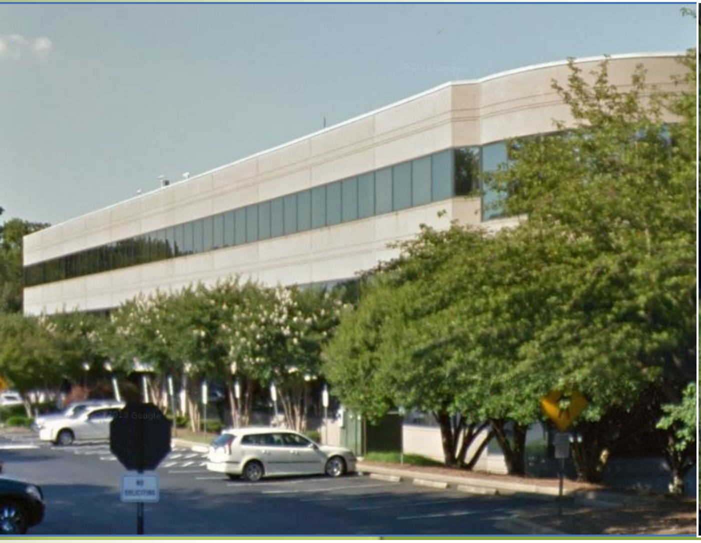
Case Study for Fortune 500 Telecom: **Retrofitting Pneumatic Controls for Energy Efficiency**

JONES LANG LASALLE®



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Summary – Major Fortune 500 Telecom Company

- Estimated 40% the corporate building portfolio still use pneumatic thermostats
- Unlike modern Direct Digital Controls (DDC), pneumatic controls cannot implement energy savings strategies such as occupancy setbacks, optimal start/stop etc.
- Pneumatic controls also do not provide any data, alarms, or diagnostics
- Retrofitting pneumatics to DDC is disruptive to operations and very costly, with typical payback periods of 10 years or more.
- In Q1 2014, three buildings were selected for DDC retrofit using a new ***non-invasive*** technology – the Wireless Pneumatic Thermostat (WPT)
- The WPT cost about 75% less than conventional DDC, with equivalent functionality
- The three buildings were projected to save xx% in HVAC energy consumption, but actually delivered more savings (XX%) per M&V data gathered one year later
- Savings were derived from both implementation of energy savings strategies, and also retro-commissioning and on-going commissioning based on WPT diagnostics
- The three projects have an average payback period of under three years

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Challenge: Legacy Pneumatic Thermostats

Background

- Pneumatic control is a robust technology for temperature regulation used in building construction up till late-1990’s
- About 70% of non-residential buildings in US use pneumatic controls

Shortcomings

- Fully manual – not networked, no programmability, no remote control, no remote monitoring/diagnostics.
- Cannot implement modern energy savings strategies: unoccupied temperature setbacks, duct static pressure control (fan savings), optimal start/stop, auto demand response etc.
- Requires more maintenance labor – no fault detection/diagnostics, no alarms if problem arises. Higher rate of occupant complaints. Requires manual labor for bi-annual mechanical calibration.
- Compared to modern “Direct Digital Control” systems, pneumatic controls use 15-25% more energy

Pneumatic Thermostats control the HVAC Systems in estimated 40% of corporate properties

Operational Issues Related to Pneumatic Thermostats

- **Energy use** – higher per sq-ft energy use than newer buildings. Can't communicate with Smart Grid.
- **Tenant Satisfaction** – Hot and Cold Calls. Facilities team is unaware till tenant complains. Space looks dated.
- **Maintenance** – fewer heads managing more sq-ft, older systems requiring high labor. Hard to troubleshoot.
- **LEED points** – LEED v4 requires continuous commissioning – how to accomplish for existing buildings
- **Cannot disrupt tenants for upgrades** – space is occupied, may have asbestos, cannot disturb

Why are we still living with pneumatics?

- Pneumatic controls are deeply embedded in a building's infrastructure. Replacing them with Direct Digital Control (DDC) typically requires opening up walls and ceilings, disrupting occupants, and possibly requiring asbestos or other types of abatement.
- Typical cost of a DDC upgrade is about $2,500 per thermostat, due to the extensive labor and materials required. This cost does not include the cost of occupant disruption.
- Typical payback period of a DDC upgrade is over 10 years.   It is economically unattractive – and is the reason why there are so many pneumatically controlled buildings still in use today.

Traditional DDC Retrofits are Invasive And Labor Intensive

Upgrading from pneumatics to DDC is extremely labor intensive, costly, and disruptive to occupants

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Non-Invasive Pneumatic to DDC Retrofit Technology

EXISTING LEGACY STAT

- Manual Setpoint Control
- No Remote Readings
- No Diagnostics
- Manual Calibration Required
- Cannot support Demand Response strategies

DDC in 20 Minutes!

WIRELESS PNEUMATIC THERMOSTAT

Air Conditioning | Heating | Refrigeration
theNEWS
THE HVACR CONTRACTOR'S WEEKLY NEWSMAGAZINE SINCE 1926

Gold Award 2010

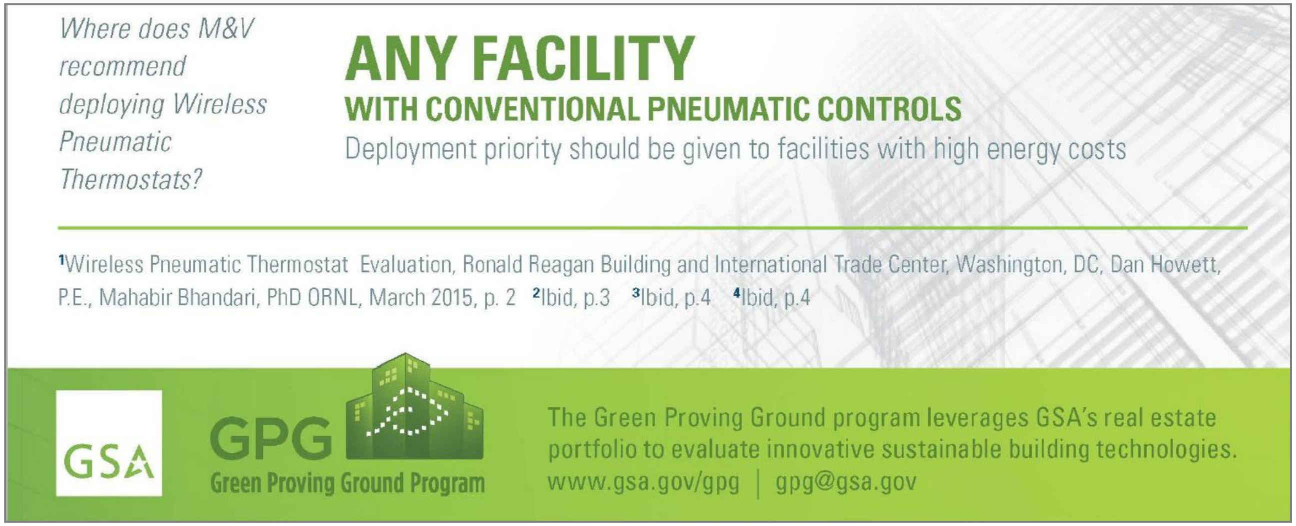
BUILDING OPERATING management 2010 Top Products Award

Building Operating Management 2012 Top Product

- Remote Wireless Setpoint Control
- Remote Monitoring of Temperature & Pressure
- Pager/Cell Notification of Excursions
- Automatic Self-calibration
- Programmable Temperature Setbacks
- Occupancy Override
- Enables Demand Response strategies
- BACnet Interface to BMS
- Compatible With Existing Johnson, Honeywell, Siemens, Robertshaw
- Battery life of 3 – 5 years
- Standalone operation with power failure

About 25% the cost of conventional DDC retrofit, with no occupant disruption

WPT Technology Recommended by DOE



Where does M&V recommend deploying Wireless Pneumatic Thermostats?

ANY FACILITY

WITH CONVENTIONAL PNEUMATIC CONTROLS

Deployment priority should be given to facilities with high energy costs

[1]Wireless Pneumatic Thermostat Evaluation, Ronald Reagan Building and International Trade Center, Washington, DC, Dan Howett, P.E., Mahabir Bhandari, PhD ORNL, March 2015, p. 2 [2]Ibid, p.3 [3]Ibid, p.4 [4]Ibid, p.4

GSA

GPG

Green Proving Ground Program

The Green Proving Ground program leverages GSA's real estate portfolio to evaluate innovative sustainable building technologies.
www.gsa.gov/gpg | gpg@gsa.gov

> *"Our wireless pneumatic thermostats are easy to use and cost-effective, and they provide access to energy-saving control strategies that weren't available through our old pneumatic system."*

—Greg Dix
Building Manager, Ronald Reagan Building
Washington, D.C.
National Capital Region
U.S. General Services Administration

GSA

OAK RIDGE
National Laboratory

U.S. DEPARTMENT OF ENERGY

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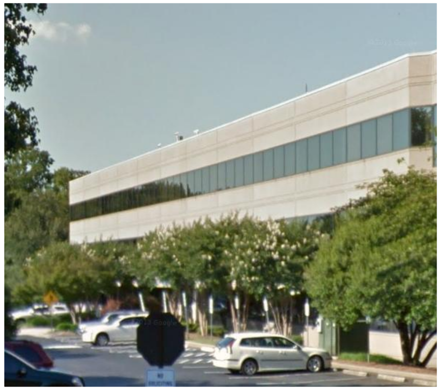
- Challenge with Pneumatic Thermostats
- New Non-Invasive WPT Technology
- Three Buildings Selected for WPT Retrofit
- Bldg 82389 Savings Strategies and Pre-Installation Savings Estimates
- Post-Installation Actual Savings Measured
- WPT Diagnostic Capability for Retro-Commissioning (RCx) and Monitoring Based Commissioning (MBCx)

Three Sites Selected for WPT Retrofit

- Nashville, TN – 82389
  Approx 54,000 sq-ft

- Charlotte, NC –21000
  Approx 103,000 sq-ft



- Raleigh, NC – 21356
  Approx 90,000 sq-ft

Bldg 82389 – Building Overview

Building Description

Type:	54,000 sq-ft office building
Location:	Nashville, TN
Usage:	Offices, training center
Total area:	54,000 sq-ft
Thermostats:	Estimated to be 70 (to be confirmed)
Terminal Units:	VAV with electric reheat around perimeter.
AHU's:	4 AHU's, one per corner of building All fans have VFD controls Varying schedules, 50% of building occupied till 10 or 11pm at night. AHU's on 24x7.
DDC:	Siemens Apogee, older model, but has BACnet interface
Utility:	Nashville Electric, avg. $0.09 per kWh.

Current Energy Consumption - Total Building

Annual electricity bill:	$245,361
Annual electricity usage (kWh):	2,674,683
Average cost per kWh:	$0.092

Estimated HVAC Portion of Energy Consumption

Est. HVAC portion of Total Electricity Bill	65%
Est. HVAC annual electricity usage (kWh)	1,738,544
Est. HVAC annual electricity bill:	$159,485
Est. HVAC annual electical use per sq-ft (kWh)	32.20
Est. HVAC annual electrical cost per sq-ft	$2.95

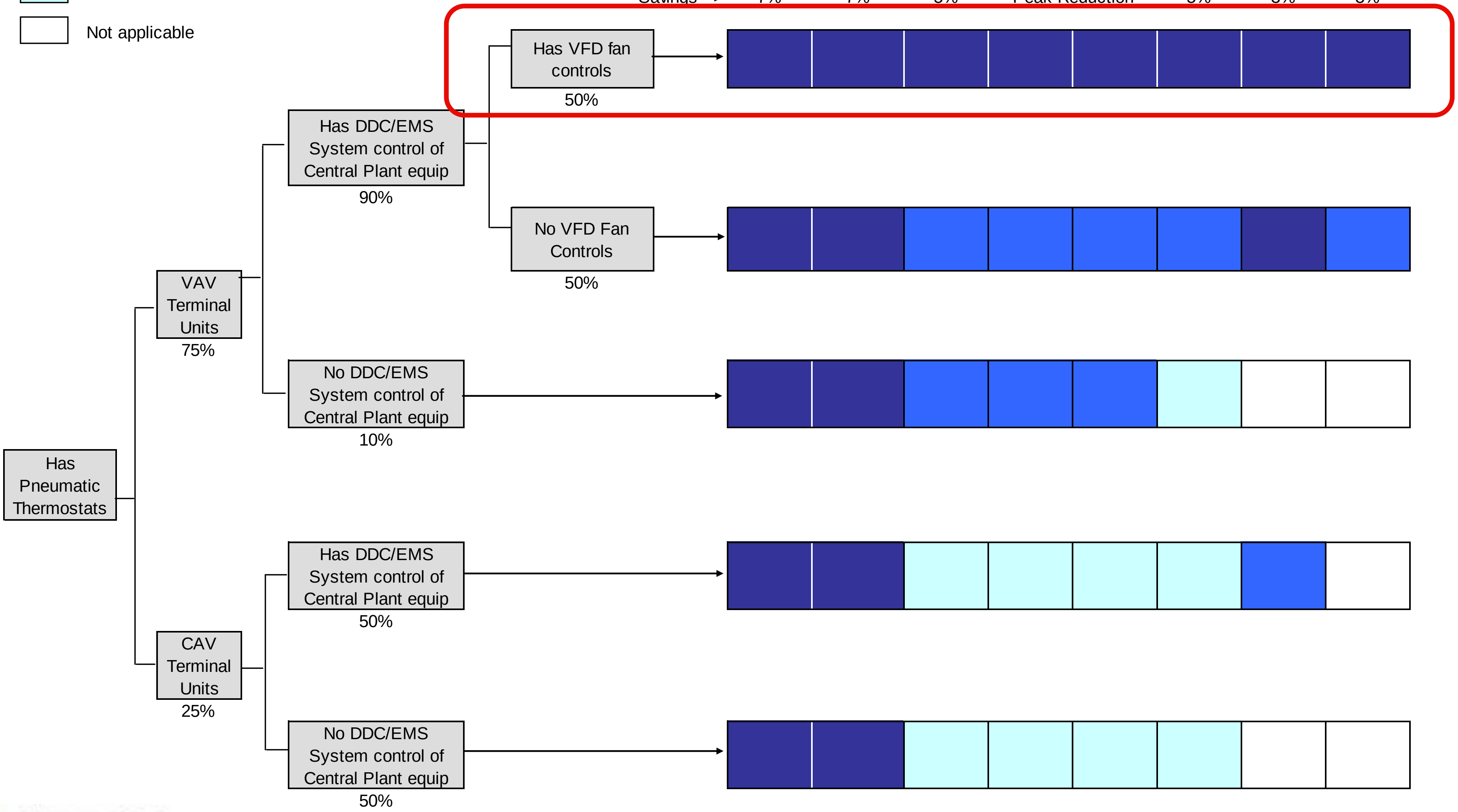
Bldg 82389 – Potential ECM's

■ Fully applicable

▩ Partially applicable, high impact

▨ Partially applicable, lower impact

□ Not applicable

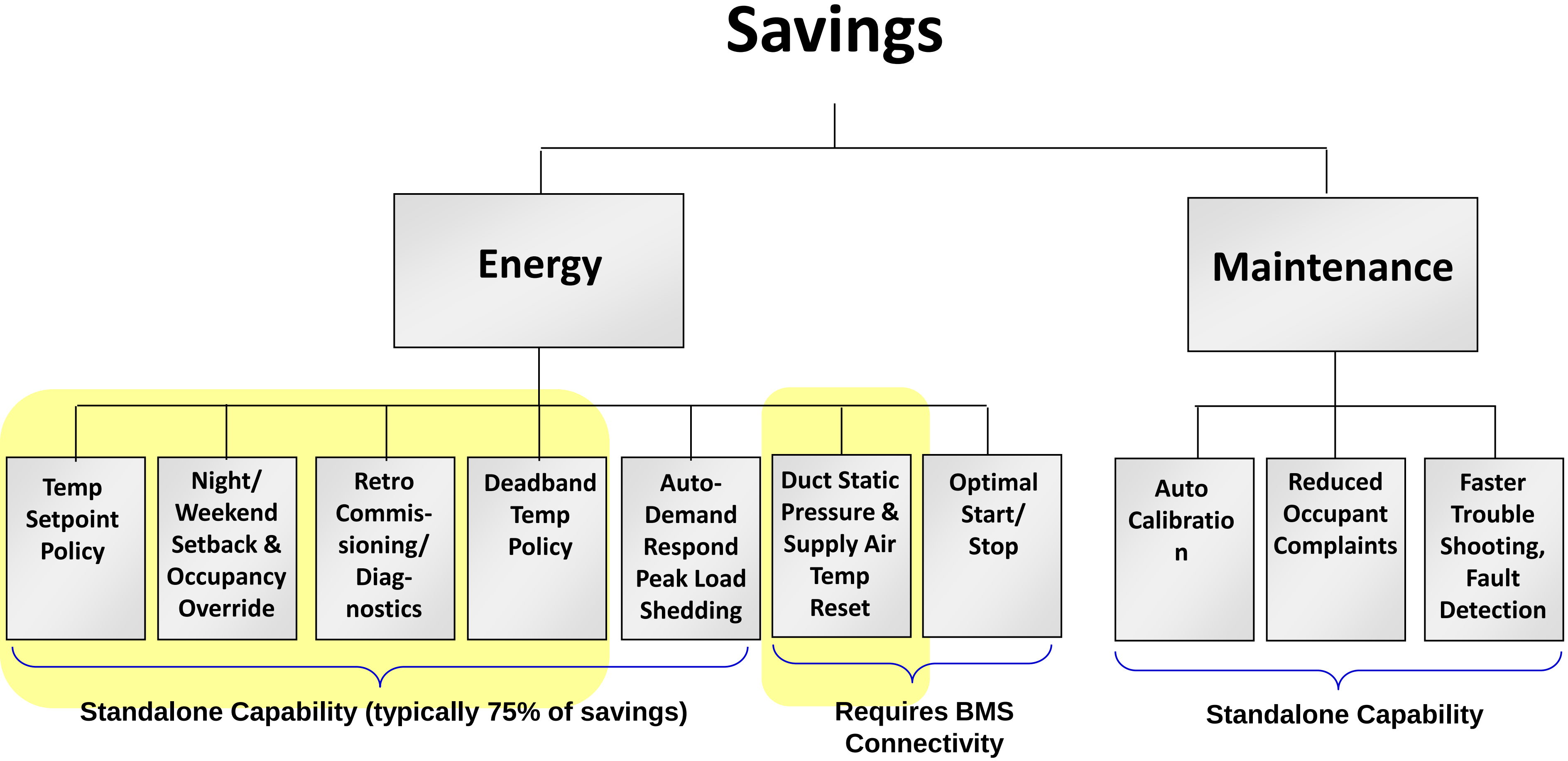


- Has Pneumatic Thermostats
  - VAV Terminal Units 75%
    - Has DDC/EMS System control of Central Plant equip 90%
      - Has VFD fan controls 50%
      - No VFD Fan Controls 50%
    - No DDC/EMS System control of Central Plant equip 10%
  - CAV Terminal Units 25%
    - Has DDC/EMS System control of Central Plant equip 50%
    - No DDC/EMS System control of Central Plant equip 50%

Energy Conservation Measures

	Setpoint Policy Enforcement	Retrocommissioning/ Ongoing commissioning	Deadband Setpoints	Pre-cooling, Load Shifting, Optimal Start/Stop	Auto-Demand Response	Programmable setbacks/ occupancy override	Supply Air Temp Resets	Duct Static Pressure Reset
Savings =>	7%	7%	5%	Peak Reduction		5%	3%	3%
Has VFD fan controls 50%	■	■	■	■	■	■	■	■
No VFD Fan Controls 50%	■	■	▩	▩	▩	▩	■	▩
No DDC/EMS System control of Central Plant equip 10%	■	■	▩	▩	▩	▨	□	□
Has DDC/EMS System control of Central Plant equip 50%	■	■	▨	▨	▨	▨	▩	□
No DDC/EMS System control of Central Plant equip 50%	■	■	▨	▨	▨	▨	□	□

Wireless Pneumatic Thermostat ECM's – Bldg 82389



Savings

Energy

Maintenance

Temp Setpoint Policy

Night/ Weekend Setback & Occupancy Override

Retro Commis-sioning/ Diag-nostics

Deadband Temp Policy

Auto-Demand Respond Peak Load Shedding

Duct Static Pressure & Supply Air Temp Reset

Optimal Start/ Stop

Auto Calibratio n

Reduced Occupant Complaints

Faster Trouble Shooting, Fault Detection

Standalone Capability (typically 75% of savings)

Requires BMS Connectivity

Standalone Capability

Same Benefits as Direct Digital Control – but at a Fraction of the Price and Disruption

Bldg 82389 can expect ~22% energy savings

	GLC 82389	Typical Savings based DDC and WPT experience	Est. Savings for GLC 82389
Programmable Setbacks	🟨 Most AHU's working all the time, so good opportunity to set back zones which are not occupied	5-10%	7%
Duct Static Pressure Reset	🟩 Use Branch Pressure reading from WPT to reduce fan speed on VFD's optimally via Apogee	5-10%	5%
Setpoint Enforcement, auto-calibration, continuous commissioning	🟩 Enforce setpoints to reasonable levels (i.e. between 65 and 75 degrees) to avoid simultaneous heating/cooling. Auto-calibration will prevent drift.	5-10%	5%
Supply Air Temp Reset	🟩 Use WPT temperature sensors to optimize supply air temp at AHU's, via Apogee	2-4%	3%
Deadband Setpoints	🟨 **Deadband setpoints may be applicable for some areas**	3-5%	2%
Optimal Start/Stop	🟥 AHU's on virtually all the time, so no optimal start or stop times	5-10%	0%
Potential Energy Savings via Applicable ECM's			**22%**

🟩 ECM Fully Applicable 🟨 ECM Partially Applicable 🟥 ECM Not Applicable

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12 Month Actual Measured Energy Savings

ID	Location	Sq-ft	First installed	Original projection of savings (HVAC)	12 Month Measured Energy Savings (HVAC)	Realized savings per sq-ft per year
GLS 82389	Nashville, TN	54,000	Jan-2014	22%	31%	7.3 kWh
GLS 21000	Charlotte, NC	103,000	Jan-2014	23%	15%	3.7 kWh
GLS 21356	Raleigh, NC	90,000	Feb-2014	24%	47%	7.5 kWh

Note: Charlotte, NC was not able to fully implement all strategies originally planned due to delay of BACnet interface

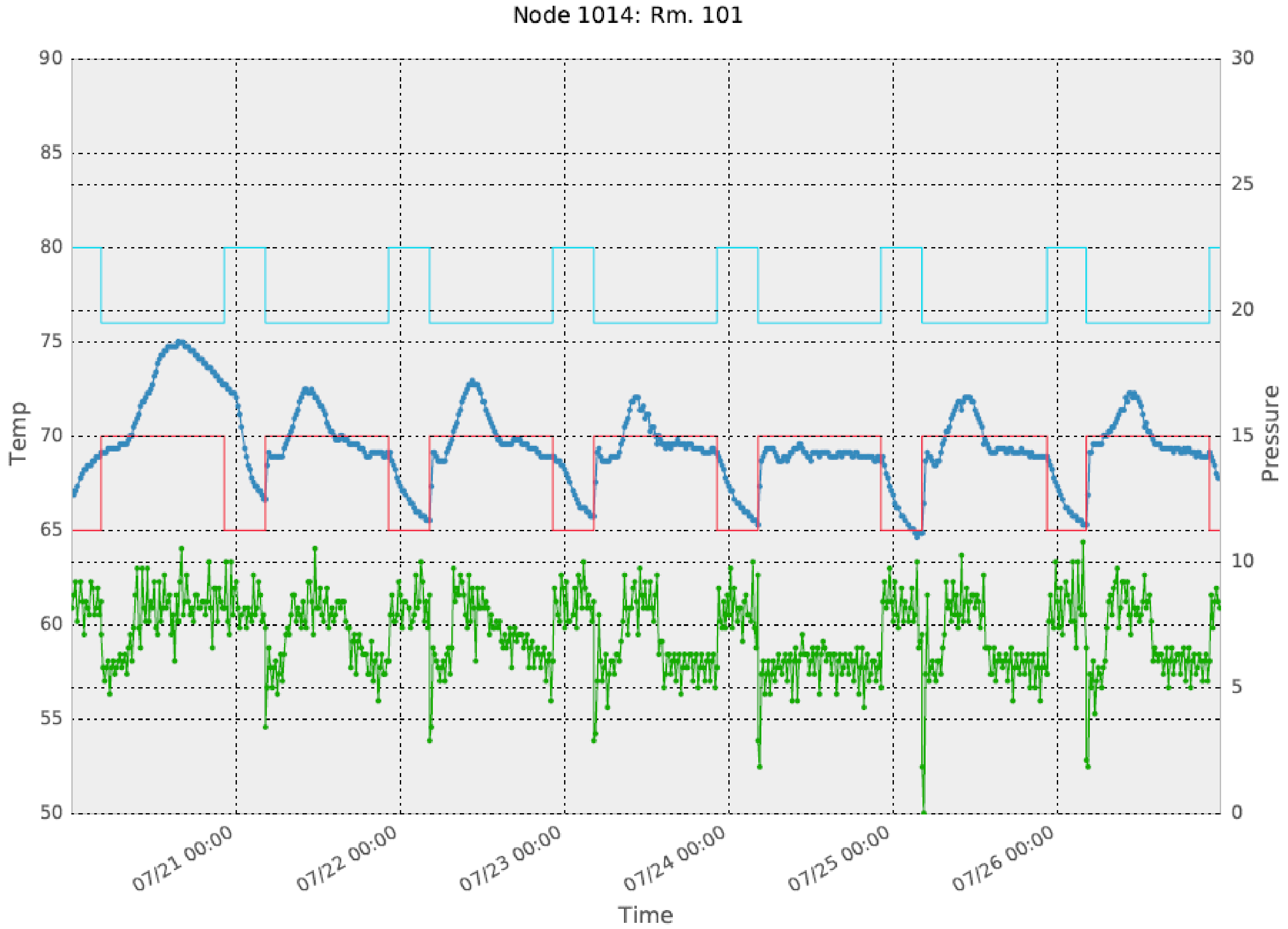
Average Measured Energy Savings of 30% vs. 23% Pre-Installation Projection

Data Gathered from WPT Played Big Role in Savings

Data for fault detection, RCx, MBCx:

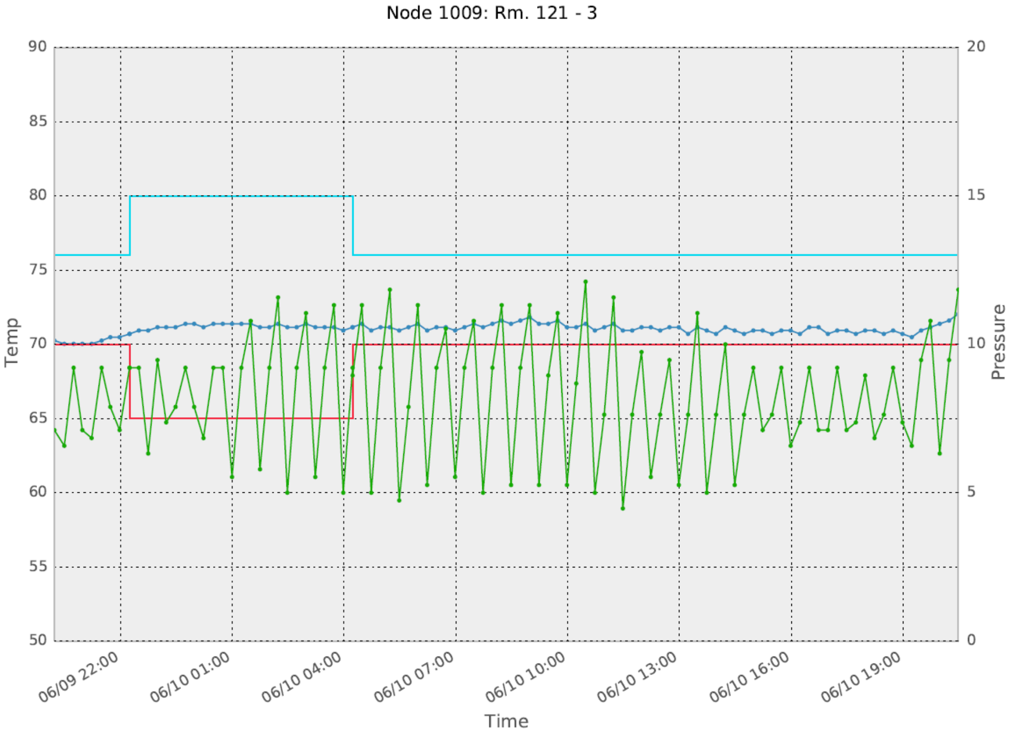
- Zone Temperature
- Branch Pressure (indicator of thermal demand)
- Setpoint Temperature
- Occupancy Mode
- Occupancy Override (afterhours work override)

Typical Correct Behavior of a Terminal Unit



Green Line = Branch Pressure
Dark Blue Line = Room Temperature
Light Blue Line = Cooling Setpoint
Red Line = Heating Setpoint

e.g. Fault Detection: Damper/Valve Oscillation



Green Line = Branch Pressure
Dark Blue Line = Room Temperature
Light Blue Line = Cooling Setpoint
Red Line = Heating Setpoint

What's going on:

- Zone temperature is relatively comfortable.
- But heating and cooling goes on and off constantly to maintain the setpoint - waste of energy
- Many zones have oversized cooling (possibly rezoned since construction), and most zones have oversized reheat elements.
- Result is system overshoots and tries to compensate, with oscillating behavior.

Cypress Analysis to Correct Oscillations

WPT Oscillation Simulation

Appleton Simulation **Typical WPT Site**

Enter data in Orange Cells

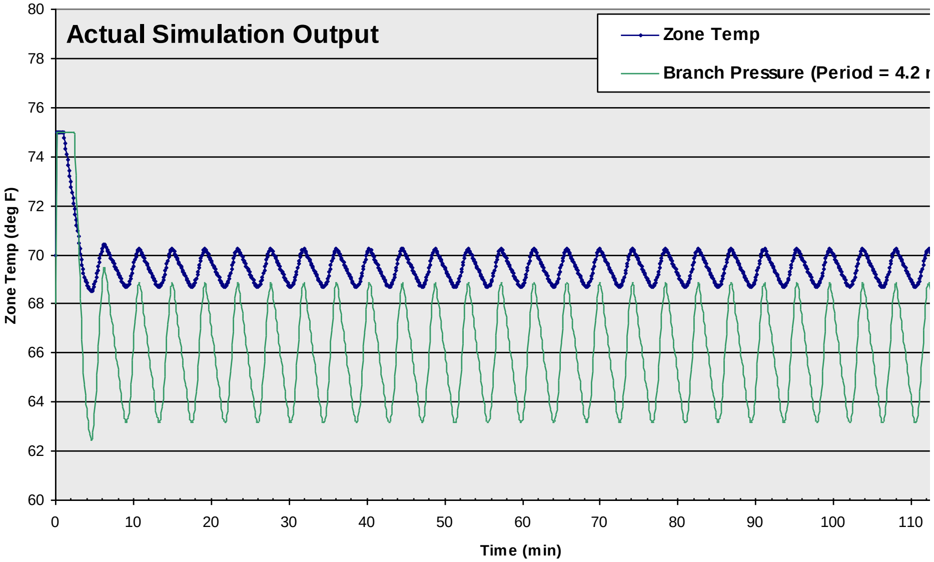
Heater	Low Pressure (psi) - Max	3	Known
	High Pressure (psi) - Min	6	Known
	Max kW	1	Guess
	Delay action (min)	1	Guess
A/C	Low Pressure (psi) - Min	8	Known
	High Pressure (psi) - Max	15	Known
	Min cooling setting	30%	Known
	Max kW	1	Set same as heating
	Delay action (min)	1	Set same as heating
Stat	Min Branch Pressure (psi)	2	Known
	Max Branch Pressure (psi)	15	Known
	Throttle Range (deg F)	3.5	Enter Value
	Setpoint (deg F)	70	Enter Value
	Neutral Pressure (psi)	8	Known
Room	Mass of Air in Room (kg)	40	Guess
	Specific Heat of room (kJ/kg deg C)	1.2	Guess (avg thermal mass)
Constant	Deg F per Deg C	1.8	Known
Model	Calculation Interval (min)	0.1	Enter Value
	Initial Impulse Temp (deg F)	75	Enter Value

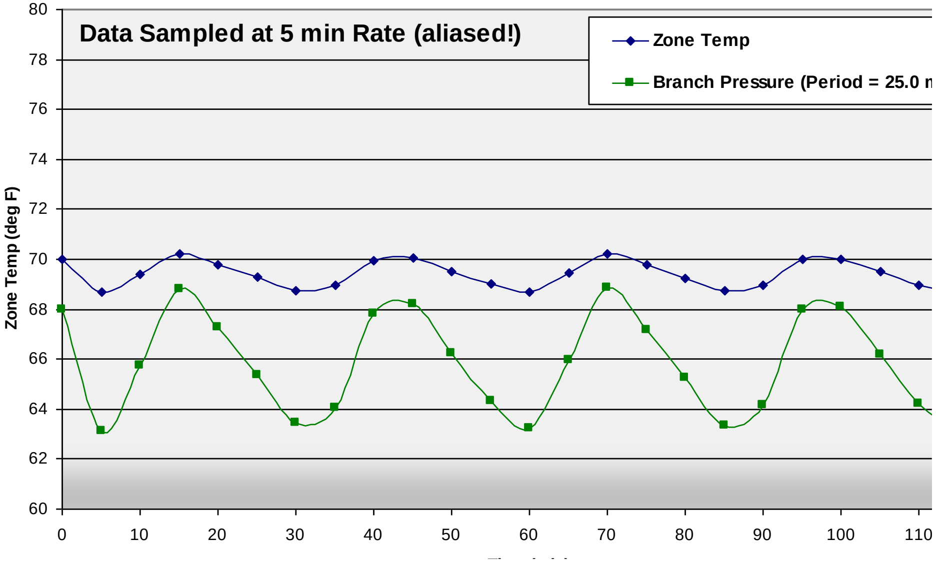
Notes:

- Upper right chart shows actual model data at 0.1 minute calculation interval
- Lower right charts shows same data, but sampled at 5 min interval
- Note aliasing occurs at 5 minute sample rate (period of 20 min observed vs. actual period of 4 minutes in simulation model).
- Try changing Throttle Range to 7 deg to dampen oscillations

Dependencies Observed:

	Branch Pressure change	
Variable changed	Frequency	Amplitude
Time Delay	Y	
Room Thermal Mass (specific heat)		Y
Throttle Range		Y
Sampling Rate		Y



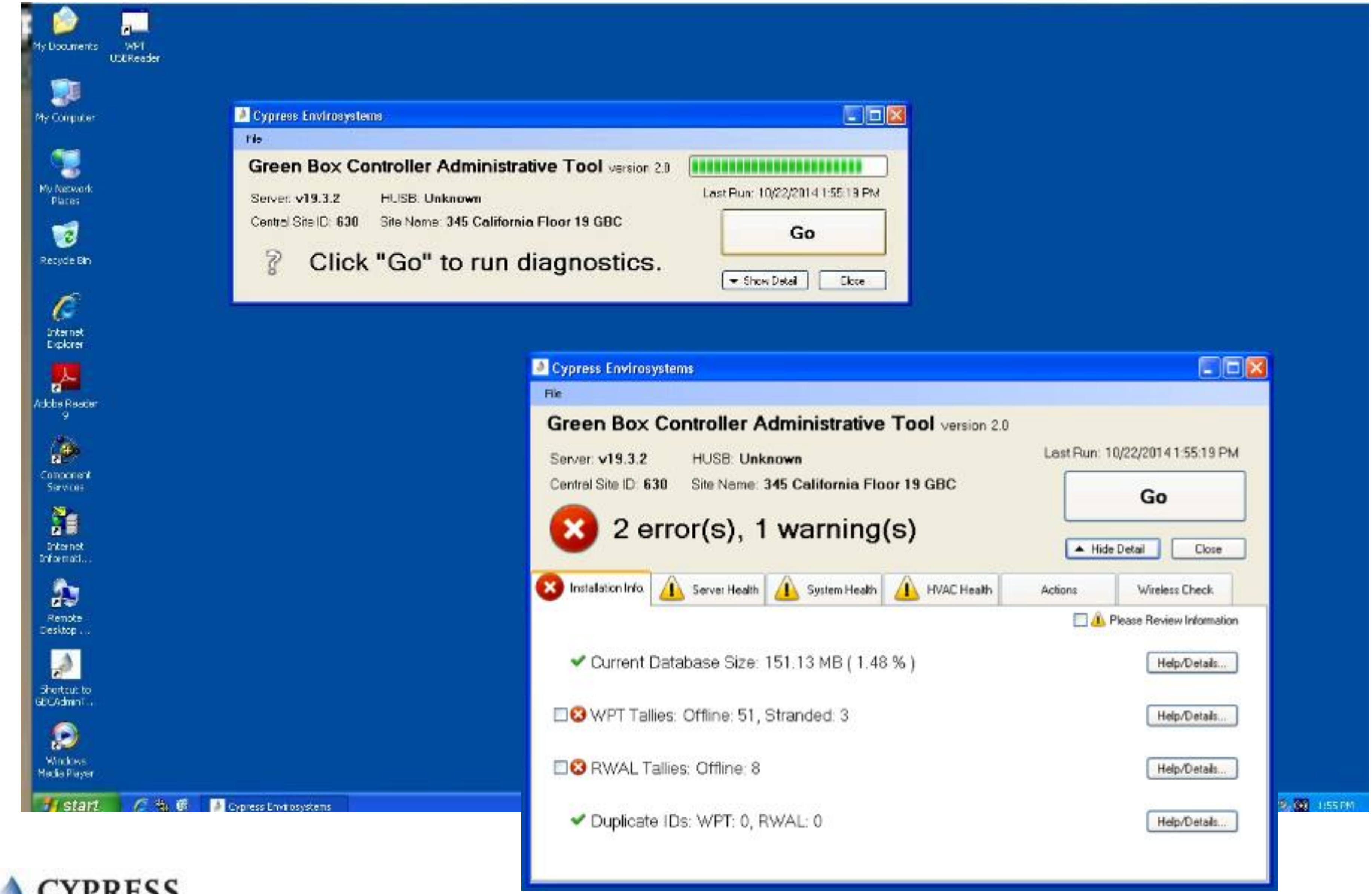


Corrective/Retrocommissioning Actions

- Adjust cooling damper and reheat spring ranges to implement mechanical deadband of 3 psi to avoid short cycling of heating/cooling.
- Adjust reheat spring ranges to provide less heating when zone temperature close to setpoint.
- Adjust thermostat throttle range to maximum (from 4psi to 12psi) to prevent overshooting.
- Increase thermostat deadband to 65F to 78F during unoccupied hours.

Would not have been possible without diagnostic data provided by WPT

WPT Built-In Tools for Automated Diagnostics



Cypress Envirosystems

File

Green Box Controller Administrative Tool version 2.0

Server: **v19.3.2** HUSB: **Unknown**

Central Site ID: **630** Site Name: **345 California Floor 19 GBC**

Last Run: 10/22/2014 1:55:19 PM

Click "Go" to run diagnostics.

Go

▾ Show Detail Close

Cypress Envirosystems

File

Green Box Controller Administrative Tool version 2.0

Server: **v19.3.2** HUSB: **Unknown**

Central Site ID: **630** Site Name: **345 California Floor 19 GBC**

Last Run: 10/22/2014 1:55:19 PM

2 error(s), 1 warning(s)

Go

▴ Hide Detail Close

Installation Info | Server Health | System Health | HVAC Health | Actions | Wireless Check

☐ Please Review Information

✓ Current Database Size: 151.13 MB (1.48 %) Help/Details...

☐ WPT Tallies: Offline: 51, Stranded: 3 Help/Details...

☐ RWAL Tallies: Offline: 8 Help/Details...

✓ Duplicate IDs: WPT: 0, RWAL: 0 Help/Details...

Recap

- Installation of WPT’s enabled many energy savings strategies not possible with pneumatic controls.

- Non-Invasive technology was very fast and non-disruptive to install. Cost about 75% less than DDC, payback periods under three years.

- Post-installation measured energy savings of 30% compared with pre-installation estimate of 23%

- Data from WPT’s also provided one-time RCx diagnostic capability to identify and correct issues beyond the thermostat, in the Air Handling/Terminal Units.

- Use of diagnostic data can be continued for MBCx to sustain and further improve savings.

Contact Information:

Mark Wilcox, JLL, Portfolio Energy Manager
Phone: (904) 591-6865
Email: mark.wilcox@am.jll.com

Harry Sim, Cypress Envirosystems
Phone: (408) 307-0922
Email: harry.sim@CypressEnvirosystems.com
Web: www.CypressEnvirosystems.com