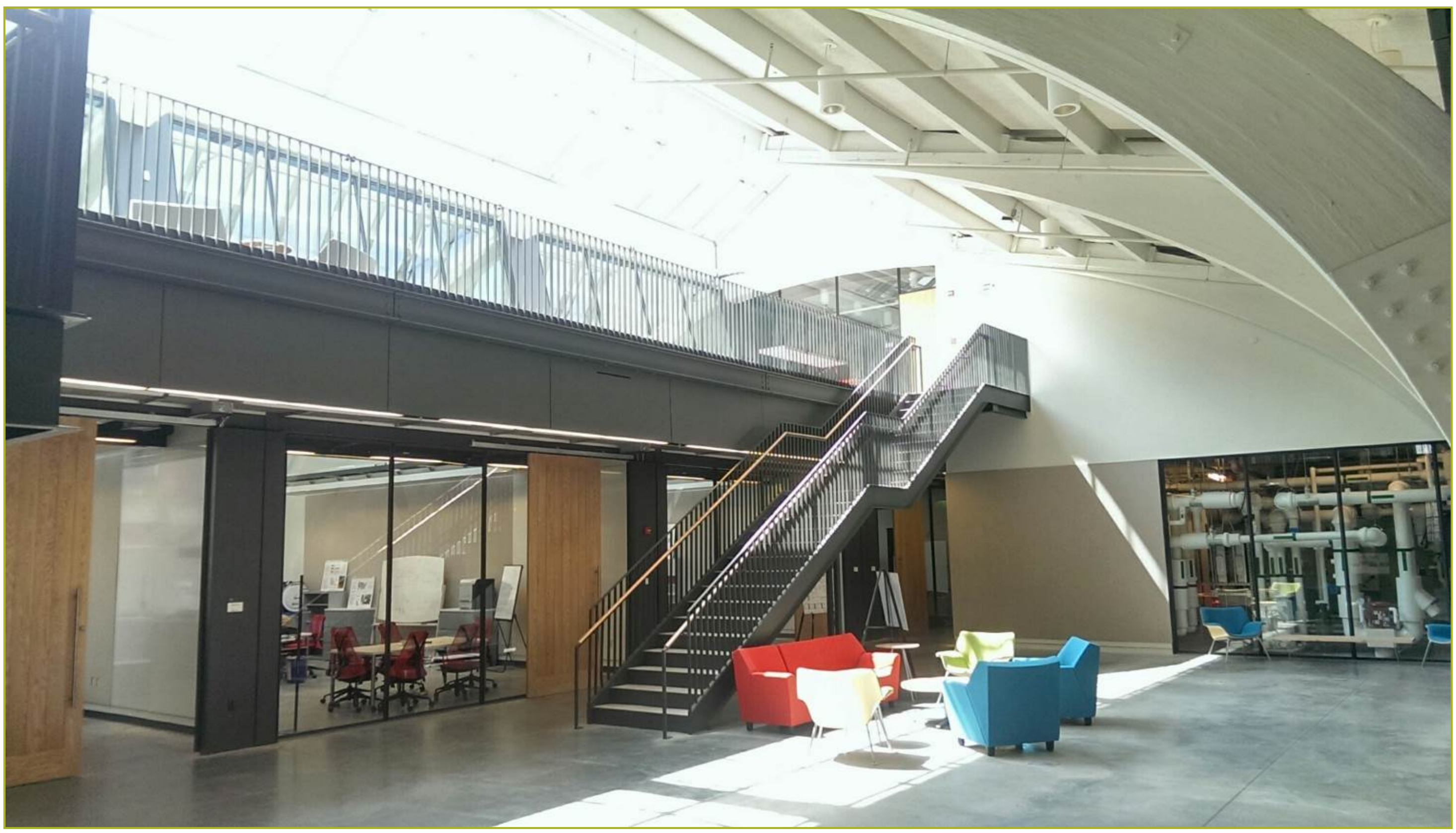
CONSORTIUM for BUILDING ENERGY INNOVATION

REPORT

Title: Building Re-Tuning Training Deployment Model

Report Date: April 30, 2016

Report Author: Lisa Shulock



Funded by U.S. DOE

CONSORTIUM for BUILDING ENERGY INNOVATION

REPORT

Report Abstract

Project objectives.

Deliverable Requirement: Model for deployment of BRT with BAS is handed off to 2 partners to deliver with new module preparing data for BRT analysis.

Deliverable report: CBEI created a series of training modules and a BRT training guide which was handed off to APPA International and BOMA International. To maintain consistency among all providers of BRT, APPA agreed to maintain the curriculum in a file sharing platform. As of April 30, 2016, information on U.S. Copyright for Building Re-Tuning Training curriculum is not finalized and is waiting for direction from DOE.

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Contributors

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DVIRC: Tony Girifalco

This deliverable includes **training modules** that have been designed to deliver via webinar or in-person. The training modules are:

4A – Value of BRT – understand the purpose of Building Re-Tuning and whether it is right for your organization

4-2 – Observation-Driven Re-Tuning – this is a new version of the training that was created in BP4 for small building re-tuning. It has been modified to include information pertinent to all commercial buildings

4C – Data-Driven Analysis – Mastering BRT. This is a significantly re-worked version of the BRT with BAS training course originally developed by PNNL

4D- Guidance for BRT through BAS interface – this is a new module to teach how to do limited data-driven analysis without requiring the use of ECAM or Open EIS

4E – Trend Data set-up – this is a new module to show how to export trend data from several representative BASs

4F – Using ECAM to Process Data – this is modified from materials created by PNNL

4G – Demand Management – during the pilots we hear that participants were interested in learning more about demand management to reduce energy costs. This is a new module to meet this need.

This deliverable also includes the **Building Re-Tuning Training Guide** which has been modified to include the data-driven program.

PDF version of the PPTs and Training Guide are attached.

One additional deliverable produced by DVIRC is a BRT module created to deliver to small industrial facility managers who are studying LEAN manufacturing processes. DVIRC has combined **Toyota Kata (TK),** a Continuous Improvement (Lean) methodology to develop everyday habits, skill sets, and capabilities in people, aligned with and in support of achieving the long-term objectives of the organization, with BRT. **Kata** are structured routines that are practiced deliberately so their pattern becomes habit. The Japanese word comes from the martial arts, where Kata are used to train combatants in fundamental moves. Toyota has applied the Kata approach to business processes. The Improvement Kata and Coaching Kata are for training managers and leaders in a new way of doing their jobs.

TK/BRT utilizes building re-tuning as the content and Kata as the process to learn about and embed Toyota Kata habits into the culture. The idea is to introduce Toyota Kata by using BRT as the content area. The 1-day session will include an introduction to the essentials of BRT and a “walkdown” of the building envelope. BRT & TK both use practiced repeatable behaviors to support sustainability.

The summary and course module are attached.

Building Re-tuning Training

Date

Location

Welcome & Introductions

- Introductions
- Agenda Review
- Binder Review

Training Objective

- Gain understanding of what building re-tuning is and how it fits into your company's energy management program
- Learn how to re-tune buildings

Acknowledgements:

- The U.S. Department of Energy funded the development of Building Re-Tuning Training
- Much of the content of the Building Re-Tuning training was developed by the Pacific Northwest National Laboratory (PNNL)
- Additional content was added and modifications were made by Penn State, Performance Systems Development (PSD) and Facility Engineering Associates

Building Re-Tuning: Purpose

- Utilize field observation data and/or data from the building automation system (BAS) to diagnose changes to building O&M practices, repairs, and/or the BAS control logic
- Improve the building's energy efficiency and tenant comfort
- Identify and correct no/low cost operational problems that lead to energy waste
- Identify problems that require physical repair such as sensors or air dampers

Building Re-tuning: Basic Energy Management Principles

- If you don't need it, turn it off
- If you don't need it at full power, turn it down
- Make holistic energy decisions when adjusting systems to the real building needs
- Save energy without negatively impacting the comfort of the occupants

Building Re–tuning: Multiple Paths

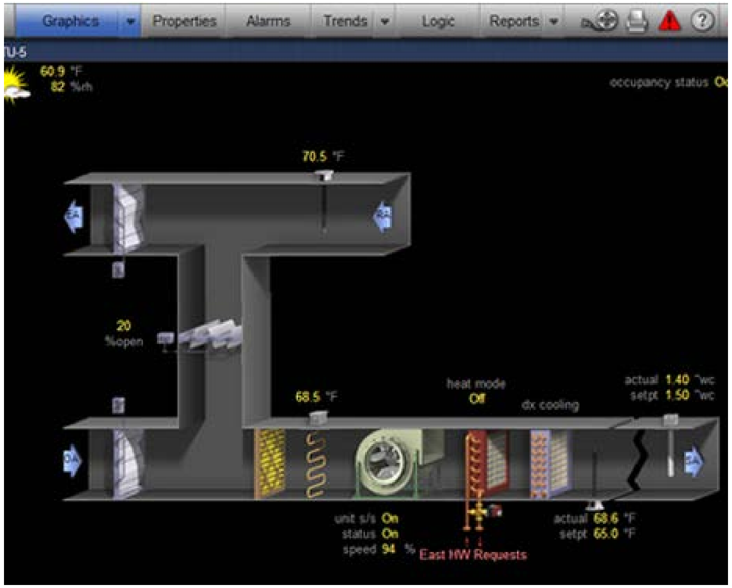
- **Observation-driven** – walk through of building and equipment following a checklist of visual and simple measurement checks
- **Guidance for BRT through BAS interface**– check for and correct a limited set of operational control issues within the building automation system (BAS)
- **Data-driven** – deeper investigation of many and complex control issues from the BAS and energy meters

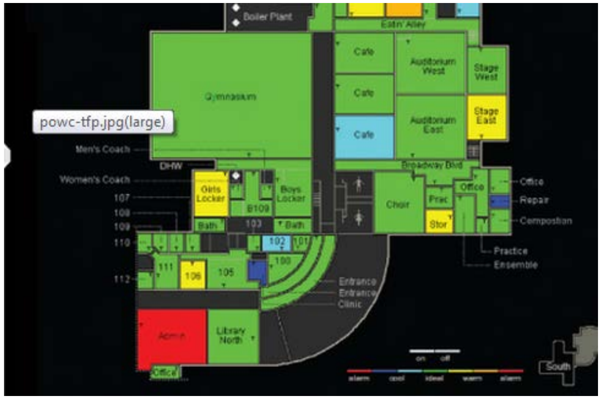
Building Re-tuning: Observation-driven

- Applicable to all buildings but most useful for smaller commercial buildings with rooftop HVAC equipment and no BAS
- Enables staff to diagnose malfunctioning or broken equipment and maintenance issues
- Requires sufficient knowledge of the equipment operation and the schedules of the building

Building Re–tuning:
BRT within the BAS Interface

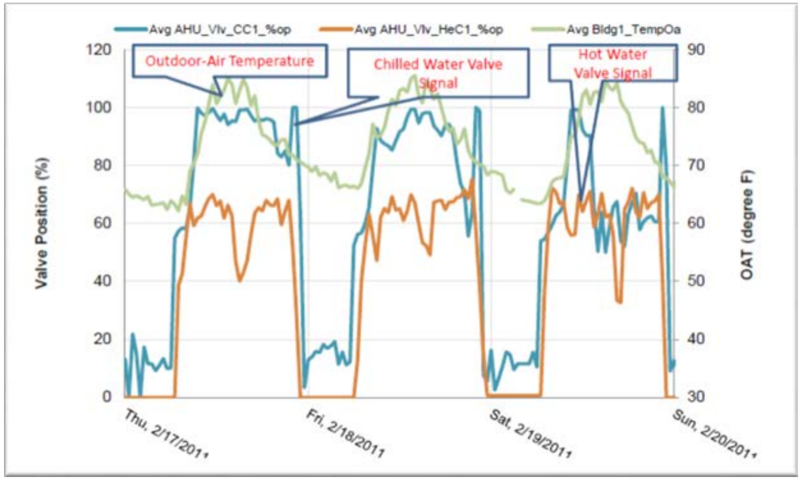
- Applicable to buildings that are controlled by a building automation system (BAS)
- Enables staff to determine if a limited set of the simpler re-tuning measures are present
- Requires sufficient knowledge of the equipment operation and the schedules of the building, and basic knowledge of and read-only access to the BAS user interface





Building Re-tuning: Data-Driven Analysis

- <u>Applicable to</u> buildings that are controlled by a building automation system (BAS)
- <u>Enables staff to</u> determine the presence of a wide range of simple and complex re-tuning measures
- <u>Requires</u> sufficient knowledge of the equipment operation and the schedules of the building, setting up and exporting trend data (history of equipment's set points and performance) from the BAS, as well as working in Excel



Benefits of BRT

- Energy Savings (and GHG reductions)
- Cost Savings
- Improved Tenant Comfort
- Improved Energy Ratings

Building Re–tuning: Why?

- Re-tuning skills can be developed in almost any job skill set
- Low- to no-cost method for improving your building’s energy performance and savings money
- Often results in improved tenant comfort and fewer tenant complaints

Re-tuning Case Study:
Parmenter (Las Colinas Tower , Dallas, TX)

- In January 2014, with retuning experts from the Pacific Northwest National Laboratory (PNNL), Parmenter re-tuned its Las Colinas Tower II building in Irving, TX

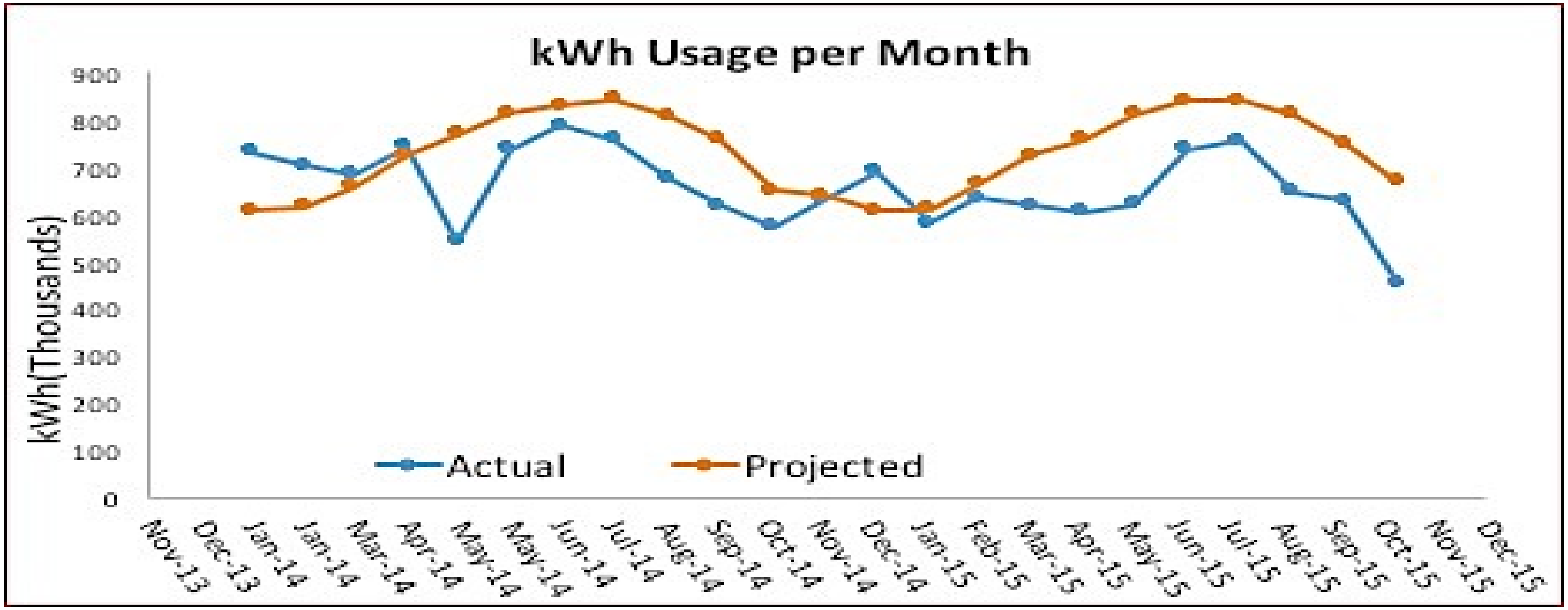
- Re-tuning provided the facilities management team with the ability to identify and understand building scheduling opportunities that drove significant and low-cost energy savings

- Las Colinas Tower II improved its ENERGY STAR score by 24 points from 55 to 79

Projected kWh usage based on a year's monthly consumption prior to re-tuning and weather normalization.

Re-tuning Case Study:
Parmenter (Las Colinas Tower , Dallas, TX)

In the 2 years post-training, the building has saved an average of **9.7%** on its electricity usage due to a long list of energy savings opportunities.



Projected kWh usage based on a year's monthly consumption prior to re-tuning and weather normalization.

Re-tuning Case Study:
Parmenter (Las Colinas Tower , Dallas, TX)

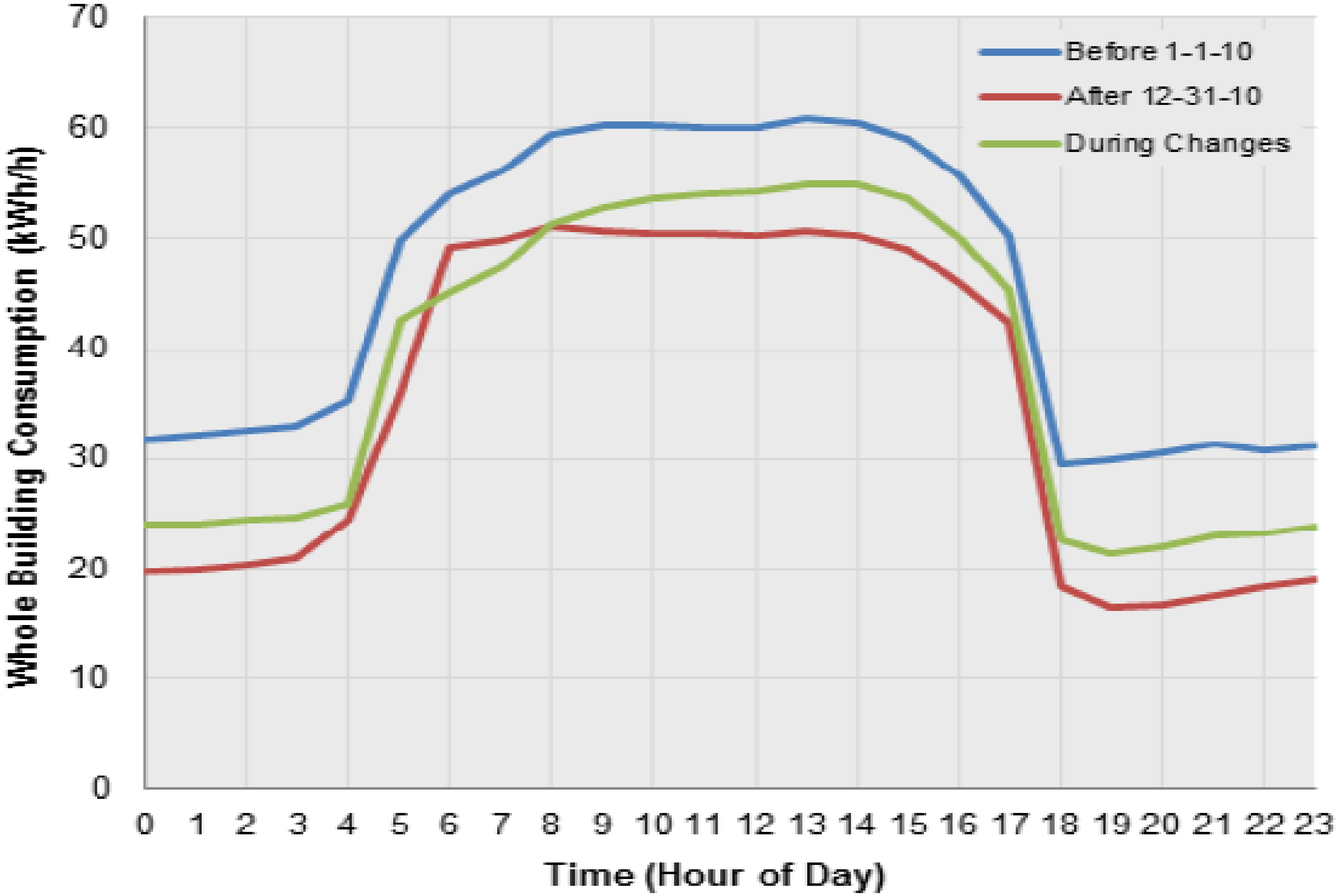


Figure: Weekday Load Profiles for Before, During, and After Re-Tuning Project.

Re–tuning Case Study:
Georgia Tech (Research Building, Atlanta, GA)

- The Technology Square Research Building (TSRB) is an academic research center at the Georgia Institute of Technology

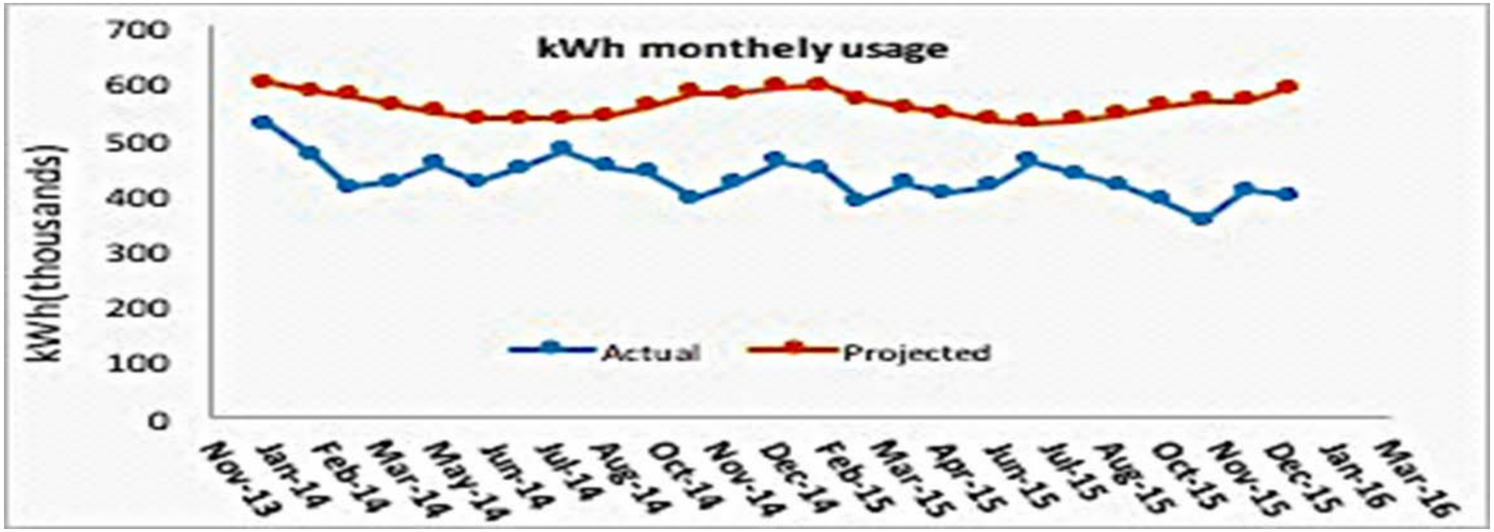
- In July 2013, experts from the Pacific Northwest National Lab conducted a re-tuning training with the property management staff

- The building automation system (BAS) and indoor and outdoor building walk-downs were utilized to identify re-tuning opportunities

The University Financing Foundation
Lease: Georgia Tech, Triple Net Lease
Size: 209,000 Square Feet

Re-tuning Case Study:
Georgia Tech (Research Building, Atlanta, GA)

Five re- tuning measures were implemented, which contributed to electricity savings of **23.6 %** over 2 years compared to projected usage.



Projected kWh usage based on a year's monthly consumption prior to re-tuning and weather normalized

Re-tuning Case Study:
GSA National Capital Region, Washington, D.C.

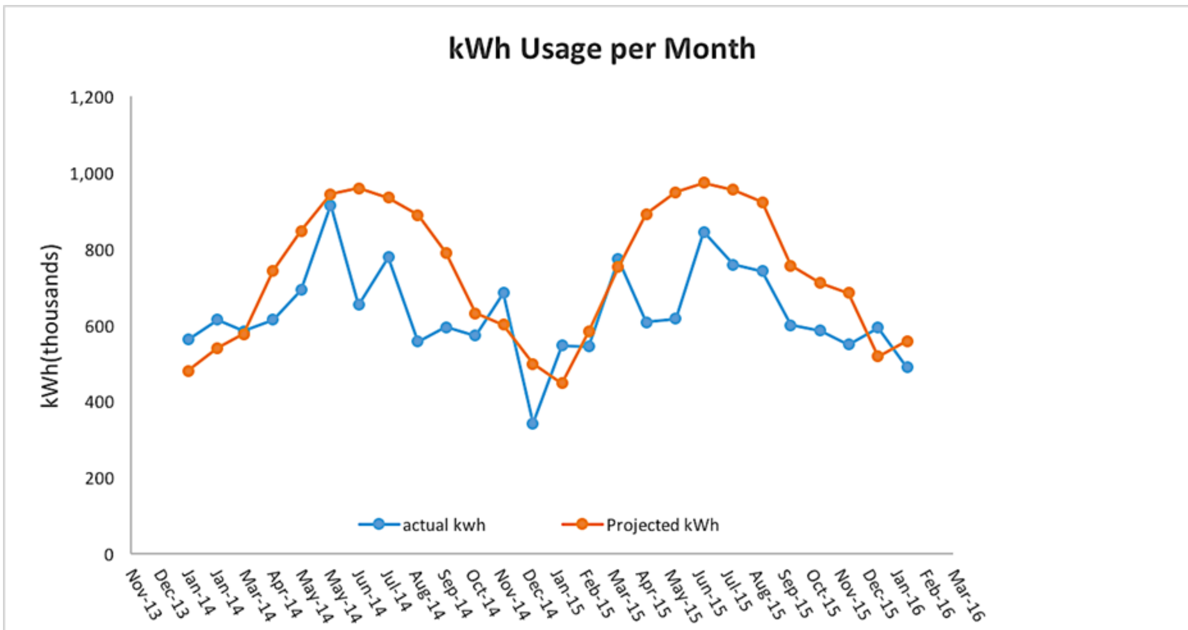
- The U.S. General Services Administration (GSA),National Capital Region (NCR's) teams of property and energy management professionals help reduce energy consumption and costs in GSA-owned buildings

- In March of 2014, experts from the Pacific Northwest National Laboratory (PNNL) delivered re-tuning training to property managers, building engineers, and O&M contractor staff

LBJ Department of Education Building Address: 400 Maryland SW, Washington, DC 20202 Owner: U.S. General Services Administration Size: 550,800 Rentable Square Feet

Re–tuning Case Study:
GSA National Capital Region, Washington, D.C.

In two years since re-tuning the LBJ Dept. of Education Headquarters, facilities staff from GSA saved **14.2%** on electricity usage

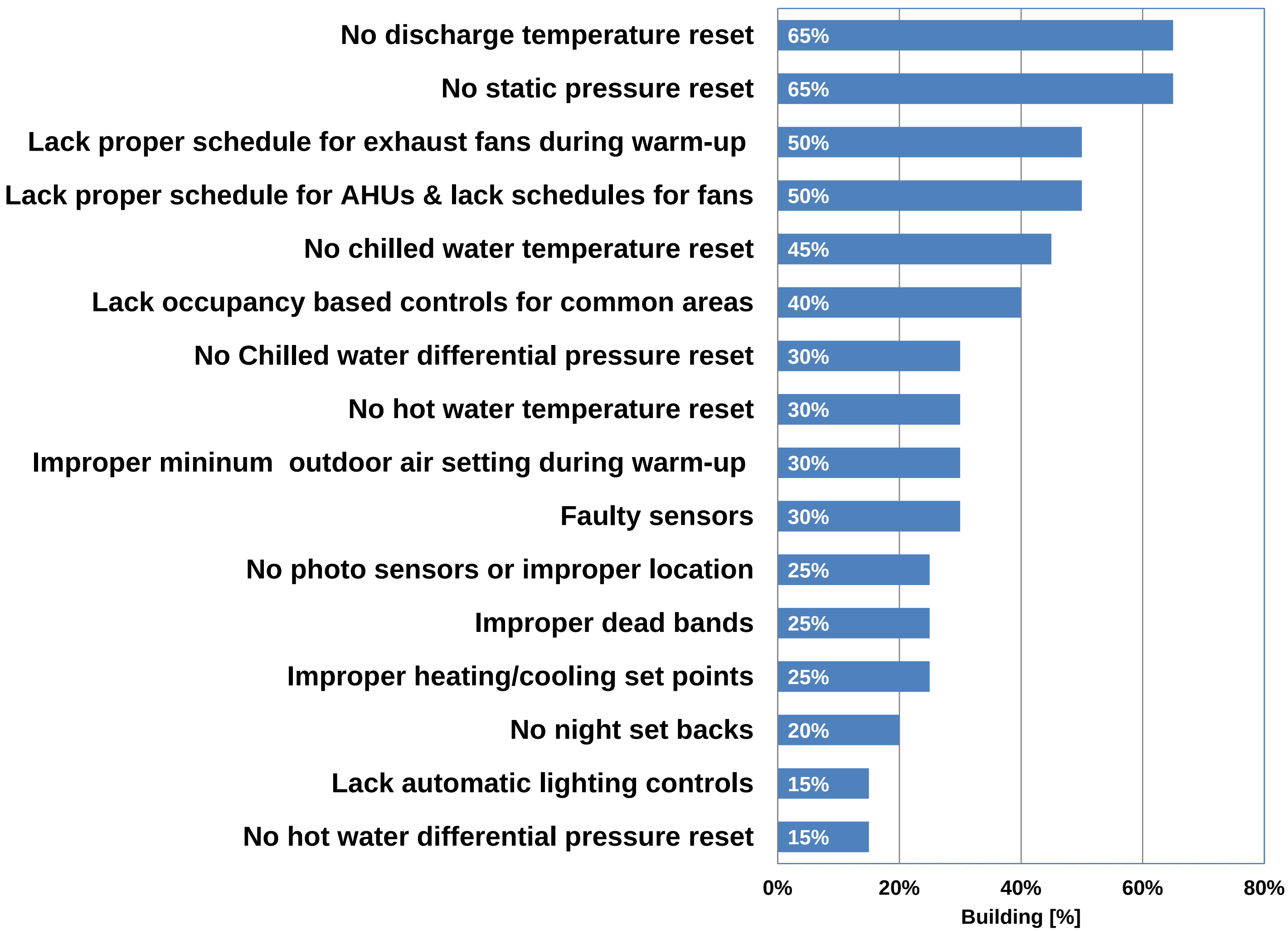


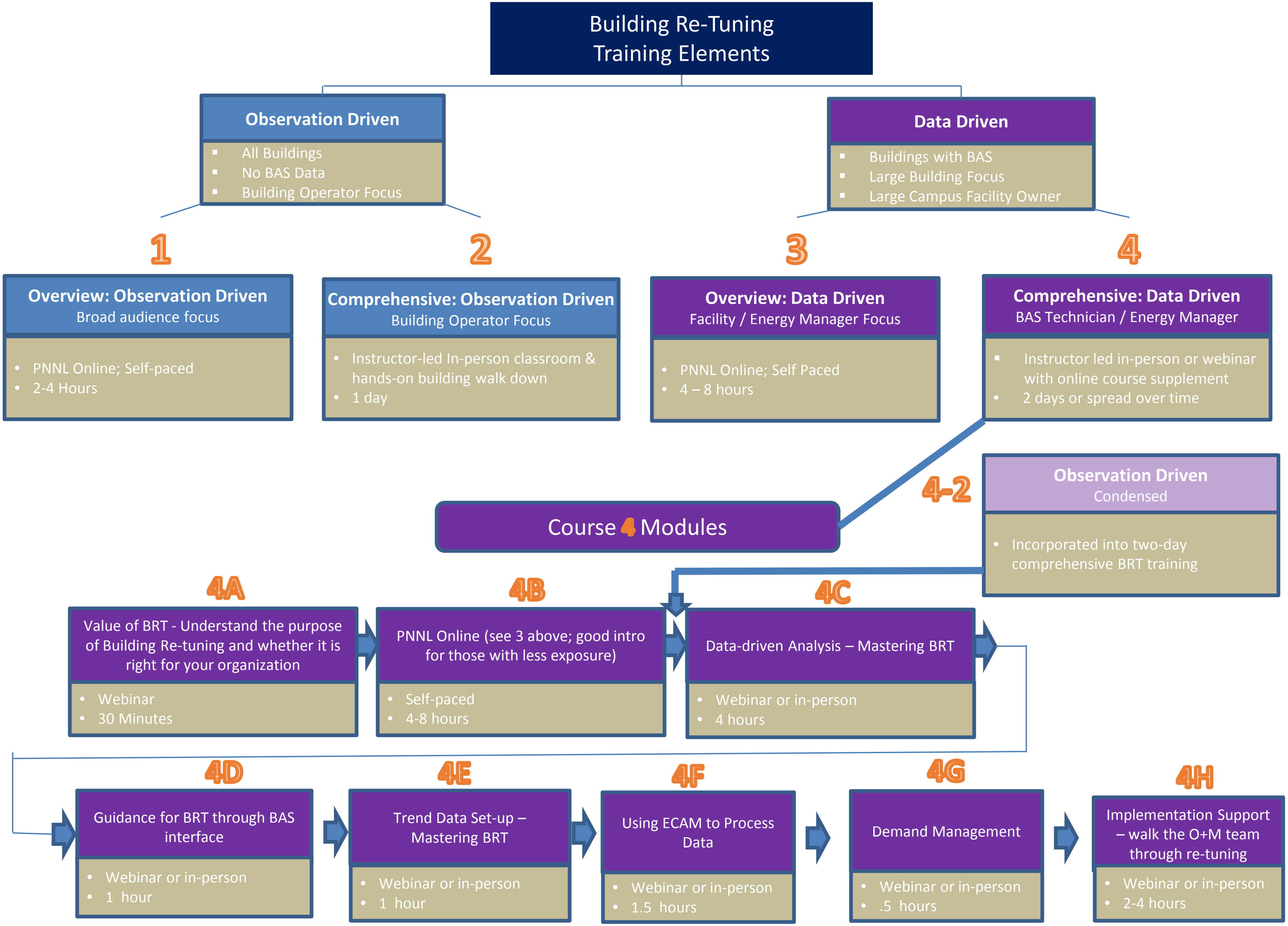
Projected kWh usage based on a year's monthly consumption prior to re-tuning and weather normalized

Real Results from BRT:
PNNL Meta-Analysis

- 100 buildings underwent re-tuning using the BAS Data-driven Analysis technique
- The majority of the buildings were from large portfolio owners and the GSA
- Annual energy savings ranged between 2% to 26%, with a median savings of 15%
- Annual normalized cost savings ranged between \$0.05/sf to \$0.60/sf, with a median savings of \$0.12/sf

Real Results from BRT:
Most Common Re-tuning Measures




Building Re-Tuning Training Elements
Observation Driven
All Buildings
No BAS Data
Building Operator Focus
Data Driven
Buildings with BAS
Large Building Focus
Large Campus Facility Owner
1
Overview: Observation Driven
Broad audience focus
PNNL Online; Self-paced
2-4 Hours
2
Comprehensive: Observation Driven
Building Operator Focus
Instructor-led In-person classroom & hands-on building walk down
1 day
3
Overview: Data Driven
Facility / Energy Manager Focus
PNNL Online; Self Paced
4 – 8 hours
4
Comprehensive: Data Driven
BAS Technician / Energy Manager
Instructor led in-person or webinar with online course supplement
2 days or spread over time
4-2
Observation Driven
Condensed
Incorporated into two-day comprehensive BRT training
Course 4 Modules
4A
Value of BRT - Understand the purpose of Building Re-tuning and whether it is right for your organization
Webinar
30 Minutes
4B
PNNL Online (see 3 above; good intro for those with less exposure)
Self-paced
4-8 hours
4C
Data-driven Analysis – Mastering BRT
Webinar or in-person
4 hours
4D
Guidance for BRT through BAS interface
Webinar or in-person
1 hour
4E
Trend Data Set-up – Mastering BRT
Webinar or in-person
1 hour
4F
Using ECAM to Process Data
Webinar or in-person
1.5 hours
4G
Demand Management
Webinar or in-person
.5 hours
4H
Implementation Support – walk the O+M team through re-tuning
Webinar or in-person
2-4 hours

Thanks

- Next up: Observation-Driven Building Retuning

Observation-Driven Re-tuning Training Module 2

Goals for this portion of training

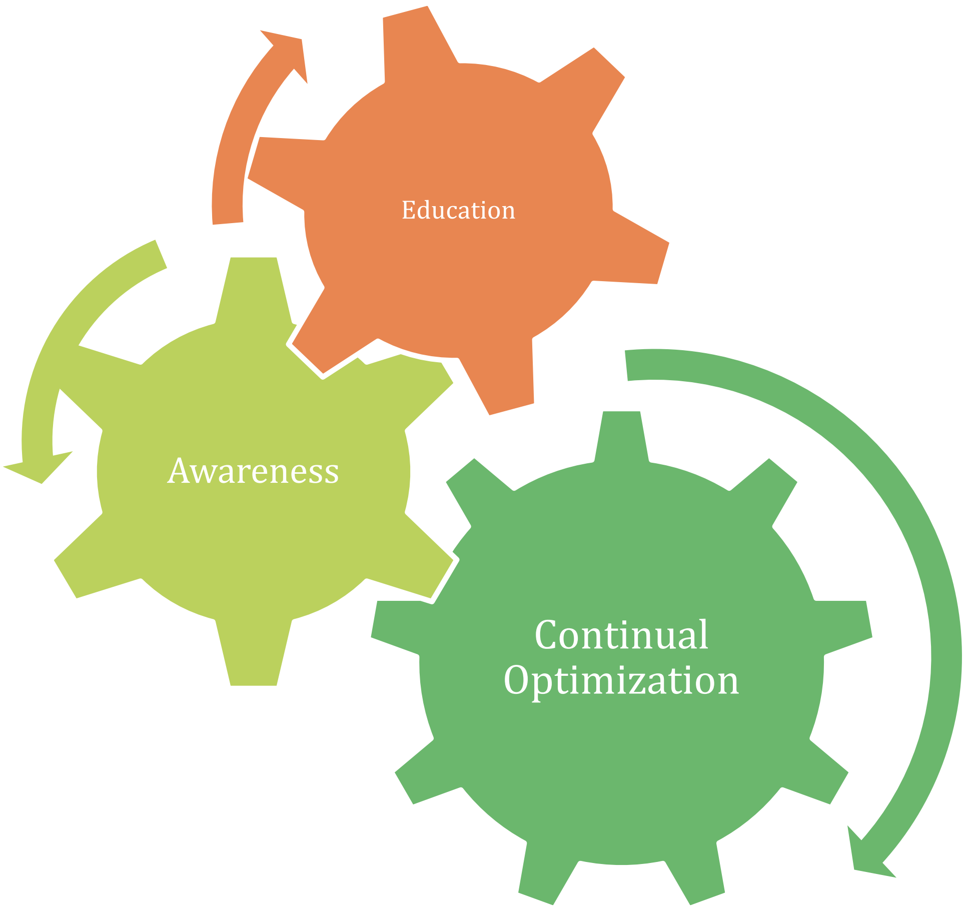
- Become familiar with building re-tuning process for non-BAS applications

Observation-Driven Building Re-tuning Training: Introduction

- The purpose of this training is to train students/technicians on how to make buildings more efficient, leading to energy savings and reduced costs
- The knowledge and skills learned through the training will be highly valued by organizations and companies seeking to improve the performance of buildings
- It will also prepare the participating students/technicians for hands-on field training
- It will also provide an opportunity for students/technicians to ask questions and get clarification on any aspect of the re-tuning process

Observation-Driven Building Re-tuning Training: Definition

Re-Tuning Is Going Back To Basics



Observation-Driven Building Re-tuning Training: Common Energy Conservation Efforts

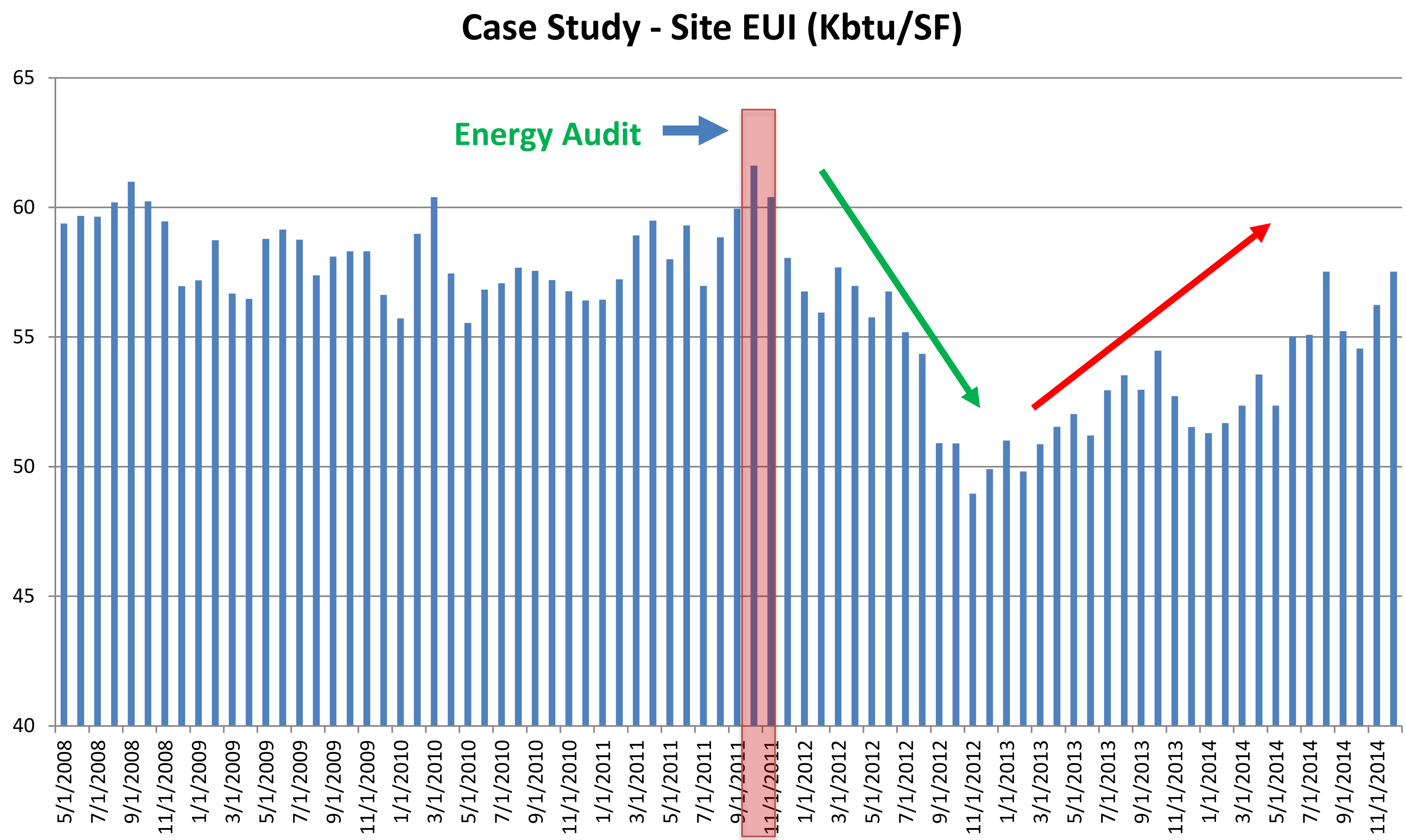
New Construction Commissioning

Energy Audits

Retro-commissioning

New --- Building Life Cycle --- Existing

Observation-Driven Building Re-tuning Training: Definition



Observation-Driven Building Re-tuning Training: Definition

Building re-tuning is a systematic process to identify and correct no/low cost operational problems that lead to energy waste

- Many of the recommendations for efficiency improvements will be prescriptive

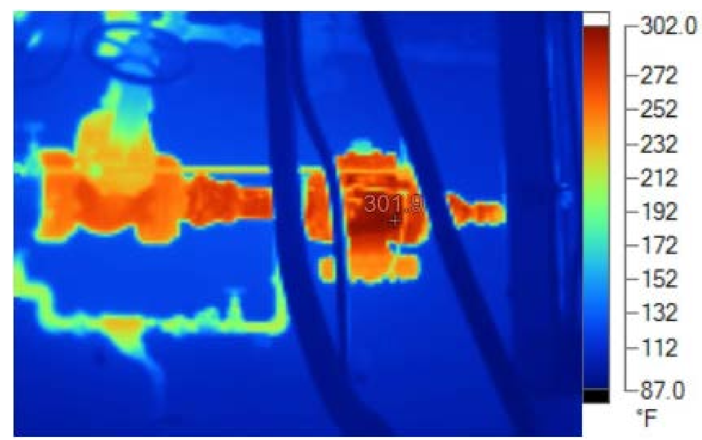
Observation-Driven Building Re-tuning Training: Approach

It will use a **four step approach**

1. **Initial data collection phase:** Collection of information about the building
2. **Investigation phase:** Building walkdown to identify and characterize the building operations
3. **Implementation phase:** Application of prescriptive re-tuning measures
4. **Documentation phase:** Reporting of measures implemented and calculation of energy savings

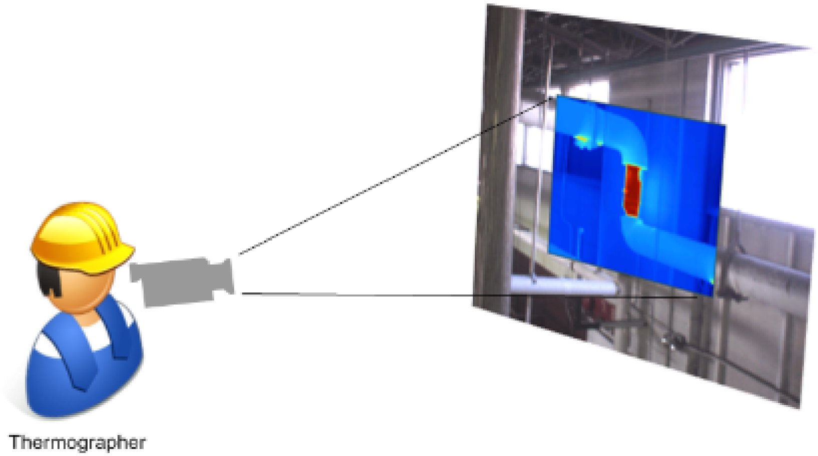
Small/Medium-Sized Building Re-tuning Training: Major Focus Areas

- Building Envelope
- Heating, Ventilation and Air-Conditioning Systems and Controls
  - Packaged air conditioners, heat pumps and gas furnaces
- Lighting System and Controls
- Hot Water
- Office Equipment
- Air distribution system
- Meter Profile



Observation-Driven Building Re-tuning Training: Basic Energy Management Principles

- If you don't need it, turn it off
- If you don't need it at full power, turn it down
- Make "smart" energy decisions when adjusting systems to the real building needs
- Save energy without negatively impacting the comfort of the occupants



Observation-Driven Building Re-tuning Training: Basic Energy Management Principles

Parents
- Buildings designed by "Parents"
- Engineers with best guess use information
- Some weather and load conditions

Design

Childhood Years
- Built with low bid or value engineered design
- Tight schedules
- Limited inspections or commissioning

Construction

Teenage Years
- Use changes
- Staff changes
- Wear and tear

Early Use

Adult Years
- High energy use
- High complaints

Current

Result:
Best guess design can result in improper configuration of HVAC systems

Result:
Lack of commissioning can leave installation issues unresolved

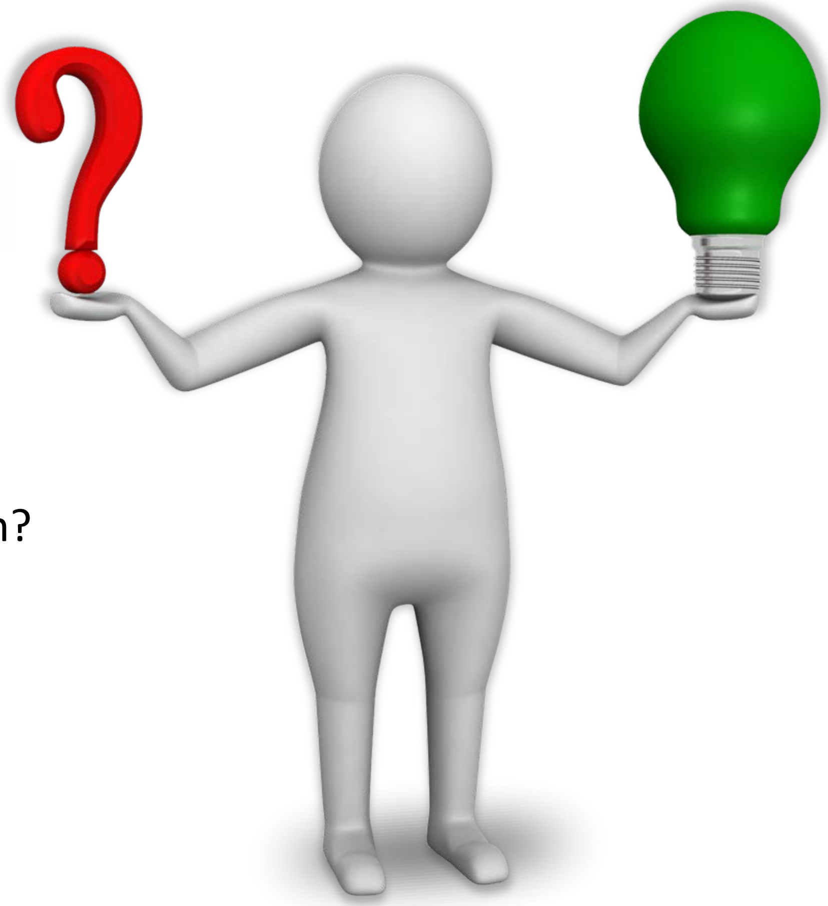
Result:
Staff changes and lack of training can perpetuate problems

Result:
Complaint based operations can lead to poor operations

Get to Know Your Building:
What is Your Building's Personality?

- How does it act or respond to changing internal conditions?
- How does it respond to weather changes?
- What is its balance point, a point where no heating or cooling is required to maintain comfort in the building?
- If the building is lightly occupied on weekends, how does it behave?
- How does it react at night with setbacks?

If it is status quo, ask why?



Questions

- Why is this temperature set at this level?
- Why is equipment turned on at 6:00 am?
- Who made that decision?
- To those conditions still exist?

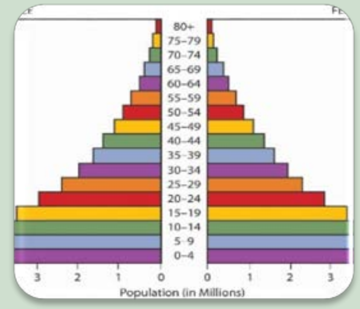
Results

- If conditions have changed, try new settings
- If people who made the decision are gone, revaluate the decision
- Consider trying new retuning ideas and see what happens

Collection of Basic Building Information: Initial Data Collection Phase

- This is the first step in the building re-tuning process
- Information collected in this step is used to plan the building walkdown or the **Investigation Phase**

Collection of Basic Building Information



Building & Usage Basics

Cooling Degree Days

Heating Degree Days

Occupant Complaints

Collection of Basic Building Information

- Size, age and type of building
- As-built and construction documents
- O&M Manuals, Sequence of Operations (SOO)
- Types of equipment, recent repairs
- Equipment maintenance schedules
- Review logs (e.g. tenant complaints, etc.)
- Construction or changes to the building
- Building occupancy/equipment schedules
- Use/mission of the building
- Meter data (Utility for Electric, Gas, Oil, etc…)

Collection of Basic Building Information: Building Information Log Example

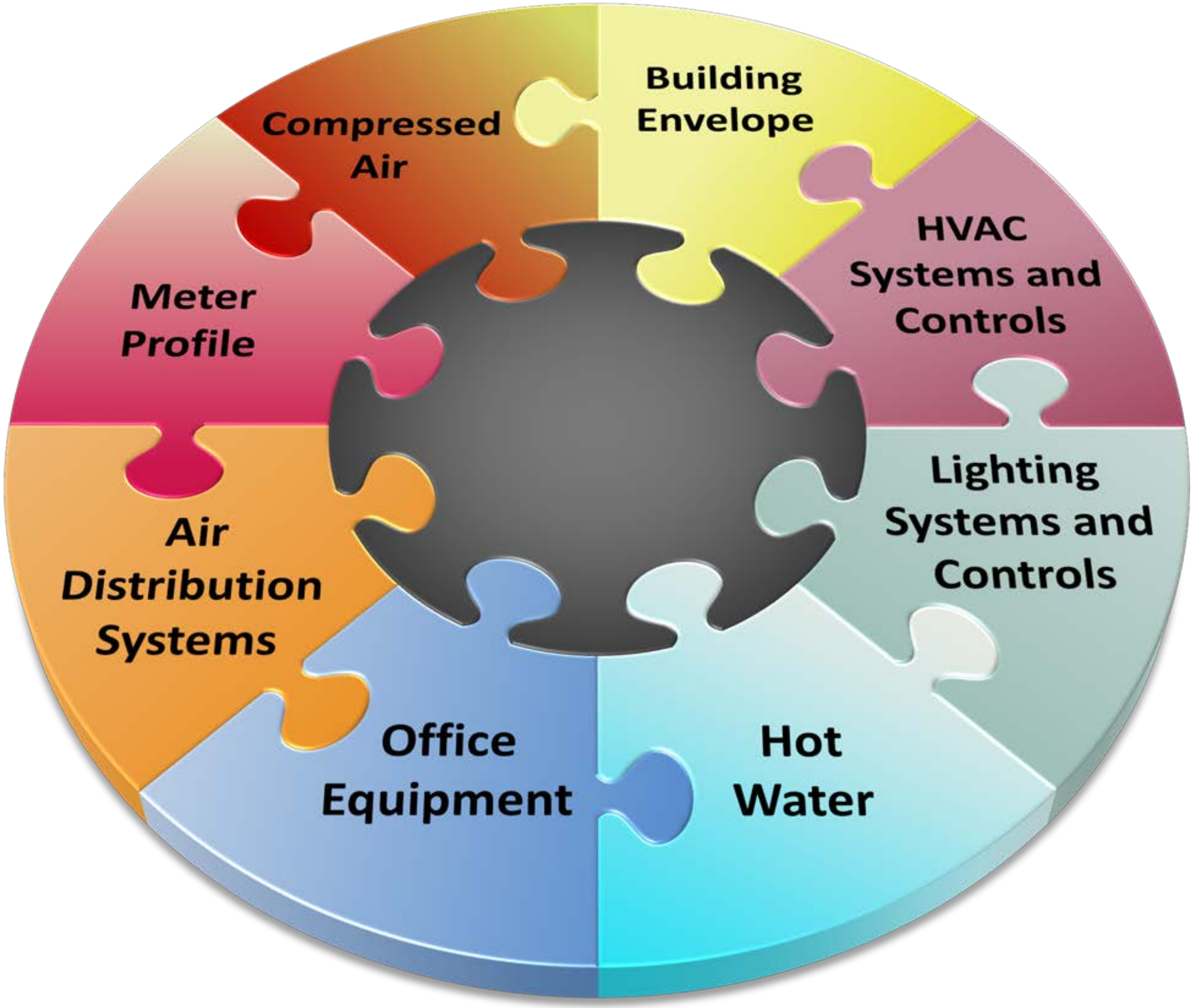
Building Survey

- ❑ When was the building constructed?
- ❑ When was the building most recently renovated?
- ❑ How many floors are there?
- ❑ What is the approximate gross square footage of the building?
- ❑ What is the general shape of the building?
- ❑ What are the different uses of the building?
  - ❑ Offices: ________
  - ❑ Classrooms: __________
  - ❑ Computers/Servers: __________
  - ❑ How many computers are in the building? __________
  - ❑ When are they on?
- ❑ What is your buildings monthly energy consumption in kWh for January through December?
  - ❑ January: ___________
  - ❑ February: __________

Building Walkdown: Investigation Phase

- This is the second step in the building re-tuning process – the **Investigation Phase**
- Information collected in this step is used to identify the operational problems and energy savings opportunities to plan implementation of re-tuning measures

Building Walkdown: Focus Areas



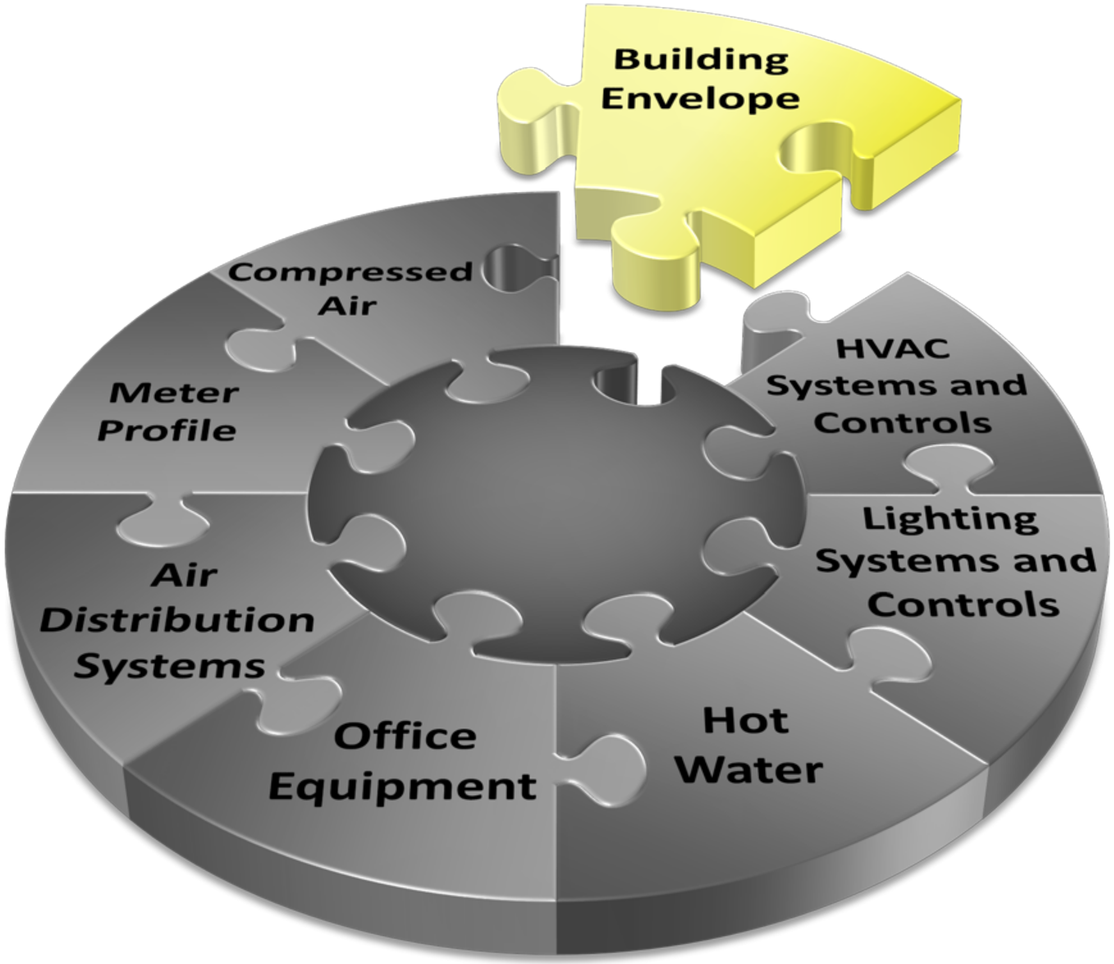
Building Walkdown: Guidance

- While walking down to investigate the building's condition and operations, be vigilant, use your senses – look, listen, smell and touch (be careful!)
- If possible, perform the walkdown during both occupied hours and unoccupied hours
- A lot of energy waste typically occurs during unoccupied periods and holidays
- Walkdown at least once during the heating season and the cooling season
- Log all information on the log sheets – this will help you calculate energy savings

"You can observe a lot by just watching."
—Yogi Berra

Building Walkdown:
Tools to Carry

Building Walkdown: Envelope



Envelope

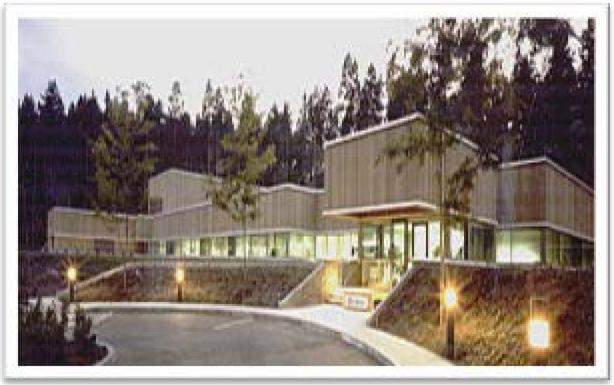
- Walking down the outside and inside the building
- Doors
- Windows
- Openings
- Shades
- Exterior Plug Loads
- Insulation
- Roof
- Attic and Crawl Spaces

Building Envelope Walkdown: Doors and Windows

Focus on the exterior conditions of the building

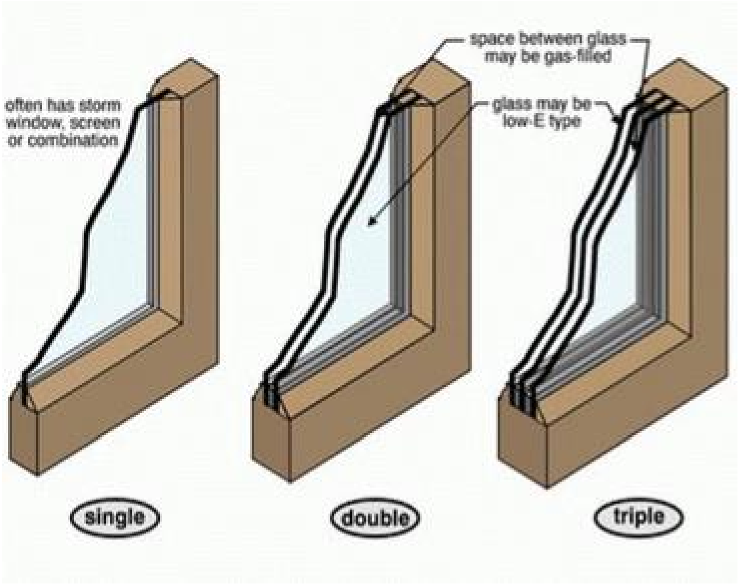
Door and window type:

- ❑ Are the windows operable?
- ❑ Are the windows single, double or triple pane?
- ❑ Are any windows and outside doors open during the walkdown?
- ❑ **If windows and doors are open, this could indicate a problem related to heating, cooling or ventilation**



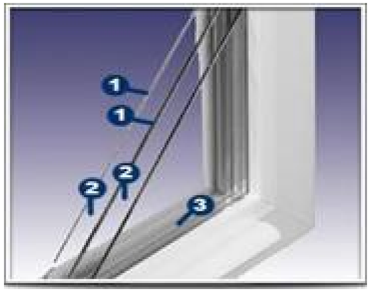
Building Envelope Walkdown: Doors and Windows

- Cost savings for upgrading windows will vary from location to location
- Local utilities may offer incentives to upgrade



www.dsireusa.org

Database of State Incentives for Renewables & Efficiency



Building Envelope Walkdown: Doors and Windows

Door and window seals:

- ❑ Check seals around doors and windows – are there large air gaps?
- ❑ Are the seals missing?
- ❑ Look for cracks in the caulking for the windows, doors and seismic joints
- ❑ Missing caulking?
- ❑ Moisture between panes? Cracks in the panes?

Building Envelope Walkdown: Openings

Cracks and penetrations in the foundation

Gaps under doorways

Use Weatherstripping Calculator

Building Envelope Walkdown: Openings

Cracked and deteriorated EIFS material, exposing insulation to elements

Damage to exterior material leading to potential water infiltration

Building Envelope Walkdown: Openings

- Lack of insulation around ac unit
- Old caulking worn off



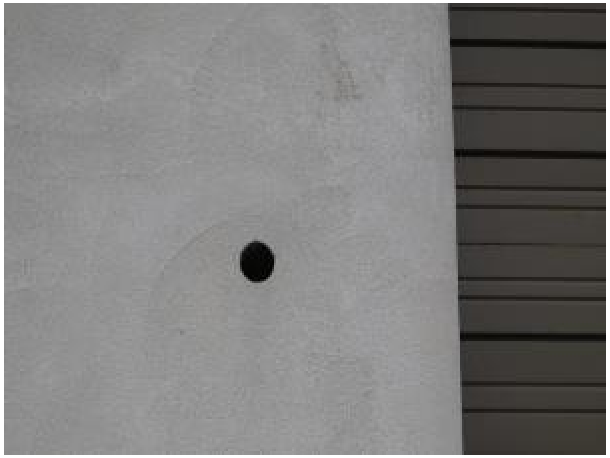
Building Envelope Walkdown: Shades

- Operable shades, if used properly, can reduce cooling load in summer time (fully closed) and provide day lighting and solar heat gain during winter time (open)
- Check if shades are being used appropriately
- If the windows are missing shades or not using shades, recommend adding shades and using them properly

Building Envelope Walkdown: Unsealed Penetrations in the Envelope

Are there unsealed penetrations in the building?

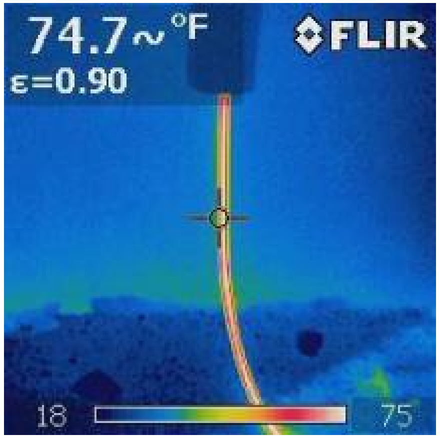
- Look for penetrations around seams or pipe penetrations in the building envelope
- Improperly sealed holes will allow for increased infiltration into the building, which will lead to increased heating and cooling loads on the HVAC equipment
- Have there been any problems or indication of vermin (mice or rats) entering the building? **This could be a health safety issue**



Building Envelope Walkdown:
Heat Traces and other exterior plug loads

Some buildings may use heat traces on outside water lines, gutters or storm drains to avoid freezing or ice/snow build up

- ❑ Touch and feel for heat (be careful!) – better to use thermal camera
- ❑ If they are on during summer, spring or fall, recommend that they be turned off until needed

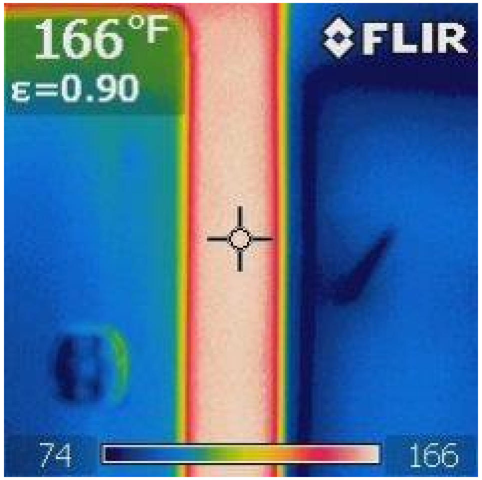


Building Envelope Walkdown: Insulation

- Use a temperature gun (or infrared camera) and take temperature readings of the walls and the ceiling
- Look for missing insulation on any piping that carries heated or chilled water or steam
- Missing insulation will contribute to energy costs and is a low cost fix

Use Insulation Calculator & 3E Plus Program

Heat loss in thermal envelope



Building Envelope Walkdown: Insulation

- Use tools to check wall temperatures
- Check interior and exterior wall temperatures.

Building Envelope Walkdown: Insulation

Building Envelope Walkdown: Insulation

- If the perimeter wall temperature of a perimeter office/space is significantly different from the other interior wall temperatures of the same space, the perimeter wall may not have adequate insulation or it has been compromised at strategic locations that should be further evaluated for potential improvements.
- A well- insulated wall should show a large temperature difference between the outdoor and indoor temperature

Building Envelope Walkdown: Insulation

- ❑ Lack of insulation for pipes
- ❑ Suction line needs to be properly insulated



Building Envelope Walkdown: Roof

- ❑ Is the roof white?
- ❑ Is it clean and no debris?
- ❑ A white membrane roof needs to be clean; it has its best insulating properties when the roof is clean
- ❑ As much as 3 degrees of improvement in surface temperature (better heat rejection) versus a dirty roof

Source: http://www.daisygreenmagazine.co.uk/lifestyle-main/features- living/paint-the-town-white/ Dec. 11, 2012

Building Envelope Walkdown: Roof

- Small leaks can lead to significant water infiltration and damage

A section of the roof was pulled up to reveal the wet insulation, which is approximately 1” thick

Building Envelope Walkdown: Roof

- Small leaks can lead to significant water infiltration and damage

Infiltration of water suspected to have corroded steel reinforcement, which in turn compromised the bond between the concrete and steel reinforcement, and led to failure of the concrete canopy

Building Envelope Walkdown: Discussion Question

There can be as much as a 3°F of improvement in surface temperature for a clean roof compared to a dirty roof.

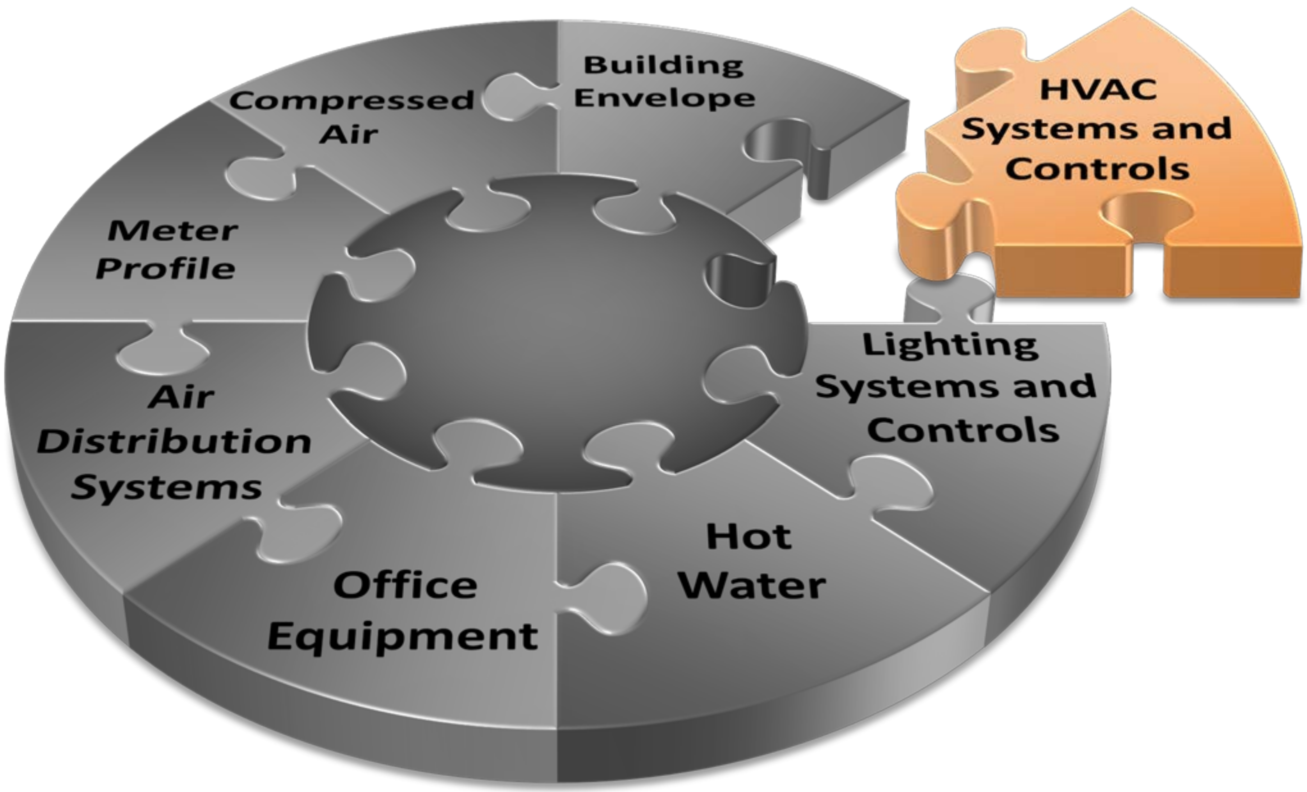
True or False?

Answer: True

Building Envelope Walkdown: Attic and Crawl Spaces

- Ventilation of attic and crawl spaces
  - Look for crawl space vents and attic vents that are closed or plugged
- Look for powered exhaust in attics
  - Do they have backdraft dampers?
  - Check if the temperature controls for the fan are working
- Look for missing or damaged insulation in attic or crawl spaces
  - Damaged by water or animals?
  - Hanging loose from roof deck?
- Look for abandoned vents in lunchrooms (that were used to exhaust stove heat)
  - These abandoned legacy vents can let outdoor air into the building if not properly sealed.

Building Walkdown:
HVAC Systems and Controls



HVAC

- Systems
- Economizers
- Air distribution systems
- Air handling units
- Pumps
- Plant are
- Thermostats

Building Walkdown:
HVAC Systems and Controls

- Small/medium-sized buildings typically have **packaged air conditioners** with gas furnaces or heat pumps with either gas furnace or auxiliary electric strip heating
- Gas-Fired Equipment
  - Verify that the combustion-air intake is properly configured with **no blockages**
  - Verify that the gas pressure regulator is set correctly (trained technician)
- Packaged units are typically **controlled by wall mounted thermostats** with varying functionality
- Many of these units are not properly maintained

Building Walkdown:
HVAC Systems and Controls

While walking down, count how many units are serving the building

Note the type of units:

- ❑ Split or packaged?
- ❑ Air conditioners with gas furnace or heat pumps with auxiliary electric heating?
- ❑ Tonnage of the units?

Source: http://www.achrnews.com/articles/rooftop-maintenance-checked Dec. 11, 2012

Building Walkdown: HVAC Systems and Controls

While examining the HVAC equipment, look for:

- ❑ Missing panels/access doors or leaking panels/access doors
- ❑ Outdoor-air dampers wide open or fully closed
- ❑ Missing condenser fans
- ❑ Poor maintenance (oil leakage at refrigerant connections, etc.)
- ❑ Other conditions that might affect performance

Building Walkdown:
HVAC Systems – Visual Inspection

What to look for:

- ❑ Missing or damaged panels/access doors or seals for them
  Damaged/Dirty indoor or outdoor coils
- ❑ Missing or damaged mechanical items (fan motors/blades/belts)
- ❑ Use cogged V-belts & high-efficiency motors for better performance

1 or 2% efficiency improvement by tightening belt

Building Walkdown:
HVAC Systems–Visual, Audible & Sensory Inspection

What to look, listen and feel for:

- Oil leaks or drips from the refrigeration system or components of the unit. This type of problem may require training on how to properly handle refrigerant & should be done by an authorized person
- Coil condition – deteriorating due to corrosive air (salt water, etc)
- Feel and listen for air leaks around exposed ductwork or the roof curb for a rooftop unit. This may be hard to fix, but it is wasting energy and should be identified
- Refrigerant line sets should be adequately protected on split systems and packaged rooftop units
- Low pressure suction lines should be adequately insulated for efficiency

Building Walkdown:
HVAC Systems – Visual Inspection

Check the P-trap on the cooling coil

- P-trap should have water in it if the equipment is located in a mechanical space that does not freeze
- P-traps that are located outside need to have water in them when the cooling is running and emptied when the weather changes to fall or winter

For good drainage of the evaporator cabinet (negative pressure across evap. coils)

Building Walkdown:
HVAC Systems – Visual Electrical Inspection

- Burnt or disconnected wiring/electrical components Smell for burning wires or burning oil
- Burnt wires are a sign that the connection is loose or the wire was undersized for the load
- Tightening of electrical connections is something that should be done during regular maintenance
- These connections are generally a screw/lug type of connection that can be tightened with a screwdriver, or Allen head wrench
- ALWAYS FOLLOW ALL SAFETY RULES WHEN WORKING WITH ENERGIZED, ROTATING EQUIPMENT!
- LOCK-OUT TAG-OUT (LOTO) SHOULD ALWAYS BE FOLLOWED!

What is wrong in this picture of a Unit Heater Burner?

Gas-fired unit heater burners that some of the flames were yellow which can cause soot to build up.

Building Walkdown:
HVAC Systems – Visual Inspection of Fan

- Note what type of fan is installed
- Is the fan direct drive, or is the fan driven with belts?
  - Direct drive fans will have the motor mounted in the fan housing
  - Belt-driven fans will have the motor mounted outside of the fan housing on a base that is near the fan housing

Building Walkdown:
HVAC Systems – Visual Inspection of Fan

- Look for debris in the fan wheel and in the fan section
- Look for insulation that has come loose and is hanging or fallen down inside the fan housing or ductwork
- If there are signs of belt debris, the belt is failing!
- Loose screws, bolts, etc.

Floor mounted fan-coil unit has a broken drive belt: motor is running at full speed with no load.

Building Walkdown:
HVAC Systems – Visual Inspection of Driven Fan Motors

Visually Inspect:

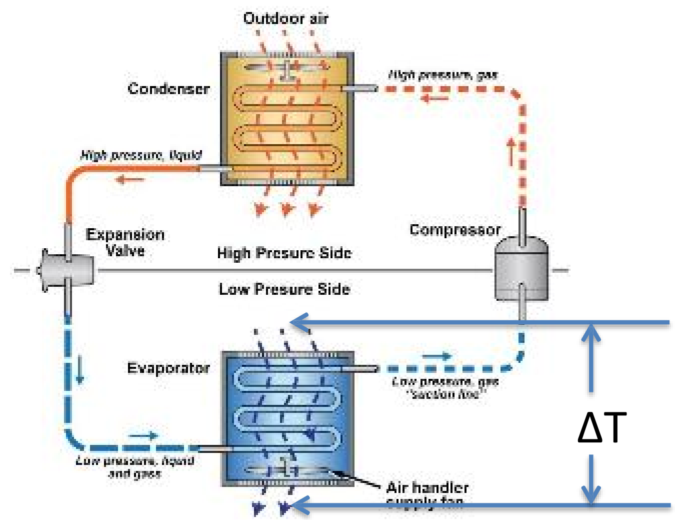
- ❑ Fan motor
- ❑ Fan Wheel
- ❑ Fan Housing
- ❑ Fan Belts
- ❑ Pulley/sheave are in good condition

- ❑ Check fan mounts
- ❑ Check fan bearings for tightness
- ❑ Ensure that the fan is rotating in the correct direction
- ❑ Check pulley alignment
- ❑ Listen for unusual noises or vibrations

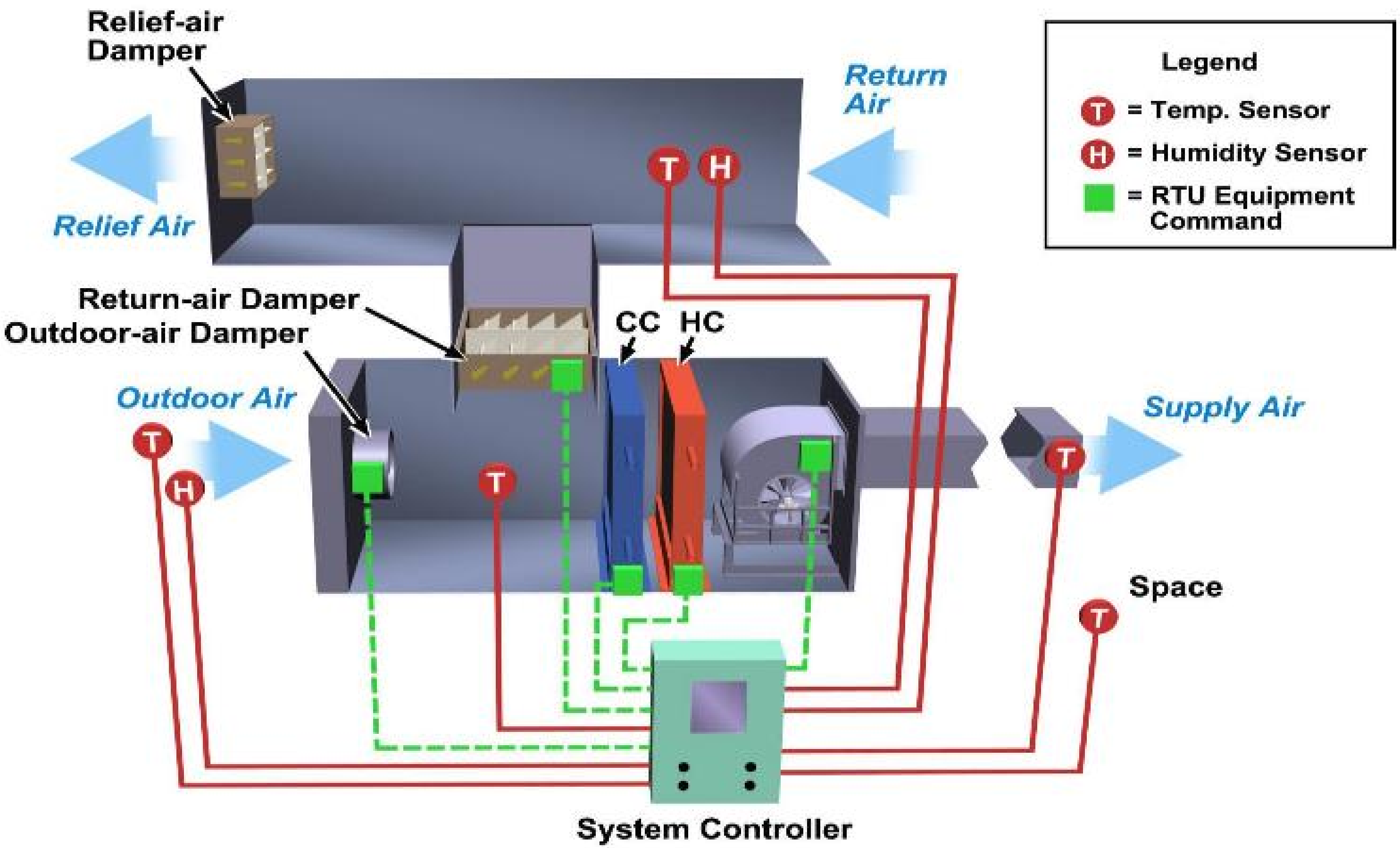
Building Walkdown:
HVAC Systems – Visual Inspection of Coil Section

- ❑ Are the indoor/outdoor coils and fins dirty? Is the coil damaged or leaking?
- ❑ Is the drain pan and drain line clean and clear of debris?
- ❑ In cooling mode, measure the temperature difference across the evaporator coil when the compressor is on
- ❑ Should be 18 to 22°F for a single compressor unit or multi-compressor unit that is fully loaded

Clean any coils that are dirty to increase efficiency of the unit



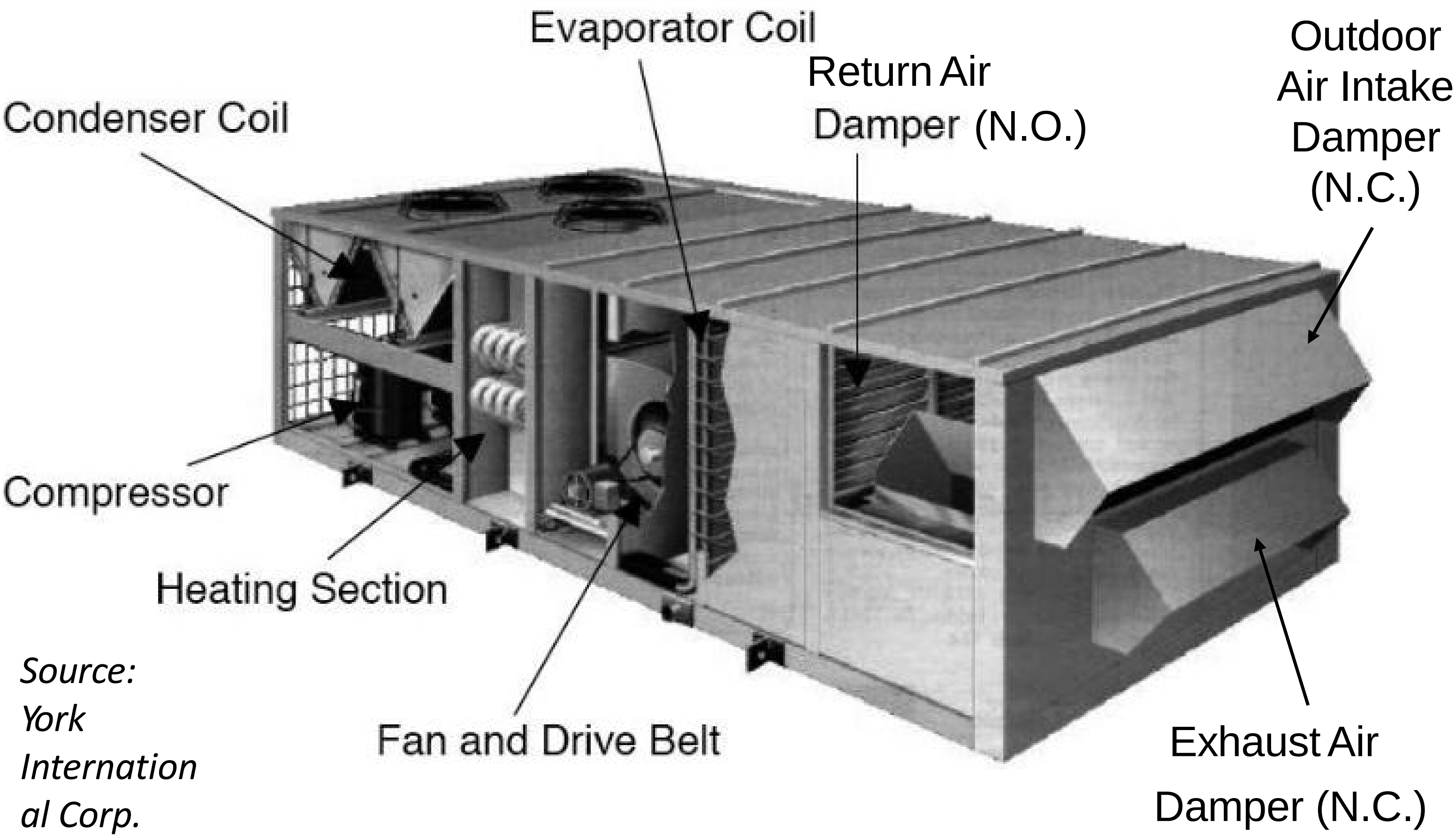
HVAC Economizer Fundamentals: The Basics of Air-side Economizers



Air-side Economizer: "A duct-and-damper arrangement and automatic control system that, together, allow a cooling system to supply outdoor air to reduce or eliminate the need for mechanical cooling during mild or cold weather." (*ASHRAE Standard 90.1-2004*)

HVAC Economizer Fundamentals: Rooftop Unit – Major Components

Notice dampers are either normally open (N.O.) or normally closed (N.C.)



Source: York International Corp.

HVAC Economizer Fundamentals: Common Component Problems

What are some common Component Problems?

- Jammed or frozen outdoor-air damper
- Broken and/or disconnected linkages
- Nonfunctioning actuator or disconnected wires
- Malfunctioning outdoor-air/return-air temperature sensors
- Malfunctioning controller
- Faulty control settings
- Installed wrong or wired incorrectly

HVAC Economizer Fundamentals: Common Component Problems

Jammed/Frozen Damper

Disconnected Damper

Wired poorly

Building Walkdown: Air–Handling Units

- Record type of unit—Variable air volume, constant air volume, single zone, multiple zone
- Variable frequency drives (VFD)
  - Current speed on drive display and current time
  - Watch speed variation
    - Should see some variation
    - No variation indicates it's probably overridden
  - Check position of inlet vanes

Source:http://www.geindustrial.com/products/drives/af-600-fp-fan-pump-drives

Building Walkdown: Pumps

- Determine and record whether each pump is running, leaking, hot, or vibrating unusually
  - If you can't hold your hand on the pump, it's too hot.
  - Isolation valves on running pumps and pumps that are in service should be wide open
- Record temperature and pressure of the water loops
  - Pressure differences of more than 40 psi should be noted and investigated later

Building Walkdown: Plant Area

- Inspect the chillers, boilers, and cooling towers
  - Note chillers and boiler running at the same time
  - Record load on each unit running
  - Record temperature difference across unit
- Inspect valves and record:
  - Alignment (fully open, partially open or closed)
  - Water flowing when not needed

Building Walkdown:
HVAC System Controls – Thermostats

What is wrong in this picture of a boiler stack?

Boiler stack and cap should be replaced with stainless steel or galvanized boiler vent piping and guy-wired braced as needed for proper support.

Building Walkdown:
HVAC System Controls – Thermostats

- Small/medium-sized commercial buildings typically lack central controls
- Typically have wall mounted thermostats to control both heating and cooling systems
- While surveying the thermostats and their capabilities, check:
  - Type of thermostat?
  - Mechanical or digital?
  - If digital, is it programmable?
  - If mechanical, replacing it with a programmable digital thermostat will save energy, if it is properly programmed

Building Walkdown: HVAC System Controls – Thermostats

1. Where are the thermostats located?
   – What is the optimal location?

2. Are the thermostats sensing the temperature of the area they serve, and are they controlling the right piece of equipment in the area they serve?

3. Is there a draft of air coming from behind the thermostat that will affect the temperature that the thermostat is sensing?

4. Are there any overrides on the thermostat?

Building Walkdown:
HVAC System Controls – Thermostats

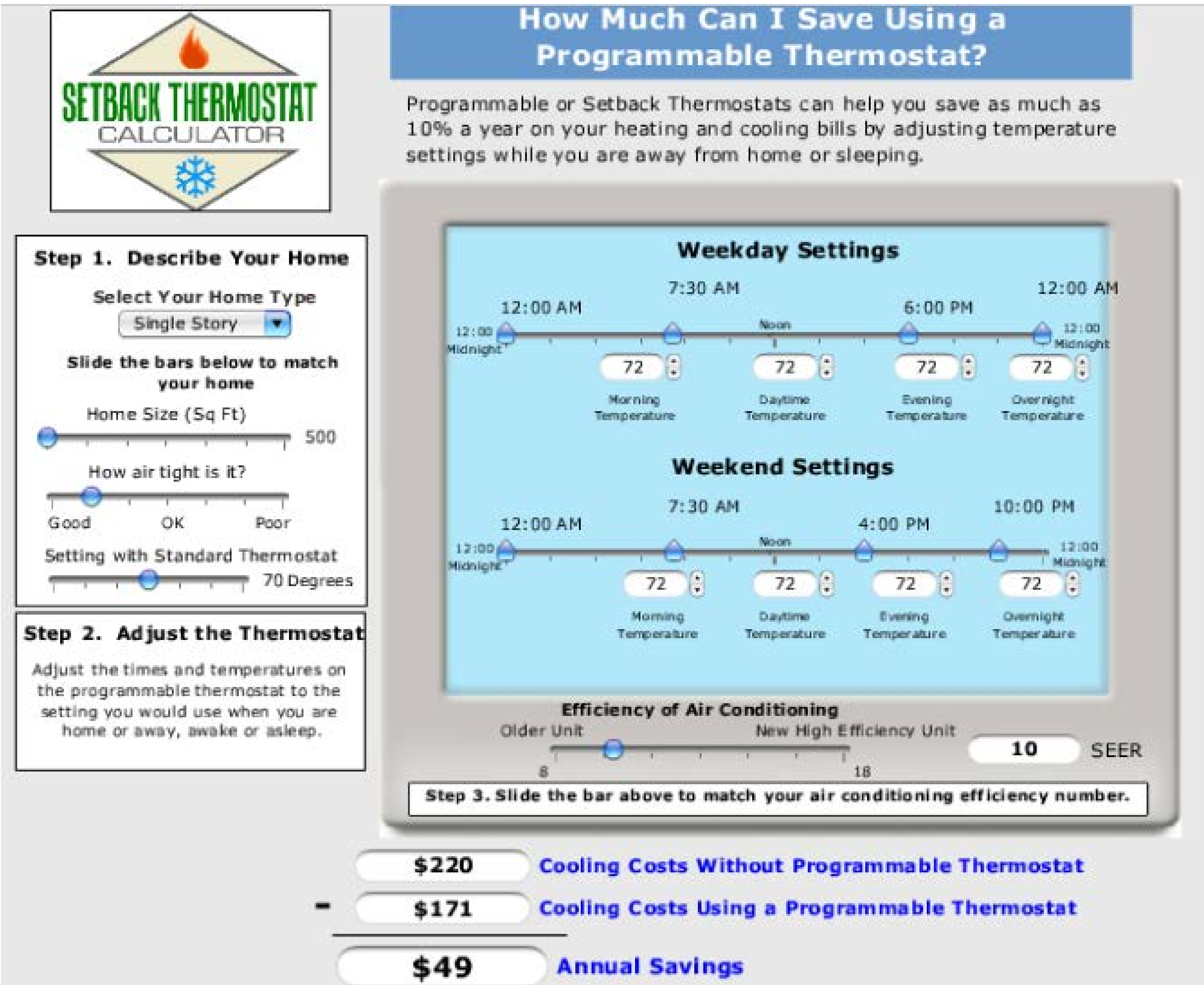
What is wrong in this picture with the thermostat?

Thermostat too close to window and on an exterior wall

What are some Retuning Ideas Related to Thermostats?

1. Digital thermostats that are programmable
2. Scheduling
3. Set points
4. Fan operation
5. Thermostat location
6. Remote sensors

Building Walkdown:
HVAC System Controls – Thermostats Schedules



Building Walkdown: HVAC System Controls – Learning Activity

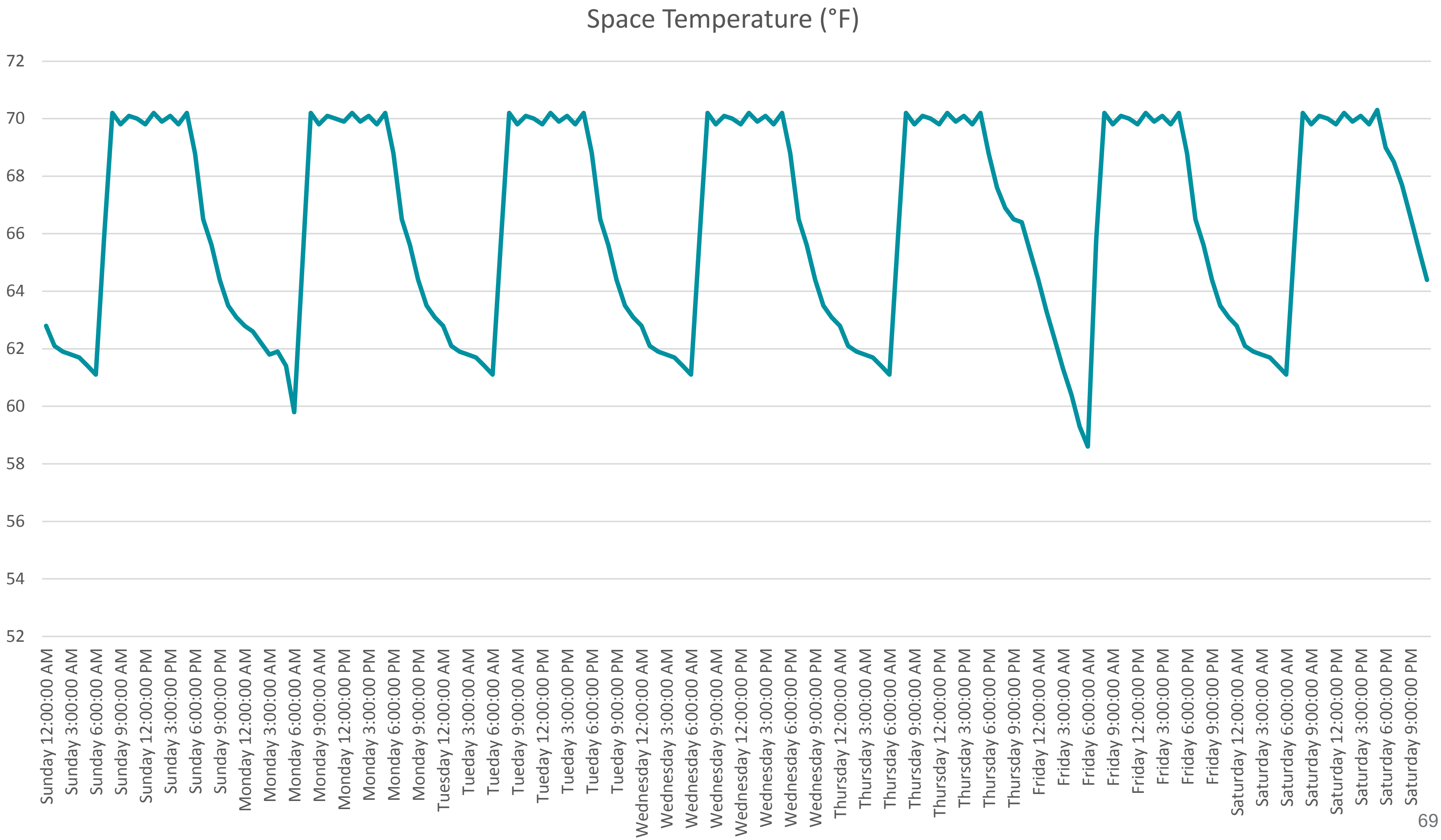
If available, it might be useful to looks at past trends/temperature data to ensure thermostats are properly programmed and system is performing as intended.

Assumptions: Space is Heated and Cooled by a packaged rooftop A/C unit with natural gas heat.

The Building Operations Plan calls for:

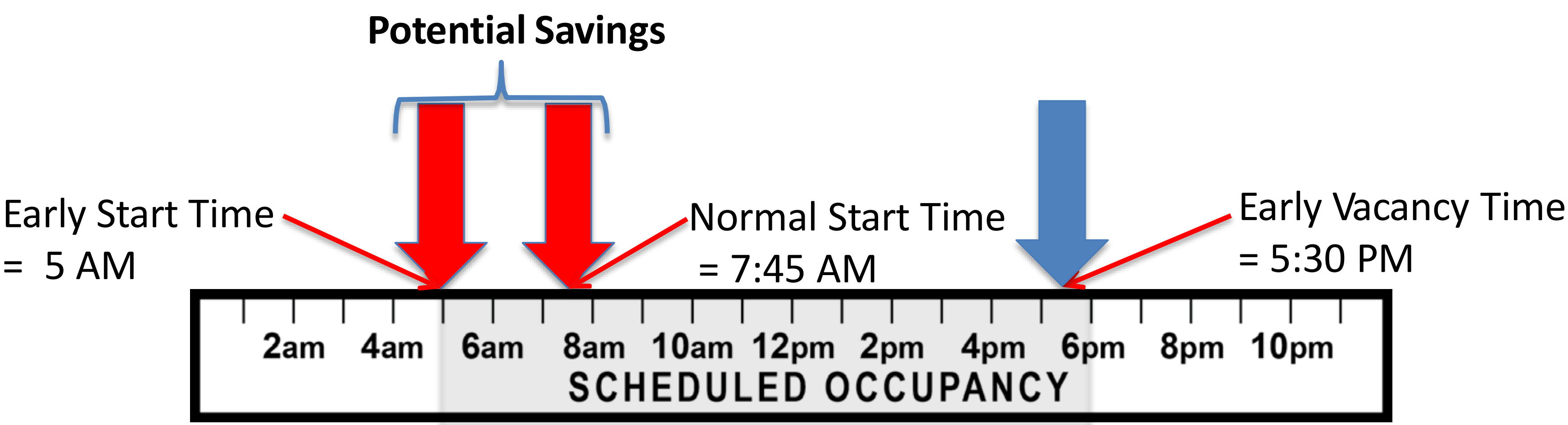
- Heating Setpoints: 70F while occupied
  55F while unoccupied.
- Cooling Setpoints: 72F while Occupied
  80F while Unoccupied
- Space is Occupied: M-F from 7 AM to 5 PM
  Unoccupied all other times

Building Walkdown:
HVAC System Controls – Learning Activity



Building Walkdown:
HVAC System Controls – Thermostats Optimal Start

- Optimal Start (OS) is a feature that can save energy over traditional scheduling programs
- Most schedules are configured to start the HVAC system at the time it would take to heat or cool the space under worst case conditions
- OS will automatically "learn" over time, the optimum time to start the HVAC system to bring space temperatures within 1 to 2oF of occupied requirements at the start of the occupied time period



HVAC Thermostats: Discussion Question

Which thermostat has a better chance of saving energy, a programmable thermostat or a mechanical thermostat?

Answer: A programmable thermostat as long as it is configured properly.

Building Walkdown:
HVAC System Controls – Thermostats Fan Control

- Is the programmable thermostat in “Fan- Auto,” which means that the fan is cycling with the cooling compressor and/or furnace?
- If the thermostat is in “Auto” (instead of “On” or “Run” in Occupied Mode) it can lead to lower ventilation rates than required, especially during spring and fall seasons, when cooling/heating needs are at a minimum
- Commercial building codes may require the RTU supply fans be running continuously to provide adequate ventilation during occupied modes

HVAC Systems:
Discussion Question

List three reasons economizers fail or don't work property.

Answers:

1. Installed wrong
2. Broken or frozen
3. Controller or sensor failure

Building Walkdown: Lighting Systems and Controls

PART OF THE INDOOR AND OUTDOOR BUILDING WALKDOWN

Building Walkdown: Lighting

Lighting

- Interior Lighting Systems and Controls
- Exterior Lighting Systems and Controls

Building Walkdown: Interior Lighting Systems and Controls

Interior Lighting Details

- ❑ Do they have any lighting controls – manual switches, dimmers or time clocks?
- ❑ **Type of lights** (Fluorescent [T12, T8, T5], CFL, LED, Incandescent?)
- ❑ Are proper light levels being maintained or over lighted? Is there opportunity to re-evaluate?
  - ❑ Use light meter to verify that light levels meet IES (Illuminating Engineer Society of North America) recommendations and/or user needs for the spaces. Take many measurements around the space.
  - ❑ Day lighting opportunities?
  - ❑ Are lamps and fixtures clean?

Building Walkdown:
Interior Lighting Systems and Controls

T-12 lighting should be switched out

Convert magnetic ballasts to electronic

Excessive lighting in unoccupied areas

Use Lighting Calculator

Building Walkdown: Interior Lighting Recommended Illumination

Activity	Space Types	Recommended Illumination (lux)	Foot Candles (FC)
Public areas with dark surroundings	Parking garage	20 - 50	2-5
Simple orientation for short visits	Lobbies, storage areas, corridors	50 - 100	5-10
Working areas where visual tasks are only occasionally performed	Waiting areas, auditoriums	50 - 150	5-15
Easy Office Work, Classes	Certain offices and classrooms	200-300	20-30
Normal Office Work, PC Work, Study Library, Groceries, Show Rooms, Laboratories	Certain offices, classrooms, libraries	350-500	35-50
Retail	Supermarkets, Mechanical Workshops	300-800	30-80

Building Walkdown:
Interior Lighting Systems and Controls – Added Notes

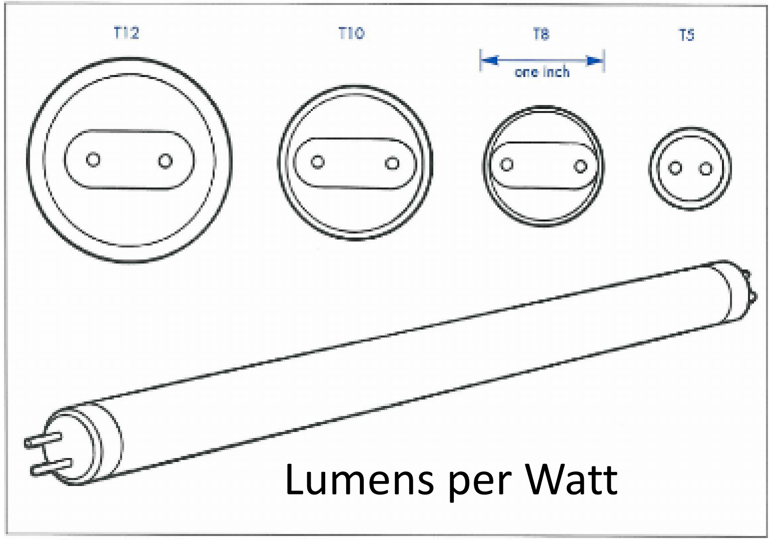
SOLUTIONS

T10s are rare & T12s still exist, but should be replaced

Reduced wattage T8 and T5 save 20% energy, have long (50,000 – 80,000 hour lives), and are inexpensive.

Tubular LEDs (TLEDs) might seem good, but **demonstrate extreme caution, do research, and test on site.**

TLEDs can fit in the fluorescent socket and some can use the existing ballast. However, not all TLEDs work with all ballasts.



Fluorescent is about 93 – 98 lm/W (like miles / gallon) – converting power into light

TLEDs must be more than 110 lm/W to save at least 10% of the energy

Building Walkdown: Exterior Lighting Systems and Controls

Exterior lighting details:

- What type of lights are used outside the building in parking lots and other places?
- Are they controlled with photo sensor or any other time-of-day control system (time clock)?
- Is the photo sensor working correctly (location)? Exterior lights on during the day or coming on too early or staying on too late?
- Do all of the lights need to operate all night long?
- Although replacing exterior lighting can be a larger cost than retuning, it quickly pays because of reduced maintenance.

Light left on during daylight hours

Lighting Systems: Discussion Question

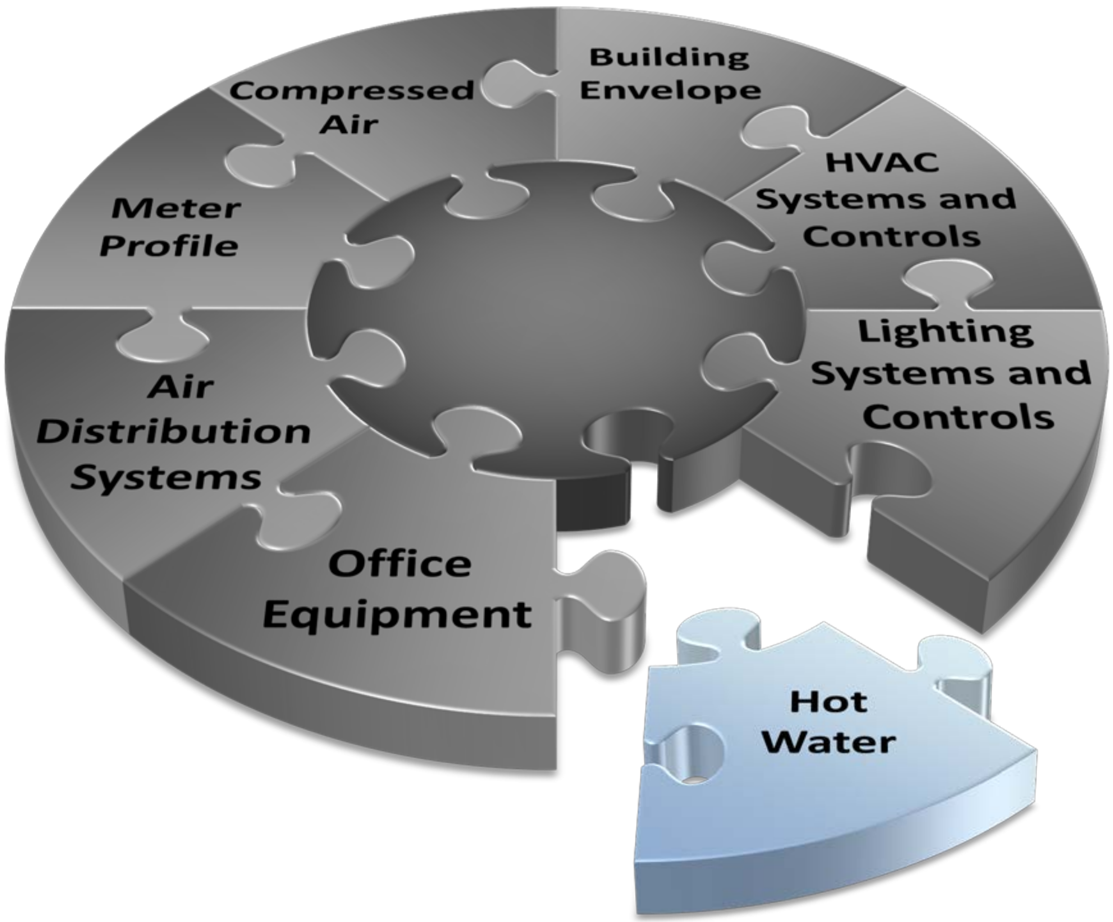
True or False:

1. Posting signs to promote turning lights off helps lower energy usage.
2. T-5 lamps use the most power.
3. When replacing T-12 lamps with T-8 lamps, the existing ballast can be left in place.
4. Dirty fixtures reduce the effectiveness of the light fixtures.

Answers:

1. True, 2. False, 3. False, 4. True

Building Walkdown: Hot Water Systems

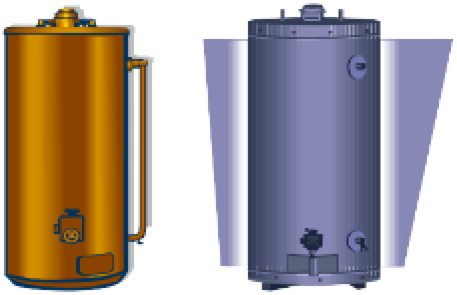


Hot Water

- Hot Water Systems and Steam
- Domestic hot water temperature
- Insulation
- Leaks

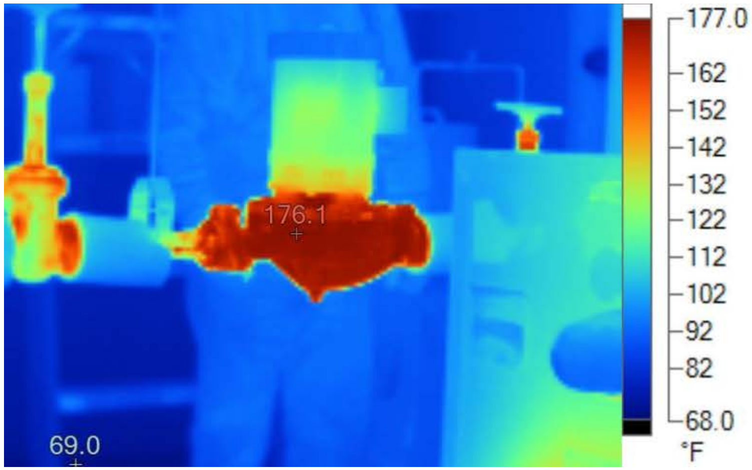
Building Walkdown: Hot Water Systems

- ❑ Type of hot water system – domestic hot water or heating hot water or both?
- ❑ Energy Star rated appliances?
- ❑ Domestic hot water temperature?
- ❑ Are the tanks insulated?
- ❑ Are the plumbing lines insulated?
- ❑ Are there any observable leaks?
- ❑ Faucets leaking?
- ❑ Relief Valves leaking?
- ❑ Zone heating controls in place and working?
- ❑ Set back controls in place and working?

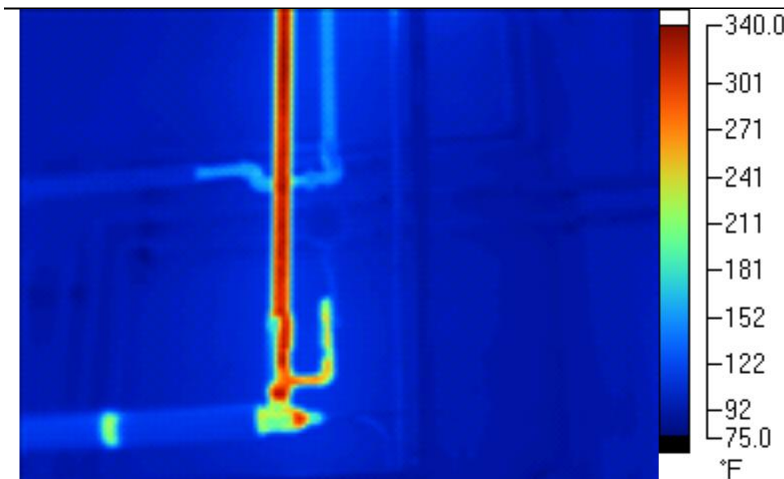


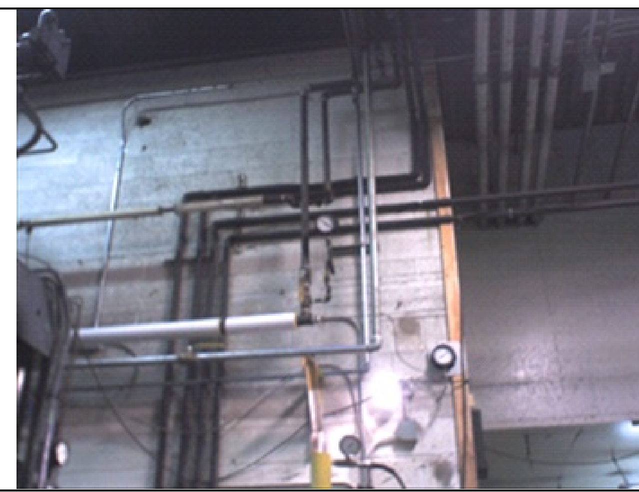
Building Walkdown:
Hot Water Systems and Steam

Use Thermal Camera to Identify Uninsulated Pipes



Pipes that aren't insulated give off a great deal of heat, making the system less efficient





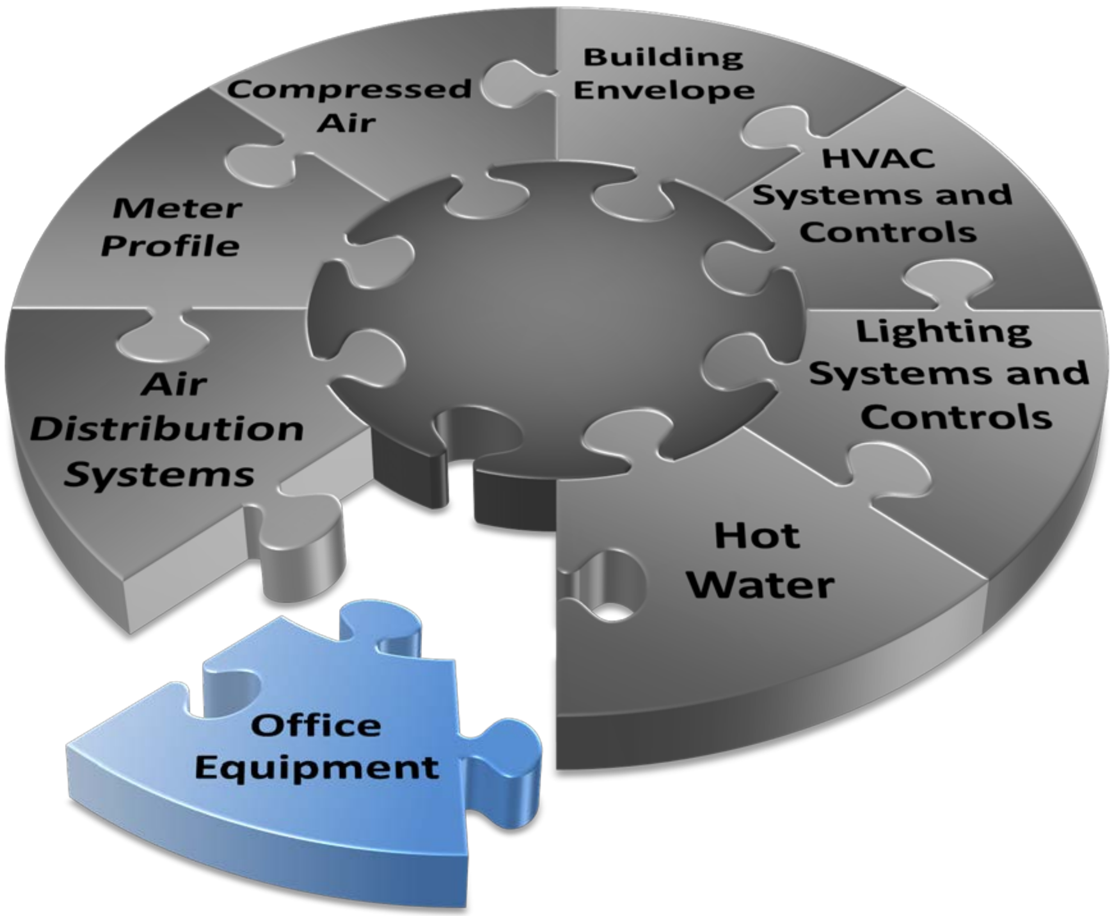
Hot Water Systems: Discussion Question

Heating hot water systems can typically be turned off above what outside air temperature?

Answer: 50-60°

Building Walkdown: Office Equipment

Building Walkdown: Office Equipment



Office Equipment

- Plug Loads
- Computer Equipment
- Energy saving mode
- ENERGY STAR rating
- Space heaters and fans

Building Walkdown: Office Equipment

- Over the past two decades use of office equipment increased significantly and still continues to increase
- There is not much that can be done with the office equipment other than inform staff to turn them off when not in use (weeknights and weekends)
- Some computer equipment can be set up to automatically go into an energy saving mode, if they are configured properly
- During the walk-through, notice if computer screens are off when the office is not occupied
- Are portable space heaters or fans running in unoccupied spaces?
- Energy Star rated appliances and computing resources?

Building Walkdown: Office Equipment

Phantom load = device plugged in but not in use

BAE Systems Plug Load Example:

- 1 phantom load (2 watts) per person
- Devices are operating as phantom loads 20 hours/day, 7 days per week
- 1200 person building
- 50% of the occupants each have one device that counts as a phantom load
- Cost of electricity is $0.14/kW

= 8,760 kWh in phantom load = $1,226*

*does not include peak demand charges

Building Walkdown: Office Equipment

BAE Systems Plug Load Example:

	kWH	Cost	Consumption %
Standard Devices per Day	709.08	**$78.00**	**68.78%**
Additional Devices per Day	321.886	**$35.41**	**31.22%**
Standard Devices per Year	258814.2	**$28,469.56**	**68.78%**
Additional Devices per Year	117488.39	**$12,923.72**	**31.22%**
Total per Day	1030.966	**$113.41**	
Total per Year	376302.59	**$41,393.28**	

Building Walkdown:
Air Distribution Systems

Air Distribution

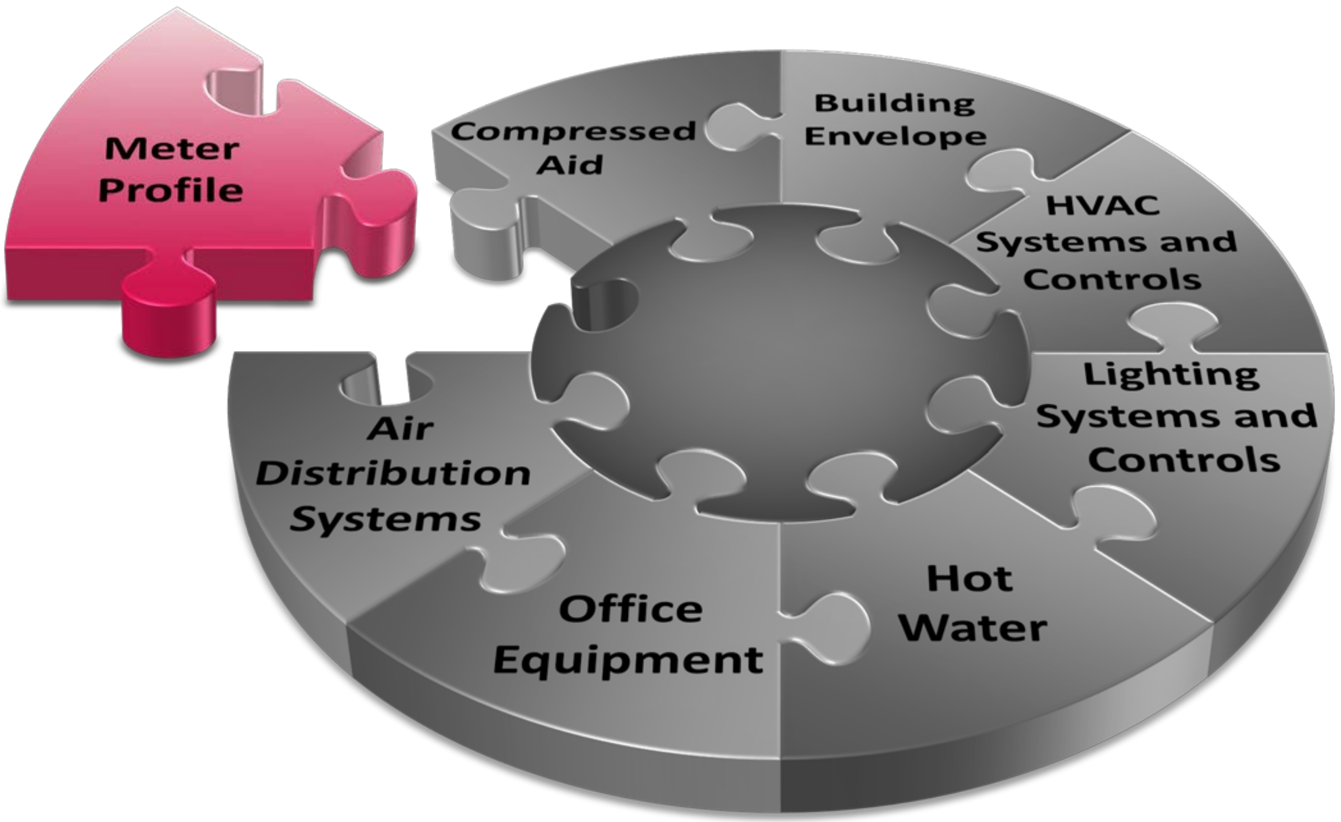
- Re-Sealing Ductwork
- Access (attics and crawl spaces)
- Support
- Duct Failure

Building Walkdown:
Air Distribution System – What to Look for

- Indications of a big leak:
  - If both the space(s) served by the ductwork and the area that the ductwork runs through are at or near the same air temperature
  - Access to attics and crawl spaces is necessary to verify ducts – be careful when in these spaces
- Ductwork that is crushed or flattened
- Ductwork that is sagging or no longer attached to its support hangers
- Dirt/dust trails near joints or seams in the ductwork
- Tape or insulation that is not attached or hanging from the ductwork

Source:http://ardenenvironmental.blogspot.com/201 0/11/duct-blaster-testing.html
Dec. 11, 2012

Building Walkdown: Meter Profile



Meter Profile

- Demand for Services
- Utilities
- Smart Meters

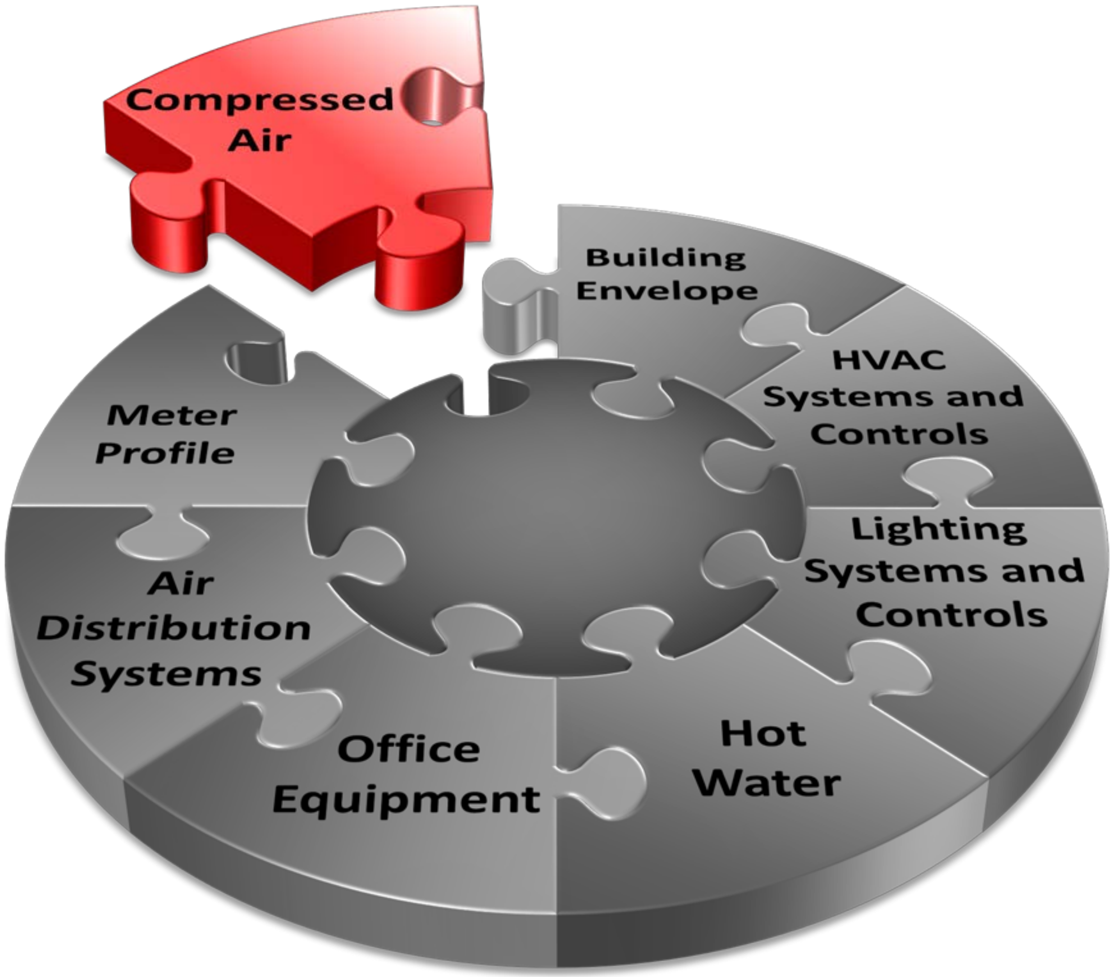
Building Walkdown:
Meter Profile

- Meter Profiles are like a heartbeat
- Will show a variation as the building consumption goes up and down as the demand for services increases

Building Walkdown: Meter Profile

- Periodic review of the meter profile will reveal inconsistent usage
- Utilities in many regions are installing interval meters that provide high resolution interval data
- Data from the utilities can be downloaded from the utilities’ website
- Smart meters may also be installed on the building

Building Walkdown: Compressed Air



Compressed Air

- Pneumatic Systems
- Air Dryers
- Pressure Regulator Setting
- Pneumatic Devices
- Compressor Run Time

Building Walkdown: Compressed Air

- Provides compressed air to pneumatic devices (thermostats, actuators, transducers, controllers, etc.)
- Record and evaluate:
  - Air dryer functioning
  - Reduced pressure regulator setting (should be between 20 and 25 psi; any lower will affect controls).
  - Compressor run (on) time versus off time (should be close to 30% run (on) time versus 70% off time.

Source:http://www.championpneumatic.com

Building Walkdown: Compressed Air

- Compressed Air Leakage
- How would you address an issue like this?

- Listen for leaks in tubing (if bad enough)
- Soap joints to look for leaks and tighten

Building Walkdown: Example Findings

SOLUTION

Remove and replace the door seal weather stripping!
Remember, you can get an estimate of the savings by calculating the BTU loss/gain.

Roll Up Doors

SOLUTION

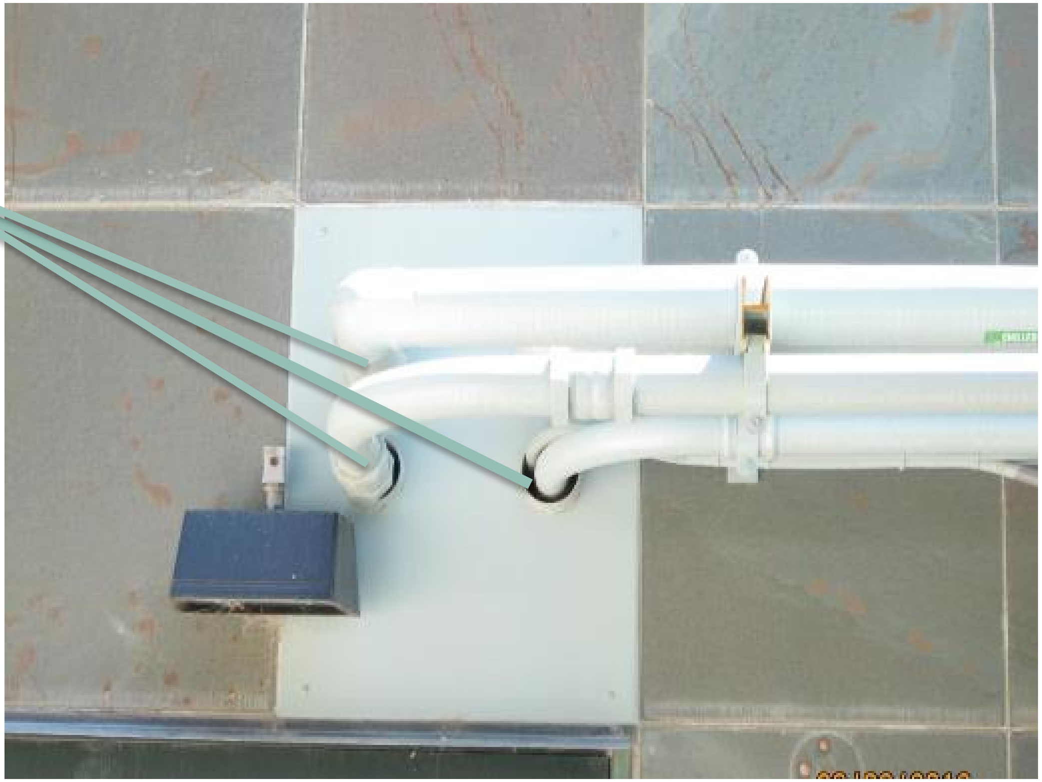
The door opening can be integrated to the HVAC system, so if it is open for more than a few minutes, the HVAC unit is turned off (or simply close the door). Also make sure the exterior lighting control is working (photocell, timer, etc.).

Building Envelope

SOLUTION **Trim the bushes or trees away from the grills**

Implementation: Exterior Wall Penetrations

Pipe chases for piping should be sealed on the inside or outside (or both)



SOLUTION

Pipe penetrations often occur from upgrades. Penetrations created by piping (gas, water, electrical, etc.) should be properly sealed.

Implementation:
Building Exterior Plug Loads – Heat Trace

Use Thermal Camera or other temperature device

SOLUTION

Heat trace should be off when not needed. Heat trace controls should be reviewed seasonally for proper temperature set points and operation.

Building HVAC Implementation:
HVAC Economizer Section – Lack of Maintenance

What are Economizer Retuning Ideas?

- ❑ Check economizer linkages and damper blades (not loose or broken, intact)
- ❑ Check that during favorable times to economize, the damper is open (partially to fully)

Building HVAC Implementation: Louvers and Grills

- Clean the intake screens on rooftop equipment before they become plugged

Building HVAC Implementation: Programmable Thermostat Set Point

- The building has a programmable thermostat, but it is not programmed to take advantage of unoccupied setbacks and set-ups
- Consider to Program the thermostat as follows:
  - Unoccupied heating set point = 65°F
  - Occupied heating set point = 72°F
  - Occupied cooling set point = 74°F
  - Unoccupied cooling set point = 80°F

Lighting Systems and Controls Implementation

What Lighting Questions Do We Ask?

- ❑ Over lighted?
- ❑ Are lights on when spaces are unoccupied?
- ❑ Are controls (occupancy, vacancy, or photo sensors or timers) installed?
- ❑ Is more efficient (reduced wattage) lighting an option?
- ❑ All T12s should be removed.
- ❑ Consider reduced wattage T8 or T5 (whichever is installed) for an easy 20% savings.
- ❑ Consider a lower output ballast.

Lighting Systems and Controls Implementation: Exterior Lighting

What are Exterior Lighting Retuning Ideas?

SOLUTIONS

Clean the photo sensor lens or move the photo sensor cell to a better location (too low to the ground and gets dirty easily)

The materials in photo sensors degrade over time and allow the time setting to drift beyond dark and light. Consider replacing if older than 5 years.

Also consider time switches – do the exterior lights need to be on all night? Consider maybe turning off a portion of the lights in the middle of the night.

Photo sensor

Building Hot Water Implementation:

- ❑ Check Temperature Setting
- ❑ Probably only needs to be set at 115 to 125°F

Hot Water Systems Implementation: Discussion Question

What Retuning ideas are there for Hot Water Systems?

Answers:

1. Lower the set points if possible.
2. For gas-fired systems, ensure the gas pressure regulator is set correctly.
3. Install hot water tanks that are “Energy-Star” rated.
4. If the pump is VFD-driven consider lower speed at night or during low load periods.
5. Set back controls in place?
6. Time clocks working correctly?
7. Turn off at night, or reduce at night.
8. Tanks and piping properly insulated? If not, install insulation where missing.
9. Fix dripping faucets and leaking pipes.

Documentation Phase and Calculating Savings

Documentation Phase

- Document prescriptive re-tuning measures by cost (no/low-medium-high)
- Select which measures are appropriate for implementation for the building based on:
  - Cost
  - Ease of implementation
  - Return on investment
  - Indoor Environmental Improvement
  - Safety and Security
- Document the selected measures so that calculation and realization of energy savings are possible

Best Practices

- Re-tuning is an ongoing process
  - Do it quarterly or at least every six months OR
  - If you see an increase in energy consumption or occupant complaints
- Every set point adjustment you make will have an impact on the utility meter
- You can save energy and keep staff comfortable
- It takes time to tune a building; there are no magic set points that work all the time (each building is unique)
- Look at the big picture when making adjustments
- Learn and know your building's personality
- Basic Energy Management
  - If you do not need it, turn it off
  - If you do not need it at full power, turn it down
  - Make the energy system smart when adjusting to the real needs of the building

Post-Walkdown: Quantifying Energy Conservation Measures (ECMs):

Objectives

- Overview of major BRT ECMs
- Ranking of BRT ECMs
  - Effort
  - Savings
- Examples of quantification of major BRT ECMs
- Tools for calculations and validation through interval utility data
- Calculators for estimating energy savings available
  - Pipe insulation
  - Closing gaps
  - Steam traps, etc.

Energy Conservation Measures (ECMs)

- Any change that impacts an area of building operation or modifications that reduces building energy use
- Ideal Building Re-Tuning (BRT) ECMs
  - Low-medium effort (required)
    - A few hours to implement
  - Medium-high savings (preferred)
    - At least 5-10% savings of energy (for specific area) saved
- What if only high-effort ECMs identified
  - Can be implemented when a major retrofit takes place (when later planned) or be integrated into a capital improvement plan

Energy Conservation Measures (ECMs)

Building Envelope

- Weather-strip doors and windows
- Caulk gaps in building

HVAC & Controls

- Keep chiller temperature as high as possible
- Test boiler efficiency on a continuing basis

Lighting

- Evaluate light sources – replace with higher efficiency versions
- Install controls: occupancy, vacancy, or photo sensors; timers
- Reducing lighting in over-lighted areas

Water Heating

- Minimize the hot water temperature
- Install instantaneous hot water

Energy Conservation Measures: Top Three ECMs Based on SAVINGS

ECM	CATEGORY	EFFORT	ESTIMATE	PAYBACK
Replace fluorescent lamps with reduced wattage fluorescent	Lighting	Low	20% of lighting energy	1 year
Replace fluorescent, ballasts or install TLEDs	Lighting	Medium	10-40% of lighting energy	2-6 years
Applying Low-E film / adding Low-E panes	Building Envelope	Low/Medium	10% of total energy costs	2-6 years
Optimize boiler air-fuel ratio	HVAC	Medium	1-10% of fuel costs	0-1 year

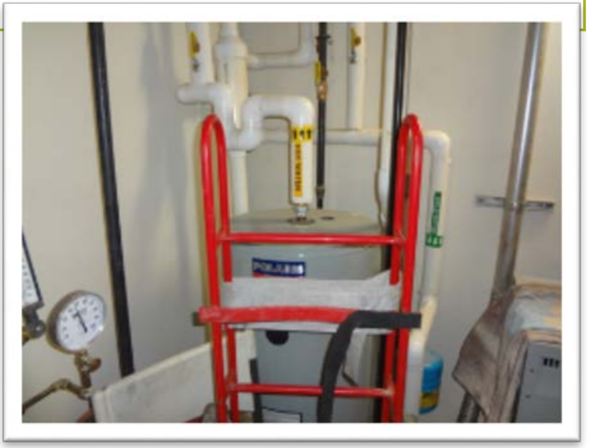
Energy Conservation Measures: Top Three ECMs Based on EFFORT

ECM	CATEGORY	EFFORT	HOURS	LABOR COST
Keep chiller temperature as high as possible	HVAC	Low	0	0
Minimize the hot water temperature	Water-heating	Low	0	0
Use temperature setbacks for programmable thermostats	Sensors & Controls	Low	0	0

Source: *Energy Efficiency Manual,* Wulfinghoff

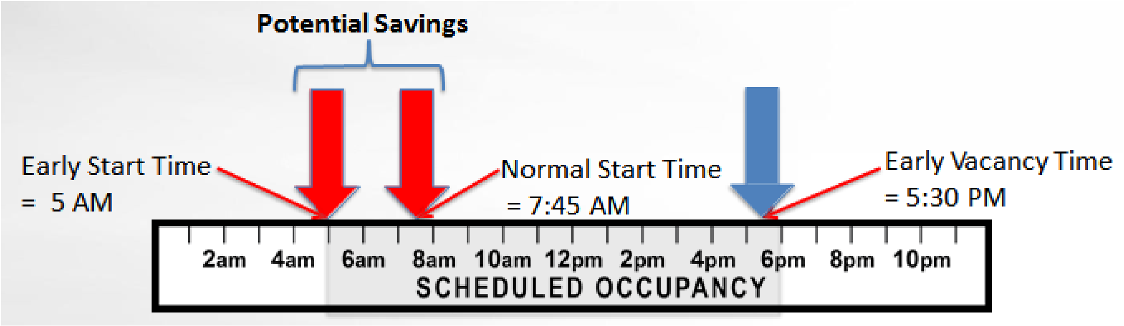
Energy Conservation Measures: Medium Effort / High Savings ECM

ECM Category	ECM Description	Effort/ Savings
Domestic Hot Water ECM	**Replace Existing DHW System with an On-Demand Water Heater** Tankless natural gas or electric water heaters typically result in energy savings on the order of 8% to 25%. Tankless water heaters eliminate standby energy losses associated with hot water storage tanks.	**Medium/High**



Energy Conservation Measures: Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
Air Distribution Systems	**Implement an HVAC System Night Setback Schedule** For all HVAC systems that serve intermittent-occupancy rooms or non 24/7 areas, make sure that night setback controls have been implemented. Conference rooms, especially, have intermittent use. You have only a few zones, but if managed properly, you can realize energy savings > 10%.	**Low/Medium**



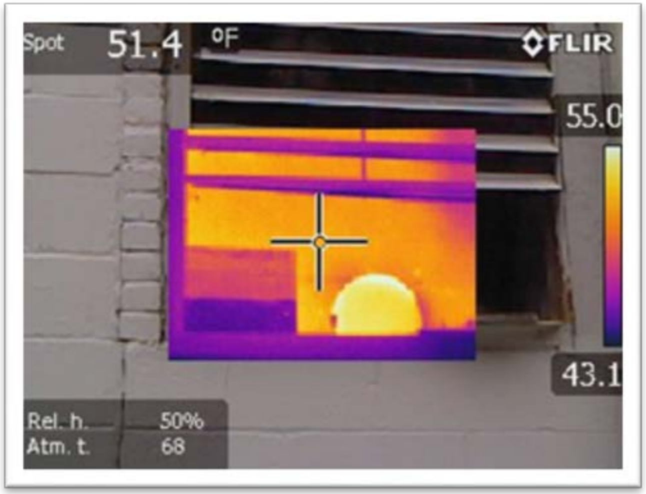
Energy Conservation Measures:
Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
HVAC	**Verify Proper Operation of Air-side Economizer** Check the DDC system control sequence to see if the current control system is using an air-side economizer. Make sure the economizer is working correctly by viewing damper positions and outside airflow rates at different outside air temperatures.	**Low/Medium**

Economizer damper closed with 65°F outside air temperature

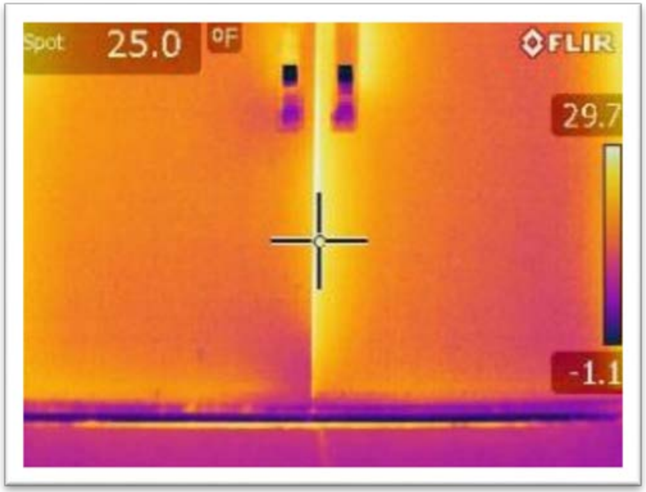
Energy Conservation Measures:
Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
Envelope	**Seal areas of infiltration using caulk or weather-stripping to reduce the thermal exchange that takes place at openings.**	**Low/Medium**



Energy Conservation Measures: Low Effort / Low Savings ECM

ECM Category	ECM Description	Effort/ Savings
Envelope	**Seal Penetrations in Building Envelope Including Door Gaps** Energy loss is proportional to inside/outside temperature difference	**Low/Low-Medium**



Energy Conservation Measures:
Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
Domestic Hot Water	**Insulate Hot Water Pipes** Pipe insulation reduces heat loss through distribution pipes and increases overall system efficiency. Any heated pipe with exterior temperatures over 120°F should be insulated.	**Low/Medium**

Thanks

- Next up: Lunch and then Building Walkdown

HVAC Systems Controls Historical Trends Learning Activity

Participant Directions

Review the general information and answer the questions below. Discuss as a group and be prepared to present answers to the class.

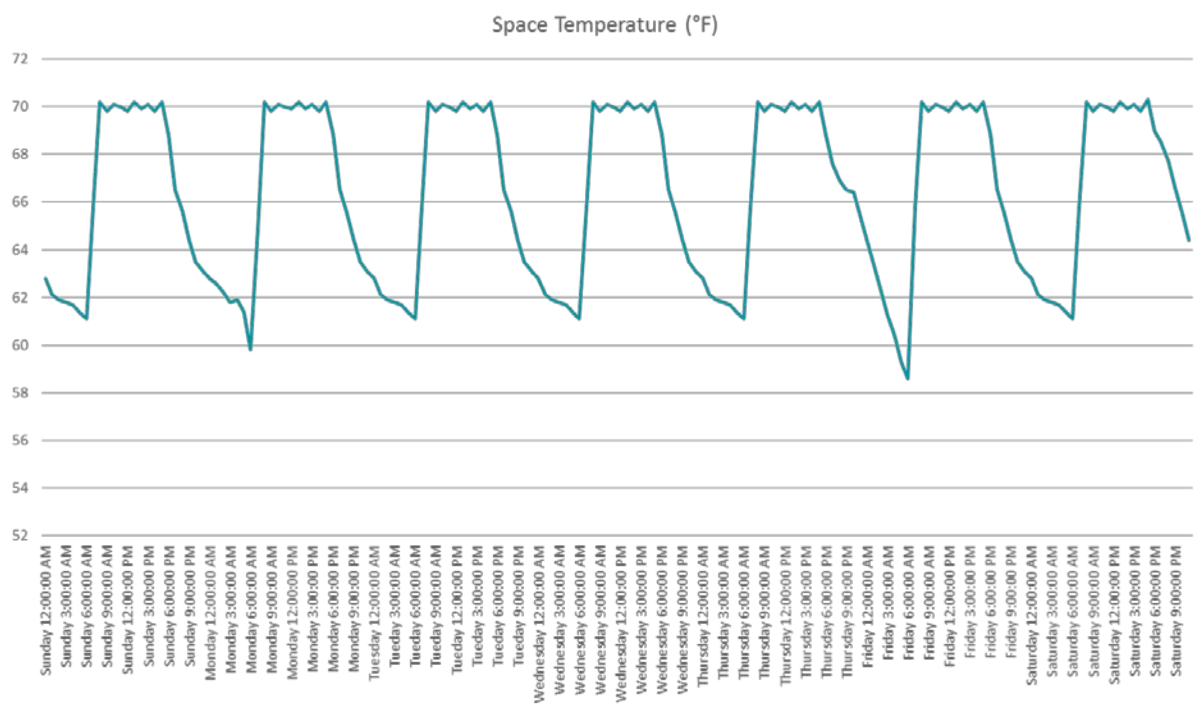
General Information:

Assumptions: Space is Heated and Cooled by a packaged rooftop A/C unit with natural gas heat.

The Building Operations Plan calls for:

- Heating Setpoints: 70F while occupied
  55F while unoccupied.
- Cooling Setpoints: 72F while Occupied
  80F while Unoccupied
- Space is Occupied: M-F from 7 AM to 5 PM
  Unoccupied all other times

Trend Data: One week's worth of data of space temperature.



A quick look at a week's worth of data can provide insight into how the system is operating. Answer the following questions to determine if the system is programmed to operate according to the occupancy schedule?

Questions	**Answers**
Is this heating or cooling season?	
Is Occupied Temperature set correctly?	
Is Unoccupied Temperature set correctly?	
Is occupancy schedule correct?	

HVAC Systems Controls Historical Trends Learning Activity

Instructor Directions:

This activity is expected to take 15-20 minutes. Break the class into groups of 3-4 people.

Participant Directions

Review the general information and answer the questions below. Discuss as a group and be prepared to present answers to the class.

General Information:

Assumptions: Space is Heated and Cooled by a packaged rooftop A/C unit with natural gas heat.

The Building Operations Plan calls for:

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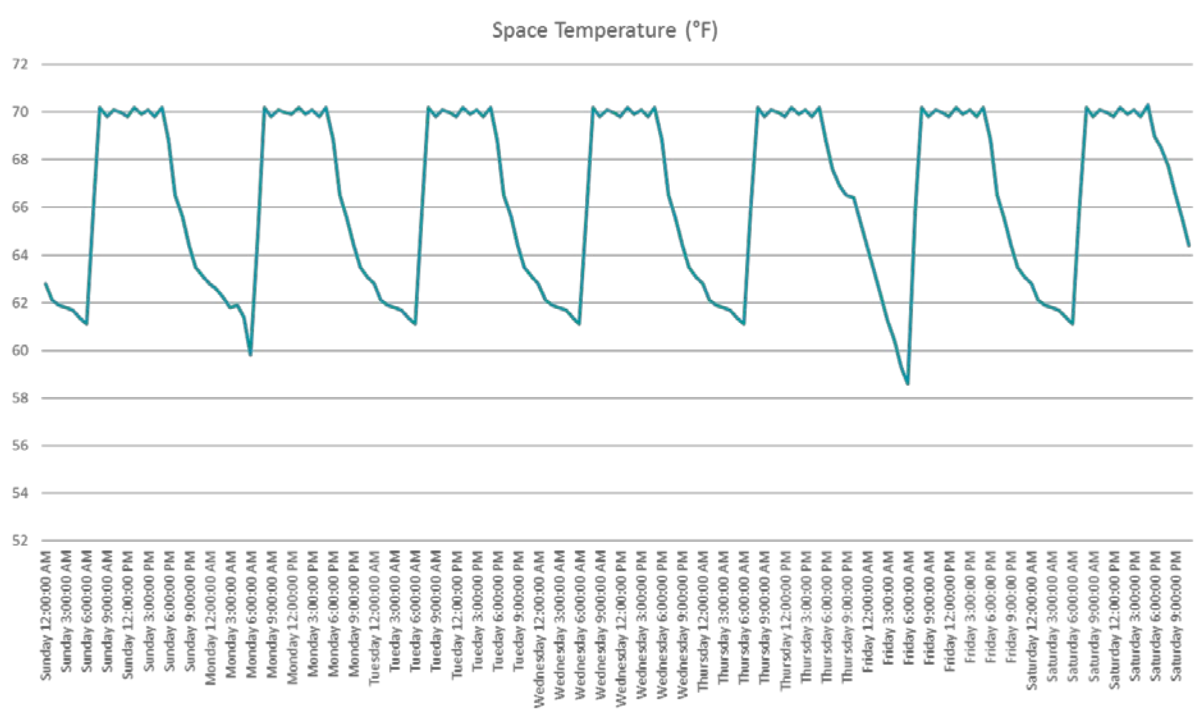


A quick look at a week's worth of data can provide insight into how the system is operating. Answer the following questions to determine if the system is programmed to operate according to the occupancy schedule?

Questions	Answers
Is this heating or cooling season?	Heating season since temperature drops after unoccupied times
Is Occupied Temperature set correctly?	Yes, Operations Plan calls for 70F in heating season and temperature hits set point.
Is Unoccupied Temperature set correctly?	Not enough information, unoccupied set points should be 55F, but interior temperature never drops that low so it's possible that it is correctly set up, but we don't know for sure.
Is occupancy schedule correct?	Yes, on weekdays as temperature is at set point between 7am and 5pm, but No on weekends – space is supposed to be unoccupied but system still turns on and hits set point.

Data-driven Analysis:
Mastering BRT

Module 4C

Objectives

- ❑ Understand the building re-tuning (BRT) process
- ❑ Learn how to diagnose the BRT opportunities through viewing and understanding trend data charts
- ❑ Understand the uses of Energy Charting and Metrics (ECAM)

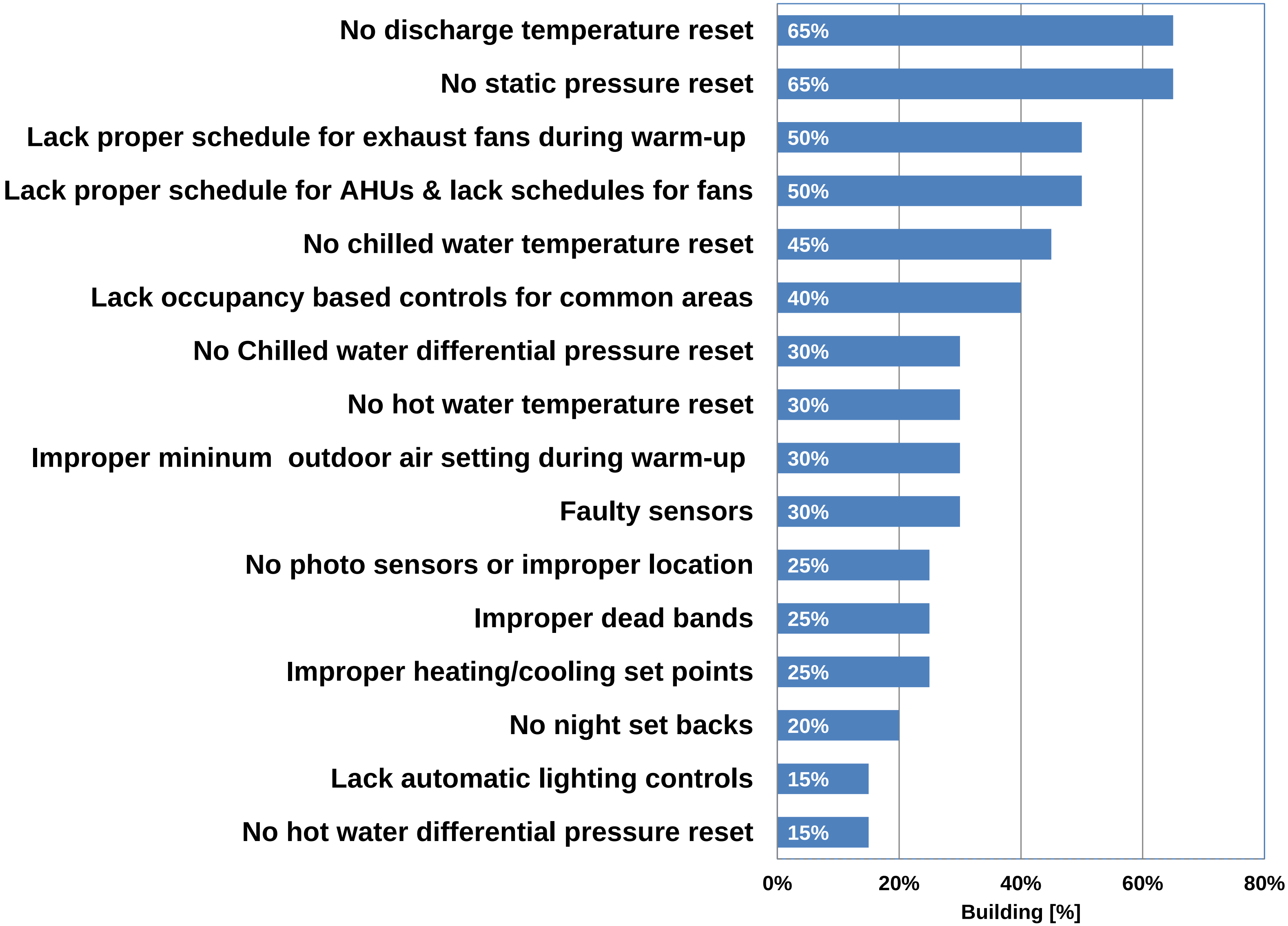
Re-tuning Control Strategies

Overview of Re-tuning Process

Data-Driven Re-tuning: Analysis Process Steps

1. Download trend log data files from BAS
2. Format data files for compatibility with the Energy Charting and Metrics (ECAM) spreadsheet analysis tool buildingretuning.pnnl.gov
3. Open data files in the ECAM, map the data points, select the desired re-tuning charts to be generated
4. Review the charts to identify operational issues following PNNL guides
5. Record operational set points and issues found for each piece of equipment

Common Re-tuning Measures: PNNL Meta Analysis of 100 Buildings



Interpreting ECAM BRT Charts

BRT Categories

- Occupancy Scheduling
- AHU Discharge Air Temperature Control
- AHU Discharge Air Static Pressure Control
- AHU Heating and Cooling Coils
- AHU Outdoor Air Operation
- AHU Economizer Operation
- Zone Conditioning
- Heating Plant
- Cooling Plant

Single-Duct Variable Air Volume (VAV)

Energy Charting and Metrics: Discussion Question

True or false: A data range of one week will sufficiently reflect a building's occupancy schedule.

Answer: False, two weeks is ideal so that complete weekends may be examined.

Expectations for BRT Charts of BAS Data

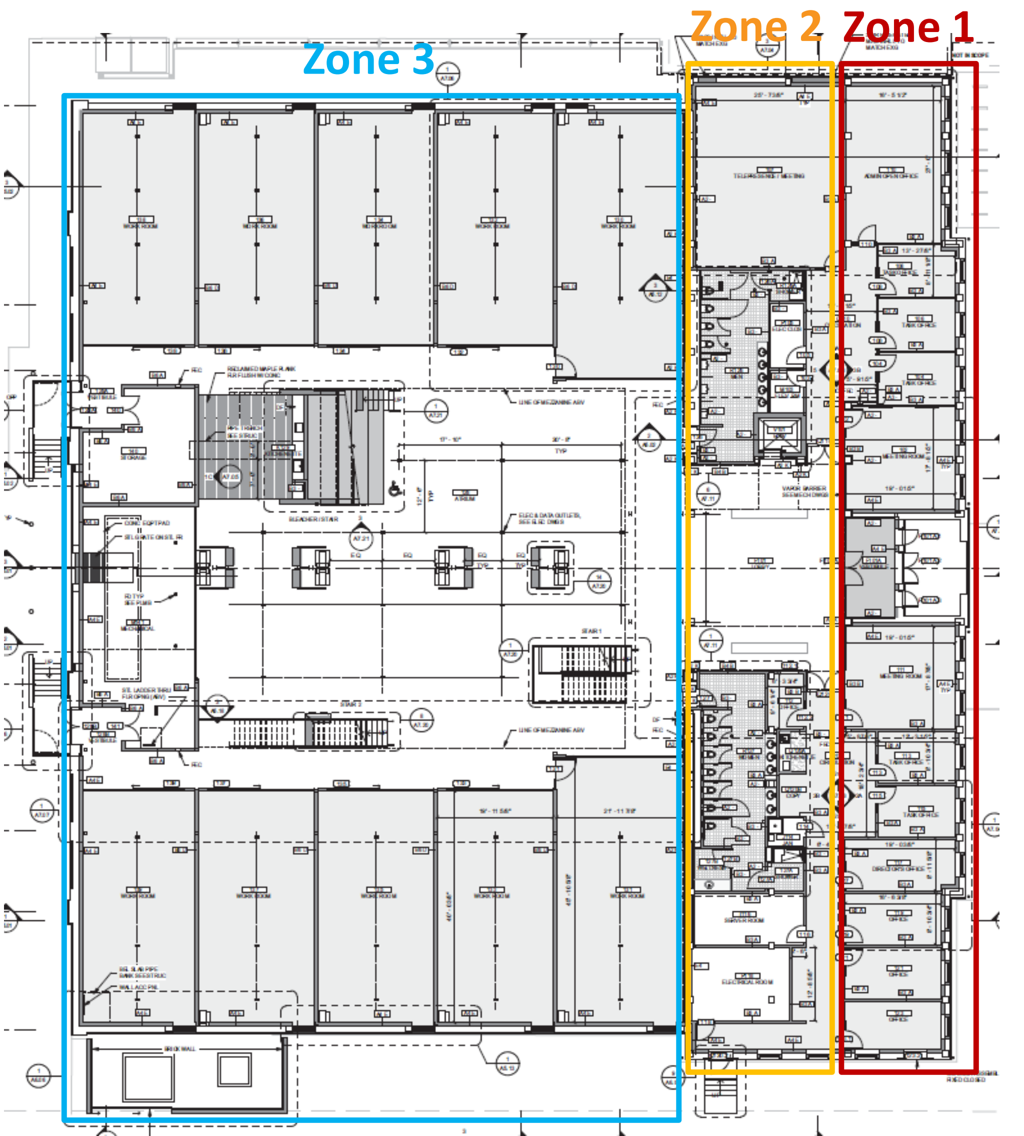
- BRT from BAS trend data is a sleuthing process!
- The software does not do it for you.
- The charts usually have two or more lines of recorded data signals from the BAS.
- Sometimes it is helpful to look at two weeks of data on one chart, and other times it helps to zoom into one or two days of data.
- The sleuthing process requires user to interpret the relationships between the trend data lines on the chart.

Limitations of the BRT Charts of BAS Data

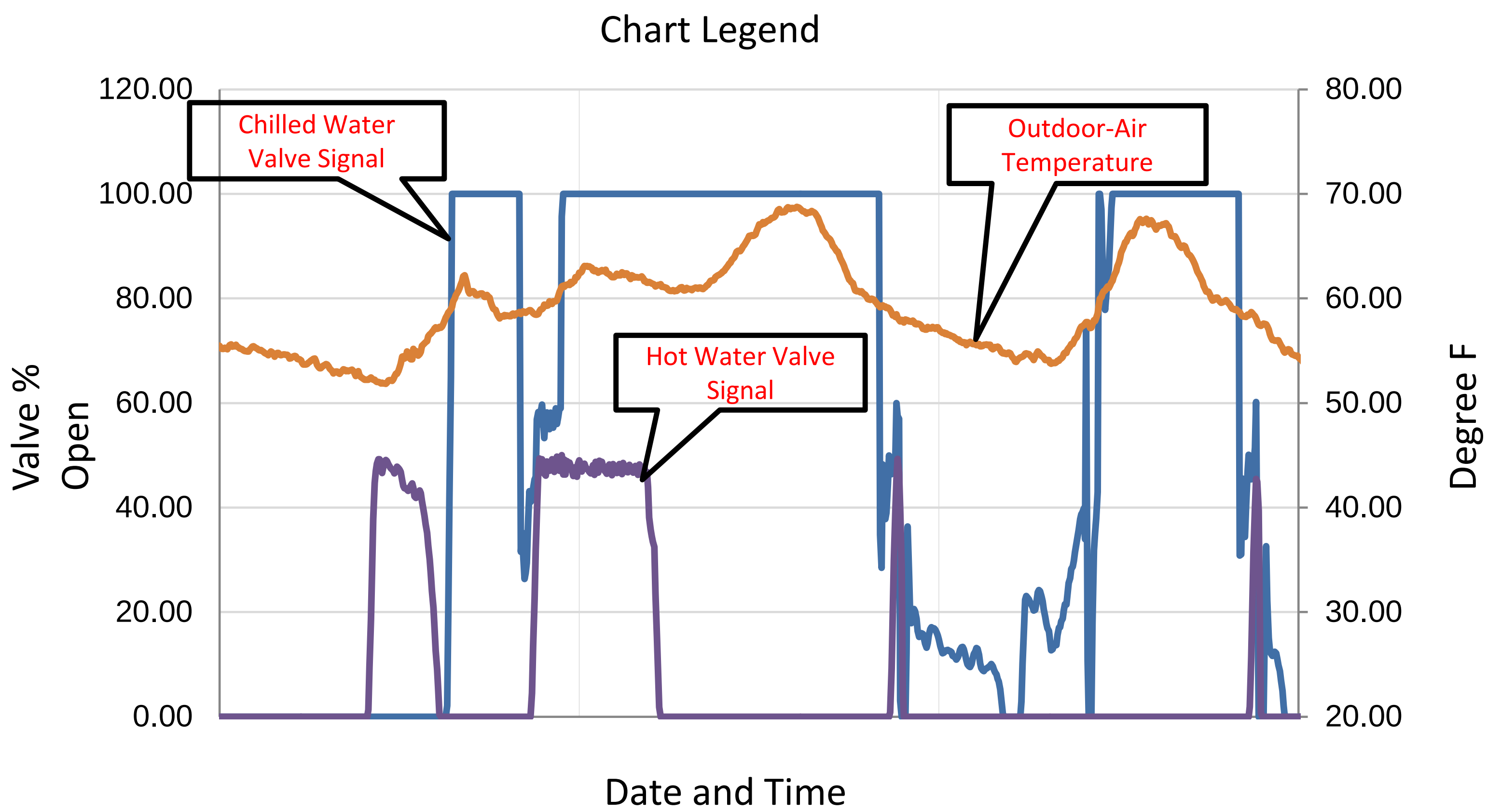
- Need to understand and know the use and intended operation of the building and the system being charted.
- Need to know the fundamental and ideal relationships to look for with BRT with BAS.
- PNNL has a separate re-tuning guide for each of the BRT categories listed in the first slide of this section.
- Follow the PNNL re-tuning guides!

Example Building

- Higher Education sector – "living laboratory"
- Three HVAC zones:
  1. Ductless mini-split
  2. Dedicated outdoor air system (DOAS) + Hydronic system (chilled beams)
  3. Rooftop units (RTU)



BRT Charts of BAS Data



Re-tuning Control Strategies

Occupancy Scheduling

Data Needed

- Outdoor-air temperature (OAT)
- Outdoor-air damper position signal (OAD)
- Supply fan status
- Discharge-air temperature (DAT)
- Duct static pressure (SP)

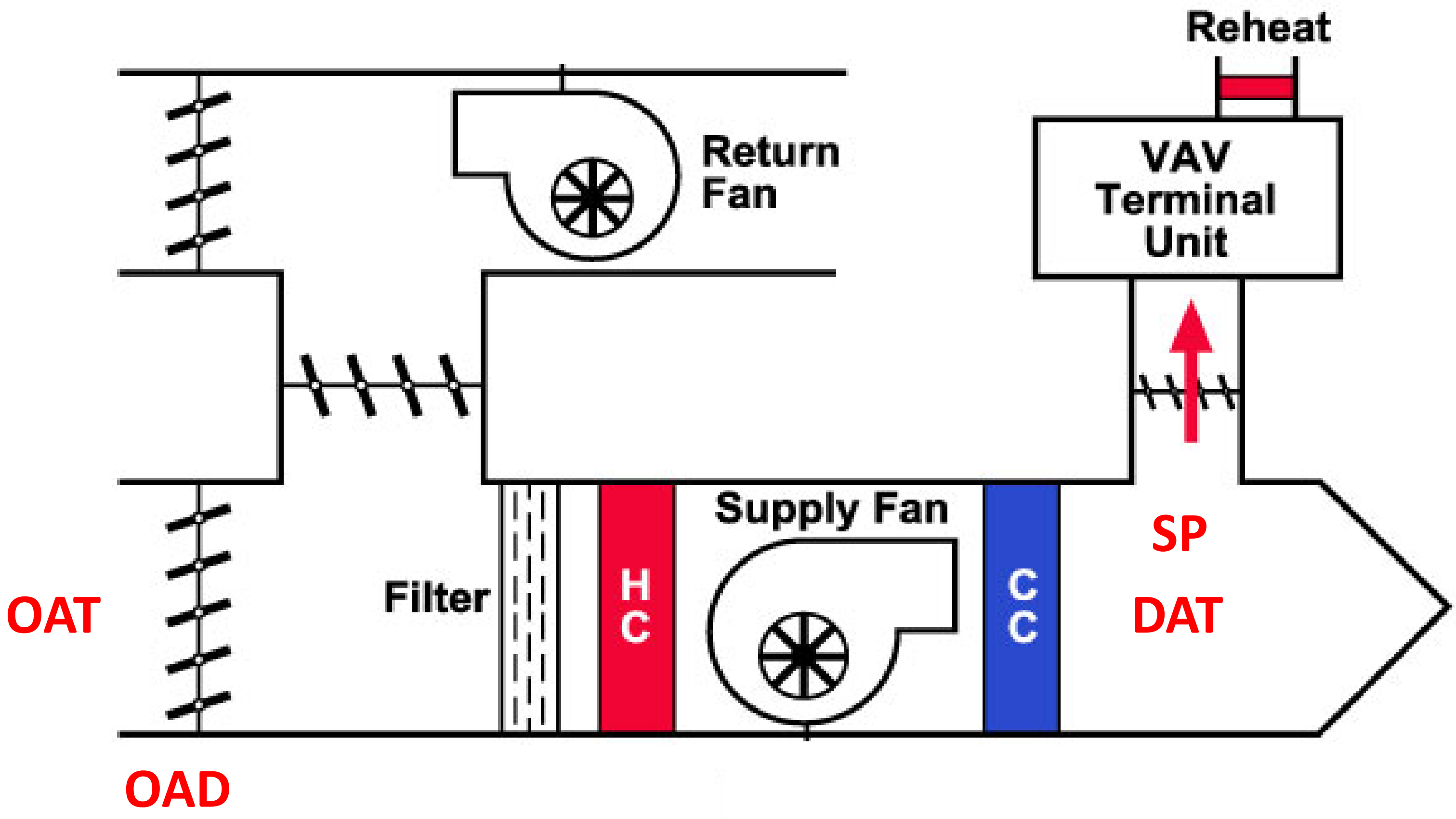
Occupancy Scheduling: Discussion Question

Which variable is the most costly in terms of energy use?

- Outdoor-air temperature (OAT)
- Outdoor-air damper position signal (OAD)
- Supply fan status
- Discharge-air temperature (DAT)
- Duct static pressure (SP)

Answer: Discharge-air temperature (DAT)

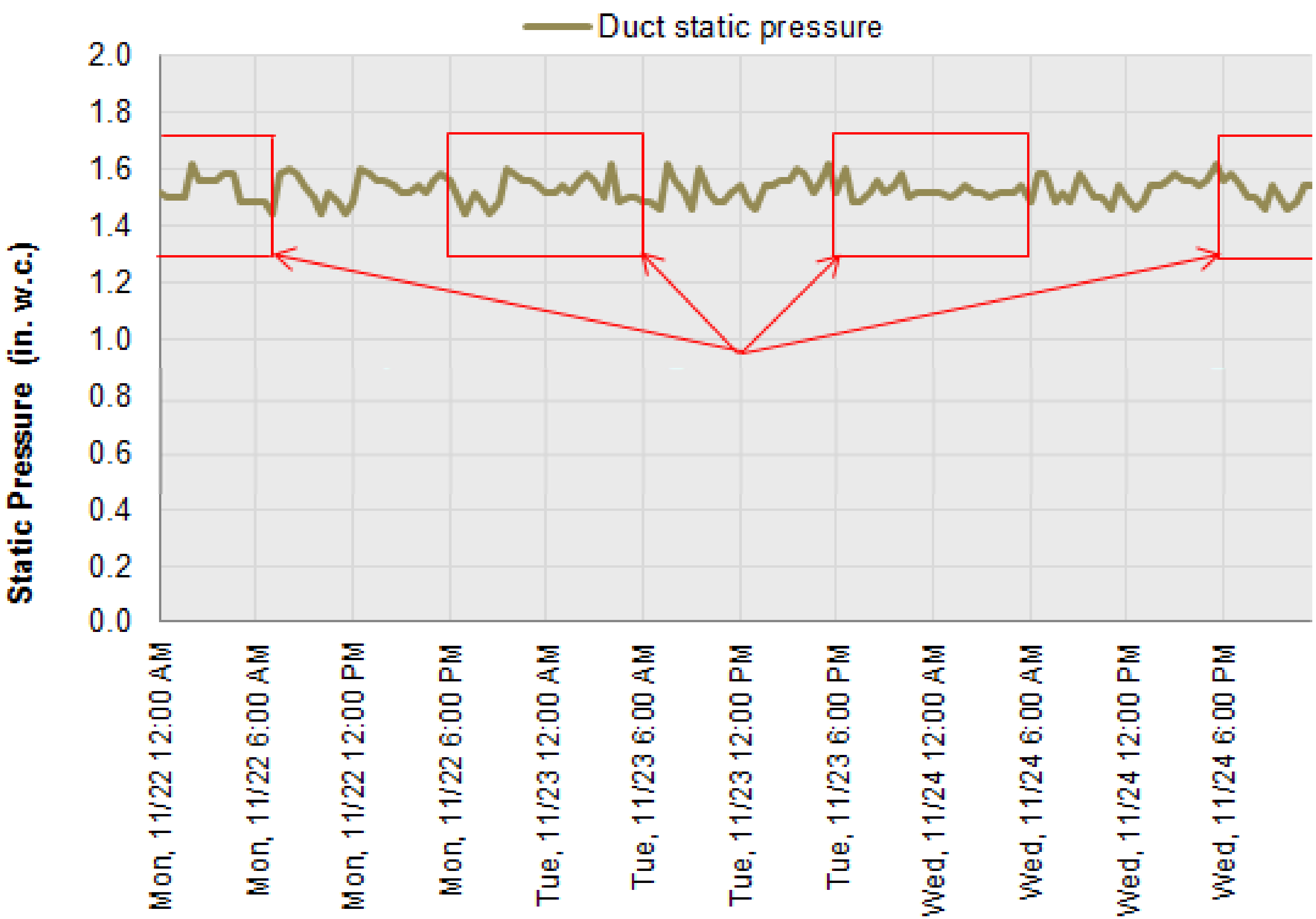
Data Points Being Used



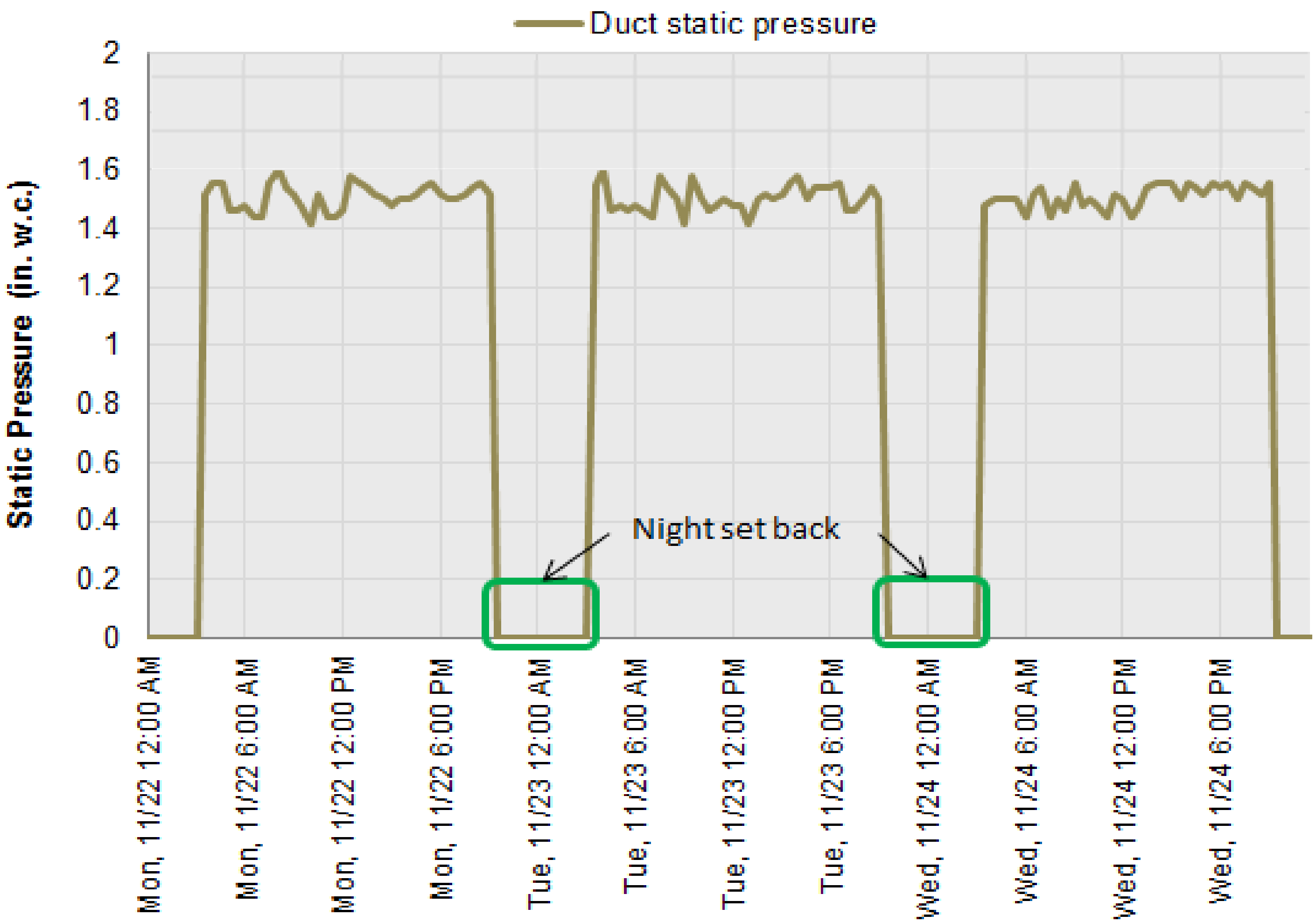
Trends To Look For

- Is there night setback for unoccupied hours?
- Is there weekend setback if the building is unoccupied on the weekends?
- Does the supply fan cycle frequently during unoccupied hours?
- Does the outdoor-air damper open during unoccupied hours or when the building is in warm-up/cool-down mode?

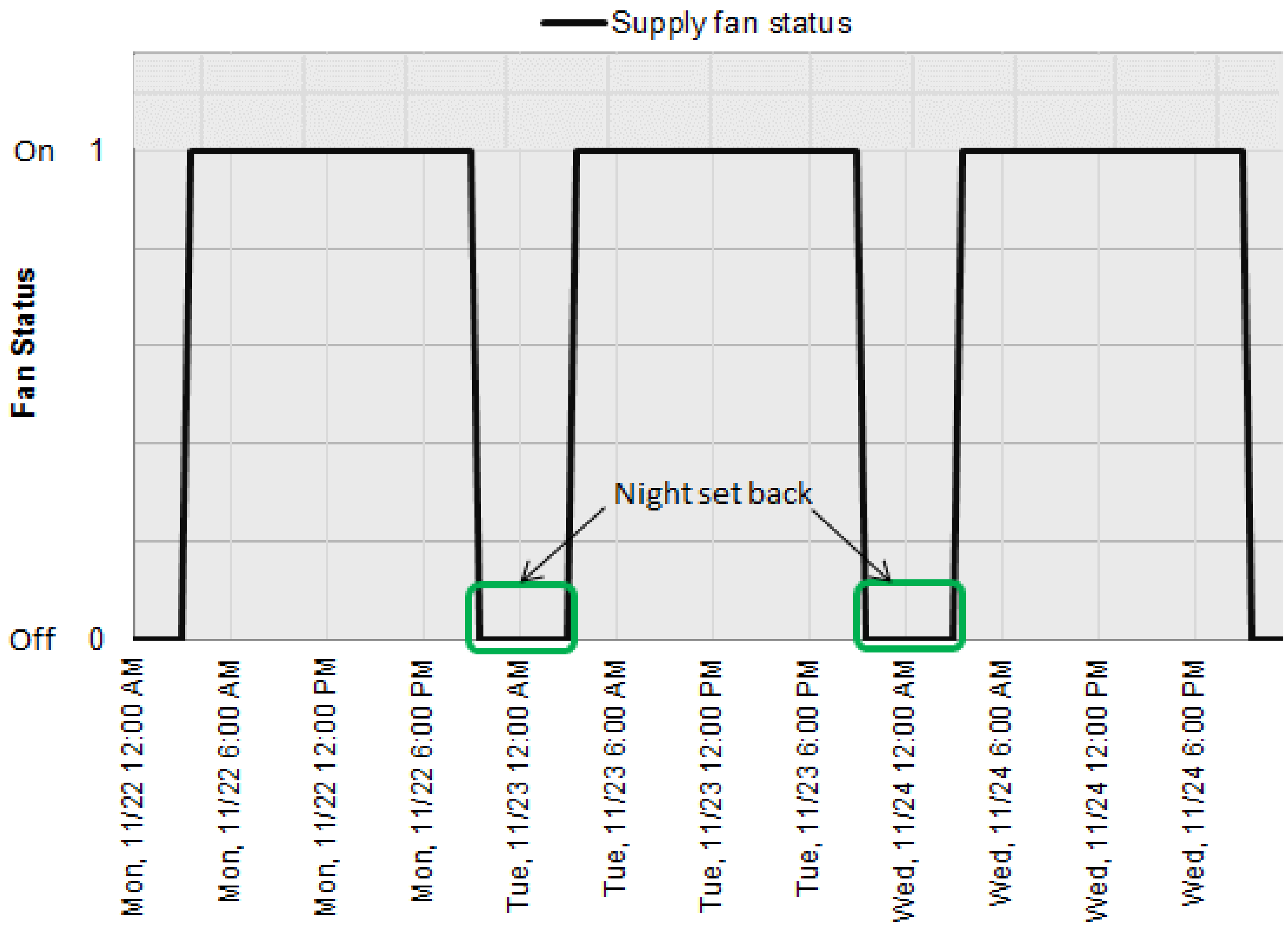
Set back for Unoccupied Hours?



Set back for Unoccupied Hours?

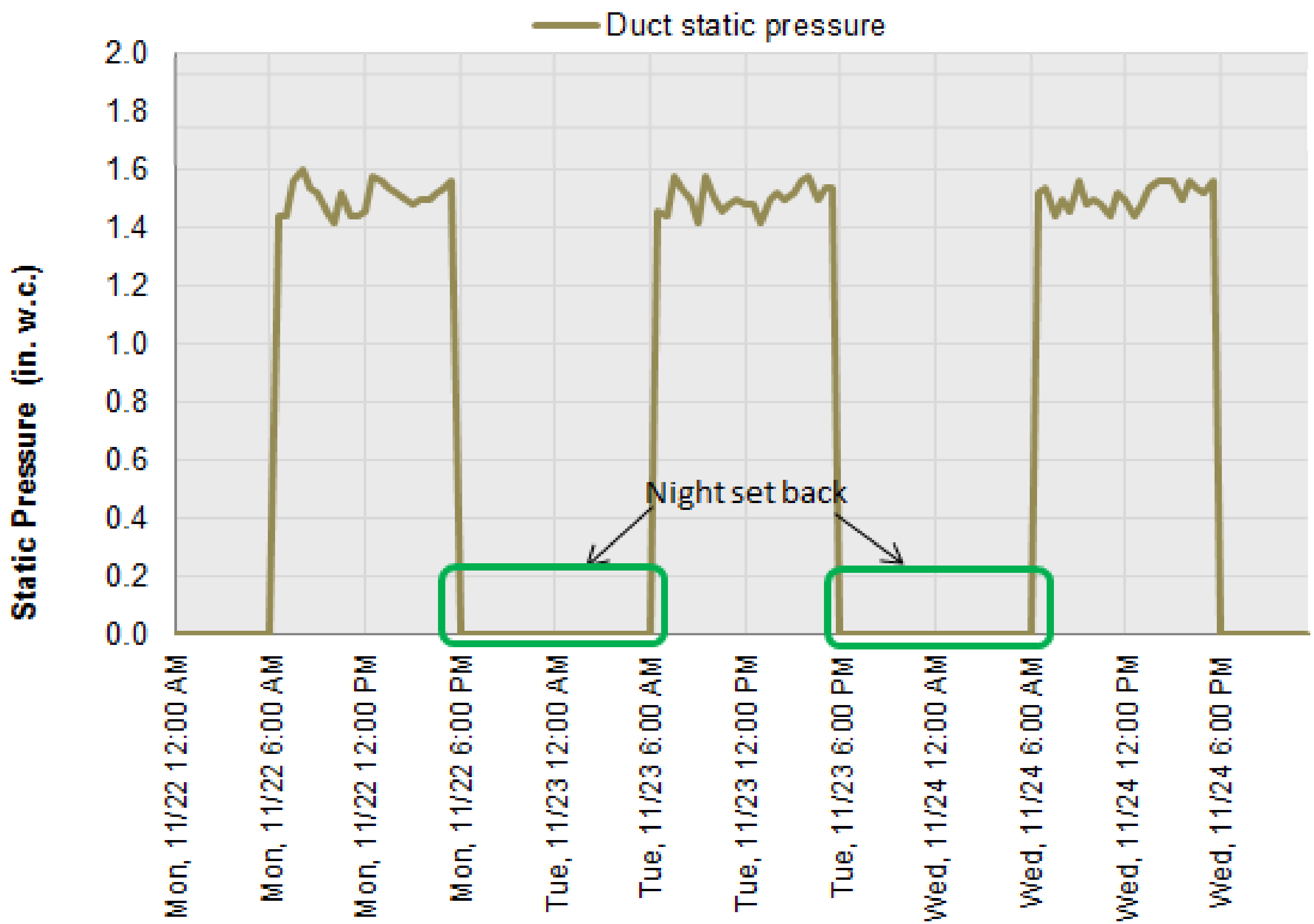


Set back for Unoccupied Hours?

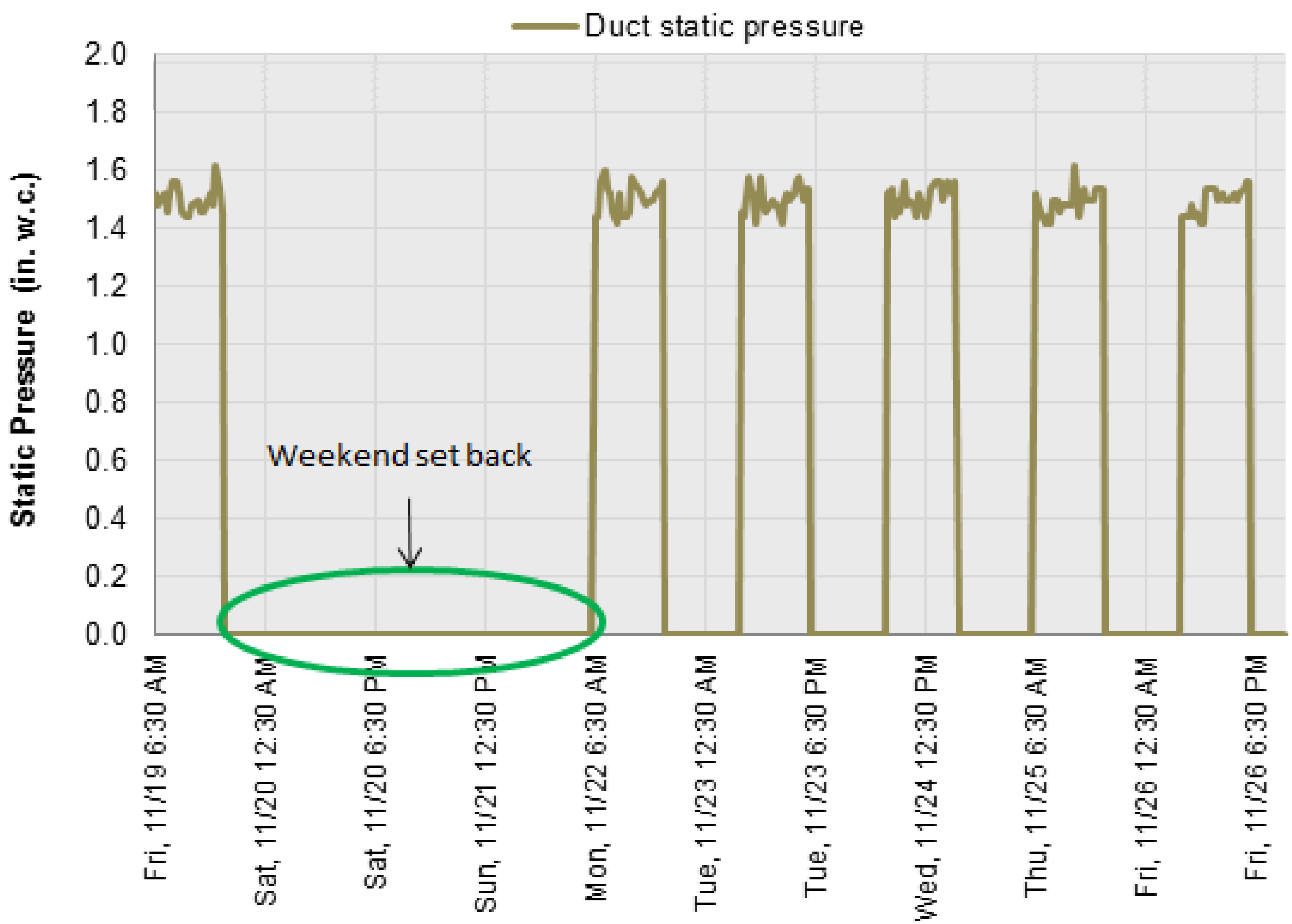


Supply fan status works but not as reliable as duct static pressure

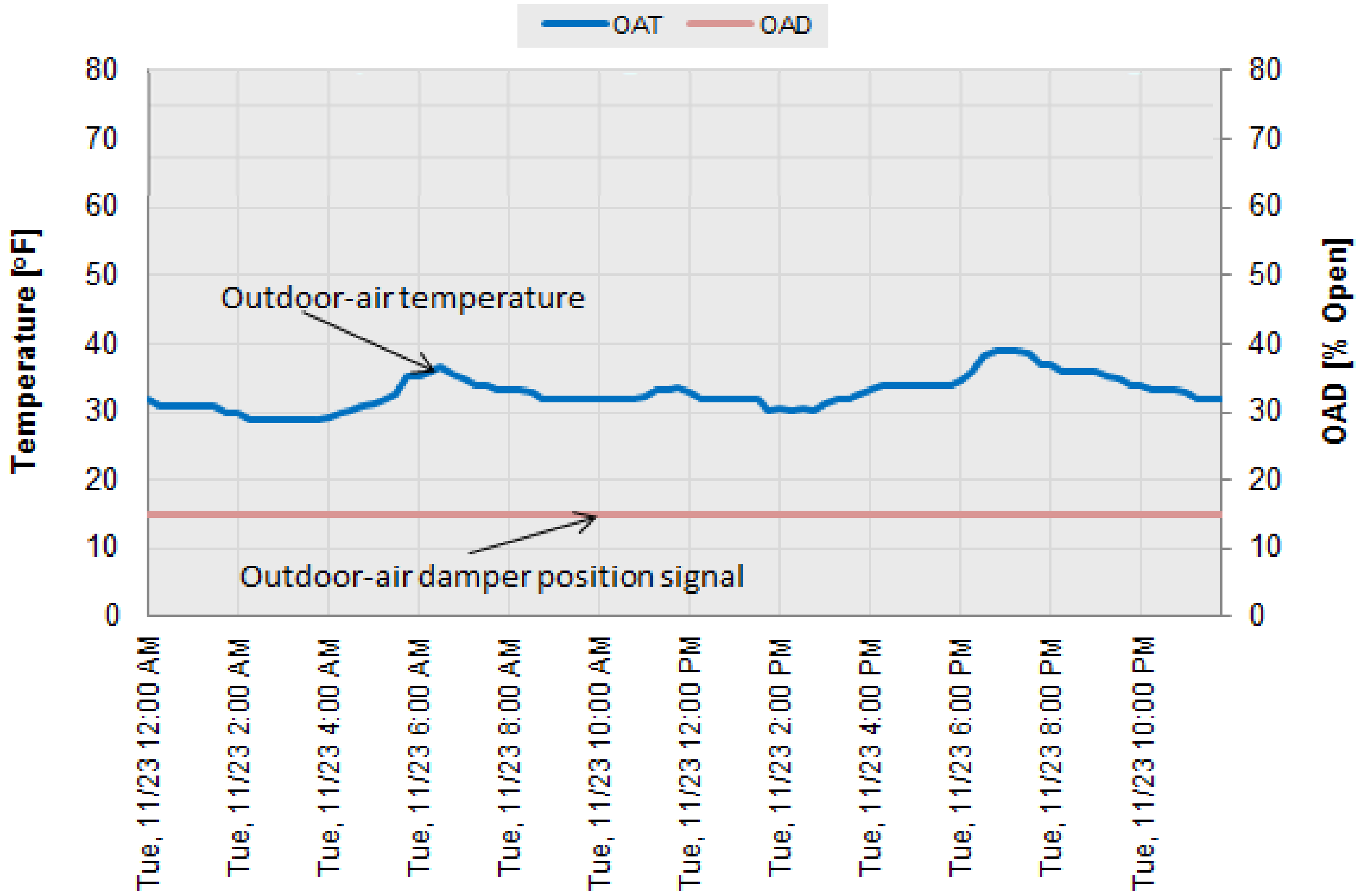
Set back for Unoccupied Hours?



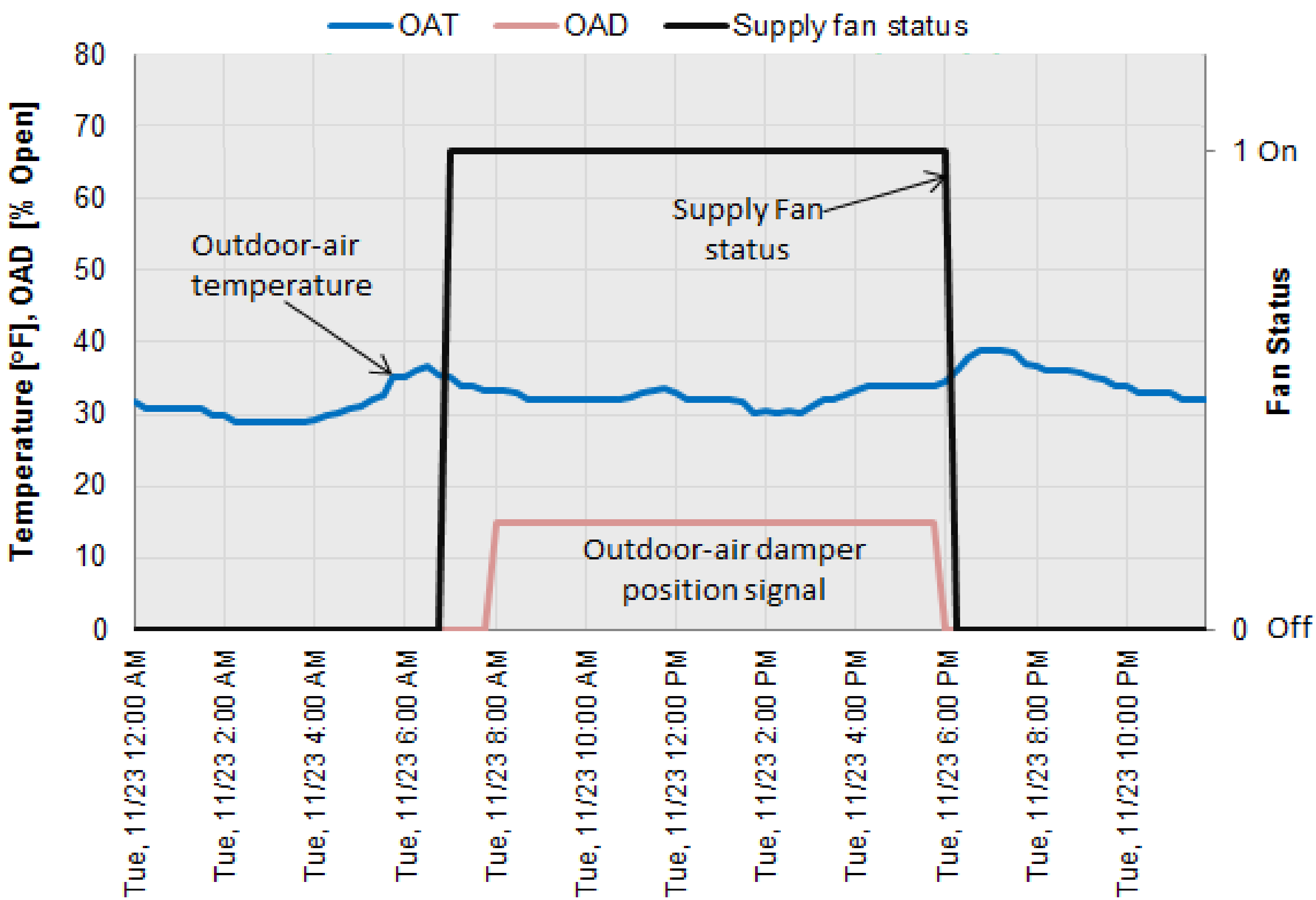
Set back for Weekend Hours?



Outdoor Air Damper during Unoccupied Hours

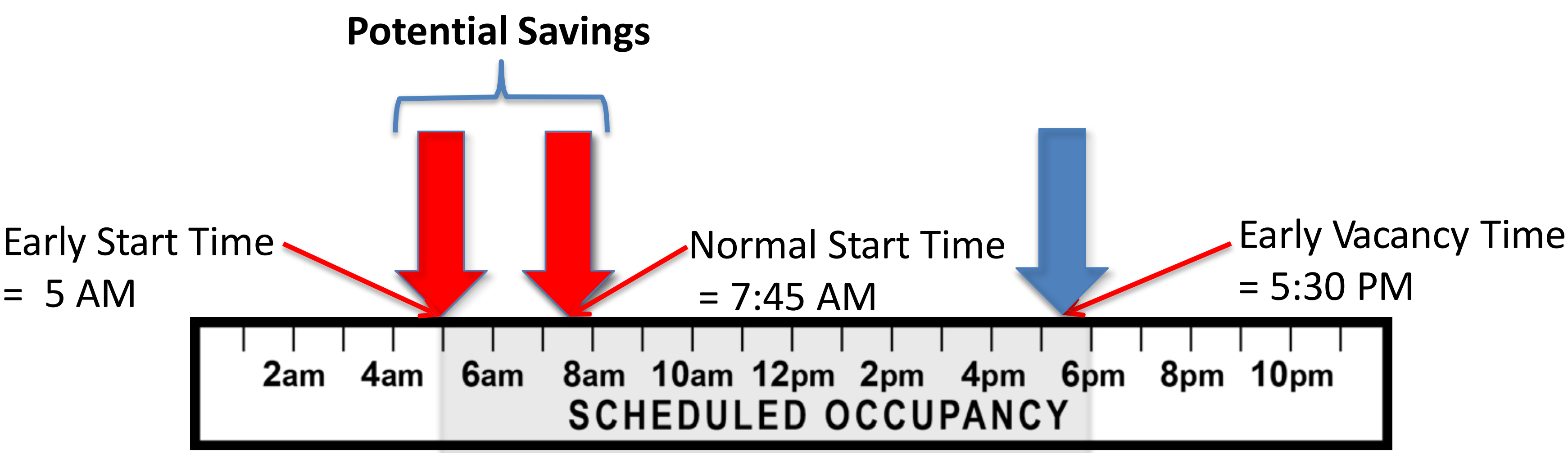


Outdoor Air Damper during Unoccupied Hours



Optimal Start

- Optimal Start will automatically "learn" over time the optimum time to start the HVAC system to bring space temperatures within 1 to 2°F of occupied requirements at the start of the occupied time period



Recommendations and Actions

- Look for re-tuning opportunities during night, weekend, and holiday unoccupied schedules.
- If your organization has moved to a four-day work week, make sure systems aren't running at full capacity on the fifth day.
- Look for re-tuning opportunities during workday no- or low-use schedules (auditorium, classrooms, conference rooms).
- Do not restart too early - use a startup schedule based on building needs (employ ***optimal start***, if possible).
- Do not use outside air during warmup except the last 30 minutes for flushing the building.

Recommendations and Actions

- Refrain from starting up a system for the occasional nighttime or weekend user.
  - Use bypass/override buttons for occasional night or weekend users (set for no more than 2 - 4 hours).
- Do not make radical changes. Instead, make small changes and observe how they work, and then readjust as needed.
- Notify occupants that you are implementing changes and let them know who to contact if the changes are not working for them.
- Consider switching to smaller-capacity equipment for early evening loads.

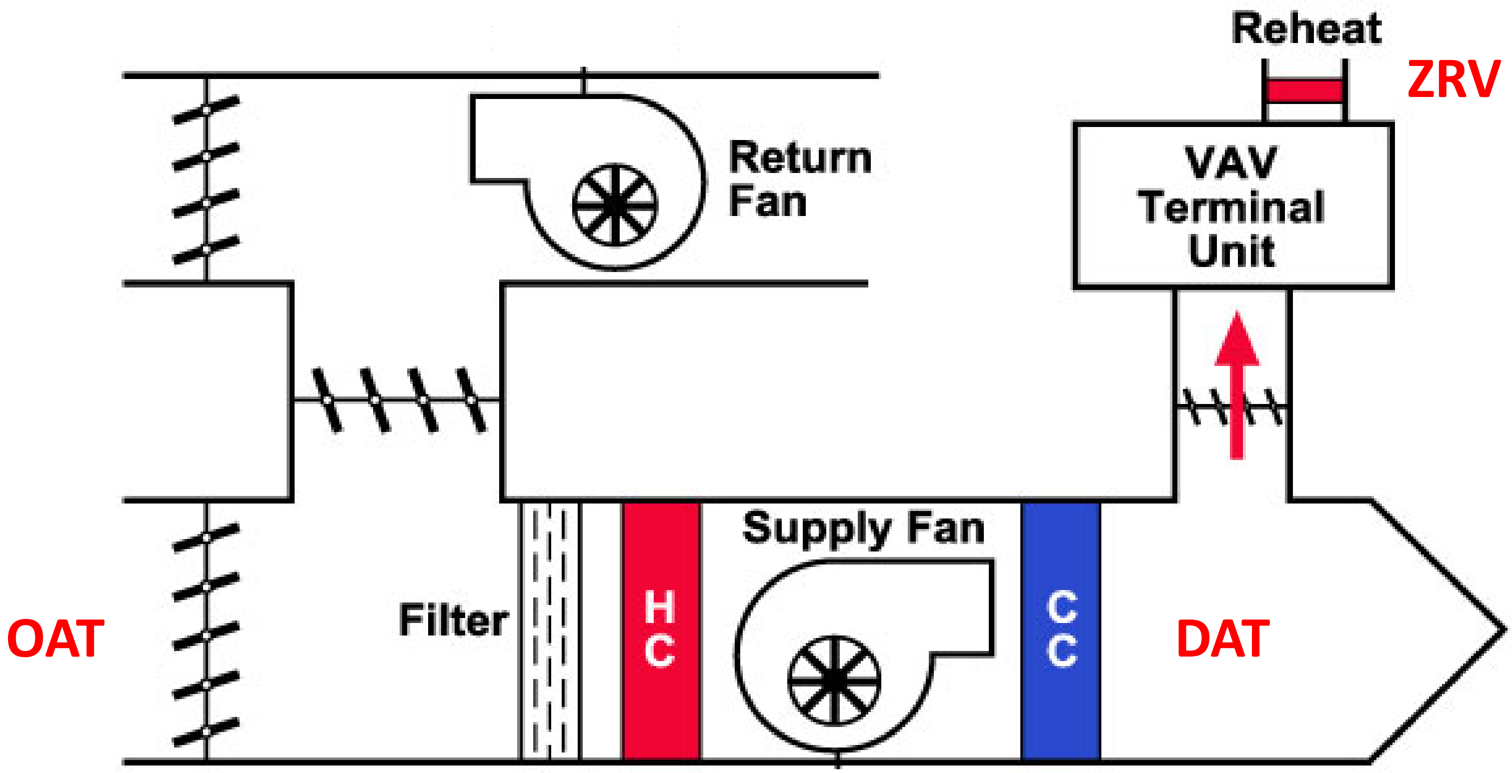
Re-tuning Control Strategies

AHU Discharge-Air Temperature Control

Data Needed

- Outdoor-air temperature (OAT)
- Discharge-air temperature set point
- Discharge-air temperature (DAT)
- Zone reheat valve signal (ZRV)

Data Points Being Used



Trends To Look For

- Is reset being used to control the discharge-air set point?
- Is the discharge-air temperature meeting set point, or do deviations occur?
- Is the discharge-air temperature set point too high or too low?
- Is the discharge-air temperature too cool (<55°F) or too warm (>70°F)? Usually too cool
- Does the discharge-air temperature remain relatively stable?

Issues

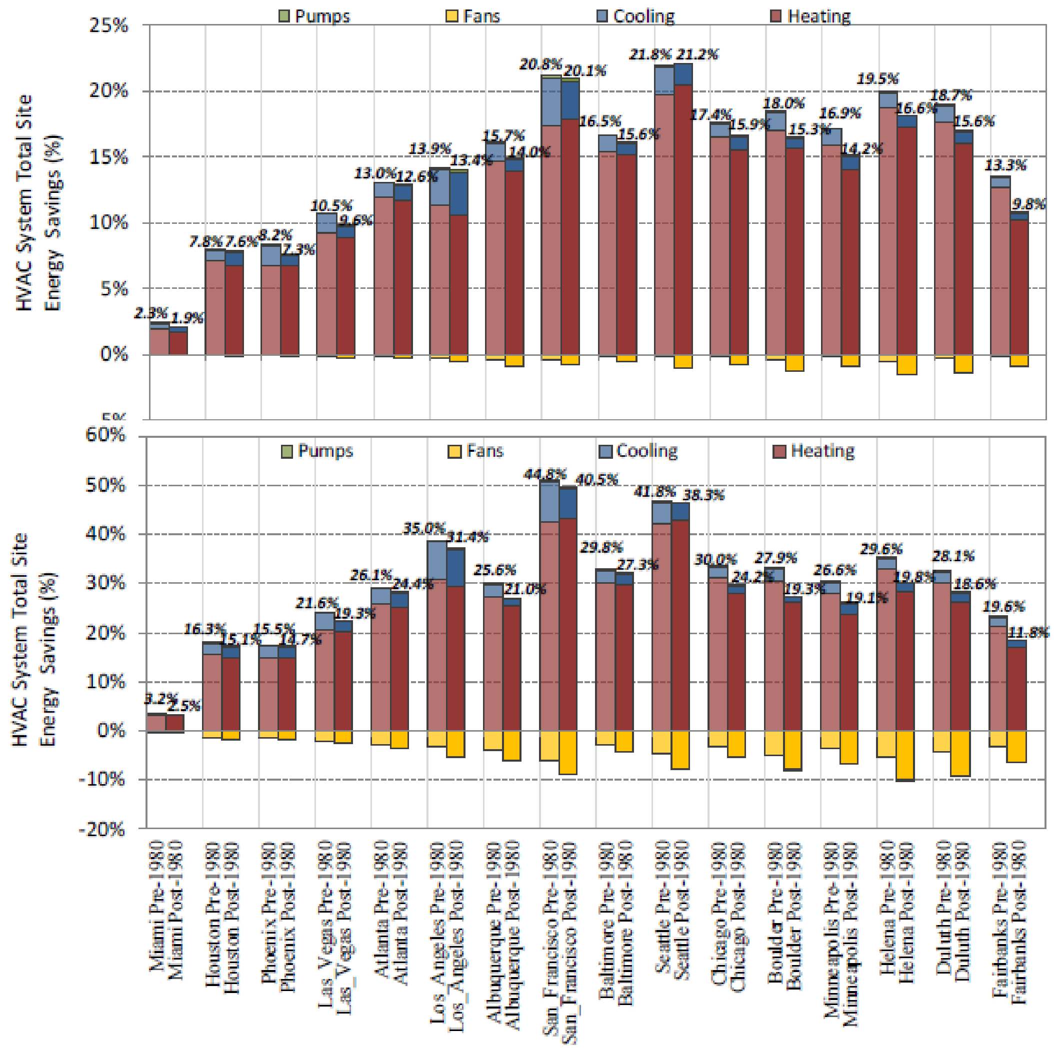
- Low discharge-air temperature will cause:
  - Overcooling
  - Reheating in cooler zones
  - Portable heaters in offices
  - Drafts and cold complaints
  - Extra load on the cooling plant
  - Excess discharge-air pressure
  - Excess energy in reheating the overcooled zones

Issues Continued

- Discharge-air temperature needs to be set low enough to handle the peak cooling load
  - Summer weather peak
  - Interior load peak
  - Staffing peak
  - Maybe 1% to 2% of the operating hours are at this condition, yet most systems run 100% of the time at this set point
- Reheat makes up for all areas that are too cold from a lower than needed discharge-air temperature

DAT Reset Potential Savings

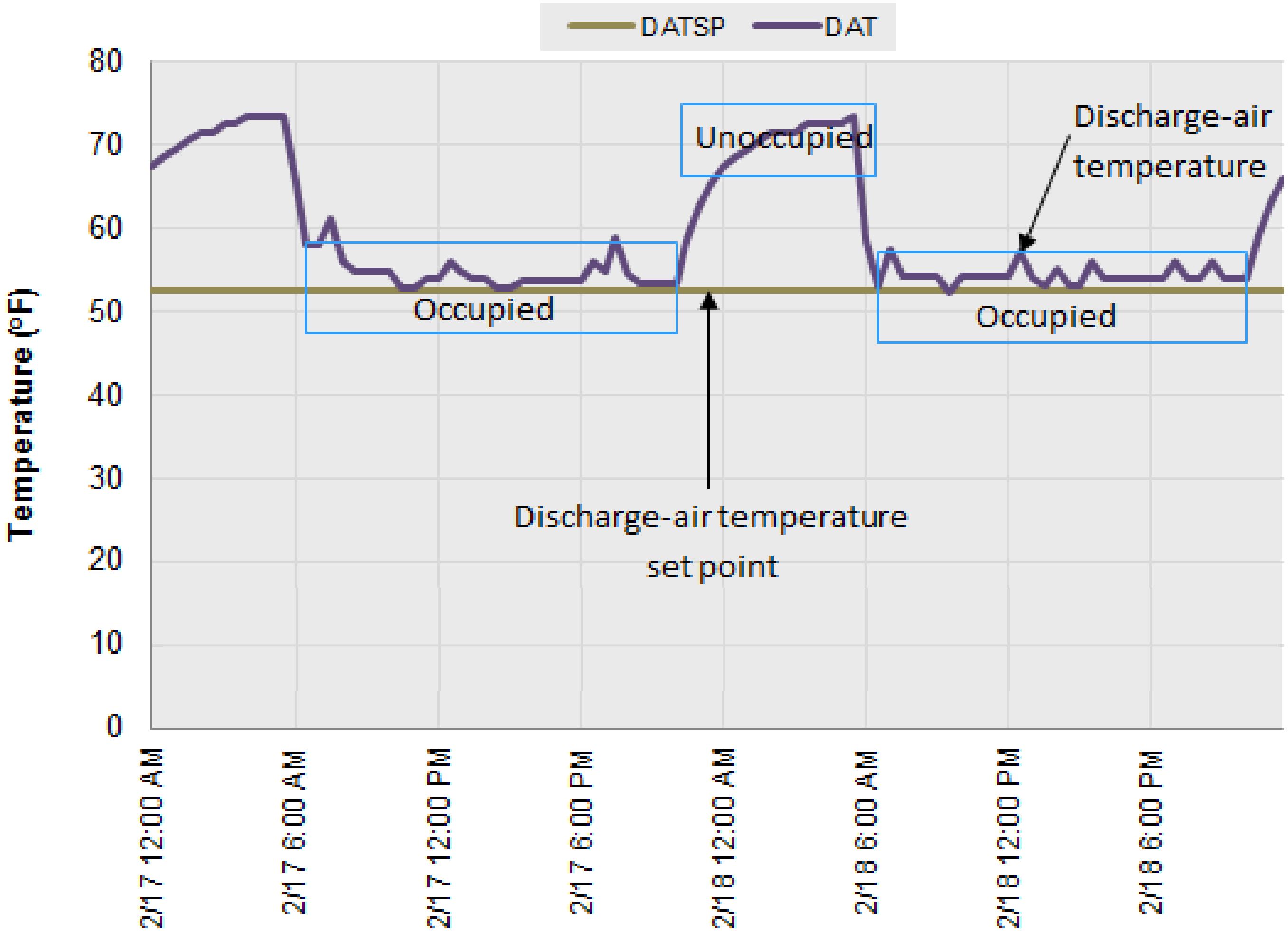
- HVAC % Savings from PNNL simulation-based analysis
- Top chart = DAT reset based on OAT
- Bottom chart = DAT reset based on zone temp



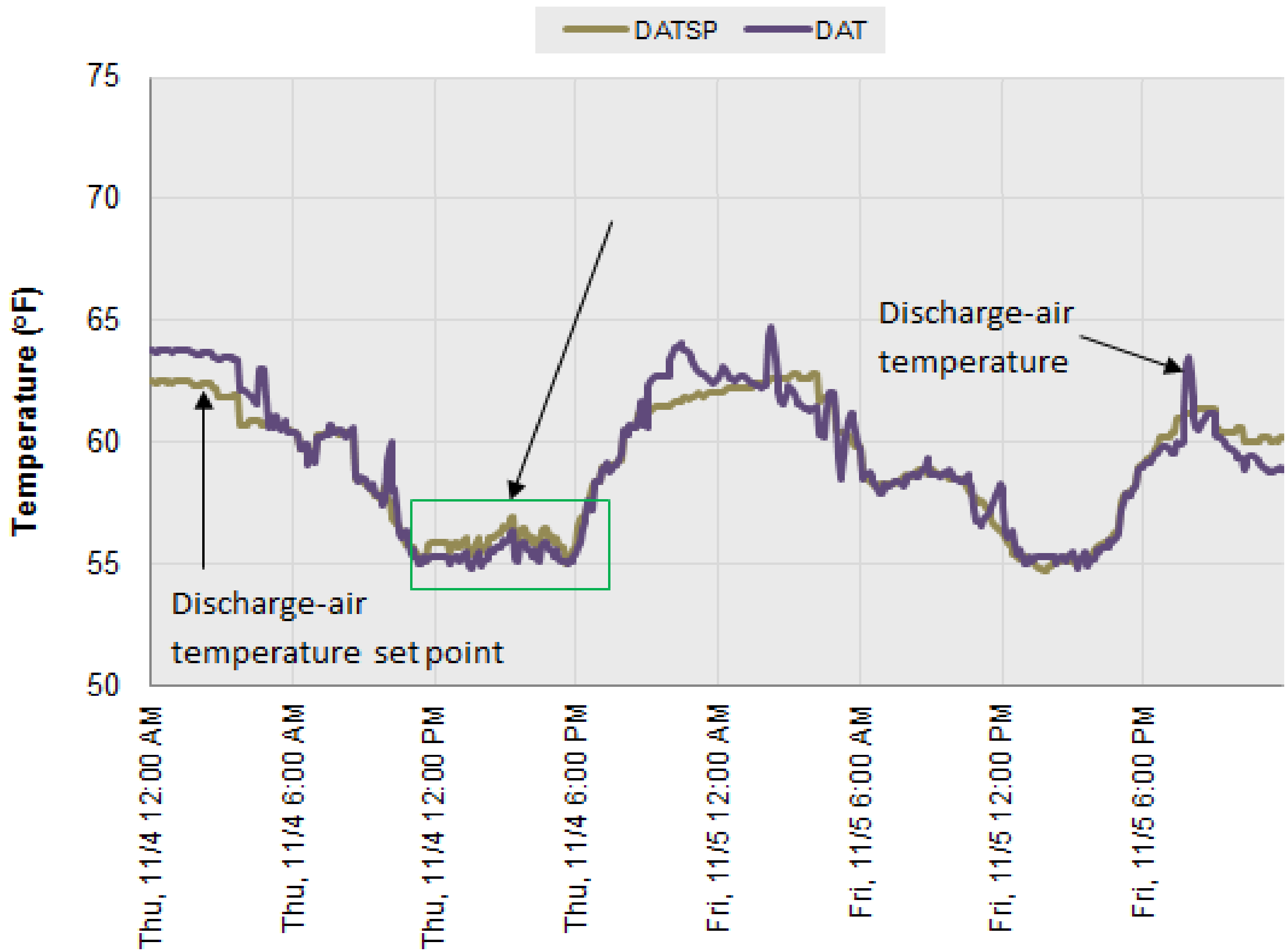
Things to Look For

- Discharge-air temperature control scheme
- “Flat” discharge-air temperature trends
- Sharply falling discharge-air temperatures
- Sharply rising discharge-air temperatures

Discharge-Air Temperature Reset Schedule



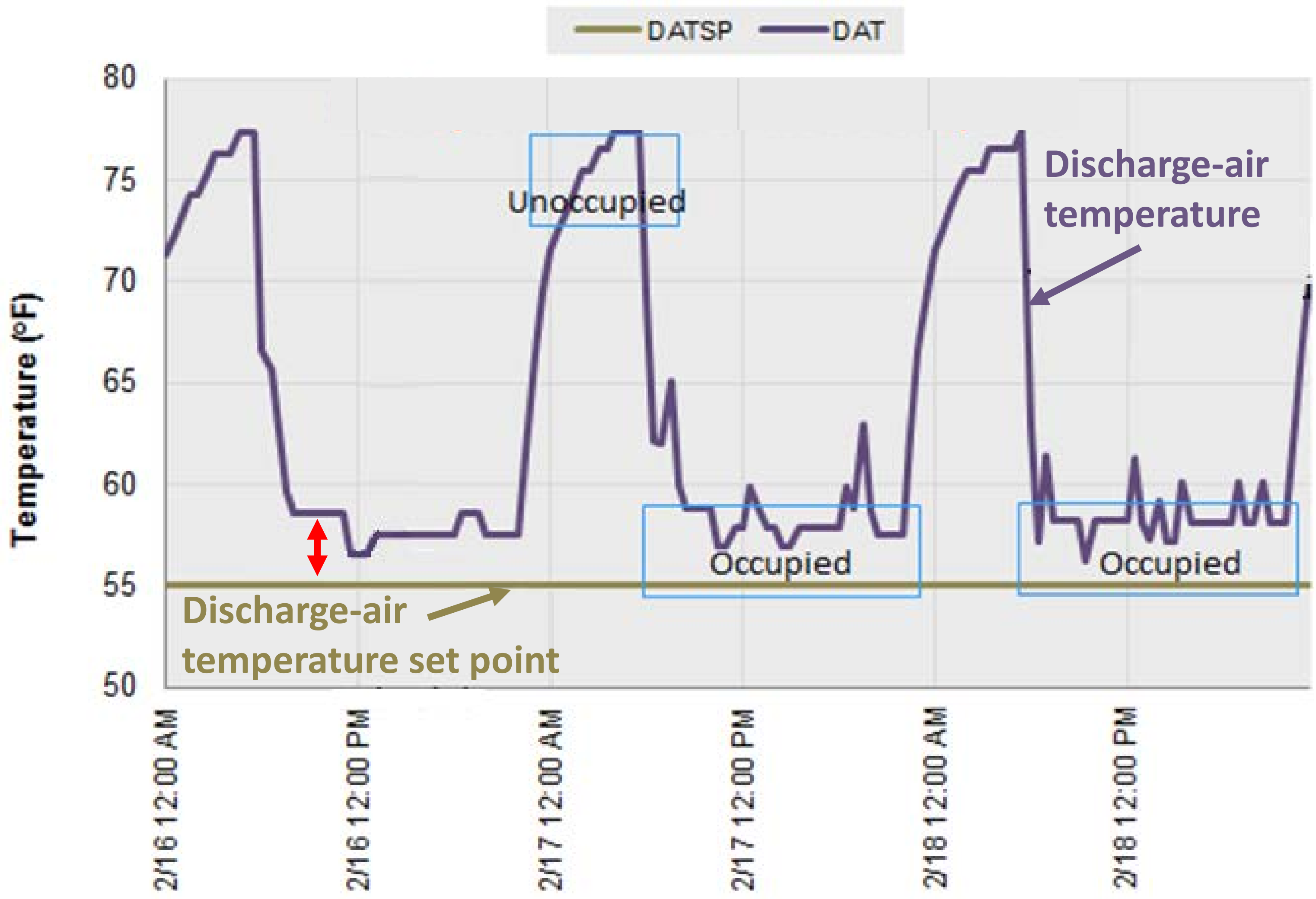
Discharge-Air Temperature Reset Schedule



Discharge-Air Temperature Reset

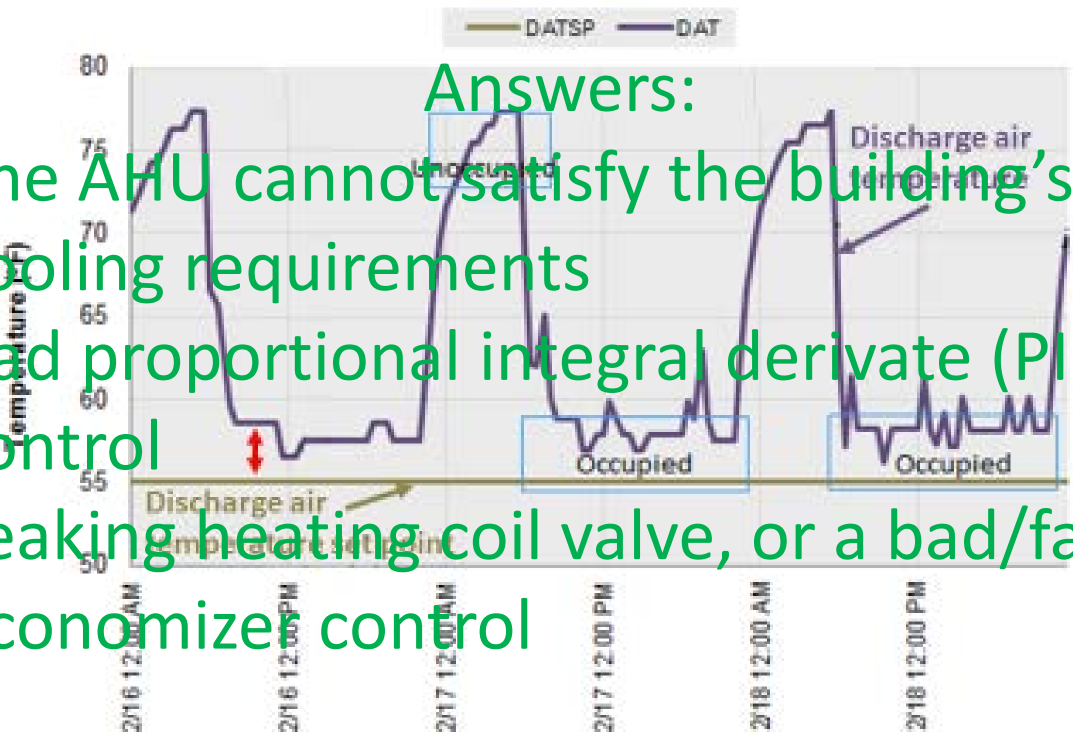
- To get true building load conditions, base reset discharge-air temperature on the following order:
  1. Zone conditions (lowest, highest, average?)
  2. Return-air temperature
  3. Outside-air temperature

Discharge-Air Temperature Reset



Discharge-Air Temperature Reset: Discussion Question

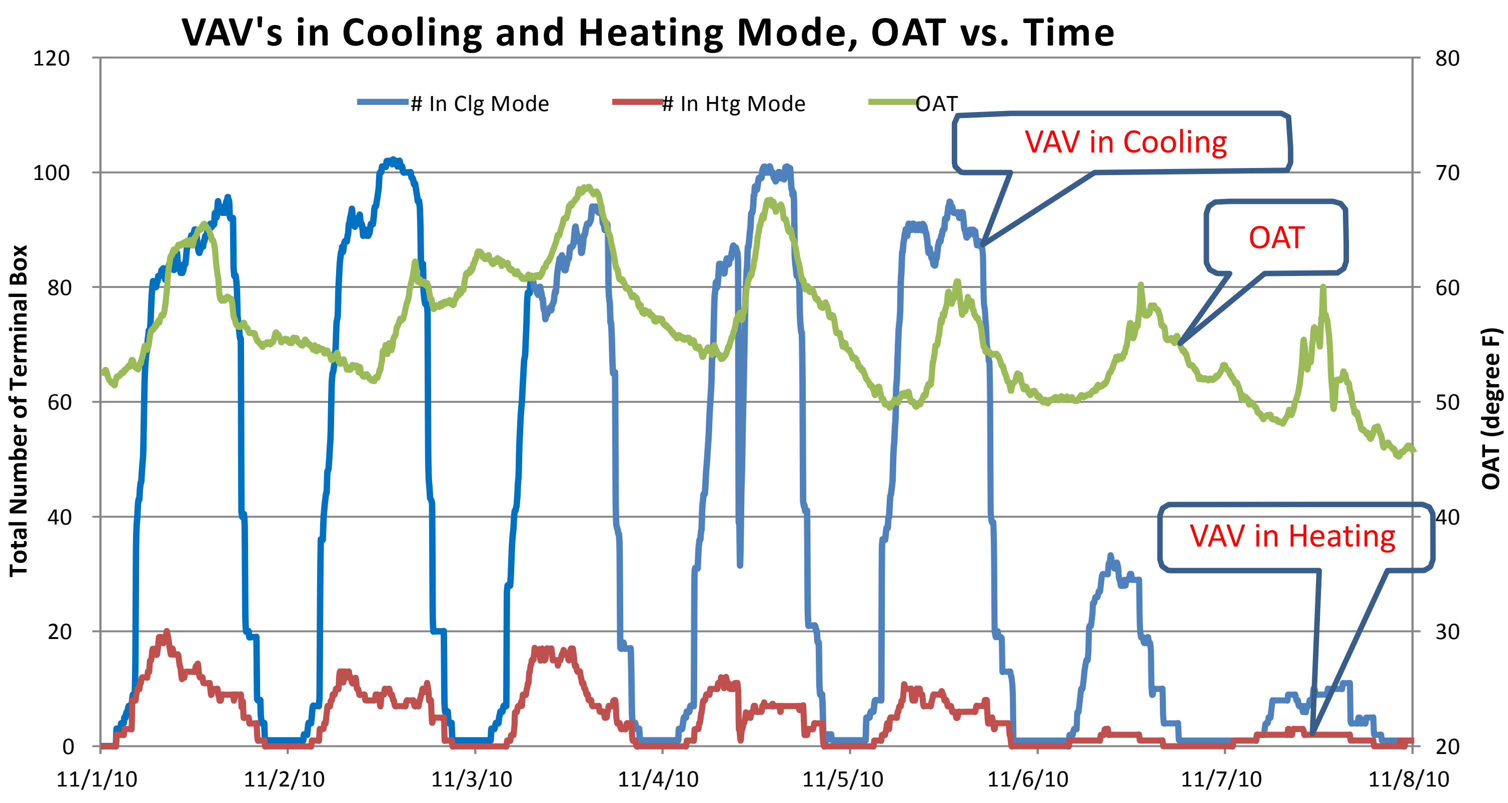
If the DAT is running higher than the DAT set point, what could this indicate?



Answers:

- ❑ The AHU cannot satisfy the building's cooling requirements
- ❑ Bad proportional integral derivate (PID) loop control
- ❑ Leaking heating coil valve, or a bad/failing economizer control

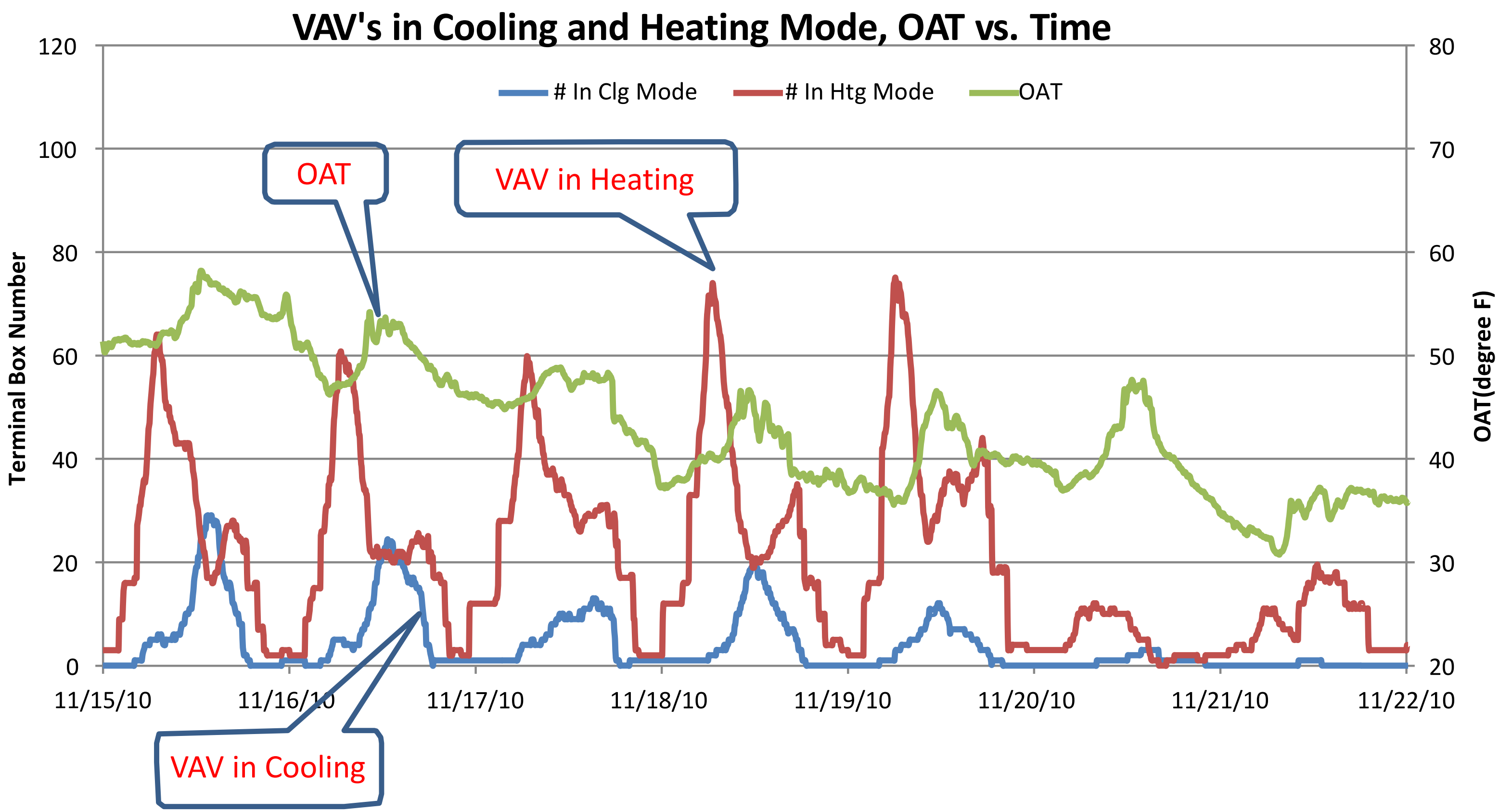
Discharge-Air Temperature Reset



Example of Bad Operation - No Reset

Opportunity to ***decrease*** the DAT

Discharge-Air Temperature Reset



Example of Bad Operation - No Reset

Opportunity to ***increase*** the DAT when OAT lower than 50°F

Recommendations and Actions

- Reset discharge-air temperature based on one of the following:
  - Zone conditions (preferred)
  - Return-air temperature
  - Outside-air temperature (least preferable).
- If you implement changes, start with small changes and continue to adjust as needed over time as you learn the "personality" of the building

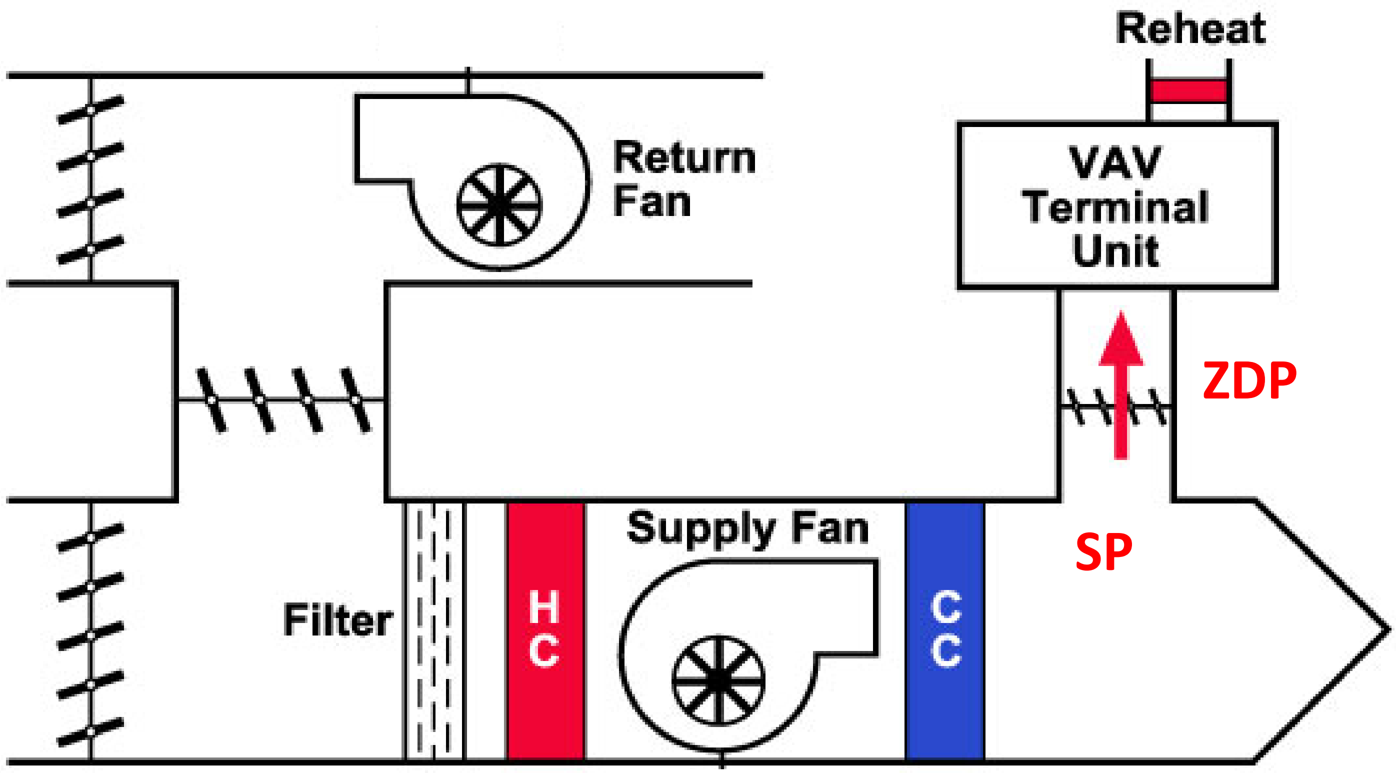
Re-tuning Control Strategies

AHU Static Pressure Control

Trend Data Needed

- Duct static pressure (SP)
- Duct static pressure set point
- Zone damper position signal (ZDP)

Data Points Being Used



Trends To Look For

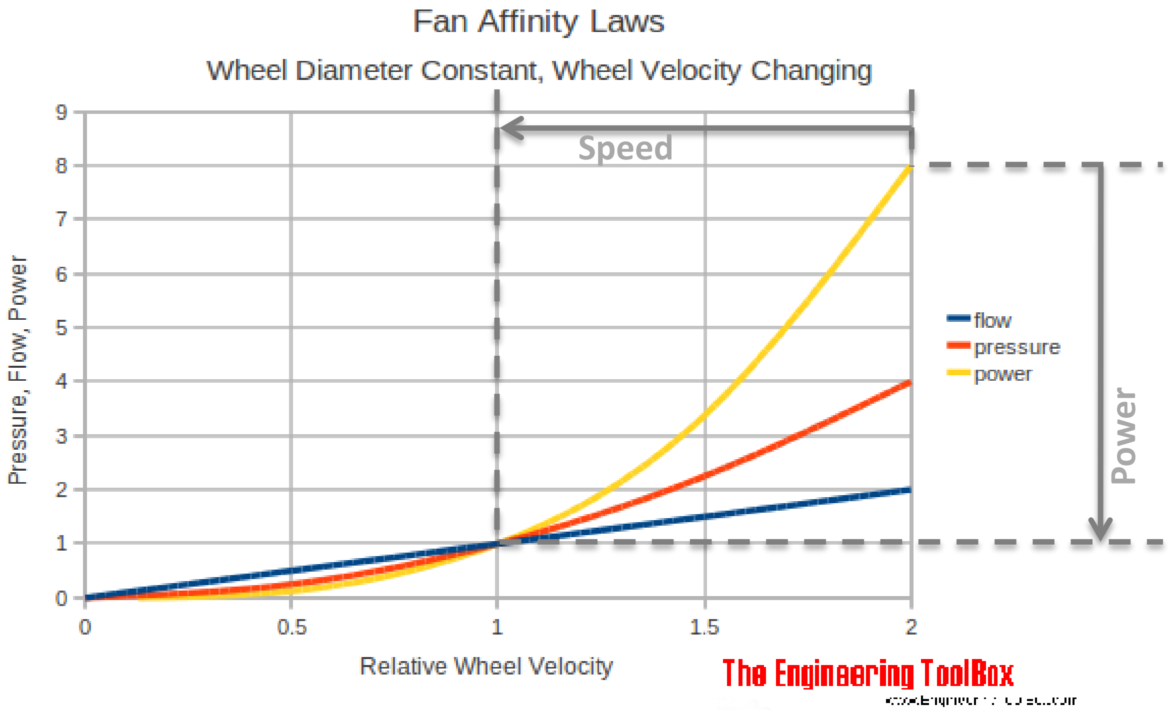
- Is there a reset-schedule for the duct static pressure?
- Is the static pressure set point too high or too low?
  - Review trends of damper position of variable air volume (VAV) boxes vs. time
  - Most dampers are nearly closed during cooling - static pressure too high
  - Several (>25%) dampers are fully open during cooling - static pressure too low (starved boxes)
- Look for dampers that aren't modulating with changing conditions, and VAV boxes that are not being controlled or not responding to control signals.

Issues

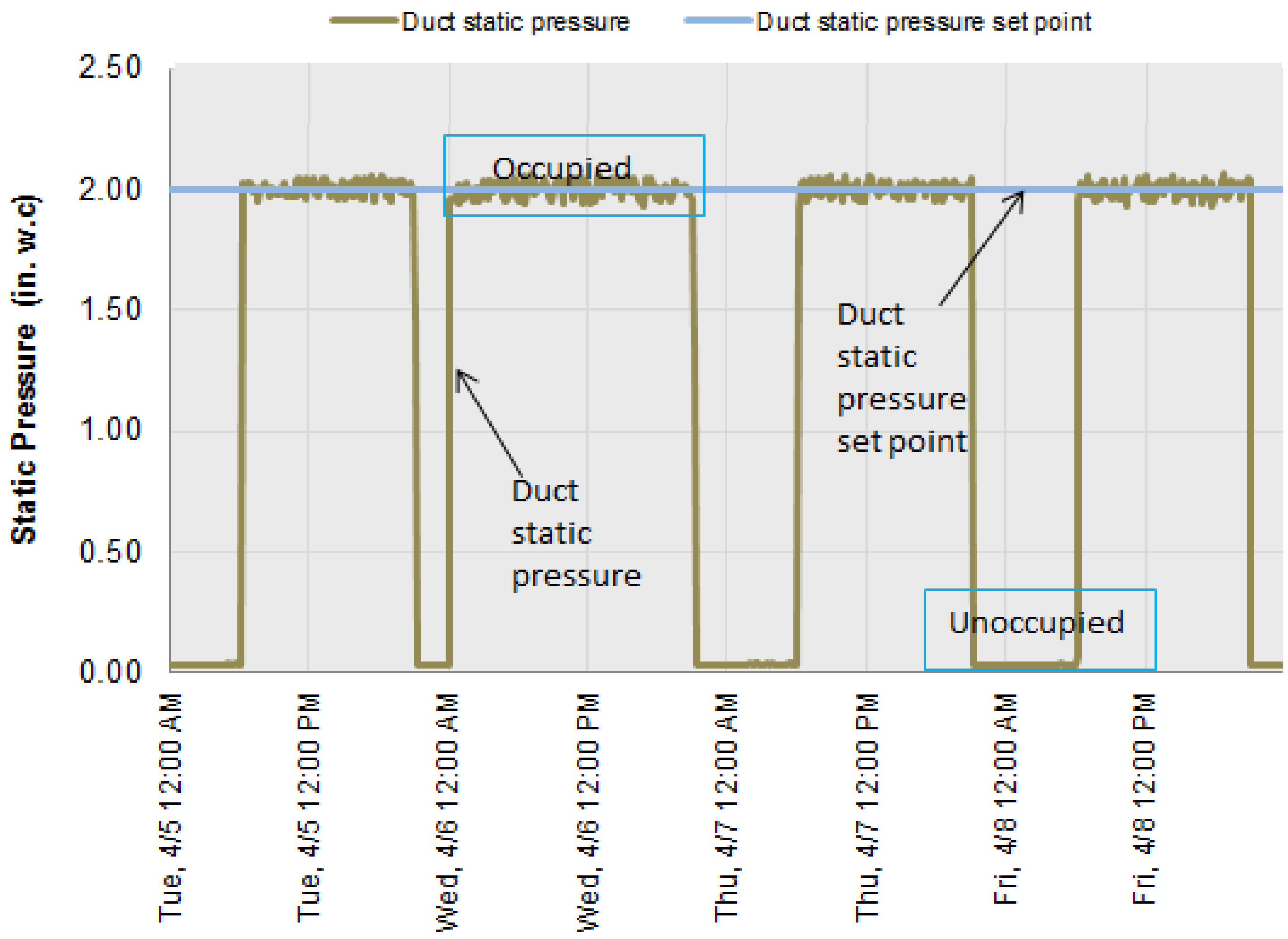
- Like discharge-air temperature, static pressure should follow the real load conditions
- Ideally, VAV dampers should run in the 50% to 75% range (non-design conditions)
- When many VAV dampers are down at 20% open, the static pressure is too high

Big Savings Potential

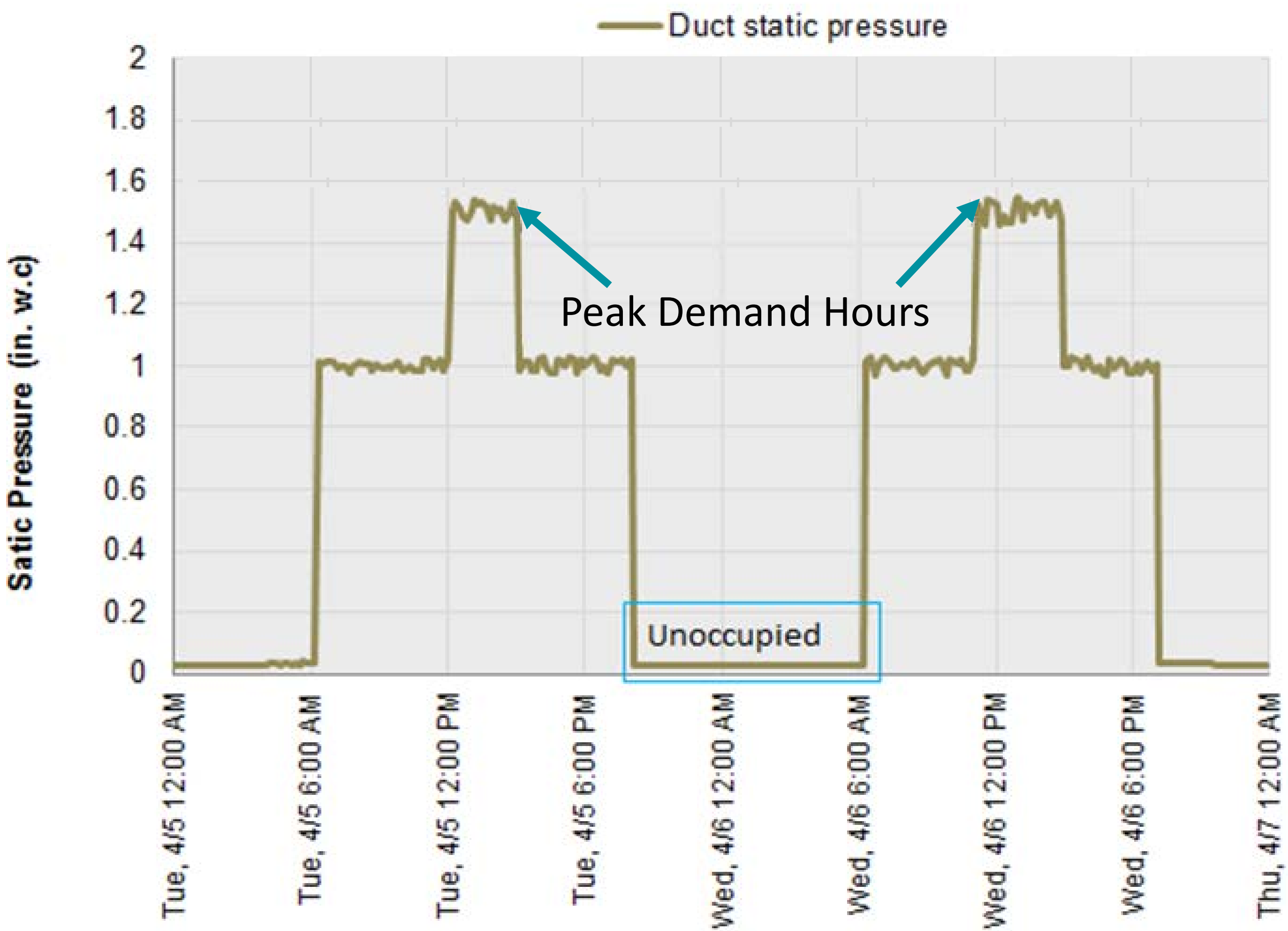
- Fan Affinity Laws: reducing fan speed by 1/2 uses about 1/8th the power



AHU Static Pressure Control



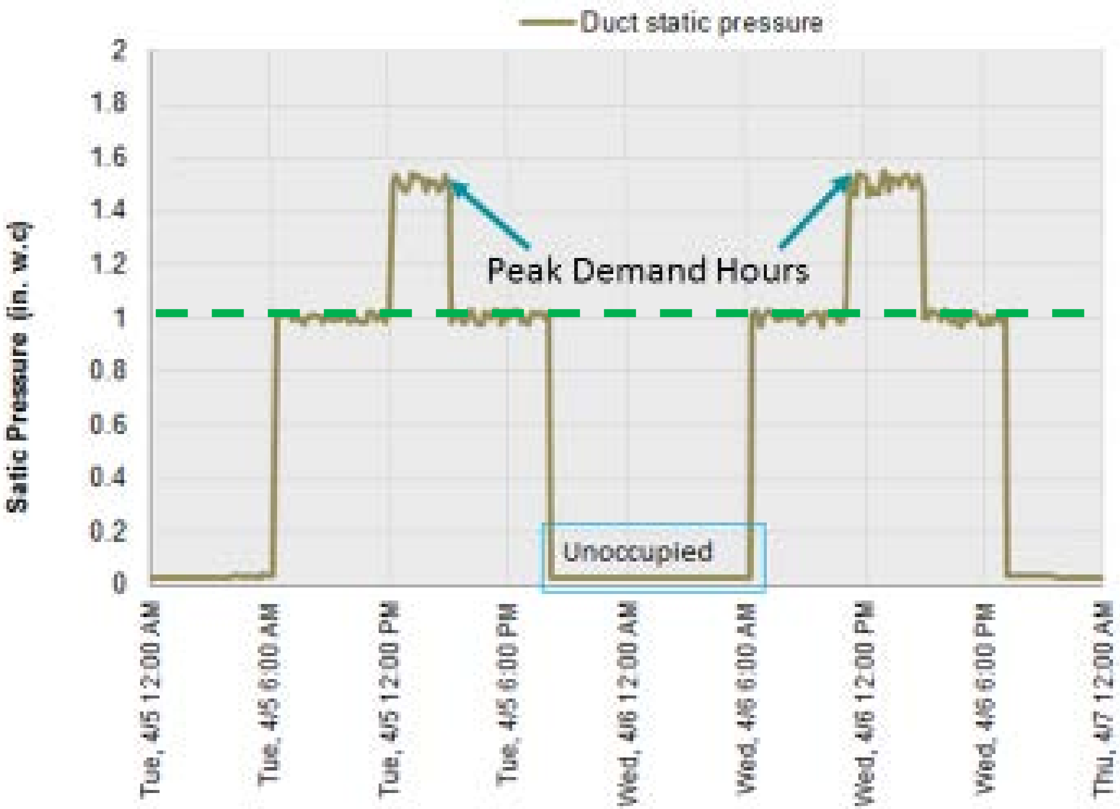
AHU Static Pressure Control



AHU Static Pressure Control: Discussion Question

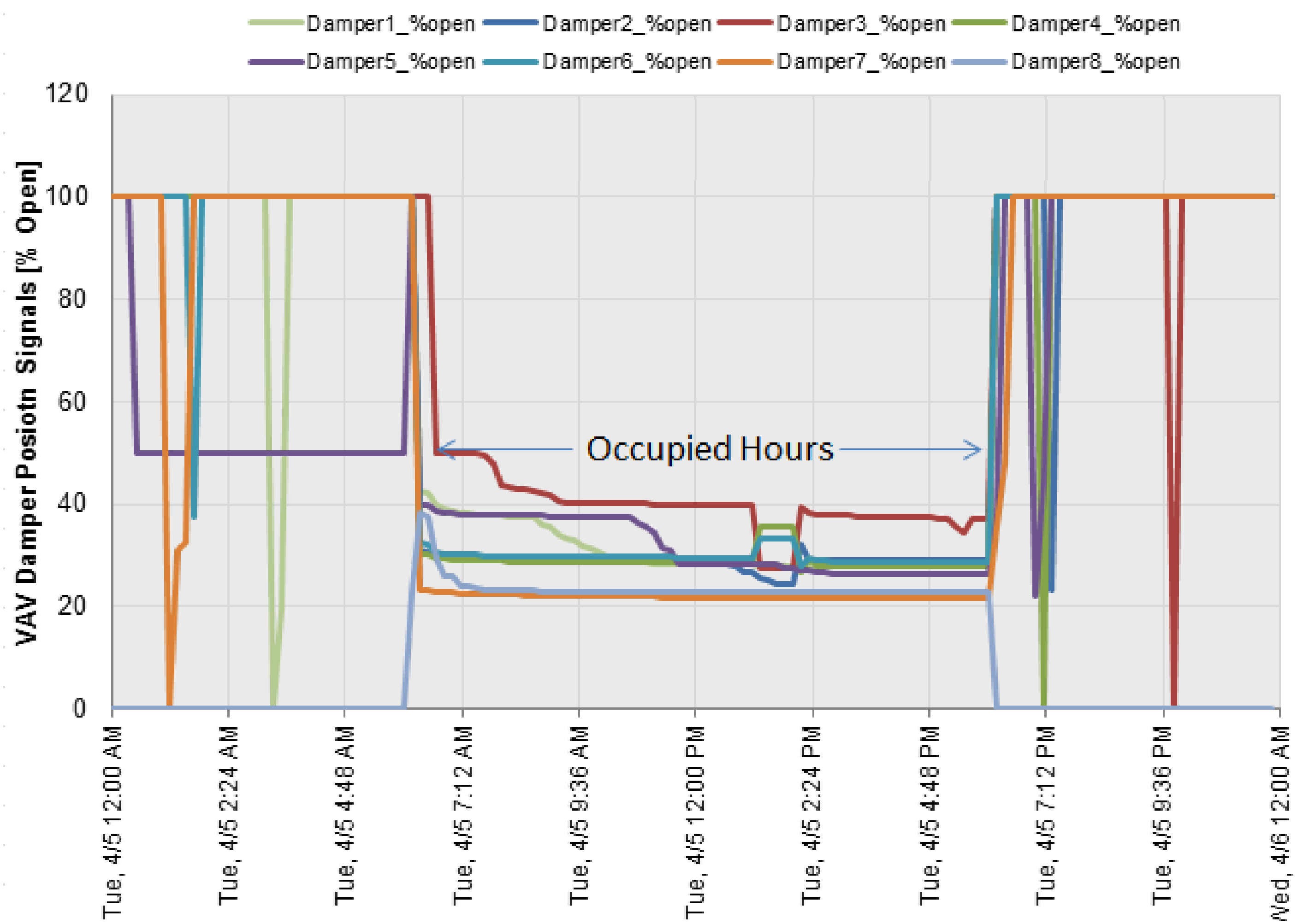
Where would the static pressure set point occur in this case?

Answer:

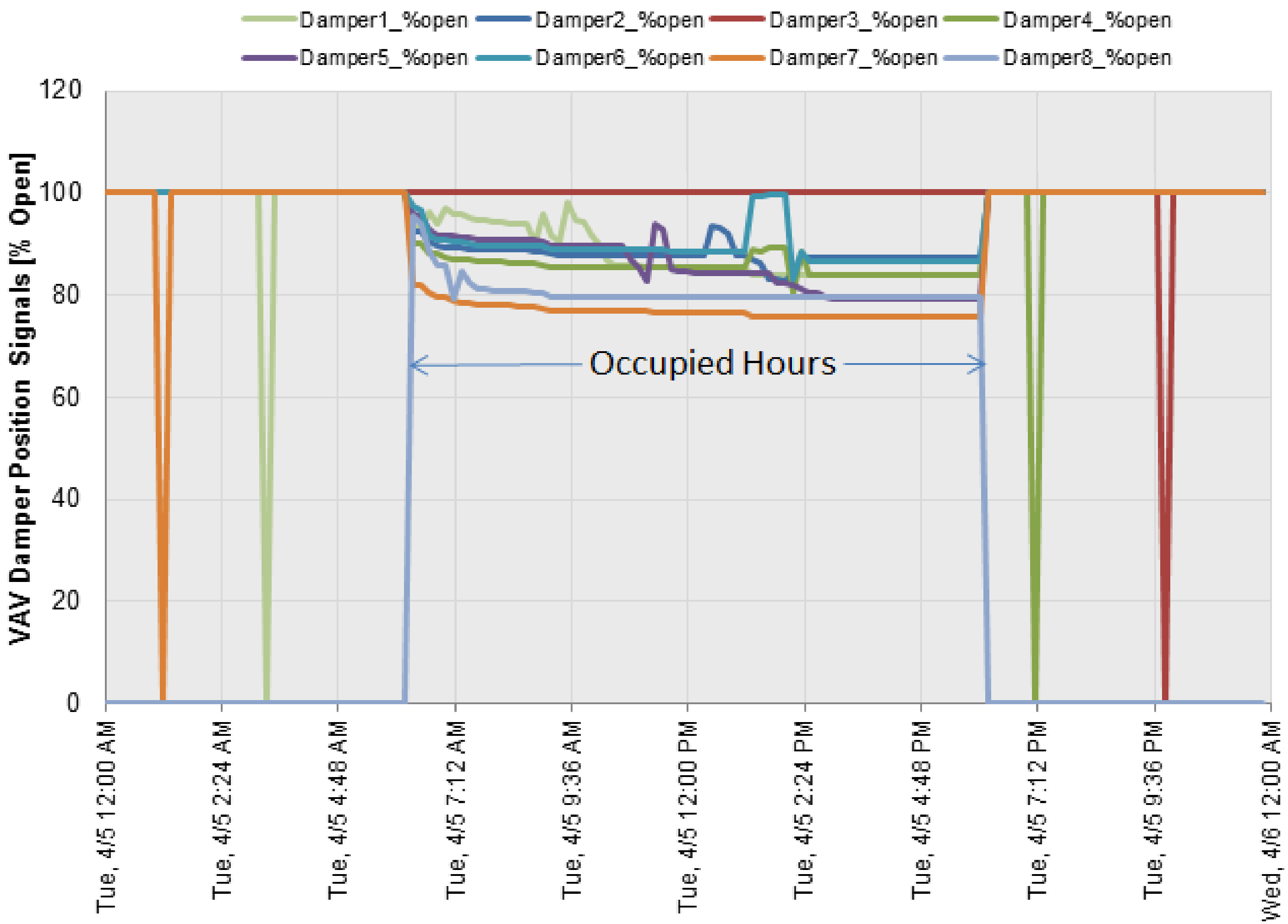


We can see from the static pressure that the set point is changing to building conditions.

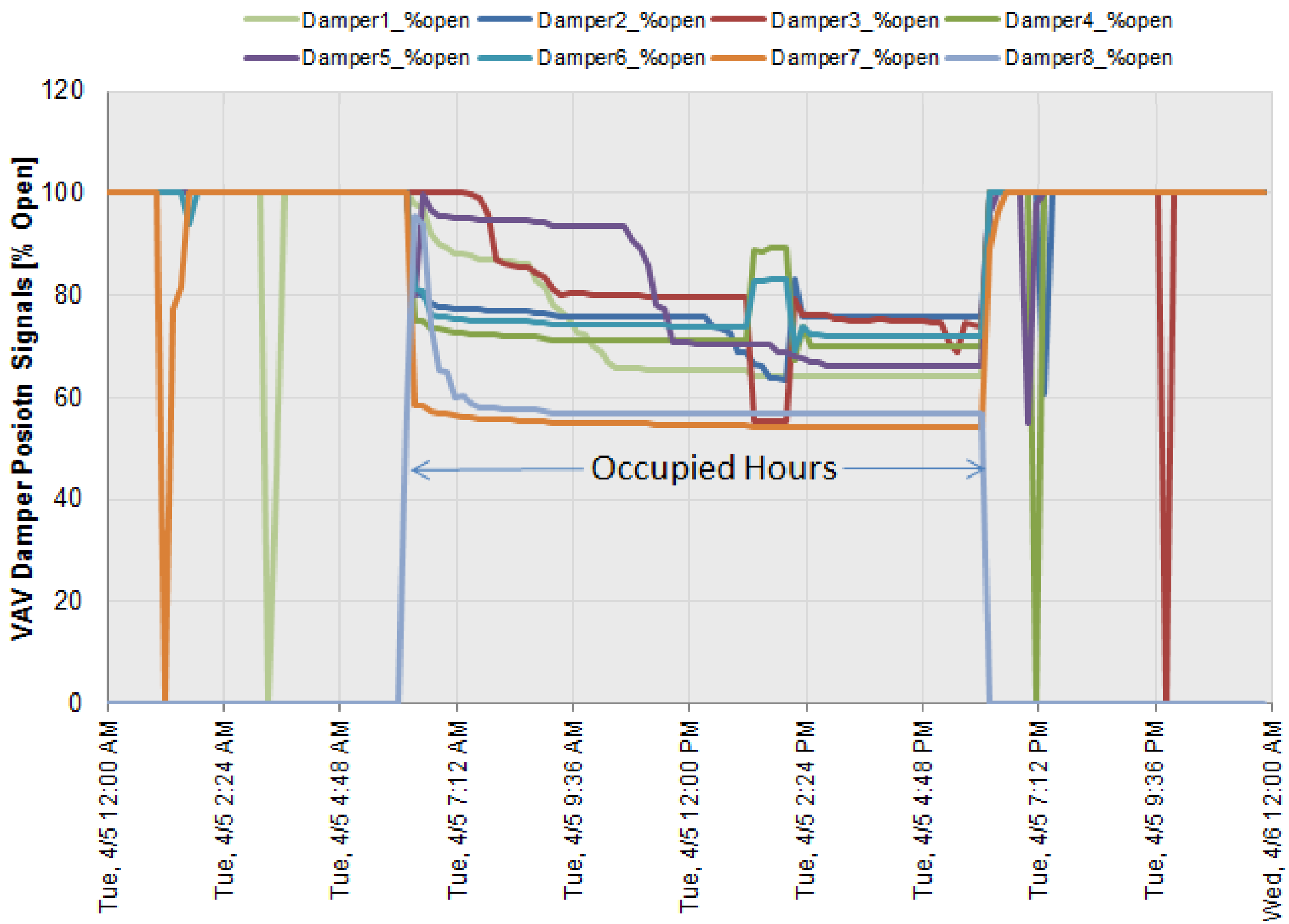
AHU Static Pressure Control



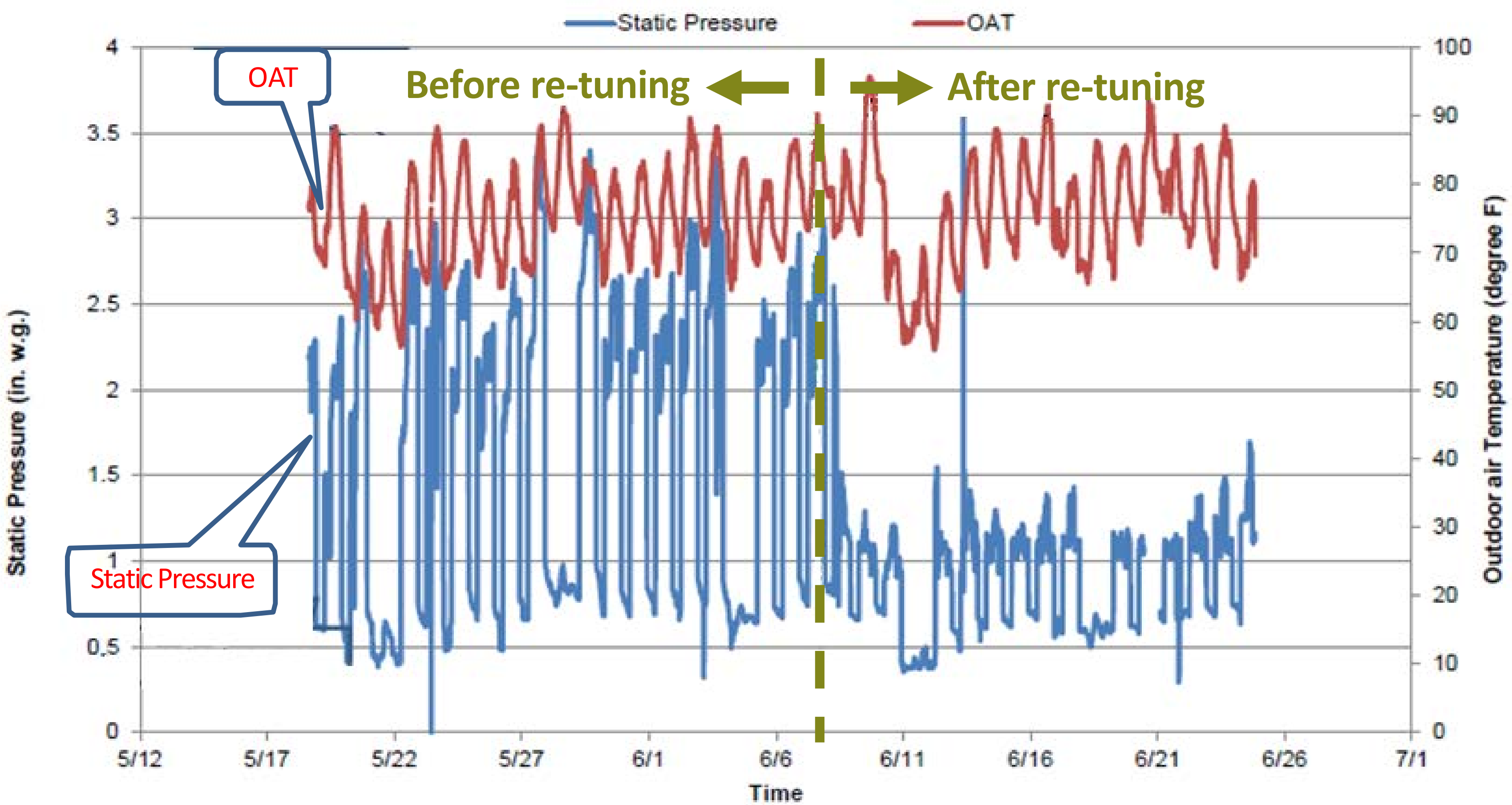
AHU Static Pressure Control



AHU Static Pressure Control



Static Pressure
Before and After Re-tuning



Recommendations and Actions

- Ideally, VAV box dampers should run in the 50%-75% range.
- Match the discharge static control set point to actual need - an example is systems that run at 0.5" in the morning and 2" in the afternoon when fully loaded.
- Numerous occupant complaints may indicate an improperly working discharge static pressure control scheme. Note that hot and/or stuffy complaints occur when discharge static pressure is too low, not when it's too high.
- Excess static pressure can cause excessive air and cold drafts as well as high noise levels in offices from diffuser noise
- Trended data for discharge static pressure control that is working should show varied static pressure.

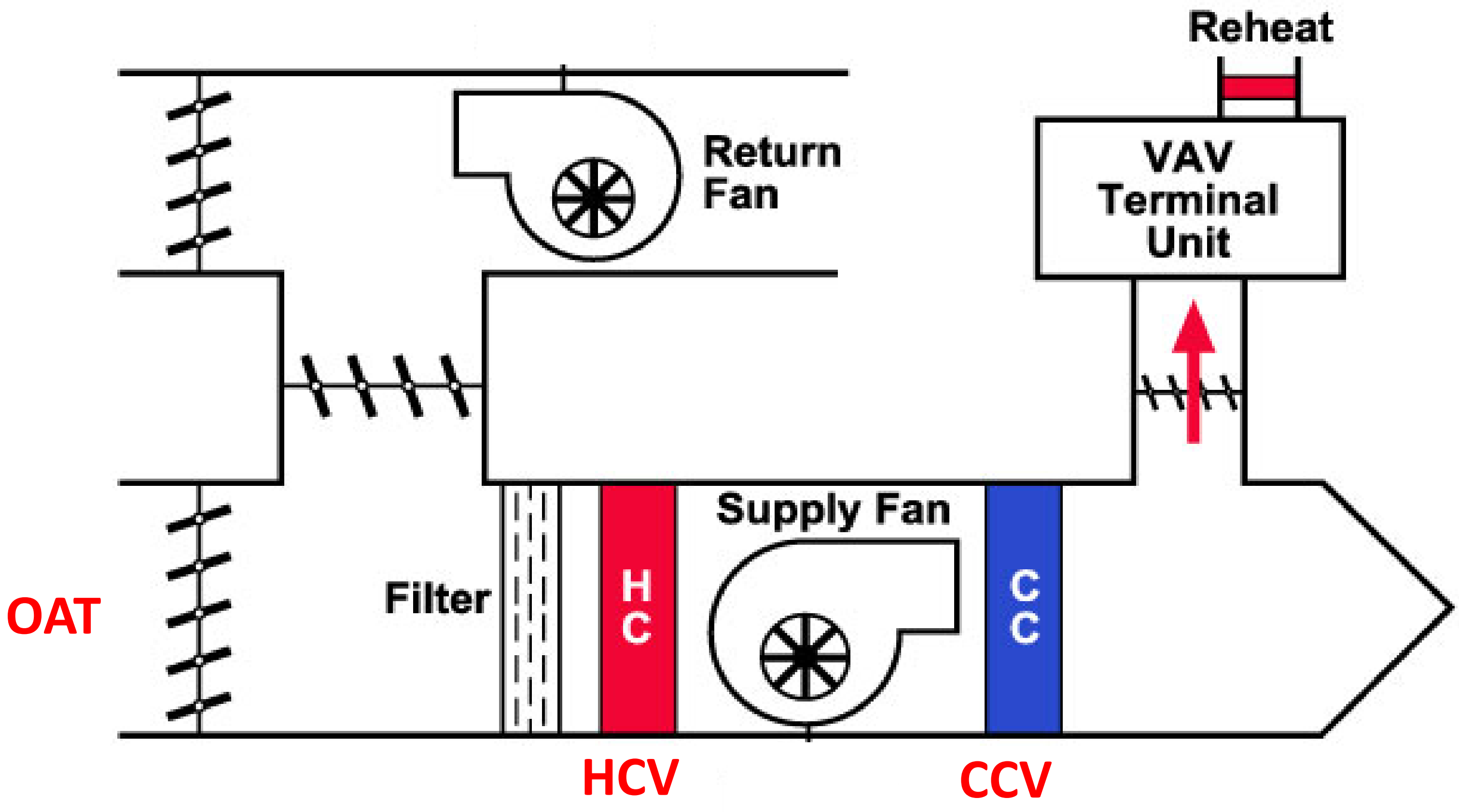
Re-tuning Control Strategies

AHU Heating and Cooling Control

Trend Data Needed

- Outdoor-air temperature (OAT)
- Heating-coil-valve signal (HCV)
- Cooling-coil-valve signal (CCV)

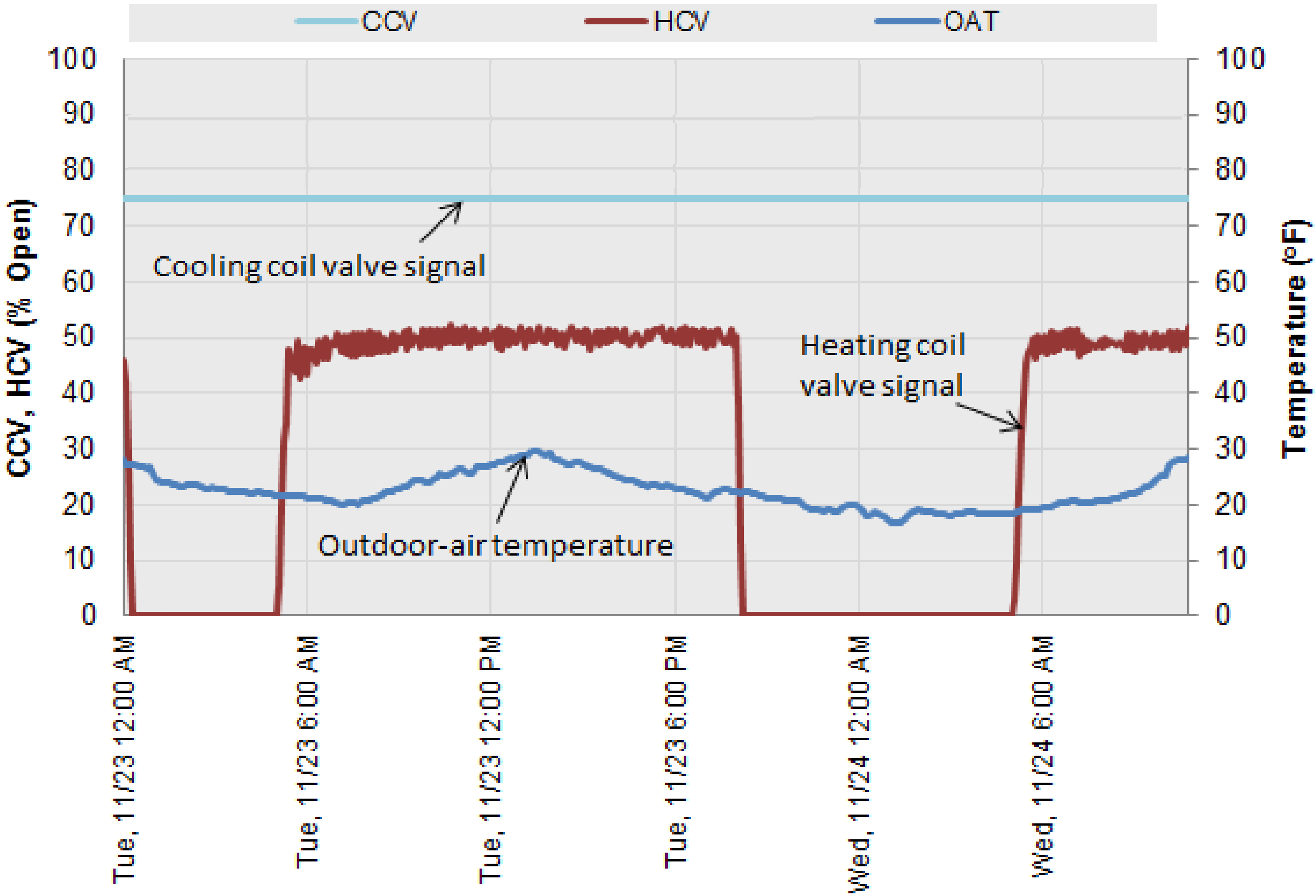
Data Points Being Used



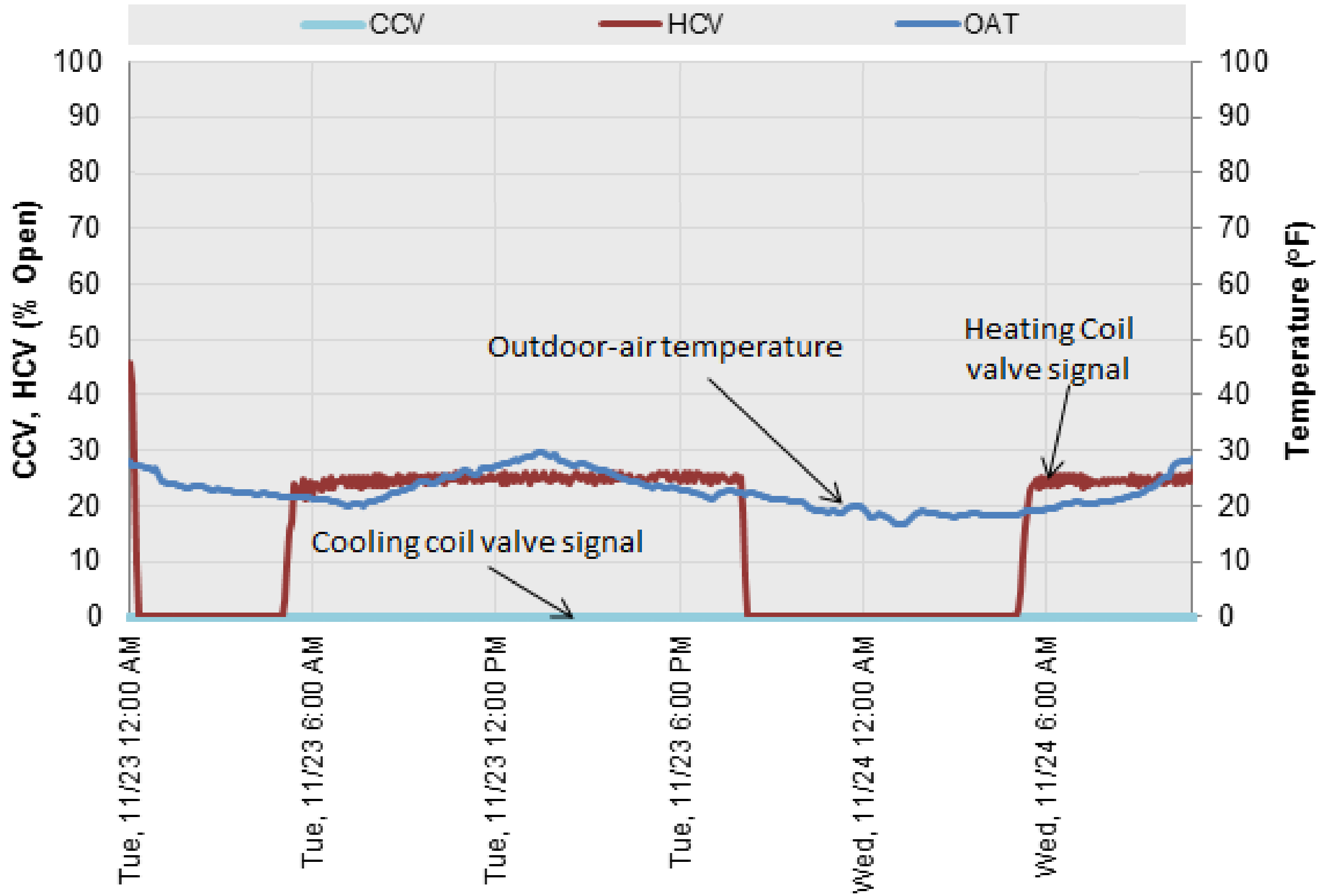
Trends To Look For

- Air-handler heating and cooling coils operating simultaneously
- Heating and cooling lockouts possibly overlapping
- Unreasonable values for the heating and cooling lockouts (usually indicates failed or leaking heating/cooling valves)
- If the VFD does not modulate, it has probably been overridden.

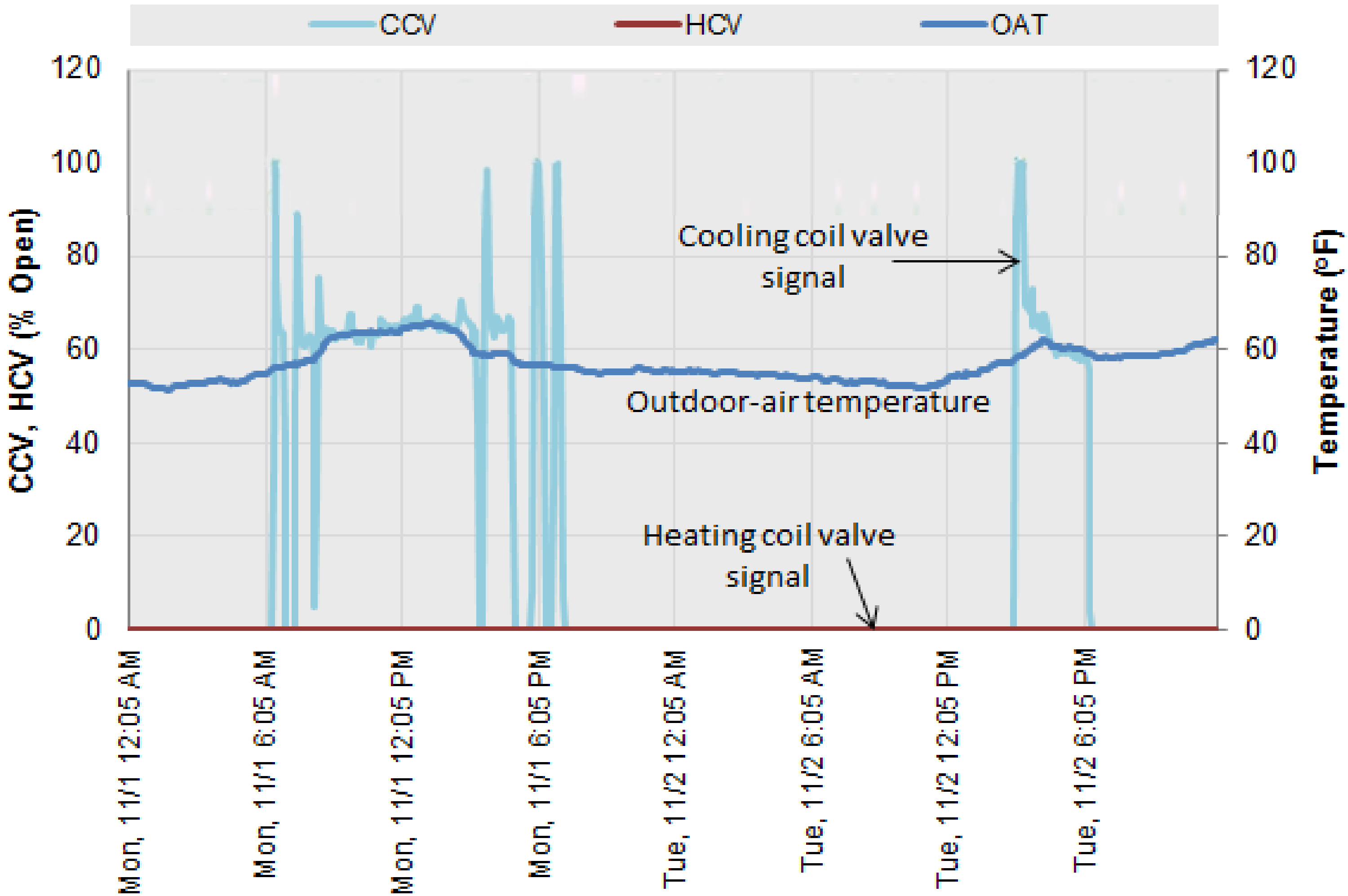
AHU Heating and Cooling Control



AHU Heating and Cooling Control



AHU Heating and Cooling Control



Recommendations and Actions

- Make sure that these lockout set points do not overlap.
- Check the heating and cooling-coil valves for leaks.
  - Coil pipes warmer/colder than room temp when outdoor air temperature is beyond the lockout temp or system should be in economizing mode.
- Loops locked out at some outdoor-air temperature preventing heating and cooling at same time
  - Heating locked out above 50°F or lowest temperature building can do without heat
  - Cooling locked out below 55°F or highest temperature building can do without cooling
  - Critical on dual-duct and multi-zone systems
  - Balance point of building is critical when setting these lockouts

Overall Recommendations

- Enable unoccupied mode and night setback control.
- Shut off units at night and on weekends.
- Turn off heating systems (for reheat only) during the summer.
- When the reheat system is shut off, comfort may be maintained by increasing discharge air temperature (for constant volume units).
- To avoid having to turn the heating system on and off repeatedly, do not turn off heating too early in the summer.
- Lock out cooling during the winter.
- When the cooling system is shut off, comfort may be maintained by decreasing discharge air temperature (for constant volume units).
- To avoid having to turn the cooling system on and off repeatedly, do not turn off cooling too early in the fall or winter.
- Turn off systems during unoccupied hours.
- Slow down systems during unoccupied and lightly occupied hours.
- Make sure there are no conditions where heating and cooling can run simultaneously.
- Make sure there are proper setpoints for locking out heating and cooling (i.e., lockouts and deadbands are correct.

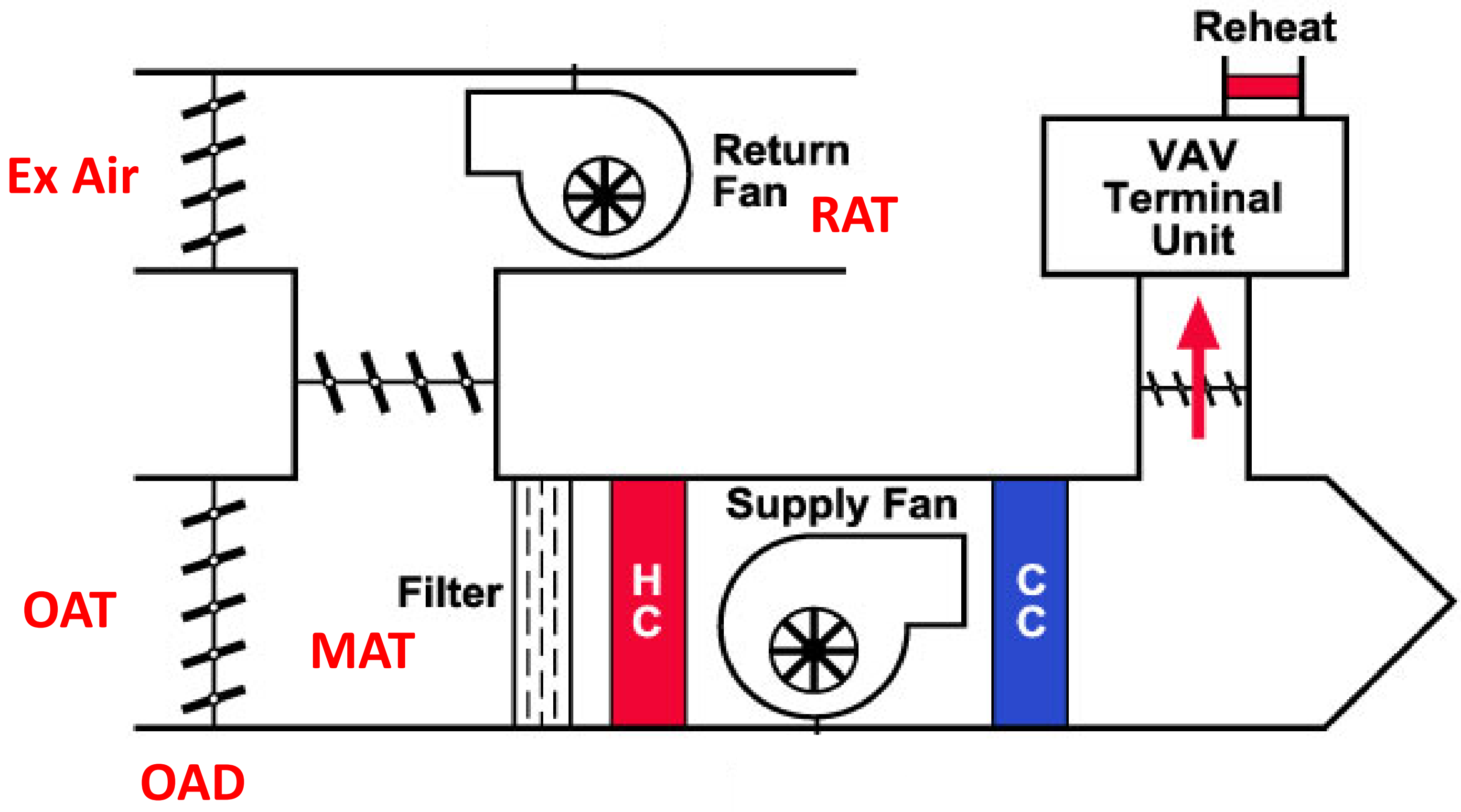
Re-tuning Control Strategies

AHU Outdoor-Air Operation

Trend Data Needed

- Outdoor-air temperature (OAT)
- Outdoor-air damper position signal (OAD)
- Mixed-air temperature (MAT)
- Supply fan speed
- Occupancy mode
- Return-air temperature (RAT)
- Outdoor-air fraction (OAF)

Data Points Being Used



Outdoor-Air Fraction (OAF)

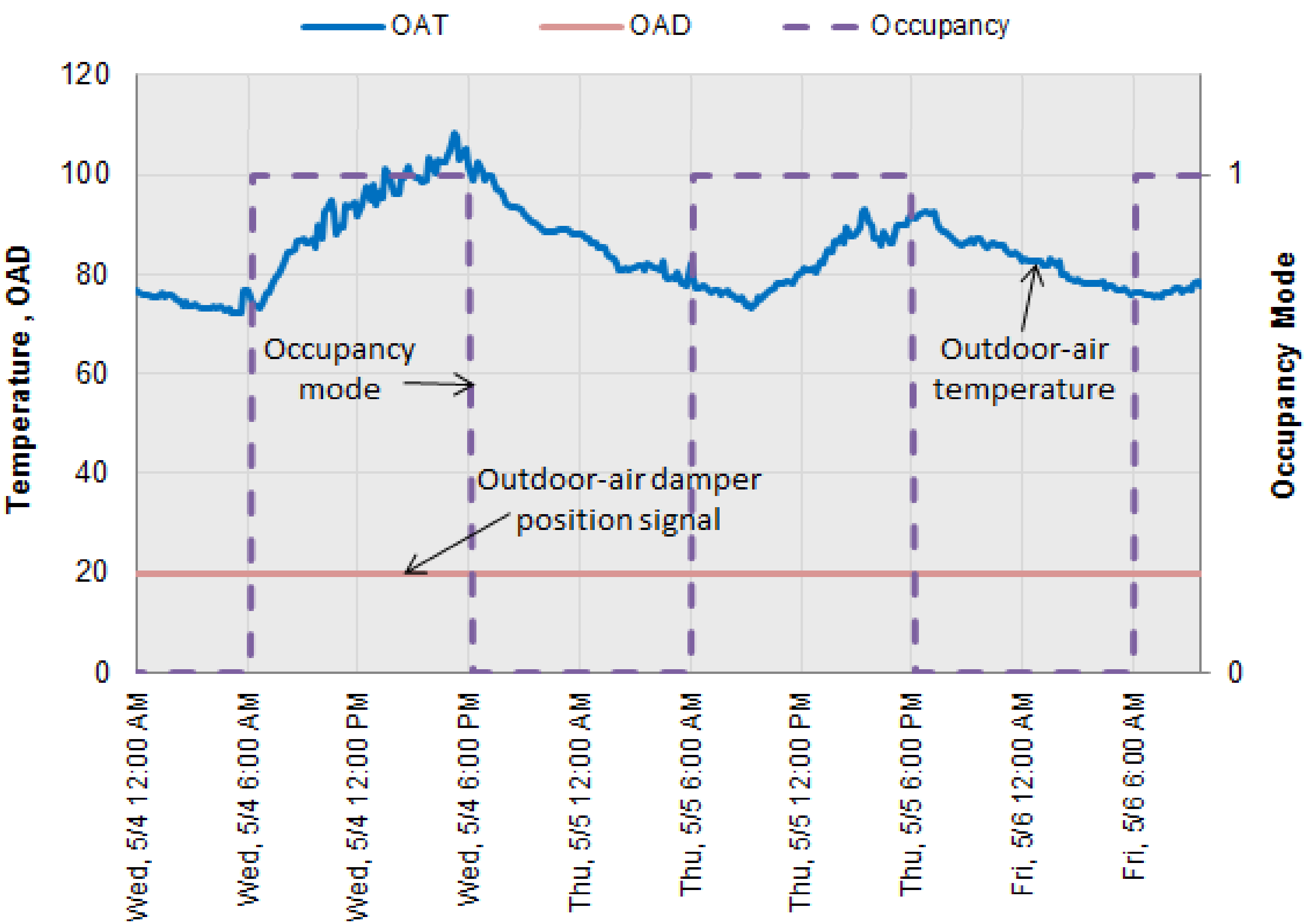
OAF = (MAT - RAT) / (OAT - RAT)

The calculated OAF should only be used to investigate the true percent of outdoor-air entering the AHU when the OAT is significantly different (+/- 5°F) than the RAT

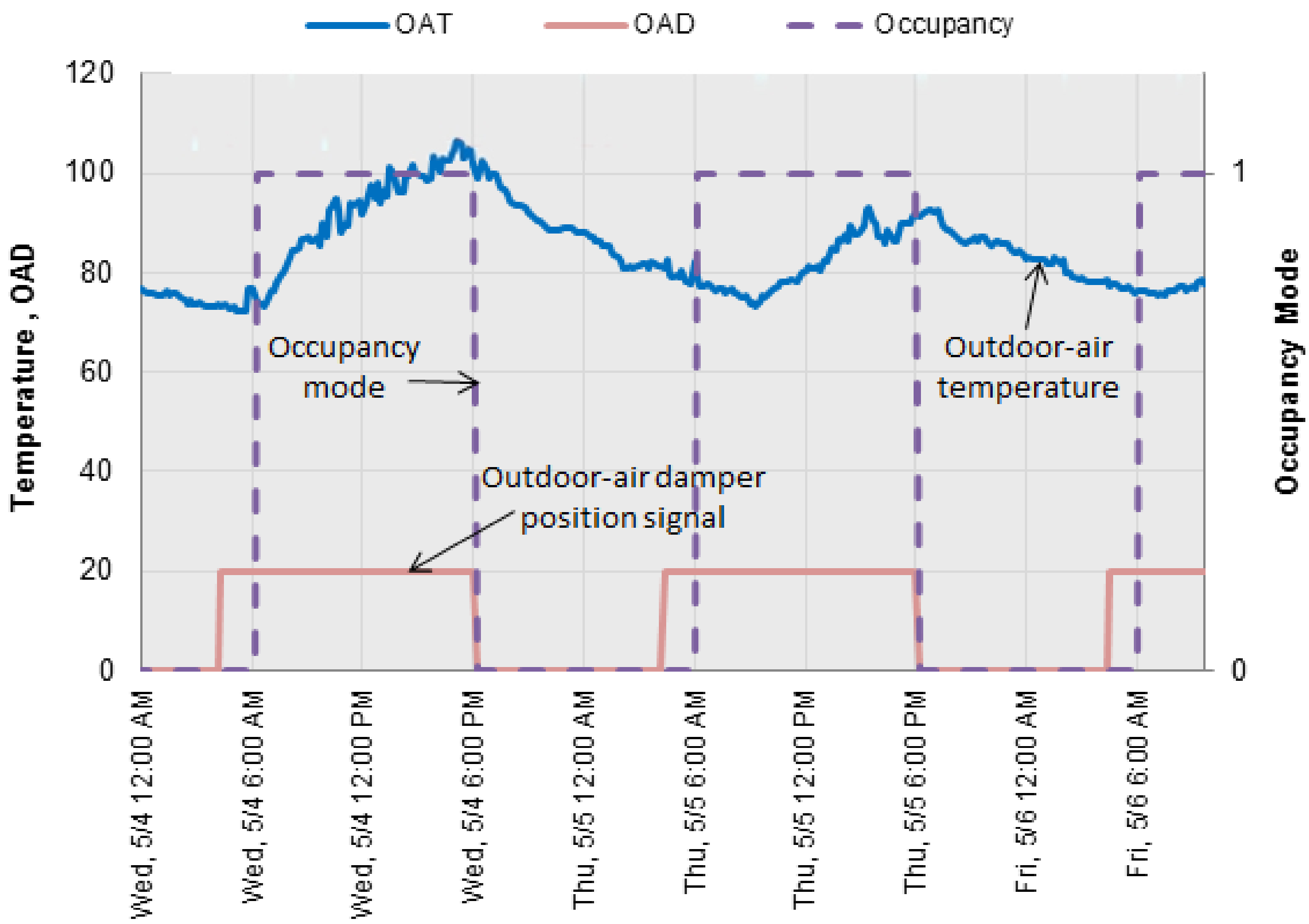
Trends To Look For

- Is outdoor air sufficient for ventilation or is over-ventilation occurring?
- Does the outdoor-air damper (OAD) close during unoccupied times?
- Does the actual outdoor-air fraction (OAF) track with the outdoor-air damper (OAD) position?
  - OAF should be within $\pm$ 10-15% of OAD position

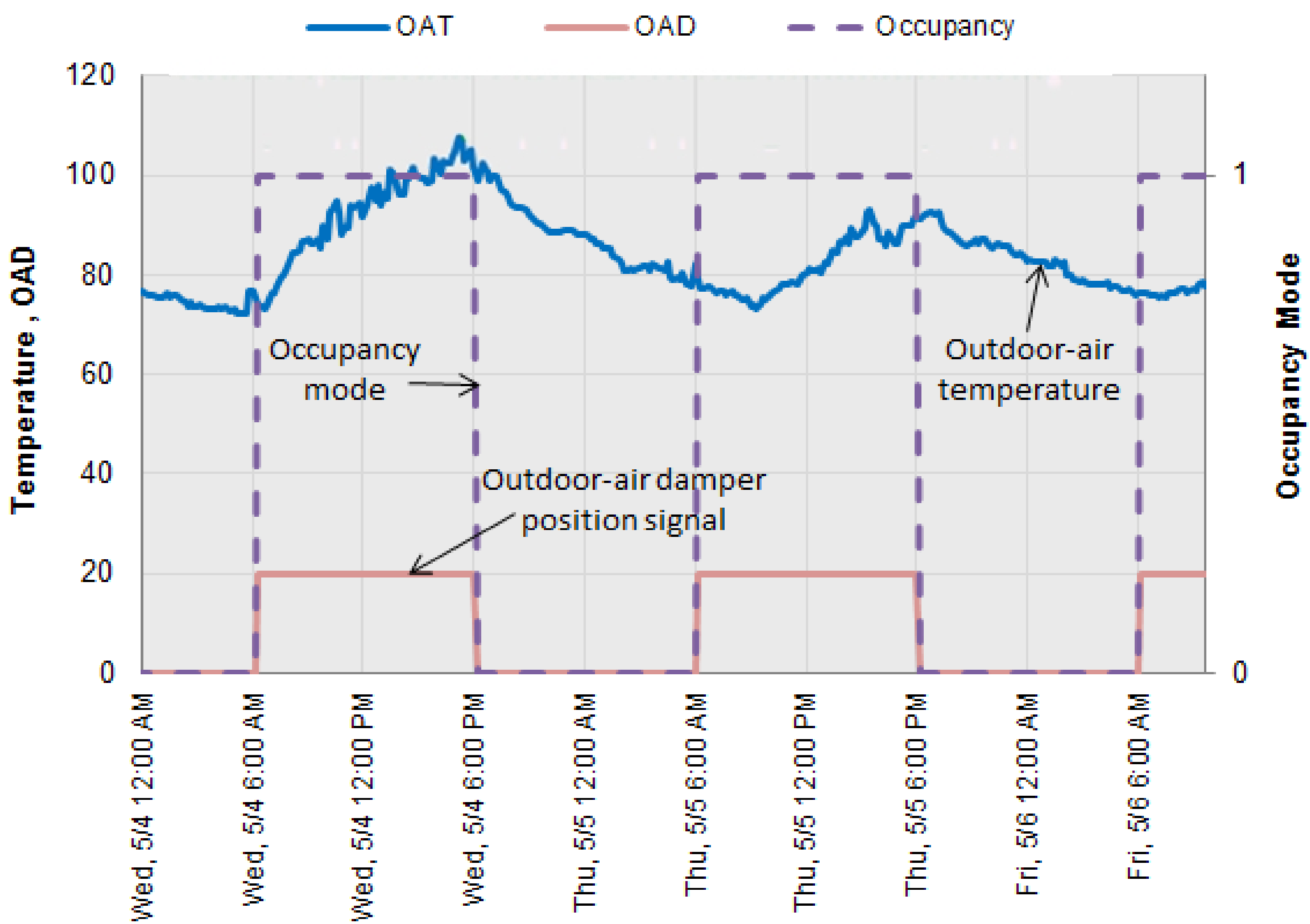
AHU Outdoor-Air Operation



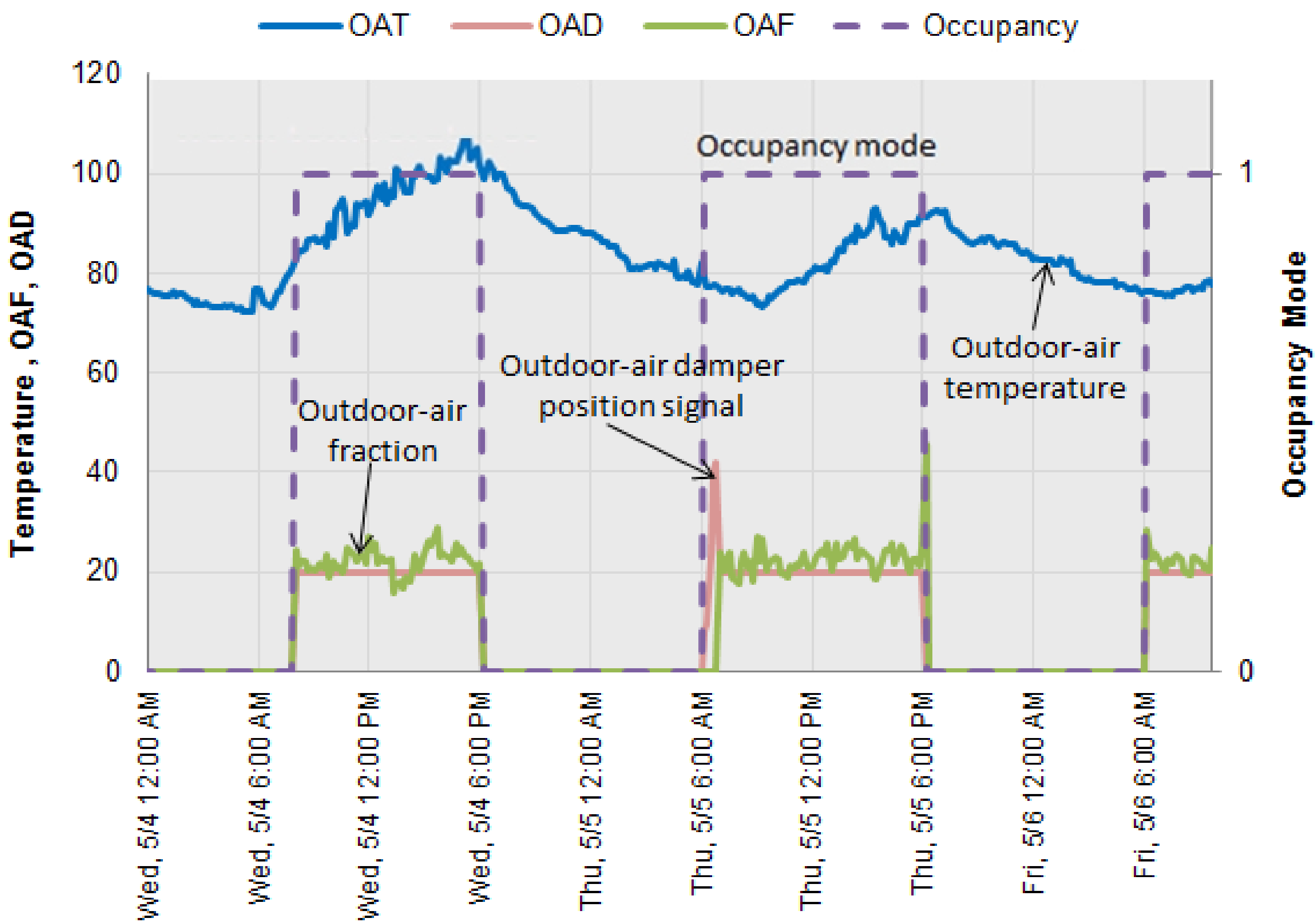
AHU Outdoor-Air Operation



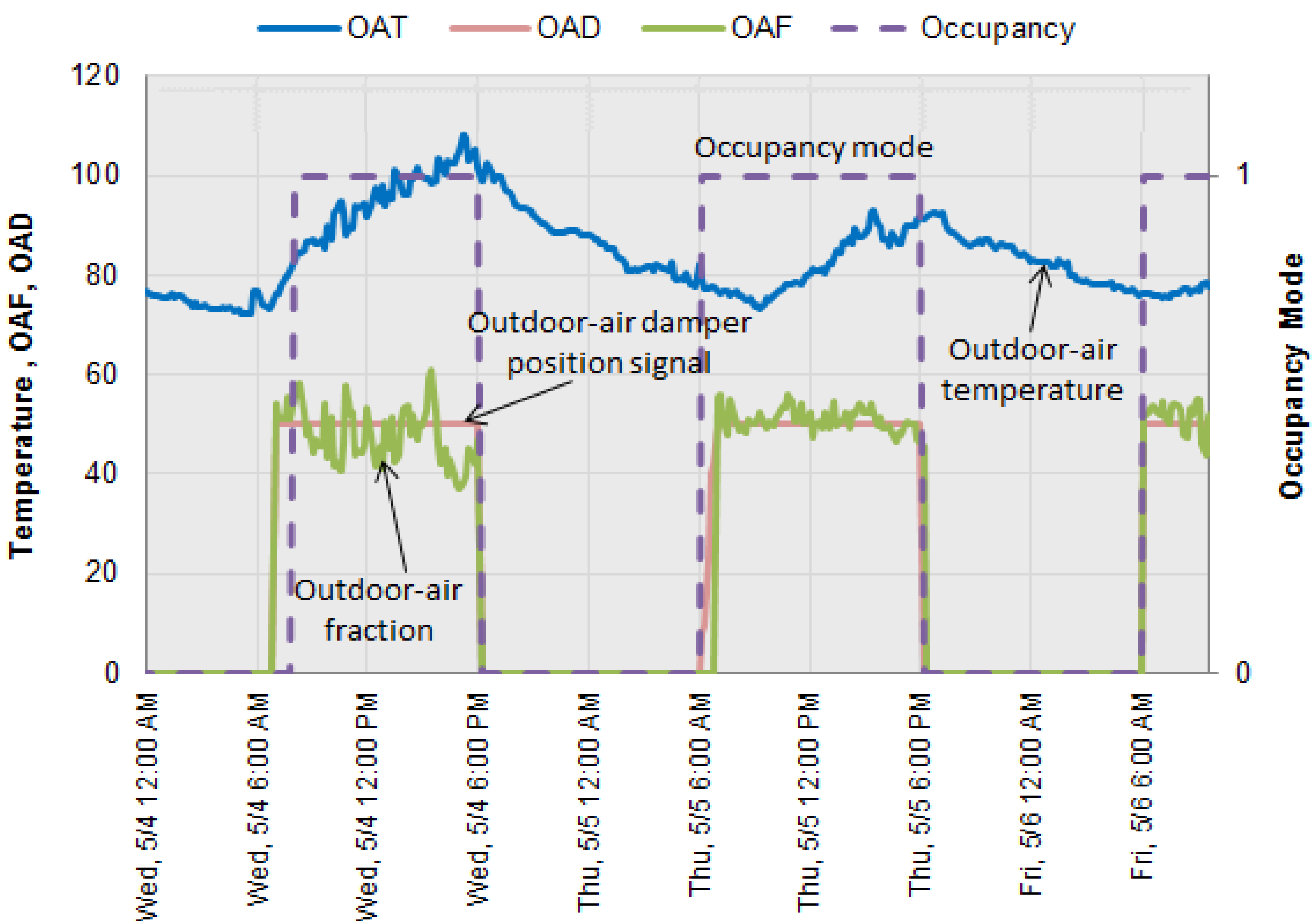
AHU Outdoor-Air Operation



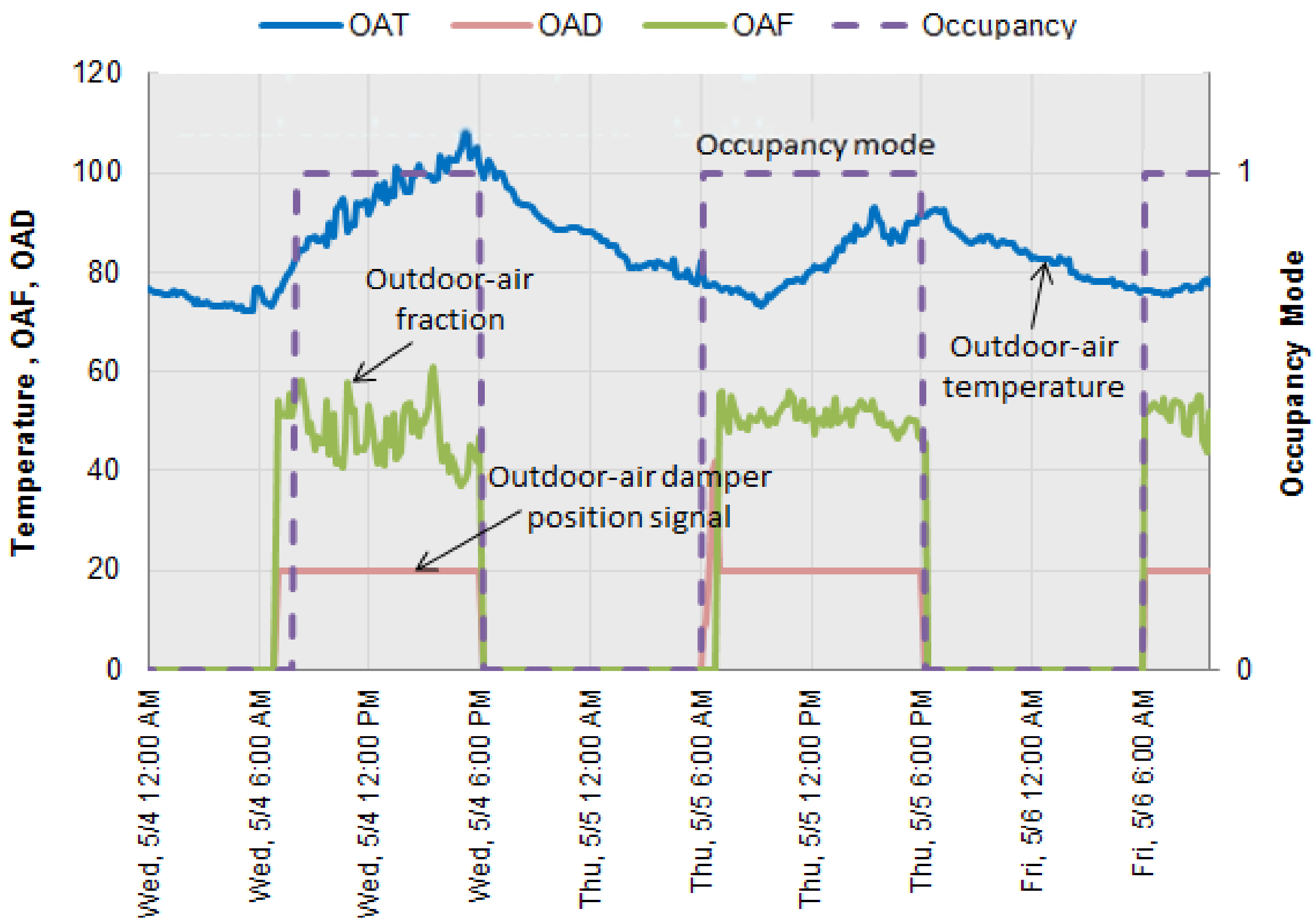
AHU Outdoor-Air Operation



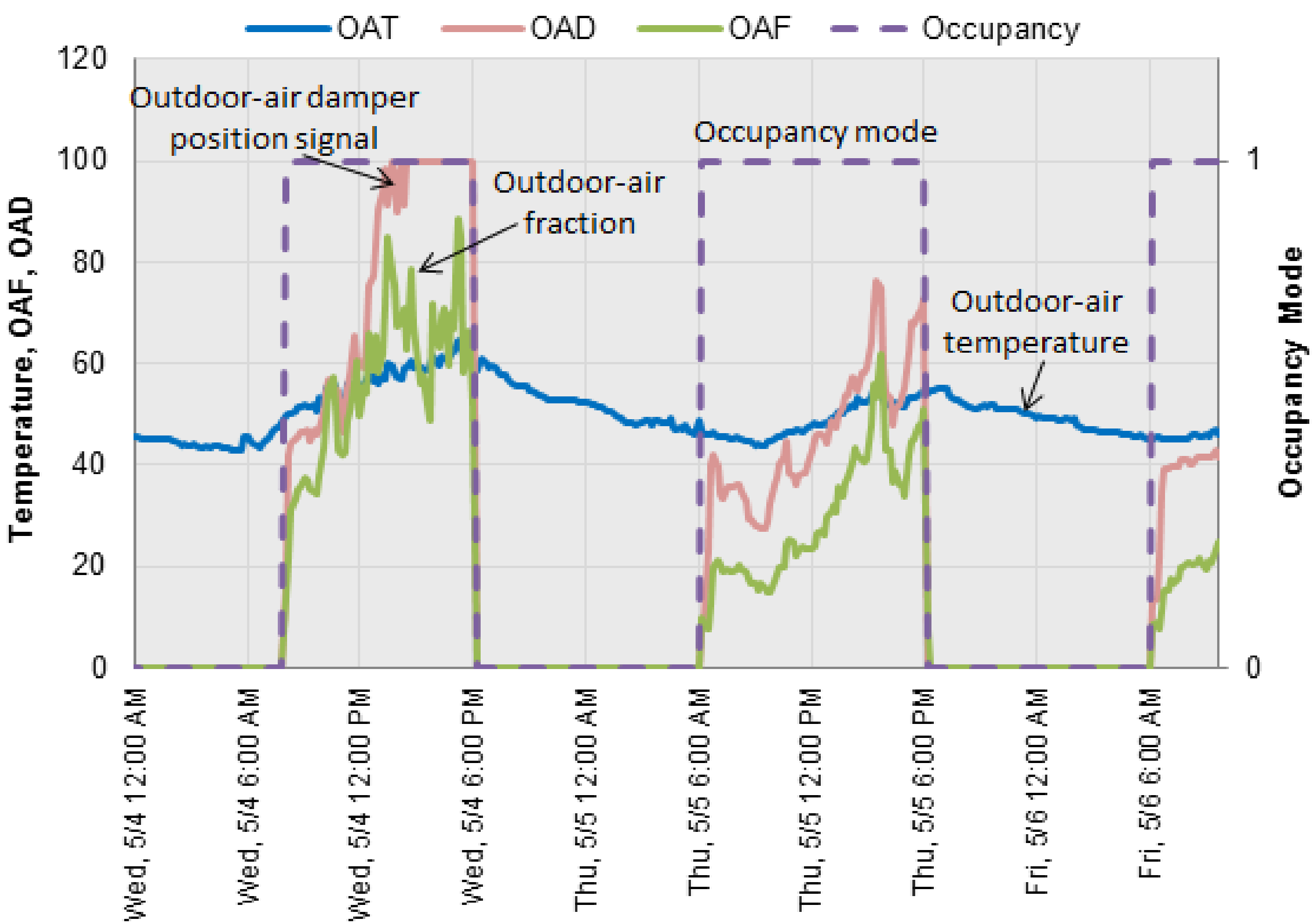
AHU Outdoor-Air Operation



OAF Greater than OAD Position



Good or Bad?



OAT
OAD
OAF
Occupancy
Outdoor-air damper position signal
Outdoor-air fraction
Occupancy mode
Outdoor-air temperature
Temperature, OAF, OAD
Occupancy Mode
120
100
80
60
40
20
0
1
0
Wed, 5/4 12:00 AM
Wed, 5/4 6:00 AM
Wed, 5/4 12:00 PM
Wed, 5/4 6:00 PM
Thu, 5/5 12:00 AM
Thu, 5/5 6:00 AM
Thu, 5/5 12:00 PM
Thu, 5/5 6:00 PM
Fri, 5/6 12:00 AM
Fri, 5/6 6:00 AM

Recommendations and Actions

- Check that the outdoor-air damper minimum position is set to 0% open during all unoccupied periods and opens to the design minimum position (5, 10, 20%) during occupied periods and last 30 minutes of morning startup.
  - 20% damper position <u>does not equal</u> 20% outdoor air
- OAF should be compared to the OAD position signal in the charts. If there are major discrepancies during times when the OAT and RAT are significantly different, then check to make sure the outdoor-air damper is responding to the signal from the BAS.

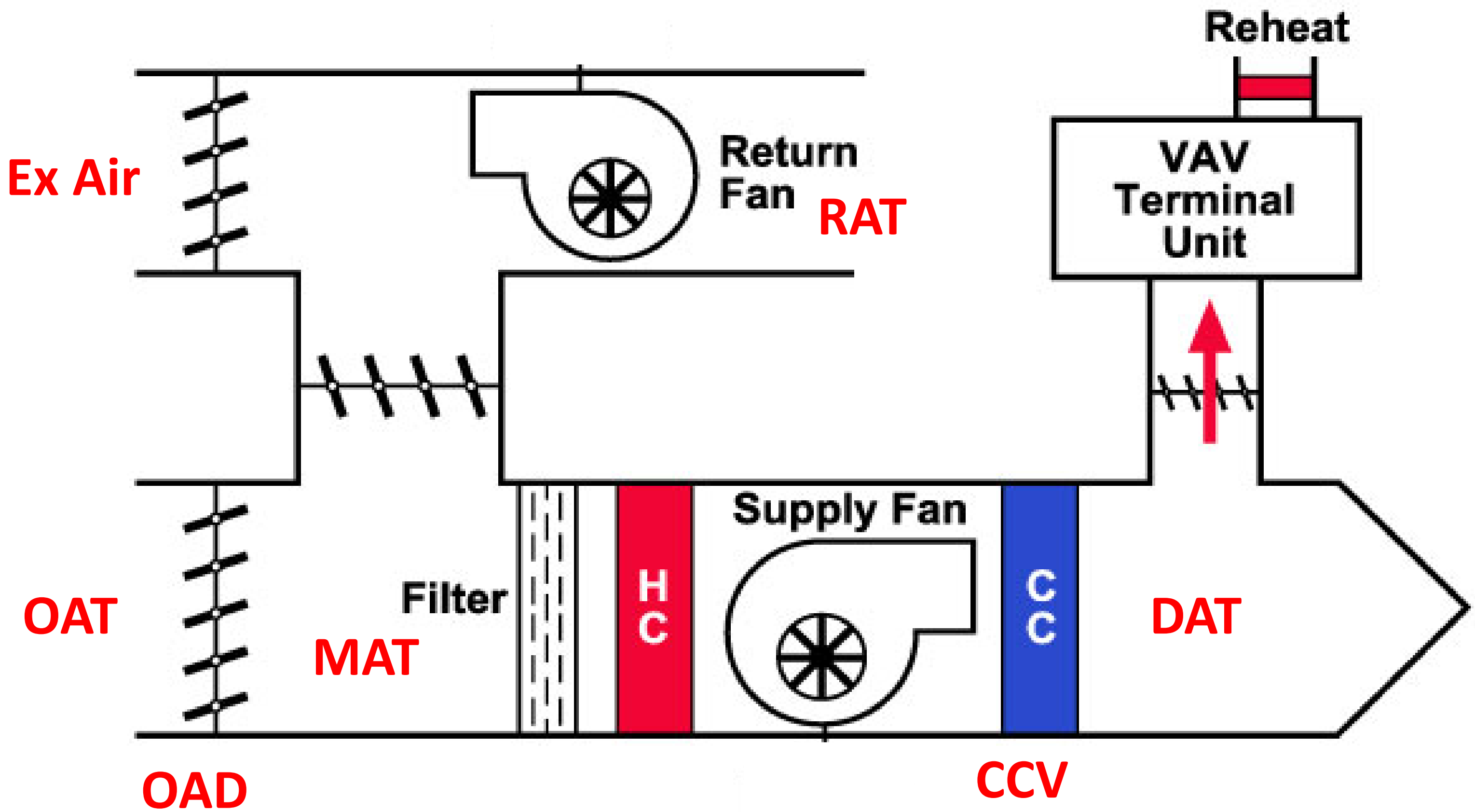
Re-tuning Control Strategies

AHU Economizer Operation

Trend Data Needed

- ❑ Outdoor-air temperature (OAT)
- ❑ Outdoor-air damper position signal (OAD)
- ❑ Mixed-air temperature (MAT)
- ❑ Cooling-coil-valve signal (CCV)
- ❑ Discharge-air temperature and set point (DAT and DATSP)
- ❑ Return-air temperature (RAT)
- ❑ Outdoor-air fraction (OAF)

Data Points Being Used



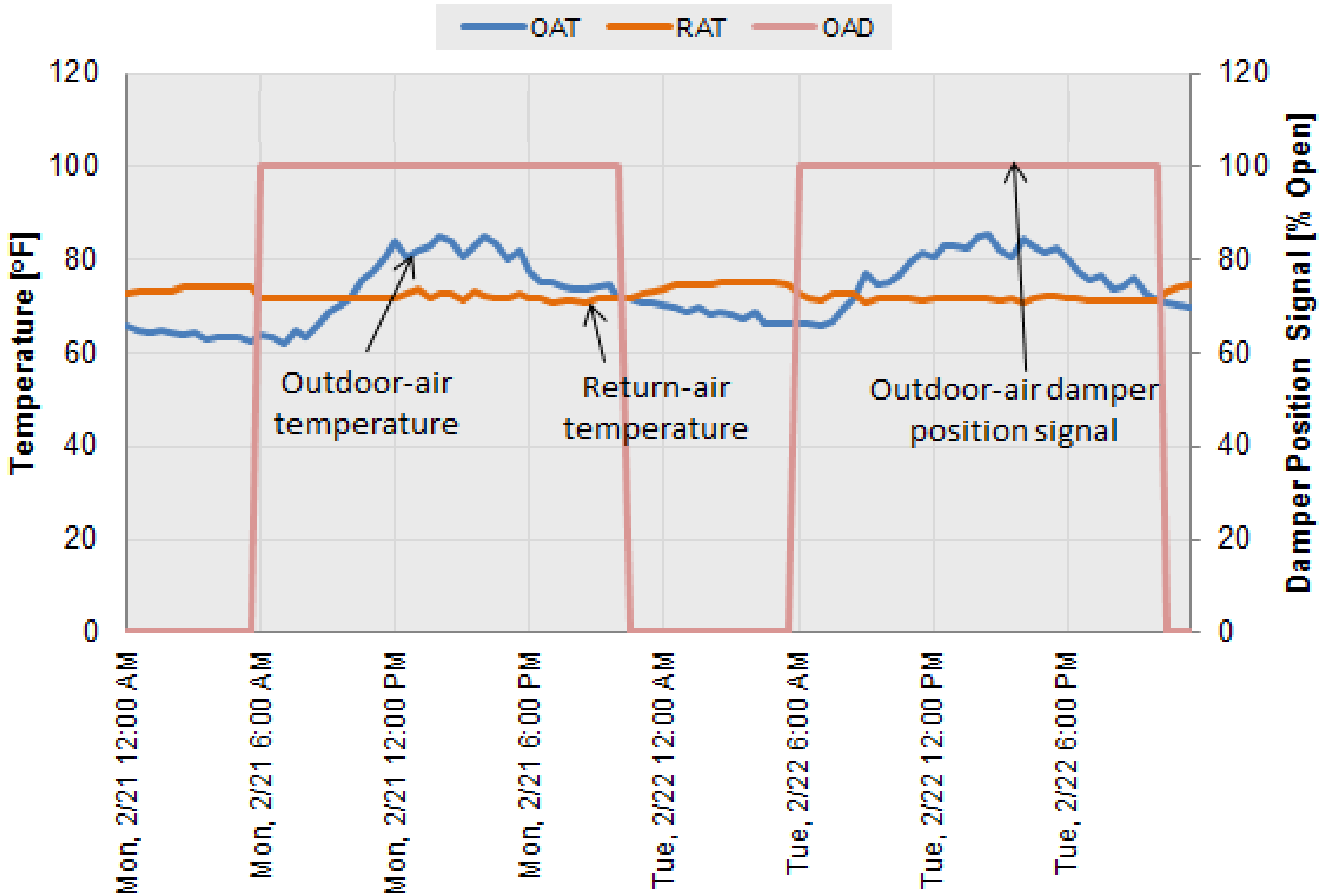
Trends To Look For

- Is the outdoor-air damper open when outdoor conditions are not favorable (OAT > RAT)
- Is the outdoor-air damper closed or at minimum position when outdoor conditions are favorable for economizing and the AHU is in cooling mode?
- When the cooling coil is open, is the outdoor-air damper fully open, if the conditions are favorable for economizing?
- Do outdoor-air dampers close to minimum position for freeze protection?

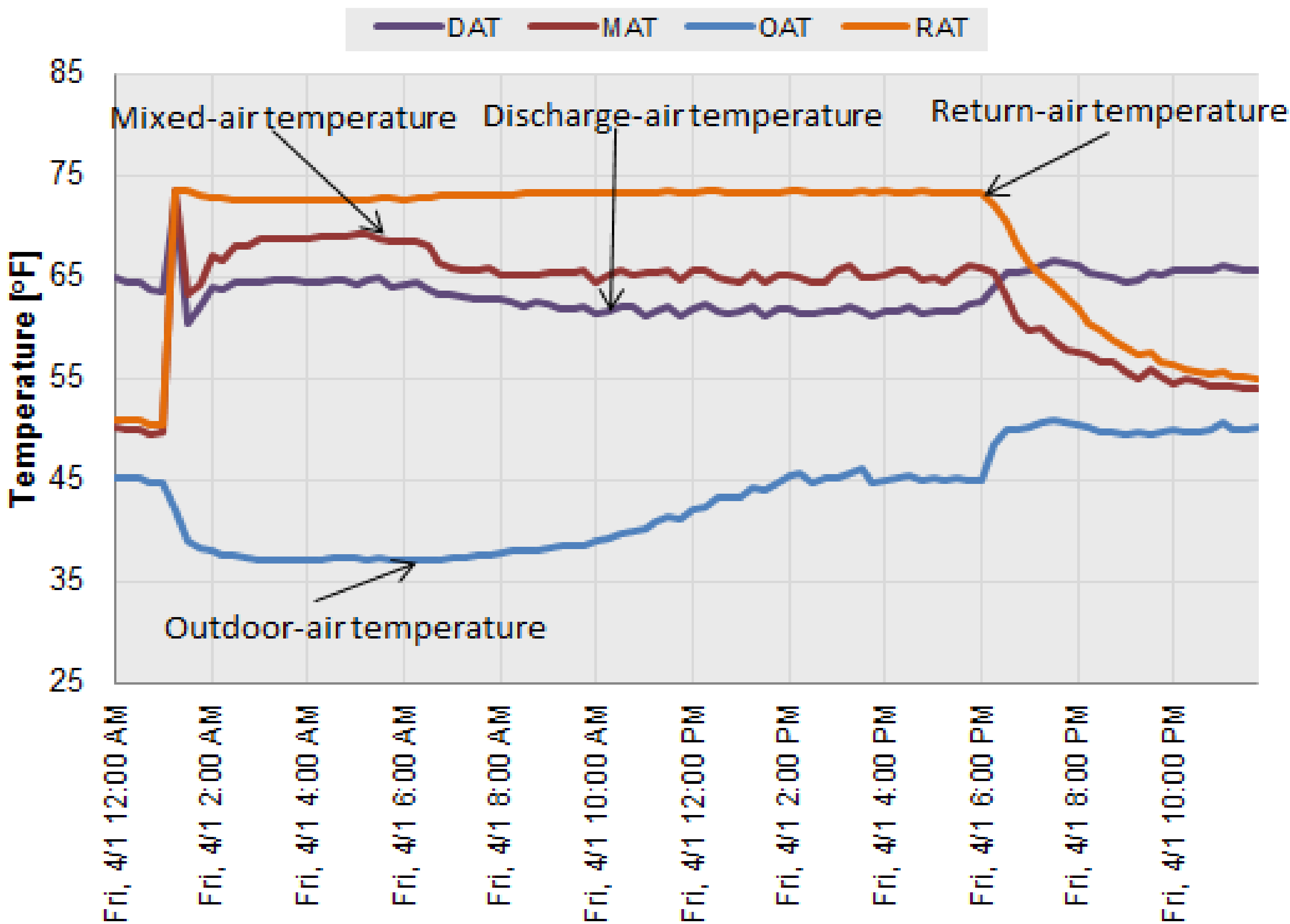
Trends To Look For Continued

- Dampers not opening or closing (observed in the field or on trend graphs)
- Mixed air temperature colder than discharge air temperature.
- Mixed air temperature warmer than discharge air temperature, but outside air temperature is cooler than discharge air temperature setpoint, and there is a need for cooling in the building.

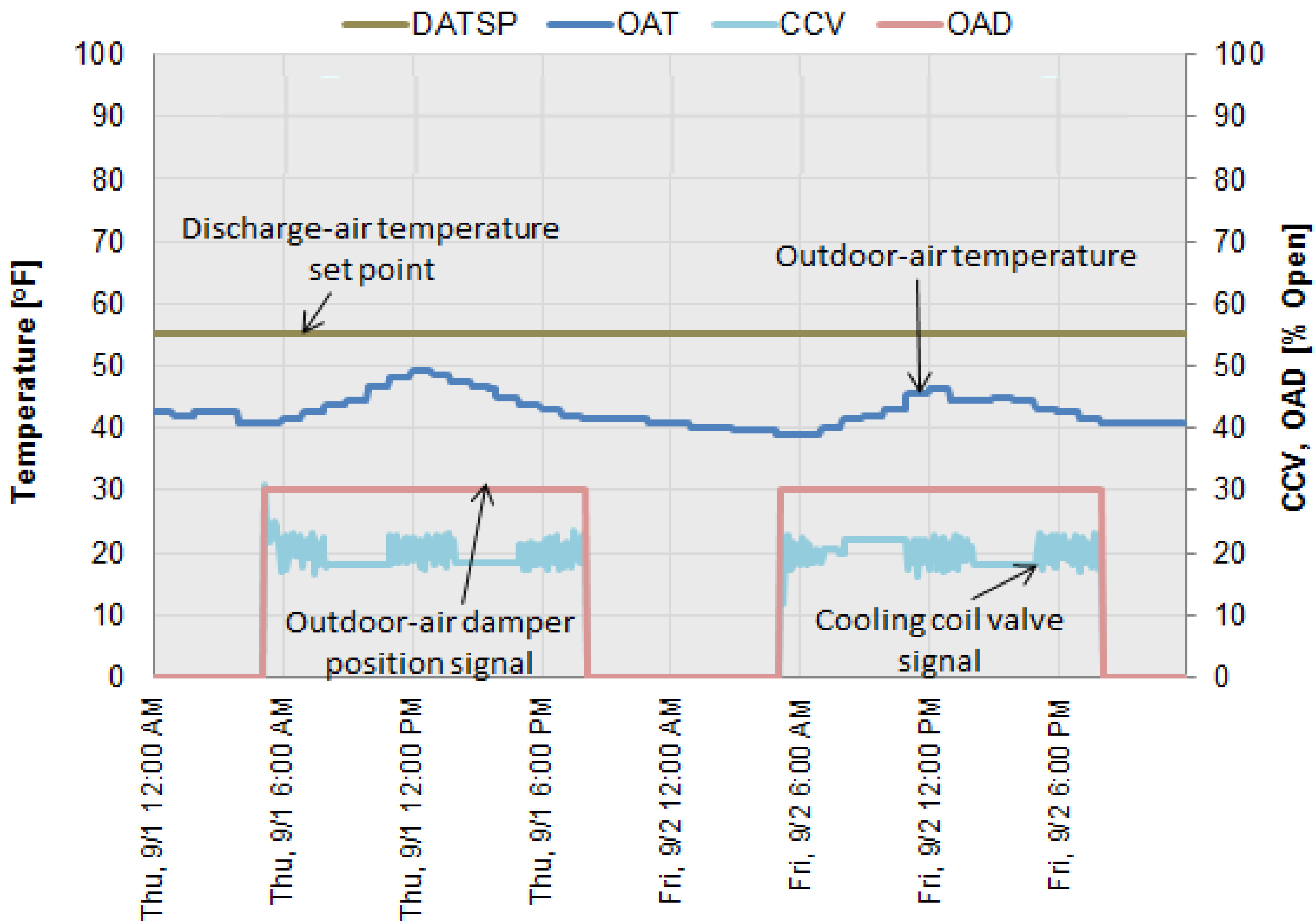
AHU Economizer Operation



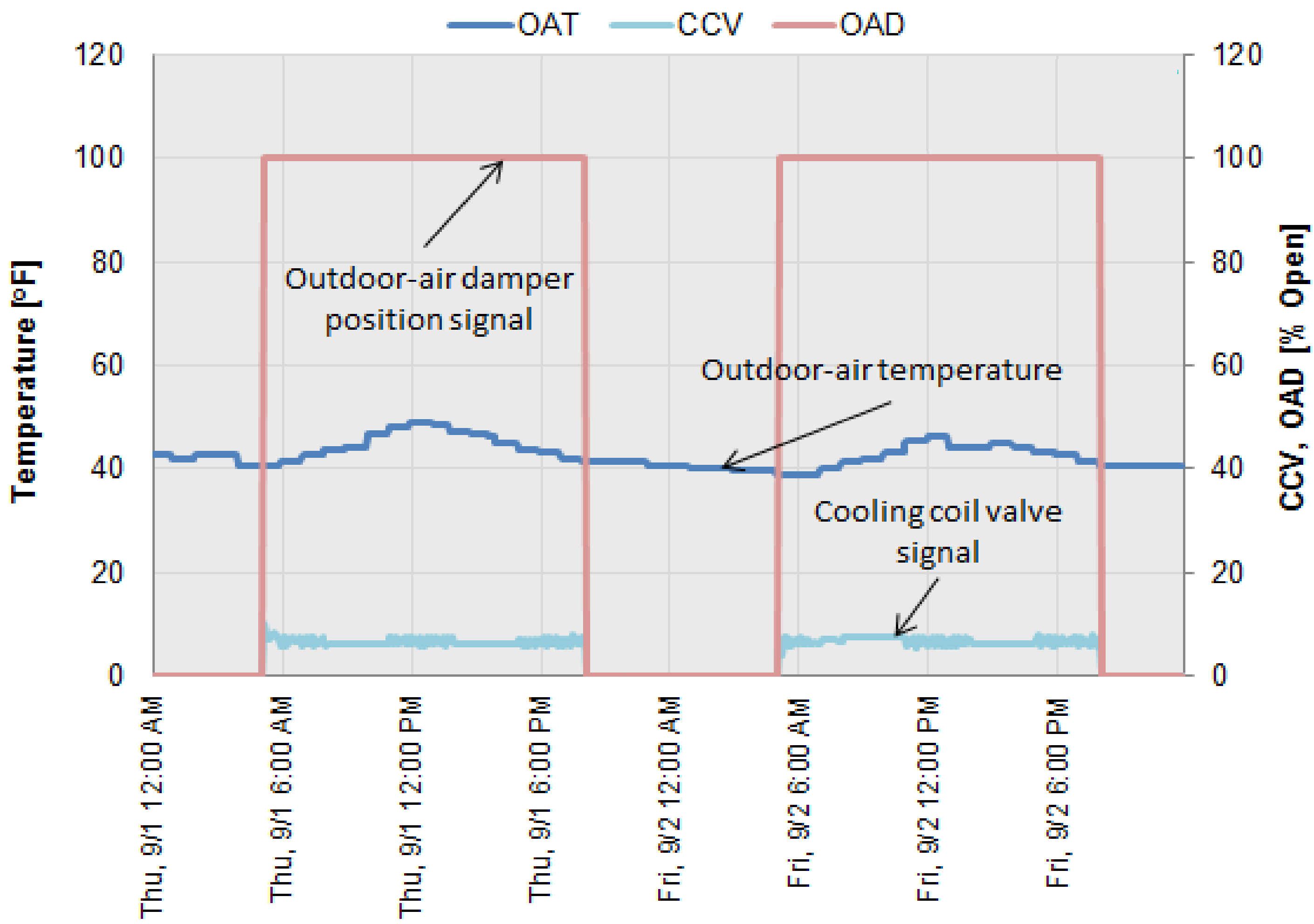
Outdoor Air Damper at Min Opening



AHU Economizer Operation



AHU Economizer Operation



Recommendations and Actions

- If outside air is cooler than return-air (most dry climates), use it, even if you have to run some additional cooling.
- Do not use outside air when preheating or during unoccupied fan operations.
- Use of CO_2 sensor control and proper maintenance of the sensor, along with correct control sequencing, can help reduce excess outside air.

Recommendations and Actions

- Add and track the calculated OAF in the BAS for all AHUs.
- Set economizer operating range as wide as possible:
  - For dry climates, set it between 30°F and 75°F.
  - For normal climates, set it between 30°F and 68°F.
  - For humid climates, set it between 30°F and 65°F.
- For outdoor-conditions favorable for economizing, require full economizing (outdoor-air damper open 100%) before mechanical cooling can occur.

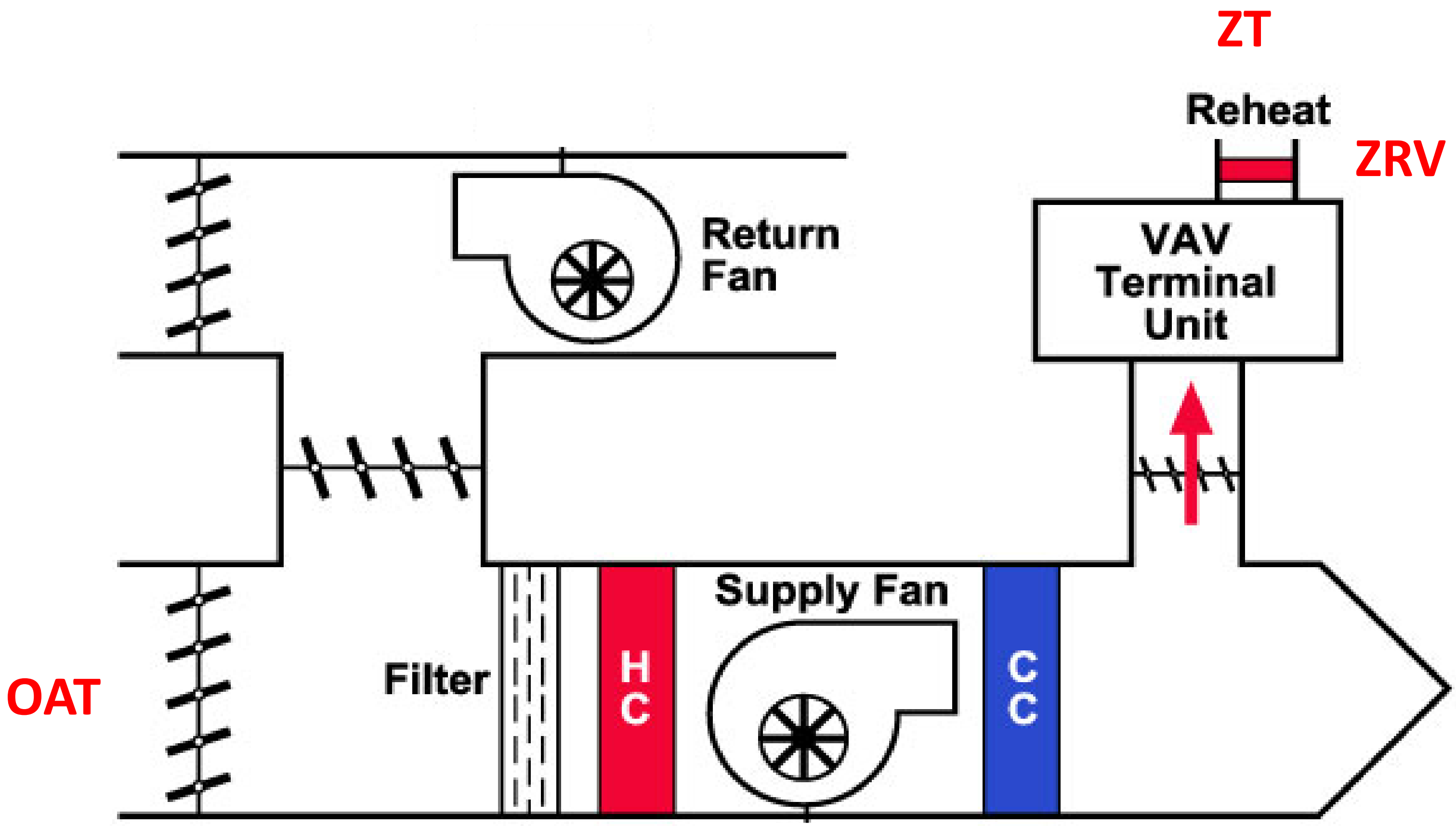
Re-tuning Control Strategies

Zone Conditioning

Trend Data Needed

- Outdoor-air temperature (OAT)
- Zone reheat valve signal (ZRV)
- Zone temperature (ZT)
- Zone occupancy mode

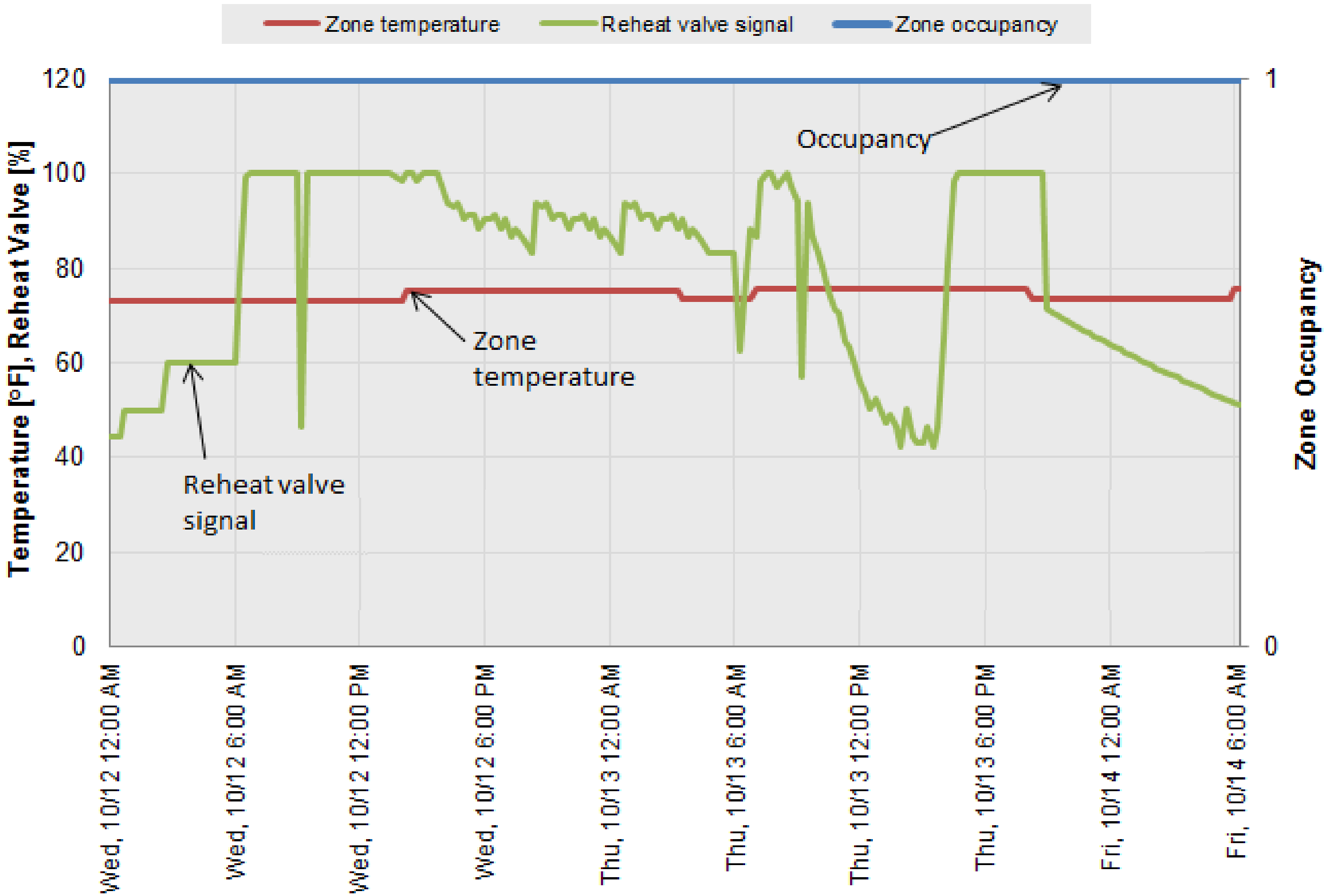
Data Points Being Used



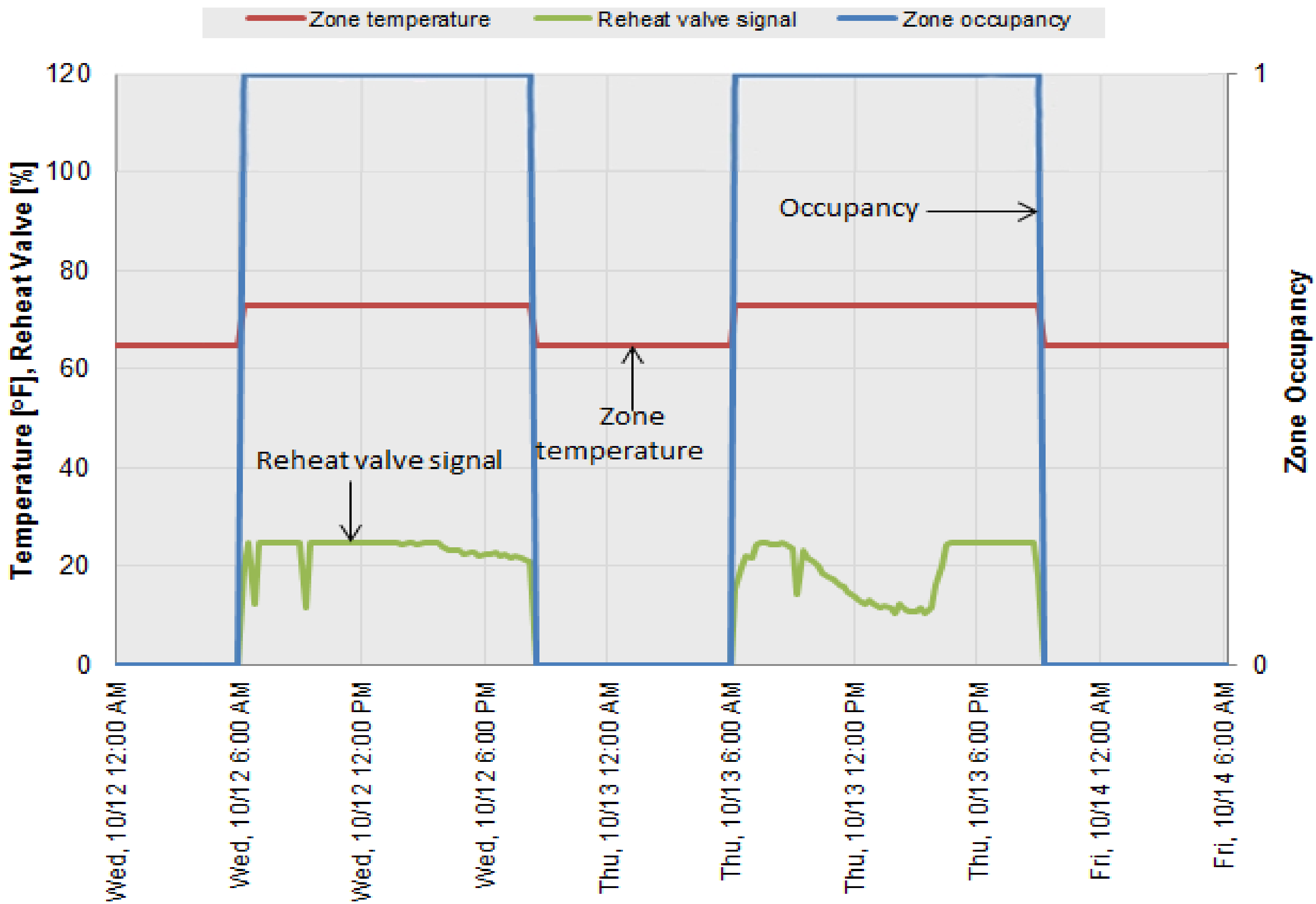
Trends To Look For

- Is there night-time set back/unoccupied mode at the zone level?
- Is there significant reheat occurring at the zones, especially interior zones?

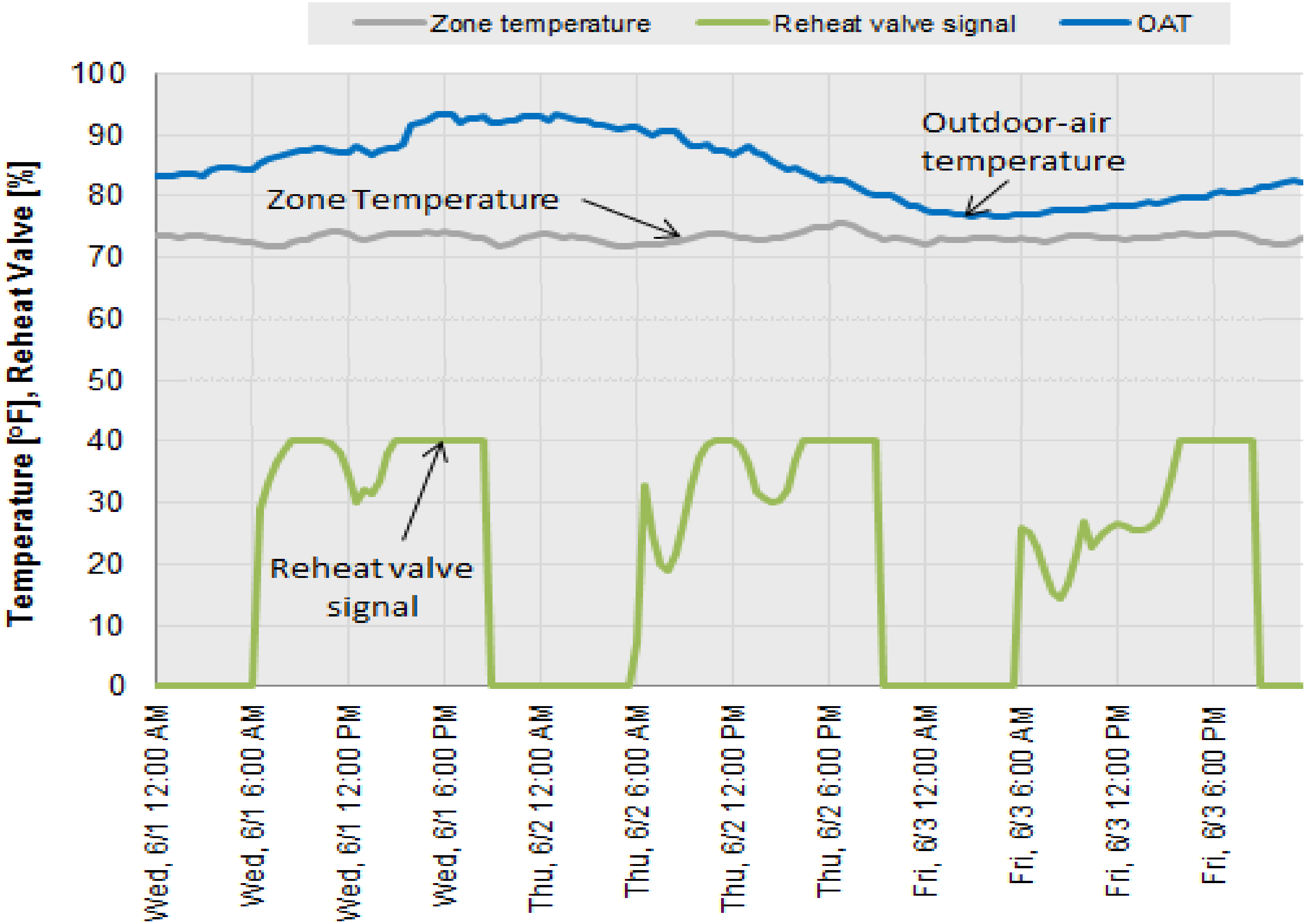
Zone Conditioning



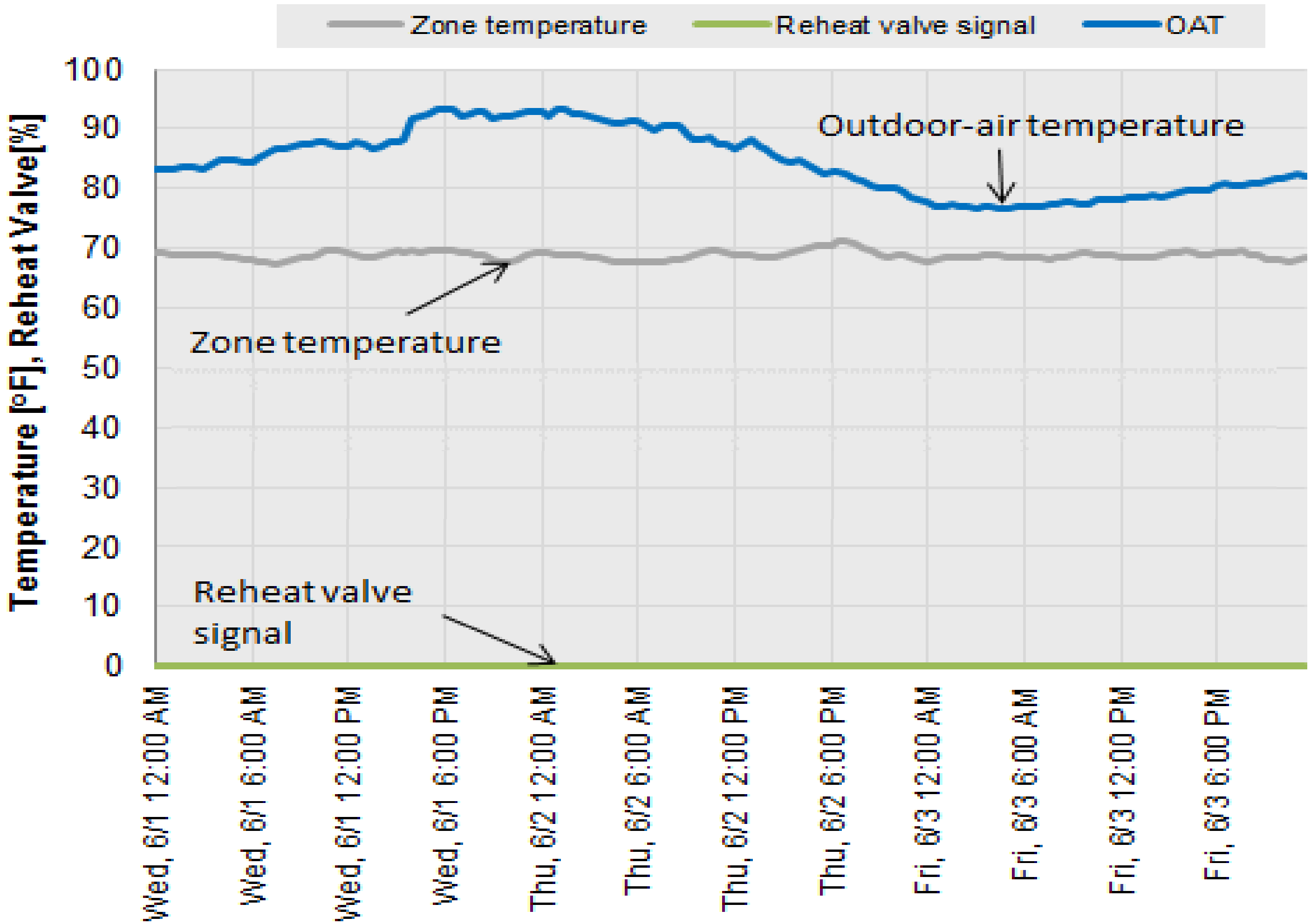
Zone Conditioning



Zone Conditioning



Zone Conditioning



Zone Conditioning: Discussion Question

In which zones should heating be disabled during the summer?

Answer:

Interior zones

Recommendations and Actions

- Enable unoccupied mode and night-time set back control, and develop a schedule for each zone
- Reduce the interior zone terminal box heating minimum air flow setting by 5-10% of the heating maximum air flow set point and trend new data.
- Disable heating for interior zones in summer months (OAT >70°F, for example) to eliminate heating leakage.
- If multiple zones are calling for reheat, increase the AHU discharge air temperature by a few degrees and trend new data.

Re-tuning Control Strategies

Heating Plant Optimization

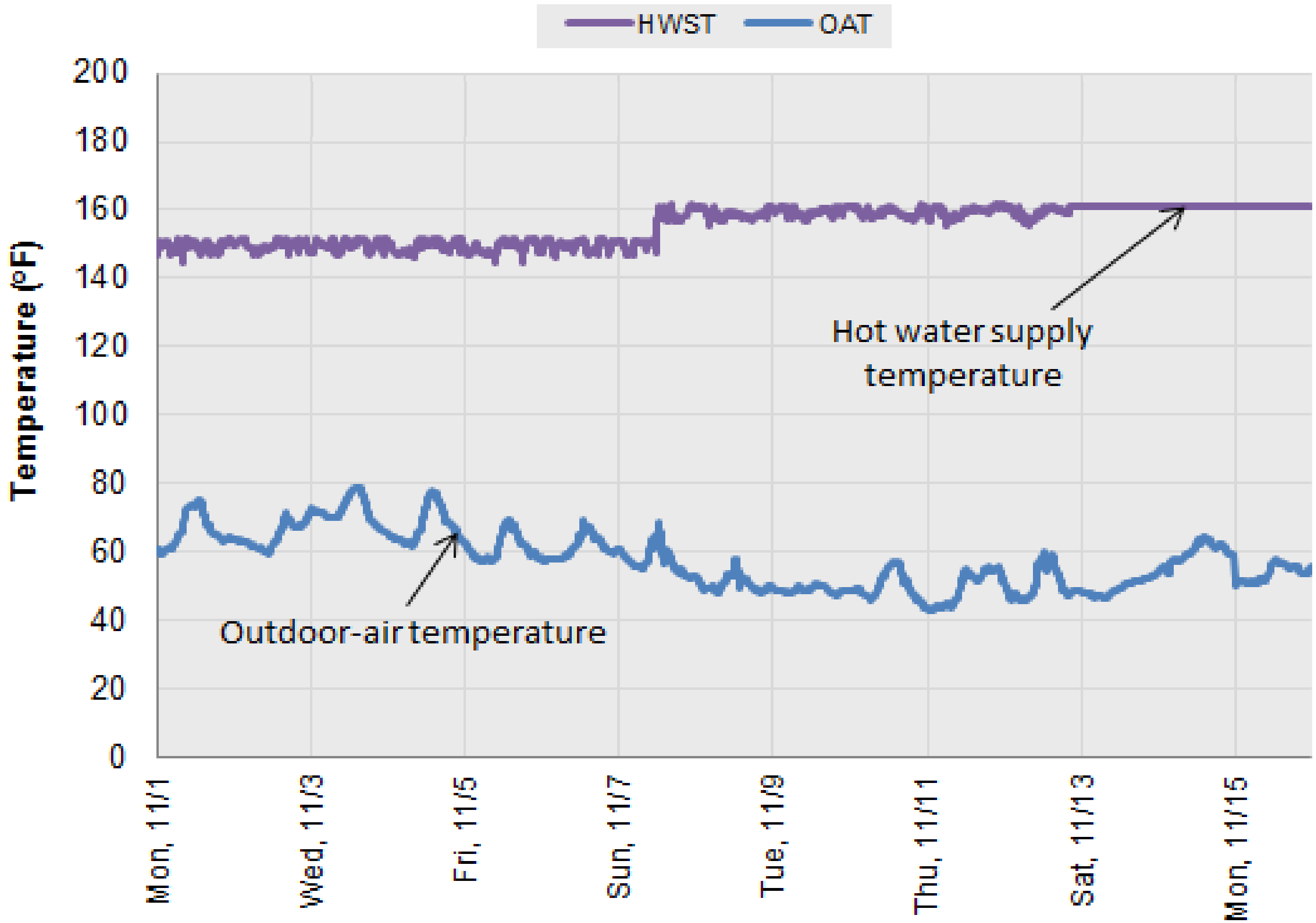
Trend Data Needed

- Outdoor-air temperature (OAT)
- Heating-coil-valve signal (HCV)
- Hot water supply temperature (HWST)
- Hot water supply temperature set point (HWSTSP)
- Hot water return temperature (HWRT)
- Hot water loop differential pressure (HWLDP)
- Hot water loop differential pressure set point (HWLDPSP)

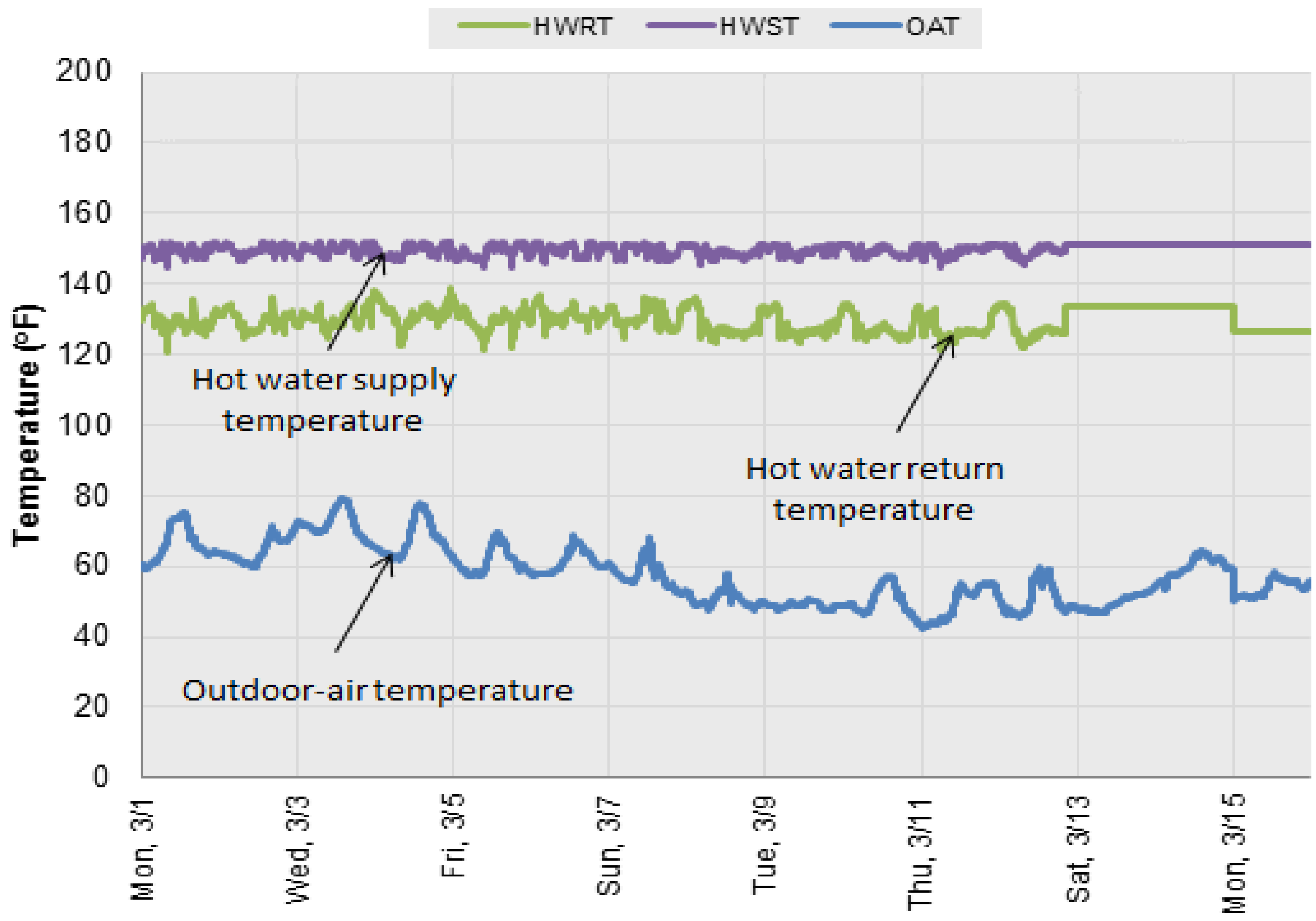
Trends To Look For

- Is reset utilized on the hot water supply temperature?
- Is the loop delta-T (HWST - HWRT) low?
- Is the hot water loop differential pressure constant and if so, can it be reset at partial load conditions?

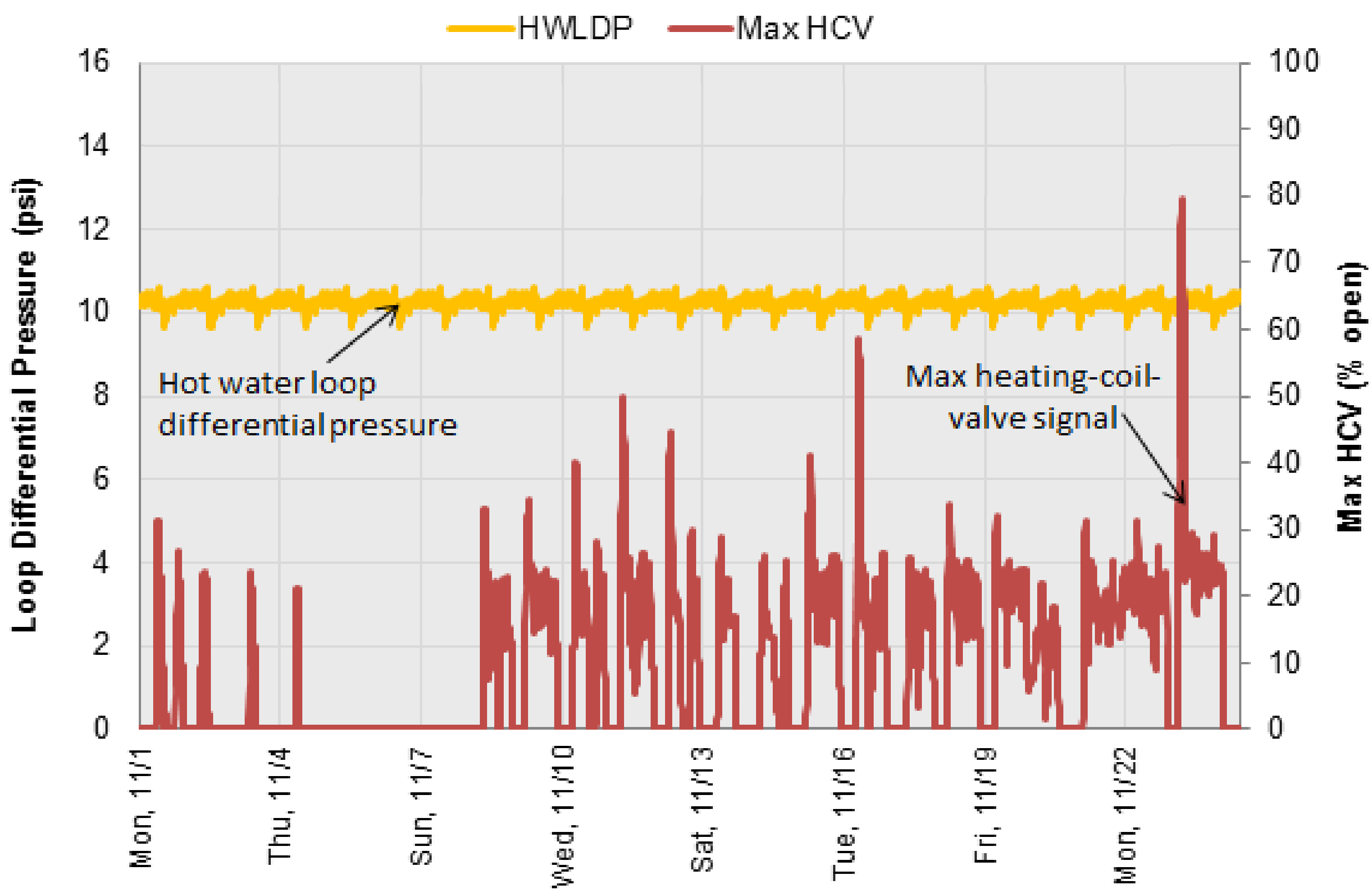
Hot Water Supply Temp Reset



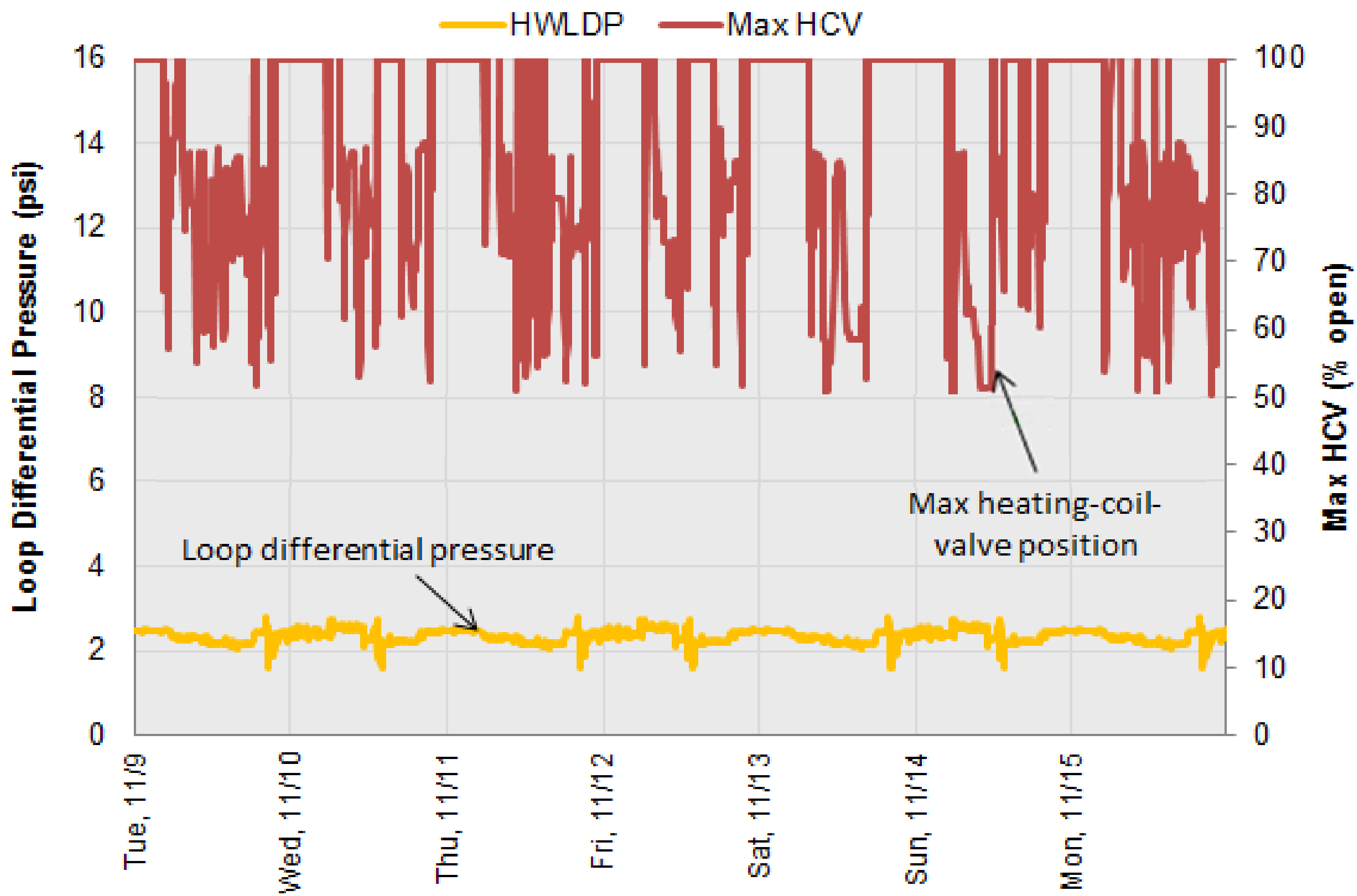
Boiler Heating Loop delta-T



Heating Plant Optimization



Heating Plant Optimization



Over-Pumping

- Reasons for “over-pumping”
  - By-passes
  - 3-way valves
- Observing “over-pumping”
  - Low delta-T
  - VFD pump speed constant
- Analogous to mostly closed VAV boxes.

Recommendations and Actions

- Reset hot water supply temperature depending on building load
- Typical control resets hot water supply temperature with outdoor-air temperature
  - Maintain 160°F – 180°F during winter season
  - Maintain 120°F – 140°F during summer season
- If the hot water supply and return temperatures are within 1 or 2 degrees, consider shutting down the boiler.

Recommendations and Actions

- Hot water heating boilers require reset schedules
  - Zone temps will stabilize better because valves can modulate better at lower zone loads
  - Caution: for non-condensing boilers use a bypass system to keep the boiler warm and the loop cool
- A variable differential pressure set point should be implemented based on the maximum heating coil valve position across all air-handlers or terminal box reheat valve positions in the building.

Re-tuning Control Strategies

Cooling Plant Optimization

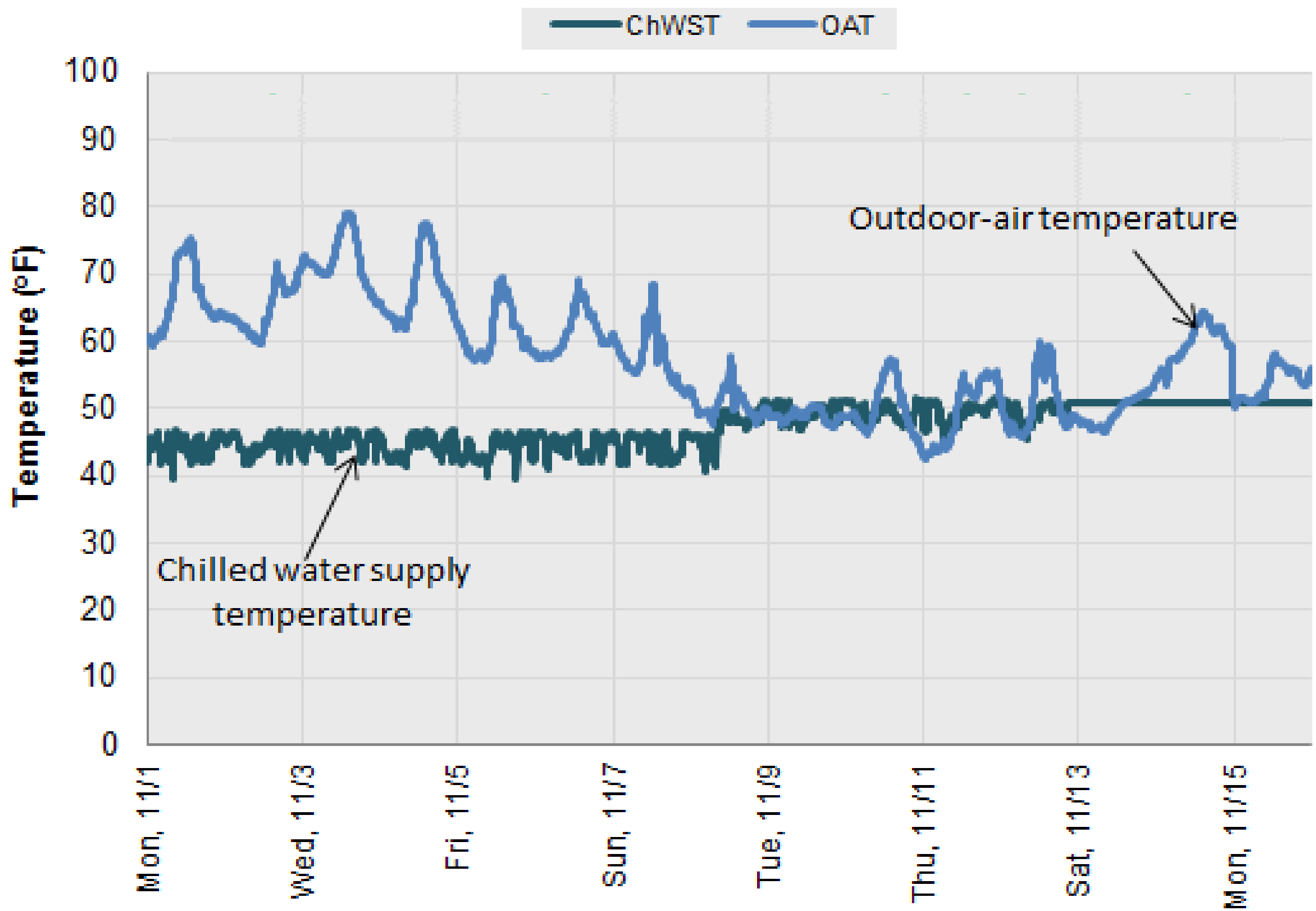
Trend Data Needed

- Outdoor-air temperature (OAT)
- Cooling-coil-valve signal (CCV)
- Chilled water supply temperature (ChWST)
- Chilled water supply temperature set point (ChWSTSP)
- Chilled water return temperature (ChWRT)
- Chilled water loop differential pressure (ChWLDP)
- Chilled water loop differential pressure set point (ChWLDPSP)

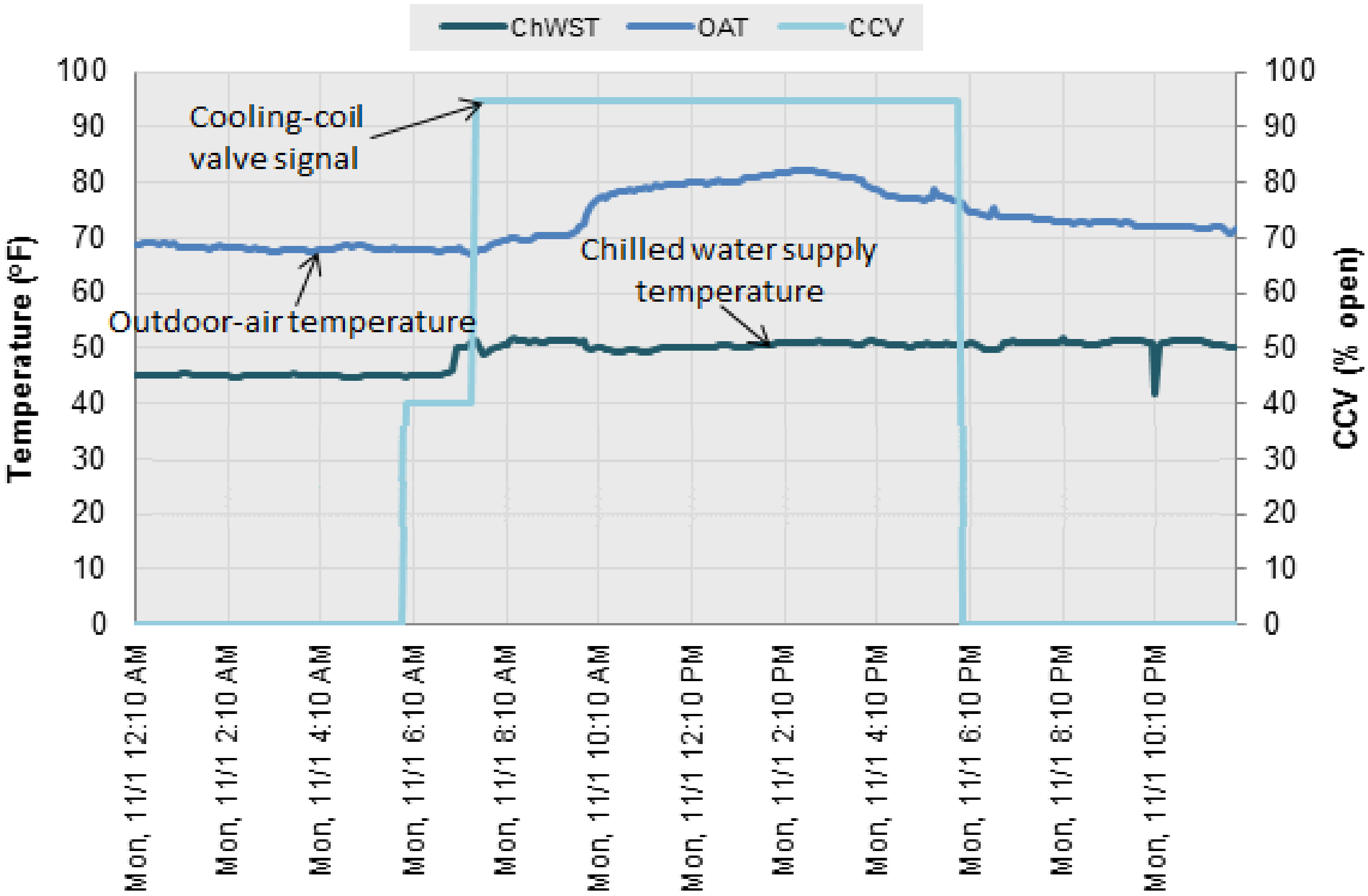
Trends To Look For

- Is reset utilized on the chilled water supply temperature?
- Is the loop delta-T (ChWRT - ChWST) low?
- Is the loop differential pressure set point constant and if so, can it be reset at partial load conditions?

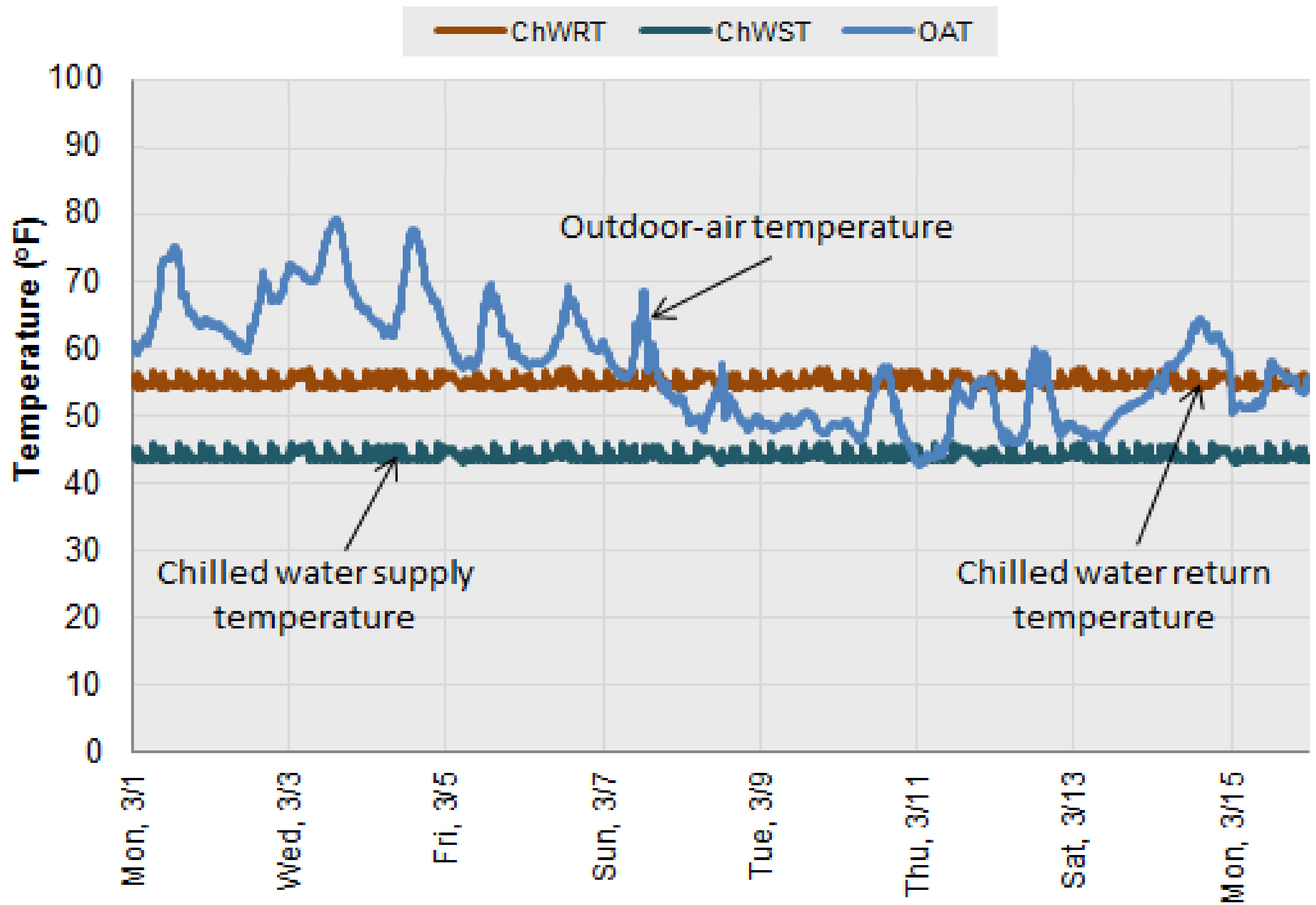
Chilled Water Supply Temp Reset



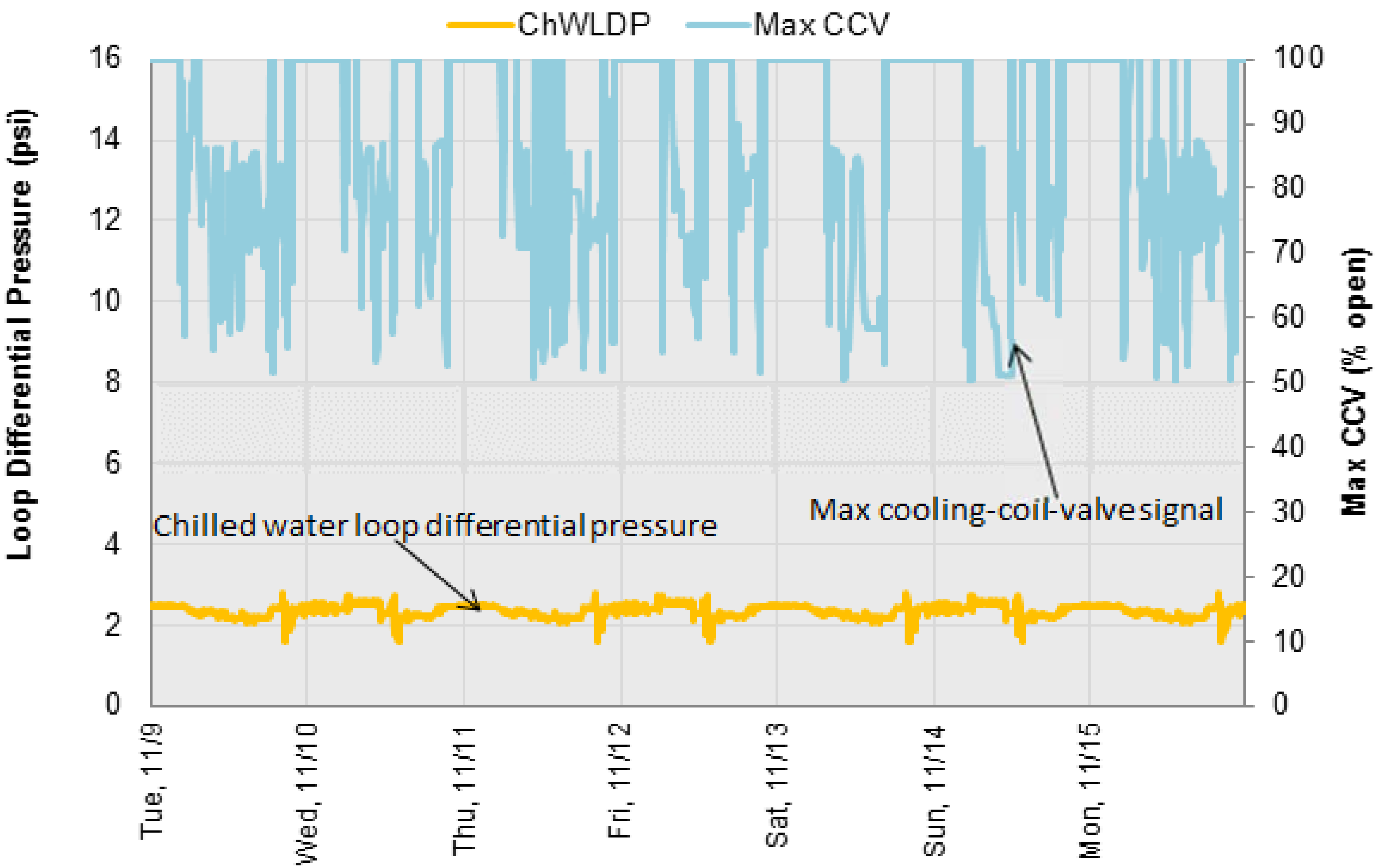
Chilled Supply Water Reset and CCV



Chilled Water Loop delta-T



Chilled Water Loop DP based on CCV



Recommendations and Actions

- Increase the chilled water supply temperature set point by 0.5°F at a time to prevent the chiller from tripping off. Also, do not increase the set point any higher than 5°F from the design value.
- Make sure the cooling valves are fully open before the pump reaches full speed.
- Use differential pressure reset control to optimize secondary chilled water pump control.

Cooling Plant Optimization: Discussion Question

Should a chiller *with* or *without* a VFD run close to full load?

Answer:

A chiller *without* a VFD

Recommendations and Actions

- Chillers with VFDs should be used for load following
- Chillers without VFDs should always run close to full load
- Let the larger chiller stay fully loaded and run the smaller chiller as the lag unit
- Use a fully integrated lead/lag control scheme so chillers are not running because this afternoon they might need it

Recommendations and Actions

- Reset condensing water return temperature based on wet-bulb temperature
  - Monitor kW/ton to determine the optimal control strategy between cooling towers VFDs and chiller VFDs
  - Cooling tower water return temperature should not be lower than 65°F for chillers made before 1999 and should not be lower than 55°F for newer chillers
  - Consult chiller manufacturer's manual for more information

Thank you

- Next up: Guidance for BRT through BAS Interface

Guidance for BRT through BAS interface (Module 4D)

CONSORTIUM for BUILDING ENERGY INNOVATION

Goals for this training:

- Review NREL's Commercial Building Checklist
- Understand which re-tuning measures may be determined directly within the BAS reviewing the current conditions and set points given in the user interface
- Be able to produce some or all of the ECAM re-tuning charts directly within the BAS interface, depending on BAS capabilities

Resources

- NREL Commercial Building Checklist - very comprehensive!

  www.nrel.gov/tech_deployment/pdfs/commercial_building_checklists.pdf

- PNNL BRT Resources

  buildingretuning.pnnl.gov

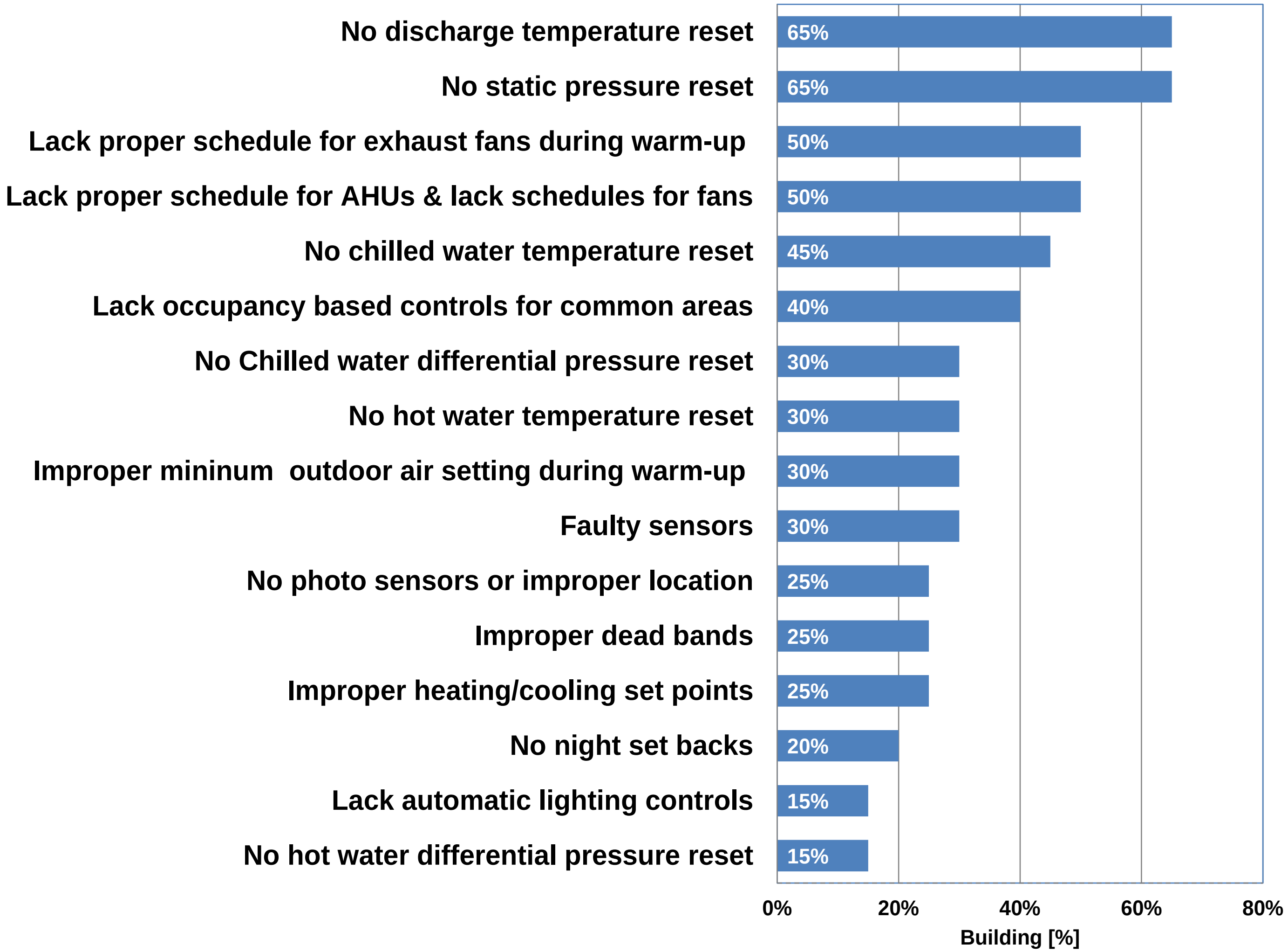
  - Online interactive re-tuning training modules
  - Re-tuning training curriculum for small commercial and large commercial (with a BAS) buildings
  - Air Economizer training – 10 modules!
  - Free ECAM tool along with training manuals, sample data, and video tutorials

Class Participation

Open and review the NREL checklist

- Which of these are currently part of your O&M?
- Which of these would you like to add?

PNNL List of Most Common Control Issues

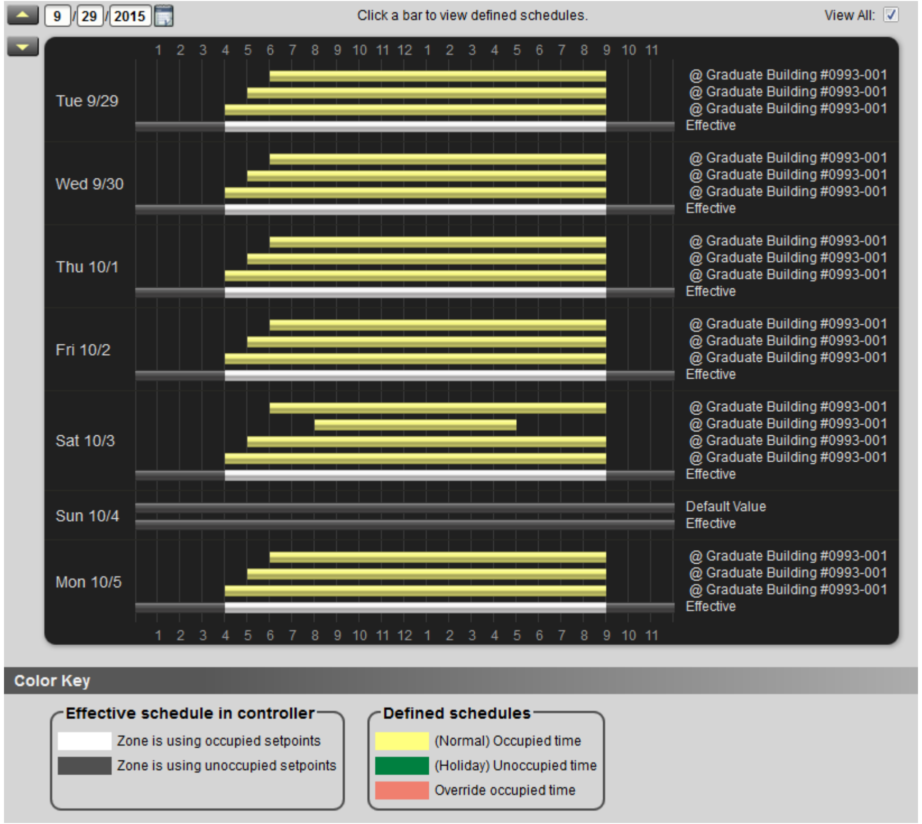


PNNL's List of Control Issues through BAS UI and Settings

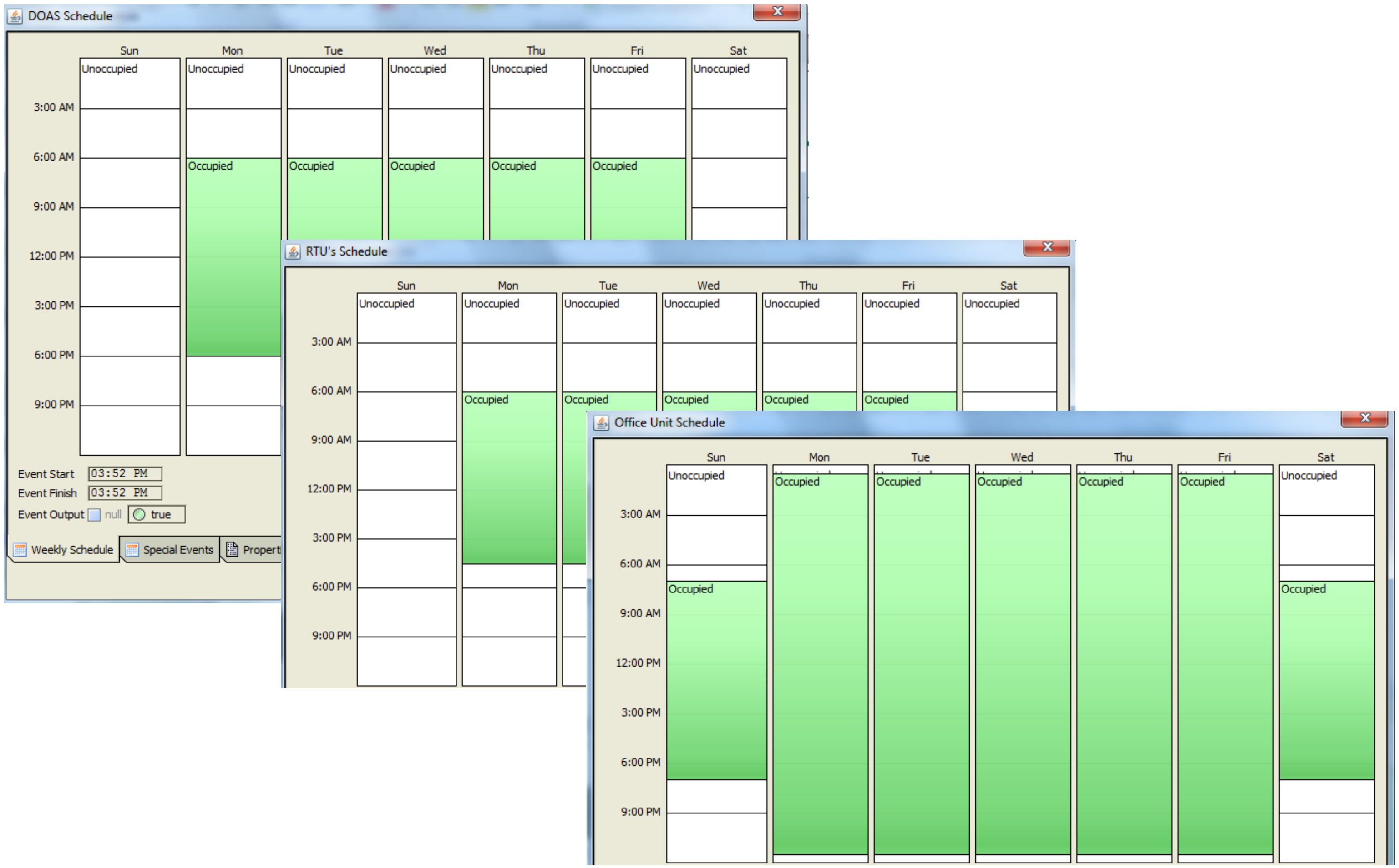
- Lack of proper schedules for AHUs and exhaust fans
- Improper minimum outdoor air setting during building warm-up
- AHU IN economizer mode when conditions ARE NOT favorable
- AHU NOT IN economizer mode when conditions ARE favorable
- Improper heating/cooling set points
- Simultaneous heating and cooling

BAS Occupied/Unoccupied Schedules

- Verify that the schedules in the BAS reflect the current use of the space(s)

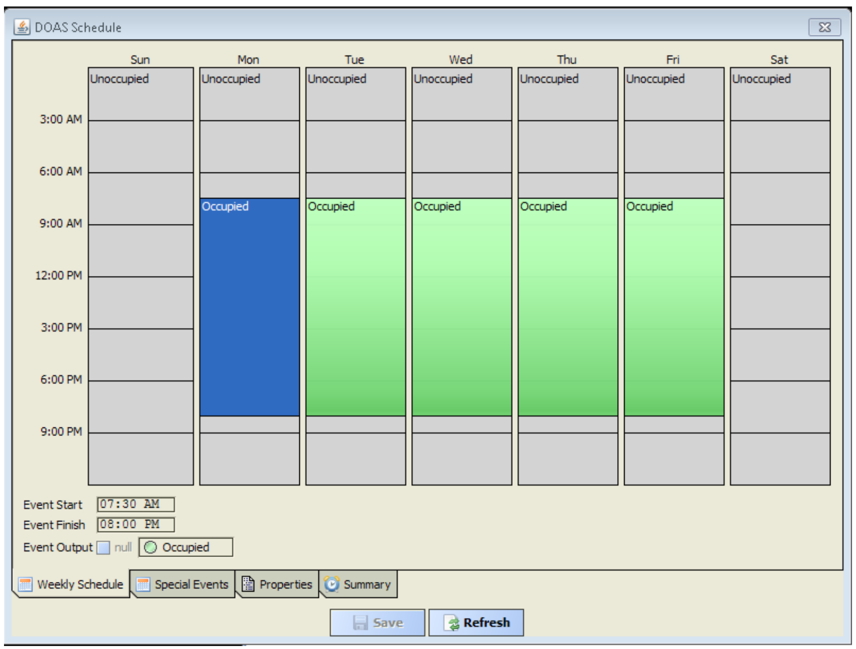


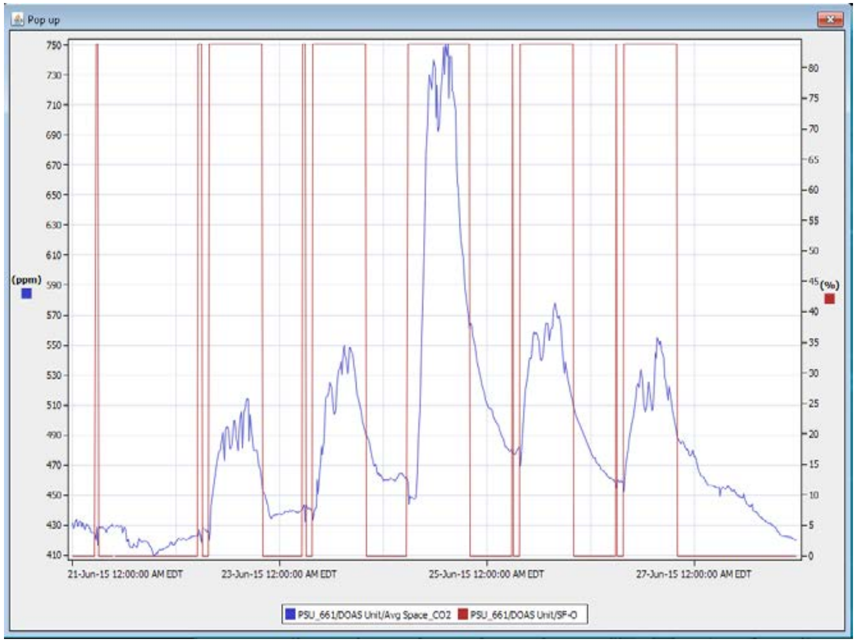
BAS Occupied/Unoccupied Schedules



BAS Occupied/Unoccupied Schedules

- DOAS Schedule is set to be running 7:30AM-8:00PM, while the building is occupied during 8:00AM-5:00PM
- Supply fan works from around 5:30am- 8:30PM
- Reschedule the DOAS system for earlier shutdown





Occupied Schedule

- RTU with very long occupied schedule

Schedule Instances

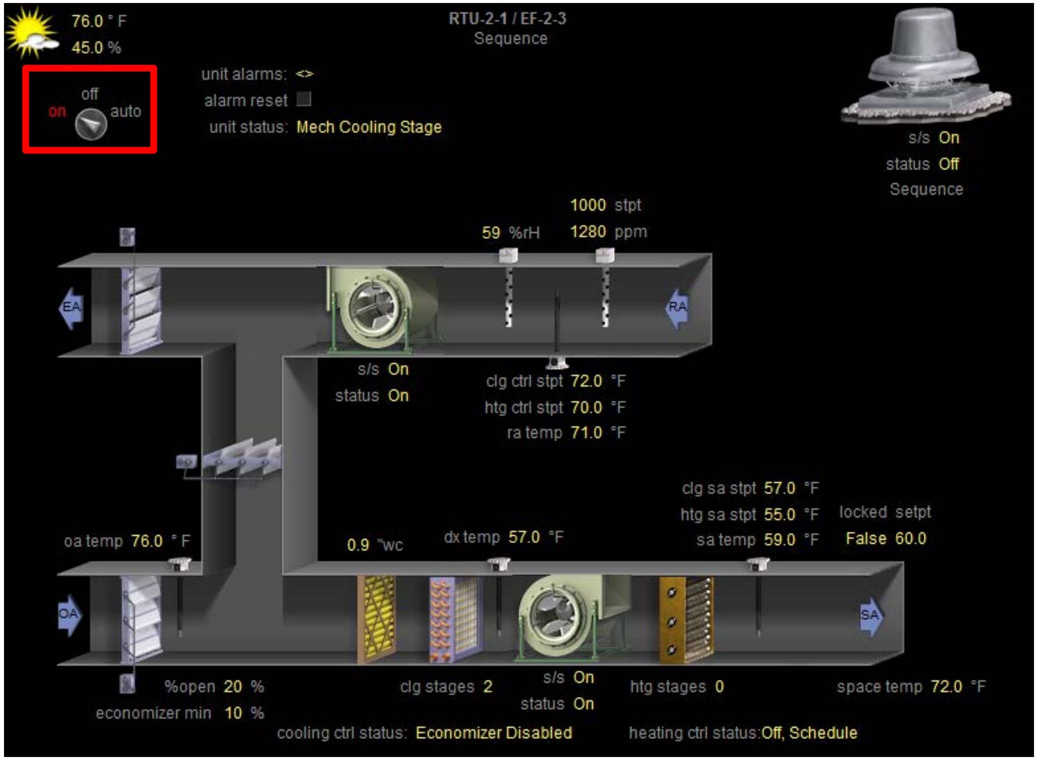
Location: Penn State / Penn State Great Valley / Graduate Building #0993-001 / Roof / RTU-2

Run Date: 10/13/2015 8:57:54 PM

Location	Priority	Description
Penn State		
Penn State Great Valley		Member of Group(s): PSU Sateltie Campuses / PSU GV Holiday Schedule
Graduate Building #0993-001	Normal	Mon,Tue,Wed,Thu,Fri,Sat Occupied from 6:00 AM to 9:00 PM
	Normal	Sat Occupied from 8:00 AM to 5:00 PM
	Normal	Mon,Tue,Wed,Thu,Fri,Sat Occupied from 5:00 AM to 9:00 PM
	Normal	Mon,Tue,Wed,Thu,Fri,Sat Occupied from 4:00 AM to 9:00 PM
Roof	Normal	Mon,Tue,Wed,Thu,Fri Occupied from 7:00 AM to 9:00 PM
	Normal	Sat Occupied from 8:00 AM to 5:00 PM
	Normal	Sat Occupied from 7:00 AM to 5:00 PM
	Normal	Mon,Tue,Wed,Thu,Fri,Sat Occupied from 12:00 AM to 9:00 PM

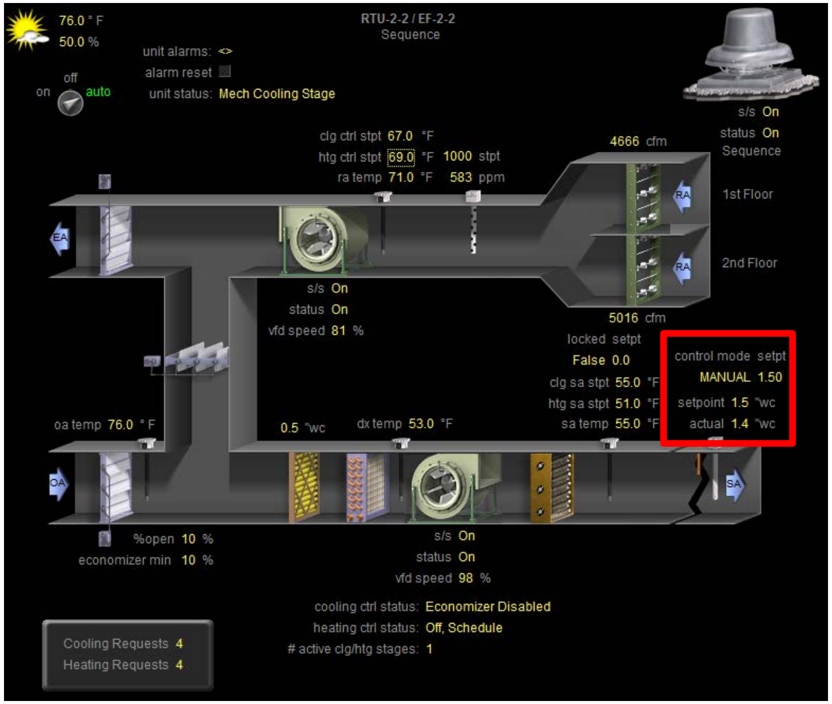
Check Manual vs Automatic Setting

- This RTU has been set to manual "on" mode.
- Why? Who? When will it be switched back?

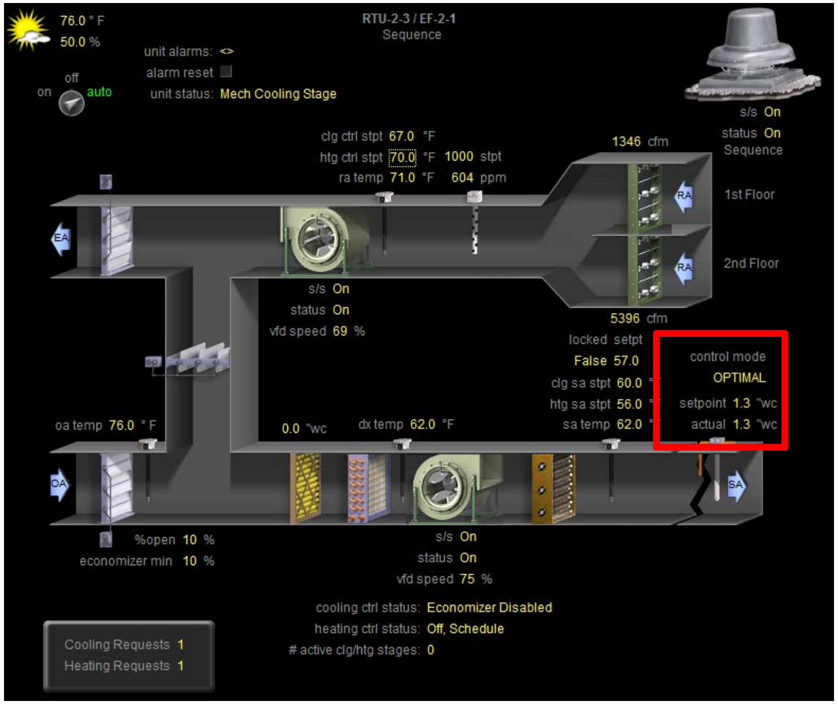


Static Pressure Reset Setting

Manual, No Reset

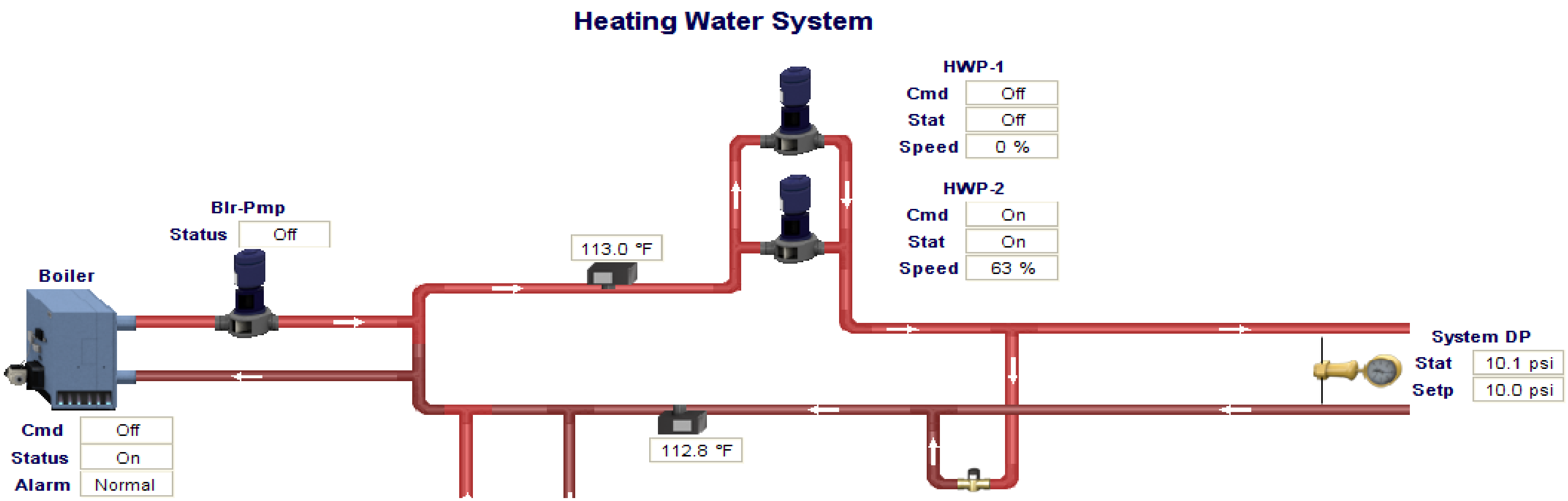


Optimized, Reset



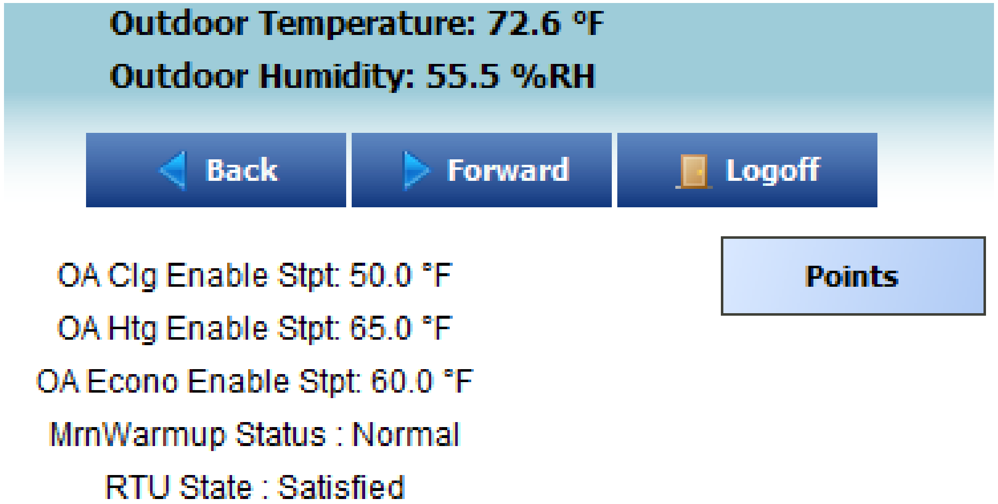
Pump Operation Correct?

- Secondary loop hot water pump running at 63% and dP = 10 psi when system is in Unoccupied mode.



Lockout/Enable Temperatures

- ❑ Do the lockout/enable outside air temperatures make sense for your system?



Exhaust Fan Status

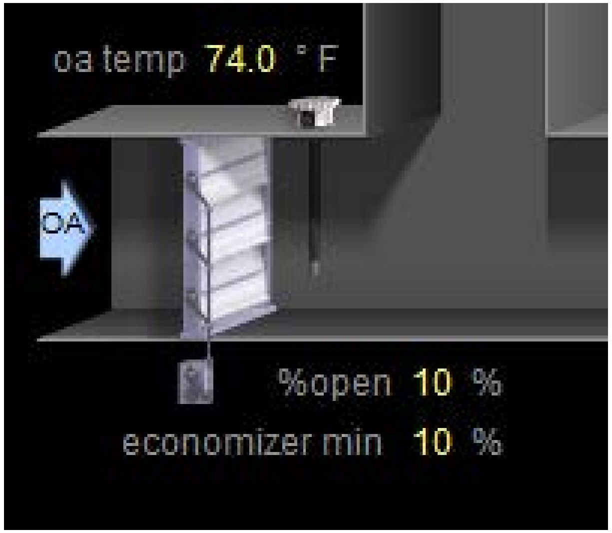
- Can check the last state of change
- Check if active during unoccupied and morning warmup hours. If so, correct the schedule of the fan

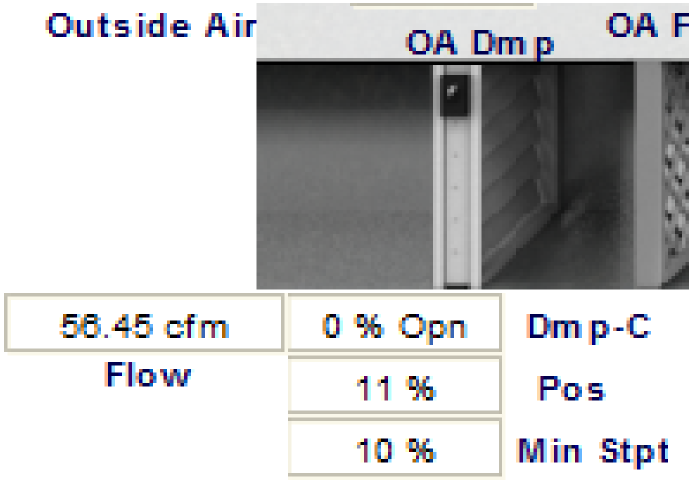
History

Change of State Time:	12:00:00 AM	*/*/* <Any>
Change of State Count:	0	Reset
Time of State Count Reset:	4:49:53 PM	12/29/2014 Monday
Elapsed Active Time:	0:00:00	Reset
Time of Active Time Reset:	4:49:53 PM	12/29/2014 Monday

Min OA Damper

- Check that OA damper is at minimum position when in occupied mode and not economizing.
- Check that OA damper is closed when in unoccupied mode.
- Check that OA damper is closed during the building warm-up and then opens for the last half hour before occupancy.





Economizers:
Discussion Question

If an air handler is in heating mode, should outside or return air be used as the supply stream?

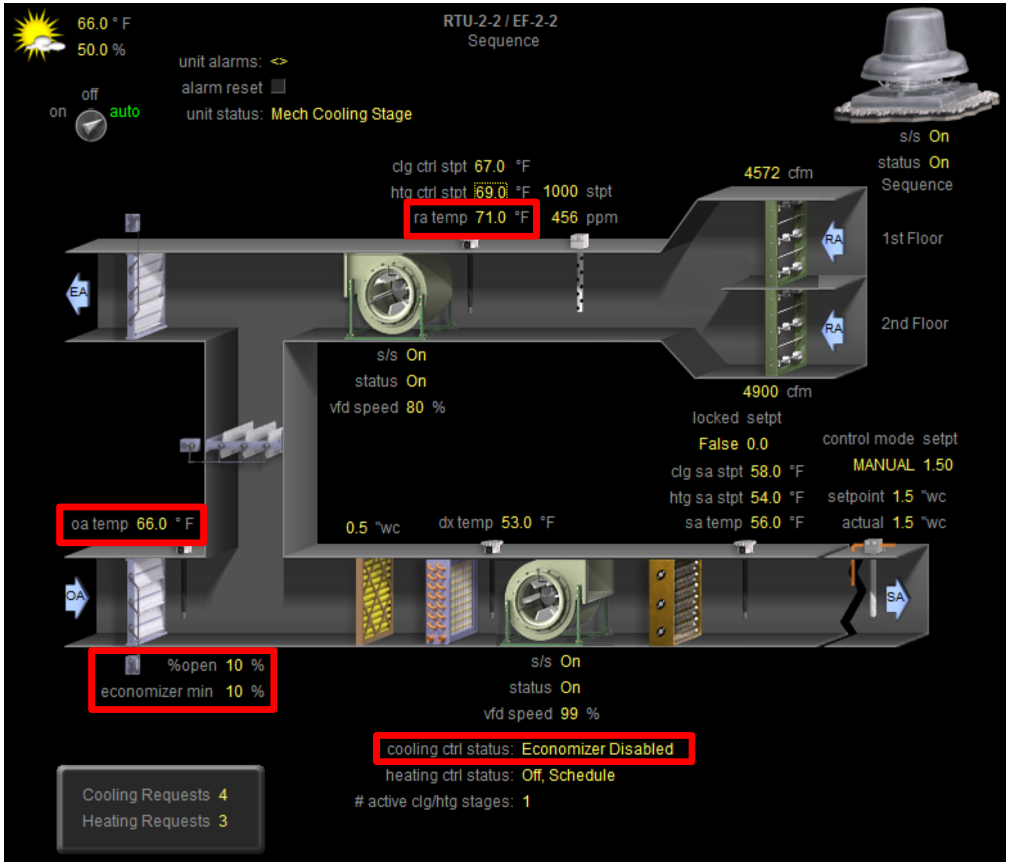
Answer:
Return Air

17

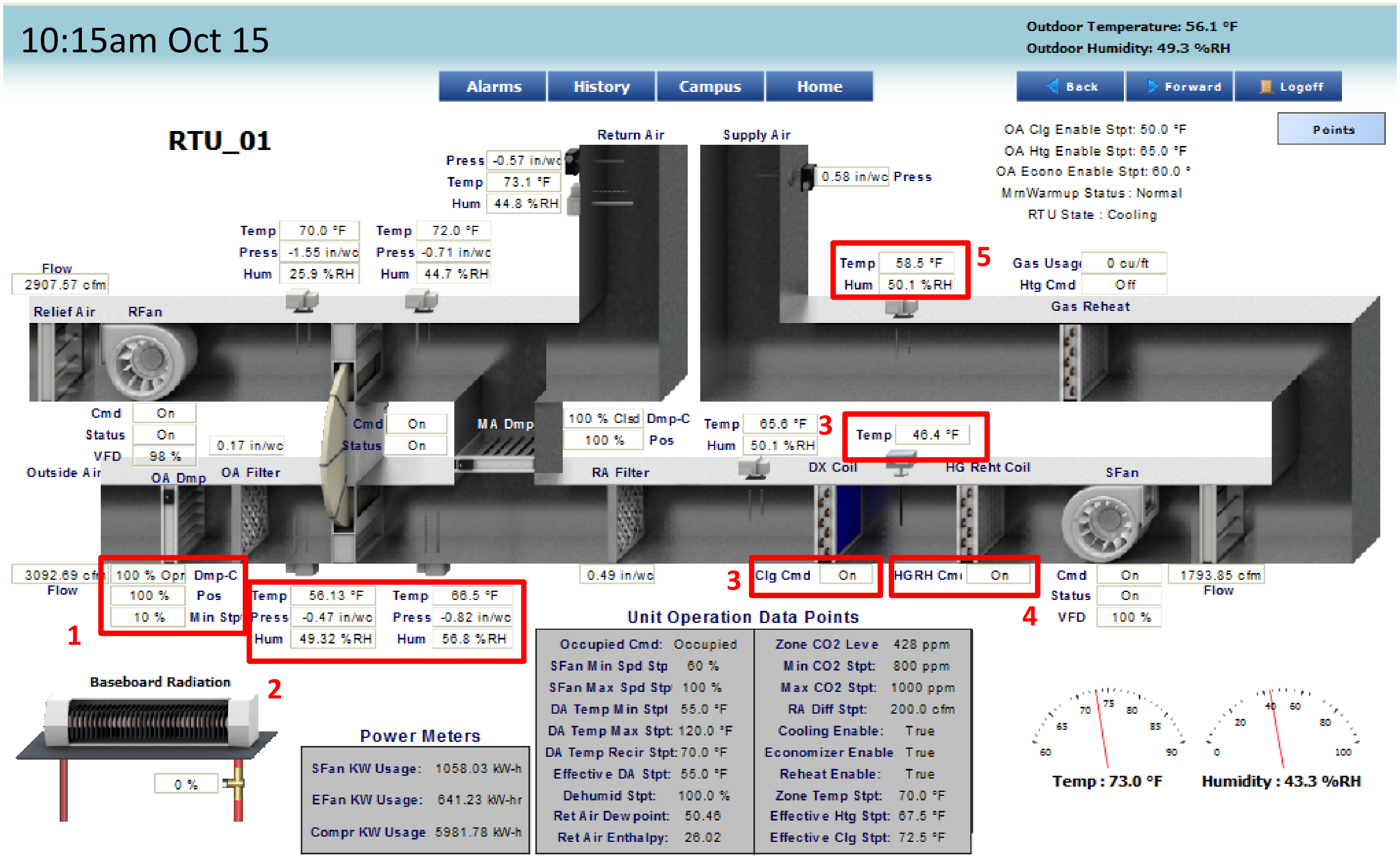
Economizer Enable Temperature

- ❑ Compare is RAT > OAT? Should the OA damper be open more than minimum?

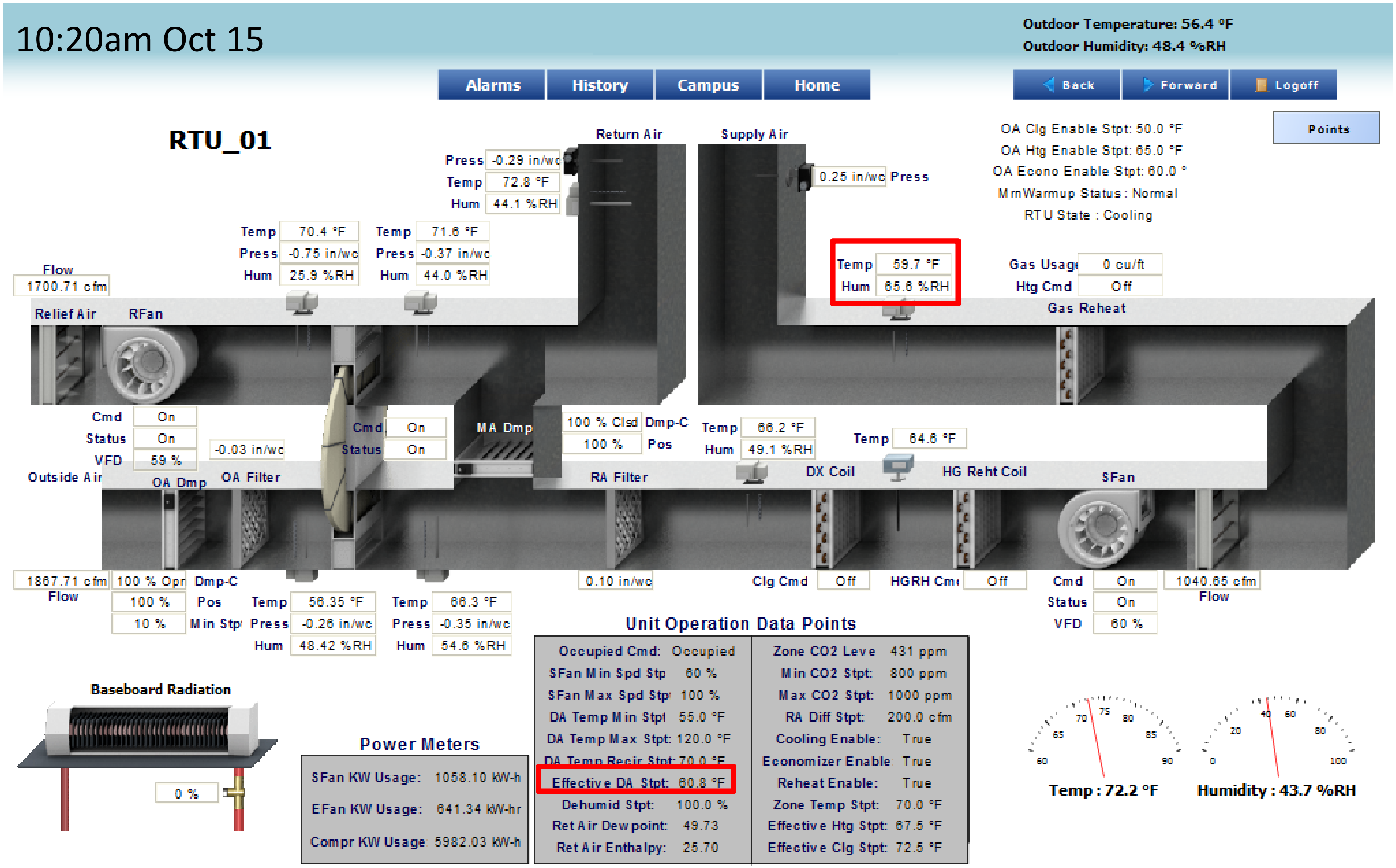
- ❑ Economizer OA damper should be 100% open for at least 5 minutes prior to activating mechanical cooling coil.



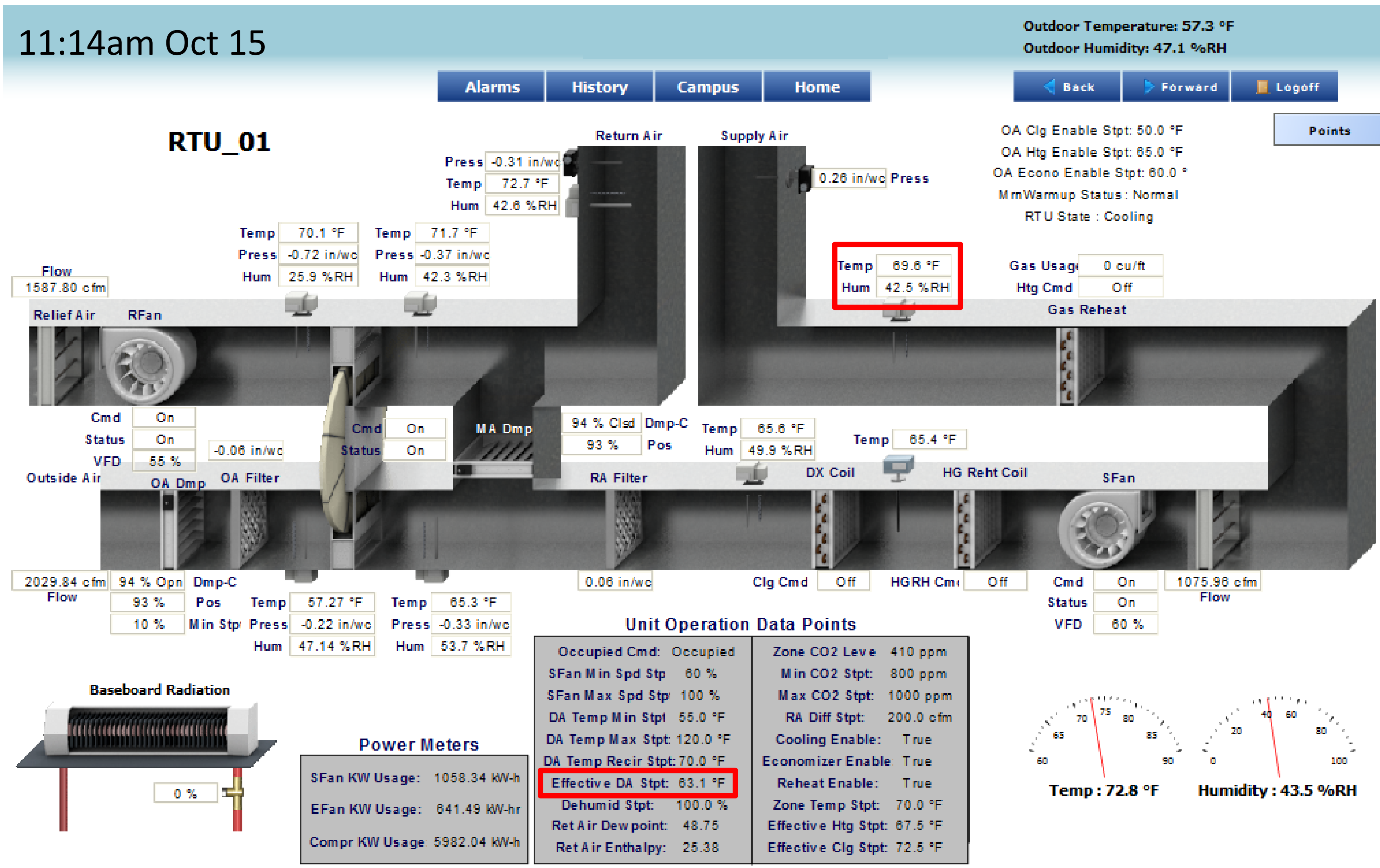
Sequence of Operations



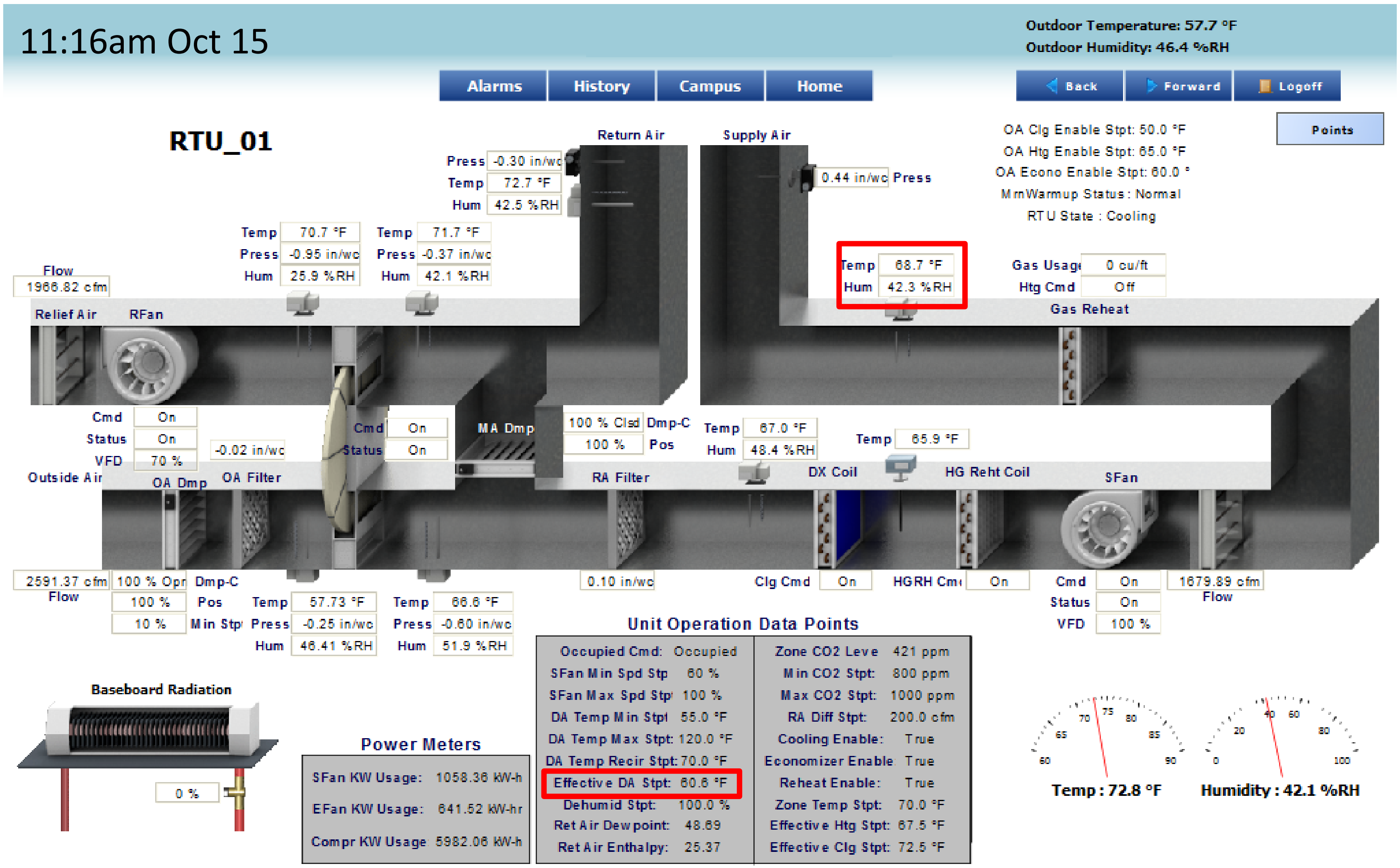
Sequence of Operations 5 Minutes Later



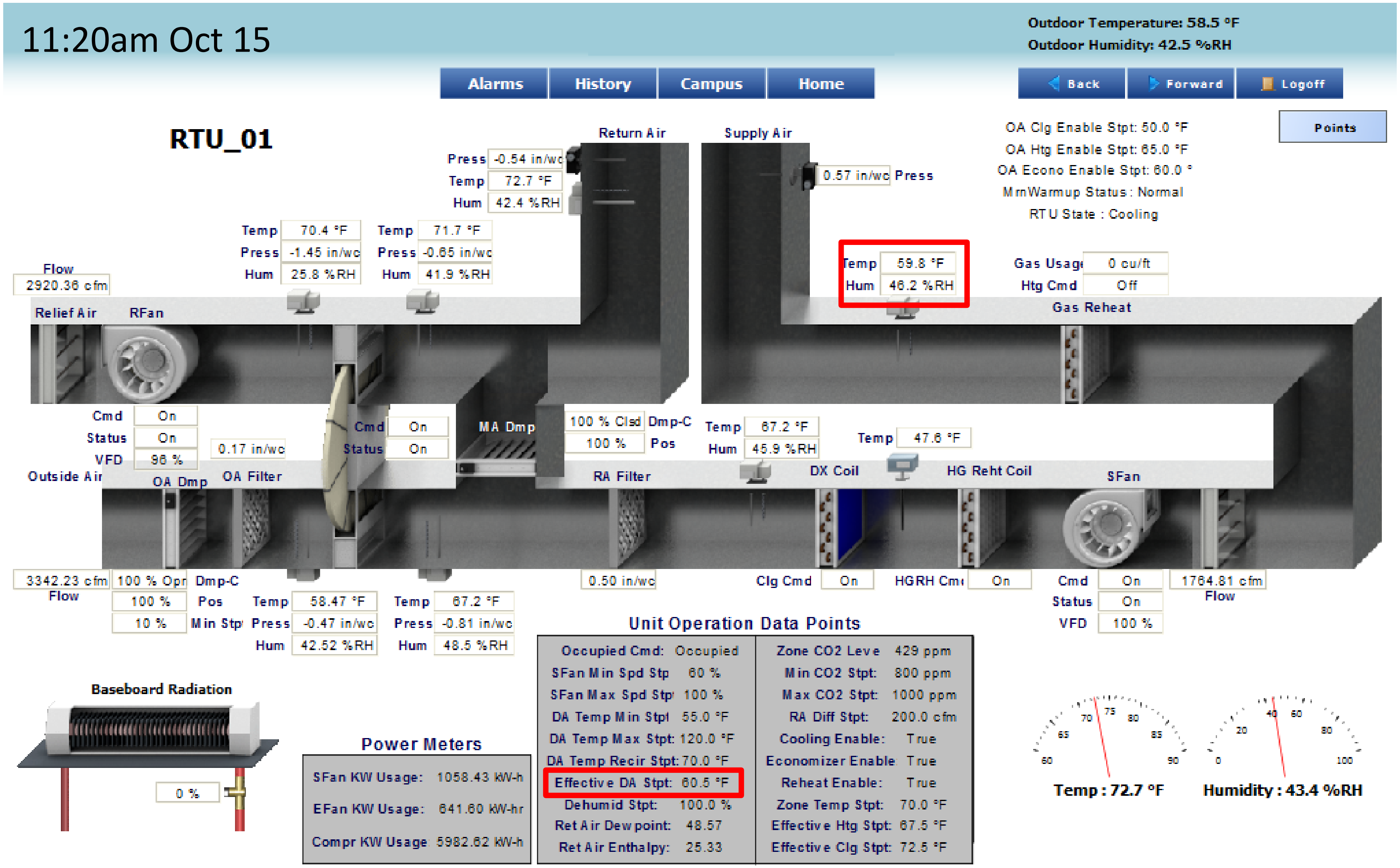
Sequence of Operations 1 Hour Later



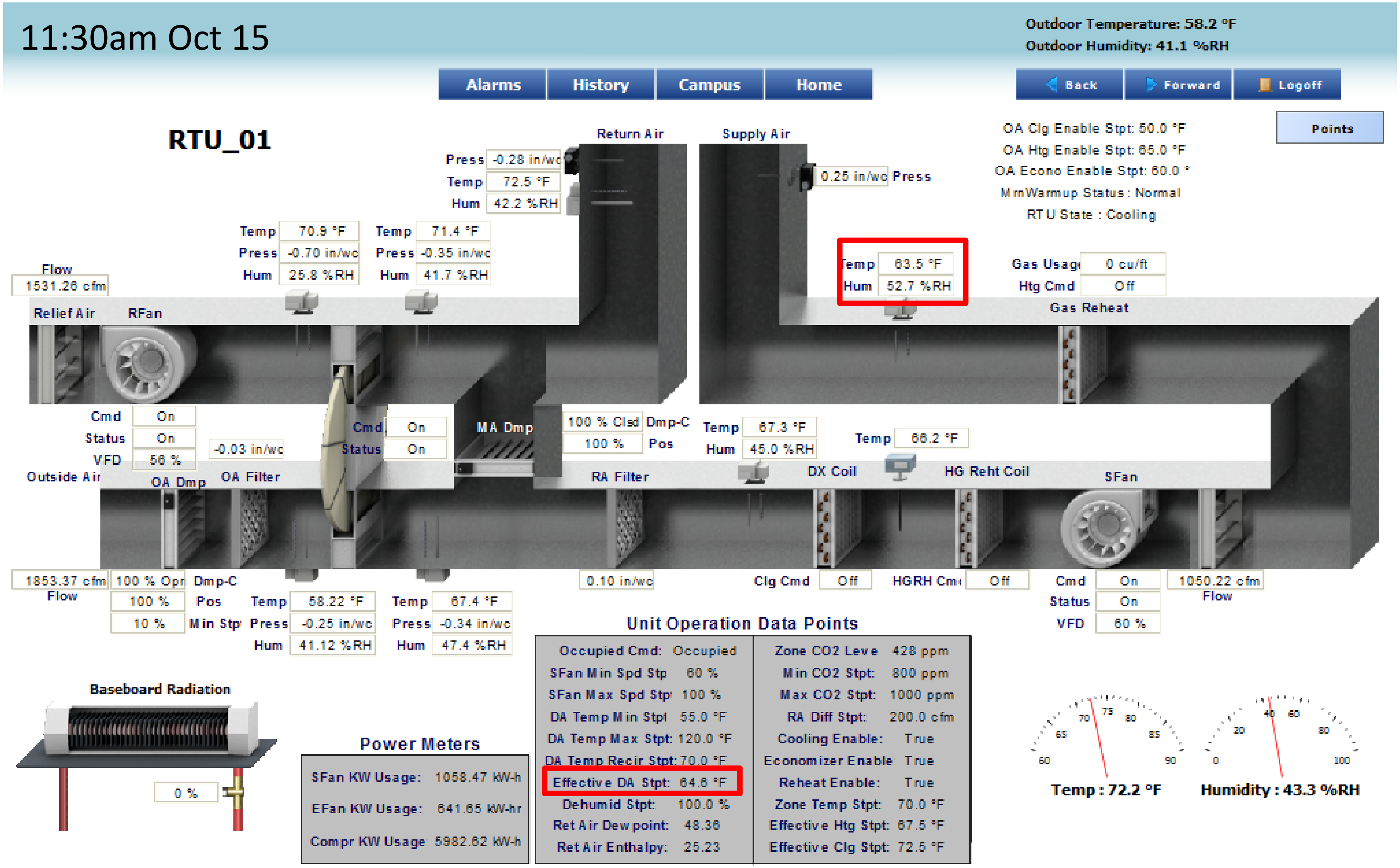
Sequence of Operations 2 Minutes Later



Sequence of Operations 4 Minutes Later



Sequence of Operations 4 Minutes Later

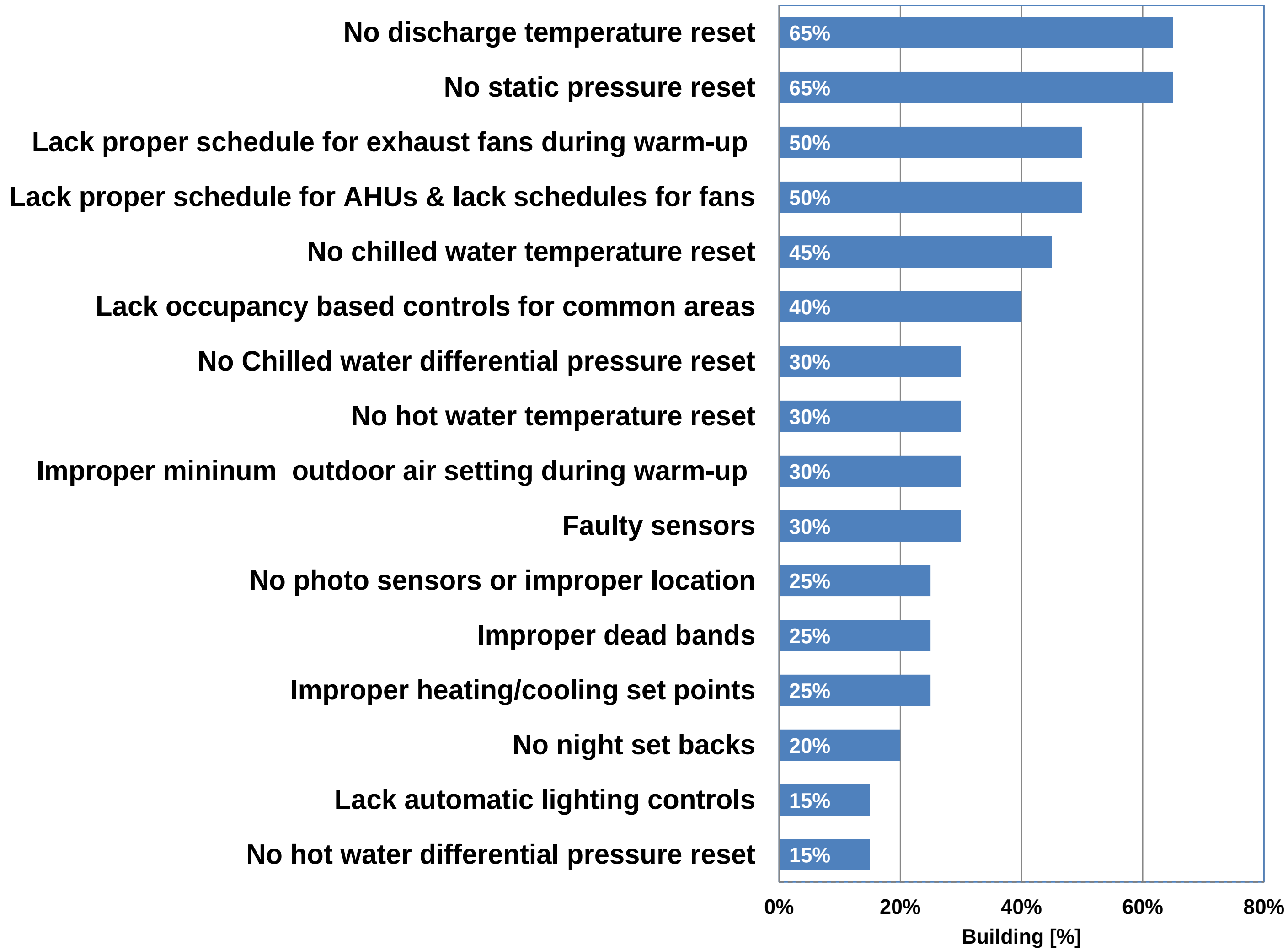


Common Re-tuning Measures Diagnosed within the BAS

BRT Trending within the BAS Requirements

- Data storage:
  - BAS currently stores at least the last two weeks of data
  - Or ability to set up trend historian to record the required date ranges
- Graphical Display of Trends:
  - Good UI to select and display multiple data points trends together
  - Flexible selection of date ranges to chart
  - Ability to export or save chart images to use as record of findings to communicate the required re-tuning changes

PNNL List of Most Common Control Issues



HVAC Thermostats: Discussion Question

Which seasons are optimal for analyzing trend data?

Answer: Fall or Spring, when there is more significant change in outdoor temperatures

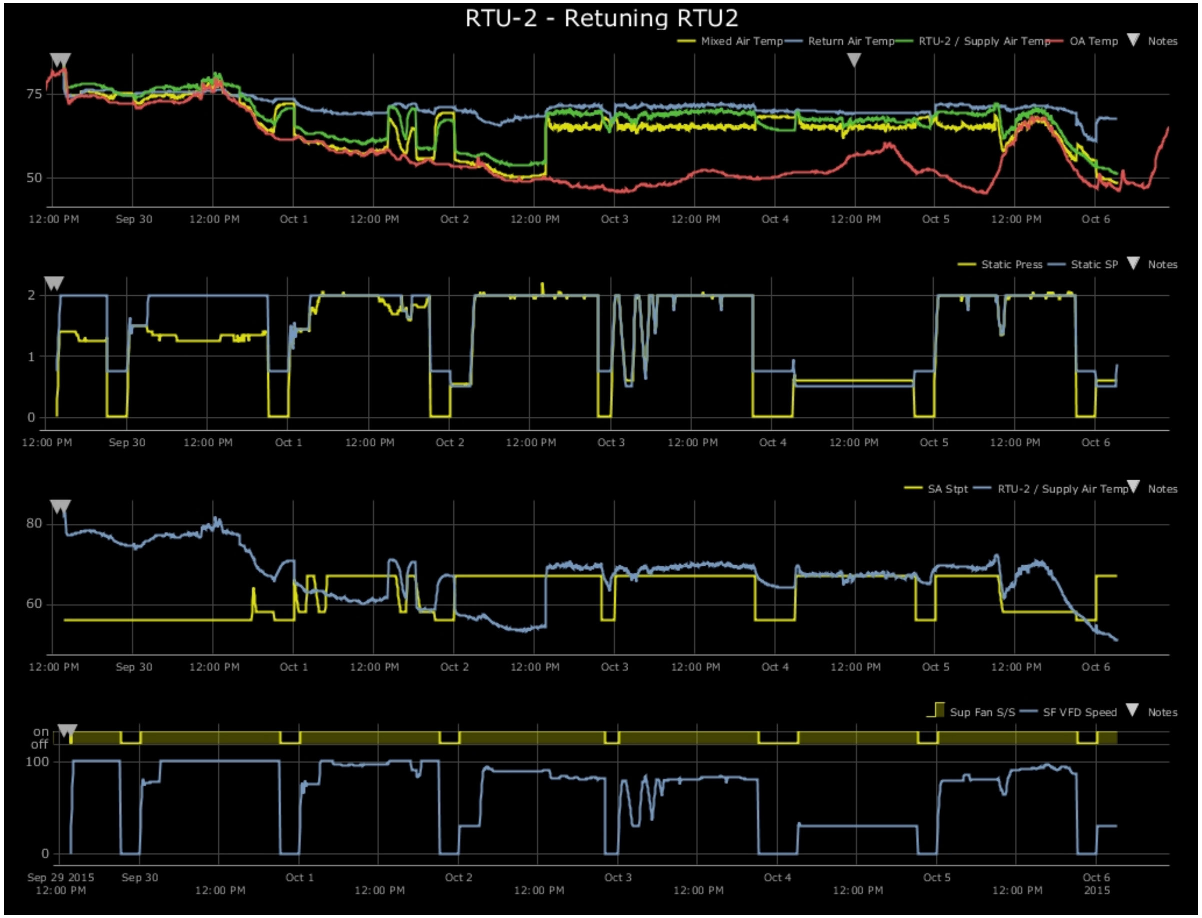
Multiple Re-tuning Trend Example

1) OAT, RAT, MAT, SAT

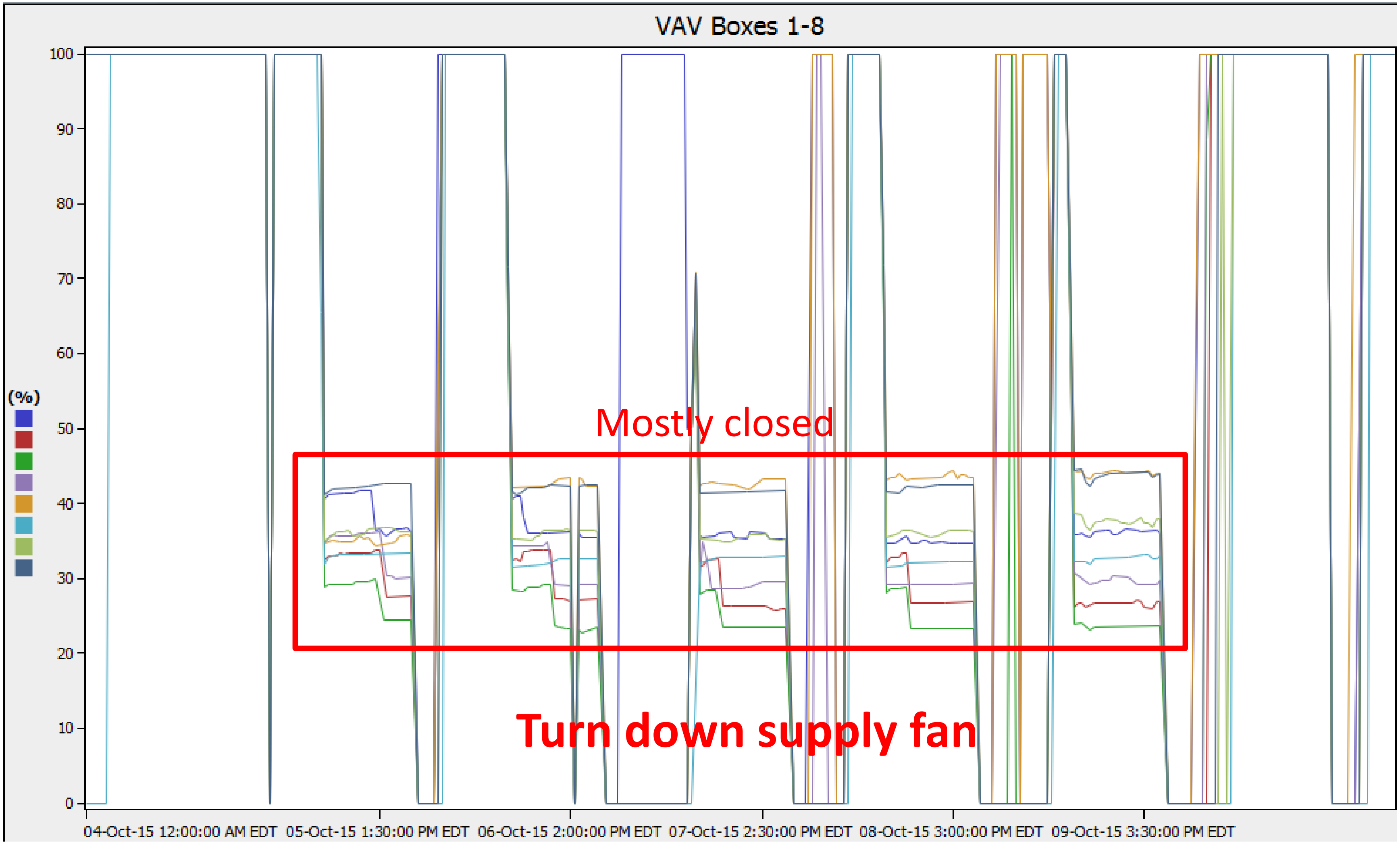
2) Static Pres, Static Stpt

3) SAT, SAT Setpoint

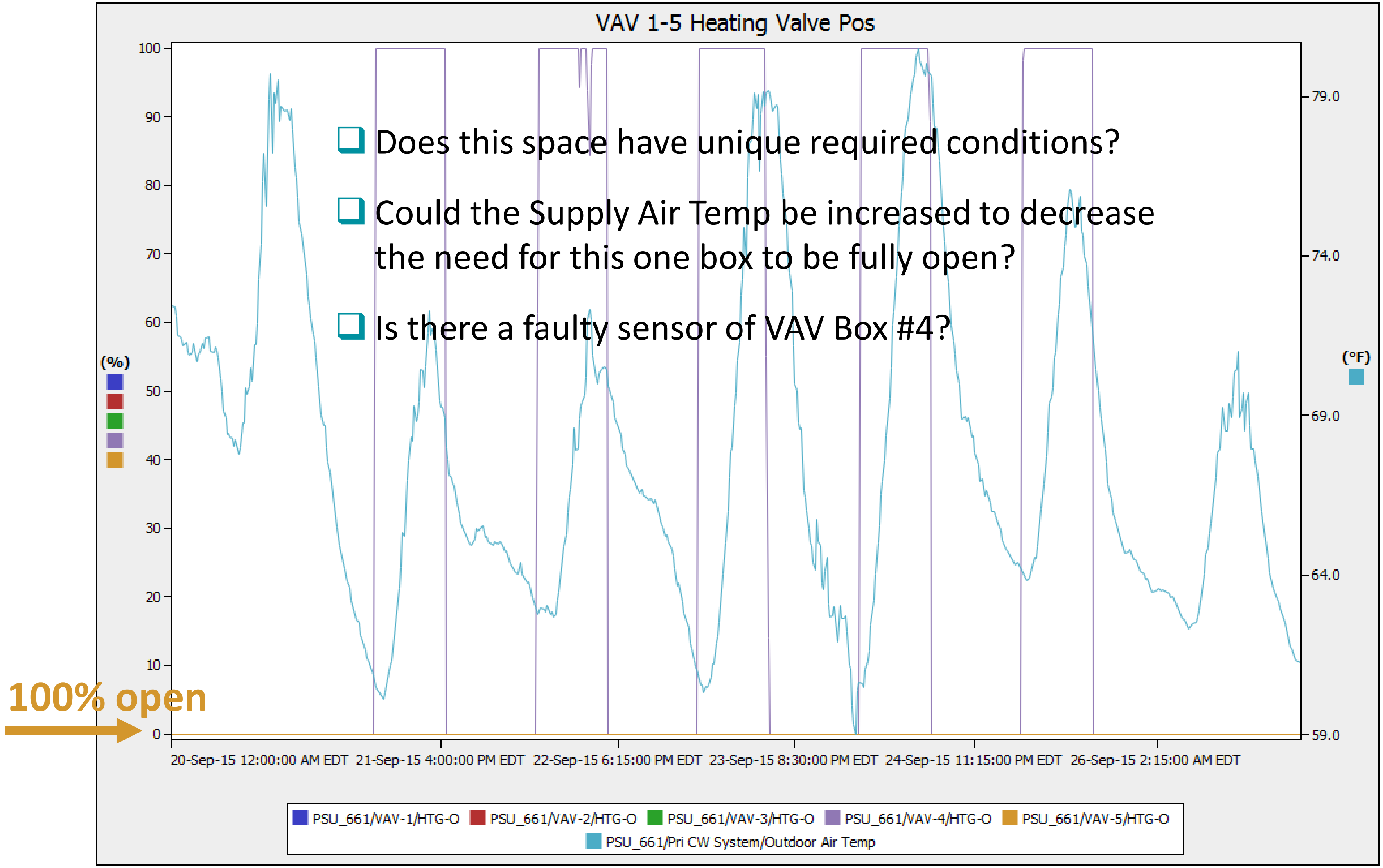
4) Supply Fan



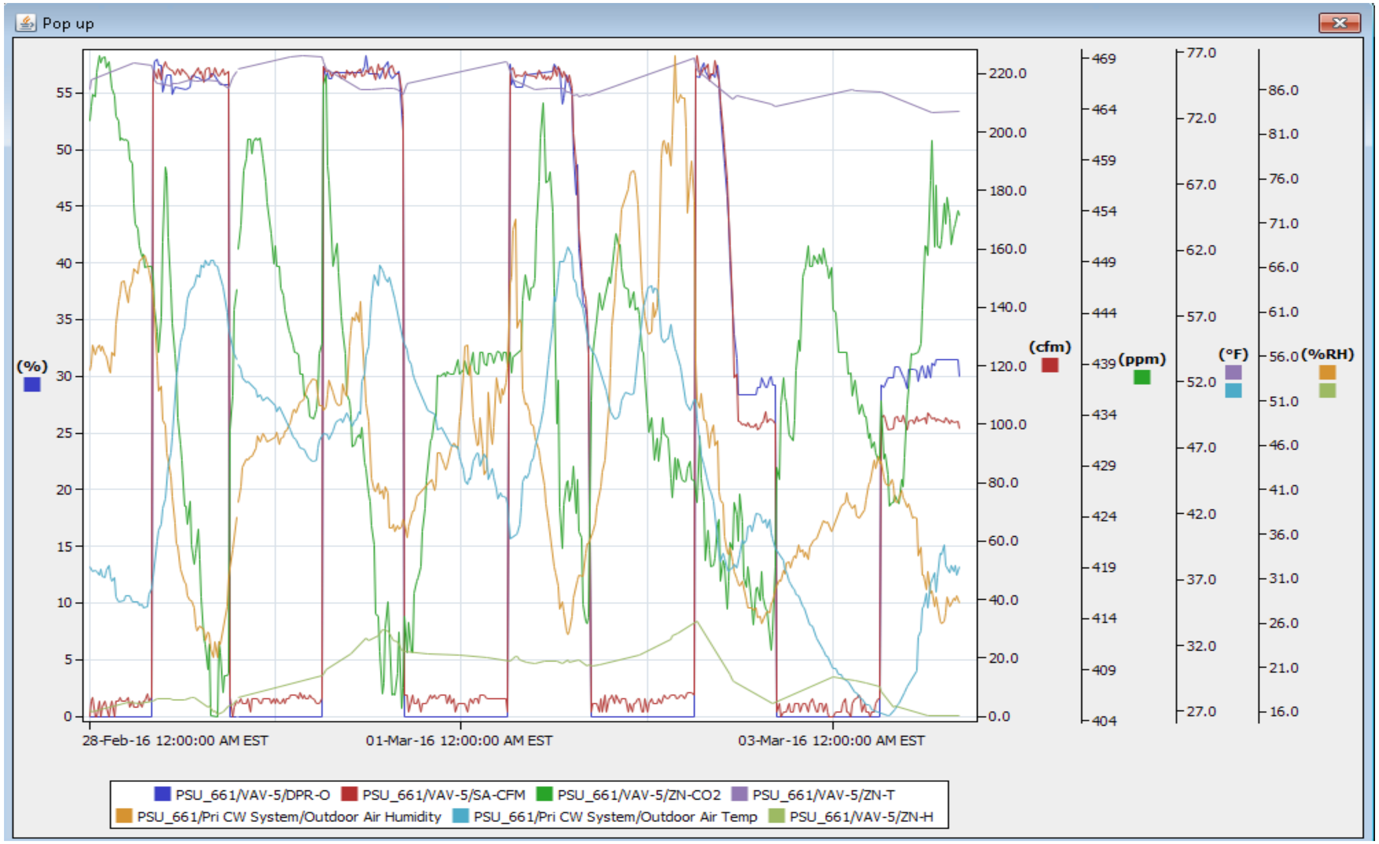
Check AHU Static Pressure through VAV Box Dampers



Check AHU Static Pressure through VAV Box Heating

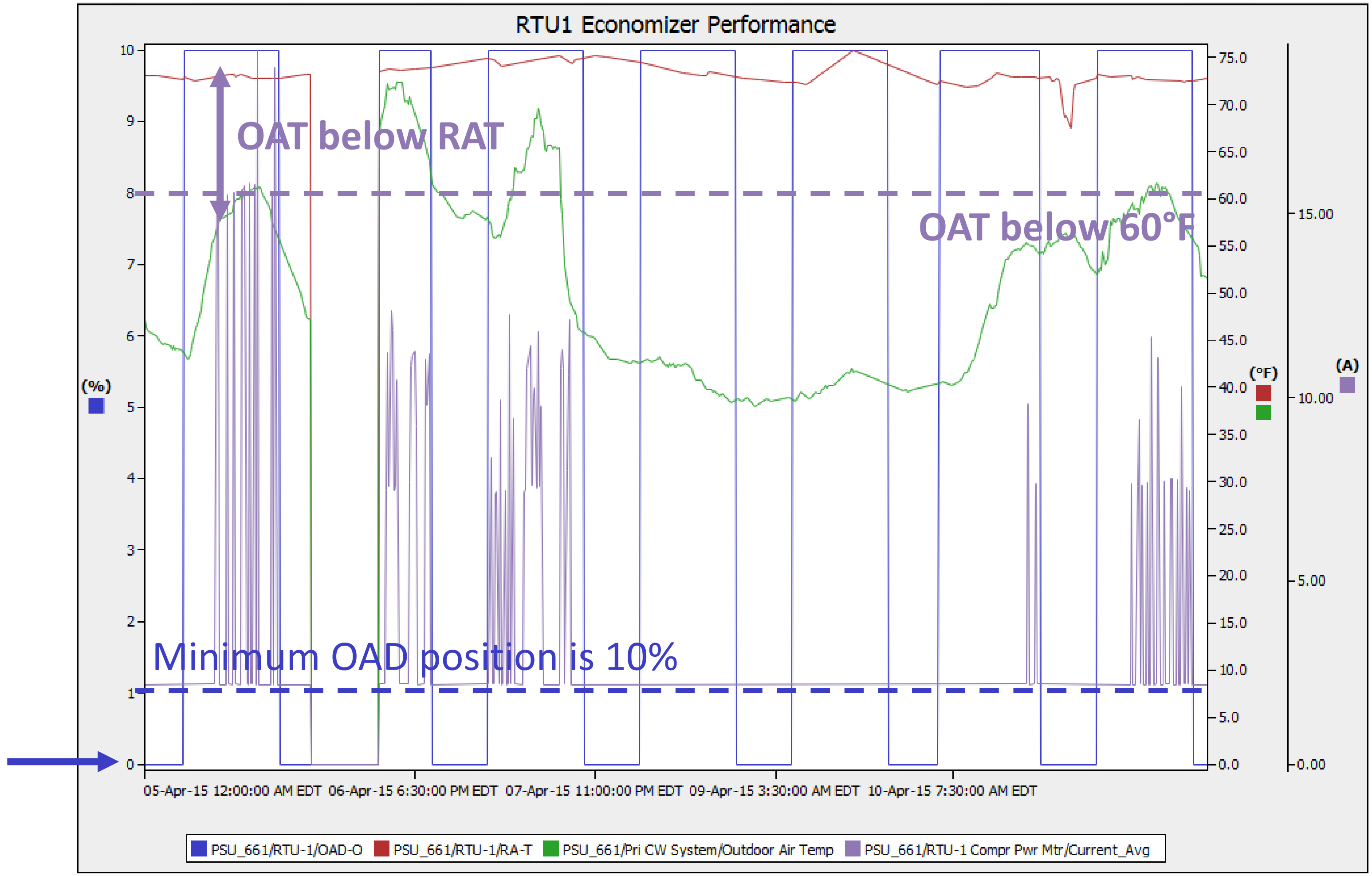


Supply Fan Modulation (Heating Season)

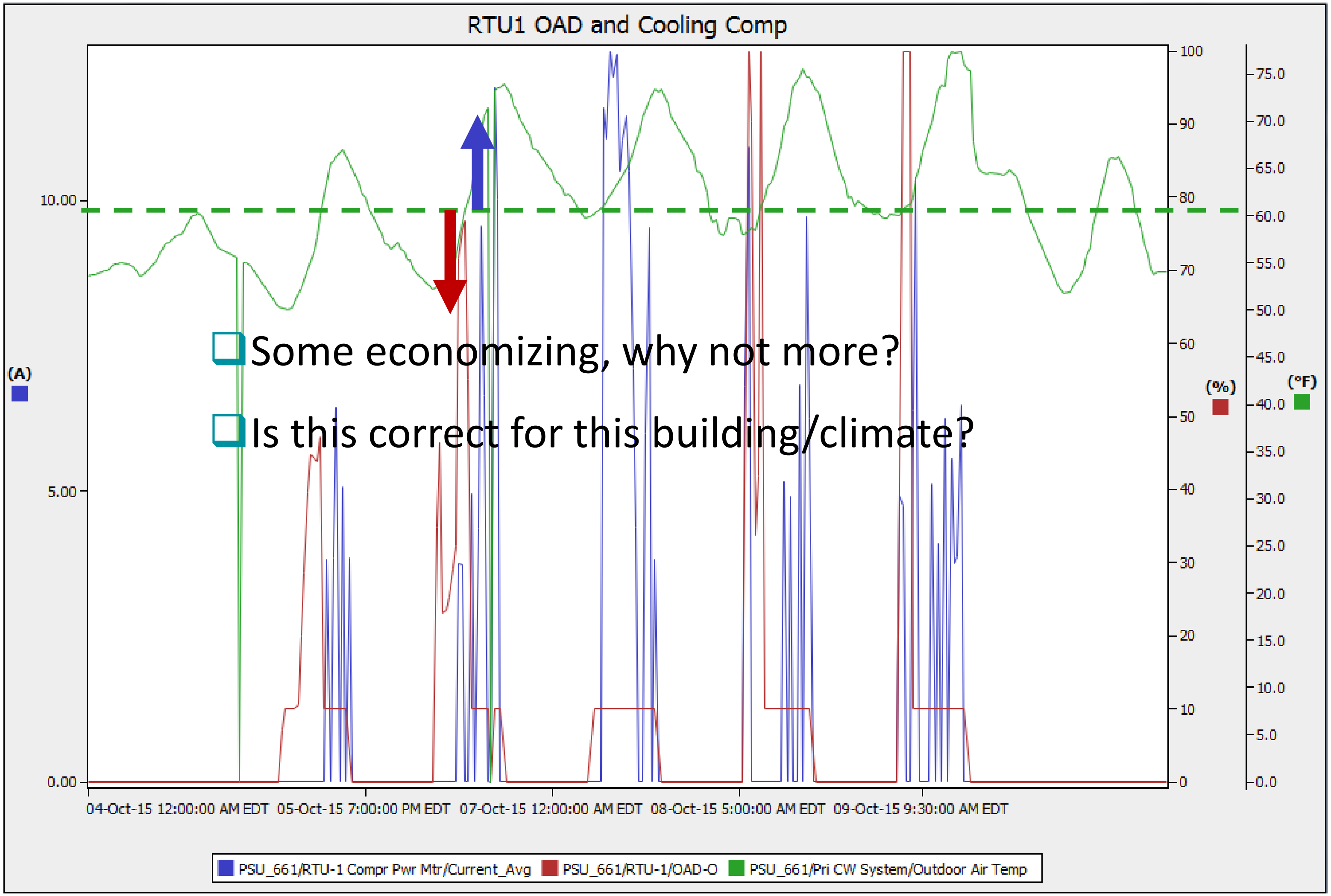


When the OA Temperature decreases, the damper is modulated while the fan speed not, the SA flow remain constant.

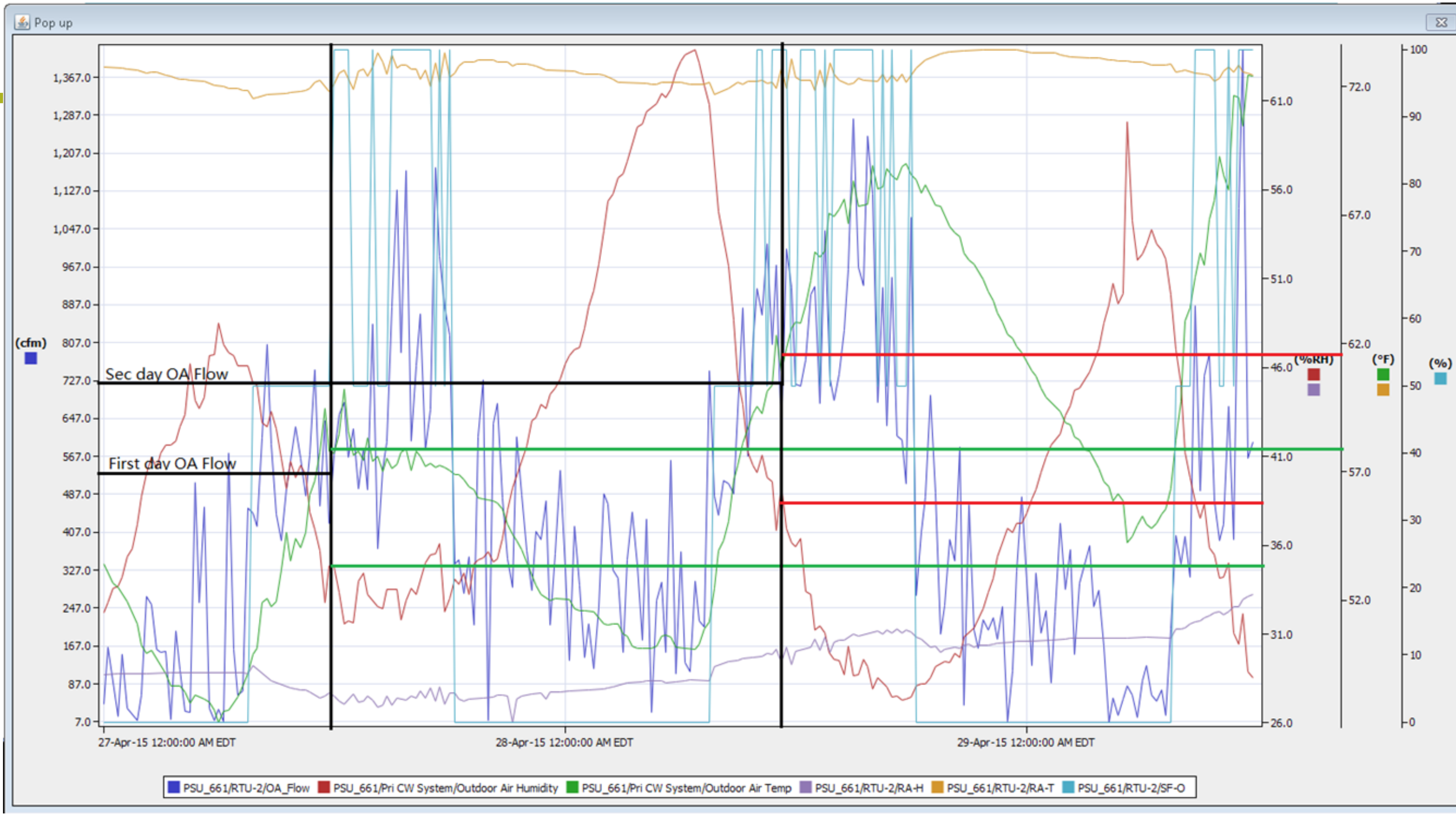
Check Economizer Performance



Check Economizer Performance



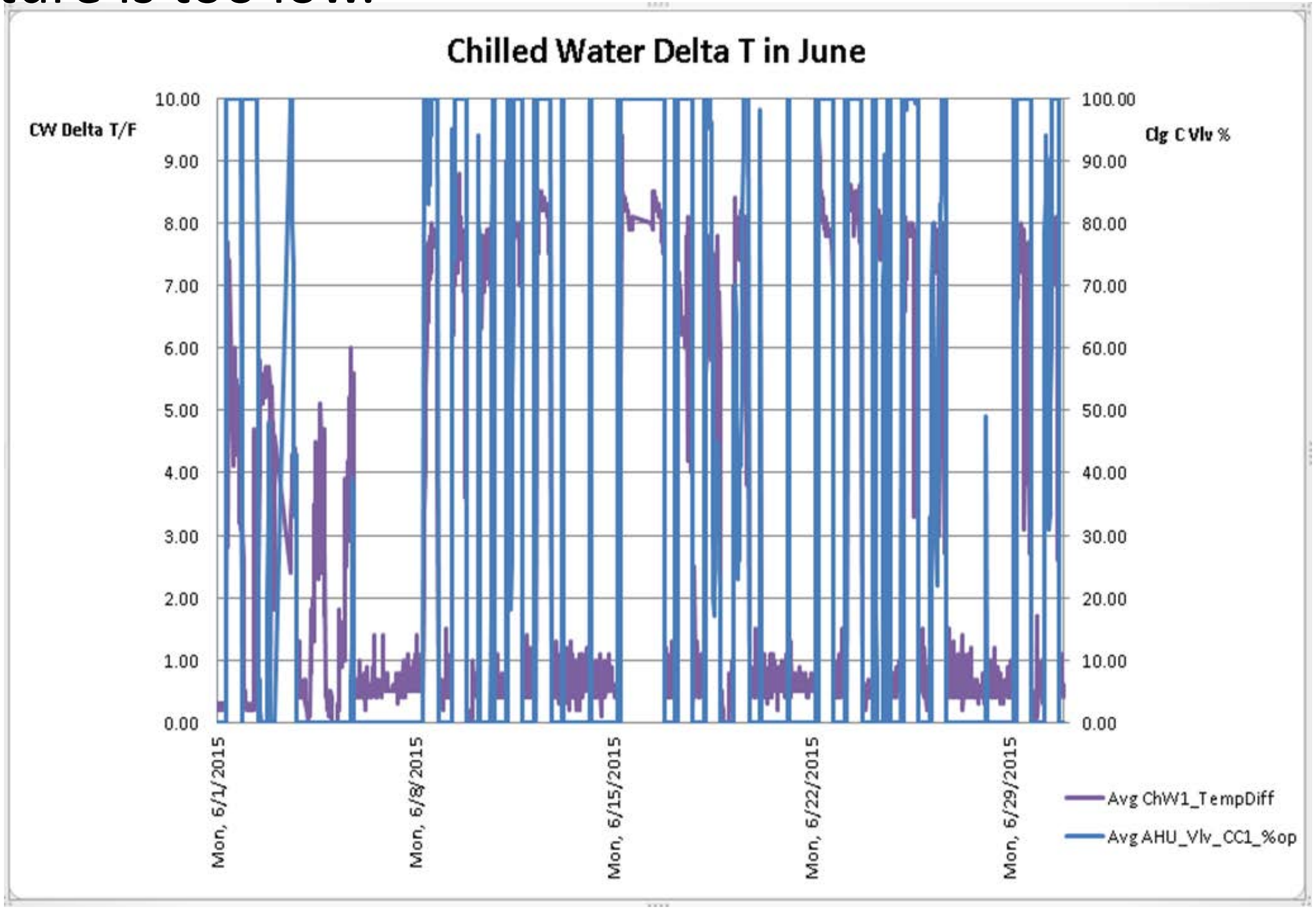
RTU Economizer



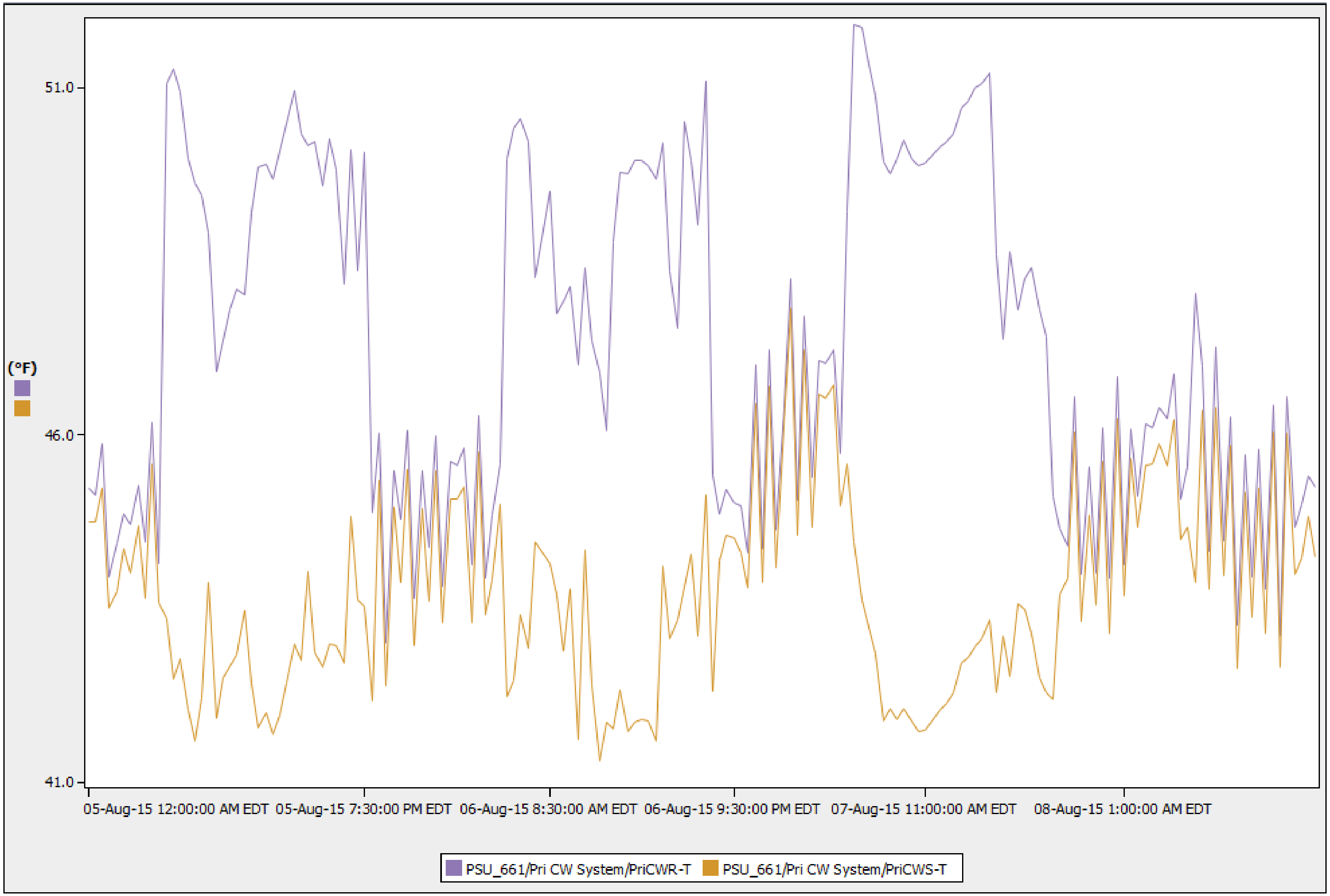
- In the Sec day the same time, OA Temp and Relative Humidity are both higher than the first day, but the system supply more OA Flow for cooling and dehumidification
- And on Apr 27, the temperature between OA and RA is around 15F, the economizer should be used

Avoid Low Delta-T

➢Both pump energy and chiller energy are wasted when delta-T, the difference between return and supply chilled water temperature is too low.



Check Chilled Water Temperature Reset



Thank you

- Next up: Trend Data Set-up

Trend Data Setup:
Module 4E

CONSORTIUM for BUILDING ENERGY INNOVATION

Goals for this training:

- [ ] Be able to create a trending data plan for your building
- [ ] Be able to set up the required trends and export the data for an Automated Logic Controls (ALC) system
- [ ] Be able to set up the required trends and export the data for a Johnson Controls (JC) system
- [ ] Be able to use Universal Translator 3 (UT3) for combing trend data files

BAS Trend Data Plan

Re–tuning with BAS Data: Data Access

- Who in your facility will be doing the re-tuning?
  - Skills: MS Excel, data manipulation, familiarity with the BAS software
- What level of access is required?
  - Read only access
  - Ability to set up and export trend data
  - Ideally, be able to save trended points as a report or template that can be used again.

Re-tuning with BAS Data: Data Collection Process Overview

- Overall building geometry
  - approximate gross square feet
  - Number of floors
- Type of heating ventilation and air conditioning (HVAC) system(s)
- Approximate number of each major type of equipment
  - Boilers
  - Chillers
  - Air handlers
- Approximate number of zones per AHU, interior vs exterior zones
- Type of building automation system (manufacturer, model, version)
- Level of access granted to BAS for the re-tuning analyst

Re–tuning with BAS Data:
Data Collection Process Overview

For VAV systems, the following data points must be trended at 15-minute maximum intervals for a minimum 2-week period.

- If there are fewer than 6 AHUs in the building, recommended that all AHUs be trended.
- If the building is less than 4 stories tall, randomly pick at least one AHU from each floor.
- If the building is more than 4 stories tall, randomly pick one AHU from every other floor (maximum of 10 AHUs trended).

Re–tuning with BAS Data: Data Collection Process Overview

Following are the guidelines for trending zone VAV boxes:

- For each floor, trend at least one zone on each of the four directions (north, south, east and west) and at least four zones in core. So, we will need at least eight VAV boxes trended per floor.
- If the building is less than 4 stories tall, trend eight zones from each floor.
- If the building is more than 4 stories tall, trend eight zones from every other floor.

Re-tuning with BAS Data: Setting Up BAS Trends

Develop a monitoring plan – plan includes the points to trend and for each point:

- Planned trend start time
- Planned trend end time
- Length of measurement period
  - Minimum of 2 weeks is recommended, preferably 3 to 4 weeks
  - Allow characterization of both weekdays and weekends
- Time interval between logged measurements
  - 5-15 minute frequency is ideal
  - Measurement units

Re–tuning with BAS Data:
Recommended Units of Measure

- Temperature - F
- Relative humidity - %
- Pressure – psig
- Damper and valve positions - % of fully open
- Fan speed – rpm
- Fan status – 1/0 (on/off)
- Occupancy mode – 1/0 (occupied/unoccupied)
- Chiller load – % loaded, amps, kW, or tons

Learning Activity #2:
Example Monitoring Plan for an AHU

Building Name:	**ABC Bank Building**
Building Location:	**123 4th Ave., Seattle, WA 99111**
Date:	**April 3, 2007**

Planned Start Date/Time:	**5/1/07 TBD**
Planned End Date/Time:	**5/15/07 TBD**

Re-Tuning Technician Name:	**John Doe, McDonalds Control Services**
Contact Information:	**(509) 555-5555; john.doe@mcs.com**

Planned Measurement Period (hours, days or weeks)	**2 weeks**
Measurement Interval (seconds, minutes, or hours):	**15 minutes**

Floor:	1
Equipment Name:	AHU-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
OAT1	Outdoor air temperature					Degrees F
MAT1	Mixed air temperature					Degrees F
RAT1	Return air temperature					Degrees F
DAT1	Discharge air temperature					Degrees F
DATSP1	Discharge air-temperature set point					Degrees F
PDIST1	Discharge Static Press					in. w.c.
OADamper1	Outdoor air damper position					% open
Fan1	Fan status					on/off
Fan Speed1	Fan speed					rpm
CWV%1	Chilled water valve position					% open
HWV%1	Hot water valve position					% open
MODE1	Occupancy mode					Occupied/ Unoccupied

Which BRT measure(s) can this point be used for?

Re-tuning with BAS Data: Example Monitoring Plan for an AHU

Building Name:	**ABC Bank Building**
Building Location:	**123 4th Ave., Seattle, WA 99111**
Date:	**April 3, 2007**

Re-Tuning Technician Name:	**John Doe, McDonalds Control Services**
Contact Information:	**(509)555-5555; john.doe@mcs.com**

Planned Start Date/Time:	**5/1/07 TBD**
Planned End Date/Time:	**5/15/07 TBD**

Planned Measurement Period (hours, days or weeks):	**2 weeks**
Measurement Interval (seconds, minutes, or hours):	**15 minutes**

Floor:	1
Equipment Name:	VAV1-1

Point Name	Measurement Description	Planned Start Date/Time	Planned End Date/Time	Planed Measurement Period (hours, days, or weeks)	Measurement Interval (seconds, minutes or hours)	Measurement Units
T1-1	Zone air temperature					Degrees F
VAV%1-1	VAV box damper position					% open
REHEAT%1-1	VAV box reheat valve position					% open
MODE1-1	Zone occupancy mode					Occupied/ Unoccupied

Which BRT measure(s) can this point be used for?

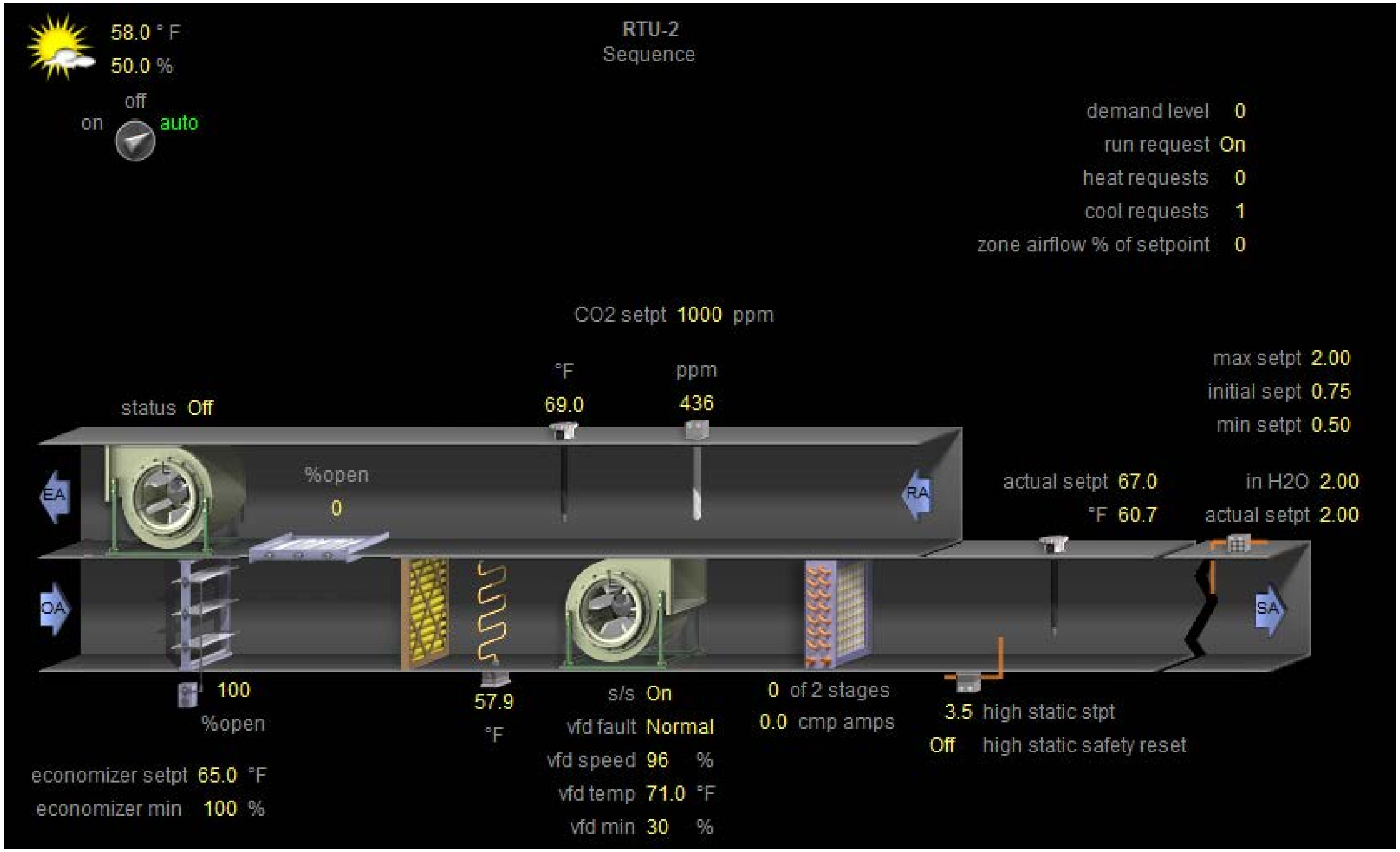
Getting the BAS Trend Data

Universal Translator 3 (UT3)

- UT3 can be very useful for combining multiple trend data files as well as synchronizing different timestamps.
- Download UT3 from http://utonline.org/cms/node/214
  - The UT3 software is much easier to install than the older UT2
- Create a user account to get access. Download the first zip file at the bottom of the page called "UT3Setup.3.0.1403.1816.beta3_.zip"
- Unzip and install the software

Understanding the Data

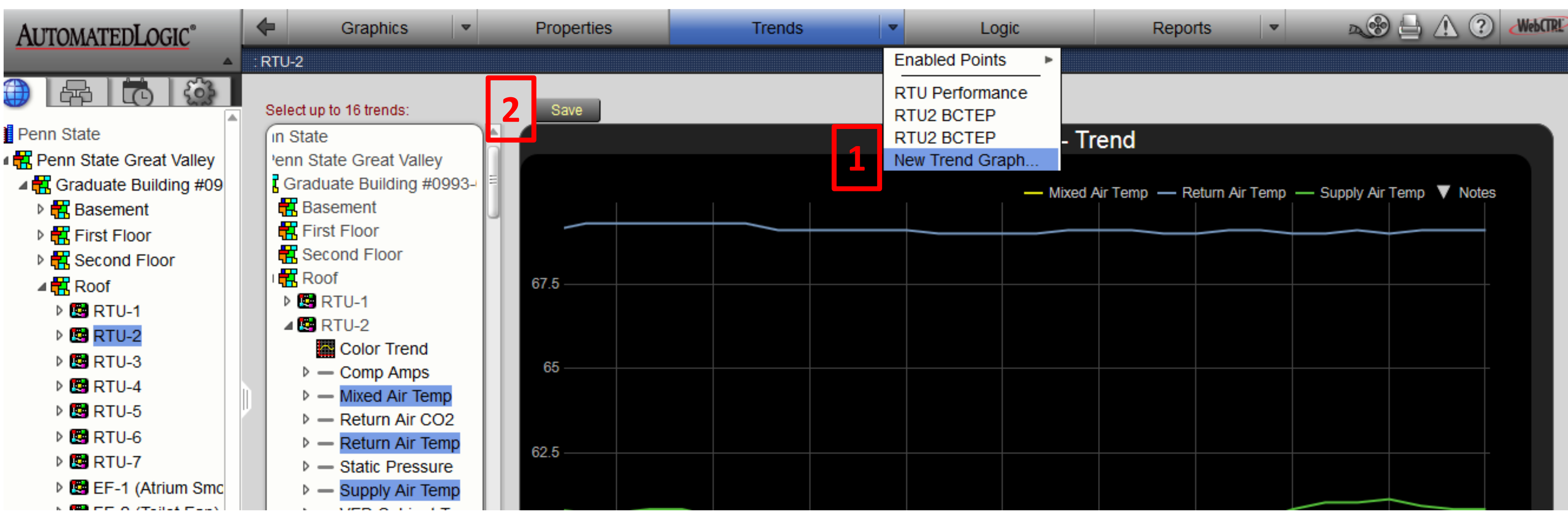
- Get familiar with the interface and available data



ALC Trend Data

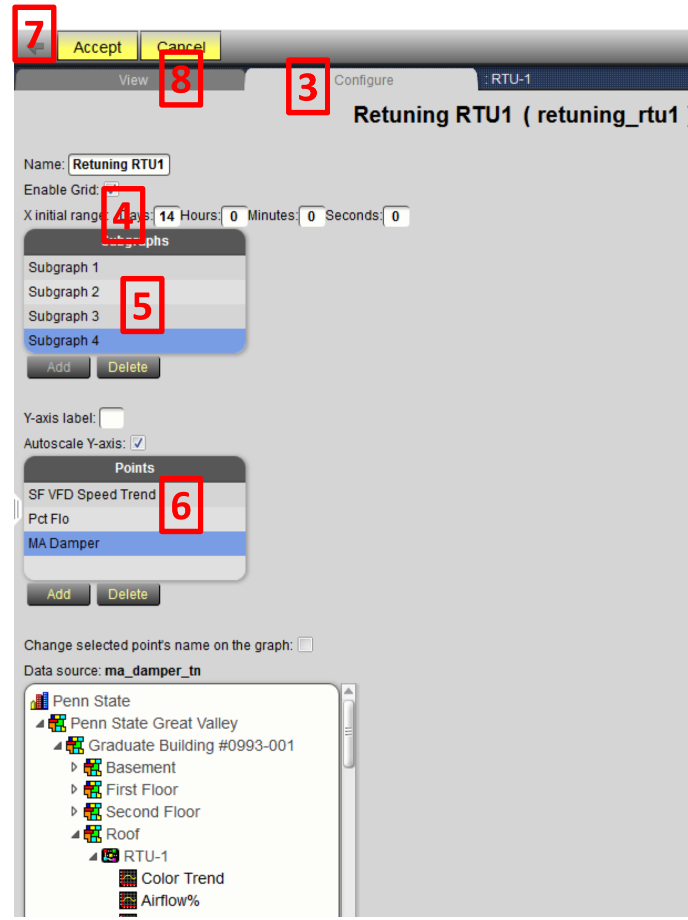
1. Select the equipment to set up trends, then select "New Trend Graph"

2. Select some or all points to trend, you will be able to add/edit points after you save the initial Trend Graph. Press Save.



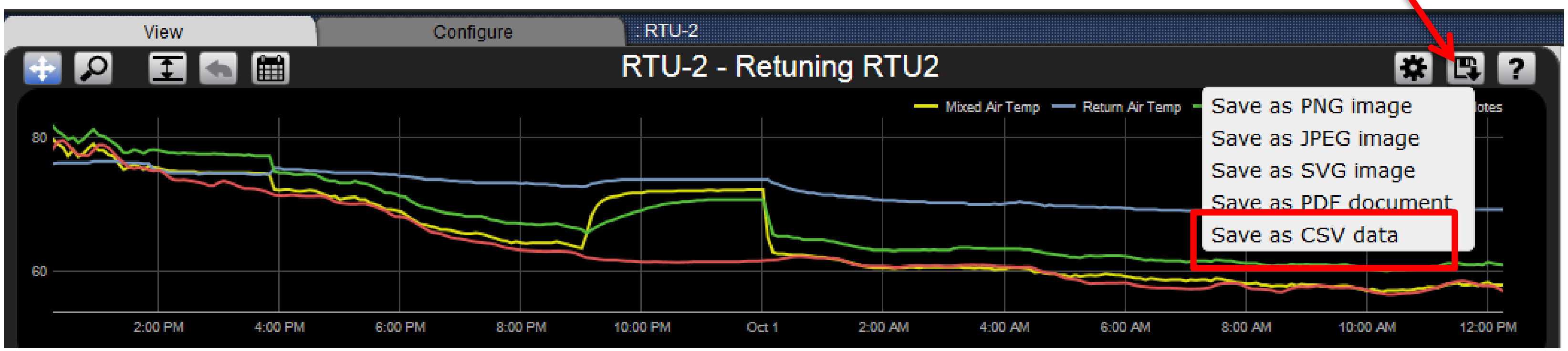
ALC Trend Data

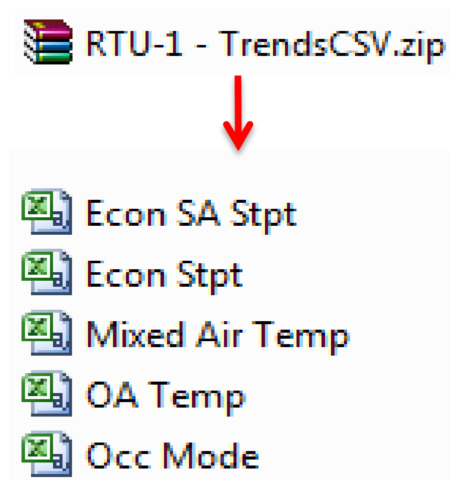
3. Click the Configure tab
4. Change Days from default of “1” to length of available data
5. Add up to 4 Subgraphs (charts)
6. Add up to 4 points per Subgraph
7. Click Accept
8. Click the View Tab



ALC Trend Data

9. Export data – “Save as CSV data”



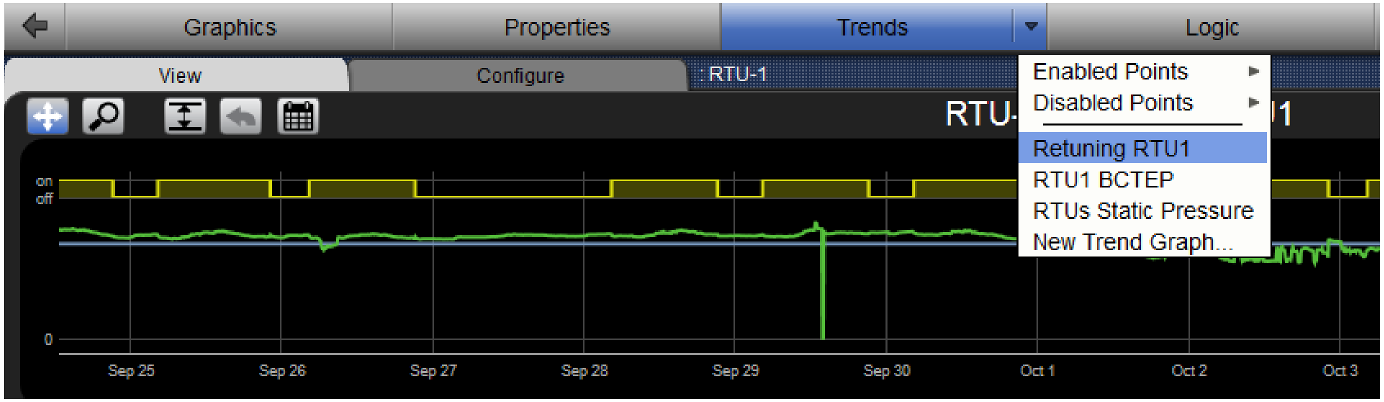


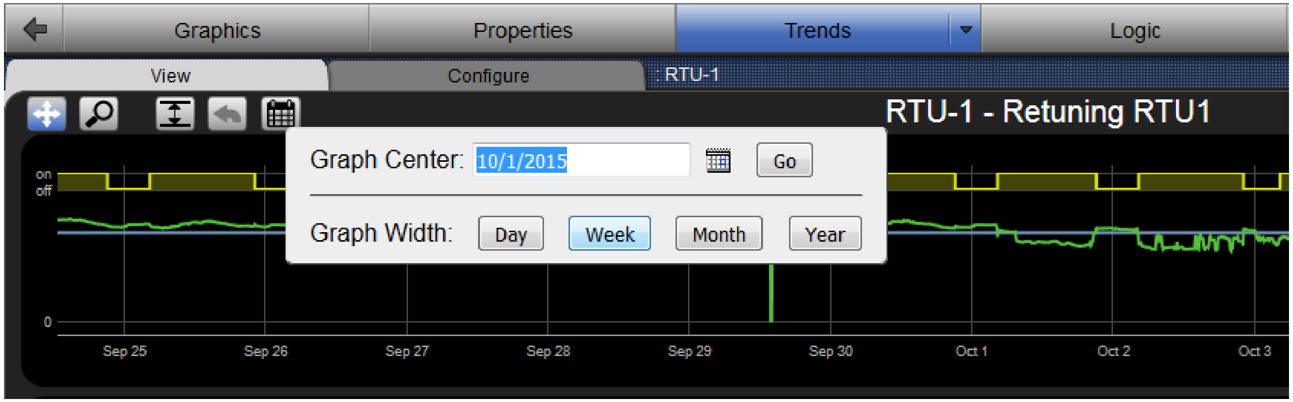
Each export is saved as a zip file

- Each point is in a separate .csv file
- The file names do not indicate which piece of equipment or zone the data were taken.

ALC Trend Data

- Notice that the new trend report is saved and can be re-run!!!
- User can select new date ranges with calendar button





ALC Trend Data

10. Reformat the csv files for import into Universal Translator (UT3)

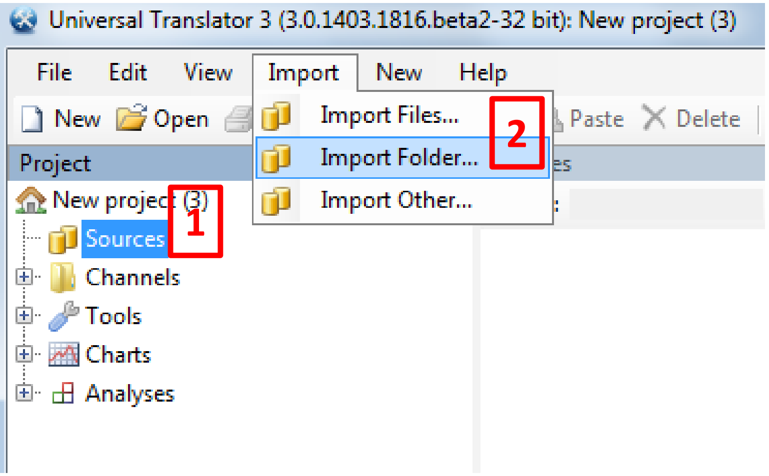
- Delete Columns A and D
- Format Date-Time of Columns B
- Delete First Row

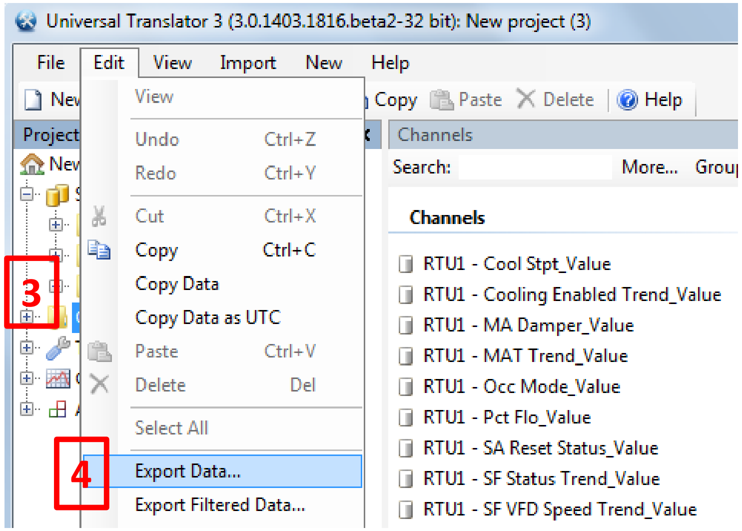
	A	B	C	D
1	Penn State / Penn State Great Valley / Graduate Building #0993-001			
2	Date	Excel Time	Value	Notes
3	9/20/2015 12:00:00 AM EDT	42267	69.69225	
4	9/20/2015 12:05:00 AM EDT	42267.00347	69.56744	
5	9/20/2015 12:10:00 AM EDT	42267.00694	69.56734	
6	9/20/2015 12:15:00 AM EDT	42267.01042	69.567215	
7	9/20/2015 12:20:00 AM EDT	42267.01389	69.634026	
8	9/20/2015 12:25:00 AM EDT	42267.01736	69.70085	
9	9/20/2015 12:30:00 AM EDT	42267.02083	69.81352	
10	9/20/2015 12:35:00 AM EDT	42267.02431	69.9262	
11	9/20/2015 12:40:00 AM EDT	42267.02778	69.96641	

Alternately, build an Excel macro

ALC Trend Data

11. Import individual data files into UT3 in order to combine all files into one file with common timestamp
    1. Click Sources to highlight it
    2. Click Import then “Import Folders” for each trend folder
    3. Click Channels then click Edit then Export Data
    4. Click Edit then “Export Data” to save the new combined .csv file





ALC Trend Data

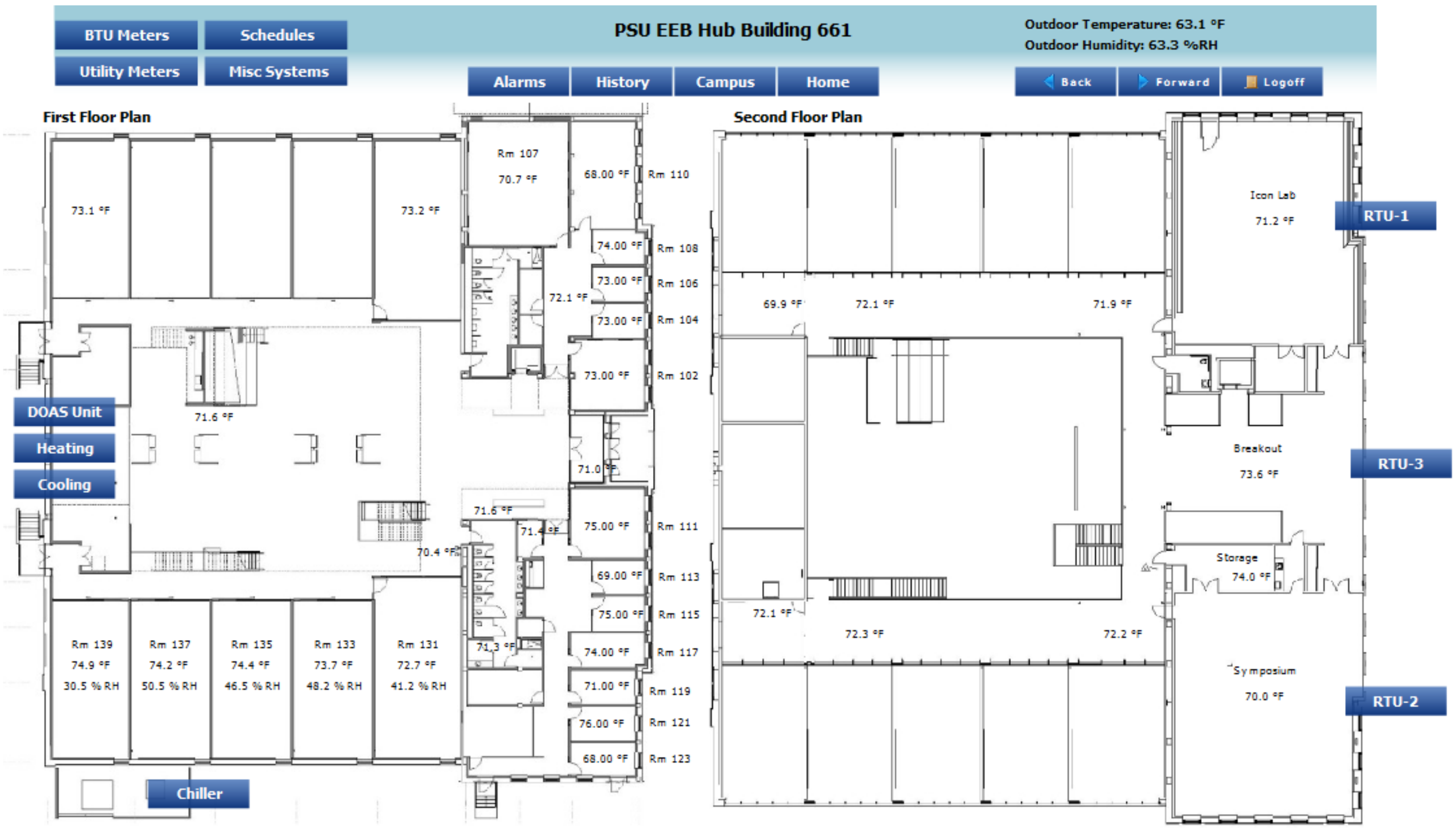
- Resulting trend data ready for ECAM processing

Date/Time	RTU1 - MA Damper_Value	RTU1 - MAT Trend_Value	RTU1 - Occ Mode_Value	RTU1 - SF VFD Speed Trend_Value	RTU1 - Static Press_Value	RTU1 - Static SP_Value	RTU2 - Econ Stpt_Value	RTU2 - Mixed Air Temp_Value	RTU2 - OA Temp_Value	RTU2 - Occ Mode_Value	RTU2 - Return Air Temp_Value	RTU2 - SA Stpt_Value	RTU2 - SF VFD Speed_Value	RTU2 - Static Press_Value	RTU2 - Static SP_Value
9/18/2015 15:15	30	75.56895	1	76	1.529251	1.5	54	76.5	85.75243	NaN	75.3	56	100	1.4	2
9/18/2015 15:30	30	75.98775	1	80	1.474901	1.5	54	76.53333	86.24649	NaN	75.3	56	100	1.4	2
9/18/2015 15:45	30	75.43199	1	75.33333	1.498932	1.5	54	76.43333	86.18881	NaN	75.3	56	100	1.4	2
9/18/2015 16:00	30	75.56521	1	78	1.44311	1.5	54	76.53333	86.60086	NaN	75.3	56	100	1.4	2
9/18/2015 16:15	30	76.01517	1	88.66667	1.452496	1.5	54	76.5	87.03023	NaN	75.3	56	100	1.4	2
9/18/2015 16:30	30	75.96969	1	83.33333	1.470015	1.5	54	76.33333	86.41523	NaN	75.4	56	100	1.4	2
9/18/2015 16:45	30	74.66231	1	74.33333	1.493741	1.5	54	76.23333	82.59105	NaN	75.4	56	100	1.4	2
9/18/2015 17:00	30	74.56131	1	73.33333	1.519225	1.5	54	76.23333	83.02629	NaN	75.4	56	100	1.4	2
9/18/2015 17:15	30	74.6567	1	82.33333	1.456976	1.5	54	76.1	82.66469	NaN	75.36667	56	100	1.4	2
9/18/2015 17:30	30	74.79457	1	82.66667	1.497448	1.5	54	76.1	83.10622	NaN	75.4	56	100	1.4	2
9/18/2015 17:45	30	74.36365	1	77.66667	1.542373	1.5	54	76.1	82.13348	NaN	75.4	56	100	1.4	2
9/18/2015 18:00	30	73.71461	1	72.66667	1.499933	1.5	54	75.96667	81.16543	NaN	75.3	56	100	1.4	2

Getting the BAS Trend Data

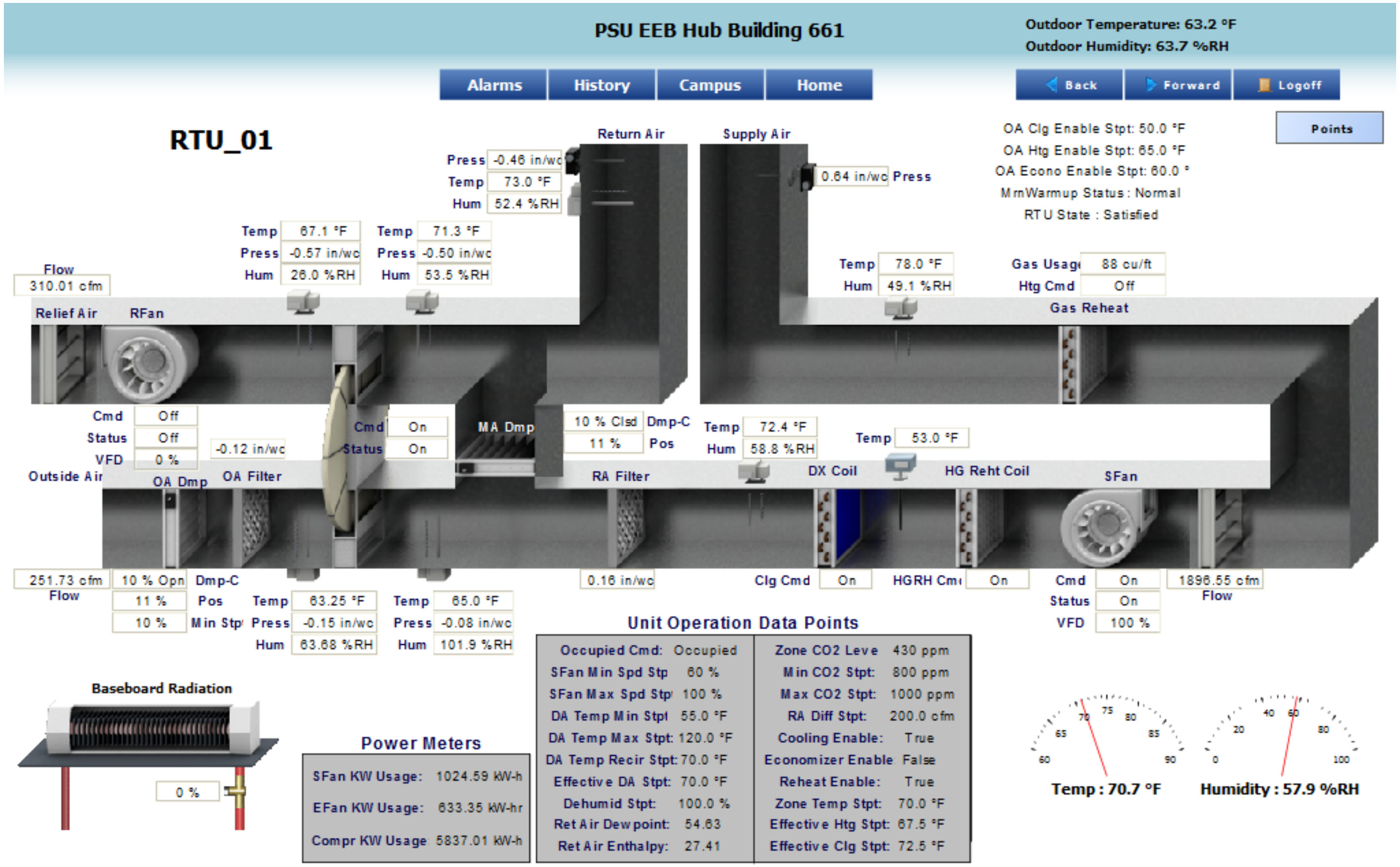
JC Trend Data

- ❑ Get familiar with the interface and available data



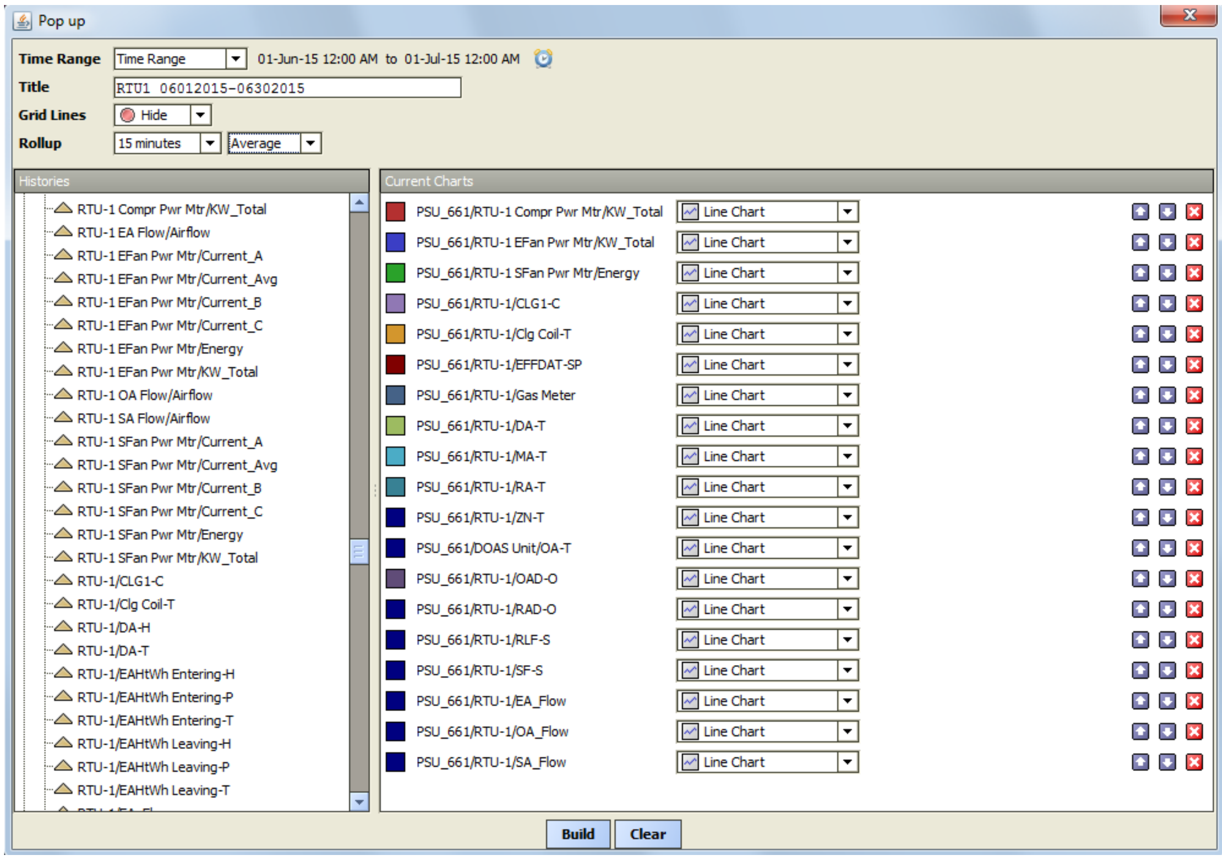
JC Trend Data

- Get familiar with the interface and available data



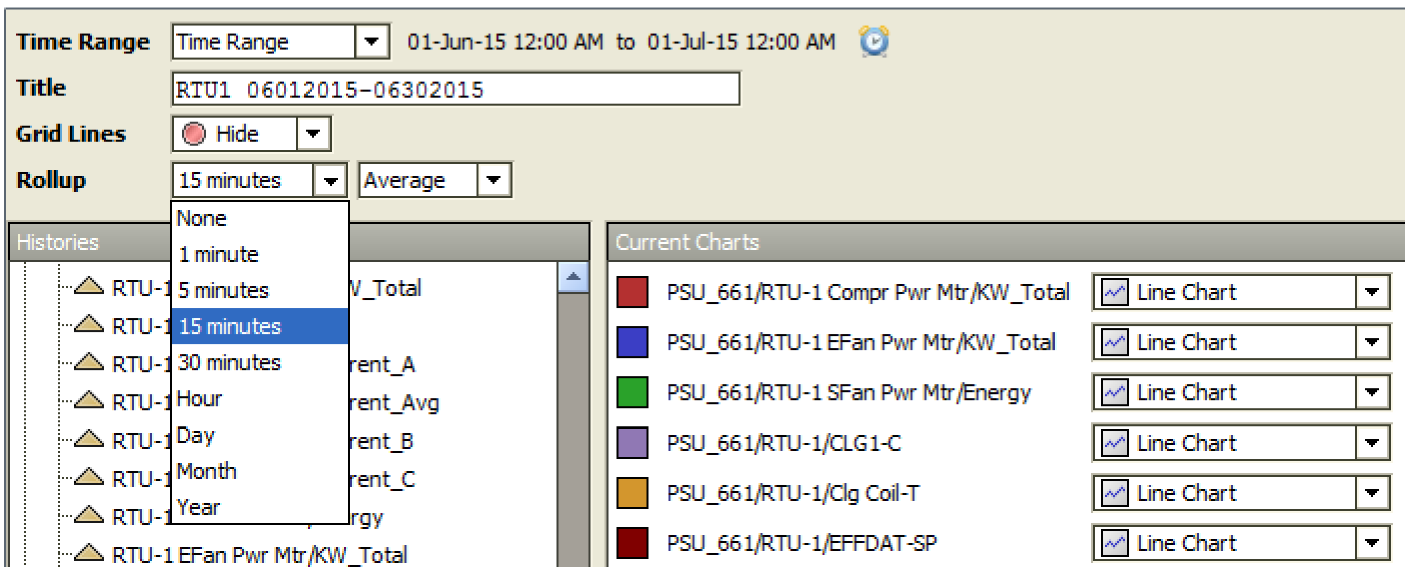
JC Trend Data

- History button on any screen brings up the trend data selector for all points and all equipment



JC Trend Data

- Time Range: enter date range or select fixed periods
- Title: optional, not part of exported data
- Rollup: Very important! Use the longest interval that corresponds to measurement of your data



JC Trend Data

- Importance of correct data rollup

No Rollup

	A	B	C	D	E	F	G	H	I	J
1	?Timestamp	PSU_661/RTU-1 Compr Pwr Mtr/Current_B (A)	PSU_661/RTU-1 OA Flow/Airflow (cfm)	PSU_661/RTU-1 SA Flow/Airflow (cfm)	PSU_661/RTU-1/DA-H (%RH)	PSU_661/RTU-1/DA-T (°F)	PSU_661/RTU-1/EAHtWh Entering-H (%RH)	PSU_661/RTU-1 SFan Pwr Mtr/KW_Total (kW)	PSU_661/RTU-1/MA-T (°F)	PSU_661/RTU-1/OAFILT-DP (in/wc)
2	04-Oct-15 12:00:12 AM EDT	nan	nan	nan	nan	nan	nan	nan	69	nan
3	04-Oct-15 12:00:12 AM EDT	nan	nan	nan	nan	73.8	nan	nan	nan	nan
4	04-Oct-15 12:00:13 AM EDT	nan	nan	nan	49.7	nan	nan	nan	nan	nan
5	04-Oct-15 12:00:18 AM EDT	nan	nan	nan	nan	nan	nan	nan	nan	-0.14
6	04-Oct-15 12:00:19 AM EDT	nan	nan	nan	nan	nan	53.1	nan	nan	nan
7	04-Oct-15 12:00:24 AM EDT	nan	nan	nan	nan	nan	nan	0.01	nan	nan
8	04-Oct-15 12:00:26 AM EDT	0	nan	nan	nan	nan	nan	nan	nan	nan

5-min Rollup

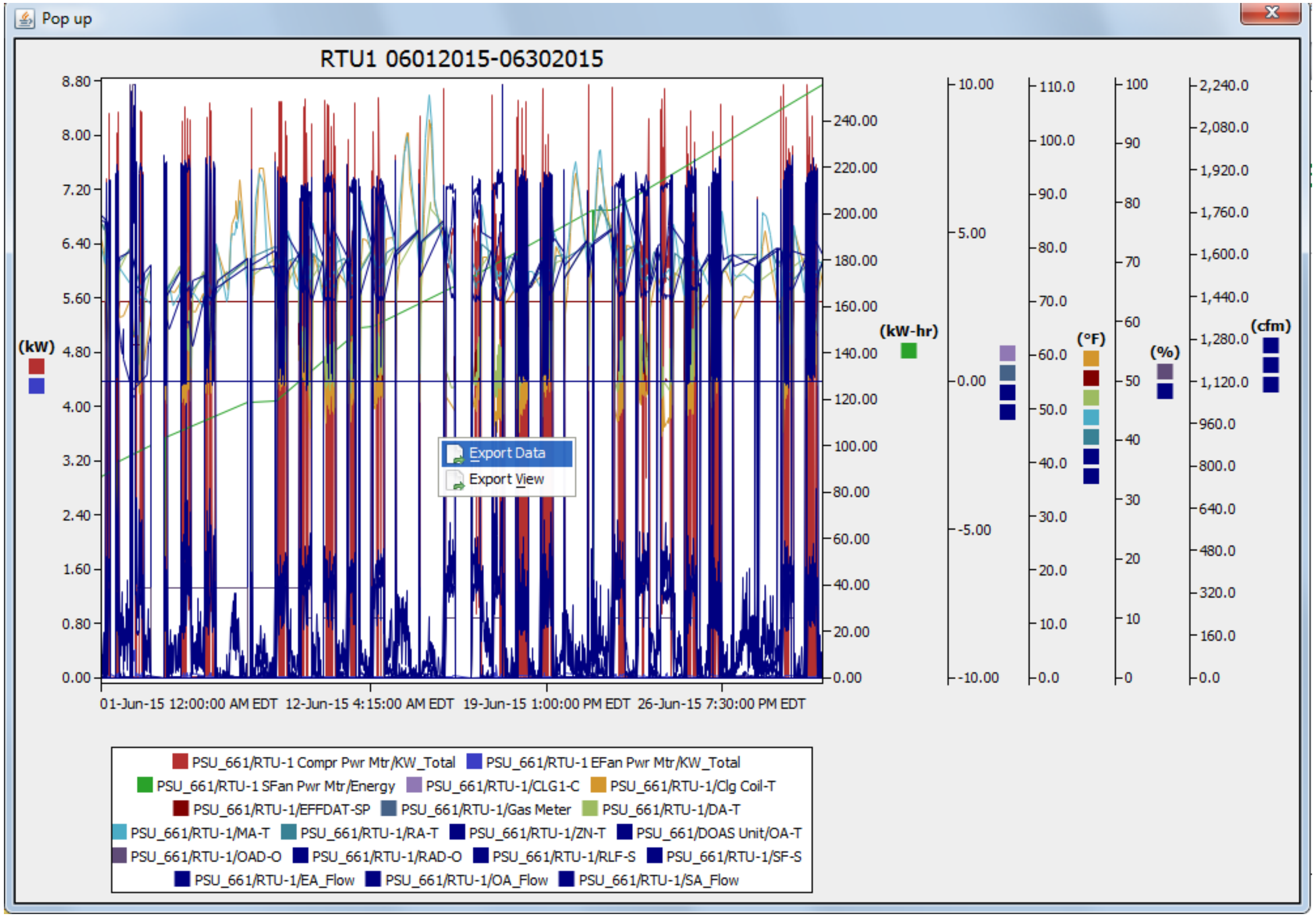
	A	B	C	D	E	F	G	H	I	J
1	?Timestamp	PSU_661/RTU-1 Compr Pwr Mtr/Current_B (A)	PSU_661/RTU-1 OA Flow/Airflow (cfm)	PSU_661/RTU-1 SA Flow/Airflow (cfm)	PSU_661/RTU-1/DA-H (%RH)	PSU_661/RTU-1/DA-T (°F)	PSU_661/RTU-1/EAHtWh Entering-H (%RH)	PSU_661/RTU-1 SFan Pwr Mtr/KW_Total (kW)	PSU_661/RTU-1/MA-T (°F)	PSU_661/RTU-1/OAFILT-DP (in/wc)
2	04-Oct-15 12:00:00 AM EDT	0	134.85	6.94	49.7	73.8	53.1	0.01	69	-0.14
3	04-Oct-15 12:05:00 AM EDT	0	0	0	0	0	0	0	0	0
4	04-Oct-15 12:10:00 AM EDT	0	0	0	0	0	0	0	0	0
5	04-Oct-15 12:15:00 AM EDT	0	108.58	6.44	49.7	73.7	53	0.01	69	-0.14
6	04-Oct-15 12:20:00 AM EDT	0	0	[illegible]	[illegible]	0	0	0	0	0
7	04-Oct-15 12:25:00 AM EDT	0	0	0	0	0	0	0	0	0
8	04-Oct-15 12:30:00 AM EDT	0	232.3	4.51	49.7	73.7	53.2	0.01	69	-0.14

15-min Rollup

	A	B	C	D	E	F	G	H	I	J
1	?Timestamp	PSU_661/RTU-1 Compr Pwr Mtr/Current_B (A)	PSU_661/RTU-1 OA Flow/Airflow (cfm)	PSU_661/RTU-1 SA Flow/Airflow (cfm)	PSU_661/RTU-1/DA-H (%RH)	PSU_661/RTU-1/DA-T (°F)	PSU_661/RTU-1/EAHtWh Entering-H (%RH)	PSU_661/RTU-1 SFan Pwr Mtr/KW_Total (kW)	PSU_661/RTU-1/MA-T (°F)	PSU_661/RTU-1/OAFILT-DP (in/wc)
2	04-Oct-15 12:00:00 AM EDT	0	134.85	6.94	49.7	73.8	53.1	0.01	69	-0.14
3	04-Oct-15 12:15:00 AM EDT	0	108.58	6.44	49.7	73.7	53	0.01	69	-0.14
4	04-Oct-15 12:30:00 AM EDT	0	232.3	[illegible]	[illegible]	73.7	53.2	0.01	69	-0.14
5	04-Oct-15 12:45:00 AM EDT	0	232.36	10.98	49.7	73.7	53.3	0	69	-0.14
6	04-Oct-15 1:00:00 AM EDT	0	251.5	9.32	49.7	73.7	53.2	0	69	-0.14
7	04-Oct-15 1:15:00 AM EDT	0	143.87	3.72	49.7	73.7	53	0.01	69	-0.14

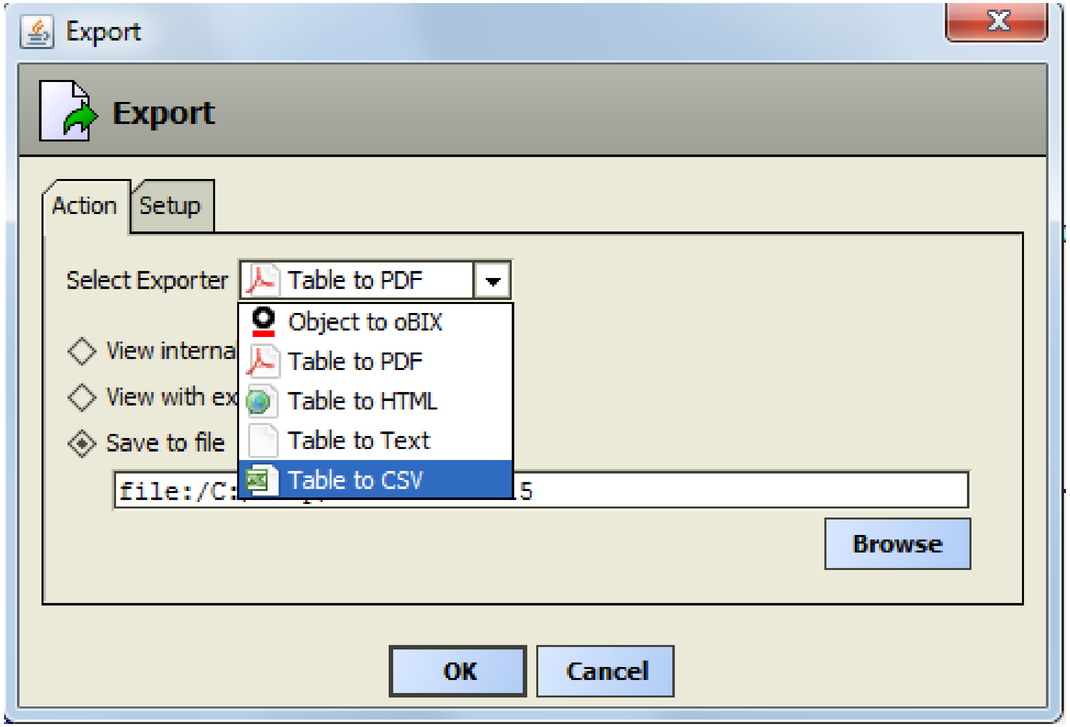
JC Trend Data

- Export the data, right click on the chart



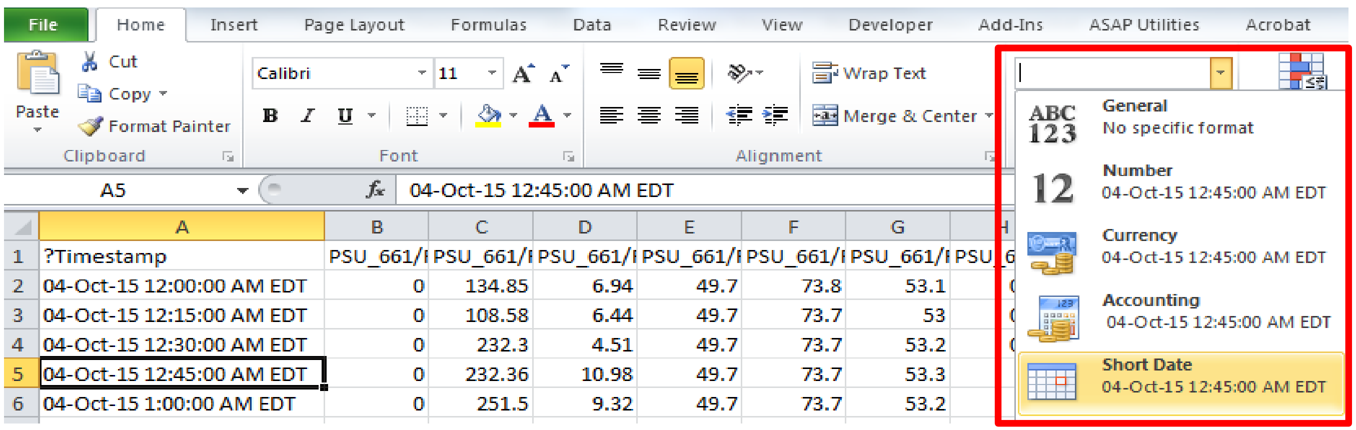
JC Trend Data

- Data export options, choose “Table to CSV”. Browse to select a location and file name

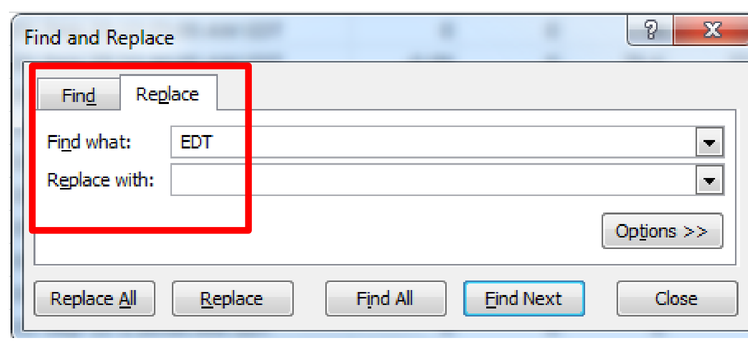


JC Trend Data

- ❑ Verify the date/time stamp is recognized as such by Excel
- ❑ Change “?Timestamp” to “Date Time” when need to use UT3



Solution: delete the “ EDT” part of the text, then Excel will automatically turn this into a date/time stamp. Highlight the column then press Ctrl + h



JC Trend Data

- Resulting trend data ready for ECAM processing

	A	B	C	D	E	F	G	H	I	J
1	Date Time	PSU_661/I	PSU_661/I	PSU_661/I	PSU_661/I	PSU_661/I	PSU_661/I	PSU_661/I	PSU_661/I	PSU_661/
2	10/4/2015 0:00	0	134.85	6.94	49.7	73.8	53.1	0.01	69	-0.14
3	10/4/2015 0:15	0	108.58	6.44	49.7	73.7	53	0.01	69	-0.14
4	10/4/2015 0:30	0	232.3	4.51	49.7	73.7	53.2	0.01	69	-0.14
5	10/4/2015 0:45	0	232.36	10.98	49.7	73.7	53.3	0	69	-0.14
6	10/4/2015 1:00	0	251.5	9.32	49.7	73.7	53.2	0	69	-0.14
7	10/4/2015 1:15	0	143.87	3.72	49.7	73.7	53	0.01	69	-0.14
8	10/4/2015 1:30	0	323.11	4.37	49.7	73.7	53.1	0.01	69	-0.14
9	10/4/2015 1:45	0	108.88	6.38	49.6	73.7	53.2	0.01	69	-0.14
10	10/4/2015 2:00	0	181.44	8.62	49.6	73.7	53.1	0.01	69	-0.14
11	10/4/2015 2:15	0	351.54	8.34	49.6	73.7	53	0	69	-0.14
12	10/4/2015 2:30	0	272.64	5.4	49.7	73.7	53	0	69	-0.14
13	10/4/2015 2:45	0	248.47	5.63	49.7	73.7	53.1	0	69	-0.14
14	10/4/2015 3:00	0	351.39	6.61	49.7	73.7	53.3	0	69	-0.14

Thank you

- Next up: Using ECAM to Process Data

Learning Activity #2: Monitoring Plan

Participant Directions

Review the monitoring plan information. Look at the points assigned to your group that are proposed for measurement. Review the BRT measure categories below and determine which of the BRT measure categories would be related to those points. Discuss as a group and be prepared to present your answers to the class. Note, more than one category may be appropriate for each point.

BRT Measure Categories:

1. Occupancy Scheduling
2. AHU Discharge Air Temperature Control
3. AHU Discharge Air Static Pressure Control
4. AHU Heating and Cooling Coils
5. AHU Outdoor Air Operation
6. AHU Economizer Operation
7. Zone Conditioning
8. Heating Plant
9. Cooling Plant

VAV1-1		
Point Name	**Measurement Description**	**BRT Measure Category**
T1-1	**Zone air temperature**	
VAV% 1-1	**VAV box damper position**	
Reheat% 1-1	**VAV box reheat valve position**	
Mode 1-1	**Zone occupancy mode**	

AHU-1		
Point Name	**Measurement Description**	**BRT Measure Category**
OAT1	**Outdoor air temperature**	
MAT1	**Mixed air temperature**	
RAT1	**Return air temperature**	
DAT1	**Discharge air temperature**	
DATSP1	**Discharge air-temperature**	
PDIST1	**Discharge Static Press**	
OADamper1	**Outdoor air damper position**	
Fan1	**Fan status**	
Fan Speed1	**Fan speed**	
CWV%1	**Chilled water valve position**	
HWV%1	**Hot water valve position**	
MODE1	**Occupancy mode**	

Learning Activity #2: Monitoring Plan

Instructor Directions:

This activity is expected to take 30 minutes. Break the class into groups of 3-4 people. Assign 3-4 points per group to review.

Participant Directions

Review the monitoring plan information. Look at the points assigned to your group that are proposed for measurement. Review the BRT measure categories below and determine which of the BRT measure categories would be related to those points. Discuss as a group and be prepared to present your answers to the class. Note, more than one category may be appropriate for each point.

BRT Measure Categories:

1. Occupancy Scheduling
2. AHU Discharge Air Temperature Control
3. AHU Discharge Air Static Pressure Control
4. AHU Heating and Cooling Coils
5. AHU Outdoor Air Operation
6. AHU Economizer Operation
7. Zone Conditioning
8. Heating Plant Optimization
9. Cooling Plant Optimization

VAV1-1		
Point Name	**Measurement Description**	**BRT Measure Category**
T1-1	Zone air temperature	1, 7
VAV% 1-1	VAV box damper position	3, 7
Reheat% 1-1	VAV box reheat valve	4, 7
Mode 1-1	Zone occupancy mode	1, 5, 7

AHU-1		
Point Name	**Measurement Description**	**BRT Measure Category**
OAT1	Outdoor air temperature	1, 2, 4, 5, 6, 7, 8, 9
MAT1	Mixed air temperature	5, 6
RAT1	Return air temperature	5, 6
DAT1	Discharge air temperature	1, 2, 6
DATSP1	Discharge air-temperature set point	2, 6
PDIST1	Discharge Static Pressure	3
PDISTSP1	Discharge Static Pressure set point	3
OADamper1	Outdoor air damper position	1, 5, 6
Fan1	Fan status	1
Fan Speed1	Fan speed	1, 5

CWV%1	**Chilled water valve position**	**2, 4, 6, 9**
HWV%1	**Hot water valve position**	**2, 4, 8**
MODE1	**Occupancy mode**	**1, 5**

Instructor Notes: The answers above are not exhaustive. Several additional points COULD be used for investigating each category. For example, VAV reheat valve position could be used for heating plant optimization; a low number of VAV boxes calling for heat could be used to justify lowering the heating water loop temperature (Temperature Reset).

It is more important to get the class to justify any answer given and engage in class participation.

Using ECAM to Process Data

Module 4F

Objectives

- Learn how to use ECAM to chart your BAS trend data and diagnose re-tuning opportunities through interactive participation

Re-tuning Chart Strategies

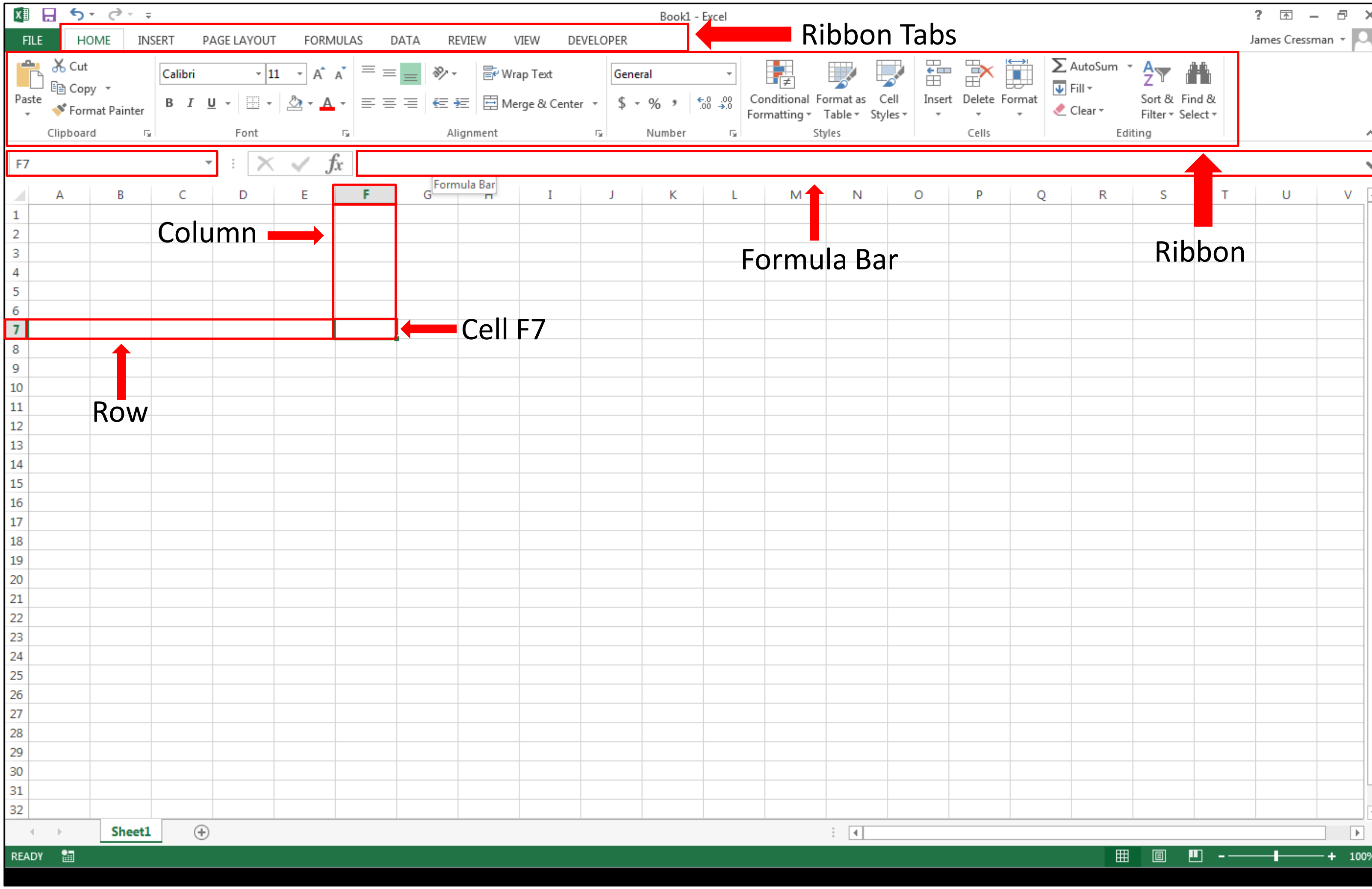
Energy Charting and Metrics (ECAM)

Objectives

- Understand the capabilities of ECAM
- Understand the ECAM requirements for data format, data mapping, and setting up occupancy schedules
- Successfully process the example Air_Handlers dataset
- Successfully map the Air_Handlers dataset in ECAM
- Successfully set up occupancy schedules for the Air_Handlers dataset

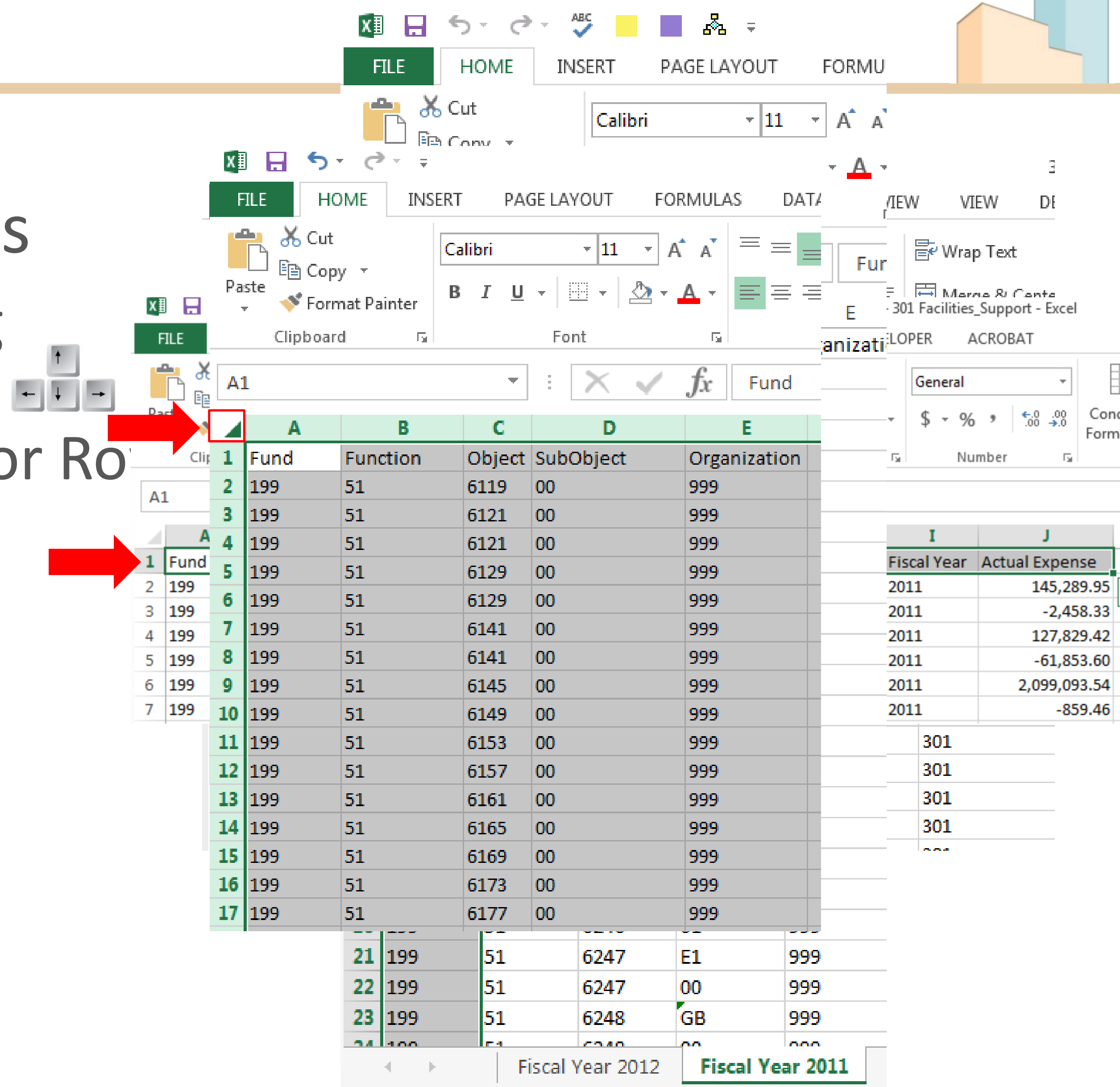
Excel Basics

Layout



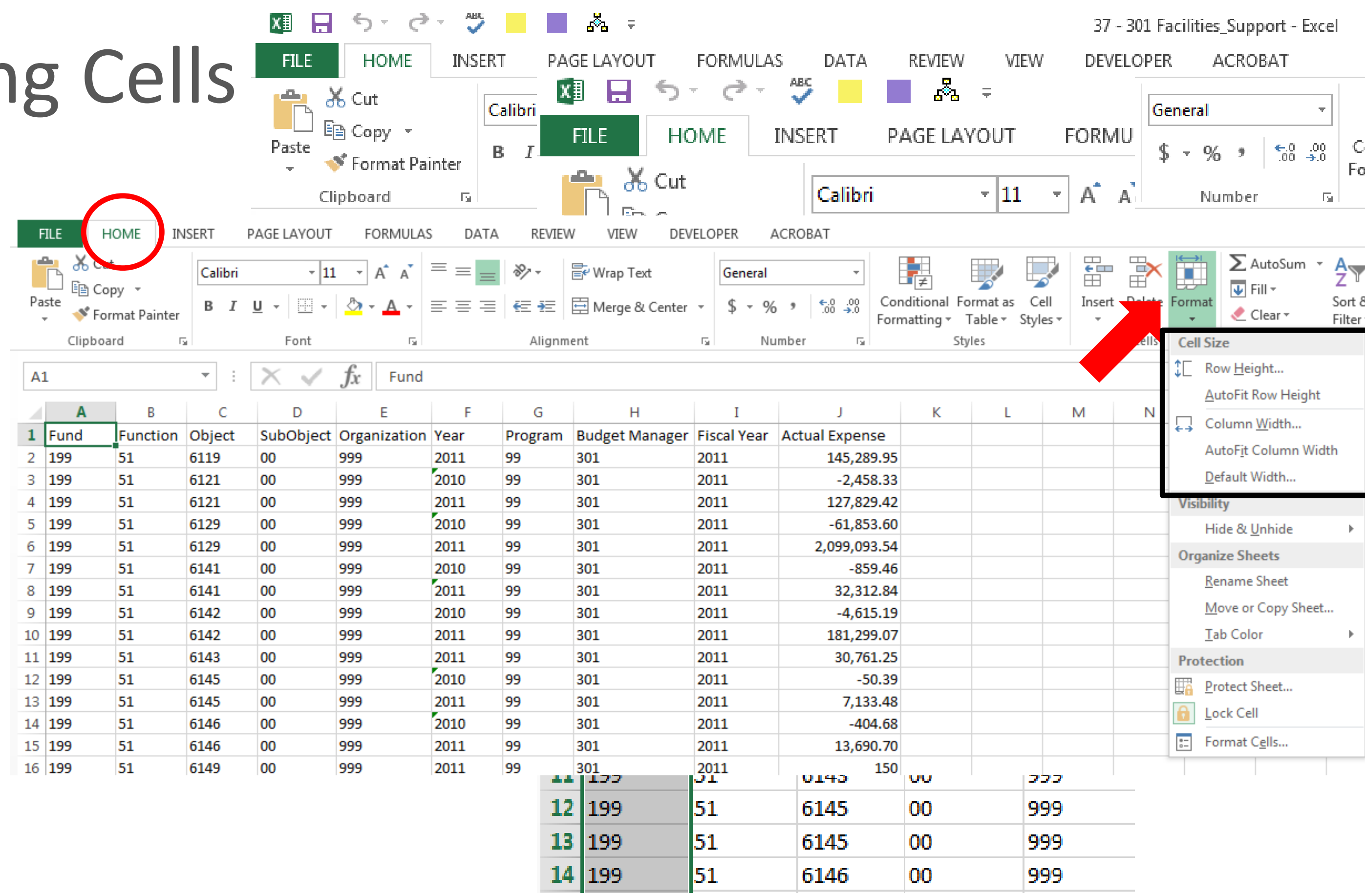
Excel Basics

- Selecting Cells
    1. Click & Drag
    2. CRTL+Shift+
    3. By Column or Ro
    4. All Cells



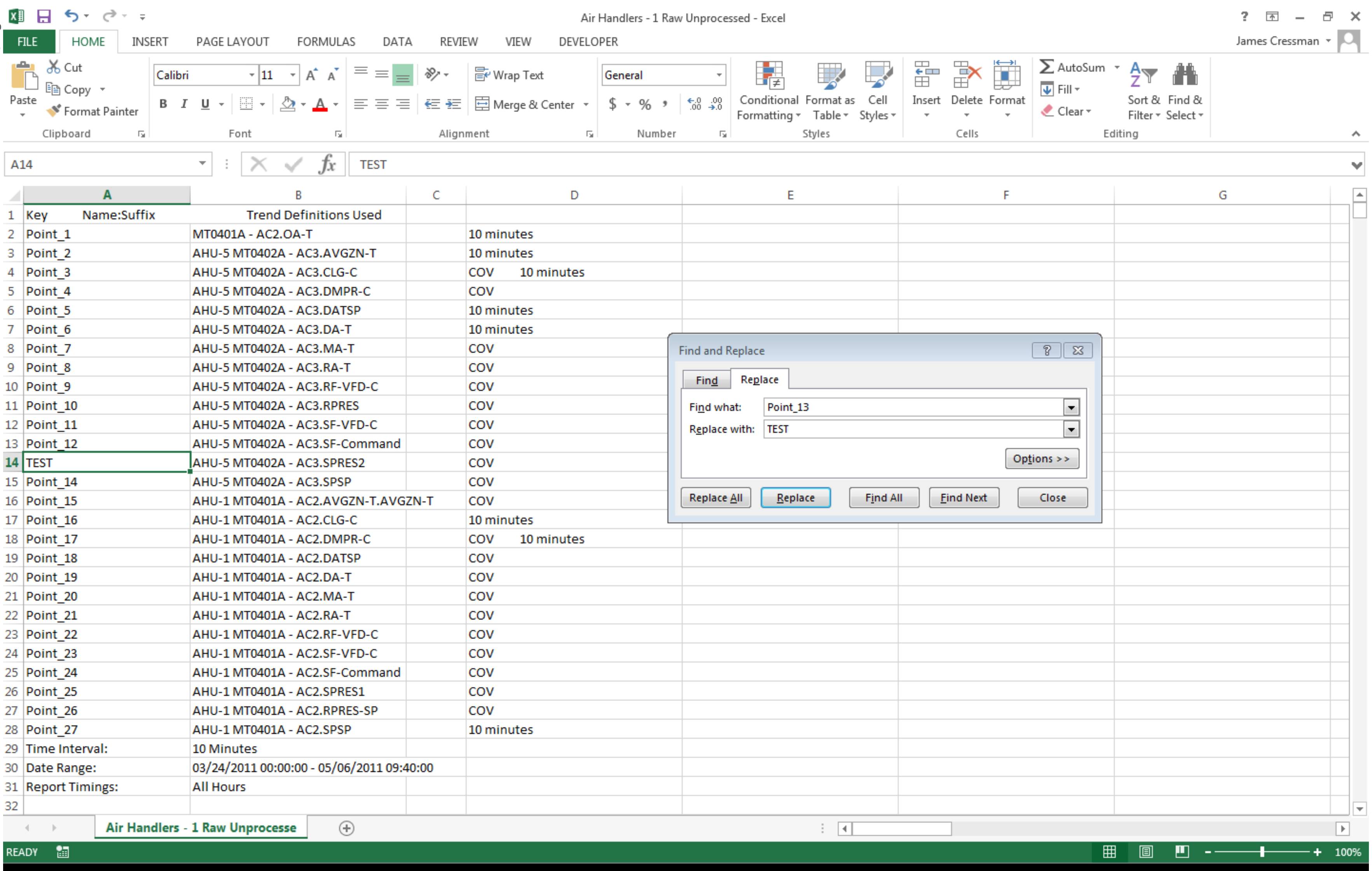
Excel Basics

- Formatting Cells
  1. Resize



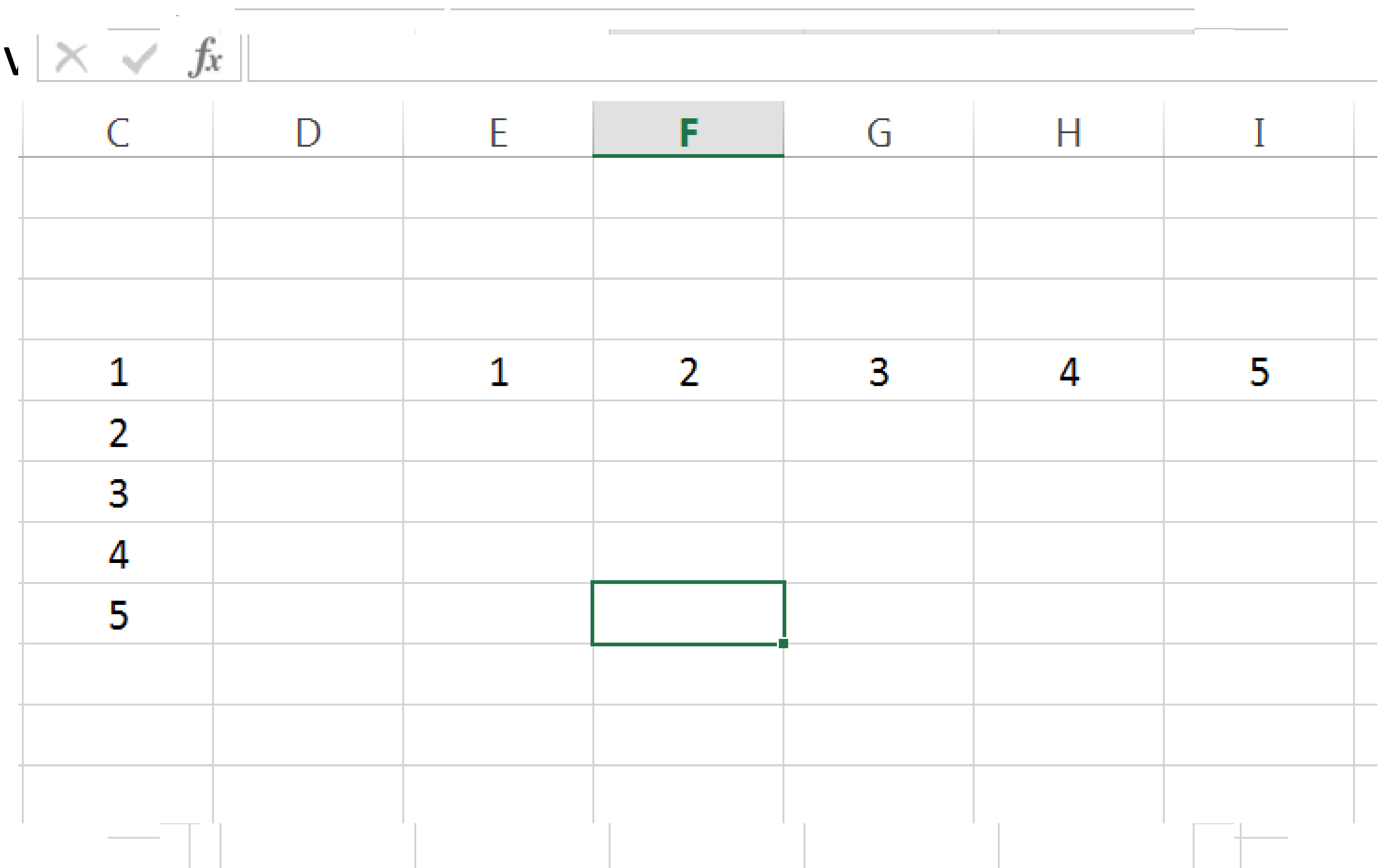
Excel Basics

F



Transpose

Conv



Capabilities

- Interval Meter Data Diagnostics
  - Energy load profiling, usage and demand metrics and statistics
- M&V (pre/post energy savings)
  - Powerful single-variable regression analysis
  - IPMVP and ASHRAE Guideline 14 compliant
  - Analyze interval data *or* monthly data
- PNNL Re-tuning Charts
  - AHU Charts
  - VAV Charts
  - Central Plant Charts

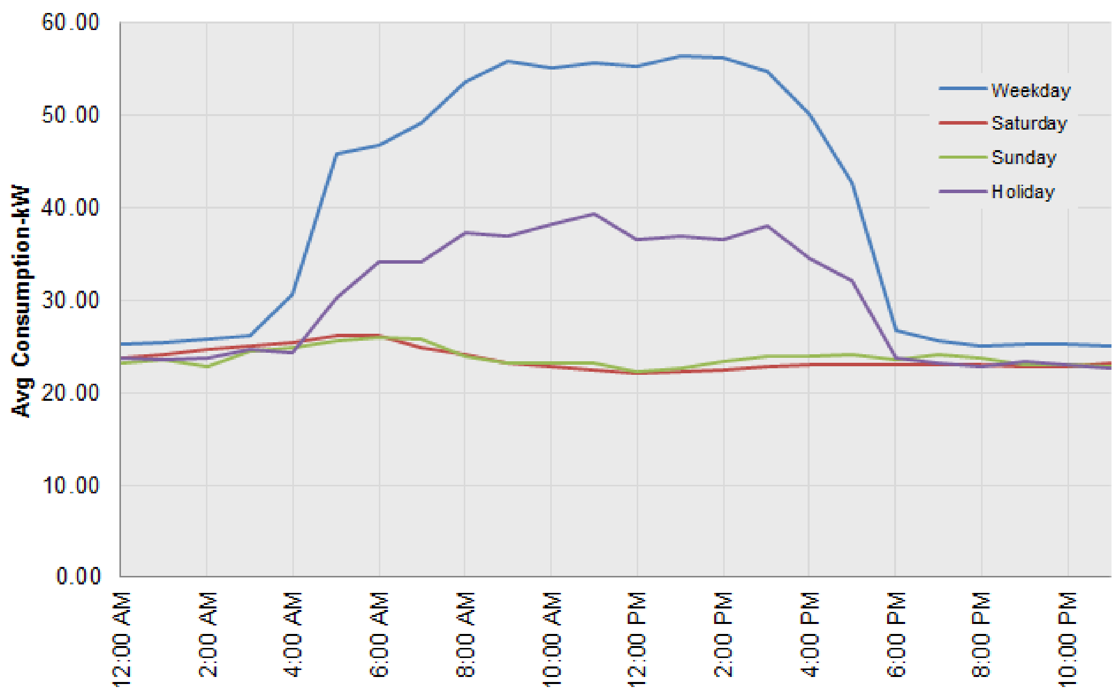
Additional Features

- Occupancy scheduling and day type (e.g. weekdays, Saturdays) are part of charts
- Filter data in the charts (analyze in greater depth) by:
  - Day-type
  - Occupancy schedule
  - Month, year, day
  - Pre- vs post-retrofit (energy projects)

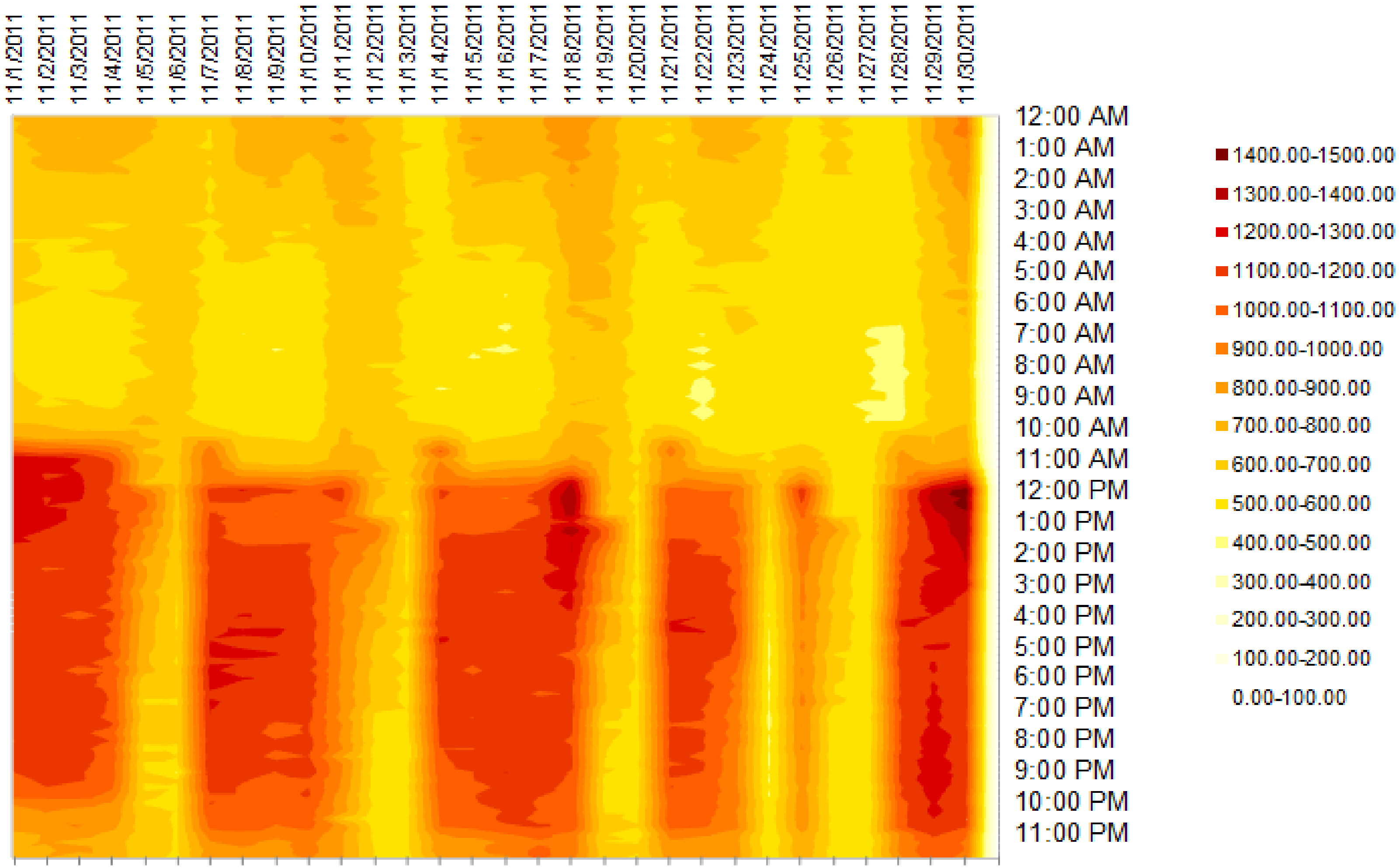
Meter Profiling

- Profile interval or monthly energy data
- Profile by month, day-type, occ vs un-occ, etc

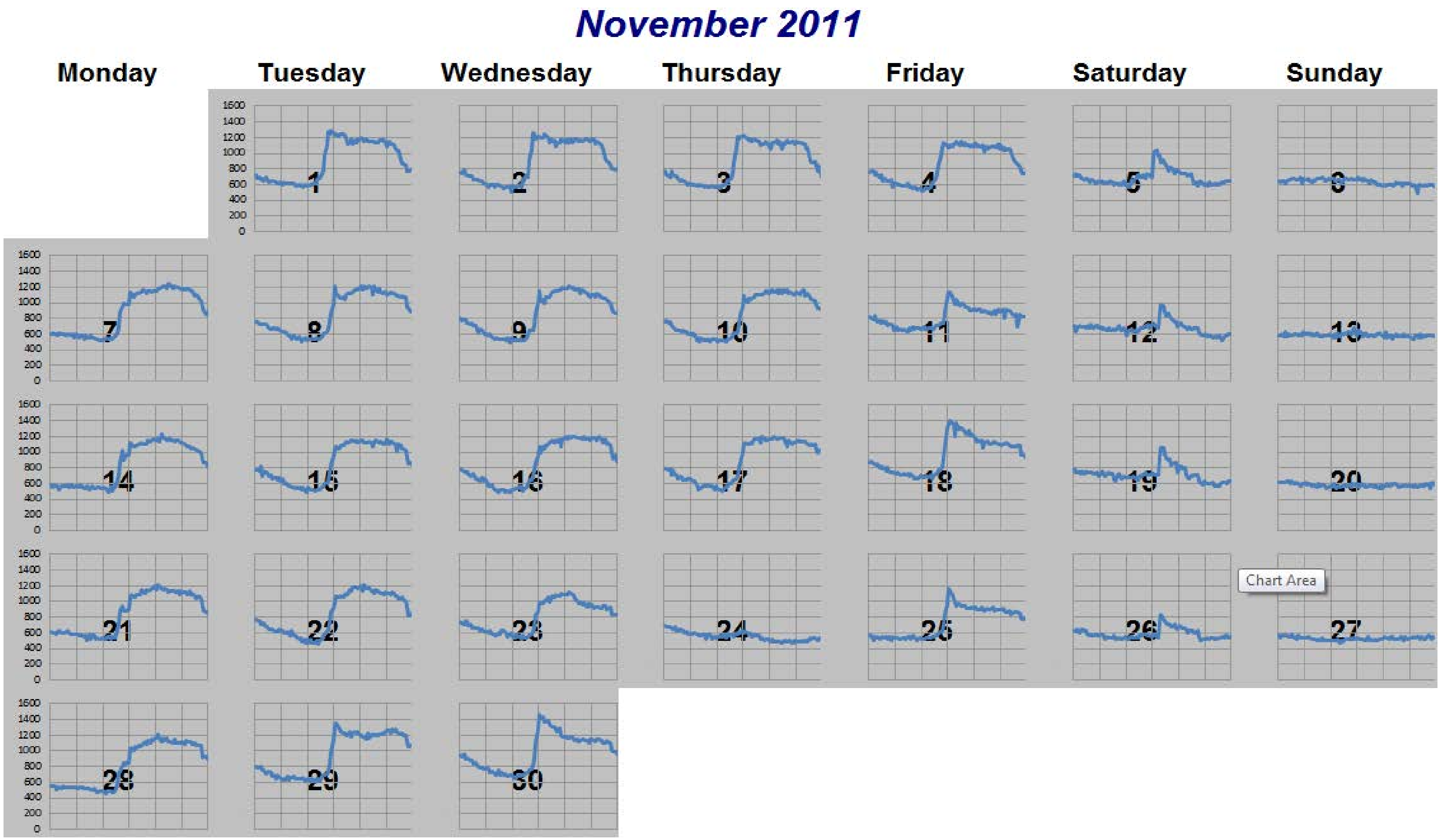
DateRng	(All)
Date	(All)
Year	(All)
Month	(All)
MonthYr	Apr 2009
Hour	(All)
Occupancy	(All)
Weekday	(All)
Day	(All)
Holiday	(All)
5degBin	(All)
1degBin	(All)
TempRng	(All)



Demand Profiling:
Heat Map



Demand Profiling:
Load Profile Calendar

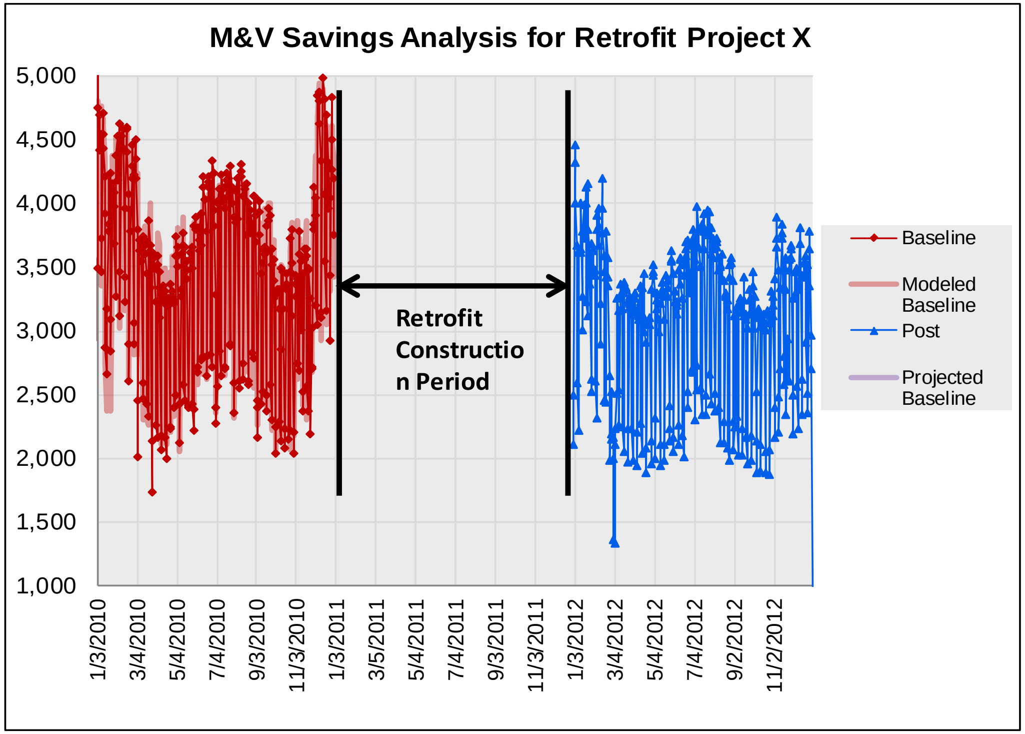


Savings M&V Tool

- IPMVP and ASHRAE G14 Compliant
- Monthly or interval data

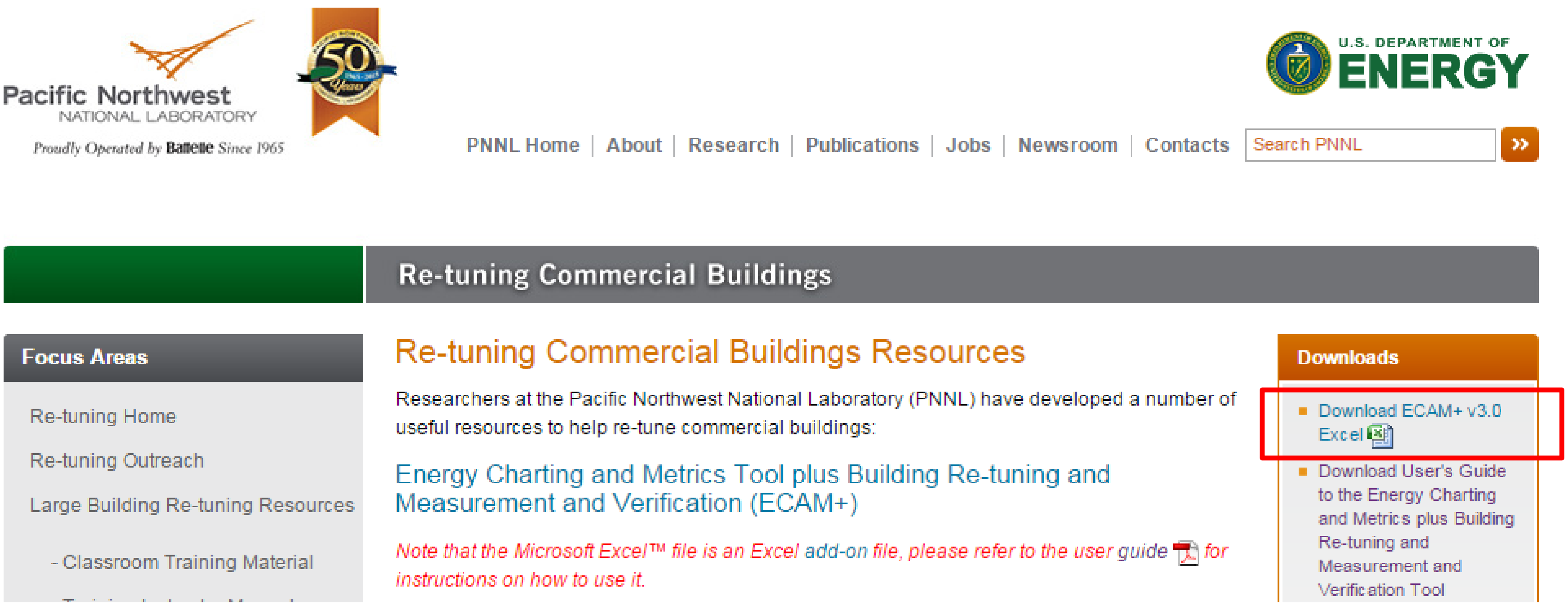
Project Energy Savings

29,241,672	Projected Baseline Energy
	(If the retrofit had not been done scenario)
26,891,038	Actual Measured Energy for this period
2,350,634 ±272,073	**Energy Savings and Uncertainty @ 90% Confidence Level**
8.0% ±0.9%	**Energy Savings and Uncertainty @ 90% Confidence Level**



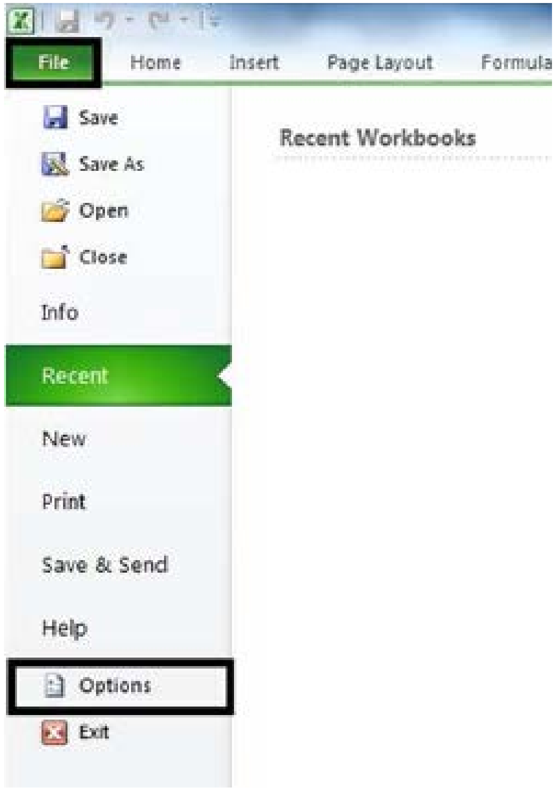
ECAM Software Download

buildingretuning.pnnl.gov/ecam.stm



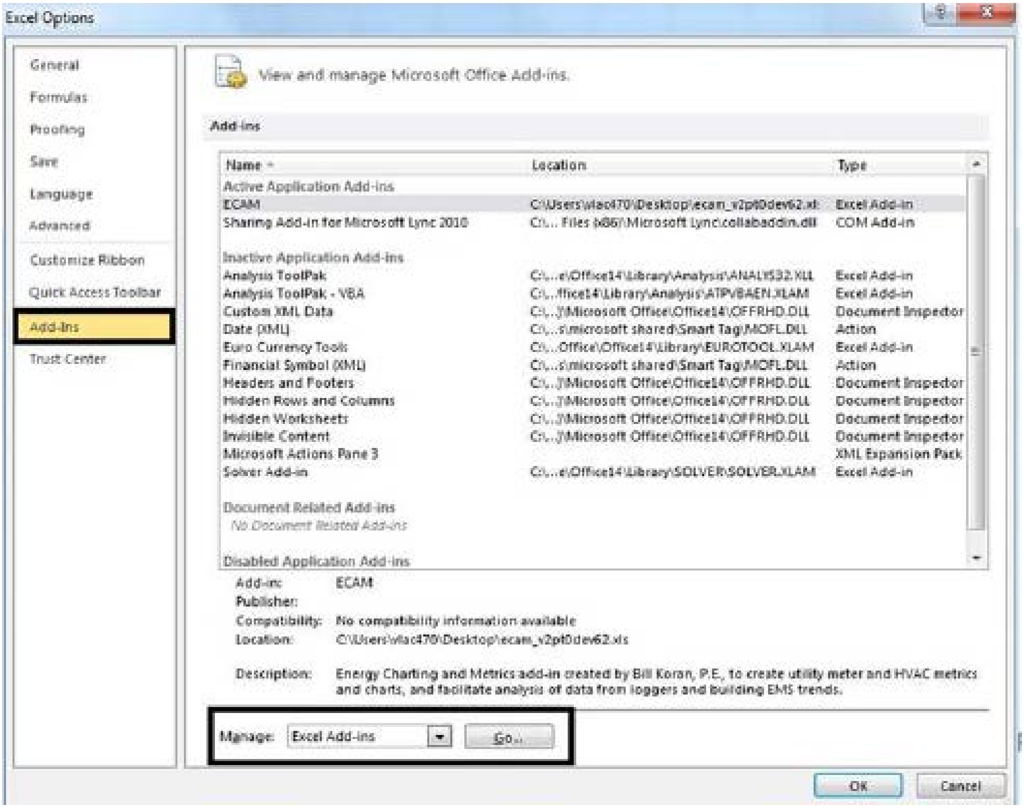
ECAM Software Installing

- The ECAM xla file can be installed as an Add-In so it is available any time you open Excel
- Click “File” then click “Options” then click on “Add-Ins”



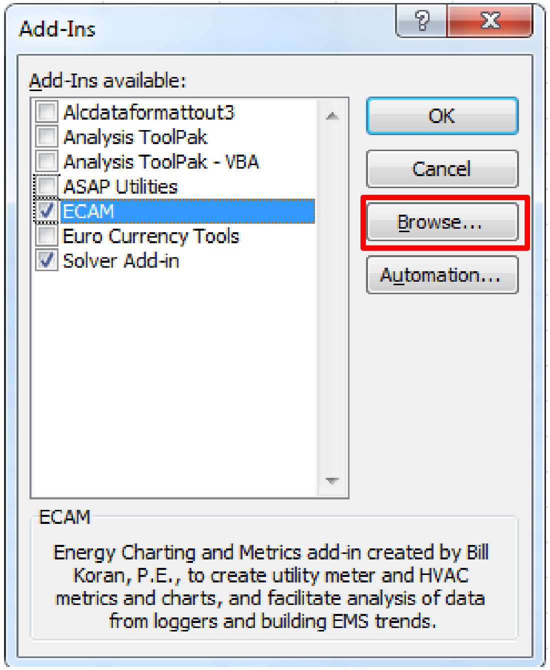
ECAM Software Installing

- On next screen, click "Excel Add-Ins" is visible in the drop-down, then click the adjacent "Go…" button.



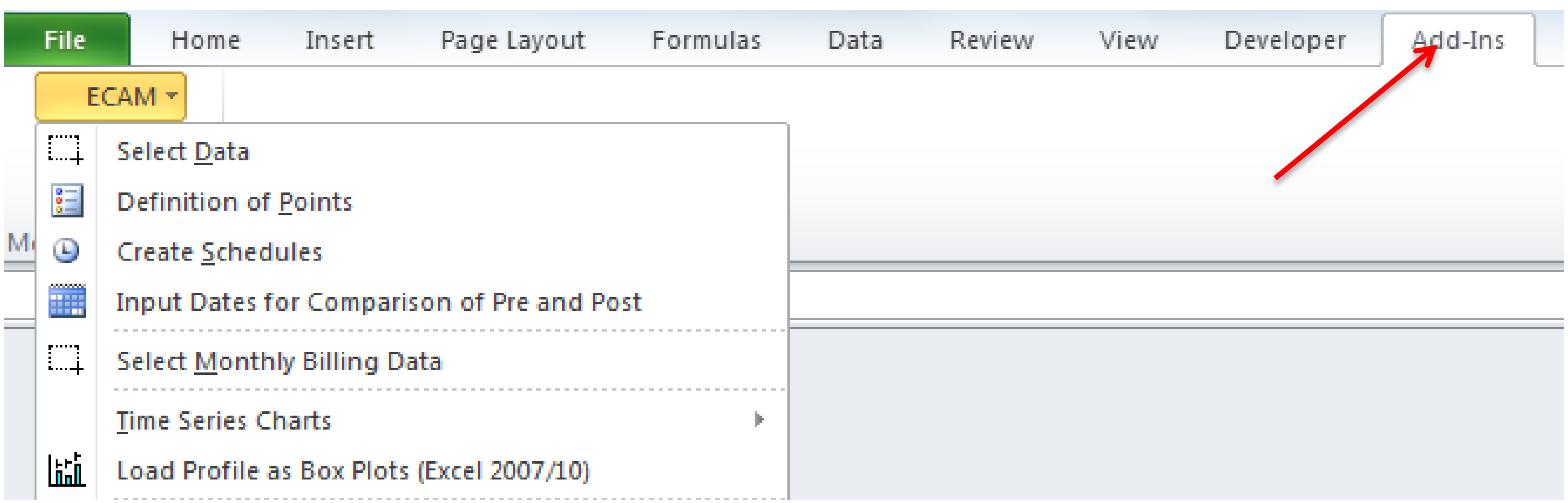
ECAM Software Installing

- Browse to where the ECAM file was saved, select it, then click Open
- ECAM will show up checked in Add-Ins available screen
- Also, check the Solver Add-In on this screen if you plan to use the M&V features of ECAM.



ECAM Software
Use in this Training

- For this training, we will simply open the ECAM xla file (double click on the file)
- Click on Add-Ins tab to show the ECAM menu



ECAM
BAS Trend Data Mapping

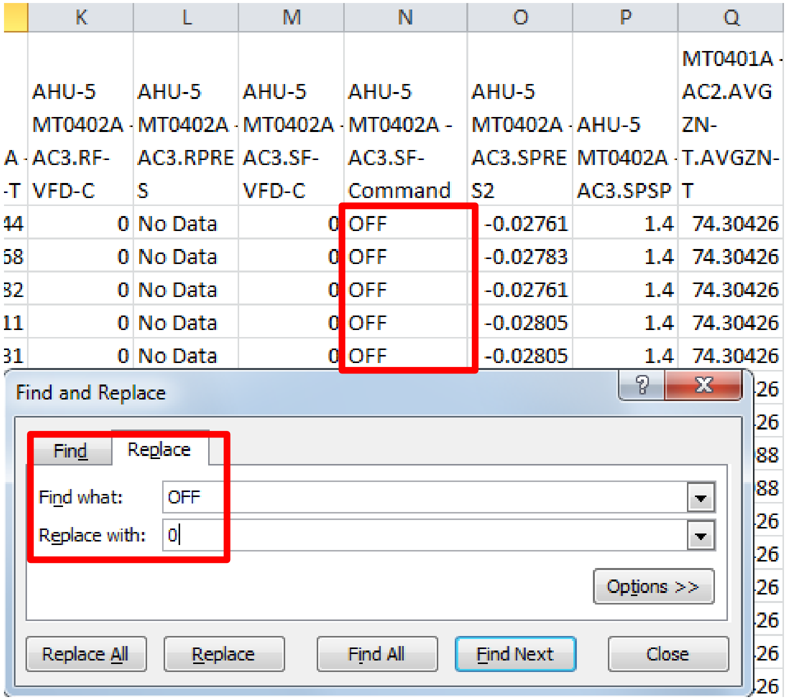
ECAM Data Formatting

1) ECAM needs all trend data to be in one spreadsheet and on the same data/time stamp
   - This is why we use UT3 to combine multiple data trend files and synchronize time stamps
2) Make sure the trend data column headers have names that you understand (e.g. DAT vs Discharge Air Temp)
3) Delete any columns of data that do not contain data (e.g. “No Data”, “NaN”)
4) First column should be the date/time stamp, or first column with date and second column with time.

ECAM Data Formatting

6) Convert any equipment status using ON/OFF to numeric 1/0. Likewise, convert occupied/unoccupied to numeric 1/0.

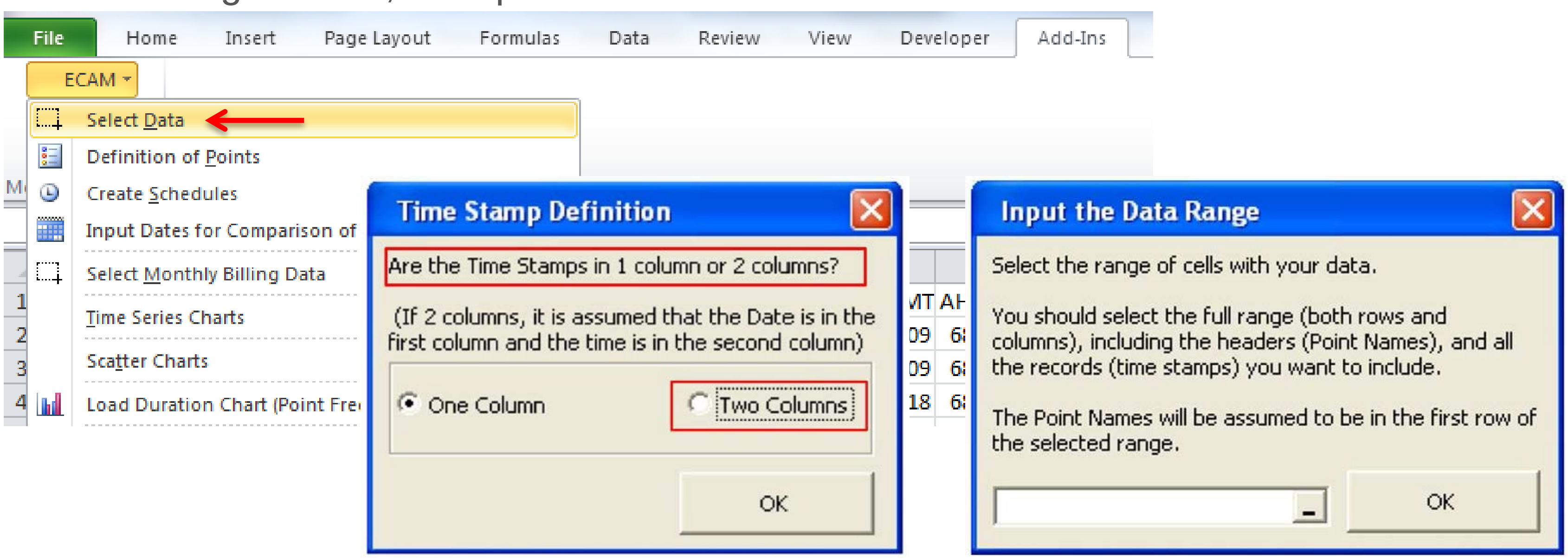
- Solution: press Ctrl + h, replace “ON” with “1” and “OFF” with “0”



Data Input

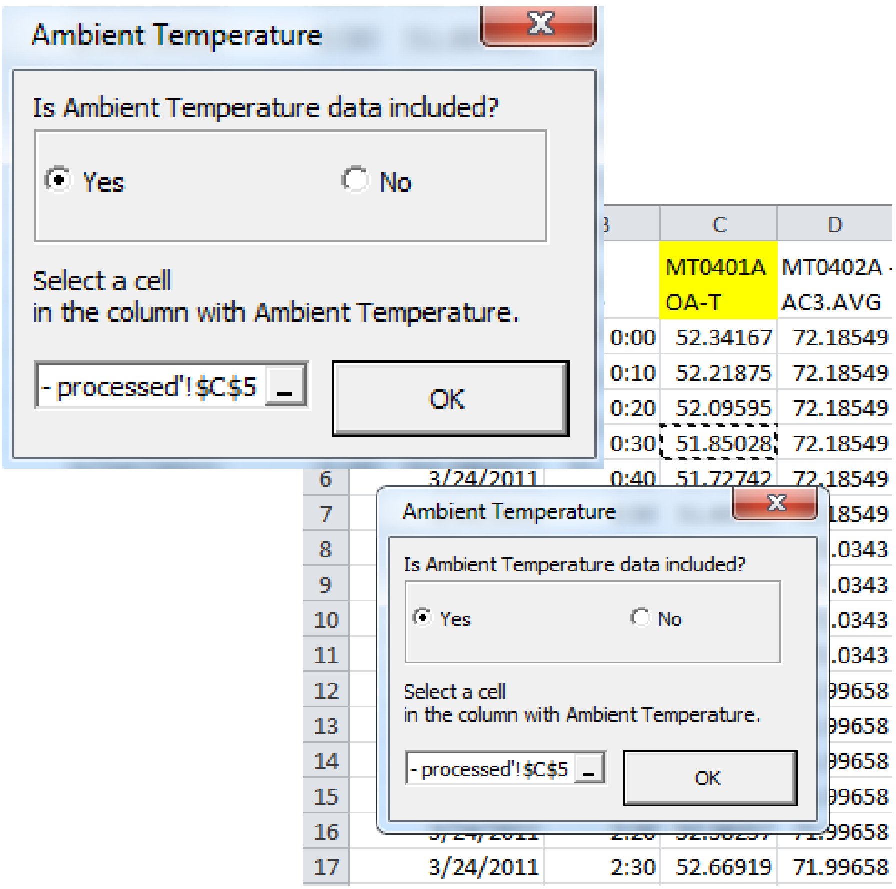
1) With the trend data file open in Excel, go to Add-Ins, then ECAM, then Select Data

- Select if date/time stamps are in one or two columns
- Tip for selecting data: Select cell A1, then hold down Crtl + Shift, then press Right Arrow, then press Down Arrow



Data Input

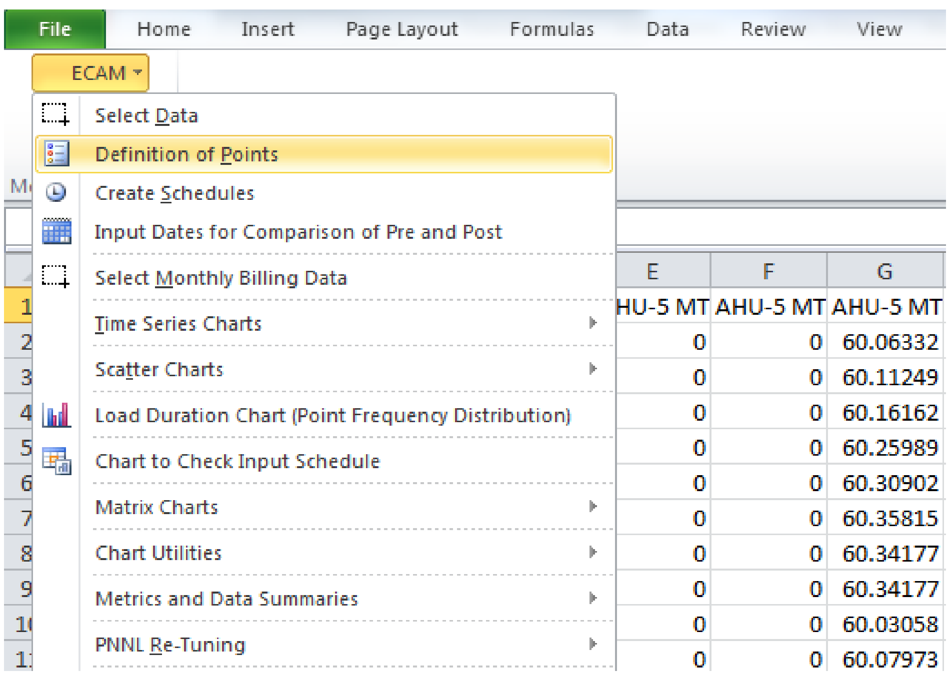
2) Select if outdoor temperature data is included

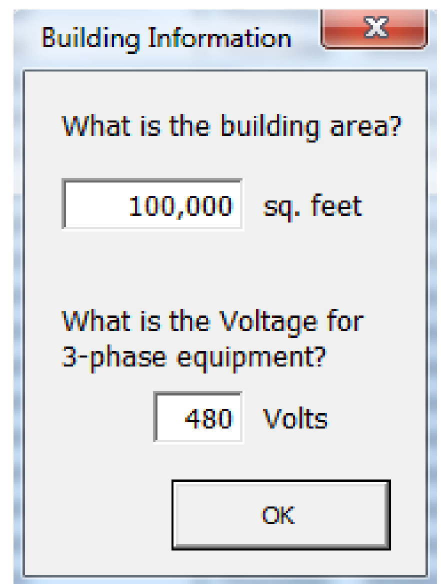


DateTime	Year	Month	MonthYr	Day	Hour	Date	Time
3/24/11 12:00 AM	2011	March	Mar 2011	24	1	3/24/2011	12:00 AM
3/24/11 12:10 AM	2011	March	Mar 2011	24	1	3/24/2011	12:10 AM
3/24/11 12:20 AM	2011	March	Mar 2011	24	1	3/24/2011	12:20 AM
3/24/11 12:30 AM	2011	March	Mar 2011	24	1	3/24/2011	12:30 AM
3/24/11 12:40 AM	2011	March	Mar 2011	24	1	3/24/2011	12:40 AM
3/24/11 12:50 AM	2011	March	Mar 2011	24	1	3/24/2011	12:50 AM
3/24/11 1:00 AM	2011	March	Mar 2011	24	2	3/24/2011	1:00 AM
3/24/11 1:10 AM	2011	March	Mar 2011	24	2	3/24/2011	1:10 AM
3/24/11 1:20 AM	2011	March	Mar 2011	24	2	3/24/2011	1:20 AM
3/24/11 1:30 AM	2011	March	Mar 2011	24	2	3/24/2011	1:30 AM
3/24/11 1:40 AM	2011	March	Mar 2011	24	2	3/24/2011	1:40 AM
3/24/11 1:50 AM	2011	March	Mar 2011	24	2	3/24/2011	1:50 AM
3/24/11 2:00 AM	2011	March	Mar 2011	24	3	3/24/2011	2:00 AM
3/24/11 2:10 AM	2011	March	Mar 2011	24	3	3/24/2011	2:10 AM
3/24/11 2:20 AM	2011	March	Mar 2011	24	3	3/24/2011	2:20 AM
3/24/11 2:30 AM	2011	March	Mar 2011	24	3	3/24/2011	2:30 AM
3/24/11 2:40 AM	2011	March	Mar 2011	24	3	3/24/2011	2:40 AM
3/24/11 2:50 AM	2011	March	Mar 2011	24	3	3/24/2011	2:50 AM
3/24/11 3:00 AM	2011	March	Mar 2011	24	4	3/24/2011	3:00 AM
3/24/11 3:10 AM	2011	March	Mar 2011	24	4	3/24/2011	3:10 AM
3/24/11 3:20 AM	2011	March	Mar 2011	24	4	3/24/2011	3:20 AM
3/24/11 3:30 AM	2011	March	Mar 2011	24	4	3/24/2011	3:30 AM
3/24/11 3:40 AM	2011	March	Mar 2011	24	4	3/24/2011	3:40 AM
3/24/11 3:50 AM	2011	March	Mar 2011	24	4	3/24/2011	3:50 AM

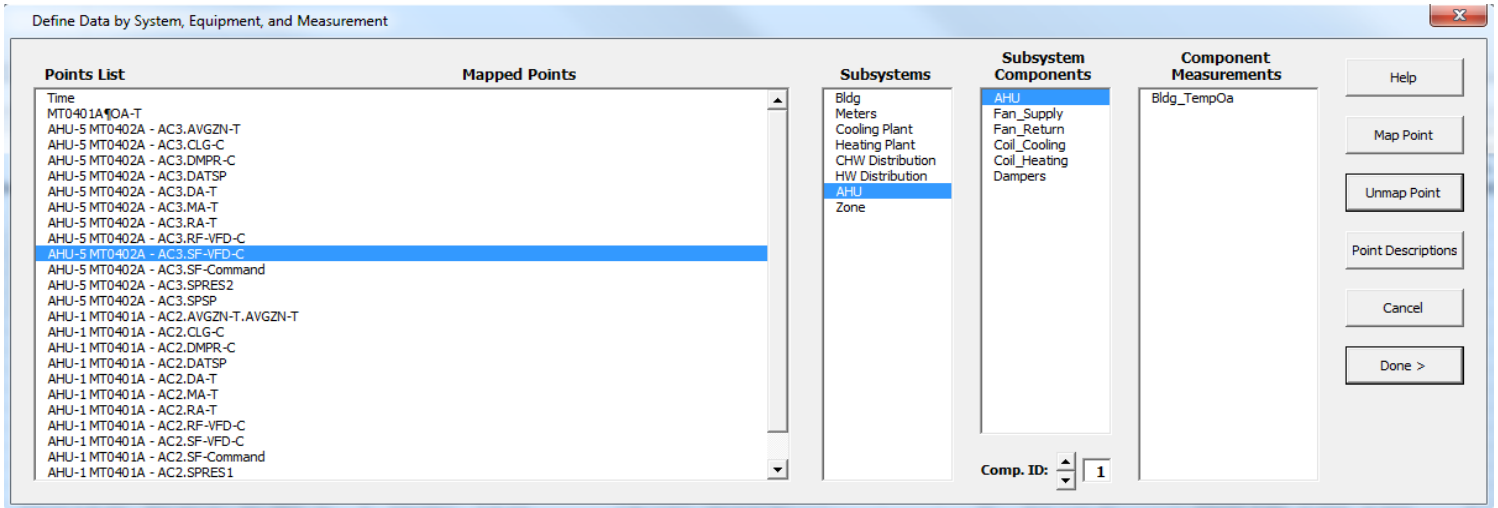
Definition of Points

3) Select Definition of Points to map the BAS trend data to points that ECAM uses for the charting.
   - For re-tuning charts, ECAM does not use Building Information data, the defaults are fine.





Definition of Points



Points List: Consists of the header names in the "data" sheet

Subsystems: A list for different systems inside of the building for the user to cycle between when defining specific points.

Subsystem Components: The individual components for the subsystem chosen.

Component Measurements: Specific measurement (with units) for the subsystem and component chosen

Component ID: ECAM designation allowing for multiple components to be mapped, and generate charts for different components (i.e., air-handling unit 1 and air-handling unit 2). The user should map all components for a specific system with the proper Comp. ID.

Mapped Points: New name given by ECAM once the point has been mapped.

Data Input and Definition of Points

Live Class Participation!

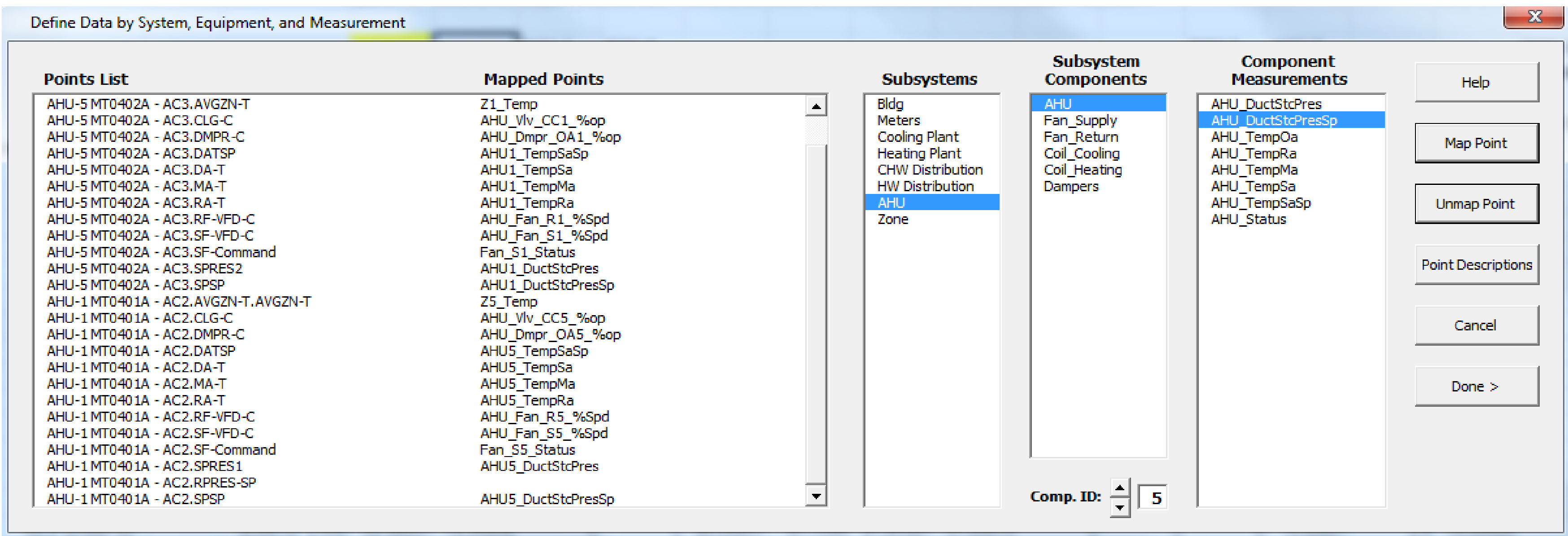
We will walkthrough getting the BAS trend data into ECAM and mapping the data points

We will use

"Air Handlers – 1 Raw Unprocessed.csv"

Data Input and Definition of Points

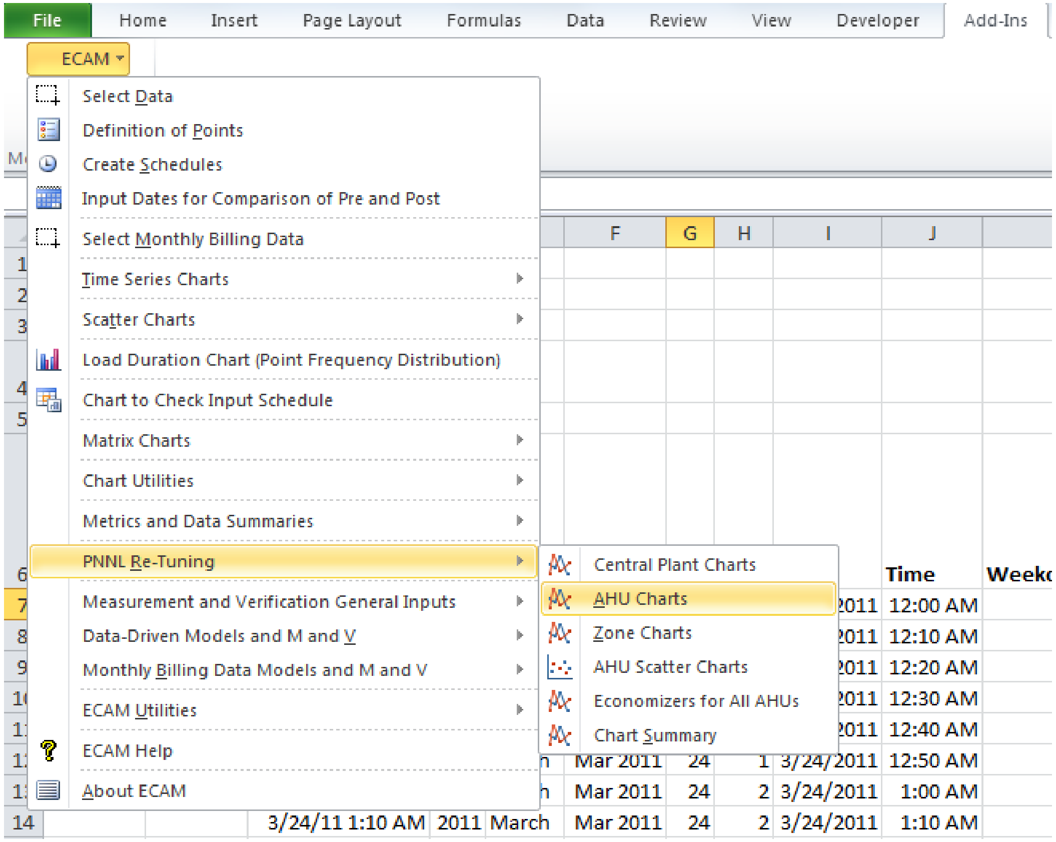
- The resulting mapping should look like this
- Do Save As to save this file "Air Handlers – Points Mapped.xlsx"



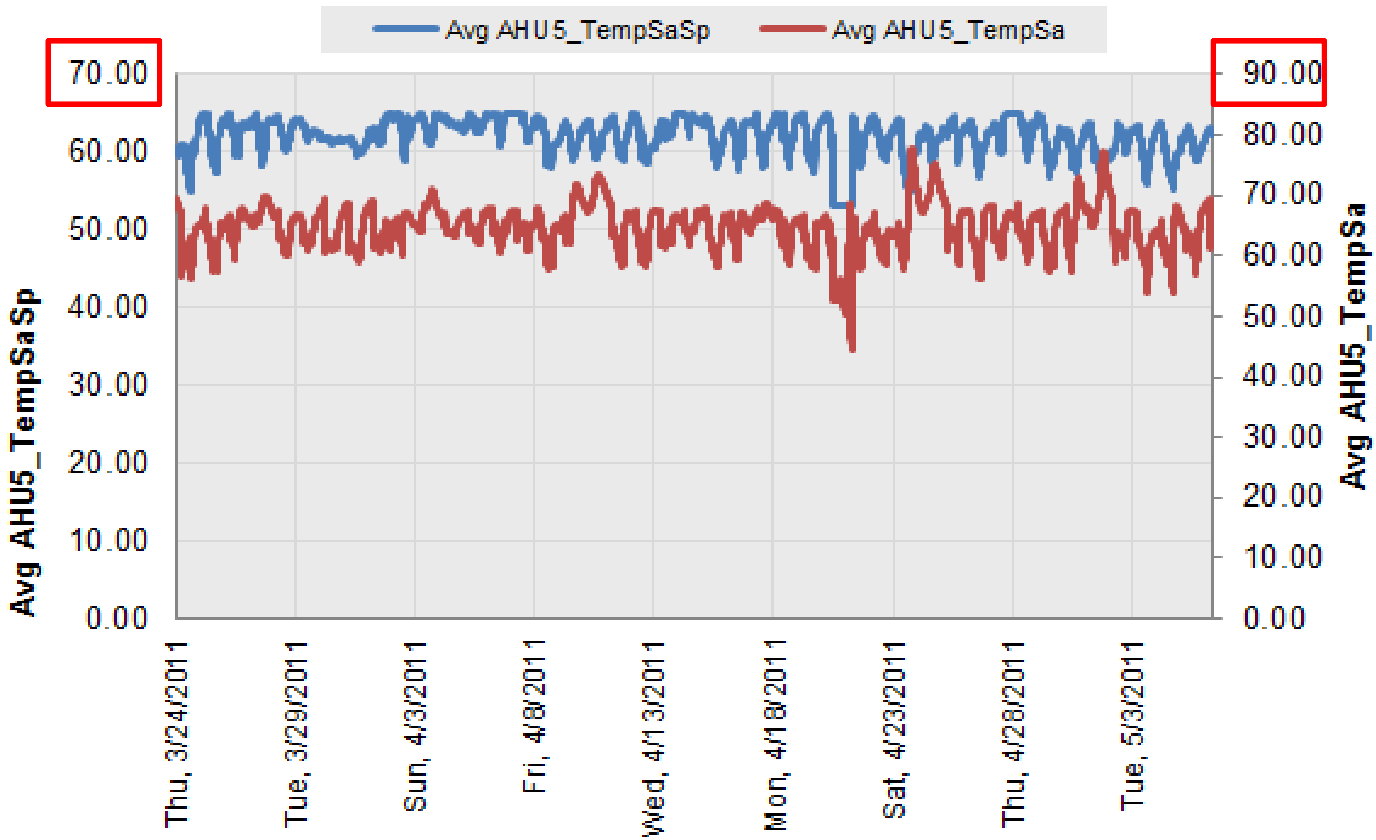
ECAM
PNNL Re-tuning Charts

Re-tuning Charts Available

1) With data mapped from previous section, select PNNL Re-Tuning then AHU Charts



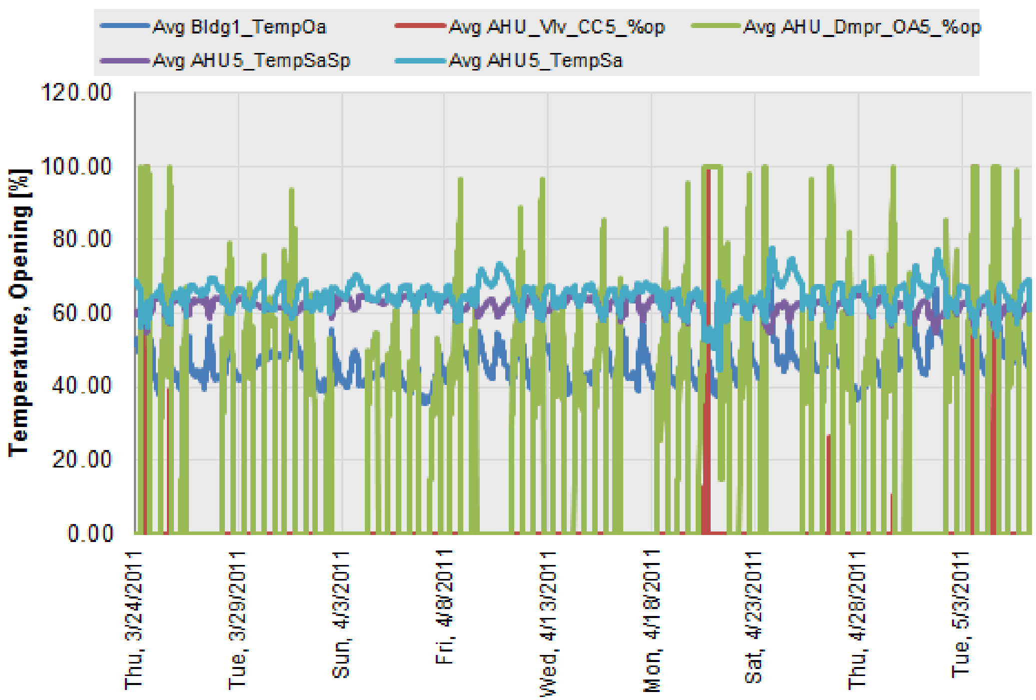
Don’t Be Fooled



Using Pivot Table Filtering

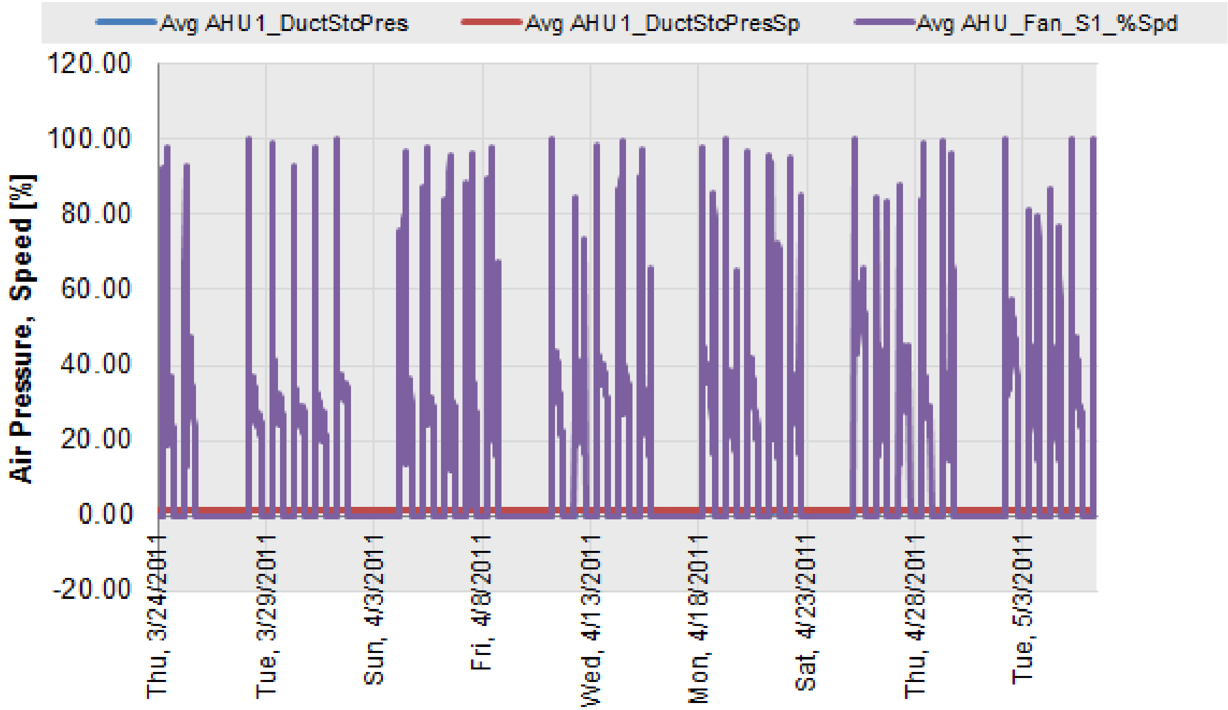
- Select MonthYr, then select Days of the week of interest

DateRng	(All)
Year	(All)
Month	(All)
MonthYr	(All)
Hour	(All)
Occupancy	(All)
Weekday	(All)
Daytype	(All)
Holiday	(All)
Day	(All)
5degBin	(All)
1degBin	(All)
TempRng	(All)
Fan_S5_Status	(All)
Fan_S1_Status	(All)



Primary and Secondary Y Axes

- Right click on the data point in the legend to change to the secondary Y axis.



AHU Re-tuning Charts

"AHU_Econ"- This sheet has charts to help analyze economizer operations for the AHU.

1. OAT, MAT, RAT, SAT, OAF vs. time
2. OAT, OAD, OAF vs. time
3. OAT, OAD, RAT vs. time
4. OAD, CCV, HCV, OAT vs. time
5. OAT, OAD vs. time
6. OAT, RAT, MAT, SAT vs. time
7. SATSP, OAT, CCV, OAD vs. time
8. SATSP, SAT, OAT, OAD, CCV, HCV vs. time

"AHU_OA"- This sheet has charts to help analyze outdoor air operations for the AHU.

1. OAT, OAD, OAF, Occupancy vs. time
2. OAT, OAD, Occupancy vs. time

"AHU_SP"- This sheet has charts to help analyze static pressure operations for the AHU.

1. DSP, DSPSP vs. time
2. DSP, DSPSP, Supply Fan Speed vs. time
3. Supply Fan Speed, Supply Fan Status, DSP vs. time
4. Supply Fan Speed, Return Fan Speed vs. time

"AHU_HeC"- This sheet has charts to help analyze AHU heating and cooling operations.

1. HCV, CCV, OAT vs. time
2. SATSP, SAT, OAT, OAD, CCV, HCV vs. time

"AHU_SA"- This sheet has charts to help analyze supply air operations for the AHU.

1. SAT, SATSP vs. time
2. SAT, SATSP, OAT vs. time

Zone Re-tuning Charts

- This generates one sheet per zone mapped in ECAM, and generates the following charts:
- Zone Temp, Zone Reheat Valve Signal, Zone Damper Position Signal, Zone Occupancy vs. time
- In addition, another sheet will be generated that has the following information for all zones mapped in ECAM:
- All Zones Damper Position Signals vs. time
- All Zones Reheat Valve Signals vs. time

Central Plant Charts

1. CHWS, CHWR, delta-T, OAT vs. time
2. CHWS, CHWS SP vs. time
3. CWS, CWS SP, OAT vs. time
4. CWS, CWR, delta-T, OAT, OAH, Wet Bulb Temp vs. time
5. CHW Loop DP, CHW Loop DPSP, CHW Pump VFD Speed vs. time
6. HWS, HWR, delta-T, OAT vs. time
7. HWS, HWS SP, OAT vs. time
8. HWDP, HWDP SP, HW Pump VFD Speed vs. time
9. CHW Flow, CHW delta-T, CHW Calc. BTU/Tonnage, OAT vs. time
10. HW Flow, HW delta-T, HW Calc. BTU/Therms, OAT vs. time

Look for Re-tuning Opportunities

Live Class Participation!

We will continue with our last file to run the AHU charts and start diagnosing potential re-tuning issues.

We will use

"Air Handlers – 3 Points Mapped.xlsx" file

Thank you for your participation!

Demand Management

Module 4G

Objectives

- Learn basic strategies to manage electrical consumption and demand more efficiently

Demand Management

Demand Management Strategies

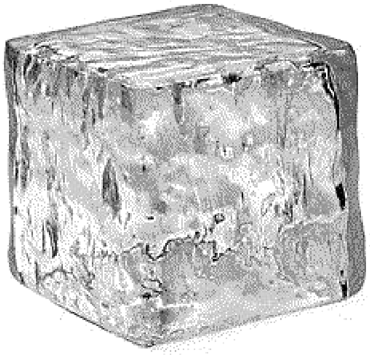
Objectives

- Understand the impact of peak demand charges
- Understand the different demand management strategies
- Review a case study in peak demand management

Common Terms

Energy
- Therms (natural gas), 1 Therm = 100,000 Btu
- kWh (electricity), 1 kWh = 3,412.3 Btu
- kBtu = 1,000 Btu

Power
- Btu/hr or Btuh: 3,412 Btuh = 1kW
- kW: 1kW = 3,412 Btuh
- Ton (A/C), 1 ton = 12,000 Btu/hr = 3.517 kW



A "ton of refrigeration" is defined as the cooling power of one short ton (2,000 pounds) of ice melting in a 24-hour period.

Demand Management

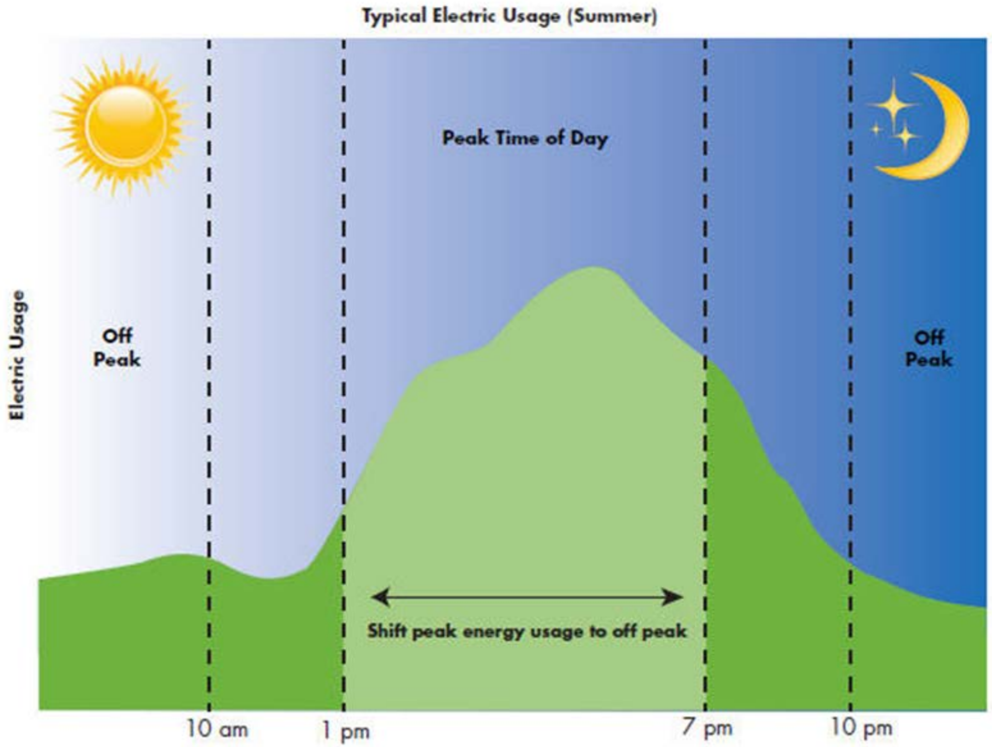
- Demand response is a tariff or program established to motivate changes in electric use by end-use customers in response to changes in the price of electricity over time, or to give incentive payments designed to induce lower electricity use at times of high market prices or when grid reliability is jeopardized.

  – Price-based demand response such as real-time pricing (RTP), critical-peak pricing (CPP) and time-of-use (TOU) tariffs, give customers time-varying rates that reflect the value and cost of electricity in different time periods. Armed with this information, customers tend to use less electricity at times when electricity prices are high.

  – Incentive-based demand response programs pay participating customers to reduce their loads at times requested by the program sponsor, triggered either by a grid reliability problem or high electricity prices.

Peak Demand

- **Peak Demand** – highest power load measured during a segment of a hour in a billing period which represents the highest point of customer consumption of electricity.



Graphic Source: https://www.dom.com/residential/dominion-virginia-power/ways-to-save/smart-pricing-plan/smart-pricing-plan-home/smart-pricing-plan-faqs-home

During certain periods of a given day, the same unit of electricity can cost up to 100 times more!

Peak Demand

FEA

CUSTOMER BILL
Phone Inquiries: (888) 222-3344
Power Outages: (888) 258-5566

Page 1 of 1

Account Number: 123456789

Sample Building
Issue Date: 8/1/08

Total Amount Due 8/28/08 $54,565.88

Location:	123 Main Street
	My Town, USA
Rate:	GS-1

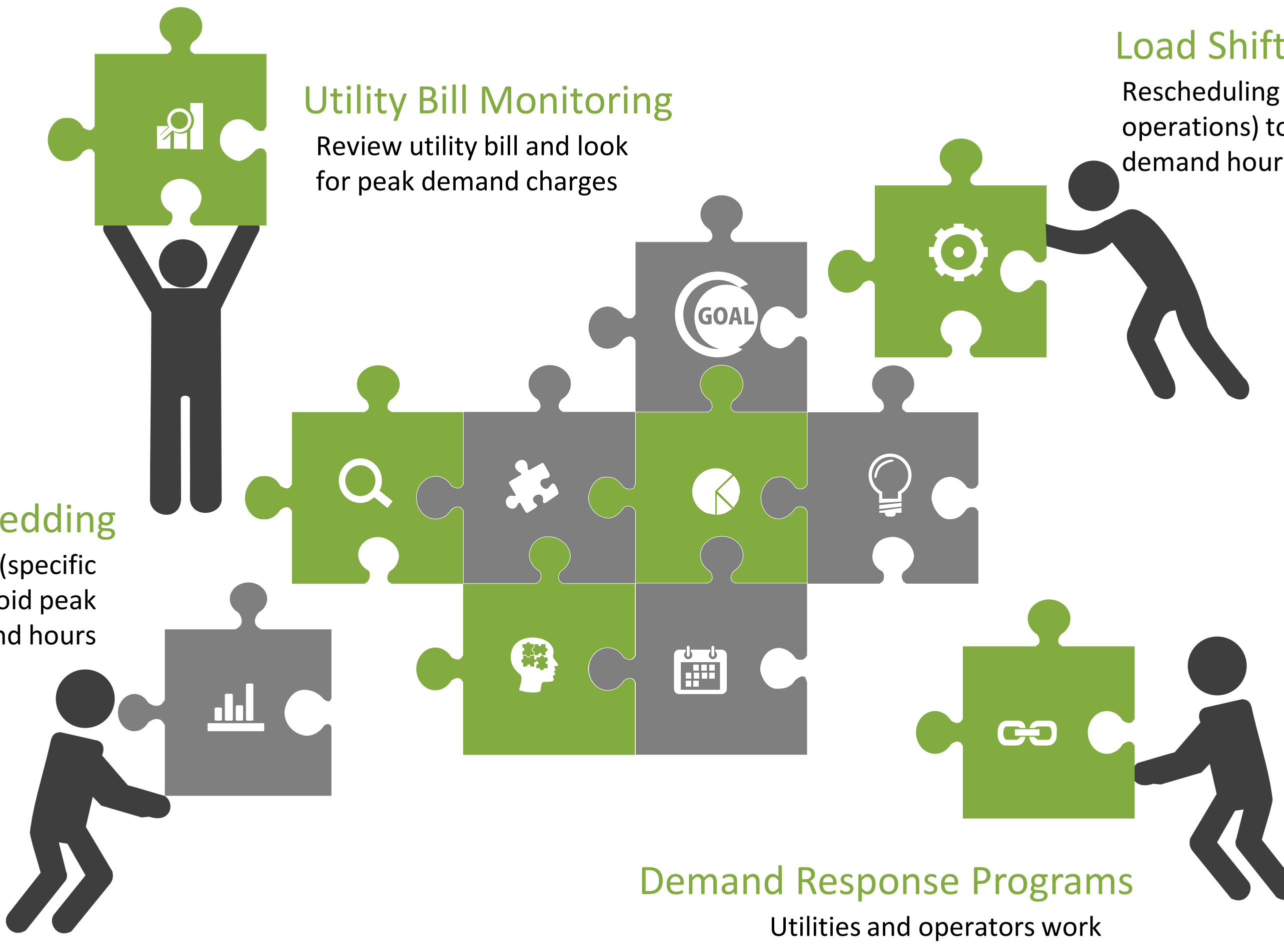
Usage History	Dates	Days	kWh/Day	$/Day
Billing Period	7/1/08 - 7/31/08	31	24,053.6	$2,521.52
Last Year	7/1/07 - 7/31/07	31	23,824.8	$2,496.88
Last Month	6/1/07 - 6/30/07	30	24,231.9	$2,580.46

ELECTRIC SERVICE CHARGES/CREDITS	USAGE	TYPE	RATE	TOTAL
Power Factor	0.8781			
Energy Charge	194,598	Summer Off Peak kWh @	0.077990	15176.70
Energy Charge	95,432	Summer On Peak kWh @	0.101100	9648.18
Energy Charge	180,244	Summer Super Peak kWh @	0.127500	22981.11
Subtotal Electricity Consumption	*470,274*			
Facilities Charge	2,146	Maximum kW @	3.150000	6759.90
TOTAL ELECTRIC SERVICE CHARGES/CREDITS				**54565.88**

GAS SERVICE CHARGES/CREDITS	USAGE (THERMS)	RATE	TOTAL
Gas Charges	563	0.79899	449.83
TOTAL GAS SERVICE CHARGES/CREDITS			**449.83**

https://www.dom.com/residential/dominion-virginia-power/ways-to-save/smart-pricing-plan/smart-pricing-plan-home/smart-pricing-plan-faqs-home

Demand Management Strategies



Utility Bill Monitoring

Review utility bill and look for peak demand charges

Load Shifting

Rescheduling load (specific operations) to avoid peak demand hours

Load Shedding

Reducing load (specific operations) to avoid peak demand hours

Demand Response Programs

Utilities and operators work together for a common goal

Demand Management

Match the demand management strategy to its definition

Strategy	Definition
1. Load Shifting	A. Reducing Load
2. Load Shedding	B. Financial arrangement –Utility & Operator
3. Demand Response	C. Rescheduling load
4. Utility Bill Monitoring	D. Reviewing peak demand charges

BAE Systems Peak Demand Management Case Study

BAE Systems – New York Facilities

PEAK DEMAND TIMES/RATES –

YEAR-ROUND

- OFF-PEAK 6 pm to 10 am @ $.11 KWH
- PEAK 10am to 6 pm @ $10.56 KWH

PEAK DEMAND TIMES/RATES –

SUMMER

- OFF-PEAK 10 pm to 10 am @ $.20 KWH
- PEAK 10 am to 10pm @ $20 KWH

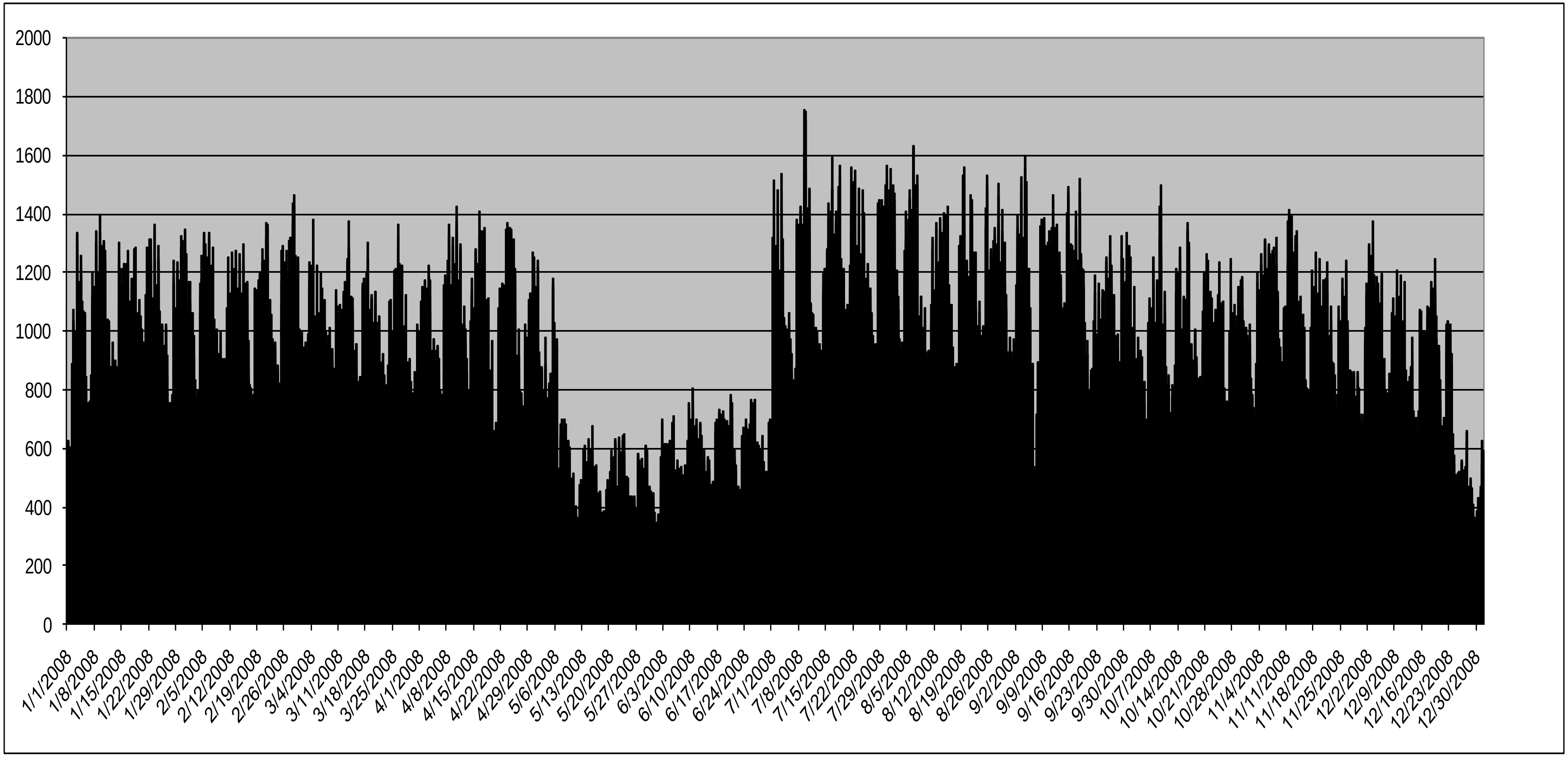
WINTER

- OFF-PEAK 10 pm to 6 am @ $.20 KWH
- PEAK 10 am to 10 pm @ $15 KWH

Peak rates 100 Times higher than off peak! Significant opportunity to save money if they can use load shedding or load shifting strategies.

BAE Systems Peak Demand Management Case Study

A BRIEF LOOK AT PEAK DEMAND



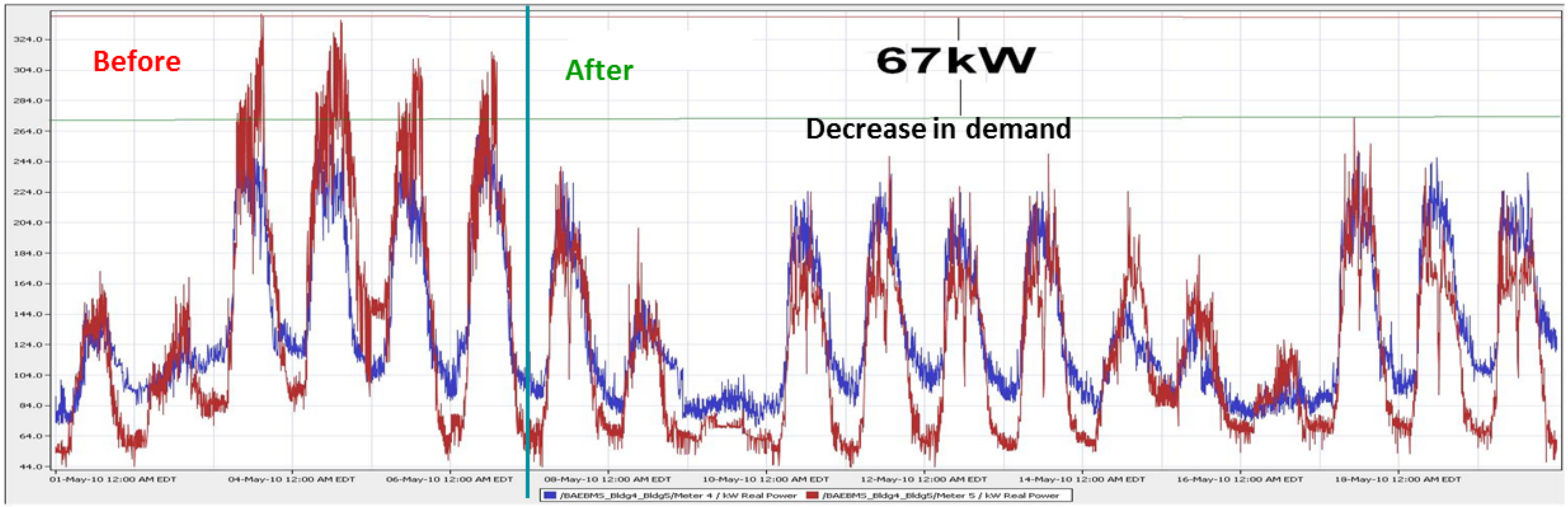
Manage Peak Demand to Mitigate Electrical Cost

BAE Systems Peak Demand Management Case Study

Spray Booth Example:

- Running the HVAC system for the spray booth is a necessity due to the fumes created while spraying coatings and paints.
- The total load of the paint booth is 100 kW or approximately 1/3 of the total demand on the 480 V service.
- Total estimated savings of this single peak demand management line item is between ~$52k-$74k annually.

BAE Systems Peak Demand Management Case Study



<u>Un-Bridled Spray Booth Operations</u>

- On in the morning, off at night

<u>Managed Spray Booth Operations</u>

- Lowers Peak Demand
- Lowers total consumption
- Anticipate savings $70K per year

Thank you for your participation!

Building Re-Tuning Training Guide

2016

This guide is for people who wish to deliver Building Re-Tuning Training to groups of facility engineers, building operators and managers

Observation Driven and Data Driven Re-Tuning

PennState

APPA LEADERSHIP IN EDUCATIONAL FACILITIES

BOMA International

Better Buildings U.S. DEPARTMENT OF ENERGY

Acknowledgements

The U.S. Department of Energy funded the development of Building Re-Tuning Training. Much of the content of the Building Re-Tuning Training was developed by the Pacific Northwest National Laboratory. Additional content was added and modifications were made by the Pennsylvania State University.

Revision

This guide was revised on April 30, 2016 by Lisa Shulock at Penn State. Questions can be directed to LShulock@psu.edu.

Contents

1. About this Building Re-Tuning Training Guide

Penn State, with funding from the U.S. Department of Energy and in partnership with the Building Owners and Managers Association (BOMA) International and APPA (Leadership in Educational Facilities), has created this guide. Its purpose is to assist individuals who are training others on how to conduct Building Re-Tuning.

Pacific Northwest National Labs (PNNL) created the Building Re-Tuning Training program and much of the content in the curriculum was developed by PNNL. PNNL maintains a website with building re-tuning resources and online, on-demand training. See the resources section for links.

In order to have deeper penetration in the commercial building market, DOE determined that instructor-led training was important to offer in addition to PNNL's online training. Furthermore, to disseminate the training, DOE and Penn State developed partnerships with BOMA and APPA as distribution channels for Building Re-Tuning Training (BRT). It is the expectation that additional organizations will adopt the BRT program and disseminate it to their members as well.

This training guide will assist trainers and facility engineers familiar with commercial building operations to teach others how to increase the energy efficiency of their building(s) and provide trainers with the necessary tools and resources to effectively teach re-tuning concepts and conduct building investigations.

The overall goal of a building re-tuning program is to increase the energy efficiency of commercial buildings with no and low cost methods resulting in up to 25 percent energy savings.

2. "Rules of Engagement" and Content Management

To ensure consistency among all providers of BRT, APPA maintains the curriculum in a file sharing platform. Any training provider with recommended updates to the curriculum must share them with APPA for inclusion in the curriculum. APPA, in consultation with BOMA, PNNL, DOE and other BRT training providers, will periodically update the curriculum. Organizations are welcome to add new modules and share them with APPA and BOMA. For example, APPA plans to create a module on re-tuning for laboratories on campuses which will be available to anyone using the BRT curriculum. See resources section for APPA and BOMA contact information.

As of April 30, 2016, information on U.S. Copyright for Building Re-Tuning Training curriculum is not finalized.

Important Note - all providers of BRT must share the following in writing with BRT audiences:
The U.S. Department of Energy funded the development of Building Re-Tuning Training. Much of the content of the Building Re-Tuning Training was developed by the Pacific Northwest National Laboratory (PNNL). Additional content was added and modifications were made by the Pennsylvania State University.

Associated logos to be included are:

PennState

Better Buildings
U.S. DEPARTMENT OF ENERGY

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

3. Small versus large buildings; observation-driven and data-driven; BAS and non-BAS Buildings

PNNL's training program is divided into two categories: (1) small buildings **without** Building Automation Systems (BAS) and (2) large buildings **with** BAS. The modified instructor-led training that this training guide supports approaches it slightly differently. Through the process of delivering multiple pilot trainings with BOMA and APPA from 2014-2016, Penn State created a model which also incorporates two categories: (1) **observation-driven** re-tuning and (2) **data-driven** re-tuning.

Observation-driven re-tuning relies on identifying energy waste through building investigations (walkdowns or walkthroughs). Data-driven re-tuning utilizes data from building automation systems (or EMS, BIS, etc.).

A stand-alone observation-driven, instructor-led curriculum is available for trainers to use to teach building re-tuning. A module on how to teach adult learners has also been created for those who have less experience training.

For people operating buildings with BAS, the data-driven curriculum has a module for observation-driven re-tuning because all re-tuning should include a physical investigation of a building and multiple modules related to data-driven re-tuning, in other words, how to use data from a BAS to identify energy saving opportunities.

4. Building Re-Tuning Training:

4.1. What It Is

Building re-tuning is a systematic process to identify and correct building operational problems that lead to energy waste. It is implemented at no or low cost other than the labor required to perform the re-tuning process. Re-tuning may include adjusting thermostats for actual occupancy patterns, changing set points in building automation systems or small, low-cost repairs such as replacing faulty sensors or caulking openings in the building envelope. By proactively utilizing the energy savings opportunities taught in the re-tuning training, operations staff can save between 5 and 25 percent of all energy used in the building.

The training is a blend of in-class instruction and discussion and building investigation (building "walkdown"). The training is most efficient when the classroom portion of the training takes place in a building that is also the subject of the experiential walkdown.

4.2. In-person and webinar delivery options

The data-driven program has been divided into modules that can be delivered in-person in a two-day program or can be delivered via webinar with time allotted between sessions for participants to complete assignments between modules.

4.3. Purpose of Building Re-Tuning Training

Commercial buildings account for almost 20 percent of the total U.S. energy consumption. A significant portion (up to 25 percent) of the energy used in commercial buildings is wasted because of improper operations. Many buildings still are not properly commissioned, operated, or maintained, and lack of proper maintenance often leads to inefficient operation and reduced lifetimes of equipment. Re-tuning ensures maximum energy efficiency and comfort for building occupants. Although a poorly tuned system can maintain comfort, it may do so at a high energy cost while compensating for undetected operational inefficiencies. Building operators trained in re-tuning will be able to increase the efficiency of the buildings they manage by up to 25 percent with minimal capital expense.

4.4. Intended Building Re-Tuning Audiences

4.4.1. Train-the-trainer for observation-driven re-tuning

Penn State created a “train-the-trainer” program for BOMA, APPA and others to use to skill-up a large number of people to become BRT instructors. The expectation is that these individuals would primarily be teaching observation-driven re-tuning. The ideal students for the “train the trainer” program are people in a position to train others. These could include individuals who operate, service or manage a portfolio of buildings who can then train the additional operators of those buildings or individuals who work for companies that provide services to commercial buildings who might then want to provide this type of training for their clients. Ultimately, the newly trained “trainers” should look to train individuals who operate, service, or manage commercial buildings. APPA and BOMA have identified their “Fellows” as trainers of the program. The “train the trainer” program is typically two days in duration; therefore, the attendees and their management need to adequately budget time for the training. When the trainers conduct their own observation-driven training sessions, these can be done in one day. For all trainees, time needs to be budgeted to actually conduct the building re-tuning program in the building(s) in which the trainees work after attending a building re-tuning training program.

In general, an individual with more than three years of building operations experience will find a portion of the material basic and foundational in nature, a portion of the material will be new and informative, and all of it will be presented in a way to bring new perspective on building energy efficiency and how to systematically reduce energy use.

4.4.2. Data-driven re-tuning audiences

Comprehensive re-tuning of a building using automation data typically requires a team with the following skills and knowledge:

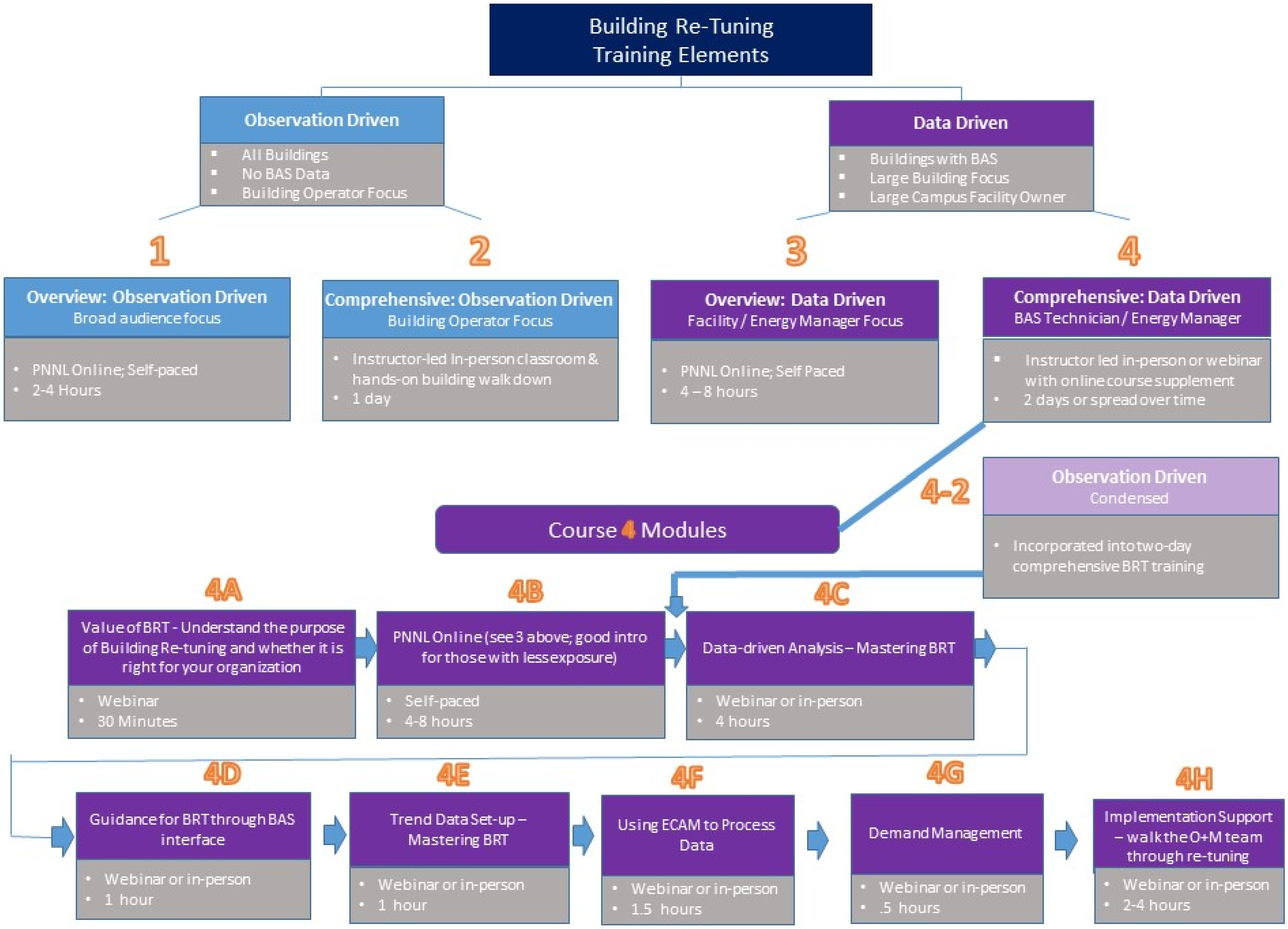
1- understanding of the subject building (operational history, occupant needs, building program, etc.)
2- understanding of building systems and their integration/interactivity) and data analysis
3- equipment-specific experts (the particular chiller or DOAS, etc. in the building)

Rarely does one person have all the knowledge and skills to perform re-tuning on their own.

Data-driven re-tuning training assumes that the attendees have basic skills in all of the above – they work in a building(s) with which they have familiarity; they know how to use and access a building automation system; they know how to generate trend logs from a BAS (or can get someone to do it for them); and they have basic computer skills including experience using Excel. A subset of the audiences trained by Penn State and its training partners (Facility Engineering Associates and Performance Systems Development) had difficulty with #3 above – they did not have strong computer skills and were not well-versed in using Excel. In order to fully benefit from data-driven building re-tuning most BAS systems on the market need analytics performed outside of the BAS interface and that is where Excel skills are important. Trainers of the data-driven program should be aware that some participants may be challenged by this aspect of the training.

4.5.Building Re-Tuning Training Elements

Building Re-Tuning Training is available online through PNNL. Trainers using this guide will be offering it in-person or via webinar. Additionally, there is observation-driven (2 below) only or data-driven with observation (4 below). The chart below depicts these elements.



Training Elements– Figure 1

4.6. Building Re-Tuning Investment and Trainer Role

- ### Host Organization

Building Re-Tuning Training is a blend of classroom instruction and discussion and an instructor-led building walkdown. The preferred training environment is to host the training in a conference room or classroom in the same building, or in very close proximity, to the building being used to perform the walkdown. The host organization provides the room, access to the building including mechanical rooms, the roof, occupied areas, etc. A facilities person familiar with the building operations should be present.

- ## Host Building

  For the best observation-driven training experience, the preferred host building is at least 10 years old, between 50,000 and 150,000 square feet, without (or with a minimal) Building Automation System, and with no recent major retrofit completed. The reason for this is so that trainees can search for, and usually find, energy-saving opportunities. Newer buildings typically (though not always) have fewer observable issues.

- ## Attendees

  The training is typically offered in a one or two-day format. In addition to attending the training, trainees should expect to spend time re-tuning their own building and implementing findings. This process can take days of effort to document findings and make corrections. Ideally, building re-tuning is performed continuously or at least on a seasonal basis.

- ## Recommended Trainer Experience

  The trainer should have at least three years of building operations experience and the desire and interest to teach others about building energy efficiency. Previous training/teaching experience is preferred. A module on how to teach adult learners is available for those who are new to teaching.

Instructor Tasks	When to Complete Prior to First Class
Study and review all BRT materials. Refer to the *Read Me First* page included in materials	5 weeks
Send students an email welcoming them to class. Provide class times, location, instructor's contact information and mention that: o Students are expected the complete the pre-work prior to coming to class. Pre-work includes taking the PNNL online class (if instructor decides to include this) o For data-driven class, students need to bring laptops to class with Excel and data files pre-loaded (send a link to the data files)	4 weeks
Follow-up reminders	2 weeks and 1 week

4.7 Observation-Driven Building Re-Tuning Curriculum Overview (Classroom portion of training)

The classroom portion of the training covers the following topics:

~ Instructing Adult Learners (For the Trainer only)
~ Building Personality / Basic Building Information
~ Building Envelope
~ HVAC Systems and Controls
~ Lighting Systems and Controls
~ Hot Water Systems and Controls
~ Office Equipment

- Indoor Environmental Quality
- Air Distribution Systems
- Baselining Energy Use
- Calculating Energy Savings
- Delivering Building Re-Tuning Training (For the Trainer only)

The classroom portion of the training is conducted through a set of power point slides. The slides are annotated with notes to assist trainers in delivering the material.

4.8 Data-Driven Building Re-Tuning Curriculum Overview

This program has been arranged in a series of modules that are designed to be delivered in-person in a two day format or via webinar over the span of several weeks. The benefit of webinars is that it minimizes cost and travel time. It also allows participants to learn concepts in a session, apply what they have learned in their own building, then attend the next webinar, apply again, etc. The benefit of in-person is that there is much more trainee interaction in the classroom and during breaks which enhances the experience, a walkdown is performed as a group, and it gets people out of their daily routine where there are distractions and interruptions. Each organization and each person will have different preferences and budgets which will determine how they approach it. Both APPA and BOMA plan to focus on in-person delivery. Training organizations including PSD and FEA are available to deliver BRT via webinar or in-person (see resources).

- Value of BRT – Understand the Process of Building Re-Tuning and whether it is right for your organization
  - 30 minutes
- PNNL online (good intro for those with less experience)
  - Online
  - 4-8 hours
- Data-driven RE-tuning – Mastering BRT
  - 4 hours
- Guidance for BRT through BAS interface
  - 1 hour
- Trend Data Set-up
  - 1 hour
- Using ECAM to process Data
  - 1.5 hours
- Demand Management
  - 30 minutes
- Implementation Support
  - Webinar follow-up

5. Building Re-Tuning Training Workshop

The training modules are primarily comprised of Power Point slides with notes. There are several supplemental learning activities to use during the workshop which are in Word and in Excel. The slide decks and supplemental materials can be found on the BRT sharing platform hosted by APPA (see resources section).

5.1. Training workshop sample agenda

Building Re-Tuning Training Agenda – Full Course (Observation and Data-Driven) Day 1, 9:00-5:00					
Total Time	**Module**	**Start**	**End**	**Topic**	**Instructor**
1 hour		8:00	9:00	Continental breakfast, networking	
30 minutes		9:00	9:30	Introductions, training goals and agenda review	Lisa Shulock, Penn State's CBEI
15 minutes		9:30	9:45	Introduction to Building Re-Tuning Training	Lisa
45 minutes	2	9:45	10:30	Observation Driven Part 1	Maureen Roskoski, FEA
15 minutes		10:30	10:45	Break	
1 hr & 15 minutes	2	10:45	12:00	Observation Driven Part 2	
30 minutes		12:00	12:30	Lunch	
2 hrs & 30 minutes		12:30	3:00	Walkdown (including break afterwards)	
2 hours	4C	3:00	5:00	Data Drive Analysis – Mastering BRT	Conrad Kelso, FEA

Building Re-Tuning Training Agenda Day 2, 8:30-3:30					
Total time	**Module**	**Start**	**End**	**Topic**	**Instructor**
30 minutes		8:00	8:30	Continental breakfast, networking	
15 minutes		8:30	8:45	Day 1 review	
2 hours	4C	8:45	10:45	Data Driven Analysis – Continued	Conrad
15 minutes		10:45	11:00	Break	
45 minutes	4D	11:00	11:45	Guidance for BRT Through BAS interface	Conrad
30 minutes		11:45	12:15	Lunch	
45 minutes	4E	12:15	1:00	Trend Data Set-up	Conrad
1 hour & 15 minutes	4F	1:00	2:15	Using ECAM to Process Data	Conrad
15 Minutes		2:15	2:30	Break	
1 hour		2:30	3:30	Demand Management; Putting it all together; feedback; next steps; course evaluation	Lisa

5.2. Training Workshop – equipment

The classroom portion of the workshop needs to be able to comfortably accommodate the training group size. Each participant should have a table or writing surface and a printed copy of the slides (2 slides per page max.). A projector is required.

Attendees of the data-driven workshop need to bring a laptop with Excel loaded on it. Wireless Internet access is also required for all participants.

The instructor should also have basic re-tuning tools to demonstrate their use while in the classroom. The list of recommended tools is below with additional descriptions found in section 7.4.

1. Common Workbench Tools

   - **a.** Screwdrivers
   - **b.** Allen Wrenches
   - **c.** Adjustable Wrenches
   - **d.** Tape Measure
2. Light Meter
3. Magnetic Ballast Detector
4. Infrared (IR) Temperature Gun
5. Wind Velocity Meter
6. IR Imaging Camera

These tools are shown in Figure 2.

5.3 Walk-down

Training groups larger than 12 individuals can be unwieldy when conducting the building walkdown. Groups of all sizes benefit when given "assignments" while conducting the walkdown, such as using different pieces of equipment, taking notes, taking photos, and/or leading efforts to find energy waste in lighting, envelope, or mechanical systems.

5.4 Implementation Support

The concepts, tools and techniques conveyed in data-driven BRT training are complex and often are challenging to implement. One or more follow-up webinars are recommended in which the participants are invited to share their experiences with BRT implementation including sharing charts of any findings or screen shots from their BAS so that the group can discuss and provide input and support. The greatest success has been when intact teams train together and work together back at their facility to implement BRT. Another key success factor is the involvement and commitment of management. When building managers understand the value of BRT and hold facilities staff accountable for implementing BRT is when the greatest savings are realized.

5.5. Pre-training Information Collection

Pre-training Building Survey

The pre-training building survey is intended to gather information about any non-BAS building that is being re-tuned. This survey is designed to familiarize the building representative and the class instructor with the layout and systems of the building before a more detailed inspection is done during the walkdown. For this survey the building representative needs to provide information on the basic layout of the building, heating and cooling systems, lighting, occupancy and appliance usage, ventilation, and specific energy consumption data for at least the last 12 months.

Sections include:
Building Envelope
HVAC Systems
Lighting
Ventilation
Occupancy and Appliance Usage

5.6 The Building Walkdown

5.6.1 Walkdown Guide:

1. PURPOSE

a. The purpose of the building walkdown is to identify specific areas of opportunity for energy conservation.

b. By examining systems, talking to occupants and engineers, and taking measurements, you will get a good impression of the building's various systems and their conditions.

2. MAJOR STEPS

c. Electrical and mechanical prints will enable you to identify electrical loads worth controlling, provide you with the type of air handlers used, and provide you with the approximate number and size of perimeter and interior zones.

d. Walk the exterior of the building: examine windows, HVAC grills, doors, outside lights, and exterior outlets.

e. Walk the inside of the building: examine lighting, hallways, perimeter and interior offices, and talk to tenants and the facility manager.

f. Walk the roof: note HVAC equipment condition, roof condition, check seals, and examine exhaust fans and vents.

g. Because air handlers are critical, you should examine most if not all air handlers.

h. Walk the plant area: inspect pumps, chillers, boilers, cooling towers, and DDC controllers.

2. REVIEW ELECTRICAL AND MECHANICAL PRINTS

a. When reviewing the mechanical prints, note the air handlers of each style (VAV or CV). Note the rough number and size of perimeter zones (one way to do this is to count the number of thermostats or the terminal box distribution). Note the number and size of the interior zones.

b. When reviewing the electrical prints, identify the individual electrical loads potentially worth controlling—greater than 3.7 kW (> 5.0 hp). Record these loads in a table.

3. WALK THE OUTSIDE OF THE BUILDING

a. Examine windows. Purpose: Get a rough sense of the solar load on the perimeter zones

b. Estimate fraction of windows on each side of the building

c. Note the orientation of each side of the building; using Google Maps in advance of the walkdown is effective

d. Note the types of windows and, if they can be opened, note the percentage of open windows

e. Note any significant shading by side of the building, and note foliage for problems or opportunities

f. Examine HVAC grills. Purpose: Identify potential sources of ventilation problems

g. Estimate rough number of grills, their relative size, and their locations; distinguish between large grills for HVAC and small exhaust grills

h. Note any HVAC intakes near sources of automotive exhaust and possible short circuits for air between exhaust air and intakes: look for weather-damaged caulking, cracks, and seals around windows and doors.

4. OUTSIDE – DOORS, EXTERIOR LIGHTS, ELECTRICAL OUTLETS

a. Examine exterior doors—Purpose: identify potential sources of excess infiltration or exfiltration

b. Estimate the number of doors, their locations, and their uses (e.g., main entrance, side entrance, service door, etc.)

c. Listen for air leakage around doors or poor or missing door seals along the edges and thresholds. Double doors should be sealed adequately between the two doors when they close. Look for doors slamming shut or staying open—this may be lack of positive pressure or too much positive pressure.

d. Examine outside lights, including parking lot lights on during daylight hours

e. Excess electric loads: note any exterior outlets or electrical devices with poor seals, poor caulking, or air noise

f. Note any piping penetrations into or out of the building (water, gas, electrical, etc.). These penetrations should be completely sealed.

5. INSIDE – LIGHTING AND HALLWAYS

a. Examine interior lighting
b. Note type of lighting and kind of lamps predominantly used
c. Not directly related to re-tuning, but you could identify a simple, cost-effective relamping retrofit opportunity. For example, replace incandescent bulbs with CFL and replace T12 lamps and ballasts with high-efficiency electronic ballasts and T8 lamps.
d. Inspect hallways: for each hallway, note whether it's comfortable, warm, or cool
e. Note whether hallways are warmer, cooler, or about the same temperature as the rooms they service
f. Note whether or not the hallways are over lit or lit to the same level as adjoining office spaces. If over lit, this could be an opportunity to de-lamp, as long as safety standards are not compromised.

6. PERIMETER OFFICES AND ROOMS

a. Note type of heating
b. Discharge duct locations and whether registers are open, closed, covered with paper or cardboard or treated in some other way
c. Measure the temperature of the discharge with an infrared (IR) gun.
d. Measure the room temperature with IR gun by measuring the temperature of interior walls—take a few readings—and record them.
e. Portable heaters used (look under desks)
f. Thermostat locations—Purpose: Determine if location may influence over- or under-cooling or heating of a zone
    - i. Over heat sources, such as computer monitors or copiers
    - ii. Behind shelves or other obstructions
    - iii. Properly located, unobstructed on interior walls
    - iv. Located in spaces served and not fighting with other zones caused by wall changes
g. Use of space—Note general use of space and any special ventilation or conditioning requirements
h. Corner offices
    - i. Note if two walls have glass (potential source of extra load)
    - ii. Note if corner offices are comfortable while nearby offices are not
        1. Corner office driving conditions
i. Lighting occupancy sensors
    - i. Check if they are used in each space
    - ii. Note if any are hidden or blocked so they won't work
j. Occupants
    - i. Ask if they are comfortable or are frequently hot or cold
    - ii. Ask building staff about excessive hot and/or cold complaints in particular rooms, zones, or hallways.

7. INTERIOR ROOMS

a. Note if there is any heating, and if so, what type, for interior zones.
b. Note the heat source (duct heat from ceiling, wall radiators, forced air from walls, induction heat, radiant heat, etc.). Purpose is to determine whether heating is part of air handling system.
c. Note locations of discharge ducts and whether they are open, closed, covered, etc. Measure the temperature of the discharge with an IR gun and record it.
d. Use an IR gun to measure the air temperature of the walls in a few spots to get a rough average for the room and record it. Note any use of portable heaters (look under desks).

e. Note if thermostats are located over heat sources, behind shelves or other obstructions, or are properly located on interior walls. The purpose is to determine if location may influence over- or under-cooling or heating of a zone.
f. Note general use of space and any special ventilation or conditioning requirements.
g. Ask occupants if they are comfortable or frequently hot or cold. Ask building staff about excessive hot and/or cold complaints in particular rooms, zones, or hallways. Talk to the owner or facility manager to get a sense of the types and volume of complaints over the course of a year.
h. Listen for unusual noise from equipment or air flow—excessive air flow noise may indicate high duct static pressure. Look for un-insulated piping (steam, condensate return, hot water, chilled water, etc.). Steam, condensate return and hot water lines that are run in plenum spaces (above drop ceilings) or in mechanical spaces add to the cooling loads seen by the air handlers and put additional loads on the heating systems (boilers, etc.).

8. ROOF - Examine HVAC equipment. Look for:

a. Missing panels and seals around access doors
b. Panels leaking
c. Missing condenser fans
d. General poor maintenance
e. Other conditions that might affect performance
f. Examine exhaust fans:
    i. Count or estimate the number of exhaust fans of each general size (small, medium, large)
    ii. Verify fans are exhausting
    iii. Large fans are candidates for control

9. AIR HANDLERS

a. If there are a very large number of air handlers, a sample of between 50 percent and 75 percent should be adequate.
b. Try to randomly sample different floors and disperse across low, mid-level, and high floors.
c. If significant problems are found with the sample, all air handlers need to be inspected.
d. Inspect and record type of unit (VAV, CV, single-zone, multi-zone)
e. For VFDs, record speed on drive display and current time. Watch speed variation—you should see some. If there's no variation, it's probably overridden.
f. Open access door. VFD should modulate. No modulation indicates that it is probably overridden. Check position of inlet vanes.
g. Check for missing, dirty, plugged, or collapsed filters.
h. Check for dirty or plugged coils.
i. Inspect dampers and look for damage, missing mechanical connectors, leaking or missing seals, and/or and other obstructions (like 2 X 4s) between damper blades.
j. Look for water leaks, valves leaking from packing, and/or valves not fully opening or not closing completely.
k. Make sure isolation valves on working coils are wide open.
l. Inspect DDC controls and look for disconnected wires, jumpers in place, switches in hand. Record all abnormal conditions.
m. Inspect ductwork for gaps and leaks, holes in flex couplings, and vibrations.
n. Note squeals (high air leakage from pinholes in ducts), thumping, or any uncommon fan sound (excessively loud to extremely quiet).
o. Note location of outdoor air sensor(s) – temperature and/or humidity. Make sure they are not falsely impacted by sun or man-made influences

10. CENTRAL PLANT - PUMPS

a. Use visual observation and touch.
b. If you can't hold your hand on the pump, it's too hot.

c. Determine pump purpose: chilled water, hot water or condensate.
d. Also record temperature and pressure of the water loops—pressure differences of more than 40 psi should be noted and investigated later.
e. Make sure isolation valves on running pumps and pumps that are in service are wide open.

11. CENTRAL PLANT – WHEN INSPECTING VALVES, RECORD:

a. Alignment (shaft position)—fully open, partially open or closed
b. Automatic or manual control
c. Water flowing when not needed
d. Other unusual conditions
e. Record current loads:
   i. Load on each unit running
   ii. Temperature difference across unit.

12. CENTRAL PLANT - DDC CONTROLLERS

a. While looking inside the control panel, record:
   i. Disconnected wires
   ii. Jumpers in place
   iii. Switches in hand
   iv. All abnormal conditions.
b. While walking down the plant,
   i. Determine if a compressed air system exists to provide compressed air to any pneumatic devices (thermostats, actuators, transducers, controllers, etc.). If true, record:
      1. Compressed air pressure
      2. Air dryer functioning
      3. Reduced pressure regulator setting (should be between 20 and 25 psi; any lower will affect controls).Compressor run (on) time versus off time (should be close to 30 percent percent run (on) time versus 70 percent percent off time. If run time is higher, this could indicate undersized compressor, or significant system leaks (more likely) that need to be investigated/corrected.

5.6.2 Building Investigation Log Book

The log book is a checklist of items to look for when conducting a walkdown (taken from the PNNL Building Re-Tuning Primer).

5.6.3 Building Re-Tuning Trainer Field Tools Recommendations

Tools that are helpful during the walkdown of a building for re-tuning include common workbench tools (screwdrivers, allen wrenches, adjustable wrenches, tape measure) as well as other specialty tools such as a light meter, magnetic ballast detector "top," infrared (IR) temperature gun, wind velocity meter, and IR imaging camera. These tools are shown in Figure 1.

Workbench tools are helpful to carry around for opening access panels, tightening loose connectors, and taking measurements.

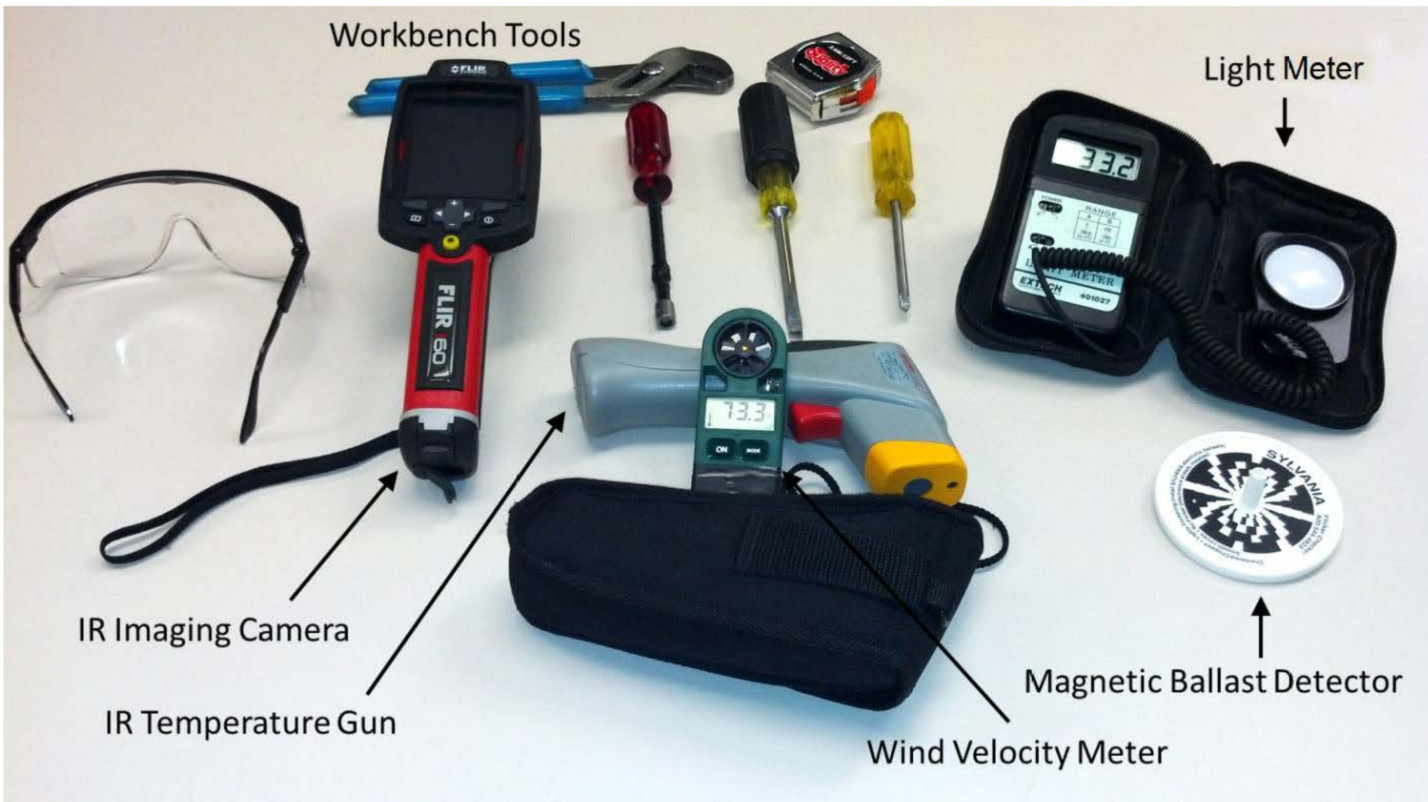
A **light meter** is used during a building walk-down to determine if areas are under-lit or over-lit. Target light levels for key areas include 37 foot-candles for office areas, 28 foot-candles in bathrooms, and 5 foot-candles in corridors.

A **magnetic ballast detector** is used to determine whether fluorescent lighting systems are using electronic ballasts. The detector is designed to be spun like a child's toy "top." If the pattern on top appears smooth when the top is spun, the ballasts are electronic. If the pattern on top has a pulsed pattern visual effect, the ballast is magnetic.

Wind velocity meters are inexpensive hand-held devices with a small, built-in fan rotor that measures the speed of a flowing air stream. Such meters can be used to measure and verify the speed of air at various places in the HVAC system (outdoor, relief air, terminal box discharge) and to calculate estimated flow rates, when duct cross-sectional area is taken into account.

An **IR temperature gun** is used to measure the temperature at a specific point, using a laser pointer as a guide. It is good for taking spot measurements of temperatures on HVAC ductwork and piping, as well as taking indoor zone and outdoor temperature readings.

An **IR imaging camera** is a more expensive device that reproduces an image of an area, color-coded by temperature. This kind of image is good for use on the building envelope to identify areas of outdoor air infiltration or wall sections without insulation, and on ductwork to identify uninsulated or leaking areas.



Walkdown Tools – Figure 2

6 Resources – can be found at APPA file share location TBD (temporary site = https://psu.box.com/s/6boxfsu9t5zspd3tf7gpyiywt0gyb5st)

PNNL Re-Tuning Website

The Pacific Northwest National Lab website contains extensive information, resources, and online training materials for small and large commercial building re-tuning. http://buildingretuning.pnnl.gov/

Automated Building Re-Tuning Report Generator

This is a Word template that is populated with data from an Excel workbook for creating reports. Re-tuning reports can be very helpful to gain support for the re-tuning process as well as document and track re-tuning findings and implementation measures.

Case Studies

Four case studies of BRT with a focus on re-tuning buildings with Building Automation Systems (BAS)

PNNL Small Building Re-Tuning Primer

http://buildingretuning.pnnl.gov/small_bldg_primer.stm

This 86-page document is an excellent resource for re-tuning instructors and trainees. It is an introduction to all the major building systems and features to which re-tuning applies. The primer is organized by the following building topic areas:

- Building exterior (e.g., roofs, walls, windows, and doors)
- Building interior
- Heating, ventilation, and air-conditioning (HVAC) systems
- Lighting
- Water-heating systems
- Meters
- Sensors and controls
- Re-tuning tools

Readers can focus on individual topic areas in which they need additional background information or read the primer as a whole. The appendix of the primer includes a glossary of terms.

Department of Energy Better Buildings

The Department of Energy Better Buildings Website has additional information including case studies and information about building re-tuning training opportunities.

Distribution partners: APPA International and BOMA International

These organizations are pushing BRT to their local associations and chapters. For information contact:
Suzanne Healy suzanne@appa.org or
Scott Morris smorris@BOMA.ORG

Training partners: Facilities Engineering Associates and Performance Systems Development

Both of these training/consulting companies contributed to developing the BRT curriculum and have experience with BRT training. For information contact:
Maureen Roskoski Maureen.Roskoski@feapc.com http://www.feapc.com/
Caleb Crow ccrow@psdconsulting.com http://psdconsulting.com/

TOYOTA KATA AND BUILDING RE-TUNING TRAINING (TK/BRT)

Building Re-Tuning Training (BRT). The core principle of the BRT is to train those involved in maintenance and management of buildings and their systems so that they can implement a continuous improvement/building management process that will provide optimum building performance.

Toyota Kata (TK). Kata is a Continuous Improvement (Lean) methodology to develop everyday habits, skill sets, and capabilities in people, aligned with and in support of achieving the long-term objectives of the organization. **Kata** are structured routines that are practiced deliberately so their pattern becomes habit. The Japanese word comes from the martial arts, where Kata are used to train combatants in fundamental moves. Toyota has applied the Kata approach to business processes. The Improvement Kata and Coaching Kata are for training managers and leaders in a new way of doing their jobs.

TK/BRT utilizes building re-tuning as the content and Kata as the process to learn about and embed Toyota Kata habits into the culture. The idea is to introduce Toyota Kata by using BRT as the content area. The 1-day session will include an introduction to the essentials of BRT and a “walkdown” of the building envelope. BRT & TK both use practiced repeatable behaviors to support sustainability.

- ***Improvement Kata*** will focus on building envelope, which the team will “walkdown” at some point during the 1-day session
- ***Coaching Kata*** will require 1-2 students to become mentors after the training so they can repeat the BRT process for the other building systems. These students will be given the full set of instructor’s notes and tools for the other systems and can do them as Kata exercises or as a kaizen—a team-based continuous improvement exercise.

Target Market. This program is designed to be made available to MEP Centers as a 1-day module offered with or as an add-on to a Lean Certification Program, or included as an in-plant project for a Lean team. The primary customers of MEP Centers are small and medium-sized manufacturers, and the program targets smaller firms without building automation systems. DVIRC’s plan is to deliver it locally, refine it based on feedback, and then make it available to other MEP centers.

Challenges for SME Market. SMEs (with smaller buildings) rightly perceive that building operations typically do not drive their energy consumption. In addition, many SMEs may not have staff that focuses on building operations, or this simply may not be a high priority. As a stand-alone training, it has been difficult to get traction for BRT alone due to the up-front marketing costs and time required for both trainers and companies (2 full days).

Approach. This training module combines the emerging Toyota Kata training with a version of BRT that breaks down the 2-day training into a 1-day training that equips the trainees to learn Kata and conduct a re-tuning on the building envelope during the 1-day training. Then, subsequent re-tuning on the other building systems will be done as Kata Improvement and Coaching exercises by the team that was trained. Participants will be asked to do pre-work, which is often part of Lean-related training.

After the initial 1-day training, the company will select someone from their team who will coach/mentor the team as they apply the principles of BRT/TK to other building systems, repeating the improvement Kata exercises and protocols. The idea, however, is to practice the same routine for each building system, engraining a set of habits and thinking behaviors into the organization, utilizing the tools of the two parts of Kata: the improvement Kata and the coaching Kata.

Toyota Kata & Small & Medium-Sized Building Re-tuning

1-day Training Module

Instructors
Jeff Kopenitz, Director Advanced Manufacturing
Tony Girifalco, Executive Vice President
DVIRC

CONSORTIUM for BUILDING ENERGY INNOVATION

DVIRC

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Slide Deck Contents

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50-56	Building Walkdown—Sample Findings
57-60	Coaching Kata
61-63	BRT—Documentation Phase & Best Practices
64-76	Quantifying Energy Conservation Measures
77-78	Kata/BRT—Next Steps

Goals for this Training

- Building Re-Tuning—What are we trying to do?
- Toyota Kata—In which direction are we going?
- Creating the A3 for Project Management—How are we going about it?
- Basics of BRT—Establishing a "Direction or Challenge"
- Building Walkdown—Grasping the Current Condition
  - Envelope, Lighting & Office Equipment, HVAC, Water Systems
- Defining Energy Conservation Measures
- Establishing Target Conditions—Repeat Exercises
- Plan, Do, Check, Act Cycles

Toyota Kata and BRT—Today's Agenda

- Agenda
- Basics of BRT—Establish a "Target Condition"
- Basics of Toyota Kata—Scientific Approach
- Review of Pre-work—Setting the Challenge
- Building Walkdown—Teambuilding & data collection on 1 or more systems:
  - Envelope, Lighting, Office Equipment, HVAC, Water Systems
- Re-convene—Plan, Do, Check, Act Report outs
- Repeatable process

Small/Medium-Sized Building Re-tuning Training: Definition

- Building re-tuning is a systematic process to identify and **correct low cost operational problems** that lead to energy waste
- Because small/medium-sized buildings will mostly have packaged units for heating and cooling with simple air distribution, and are controlled by a zone thermostat, many of the recommendations for efficiency improvements will be **prescriptive**
- Some of the topics covered are often covered in training associated with energy auditing and retro-commissioning

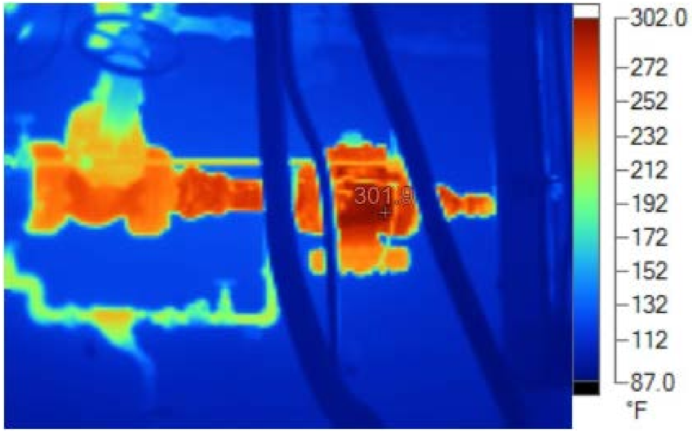
Small/Medium-Sized Building Re-tuning Training: Approach

Typically a four step approach

1. **Initial data collection phase:** Collection of information about the building
2. **Investigation phase:** Building walkdown to identify and characterize the building operations
3. **Implementation phase:** Application of prescriptive re-tuning measures
4. **Documentation phase:** Reporting of measures implemented and calculation of energy savings

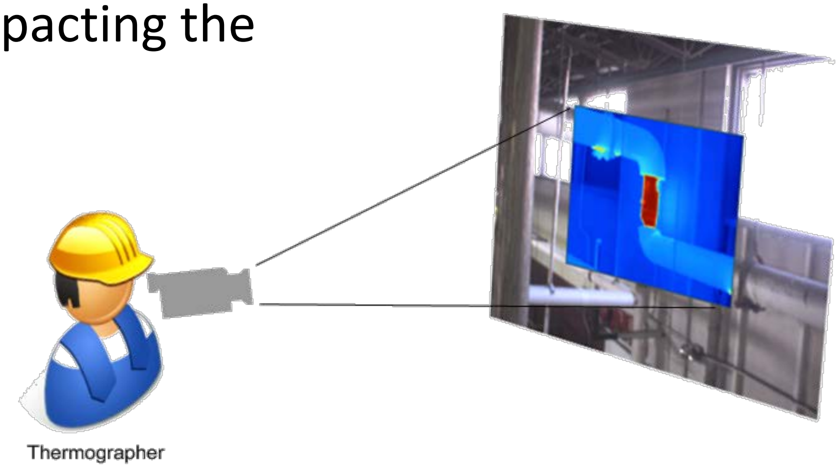
Small/Medium-Sized Building Re-tuning Training: Major Focus Areas

- ❑ Building Envelope
- ❑ Heating, Ventilation and Air-Conditioning Systems and Controls
  - ❑ Packaged air conditioners, heat pumps and gas furnaces
- ❑ Lighting and Lighting Controls
- ❑ Hot Water
- ❑ Office Equipment
- ❑ Air distribution system



Small/Medium-Sized Building Re-tuning Training: Basic Energy Management Principles

- If you don’t need it, turn it off
- If you don’t need it at full power, turn it down
- Make “smart” energy decisions when adjusting systems to the real building needs
- Learn and know your building’s personality
- Save energy without negatively impacting the comfort of the occupants



- INTRODUCTORY MATTER FOR TOYOTA KATA
  - Improvement Kata (IK)
  - Coaching Kata (CK)

PRACTICING FOUNDATIONAL SKILLS FOR SCIENTIFIC THINKING

Visible	Lean tools and techniques to improve quality, cost and delivery	
Less Visible	• A systematic, scientific way of thinking and acting • Managers as the teachers of that way	

What we're focusing on

THE IK & CK GIVE YOU AN EASY WAY TO PRACTICE SCIENTIFIC THINKING

Scientific thinking is a basis for:

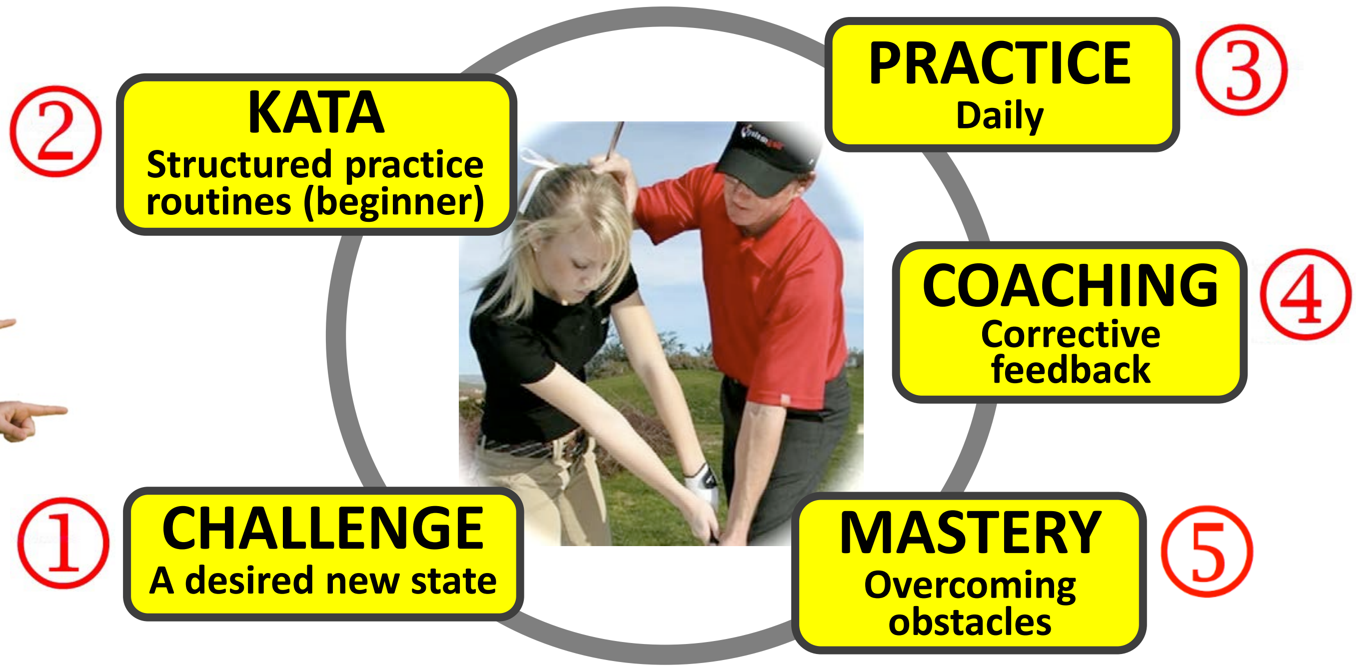
- **Successfully pursuing seemingly unattainable goals in complex systems**
- **Enabling teams to make decisions close to the action and maneuver effectively**

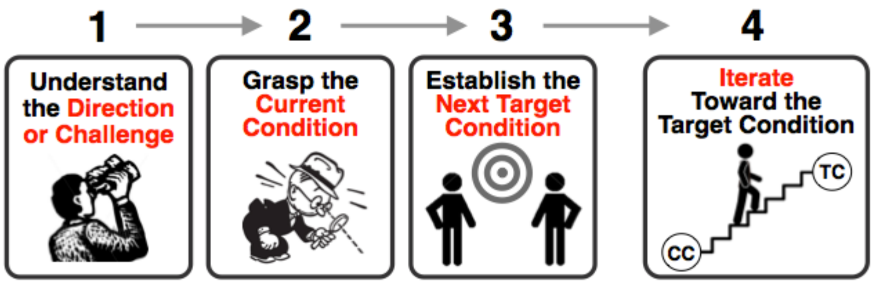
Science + Kata = Problem Solving Skill

The Improvement Kata & Coaching Kata make scientific thinking a skill anyone can learn, by combining a 4-Step scientific pattern + simple, structured routines for practicing the pattern.

5 INGREDIENTS FOR ACQUIRING NEW SKILLS

Brain research is clear: To develop new habits you should practice new routines and experience a progressive sense of mastering them (which helps generate and maintain enthusiasm). The following ingredients help us rewire our brain to acquire new skills and mindset.





THE IMPROVEMENT KATA

The Improvement Kata is a model of the human creative process. It's a 4-step pattern of establishing target conditions and then working iteratively (scientifically) through obstacles, by learning from them and adapting based on what's being learned.

THE COACHING KATA

The Coaching Kata is a pattern for managers to follow in teaching the Improvement Kata pattern in daily work, so that it becomes part of an organization's culture.

THE FOUR STEPS OF THE IMPROVEMENT KATA MODEL

A systematic, scientific pattern of working

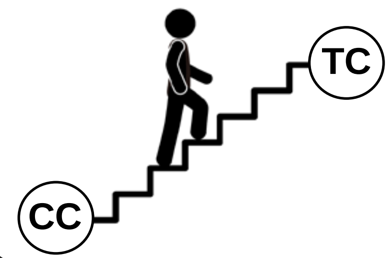
1 → 2 → 3 → 4

1. Understand the Direction or Challenge

2. Grasp the Current Condition

3. Establish the Next Target Condition

4. Iterate Toward the Target Condition



Planning Phase (steps 1–3)

Executing Phase (step 4)

The Improvement Kata combines <u>a scientific pattern</u> with <u>techniques of deliberate practice</u> to develop problem solving skill

By Mike Rother

THE FOUR STEPS OF THE IMPROVEMENT KATA FOR BRT

1 → 2 → 3 → 4

1

Understand the Direction or Challenge

2

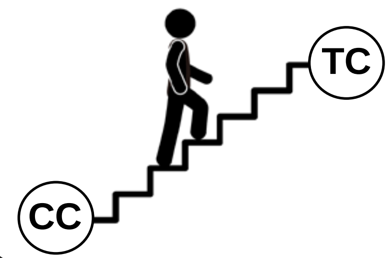
Grasp the Current Condition

3

Establish the Next Target Condition

4

Iterate Toward the Target Condition



Understand the Direction or Challenge

Reduce Building Energy Consumption

Grasp the Current Condition

Utility Bill & "Walkdown" --take notes

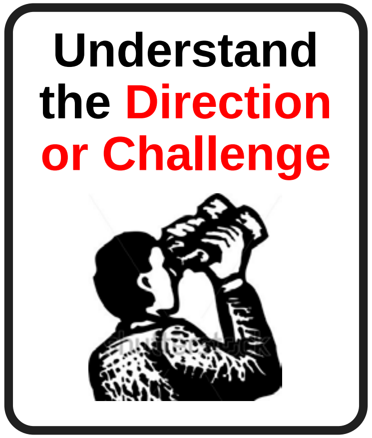
Establish the Next Target Condition

Establish Energy Conservation Measures

Iterate Toward the Target Condition

Implement ECMs

The Direction for Building Re-tuning

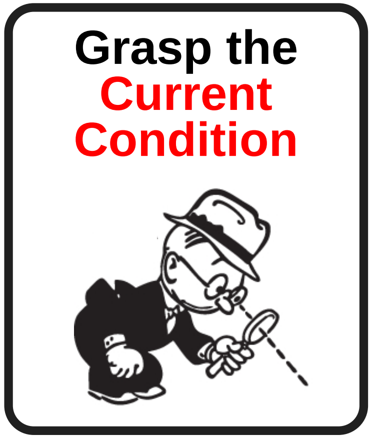


- The Direction, or Challenge, is to reduce building energy consumption by 10% within 12 months

How We Learn— Neuroplasticity

- https://www.youtube.com/watch?v=ELpfYCZa87g

Building Walkdown: Investigation Phase



- This is the second step in the building re-tuning process – the **Investigation Phase**
- Information collected in this step is used to identify the operational problems and energy savings opportunities to plan implementation of re-tuning measures

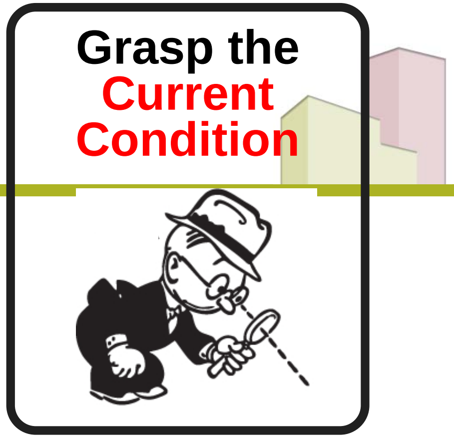
Building Walkdown: Focus Areas

- ❑ Building Envelope
- ❑ HVAC Systems and Controls
- ❑ Lighting Systems and Controls
- ❑ Hot Water
- ❑ Office Equipment
- ❑ Air Distribution Systems
- ❑ Meter Profile
- ❑ Compressed Air (leaks & air pressure)

Grasp the Current Condition

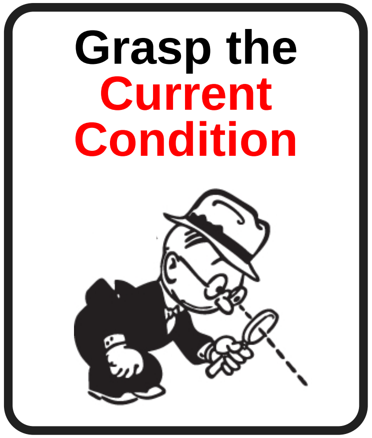
Building Walkdown:
Tools to Carry

Building Walkdown: Guidance



- While investigating the building's condition, be vigilant, use your senses – look, listen, smell and touch!
- Perform the walkdown during both occupied and unoccupied hours (nights and weekends)
- A lot of energy waste typically occurs during unoccupied periods and holidays
- Walkdown at least once during the heating season and once during the cooling season
- Log all information on the log sheets – this will help you calculate energy savings
- Establish **target, short-term conditions for improvement**

Building Walkdown: Envelope



WALKING DOWN THE OUTSIDE (& INSIDE) OF THE BUILDING

Building Envelope Walkdown: Doors and Windows

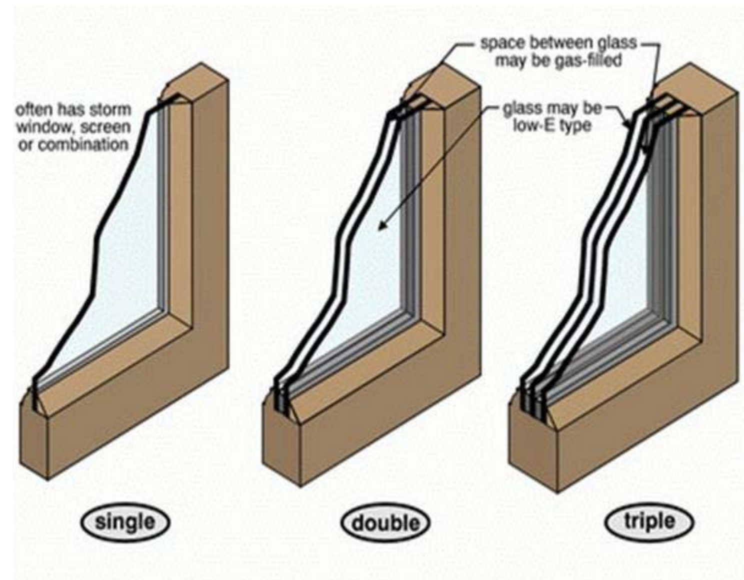
Focus on the exterior conditions of the building

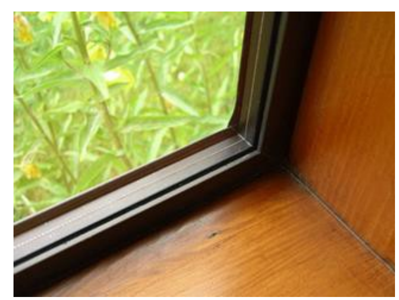
Door and window type:

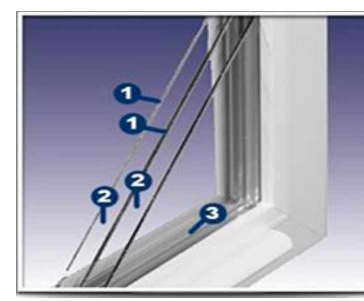
- ❑ Are the windows operable?
- ❑ Are the windows single, double or triple pane?
- ❑ Are any windows and outside doors open during the walkdown?
- ❑ **If windows and doors are open, this could indicate a problem related to heating, cooling or ventilation**

Building Envelope Walkdown: Doors and Windows

- Cost savings for upgrading windows will vary from location to location
- Local utilities may offer incentives to upgrade







Building Envelope Walkdown: Doors and Windows

Door and window seals:

- ❑ Check seals around doors and windows – are there large air gaps?
- ❑ Are the seals missing?
- ❑ Look for cracks in the caulking for the windows, doors and seismic joints
- ❑ Missing caulking?
- ❑ Moisture between panes? Cracks in the panes?

Building Envelope Walkdown: Openings

Cracks and penetrations in the foundation

Gaps under doorways

Use Weatherstripping Calculator

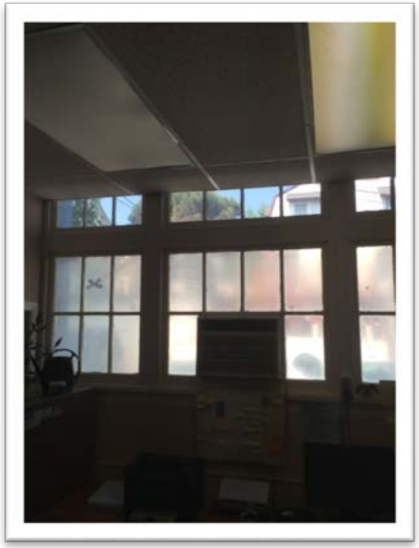
Building Envelope Walkdown: Openings

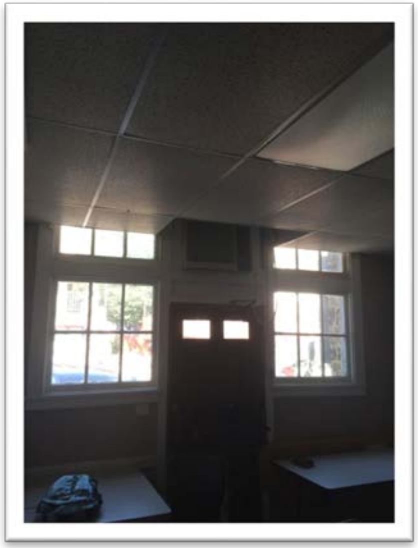
- Lack of insulation around ac unit
- Old caulking worn off



Building Envelope Walkdown: Shades

- Operable shades, if used properly, can reduce cooling load in summer time (fully closed) and provide day lighting and solar heat gain during winter time (open)
- Check if shades are being used appropriately
- If the windows are missing shades or not using shades, recommend adding shades and using them properly





Building Envelope Walkdown:
Unsealed Penetrations in the Envelope

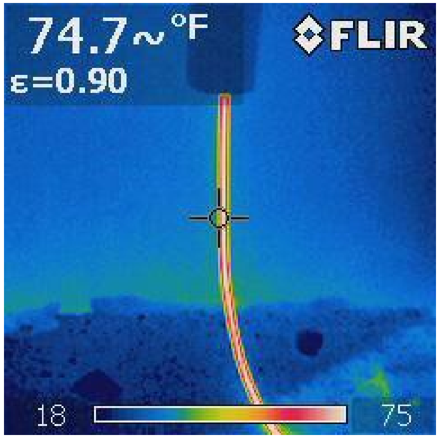
Are there unsealed penetrations in the building?

- ❑ Look for penetrations around seams or pipe penetrations in the building envelope
- ❑ Improperly sealed holes will allow for increased infiltration into the building, which will lead to increased heating and cooling loads on the HVAC equipment
- ❑ Have there been any problems or indication of vermin (mice or rats) entering the building? **This could be a health safety issue**

Building Envelope Walkdown: Heat Traces and other exterior plug loads

Some buildings may use heat traces on outside water lines, gutters or storm drains to avoid freezing or ice/snow build up

- Touch and feel for heat (be careful!) – better to use thermal camera
- If they are on during summer, spring or fall, recommend that they be turned off until needed

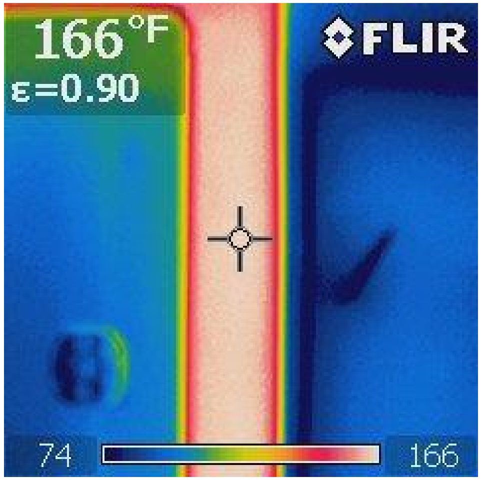


Building Envelope Walkdown: Insulation

- Use a temperature gun (or infrared camera) and take temperature readings of the walls and the ceiling
- Look for missing insulation on any piping that carries heated or chilled water or steam
- Missing insulation will contribute to energy costs and is a low cost fix

Use Insulation Calculator & 3E Plus Program

Heat loss in thermal envelope

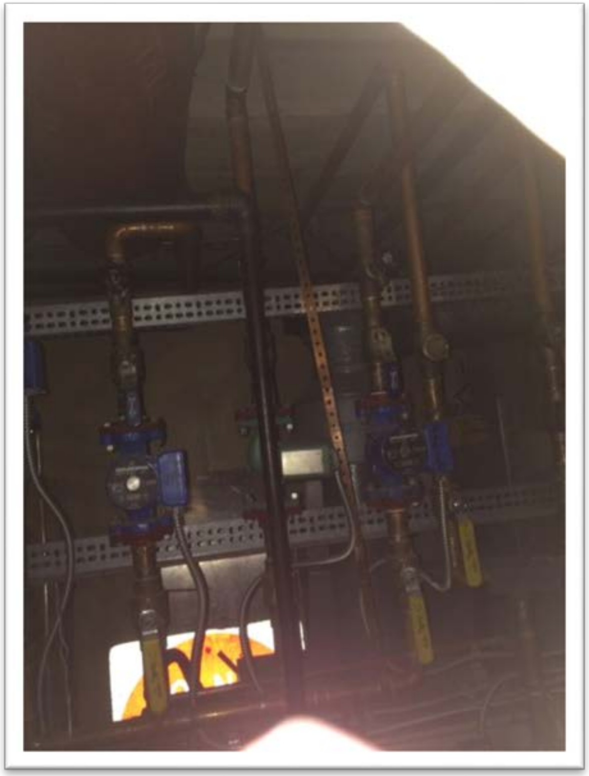


Building Envelope Walkdown: Insulation

- If the perimeter wall temperature of a perimeter office/space is significantly different from the other interior wall temperatures of the same space, the perimeter wall may not have adequate insulation or it has been compromised at strategic locations that should be further evaluated for potential improvements.
- A well- insulated wall should show a large temperature difference between the outdoor and indoor temperature

Building Envelope Walkdown: Insulation

- Lack of insulation for pipes
- Suction line needs to be properly insulated



Building Envelope Walkdown: Roof

- Is the roof white?
- Is it clean and no debris?
- A white membrane roof needs to be clean; it has its best insulating properties when the roof is clean
- As much as 3 degrees of improvement in heat rejection versus a dirty roof

Source: http://www.daisygreenmagazine.co.uk/lifestyle-main/features- living/paint-the-town-white/ Dec. 11, 2012

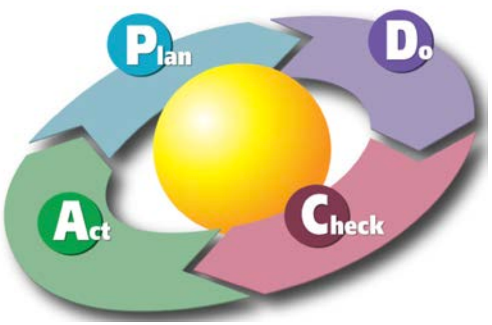
Building Envelope Walkdown: Attic and Crawl Spaces

- ❑ Ventilation of attic and crawl spaces
  - ❑ Look for crawl space vents and attic vents that are closed or plugged
- ❑ Look for powered exhaust in attics
  - ❑ Do they have backdraft dampers?
  - ❑ Check if the temperature controls for the fan are working
- ❑ Look for missing or damaged insulation in attic or crawl spaces
  - ❑ Damaged by water or animals?
  - ❑ Hanging loose from roof deck?
- ❑ Look for abandoned vents in lunchrooms (that were used to exhaust stove heat)
  - ❑ These abandoned legacy vents can let outdoor air into the building if not properly sealed.

WHY KATA FOR CONTINUOUS IMPROVEMENT?

'Continuous' means many minds engaged in improving their processes, and daily cycles of experimentation.

Yet our existing work routines rarely include improvement.



Systematically and scientifically improving processes is a complex skill set we are not naturally good at!

We can learn systematic, scientific improvement through deliberate practice of the Improvement Kata routines

THE IK & CK INCLUDE PRACTICE ROUTINES

The Improvement Kata & Coaching Kata don't just model a way of working, they also include *structured practice routines* to make their pattern teachable and transferrable. This is a way to build improvement capability into an organization and make effective empowerment possible.

A team or organization that's pursuing continuous improvement will do well to use some structured practice routines -- Kata -- for developing new behavior, habits and culture, especially at the beginning.

THE IMPROVEMENT KATA PATTERN IS A SCIENTIFIC APPROACH

Since the path to a challenging goal cannot be predicted with exactness, we have to find that path by experimenting like a scientist. With each insight a scientist adjusts his/her course to take advantage of what has just been learned.

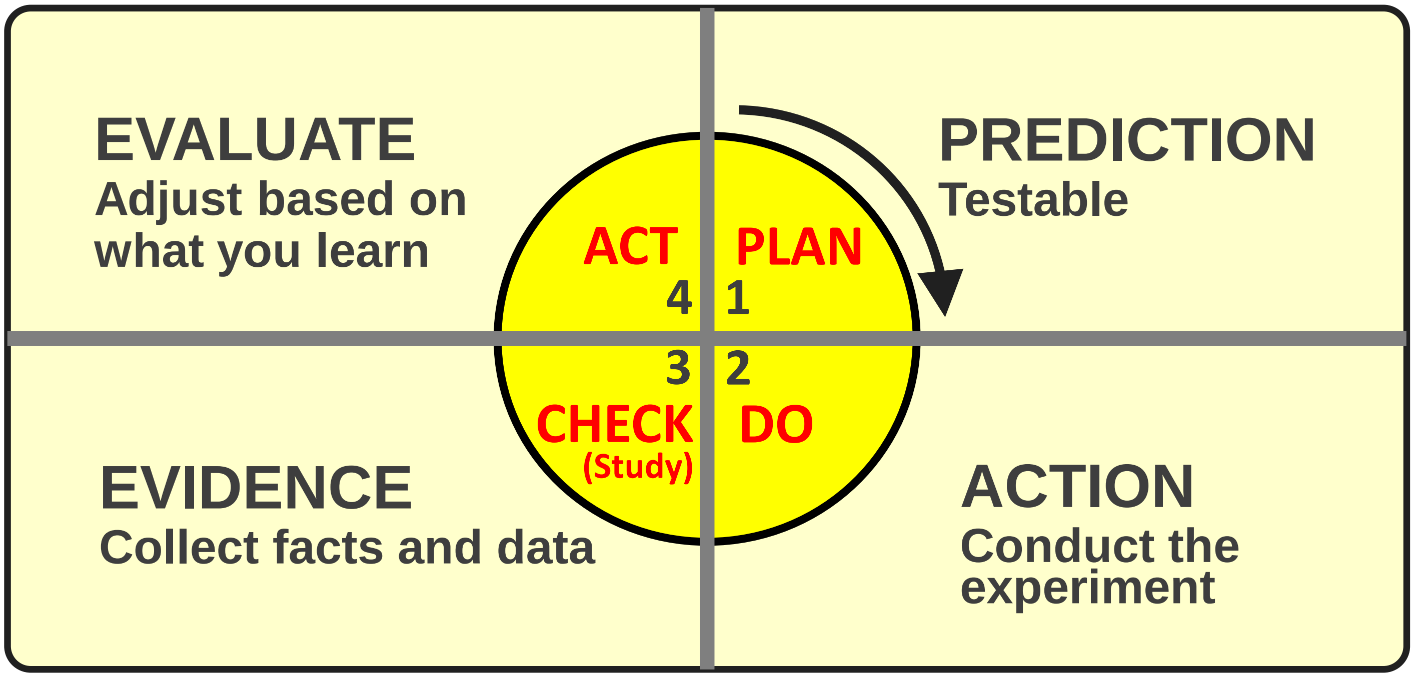
The scientific process helps you find the path not by telling you what's ahead.

It only confirms or refutes the results of experiments.

One trick to making effective progress toward a goal is not to try to *decide* the way forward, but to have your team *iterate* its way forward by experimenting as cheaply and rapidly as possible. This is the *action of innovation* and it can be taught.

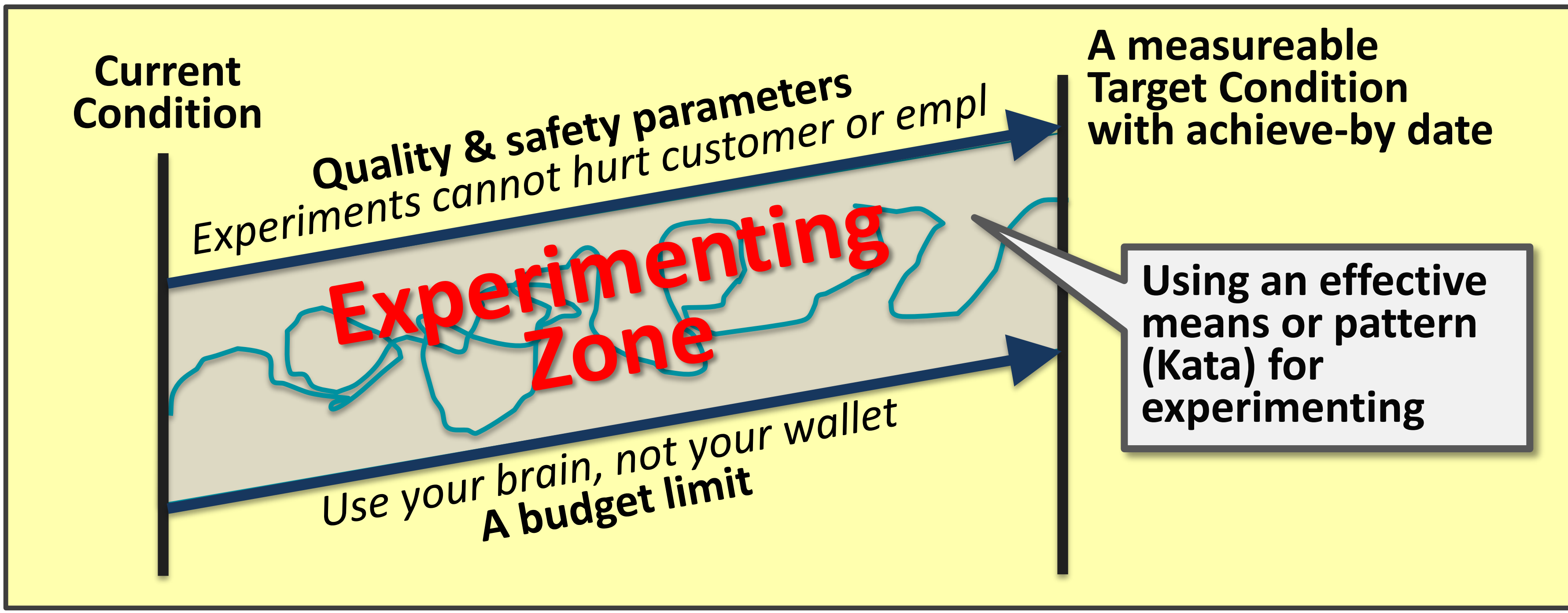
THE SCIENTIFIC LEARNING CYCLE

Is sometimes called
"Plan-Do-Check-Act" or "Plan-Do-Study-Act"



DO YOUR TESTS IN THE "EXPERIMENTING ZONE"

The Target Condition is measureable and has a firm achieve-by date. There are budget constraints and quality & safety parameters. There's an effective way (Kata) of carrying out experiments



It's *within* these boundary conditions that we design and conduct frequent, rapid, cheap, non-harmful, successive experiments toward the Target Condition. Experiments are done as cheaply, quickly and safely as possible.

LEVELS OF IK/CK SKILL DEVELOPMENT

To coach the Improvement Kata, managers first need experience with applying the Improvement Kata

Able to EVOLVE it

Now an organization can evolve its own Kata (practice routines)

Able to TEACH it

Here you understand the thinking behind the Kata and can teach others

Able to DO it

Skill development begins here

Learning begins when you start applying the Improvement Kata yourself

AWARE of it

Concepts alone generally don't change anything

There is a
LEARNING PROGRESSION

Able to TEACH it — ***Developing Others***

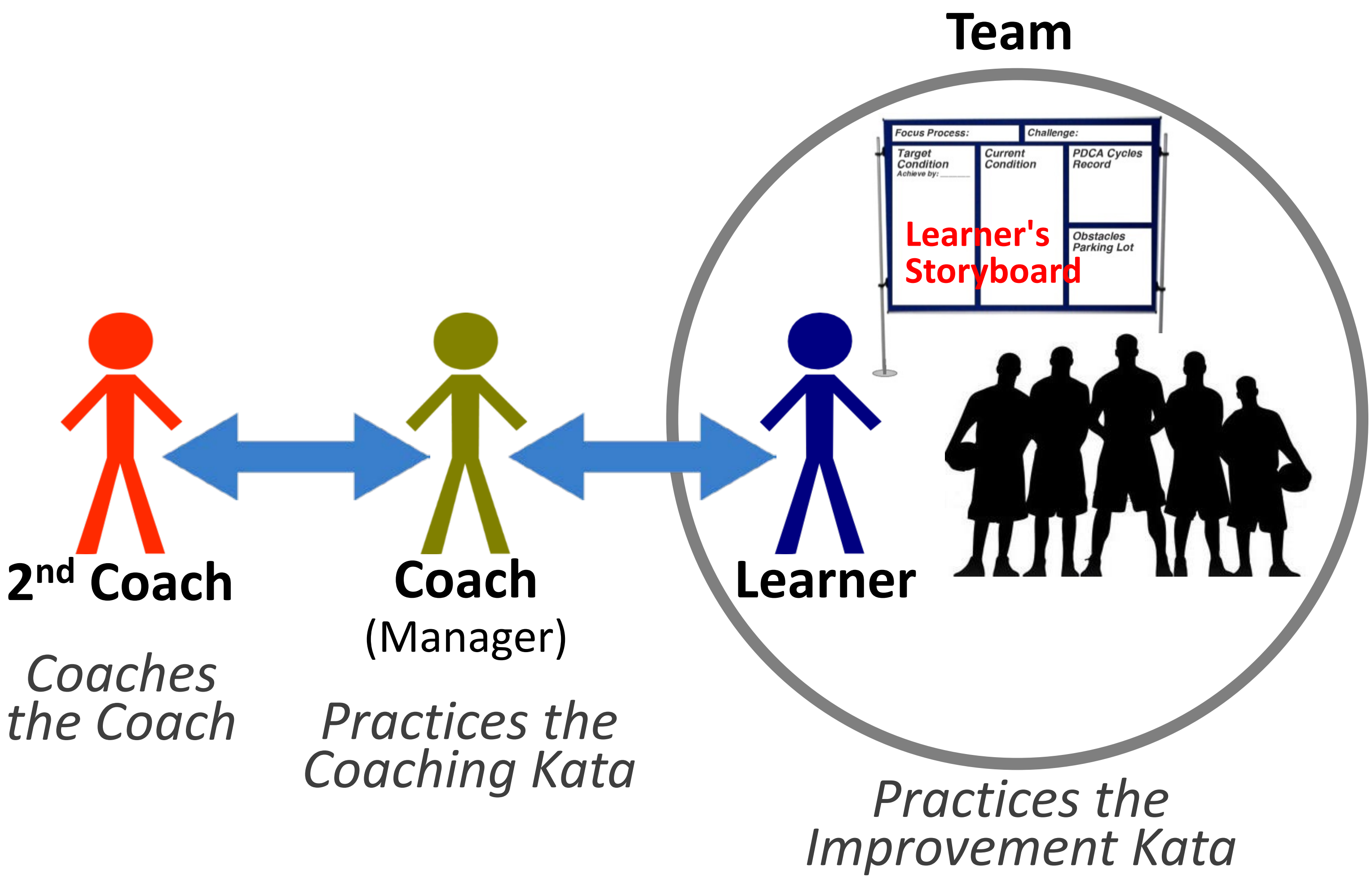
Able to DO it — ***Self Development***

AWARE of it

Sorry, no
way around it

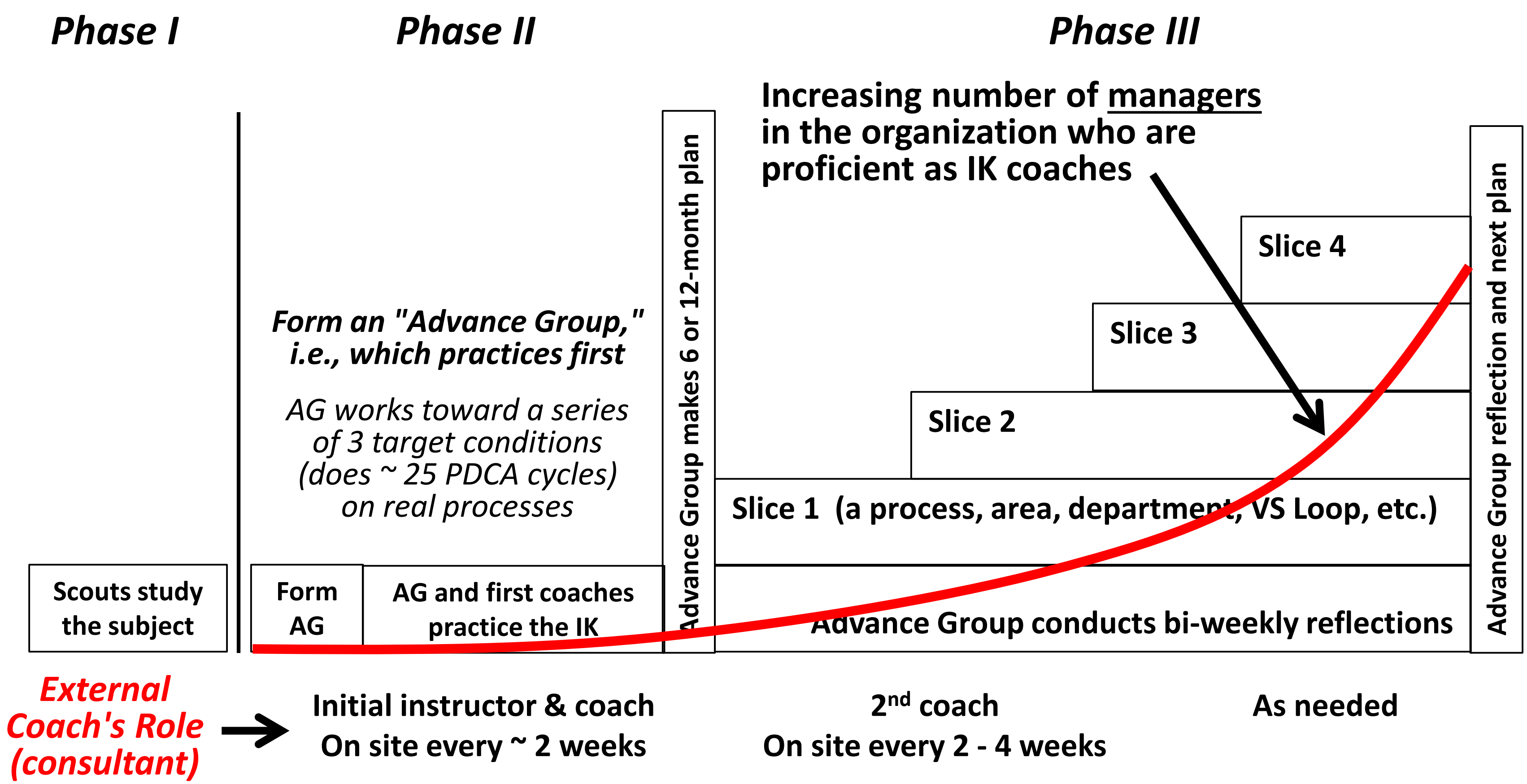
By Mike Rother

Roles / Org Structure for Practicing



WHAT DEPLOYMENT OFTEN LOOKS LIKE

Don't try to expand Improvment Kata practice faster than you can develop internal Coaching Kata proficiency!



COACHING KATA

The Five Questions

1) What is the **Target Condition**?
2) What is the **Actual Condition** now?

--------*(Turn Card Over)*-------------------->

3) What **Obstacles** do you think are preventing you from reaching the target condition?

   Which *one* are you addressing now?

4) What is your **Next Step**? (Next experiment) What do you expect?
5) How quickly can we go and see what we **Have Learned** from taking that step?

*You'll often work on the same obstacle with several experiments

Reflect on the Last Step Taken

Because you don't actually know what the result of a step will be!

1) What did you plan as your **Last Step?**
2) What did you **Expect?**
3) What **Actually Happened?**
4) What did you **Learn?**

------------------------------->
Return to question 3

Card is downloadable at:
http://www-personal.umich.edu/~mrother/KATA_Files/5Q_Card.pdf

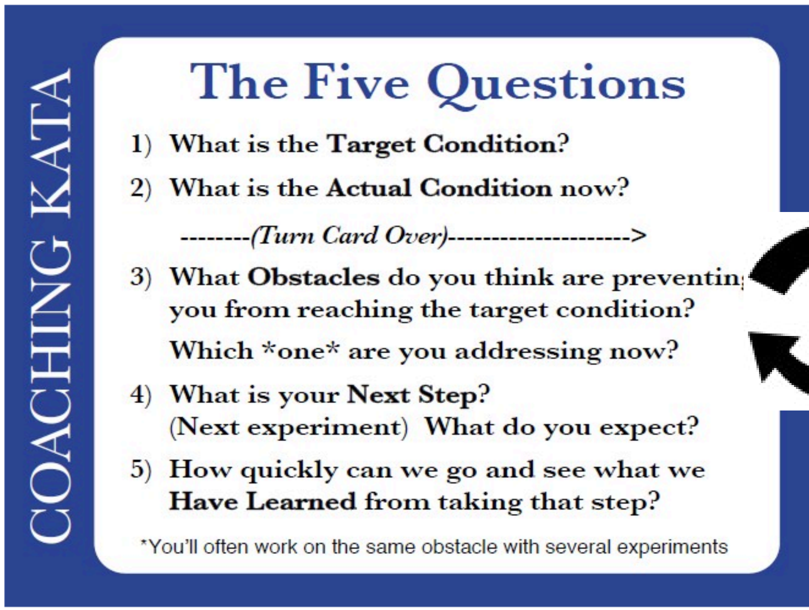
PDCA CYCLES RECORD *(Each row = one experiment)*

Obstacle:	Process:	
	Learner:	Coach:

Date, step & metric	What do we expect?	Do a Coaching Cycle	Conduct the Experiment	What happened	What we learned

The Five Coaching Kata Questions and the PDCA Cycles Record are used together

5-Question Coaching Dialog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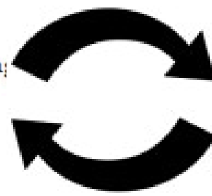
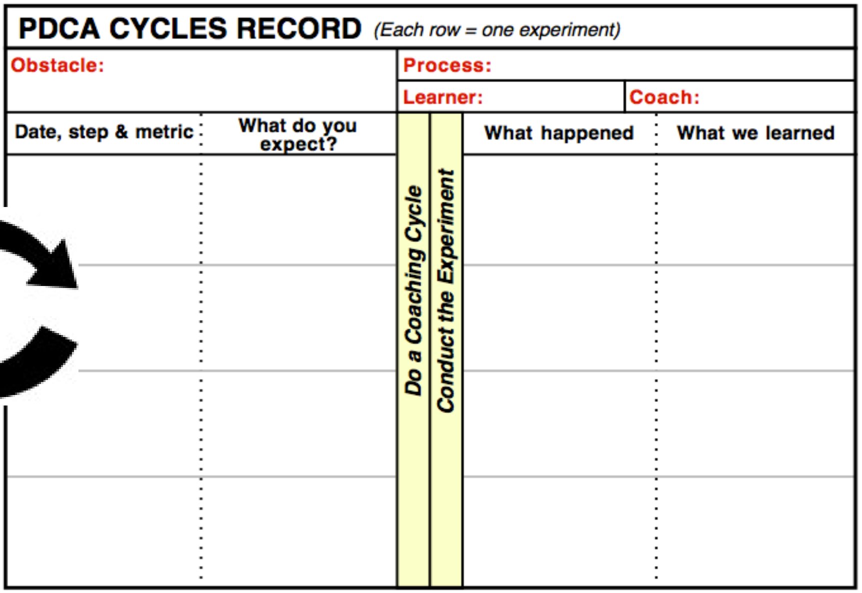


Rapid PDCA Cycles



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Date, step & metric	What do you expect?	*Do a Coaching Cycle*	*Conduct the Experiment*	What happened	What we learned

Used by the Coach

Used by the Learner

By Mike Rother

ASK THE FIVE QUESTIONS AT EACH STEP

PDCA CYCLES RECORD *(Each row = one experiment)*

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Building Walkdown: Sample Findings

Building Envelope

SOLUTION

Remove and replace the door seal weather stripping!
Remember, you can get an estimate of the savings by calculating the BTU loss/gain.

Roll Up Doors

SOLUTION

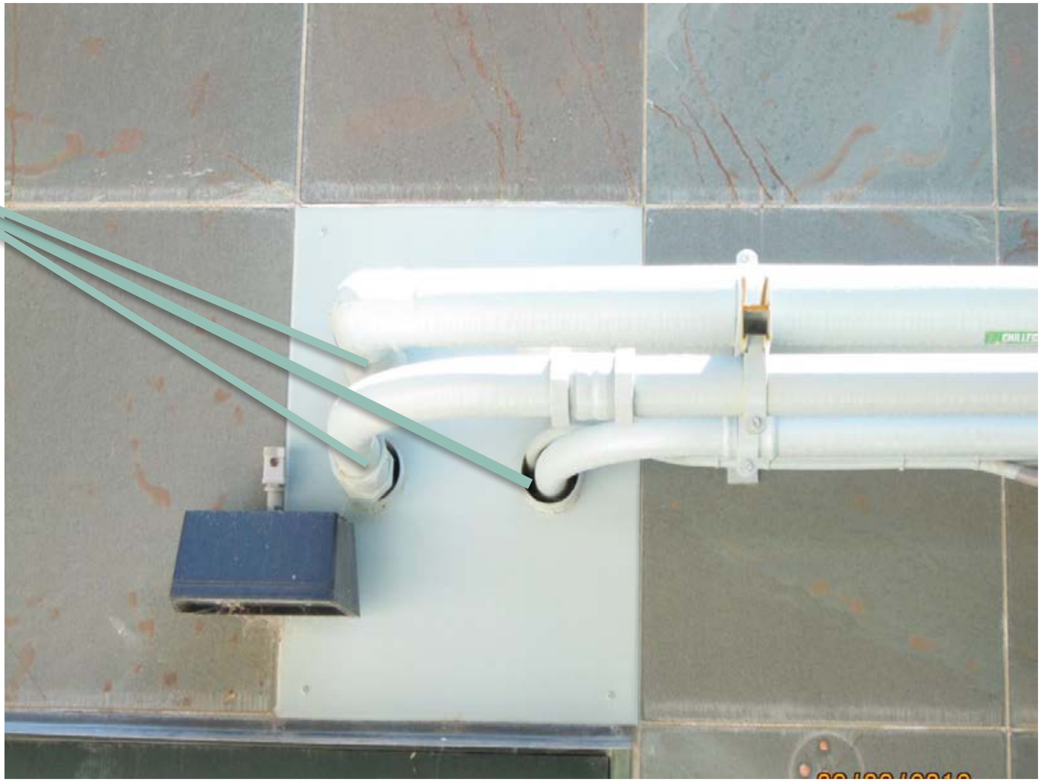
The door opening can be integrated to the HVAC system, so if it is open for more than a few minutes, the HVAC unit is turned off (or simply close the door). Also make sure the exterior lighting control is working (photocell, timer, etc.).

Building Envelope

SOLUTION **Trim the bushes or trees away from the grills**

Implementation: Exterior Wall Penetrations

Pipe chases for piping should be sealed on the inside or outside (or both)



SOLUTION

Pipe penetrations often occur from upgrades. Penetrations created by piping (gas, water, electrical, etc.) should be properly sealed.

Implementation:
Building Exterior Plug Loads – Heat Trace

Use Thermal Camera or other temperature device

SOLUTION

Heat trace should be off when not needed. Heat trace controls should be reviewed seasonally for proper temperature set points and operation.

Building HVAC Implementation: Louvers and Grills

- Clean the intake screens on rooftop equipment before they become plugged

Coaching Kata—The Five Questions
Plan-Do-Check Act Cycle

COACHING KATA

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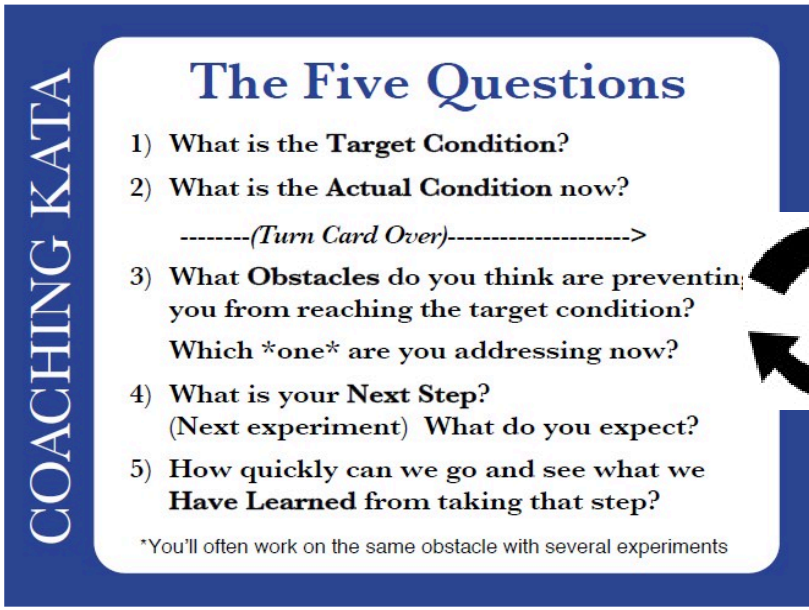

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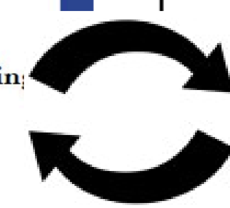

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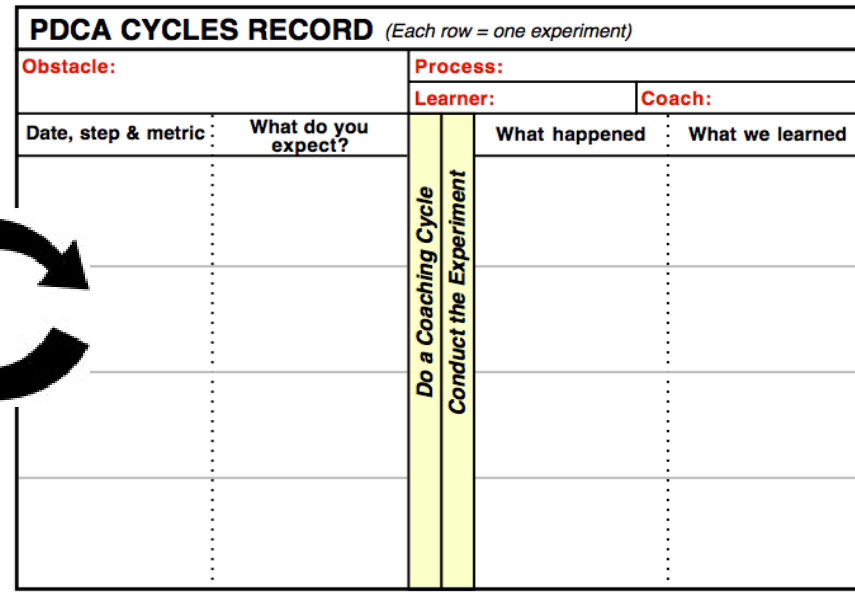

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Obstacle:

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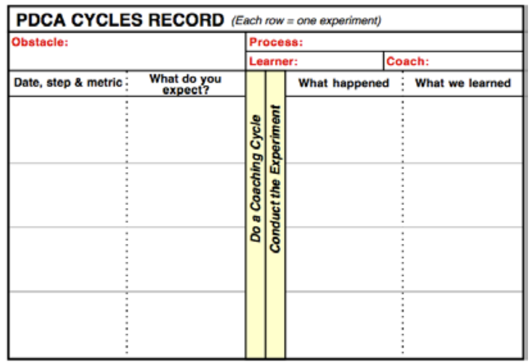

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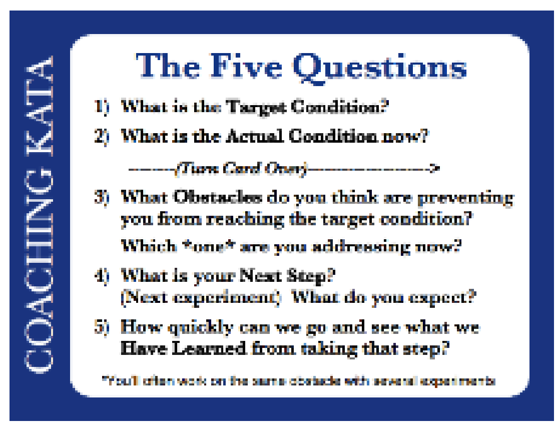

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Small/Medium-Sized Building Re-tuning Training: Documentation Phase and Best Practices

Documentation Phase

- Document prescriptive re-tuning measures by cost (no/low-medium-high)
- Select which measures are appropriate for implementation for the building based on:
  - Cost
  - Ease of implementation
  - Return on investment
  - Indoor Environmental Improvement
  - Safety and Security
- Document the selected measures so that calculation and realization of energy savings are possible

Best Practices

- Re-tuning is an ongoing process
  - Do it quarterly or at least every six months OR
  - If you see an increase in energy consumption or occupant complaints
- Every set point adjustment you make will have an impact on the utility meter
- You can save energy and keep staff comfortable
- It takes time to tune a building; there are no magic set points that work all the time (each building is unique)
- Look at the big picture when making adjustments
- Learn and know your building's personality
- Basic Energy Management
  - If you do not need it, turn it off
  - If you do not need it at full power, turn it down
  - Make the energy system smart when adjusting to the real needs of the building

Quantifying Energy Conservation Measures (ECMs)

Establish the
Next Target
Condition

Establish
Energy
Conservation
Measures

Energy Conservation Measures (ECMs)

- Any change that impacts an area of building operation or modifications that reduces building energy use
- Ideal Building Re-Tuning (BRT) ECMs
  - Low-medium effort (required)
    - A few hours to implement
  - Medium-high savings (preferred)
    - At least 5-10% savings of energy (for specific area) saved
- What if only high-effort ECMs identified
  - Can be implemented when a major retrofit takes place (when later planned) or be integrated into a capital improvement plan

Energy Conservation Measures (ECMs)

Building Envelope

- Weather-strip doors and windows
- Caulk gaps in building

HVAC & Controls

- Keep chiller temperature as high as possible
- Test boiler efficiency on a continuing basis

Lighting

- Replace fluorescent lamps with higher efficiency ones
- Install occupancy or vacancy sensors
- De-lamping/reducing lighting in over-lit areas

Water Heating

- Minimize the hot water temperature
- Install instantaneous hot water

Energy Conservation Measures: Top Three ECMs Based on SAVINGS

ECM	CATEGORY	EFFORT	ESTIMATE	PAYBACK
Replace fluorescent lights and/or ballasts with higher efficient ones	Lighting	Medium	10-30% of lighting energy	2-5 years
Applying Low-E film / adding Low-E panes	Building Envelope	Low/Medium	10% of total energy costs	2-6 years
Optimize boiler air-fuel ratio	HVAC	Medium	1-10% of fuel costs	0-1 year

Source: Modified from *Energy Efficiency Manual,* Wulfinghoff

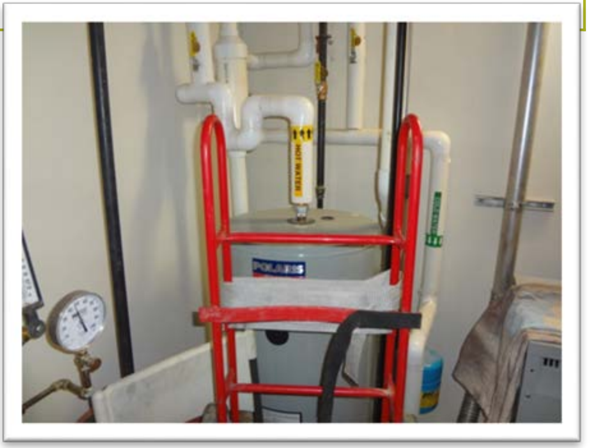
Energy Conservation Measures: Top Three ECMs Based on EFFORT

ECM	CATEGORY	EFFORT	HOURS	LABOR COST
Keep chiller temperature as high as possible	HVAC	Low	0	0
Minimize the hot water temperature	Water-heating	Low	0	0
Use temperature setbacks for programmable thermostats	Sensors & Controls	Low	0	0

Source: *Energy Efficiency Manual,* Wulfinghoff

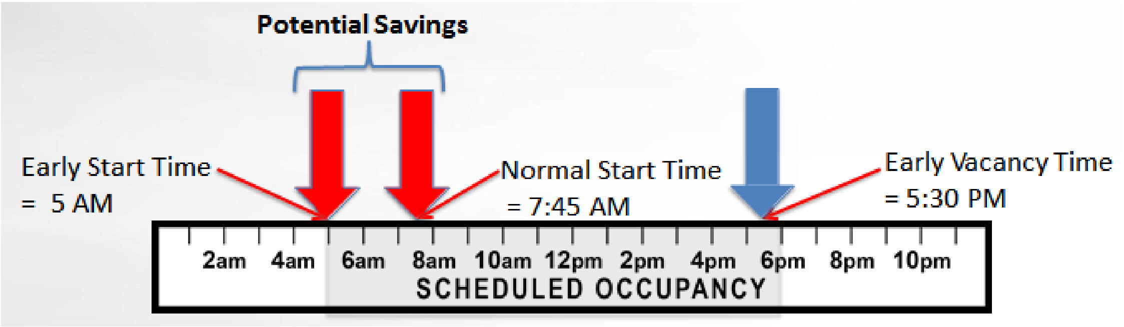
Energy Conservation Measures: Medium Effort / High Savings ECM

ECM Category	ECM Description	Effort/ Savings
Domestic Hot Water ECM	**Replace Existing DHW System with an On-Demand Water Heater** Tankless natural gas or electric water heaters typically result in energy savings on the order of 8% to 25%. Tankless water heaters eliminate standby energy losses associated with hot water storage tanks.	**Medium/High**



Energy Conservation Measures:
Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
Air Distribution Systems	**Implement an HVAC System Night Setback Schedule** For all HVAC systems that serve intermittent-occupancy rooms or non 24/7 areas, make sure that night setback controls have been implemented. Conference rooms, especially, have intermittent use. You have only a few zones, but if managed properly, you can realize energy savings > 10%.	**Low/Medium**



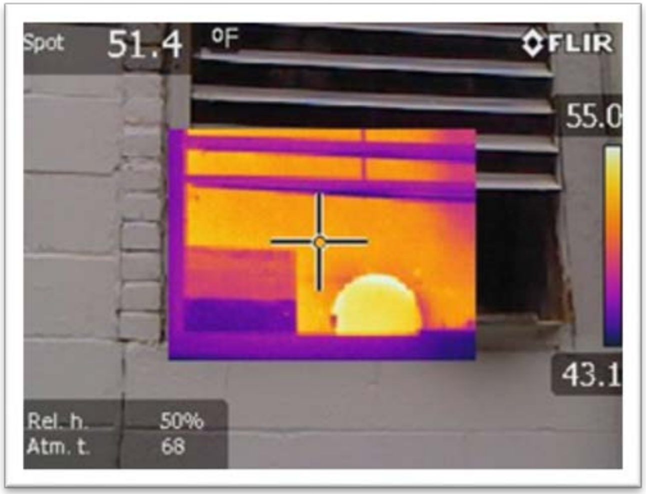
Energy Conservation Measures: Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
HVAC	**Verify Proper Operation of Air-side Economizer** Check the DDC system control sequence to see if the current control system is using an air-side economizer. Make sure the economizer is working correctly by viewing damper positions and outside airflow rates at different outside air temperatures.	**Low/Medium**

Economizer damper closed with 65°F outside air temperature

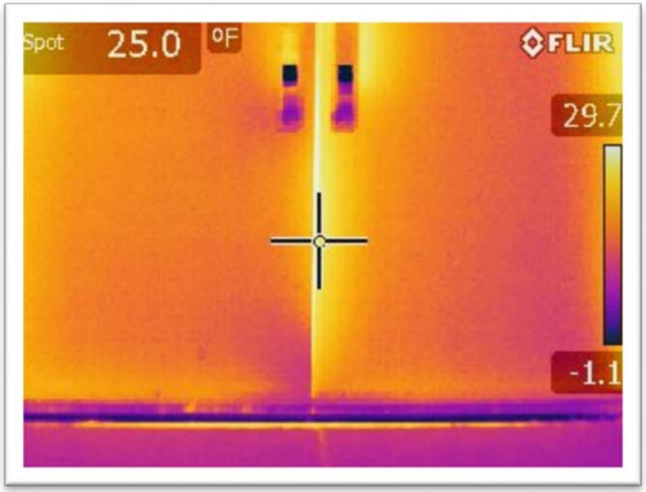
Energy Conservation Measures: Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
Envelope	Seal areas of infiltration using caulk or weather-stripping to reduce the thermal exchange that takes place at openings.	Low/Medium



Energy Conservation Measures:
Low Effort / Low Savings ECM

ECM Category	ECM Description	Effort/ Savings
Envelope	**Seal Penetrations in Building Envelope Including Door Gaps** Energy loss is proportional to inside/outside temperature difference	**Low/Low-Medium**



Energy Conservation Measures: Low Effort / Medium Savings ECM

ECM Category	ECM Description	Effort/ Savings
Domestic Hot Water	**Insulate Hot Water Pipes** Pipe insulation reduces heat loss through distribution pipes and increases overall system efficiency. Any heated pipe with exterior temperatures over 120°F should be insulated.	**Low/Medium**

Energy Conservation Measures:
Example: Calculating pipe insulation savings

- 3E Plus: http://www.pipeinsulation.org/
- Obtain per unit heat loss from the software and plug it into an Excel sheet (available from DOE)

Summary of Energy and Cost Savings

Pipe Description	Length (ft)	Bare Pipe Heat Loss (Btu/h ft)	Suggested Insulation and Thickness	Insulated Pipe Heat Loss (Btu/h ft)	Energy Savings (MMBtu/yr)	Cost Savings (per year)
Steam Supply Line - Boiler Room	25	264	0.5" of Mineral Fiber C547-93 C2	42	14.4	$36
Hot Water Line - Rendering	100	300	1" of Mineral Fiber C547-93 C2	55	268.3	$671
Supply Line - Pellet Mill	150	450	1.5" of Mineral Fiber C547-93 C2	75	234.0	$585
Hot Water Line - Gluer	50	275	2" of Mineral Fiber C547-93 C2	40	41.1	$103
Steam Supply - Corrugator	50	575	3" of Mineral Fiber C547-93 C2	200	136.5	$341
TOTALS					694.3	$1,736

Building Envelope Walkdown: Calculations

Table 3 - Summary of Energy and Cost Savings						
				Insulated		
		Bare Pipe		Pipe	Energy	Cost
Pipe	Length	Heat Loss	Suggested Insulation	Heat Loss	Savings	Savings
Description	(ft)	(Btu/h ft)	and Thickness	(Btu/h ft)	(MMBtu/yr)	(per year)
Steam Supply Line - Boiler Room	25	264	0.5" of Mineral Fiber C547-93 C2	42	14.4	$36
Hot Water Line - Rendering	100	300	1" of Mineral Fiber C547-93 C2	55	268.3	$671
Supply Line - Pellet Mill	150	450	1.5" of Mineral Fiber C547-93 C2	75	234.0	$585
Hot Water Line - Gluer	50	275	2" of Mineral Fiber C547-93 C2	40	41.1	$103
Steam Supply - Corrugator	50	575	3" of Mineral Fiber C547-93 C2	200	136.5	$341
TOTALS					694.3	$1,736

Table 4 - Implementation Cost					
			Insulation		Simple
Pipe	CS	Suggested Insulation	Cost	Total	Payback
Description	per year	and Thickness	per foot	Cost	years
Steam Supply Line - Boiler Room	$36	0.5" of Mineral Fiber C547-93 C2	$4.11	$103	2.9
Hot Water Line - Rendering	$671	1" of Mineral Fiber C547-93 C2	$4.52	$452	0.7
Supply Line - Pellet Mill	$585	1.5" of Mineral Fiber C547-93 C2	$5.95	$893	1.5
Hot Water Line - Gluer	$103	2" of Mineral Fiber C547-93 C2	$7.75	$388	3.8
Steam Supply - Corrugator	$341	3" of Mineral Fiber C547-93 C2	$9.95	$498	1.5
TOTALS	$1,736			$2,334	1.3

KATA/BRT—Next Steps

- Apply the approach learned here to other building systems under mentorship in ½-day sessions
- Could be different mentor for each system
  - Heating, Ventilation and Air-Conditioning Systems and Controls, including Packaged air conditioners, heat pumps and gas furnaces
  - Lighting and Lighting Controls
  - Hot Water
  - Office Equipment

KATA/Building Re-Tuning Training: Program Wrap-Up

- ❑ Final Comments
- ❑ Evaluation
- ❑ **Thank You!**