

# Package DX Units: Performance Optimization & Field Tests



# Background

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## Unitary equipment is ubiquitous.

- 60% of US commercial space is cooled with RTUs (DOE)
- 54% of commercial building cooling primary energy consumption (EIA)
- Total annual installations over 300,000 units
- Estimated 1.6 million legacy units operating at low efficiency levels
  - 100,000 units at DoD facilities / 20,000 buildings
  - 100,000 units at USPS facilities / 30,000 buildings
  - 500,000 units at 65,000 “big box” retail stores

RTU – Rooftop packaged air-conditioner Unit  
DOE – U.S. Department of Energy  
EIA – Energy Information Administration  
USPS – United States Postal Service



ROOFTOP



PORTABLE



PAD MOUNT



SPLIT SYSTEM

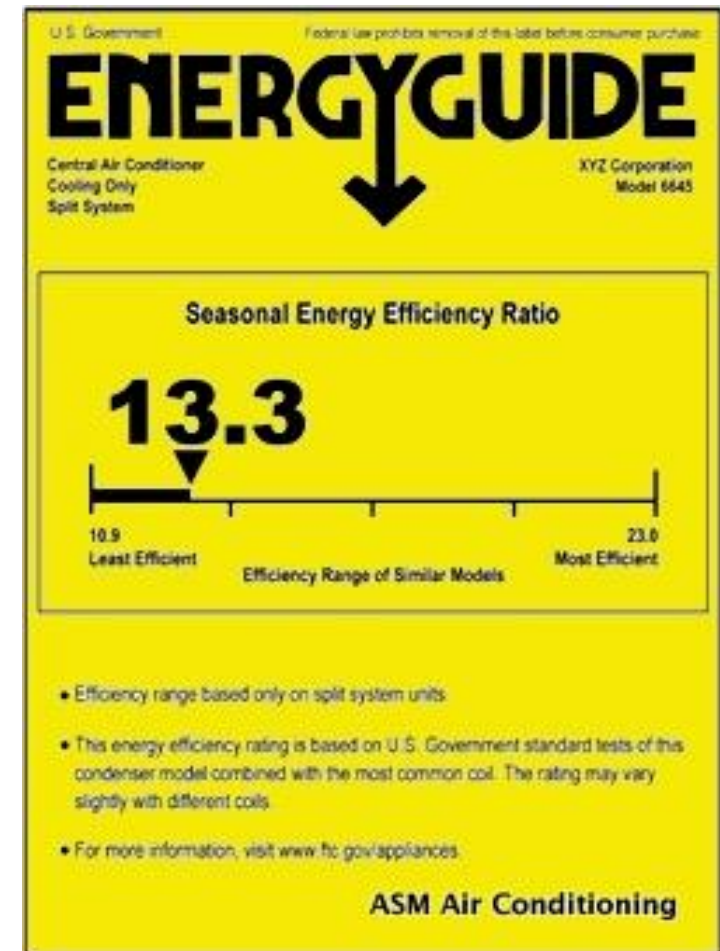
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# Performance Ratings

*“ How much cooling you get for the electricity it uses ”*

Btuh per Watt (MBH per kW)

- **EER** – Energy Efficiency Ratio  
Full Load @95F Ambient
- **IEER** – Integrated Energy Efficiency Ratio  
Weighted Full Load & Part Load @95, 81.5, 68, and 65F
- **SEER** – Seasonal EER  
Part Load @82F Ambient x 0.875  
Cyclic Performance Load Factor
- **IPLV** – Integrated Part-load Value  
Legacy rating (no longer standard)



# Drivers

## 1. Energy saving goals continue to rise

- **IEER** - Integrated Energy Efficiency Ratio 10.0 to 13.0, **EER** – Energy Efficiency Ratio 9.7 to 11.7
- Upcoming DOE 10% and 30% increases in efficiency minimums
- Single-zone VAV and DDC requirements of Energy Standard 90.1-2013 and Green Standard 189.1-2014

## 2. Dehumidification needs are increasing

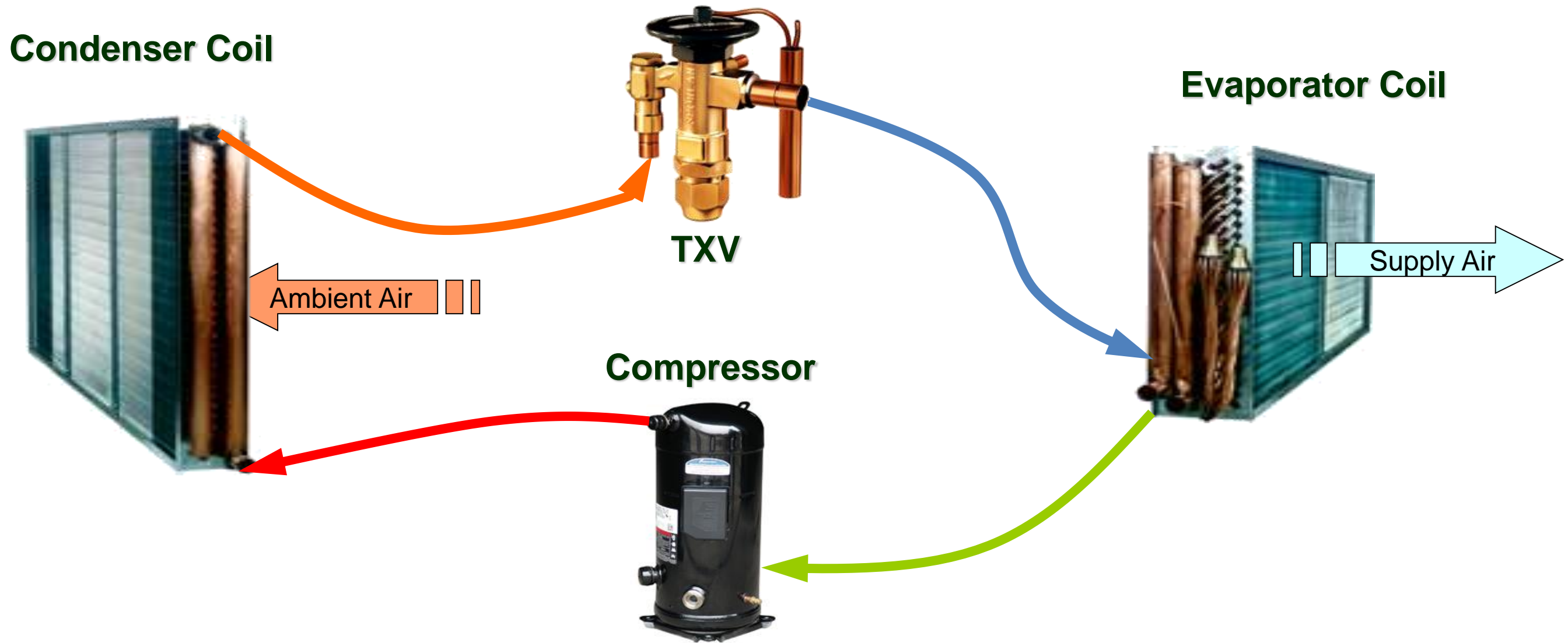
- Reduced sensible loads means lower SHR
  - Lower lighting Watts / sqft
  - Higher insulation R-values
  - Heat reflective / low-e glass
  - *often addressed with energy intensive reheat*
- Part-load requirements of IAQ Standard 62.1-2013 s.5.9 (< 65%rh)

*often “solved”  
with energy  
intensive  
reheat*



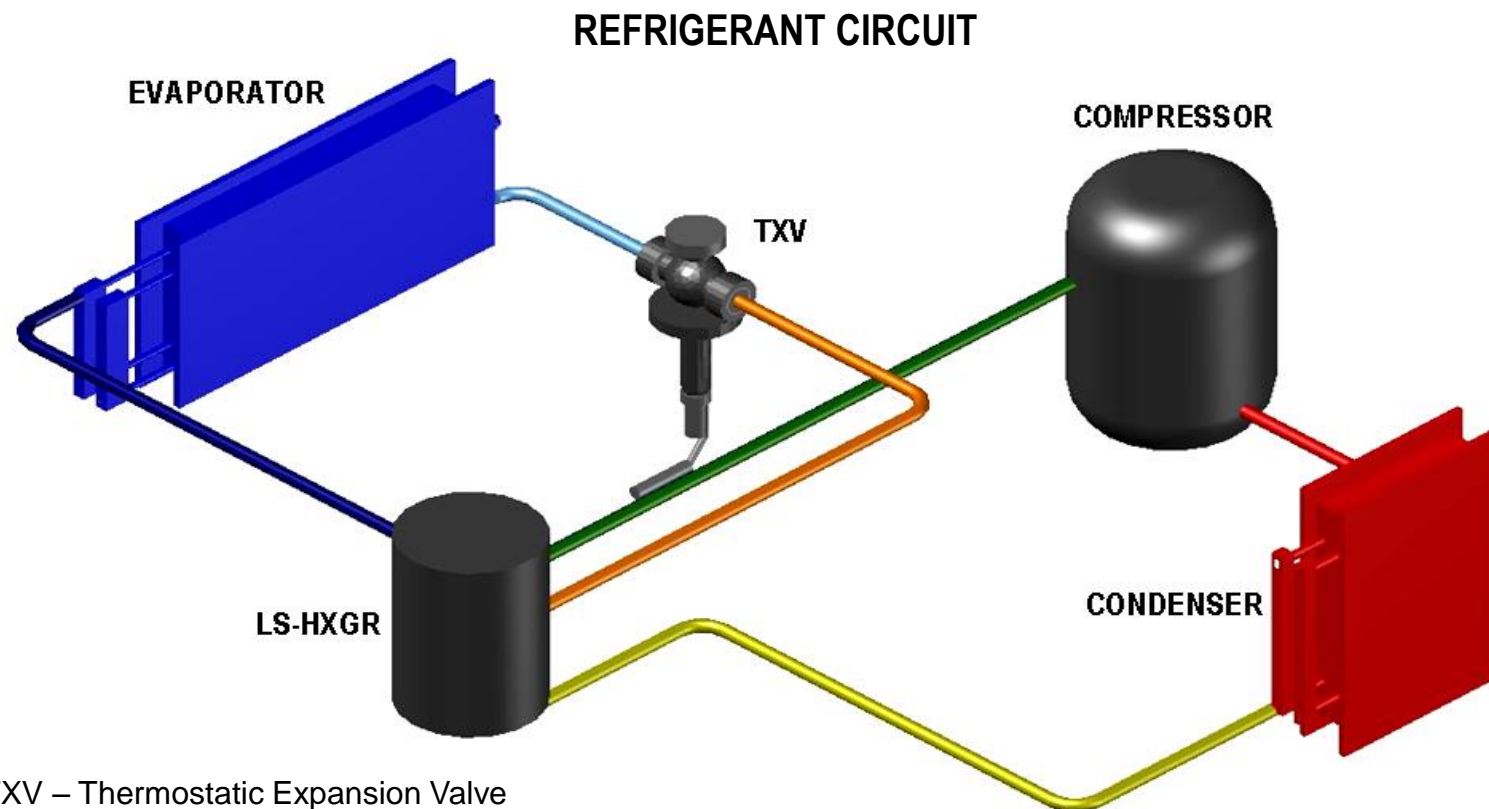
# Basic DX Cycle

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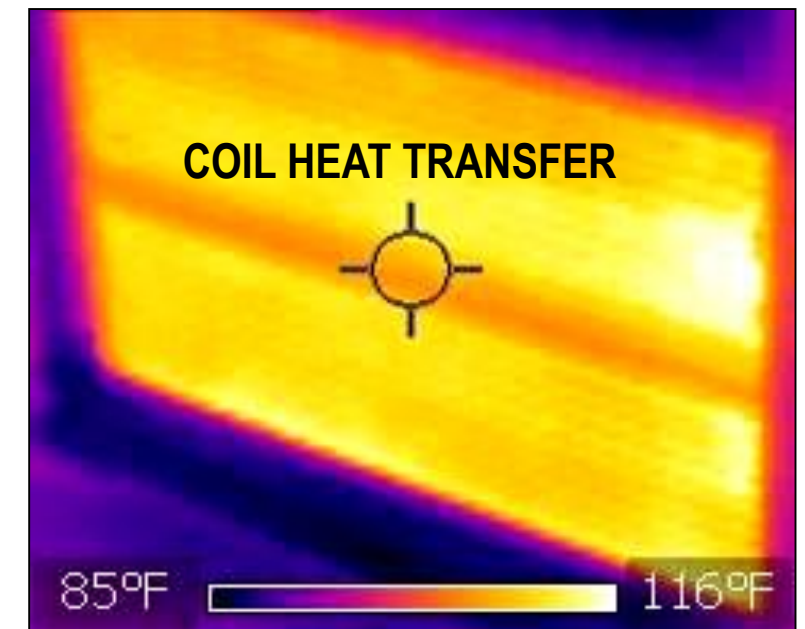


# Modified DX Cycle

**Revises the traditional refrigeration cycle at a fundamental level.**  
Improvement of evaporator refrigerant / two-phase heat transfer.  
Increased suction density improves compressor volumetric efficiency.  
**Variable sensible heat ratio optimizes airside performance.**



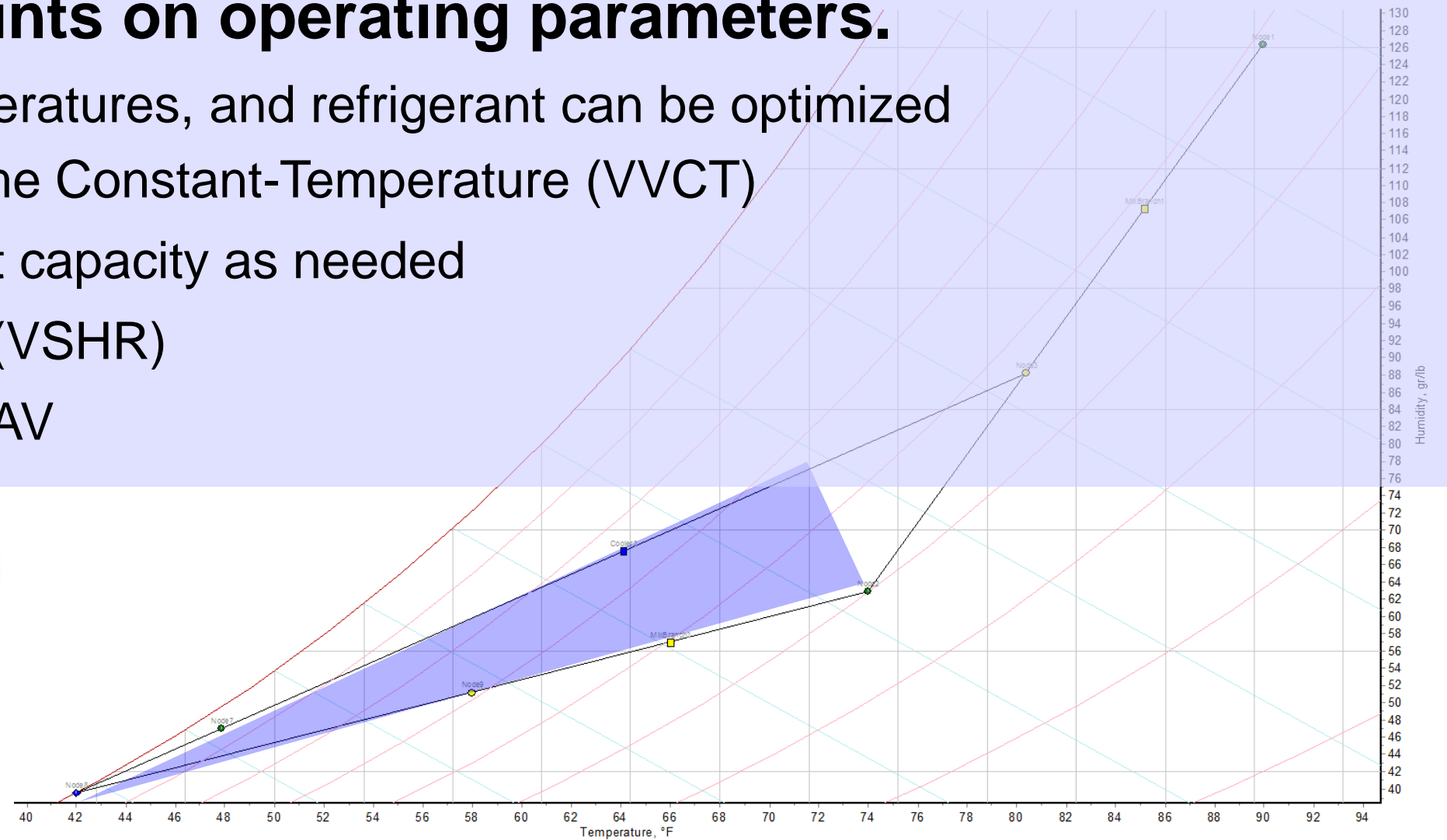
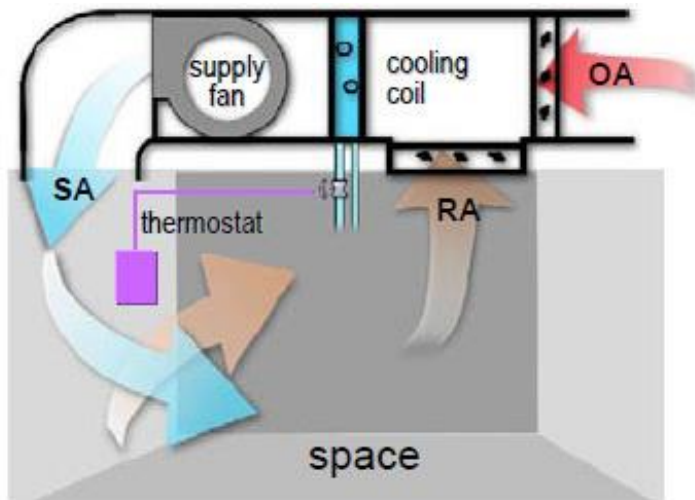
TXV – Thermostatic Expansion Valve



# Significance of DX Modification

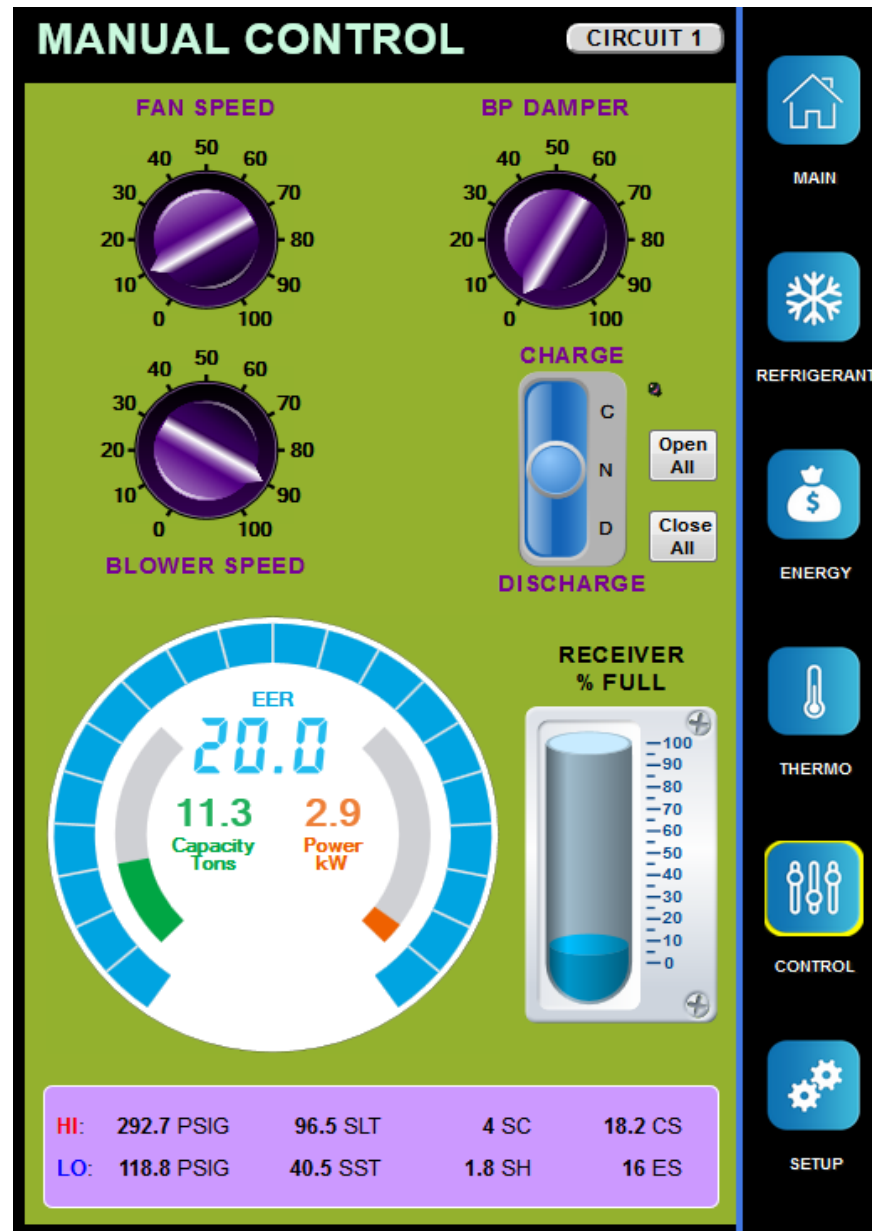
## Releases constraints on operating parameters.

1. Airflows, temperatures, and refrigerant can be optimized
2. Variable-Volume Constant-Temperature (VVCT)
3. Increase latent capacity as needed
4. Variable SHR (VSHR)
5. Single-Zone VAV



# EER Optimizer

<http://www.EERoptimizer.com/>

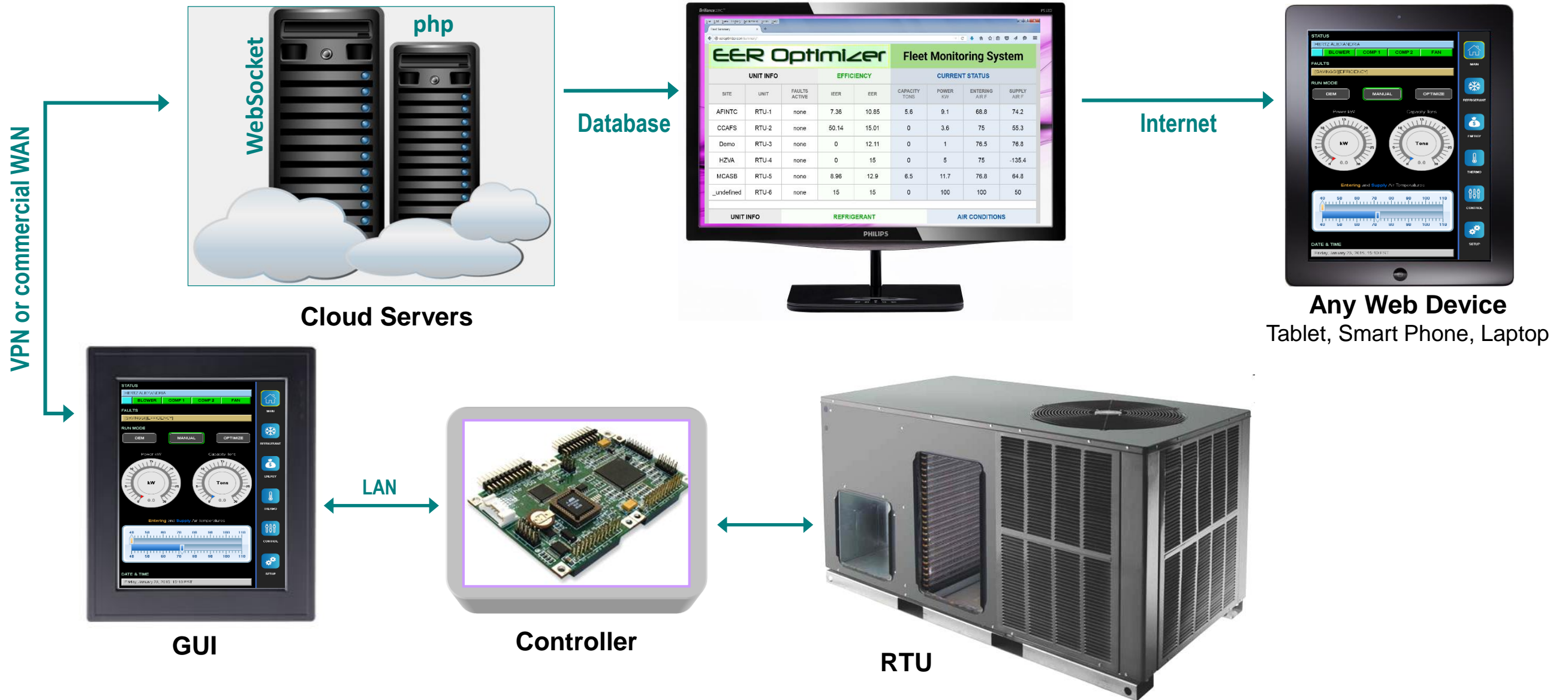


- Controls all operating parameters
- Target is maximum EER while precisely meeting sensible and latent loads
- Continuous performance tuning
  - Supply Blower Speed
  - Condenser Fan Speed
  - Refrigerant Charge
  - Supply Air Temperature
  - Coil Temperature
  - Economizer Damper
- Continuous web reporting
  - EER, IEER, Tons Capacity
  - Faults, such as low refrigerant or fouled coil
  - Diagnostics detects issues before problematic



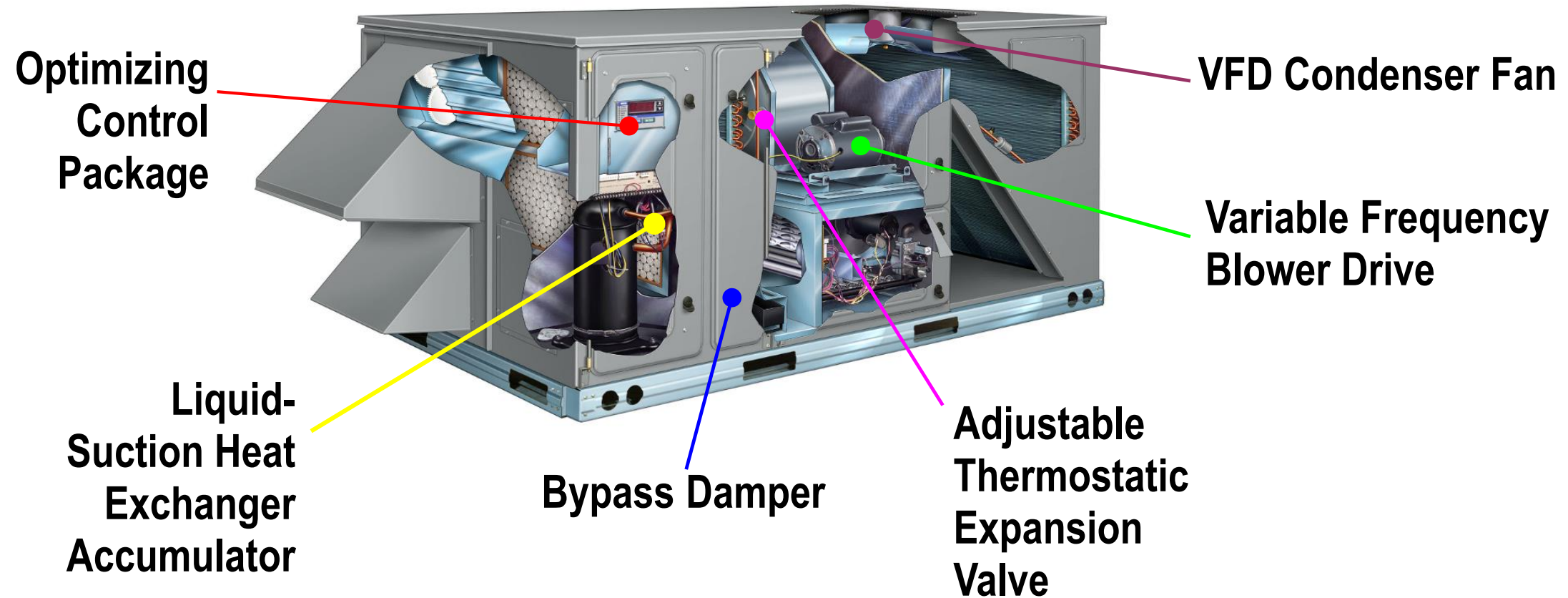
# Data Connectivity

# EER Optimizer



# Supercharged Package Unit

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**CLIMASTAT™**

**EER Optimizer**

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# Installation

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# Field Tests

**Site 1: Retail Store**  
**Beaufort, South Carolina**  
2627 cooling degree-days  
Climate zone 3A Warm-Humid



# Field Tests

South Carolina



Fresh air intake

20-ton dual-circuit  
R-22 package DX unit  
Gas heat  
Manufactured 2/2003  
Found in "poor" condition



Gas heating section

Compressors



# Field Tests

**Site 2: Classroom Building**  
**Mojave, California**  
**Elevation 2500 feet**

Climate zone 3B Hot-Dry  
3225 cooling degree-days  
2597 heating degree-days



# Field Tests

California



**12½-ton dual-circuit  
R410a package DX unit  
Heat Pump  
Installed 2010**



# Field Tests

## Site 3: Electronics Development Laboratory

Cape Canaveral, Florida

3633 cooling degree-days, Climate zone 2A Hot-Humid





# Field Tests

8½-ton dual-circuit  
R410a package DX unit  
9 kW-heat  
Installed 1/2012



# Performance Analysis

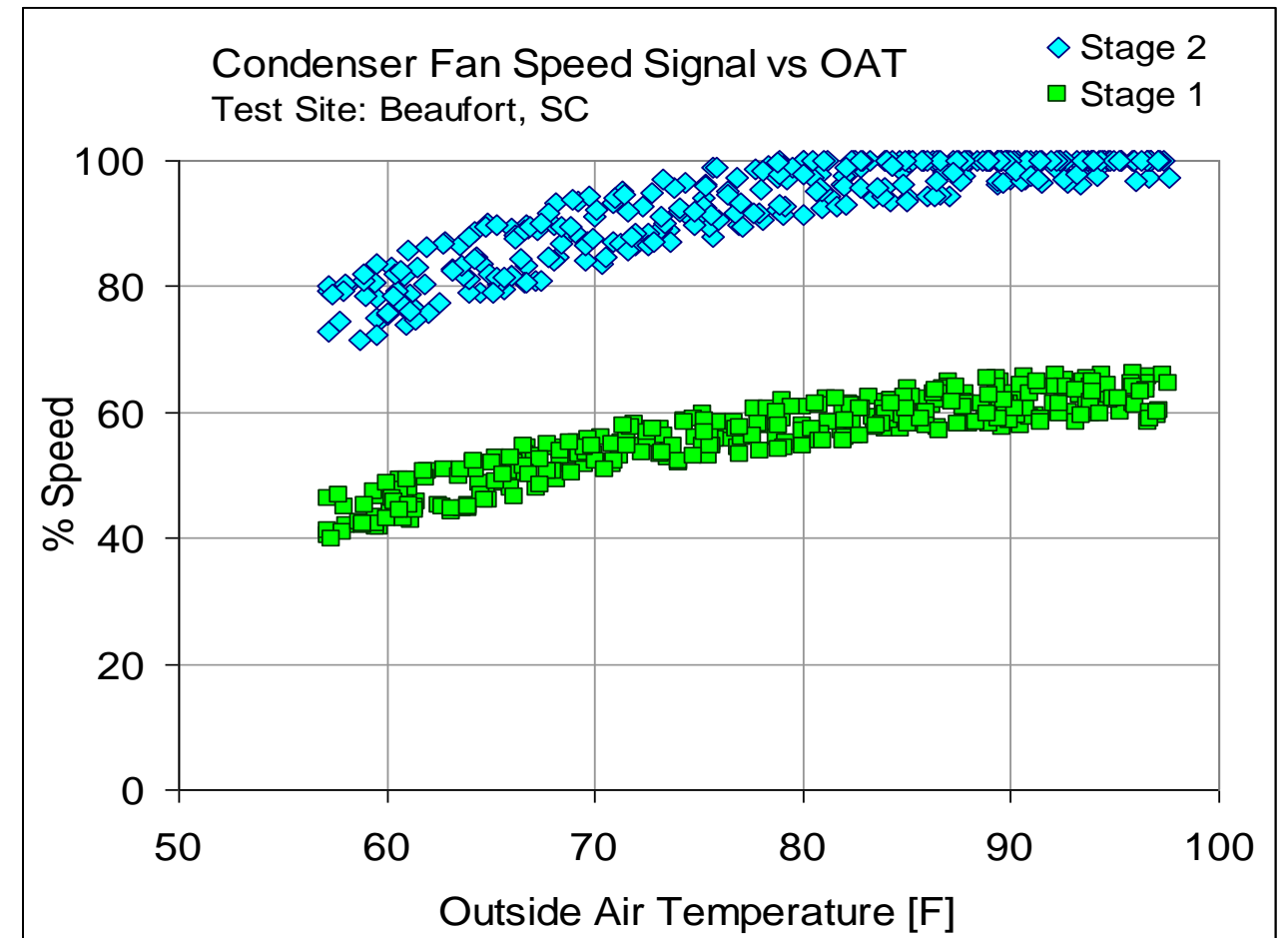
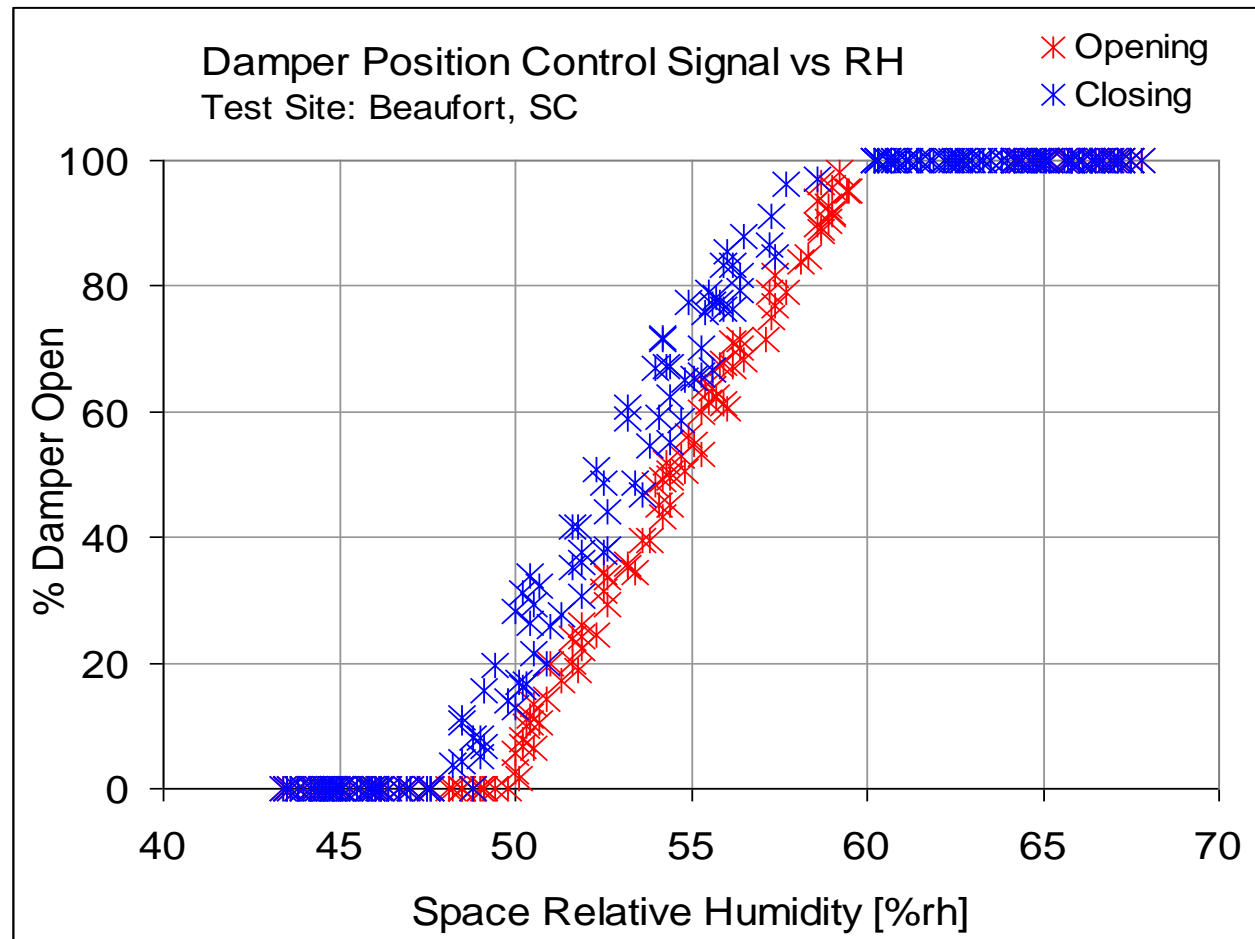
Performance measurement  
data available live via web links  
<http://www.tinyurl.com/CCAFS-EDL>



## 45 Sensors on each RTU

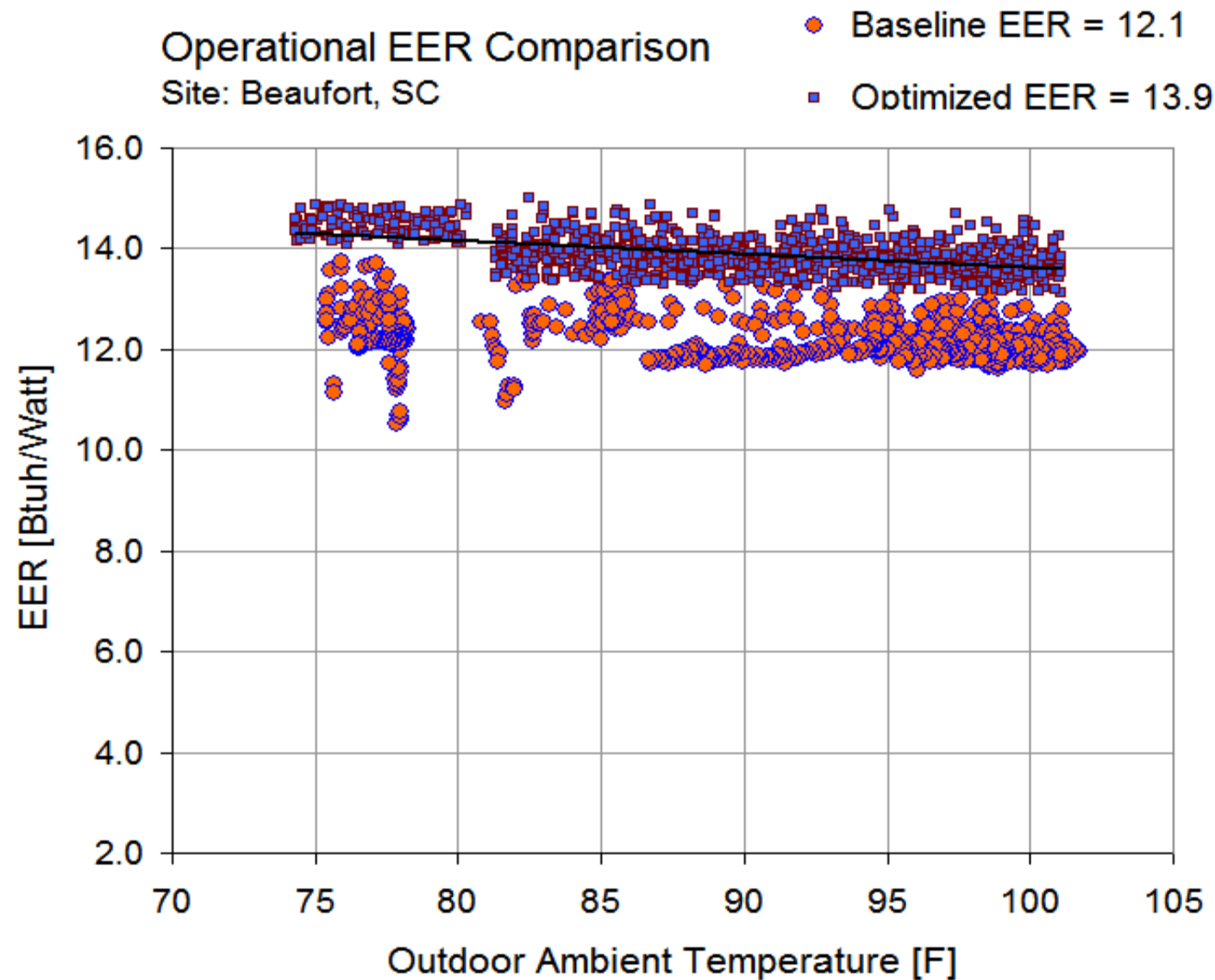
- Compressor Amps (2)
- Fan and Blower Power
- Total Unit Power
- Refrigerant Pressures (4)
- Refrigerant Temperatures (12)
- Refrigerant Flows (2)
- Air Temperatures
  - at thermostat, return, outdoor, coil, entering & leaving coil, unit discharge
- Air Humidity
  - coil entering, unit discharge, at thermostat, outdoor
- Space and Ambient CO<sub>2</sub> level
- Control point status

# Field Test Results



The optimizing controller tuned the RTU's operation according to varying conditions as expected. Shown is control of damper position and condenser fan speed with change in humidity and temperature.

# Field Test Results



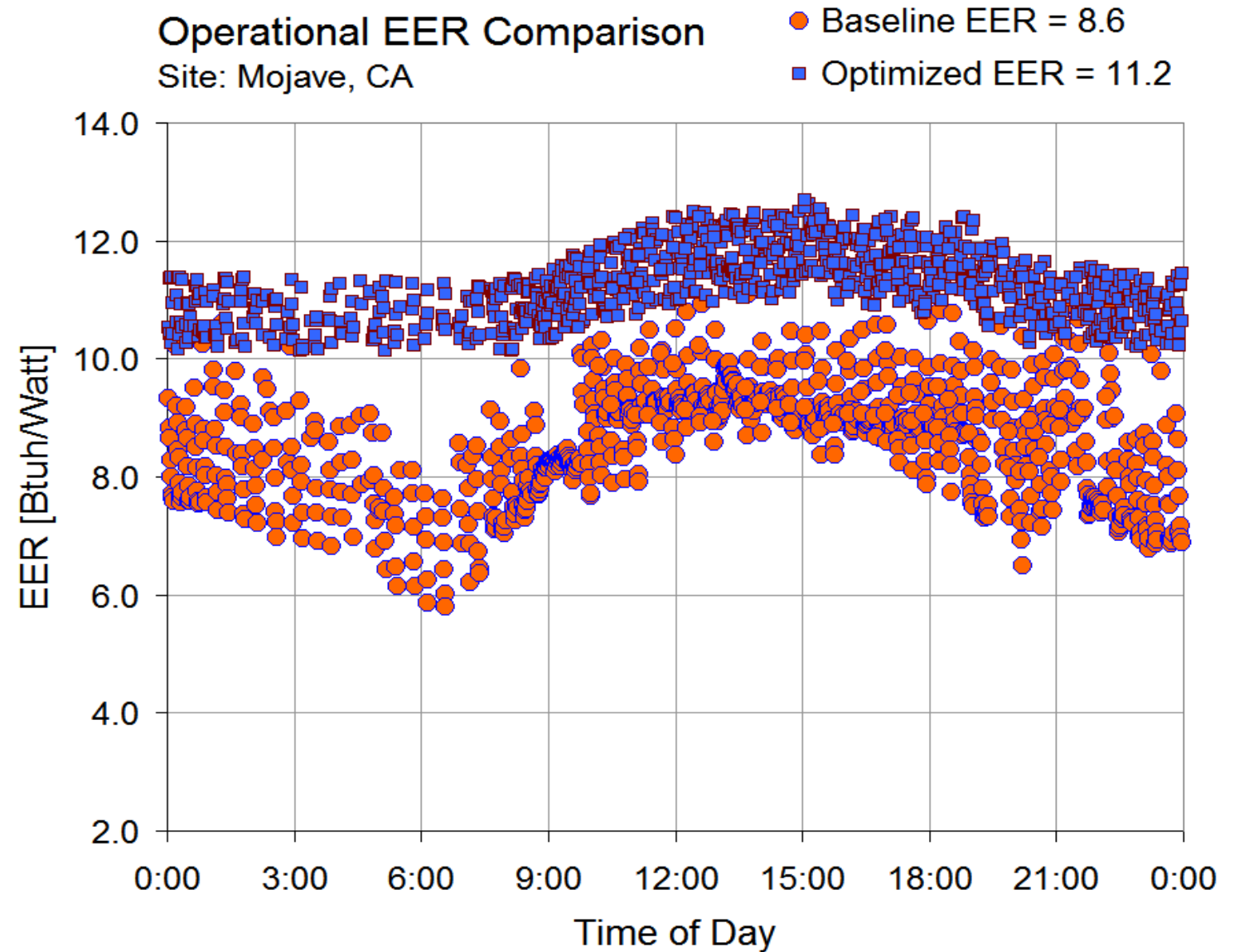
## Beaufort SC Field Test Preliminary Result

- 15% IEER increase from 12.4 to 14.3
- 15% operational EER increase
- Elimination of startup efficiency loss
- Reduced compressor cycling
- 27% less energy kWh/CDD consumed

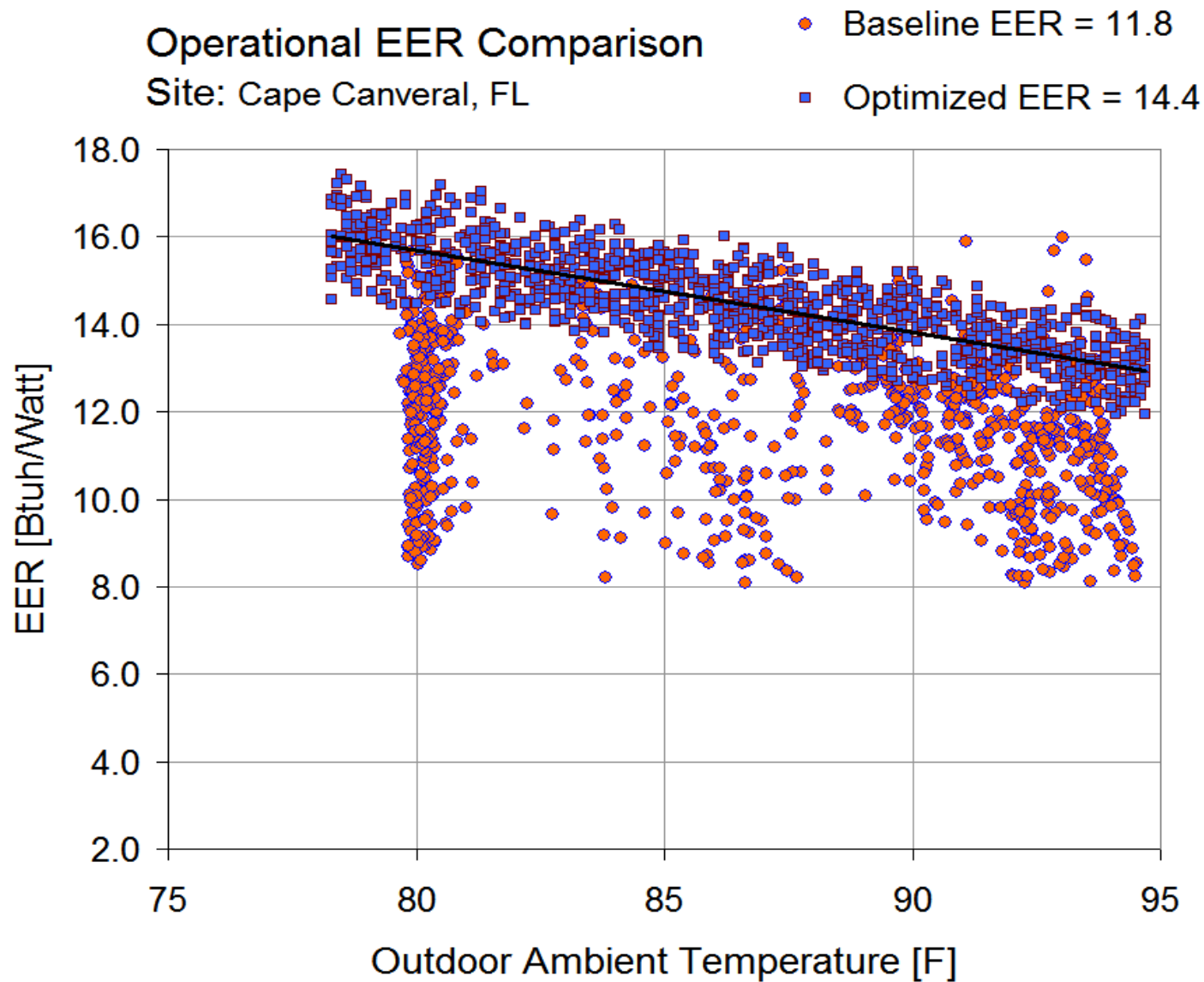
# Field Test Results

## Mojave CA Field Test Preliminary Result

- 37% IEER increase from 7.8 to 10.6
- 31% operational EER increase
- Elimination of startup efficiency loss
- Reduced variation with temperature
- 40% less energy kWh/CDD consumed



# Field Test Results



## Cape Canaveral FL Preliminary Result

- 22% IEER increase from 13.4 to 16.4
- 23% operational EER increase
- Elimination of startup efficiency loss
- Reduced compressor cycling
- 37% less energy kWh/CDD consumed
  - Not counting reheat energy savings
- Space humidity between 45 ~ 50%rh

# Results Summary

Data Summary	Operational IEER		Average EER		Efficiency Gain	
	Baseline	Optimized	Baseline	Optimized	IEER	EER
<b>Beaufort, SC</b>	12.4	14.3	12.1	13.9	15%	15%
<b>Mojave, CA</b>	7.8	10.6	8.6	11.3	37%	31%
<b>Cape Canaveral, FL</b>	13.4	16.4	11.8	14.5	22%	22%



**Beaufort, SC**



**Mojave, CA**



**Cape Canaveral, FL**

# Conclusion

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- Web connection from anywhere
- Fault detection & diagnostics
- 15 to 37% operational IEER increase
- Elimination of startup efficiency losses
- 27% to 40% less energy kWh/CDD
- Improved dehumidification
- Cooler compressor operation
- Reduced compressor cycling

