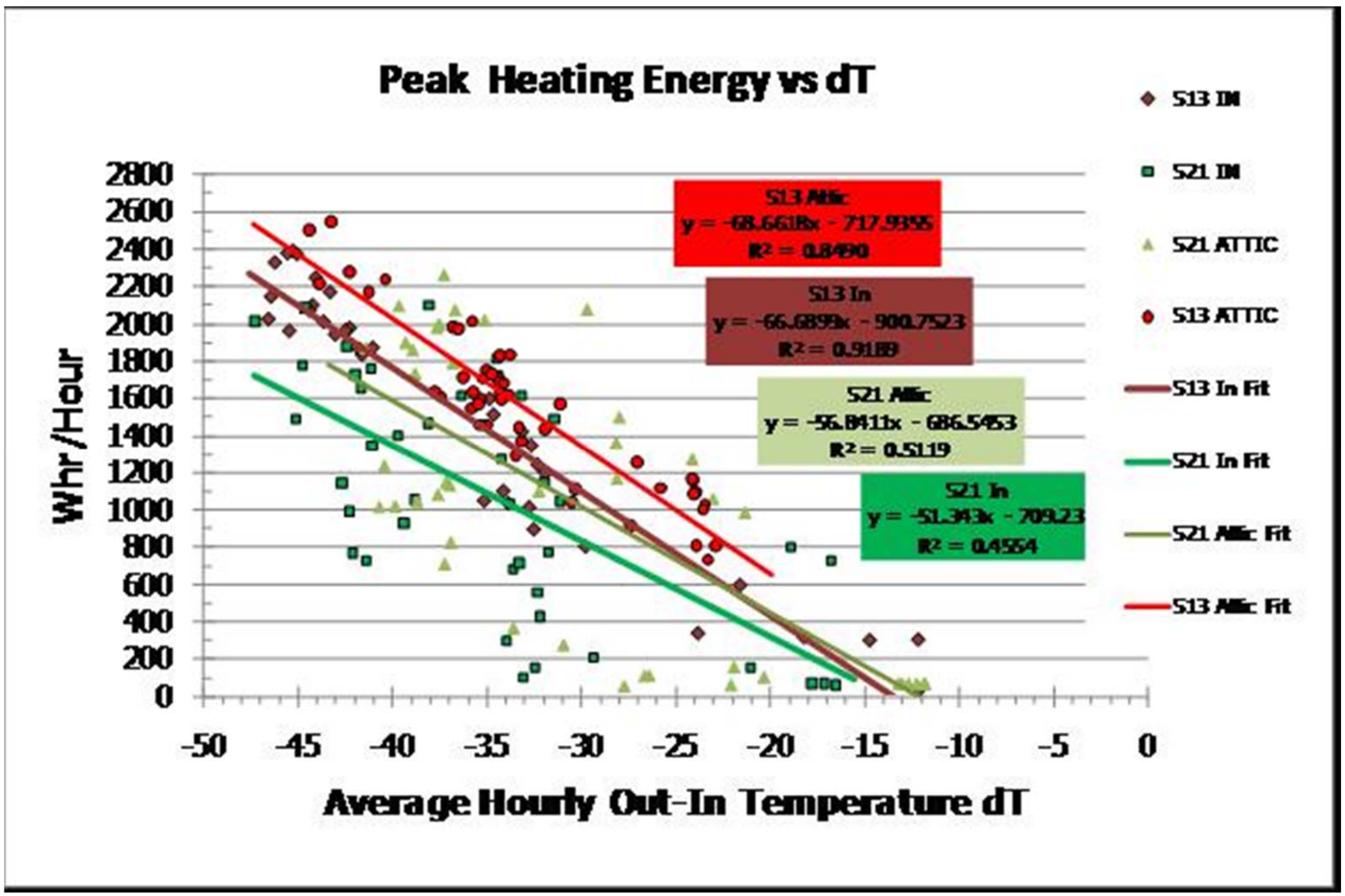


Heating energy savings

- Based on the heat pump HSPF ratings alone (9.6 and 8.0, respectively, for the SEER 21 and SEER 13 units), one would expect 16.7% heating energy savings for the SEER 21 unit compared to the SEER 13 unit. For a typical central Florida winter day (50ºF average outdoor temperature; low 40ºF and high 60ºF),
  - When using the <u>indoor duct system</u>, the measured data finds that the SEER 21 system saves 33.4% compared to the SEER 13 system
  - When using the <u>attic duct system</u>, the measured data finds that the SEER 21 system saves 27.8% compared to the SEER 13 system
  - <u>Conclusions:</u>
    - 1) the SEER 21 heat pump outperforms its rating (relative to the SEER 13 system) by a factor of 2.0 (100% outperformance relative to the SEER 13 system)
    - 2) conductive duct losses degrade system performance somewhat more for the SEER 21 (variable capacity) system than the SEER 13 system

Heating peak demand – regression analysis

Least-squares best-fit regression analysis was performed for the hours of 3 to 8 AM from a number of cold winter days using hourly data for each test configuration.



Heating peak demand savings

- Based on manufacturer's "expanded performance" COP data (3.15 and 3.01, respectively, for the SEER 21 and SEER 13 units),
  - One would expect peak demand reduction of 4.7% at 30^{o}F ambient temperature.
  - In actual fact, the SEER 21 unit performs considerably better than these COP ratings would suggest.
  - The SEER 21 system reduces peak demand, at 30^{o}F outdoor temperature, by 23.8% when using the <u>indoor ducts</u> and 21.5% when using the <u>attic ducts</u>.

Summary and Conclusions

- Seasonal cooling performance of the SEER 21 unit approximately matches expectations (relative to the SEER 13 unit).
  - 38.1% energy savings expected
  - 37.8% energy savings achieved (with indoor ducts)
  - 33.7% energy savings achieved (with attic ducts)
- Seasonal heating performance of the SEER 21 unit exceeds expected outperformance by a factor of two (100% relative outperformance).
  - 16.7% energy savings expected
  - 33.4% energy savings achieved (with indoor ducts)
  - 27.8% energy savings achieved (with attic ducts)

Summary and Conclusions (cont'd)

- Peak cooling performance of the SEER 21 unit approximately matches expectations (relative to the SEER 13 unit).
  - 9.2% peak demand savings expected
  - 45.0% peak demand savings achieved (with indoor ducts)
  - 22.7% peak demand savings achieved (with attic ducts)
- Peak heating performance of the SEER 21 unit exceeds expected outperformance by a factor of five (100% relative outperformance).
  - 4.7% peak demand savings expected
  - 23.8% peak demand savings achieved (with indoor ducts)
  - 21.5% peak demand savings achieved (with attic ducts)

Summary and Conclusions (cont'd)

- Conductive losses from attic ductwork disproportionately degrades the performance of the SEER 21 unit versus the SEER 13 unit, because of extended system run times.
- Seasonal cooling impact
  - The SEER 21 unit has about 92% greater runtime.
  - Placing the ducts indoors saves 16.8% for the SEER 21 unit
  - Placing the ducts indoors saves 11.2% for the SEER 13 unit
- Peak demand cooling impact
  - Placing the ducts indoors saves 38.8% for the SEER 21 unit
  - Placing the ducts indoors saves 14.0% for the SEER 13 unit
- Duct location conclusion
  - Locating ducts indoors is important for cooling impacts, especially for peak demand impacts.

Phase 2: assessment of the impacts of return and supply duct leaks

- Duct leaks are being introduced to both heat pump systems, for only the attic duct system.
  - 8% return leak; 50% from outdoors and 50% from the attic
    - Conditional* monitoring of return leak T/RH/cfm
  - 8% supply leak; 100% being delivered to the attic
    - Conditional* monitoring of supply leak cfm

* Conditional means recording data only when the AHU fan is operating.

Phase 2 (cont'd)

- Seasonal energy and peak demand impacts of various duct leak configurations
  - Three duct leak configurations for each system
    - 8% RL & 0% SL
    - 0% RL & 8% SL
    - 8% RL & 8% SL
  - For <u>cooling</u> with SEER 13, SEER 21, and SEER 21 with RH control
  - For <u>heating</u> with the SEER 13 and SEER 21 units