Advanced Efficiency Products

Energy Efficiency Retrofit Technologies for RTUs

POTENTIAL RTU RETROFITS

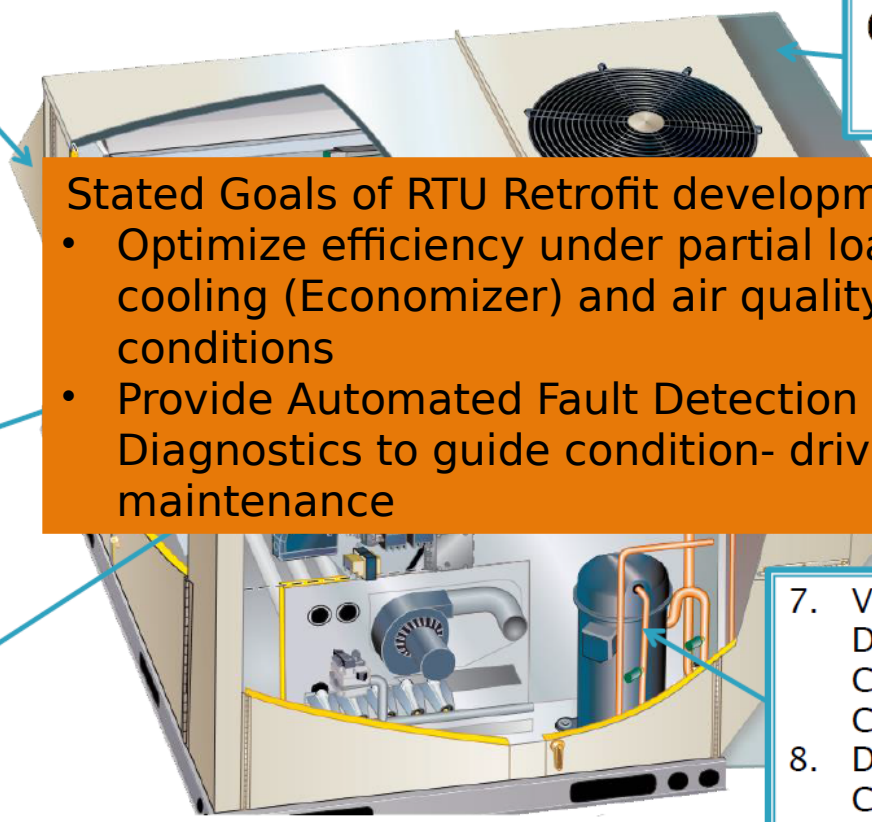
Retrofits proven to increase the energy efficiency and reduce operating costs

1. Advanced Economizer Controls
2. Demand Control Ventilation

3. Efficient Fan Motors
4. Variable Speed Drive for Fan and Controller

5. Fault detection and diagnostics

6. Evaporative Pre-coolers



7. Variable Speed Drive for Compressor and Controller
8. Downsize Compressor

Stated Goals of RTU Retrofit development (DOE):

- Optimize efficiency under partial load (VFD), free cooling (Economizer) and air quality (DCV) conditions
- Provide Automated Fault Detection and Diagnostics to guide condition- driven maintenance

ADVANCED EFFICIENCY PRODUCTS

Distribution of energy usage in RTU

Compressors consume the vast majority (80%) of RTU electrical energy

Fan energy is 23% of total RTU energy

Compressor energy is 77% of total RTU energy

	Fan Energy[a]	Comp/Cond Fan/Controller Energy[a]		Comp/Cond Fan/Controller Average Daily Usage[a]
Non-ESM Operation	31,824 kWh (23% of total)	106,225 kWh (77% of total)	461 kWh	1,539 kWh
ESM Operation	18,489 kWh (12% of total)	131,402 kWh (88% of total)	205 kWh	1,460 kWh
	Fan is 23% of total RTU energy	Compressor is 77% of total RTU energy	256 kWh (55%) ESM Savings	79 kWh (5%) ESM Savings

Source: http://www.nrel.gov/docs/fy14osti/61072.pdf

Available Retrofit Technologies

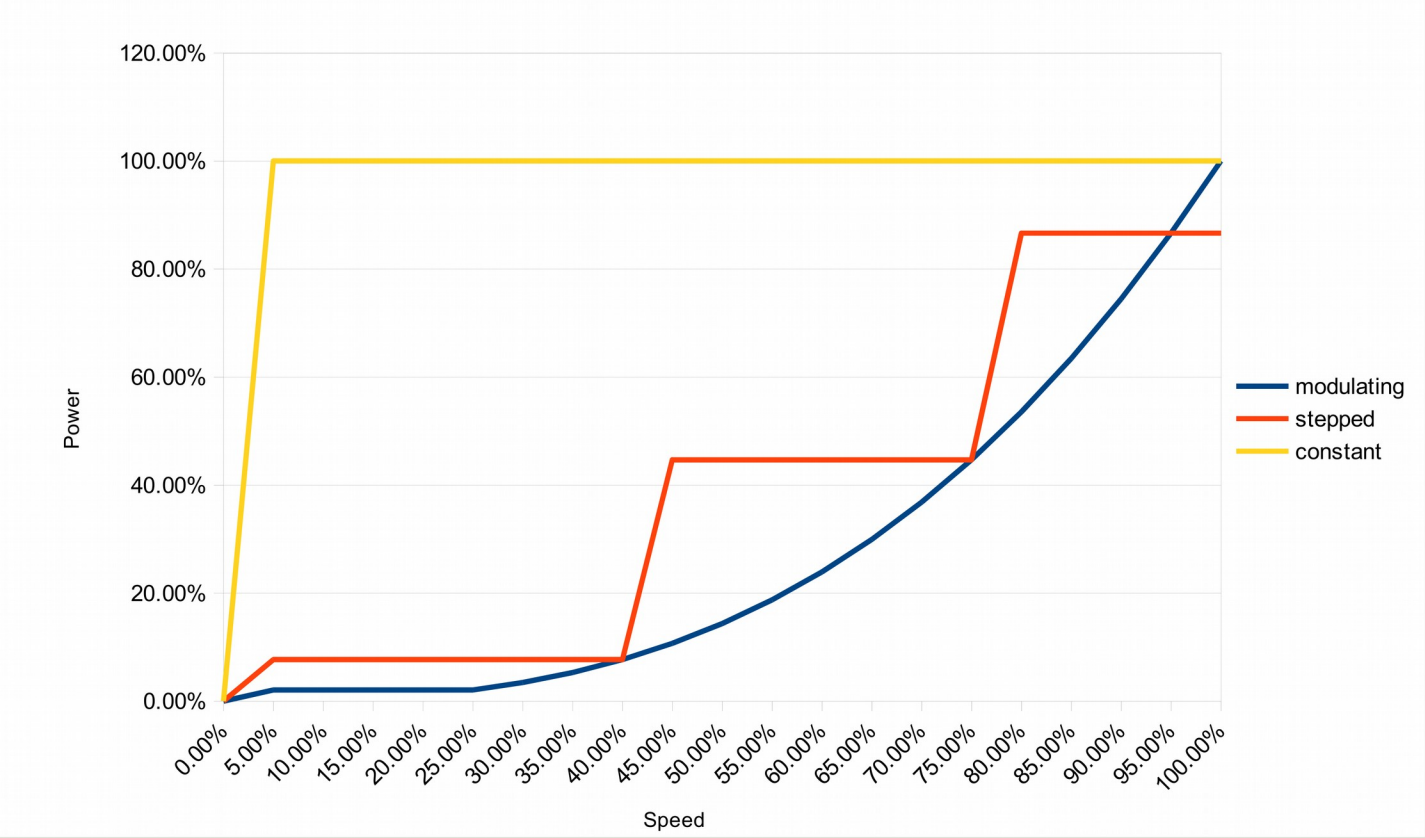
Retrofits proven to increase RTU energy efficiency and reduce operating costs

	Capacity Modulation	Variable Speed Supply Fan Control	Advanced Economizer Control	Demand Control Ventilation	Fault Detection and Diagnostics	Demand Response	Web Based BMS Control
Digi-RTU	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TWT-CATALYST	No	Yes	Yes	Yes	Yes	Yes	Yes
Enerfit	No	Yes	Yes	Yes	Yes	No	No
NexRev DrivePak ARC	No	Yes	No	No	Yes	Yes	Yes
Intellicon CAC	Yes	No	No	No	No	No	No
Pace3 by Pace Controls	Yes	No	No	No	No	No	No
Rawal APR	Yes	No	No	No	No	No	No
Encycle Swarm Logic	No	No	No	No	Yes	Yes	Yes

1. CATALYST modulates fan to three speeds only (40, 75 and 90%)
2. Rawal is hot gas bypass system only, no speed control for the compressor(s)
3. Intellicon and Pace3 provide compressor cycle management only, not incremental modulation

Comparison of VFD Operating Strategies

Reducing speed reduces power, modulating speed provides best efficiency



ADVANCED EFFICIENCY PRODUCTS

Bes-Tech Digi-RTU Controller

ADVANCED EFFICIENCY PRODUCTS

Bes-Tech: Digi-RTU Controller®

Controller that reduces both the demand (0.45 kW/ton) and the energy usage (1,500 kWh/ton/year) for Rooftop Units, Heat Pumps, and Split Systems

Heat pumps
Rooftop units
Split units

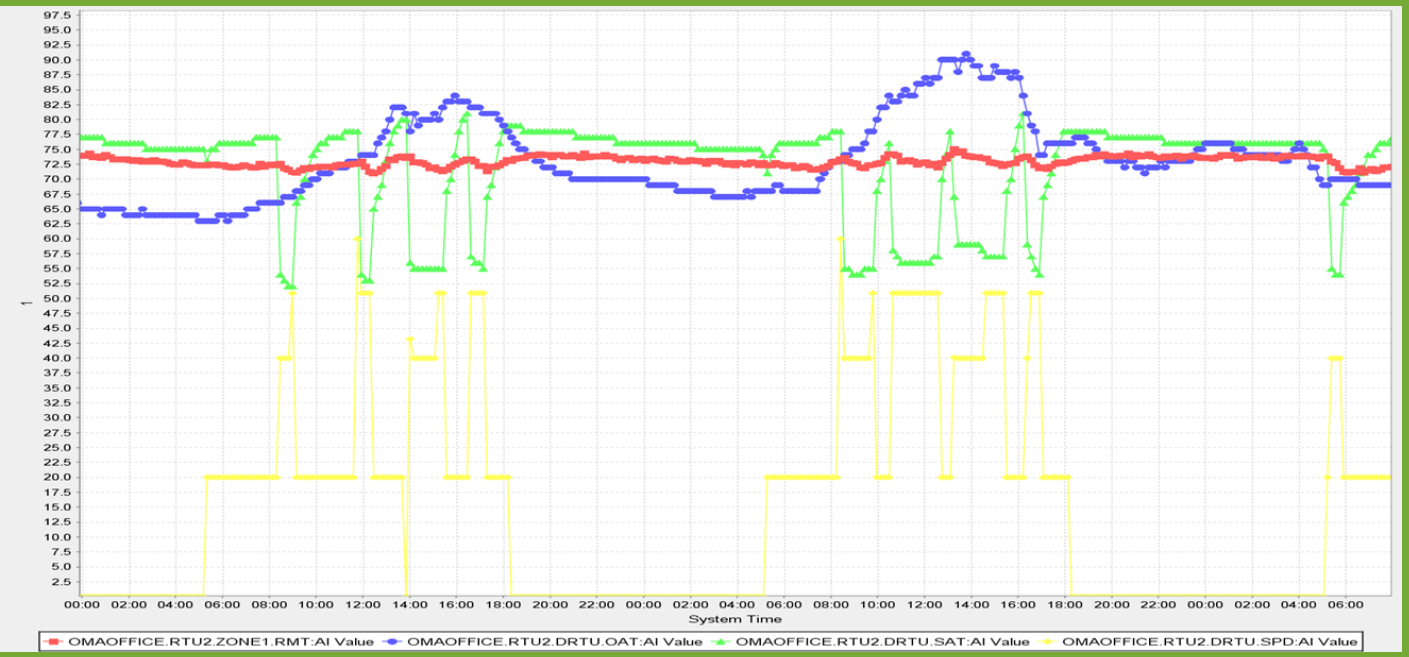


- Continuous modulation of fan and compressor with VFD (40Hz min in cooling, 45 Hz min in heating)
- Fan speed at 20 Hz when no call for heating or heating
- Economizer optimization
- DCV capability with CO_2 sensor
- Mounts inside RTU

ADVANCED EFFICIENCY PRODUCTS

How the Digi-RTU® Works

Digi-RTU® manages the compressor and fan speeds to match the capacity and space requirements



Red: Room Temp

Blue: OAT

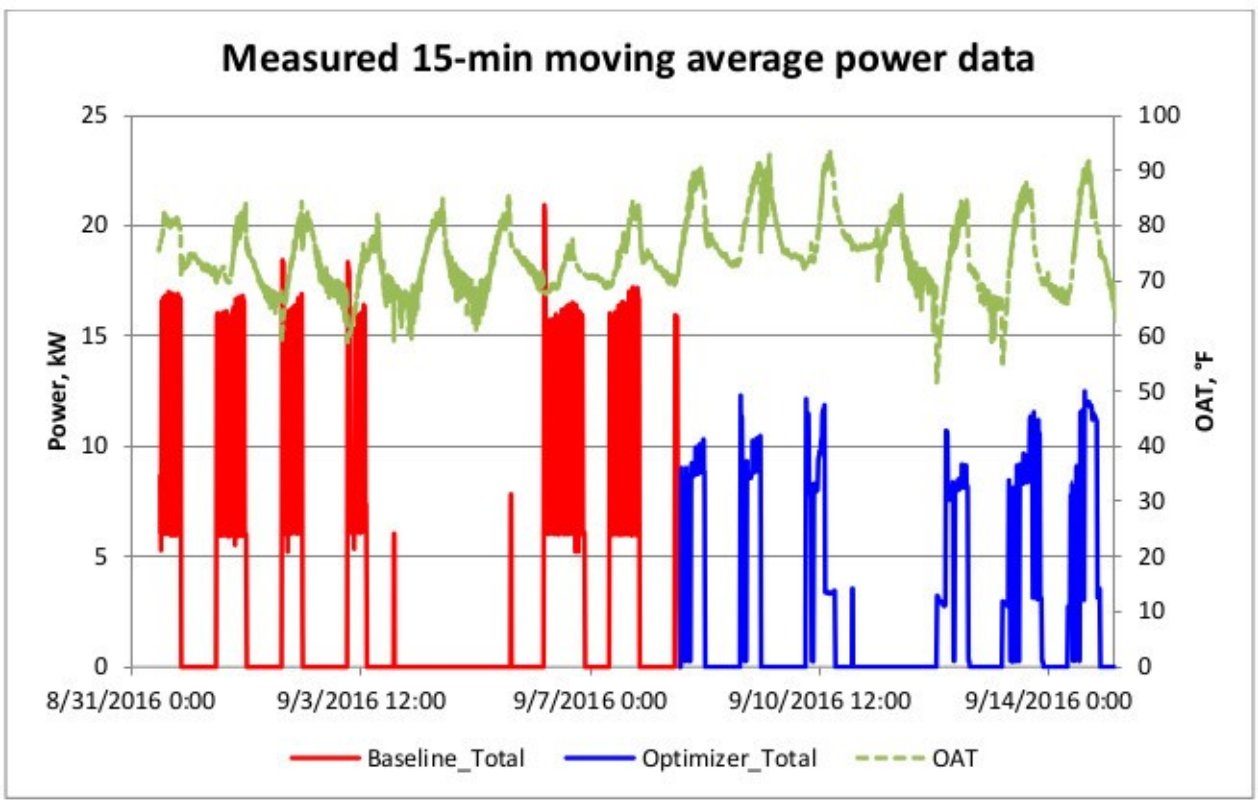
Green: Supply Air Temp

Yellow: Fan & Compressor Speed

ADVANCED EFFICIENCY PRODUCTS

Results from Digi-RTU® in Connecticut

Digi-RTU® installed in a 25 ton RTU in West Hartford



Red: Baseline Power

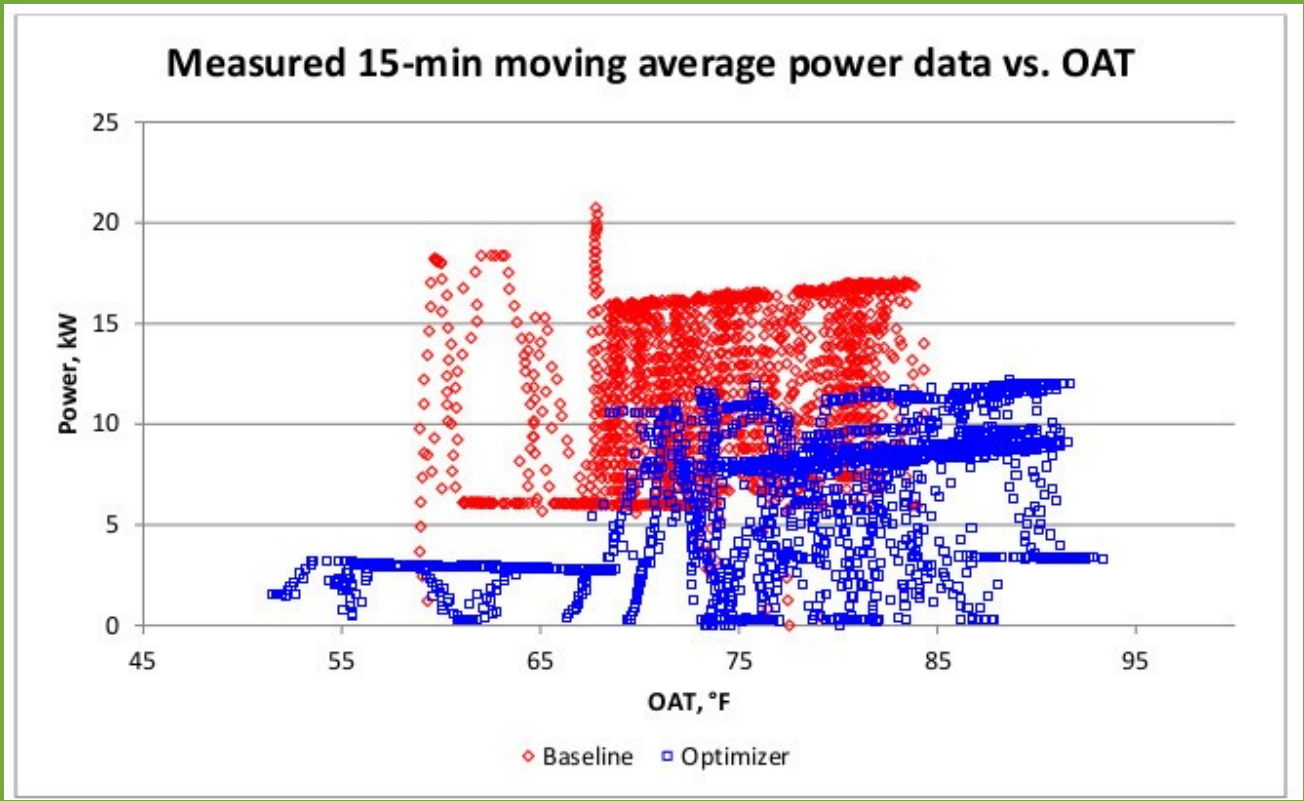
Blue: Retrofit Power

Green: OA Air Temp

ADVANCED EFFICIENCY PRODUCTS

Results from Digi-RTU® in Connecticut

Digi-RTU® installed in a 25 ton RTU in West Hartford



Red: Baseline Power

Blue: Retrofit Power

ADVANCED EFFICIENCY PRODUCTS

Transformative Wave Technologies- CATALYST

ADVANCED EFFICIENCY PRODUCTS

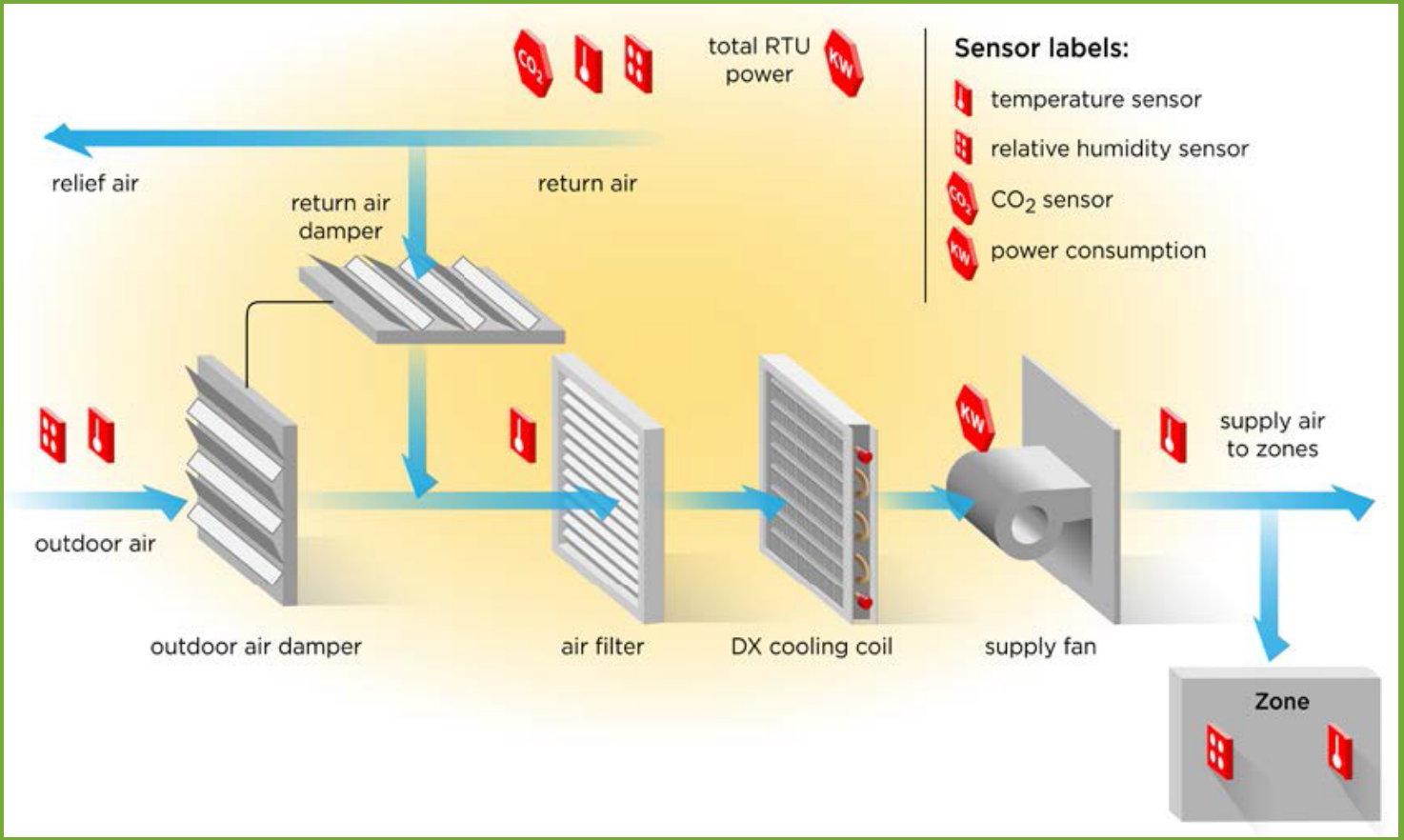
Transformative Wave: Catalyst



- Three speed fan modulation with VFD (40,75 and 90%)
- No compressor modulation
- Economizer optimization
- DCV capability with CO_2 sensor
- eIQ control system (EMCS)
- Pre-wired
- Many studies performed by DOE, NREL, Navy and others
- Energy Savings documented in ARC project as between 22-90%, with an average of 57%.

Source: http://transformativewave.com/

Catalyst Sensors



- Multiple sensors requiring significant maintenance and calibration. TWT does not field calibrate sensors nor purchase single and multi point factory calibrations “due to cost”

Source: http://www.nrel.gov/docs/fy14osti/61072.pdf

Catalyst eIQ (EMCS)



* Studied by U.S. Navy in Guam

Source: http://www.nrel.gov/docs/fy14osti/61072.pdf

Catalyst points monitored

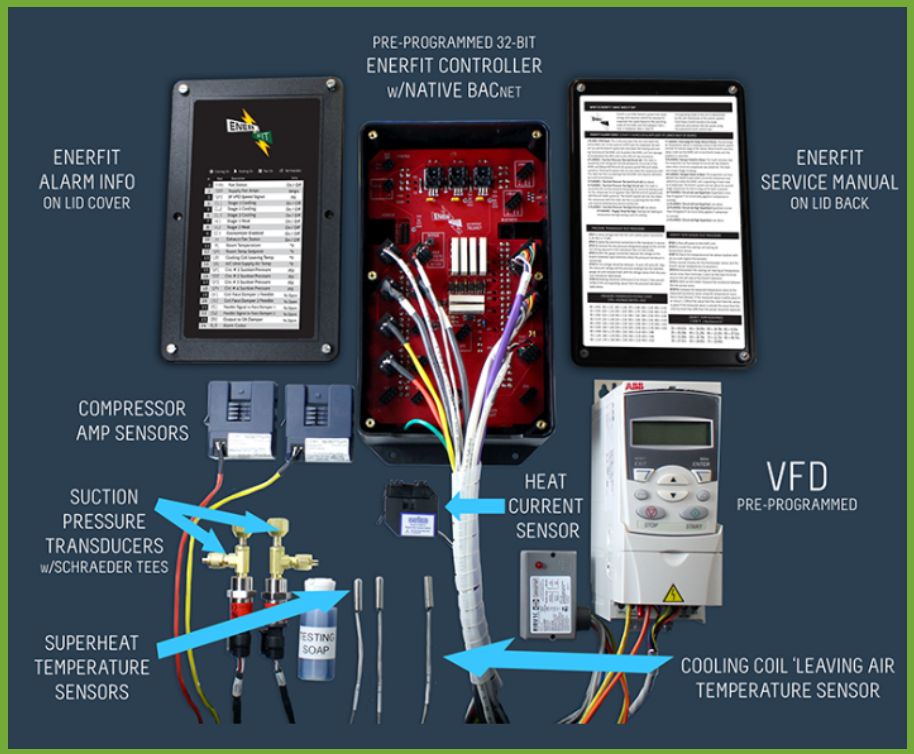
Table 3. Digital and Analog Monitoring Points on Each RTU

Digital or Analog Signal	Monitoring Point	CATALYST Standard Sensor or Demonstration Add	Sensor Manufacturer/ Model	Sensor Accuracy	Sensor Notes
Digital-1	Occupied status	Standard	N/A	N/A	Controller calculated based on programmed schedule
Digital-2	First-stage cooling	Standard	N/A	N/A	Signal from controller
Digital-3	Second-stage cooling	Standard	N/A	N/A	Signal from controller
Digital-4	Supply fan power	Standard	Yaskawa VFD Output	Could not be obtained from Yaskawa	Value is monitor via a communication output on the drive; power is measured internally on the drive.
Digital-5	Total RTU power	Add	Continental Watt-Node WNC-3D with ACT current transducers	± 3% at leading power factor of 0.866	100 Hz resolution Watt-Node; accuracy combines Watt-Node and current transducers (www.ccontrolsys.com/w/Metering_System_Accuracy)
Analog-1	OA temp sensor	Standard	Senva HD-3B	± 2°C (3.6°F) Full Range; 0.5°C (0.9°F) typ @ 25°C (77.0°F)	Resistance Temperature Detector (RTD); positioned inside the OA hood always in the shade
Analog-2	RA temp sensor	Standard	Senva HD-3B	± 2°C (3.6°F) Full Range; 0.5°C (0.9°F) typ @ 25°C (77.0°F)	RTD; Positioned at the RA inlet into the RTU
Analog-3	SA temp sensor	Standard	ACI-AN Series	± .36 F	RTD in SA ductwork
Analog-4	MA temp sensor	Add	ACI-AN Series	± .36 F	Single RTD measurement located at the filter inlet
Analog-5	OA RH sensor	Standard	Senva HD-3B	± 3%, 20-80% Range	Capacitance sensor; Positioned inside the OA hood always in the shade
Analog-6	RA RH sensor	Standard	Senva HD-3B	± 3%, 20-80% Range	Capacitance sensor; positioned at the RA inlet into the RTU
Analog-7	RA CO_2 sensor	Standard	AirTest TR-9291	± 30 PPM; ±3% reading	CO_2 sensor positioned in RA ductwork
Analog-8	Space temperature	Add	ACI A/1K-2W	± 1.1°C (1.9°F)	Wall mounted temperature sensor at the existing thermostat location
Analog-9	OA damper controller	Standard	CAT-371	0-10 VDC signal at 8 Bit resolution	Control signal generated by controller CAT-371
Analog-10	Fan speed	Standard	Communicating Modbus signal	N/A	Control signal generated by controller CAT-371

Source: http://www.nrel.gov/docs/fy14osti/61072.pdf

Enerfit

Enerfit: Supply Fan VFD control



- Evaporator Fan Modulation with VFD
- No compressor modulation
- Proactive troubleshooting and alarms, including phase drop/reversal and ground faults
- Monitors refrigerant system

Source: http://www.enerfit.com/thescience.html

NexRev DrivePak ARC

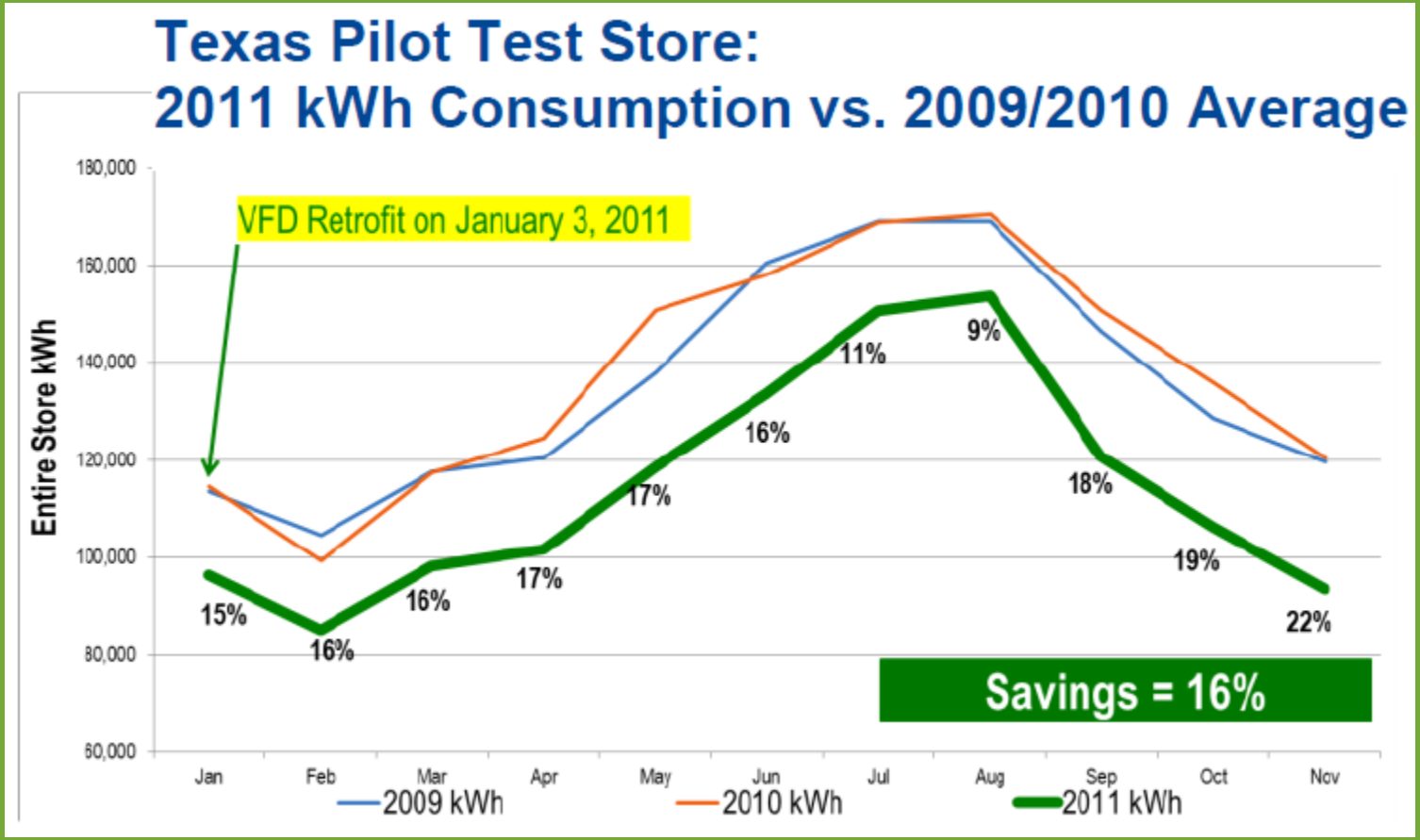
NexRev: Supply Fan VFD control



- VFD and control interface board that matches fan speed to air flow requirements for cooling, heating and ventilation
- Economizer optimization
- Demand Control Ventilation
- Fault detection
- Major DOE case study with JC Penney stores where 22% energy savings (47 million kWh) were documented at 131 stores
- No compressor modulation

Source: http://www.nexrev.com/

Fan VFD savings: JC Penney

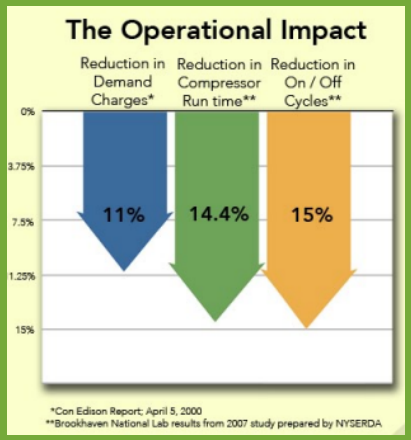


Source: http://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/JCPenney%20ARC%20Case%20Study.pdf

Intellicon CAC

Intellicon CAC: compressor controls





- Electronic compressor control
- Does not use variable drives, only manages cycling
- Energy savings stated at 10-20%
- Multiple controllers needed



Source: http://www.intellidynellc.com/index.php/products/commercial-heating/cac

ADVANCED EFFICIENCY PRODUCTS

Pace3 by Pace Controls

Pace Controls: Pace3 compressor cycling

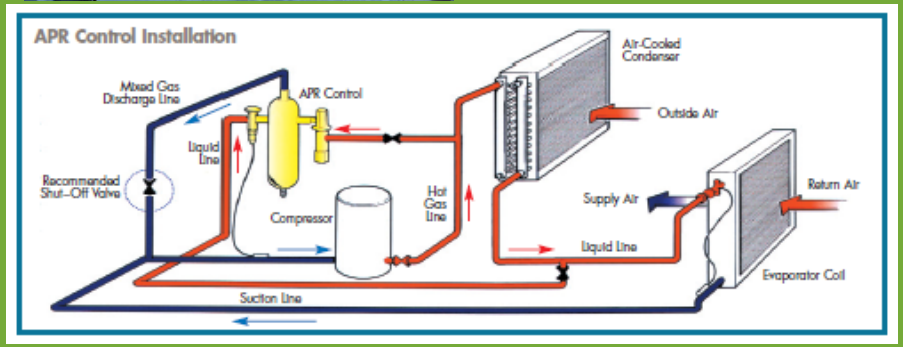


- Cycles compressors based on coil temperature and pressure
- Stand alone controller for each unit
- Works on non-centrifugal compressors
- Does not appear to have any external controls or monitoring
- Does not appear to provide any fault detection and diagnostics
- Potential energy savings stated as 10-20%

Rawal APR Control

Rawal: APR controls





- Hot gas bypass control system for compressors
- No fan modulation
- Requires soldering and valves
- No electronic controls
- Not easily transferable as a retrofit
- Possible issues with oil return to compressor

1. http://rawal.com/applications/ac-energy-efficiency

ADVANCED EFFICIENCY PRODUCTS

Encycle Swarm Logic

Encycle: “Swarm Logic” RTU cycling



- Synchronized control of RTU schedules and operation
- Uses wireless controllers connected to coordinating node
- Provides energy use and maintenance reports
- Provides intelligent demand response
- Potential energy savings stated as 15-30%
- Multiple controllers needed

Source: http://www.intellidynellc.com/index.php/products/commercial-heating/cac

Automated Fault Detection and Diagnostics

Automated Fault Detection and Diagnostics

Essential alarms to drive cost effective and condition-driven RTU maintenance

	Digi-RTU Controls	TWT Catalyst	Enerfit	NexRev DrivePak	Intellicon CAC	Pace3 Controls	Rawal APR Control	Encycle Swarm
Space Temp & Humidity	Yes	Yes	Yes	No	No	No	No	Yes
Loose Fan Belt	Yes	Yes	Yes	No	Yes	No	No	No
Duct & Filter Blockage	Yes	Yes	Yes	Yes	Yes	No	No	Yes
Low/High Refrigerant	Yes	Yes	Yes	No	Yes	No	No	No
Outside Air Damper	Yes	Yes	Yes	Yes	No	No	No	No
Heater Failure	Yes	Yes	Yes	Yes	No	No	No	Yes
Sensor degradation and/or failure	No	No	No	No	No	No	No	No
Condensor Coil Fouling	No	No	No	No	No	No	No	No
Evaporator Flow	No	No	No	No	No	No	No	No
Condensate Flow	No	No	No	No	No	No	No	No
Discharge Air Temp	Yes	Yes	Yes	No	No	No	No	No

Remote Monitoring and Control

Remote monitoring and control

Optimize efficiency through continuous monitoring of RTU operation

	Digi-RTU Controls	TWT Catalyst	Enerfit	NexRev DrivePak	Rawal APR Control	Intellicon CAC	Encycle Swarm
kWh Consumption	Yes	Yes	Yes	Yes	No	Yes	Yes
Temperature and Setpoint	Yes	Yes	Yes	Yes	No	No	Yes
VFD Speed	Yes	Yes	Yes	Yes	No	No	No
Damper Position	Yes	Yes	Yes	Yes	No	No	No
Space CO2	Yes	Yes	Yes	Yes	No	No	No
HVAC On/Off	Yes	Yes	Yes	Yes	No	Yes	Yes

ADVANCED EFFICIENCY PRODUCTS

Energy & Cost Savings

Energy cost savings

Comparison of published and/or claimed energy savings

Company & Technology	kWh savings Claimed by Manufacturer	kW savings Claimed by Manufacturer	Gas Consumption Savings Claimed	Reduction in Compressor Cycling
Digi-RTU	50% - 65%	60%>	10-15%	70%>
TWT-CATALYST	20% - 50%	not shown	not shown	none
Enerfit	50% +	not shown	not shown	not shown
NexRev DrivePak ARC	20% - 30%	not shown	not shown	not shown
Intellicon CAC	10% - 20%	not shown	not shown	not shown
Pace3 by Pace Controls	15% - 20%	not shown	not shown	not shown
Rawal APR	12%	not shown	none	not shown
Encycle Swarm Logic	15% - 30%	up to 25%	not shown	not shown

Summary

Comparison of RTU Energy Retrofits

Product	Type	Pros	Cons
Digi-RTU	Supply fan and compressor VFD with economizer, DCV and FDD	Supply fan and compressor savings, DCV, economizer optimization	Installation requires factory certified technicians
Transformative Wave Catalyst	Supply fan VFD with economizer, DCV and FDD	Supply fan savings, economizer optimization	No compressor modulation
Enerfit	Fan VFD control	Fast installation, modulates supply fan	No compressor modulation
NexRev Drive pak	Fan VFD control	Supply fan savings	Modest cost savings
Intellicon CAC	Compressor controller	Compressor savings by cycling	Savings limited to 10-20%, no fan modulation
Rawal APR Control	Hot gas bypass	Capacity modulation up to 50%	Possible oil return issues, no controller
PACE3 by Pace Controls	Compressor and heating controls	Compressor modulation	No fan modulation, modest savings of 15-20%
Encycle Swarm Logic	Swarm Logic to wirelessly control multiple equipment	15%-30% savings claimed	No VFD savings

Q&A