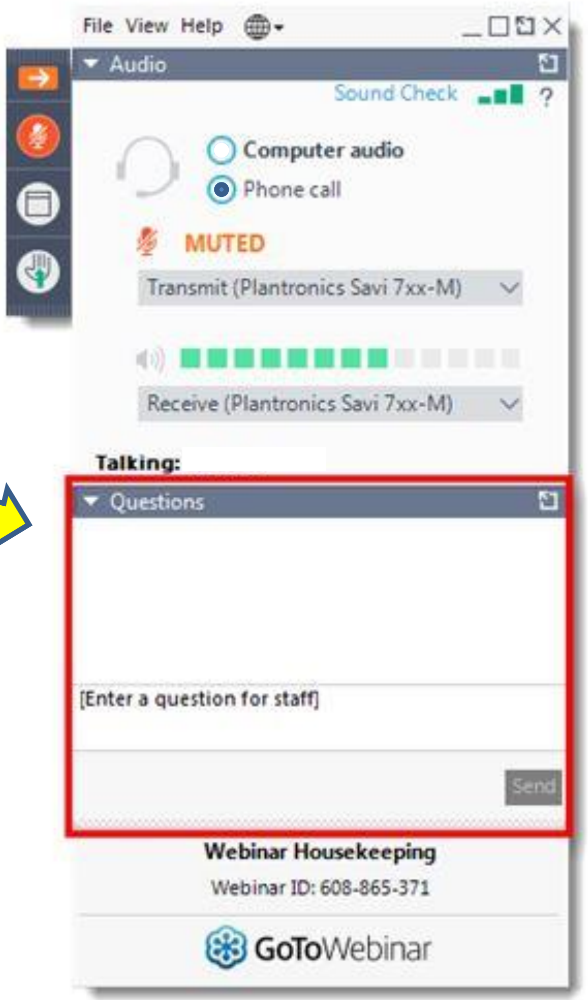
Improving Building Performance through Controls and Analytics

SRINIVAS KATIPAMULA, PHD AND RONALD UNDERHILL

Pacific Northwest National Laboratory
Washington State University Energy Extension Services Webinar Series

Webinar Housekeeping Logistics

- Minimize or maximize control panel
- Phone lines are muted
- Please use question pane to ask questions at any time, or if you have any technical issues



NOTE: Today's presentation is being recorded and will be available at http://www.energy.wsu.edu/PublicFacilitiesSupport/ResourceConservation.aspx

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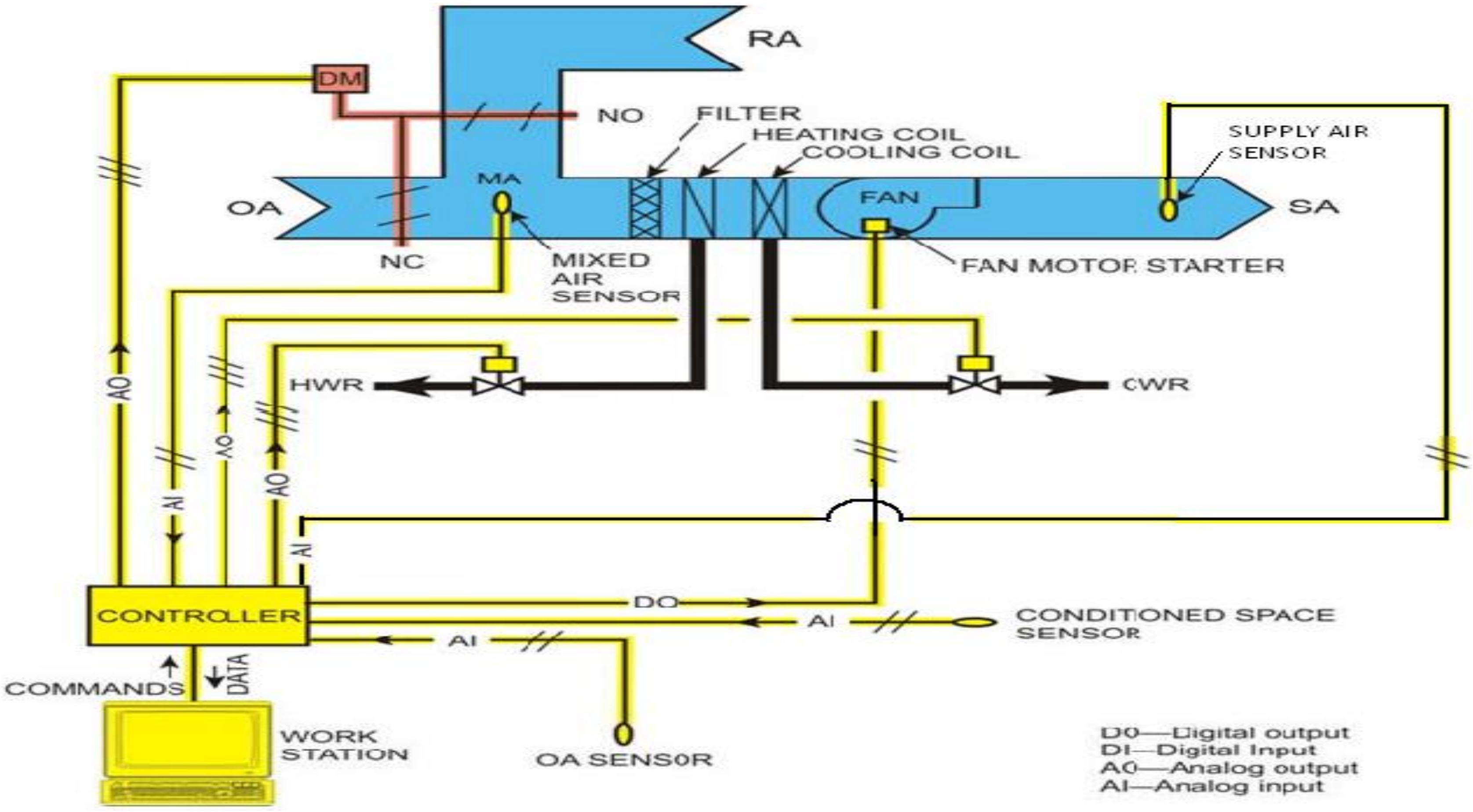
Presentation Overview

- A look at direct digital control of some commonly used heating, ventilation and air conditioning systems
- Improving building operations using building analytics
- Case studies
- Question and Answer

Single Zone AHU Control Application with DDC Controller



Courtesy LAMA Books

Variable-Air-Volume AHU System with Reheat

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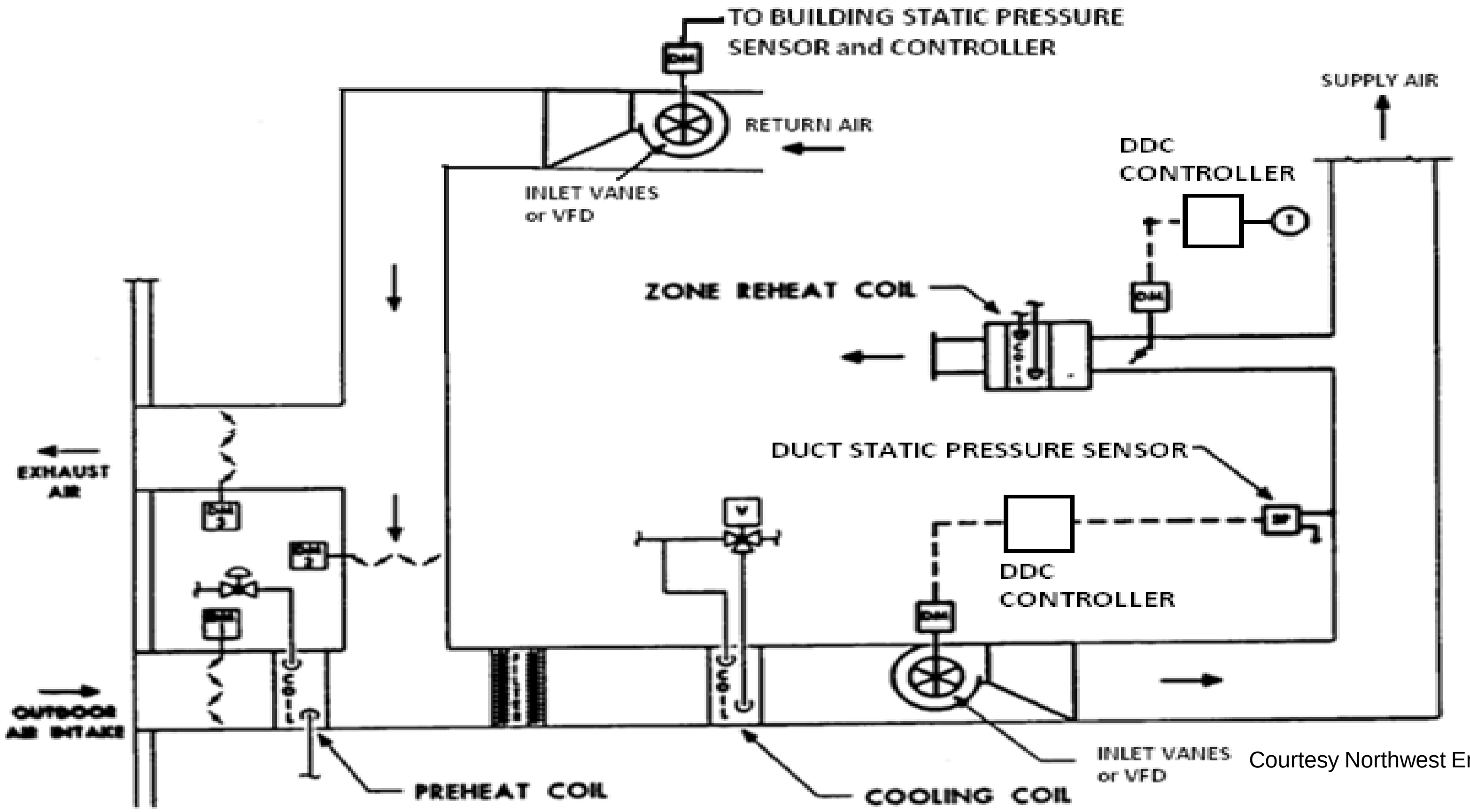

Courtesy Northwest Energy Efficiency Council

- VAV systems vary the air supplied to each zone depending on the load, saving fan energy
- VAV systems typically use cooling only air handlers with reheat at the zones
- Volume of air delivered is varied using inlet dampers or electronic speed controls (variable frequency drives) based on supply duct static pressure set point

Energy Management Techniques of HVAC Systems

- Various AHU Fan Systems
- Single Zone/Constant Volume Systems
  - Reset discharge air temperatures and mixed air temperatures based on zone requirements.
- Variable Air Volume (VAV)
  - Use VFD at the fan motor; supply and return fans should track together, but never at the expense of building pressurization (control return fan speed for slightly positive building static pressure)
  - Create an automatic discharge static pressure set point reset algorithm (based upon VAV damper position feedback) with scheduled set point reductions (during nights and weekend vacancy periods – to account for occasional after-hours work)
  - Reset discharge air temperatures and mixed air temperatures based upon zone requirements
  - Ensure VAV terminal boxes are correctly configured for ventilation requirements (area and population count – realistic population count)

General Energy Management Techniques

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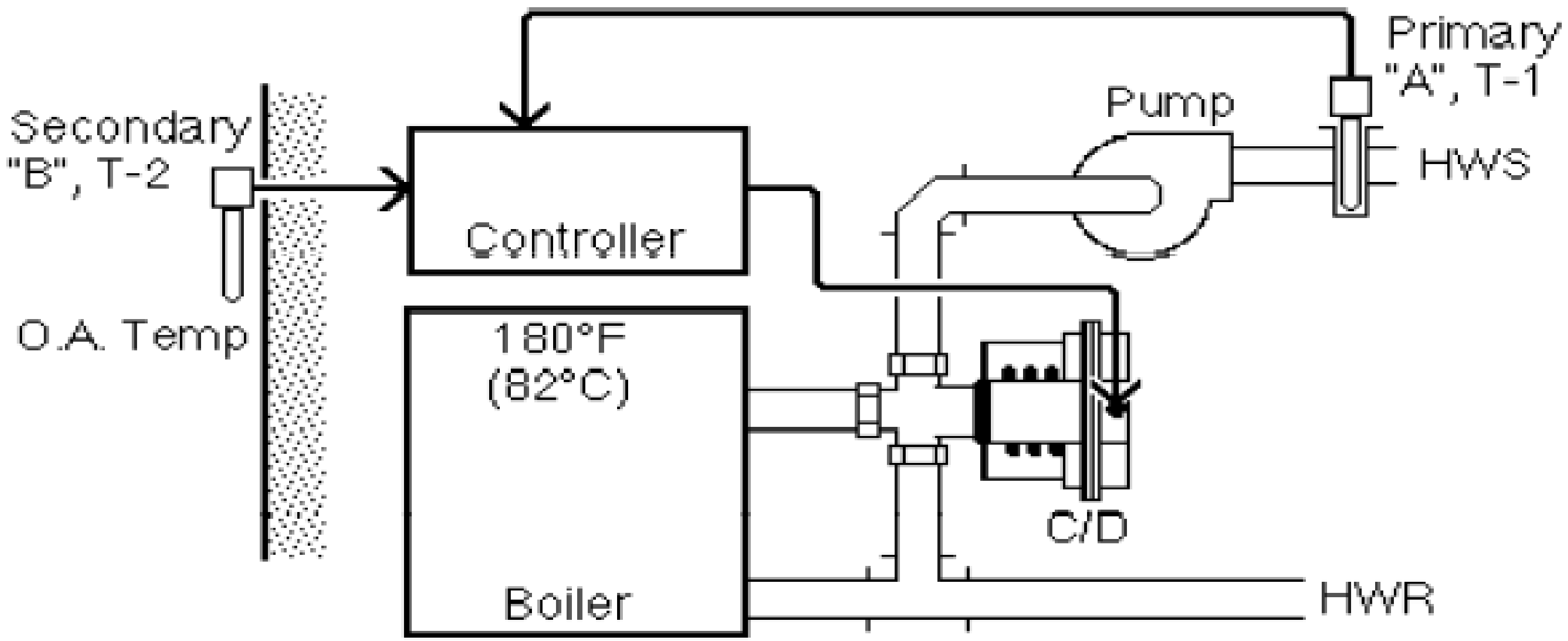
- General Energy Saving Techniques for AHUs
  - Operate zones based on load and occupancy needs (minimum 3°F dead band values between zone heating and cooling set points)
  - Configure with tight schedules and use optimal start to anticipate earlier startup requirements for hot or cold weather.
  - Ensure the economizer is configured correctly for minimum OA set point values and for proper operation (fixed dry bulb set point or differential dry bulb set point)
  - Disable the mechanical cooling coil and pumps when outside air temperatures drop below 55-60°F
  - Disable the mechanical heating coil and pumps when outside air temperatures rise above 65-70°F
  - Ensure building exhaust fan systems turn off as early as possible and startup as late as possible and only run when needed or required
  - Location, location, location (sensors – especially outdoor air temperature and duct static pressure)

Boiler Control With Outdoor Air Temperature Reset

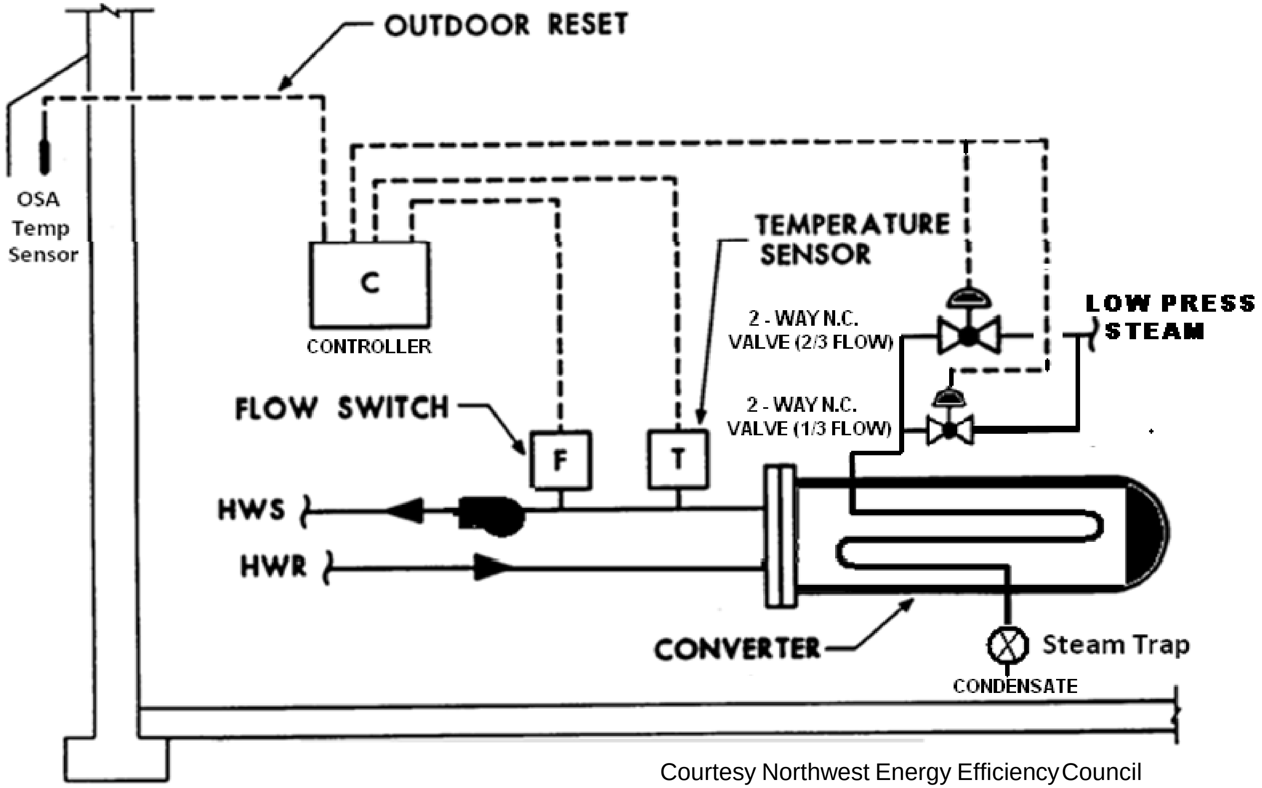


Courtesy TAC Controls/Schneider Electric

- Hot water reset based on OA should be aggressive. The schedule shown will only provide the warmest water when the OA temperature is cold
- The configuration shown is for non-condensing boilers that requires the boiler to always stay hot (180°F) to avoid condensation issues
- With condensing boilers, return water temps < 130°F offer greater efficiency (supply water temps < 150°F)
- Parallel boilers should have automatic isolation valves in the loop
- A more efficient control scheme calculates a hot water set point based upon the zone demand (average deviation from zone set point or reheat average valve command position)

O. A. Temp	HWS Setpoint
0°F / -18°C	180°F / 82°C
70°F / 21°C	90°F / 32°C

Converter Control With Reset

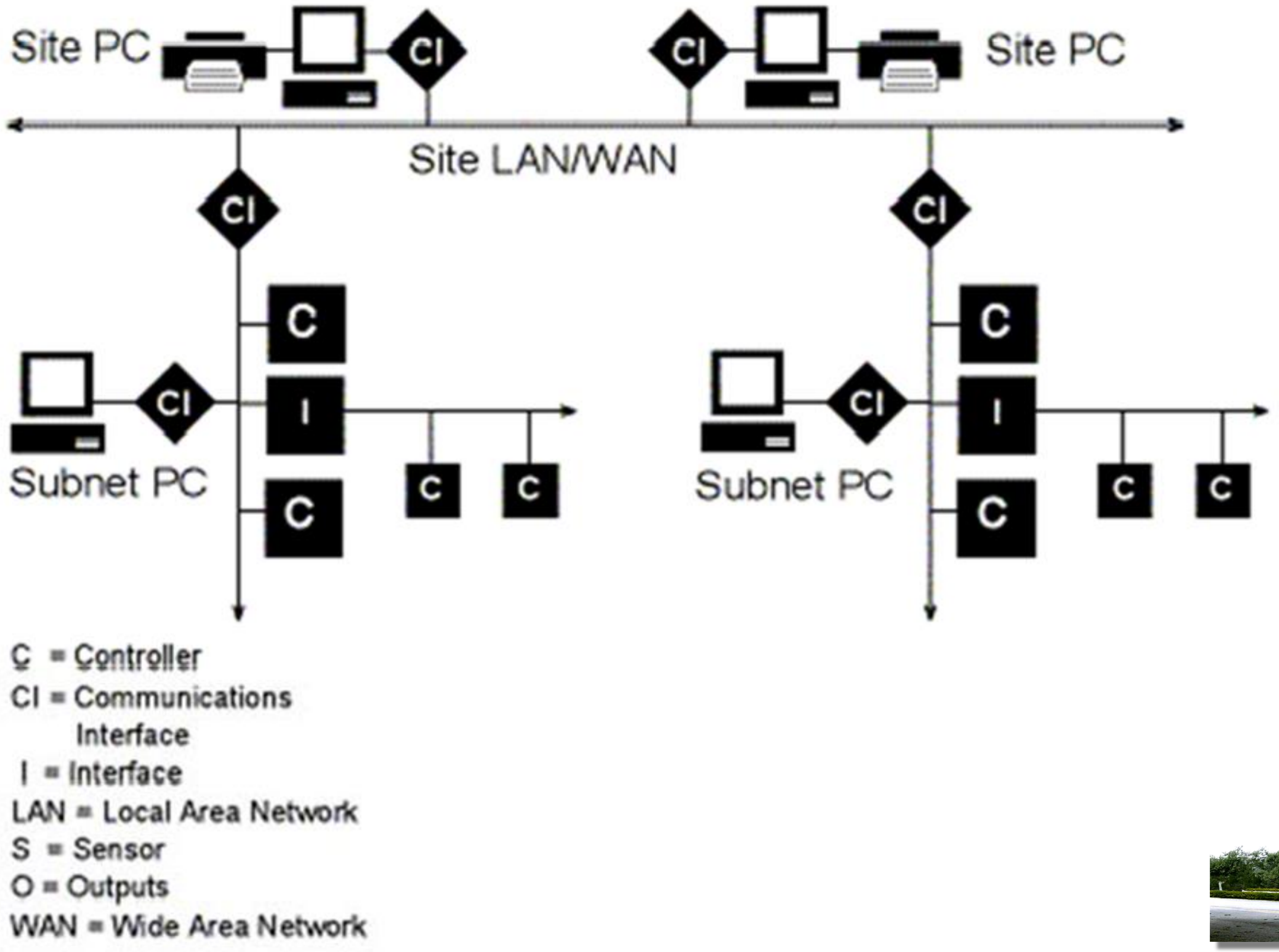


Courtesy Northwest Energy Efficiency Council

O.A. Temp	HWS Setpoint
-10°F / -23°C	190°F / 88°C
65°F / 18°C	100°F / 38°C

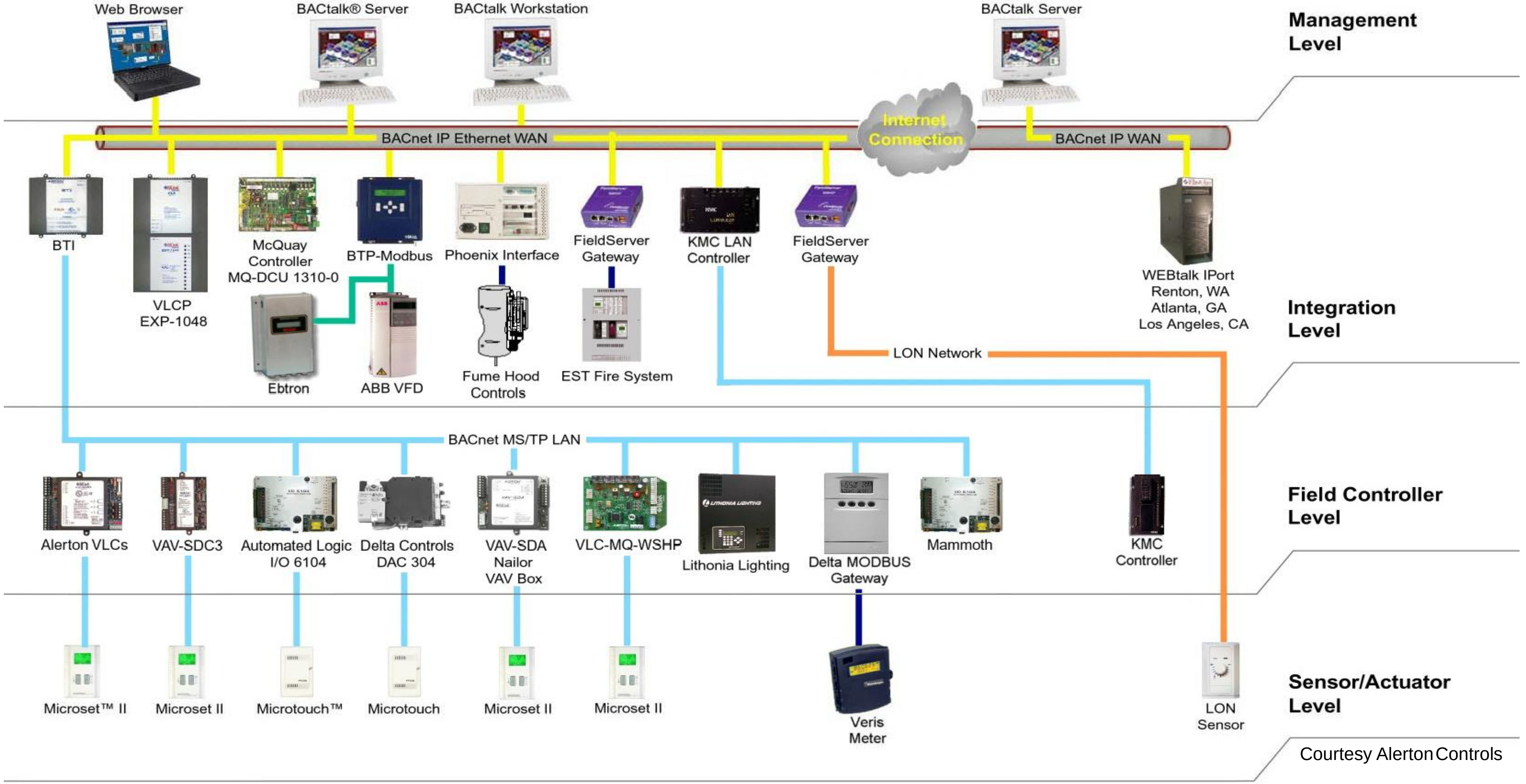
- Hot water reset based on OA should be aggressive. The schedule shown will only provide the warmest water when the OA temperature is cold
- The configuration shown is for steam-to-hot water converter. These systems have greater turn-down if the control valves are sized properly
- OA sensor location is critical for efficiency and accuracy and should be validated quarterly
- Consider a night setback with 20°F lower reset values for the hot water

DDC Networks and Architecture



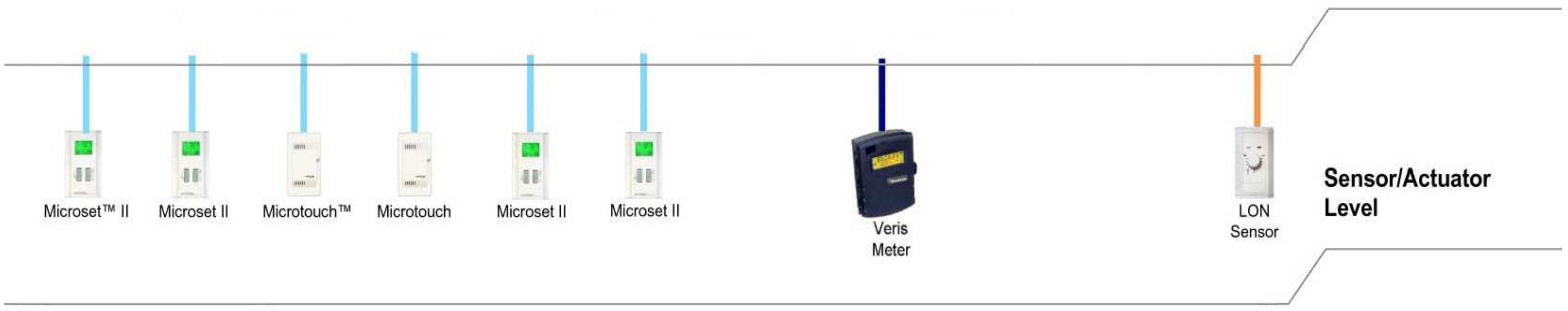
Multiple-Subnet Works System Architecture

Modern Controls Have Four-Level Architecture



Courtesy Alerton Controls

Four Level Architecture Level One "Sensors"



Four Level Architecture Level Two “Field Controllers”

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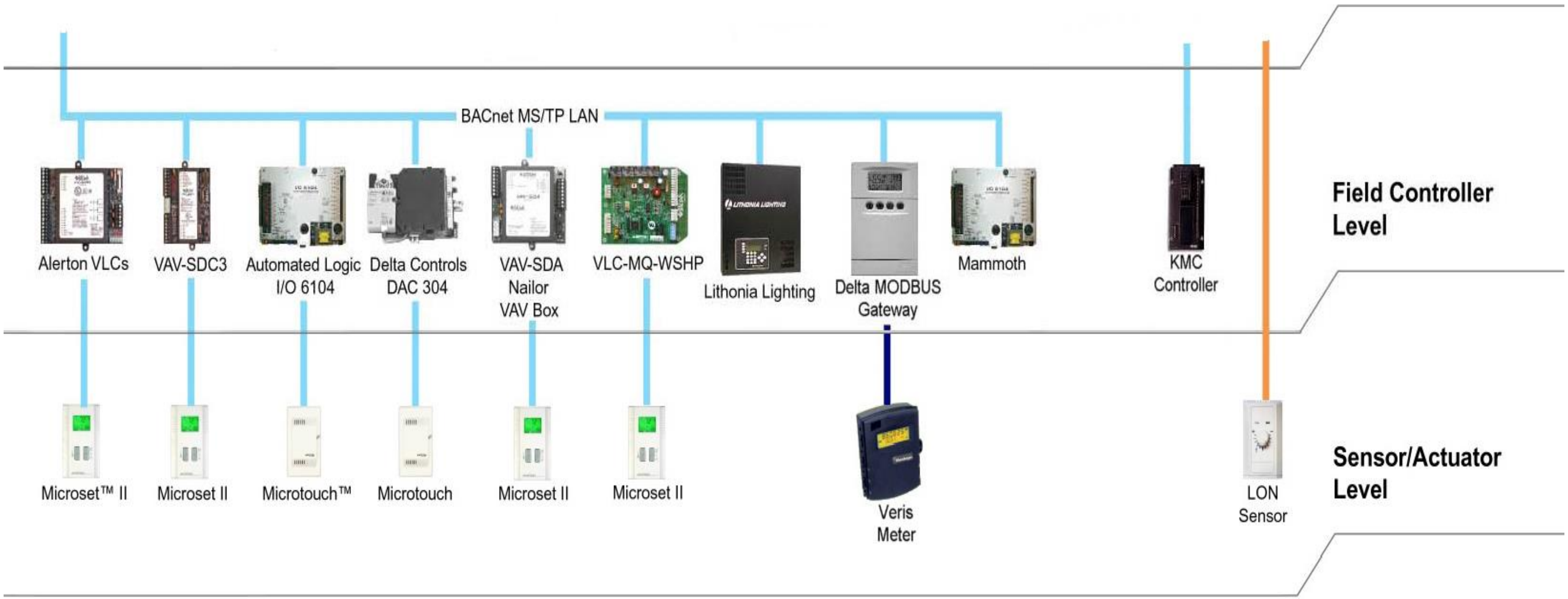

Four Level Architecture Level Three “Integration”

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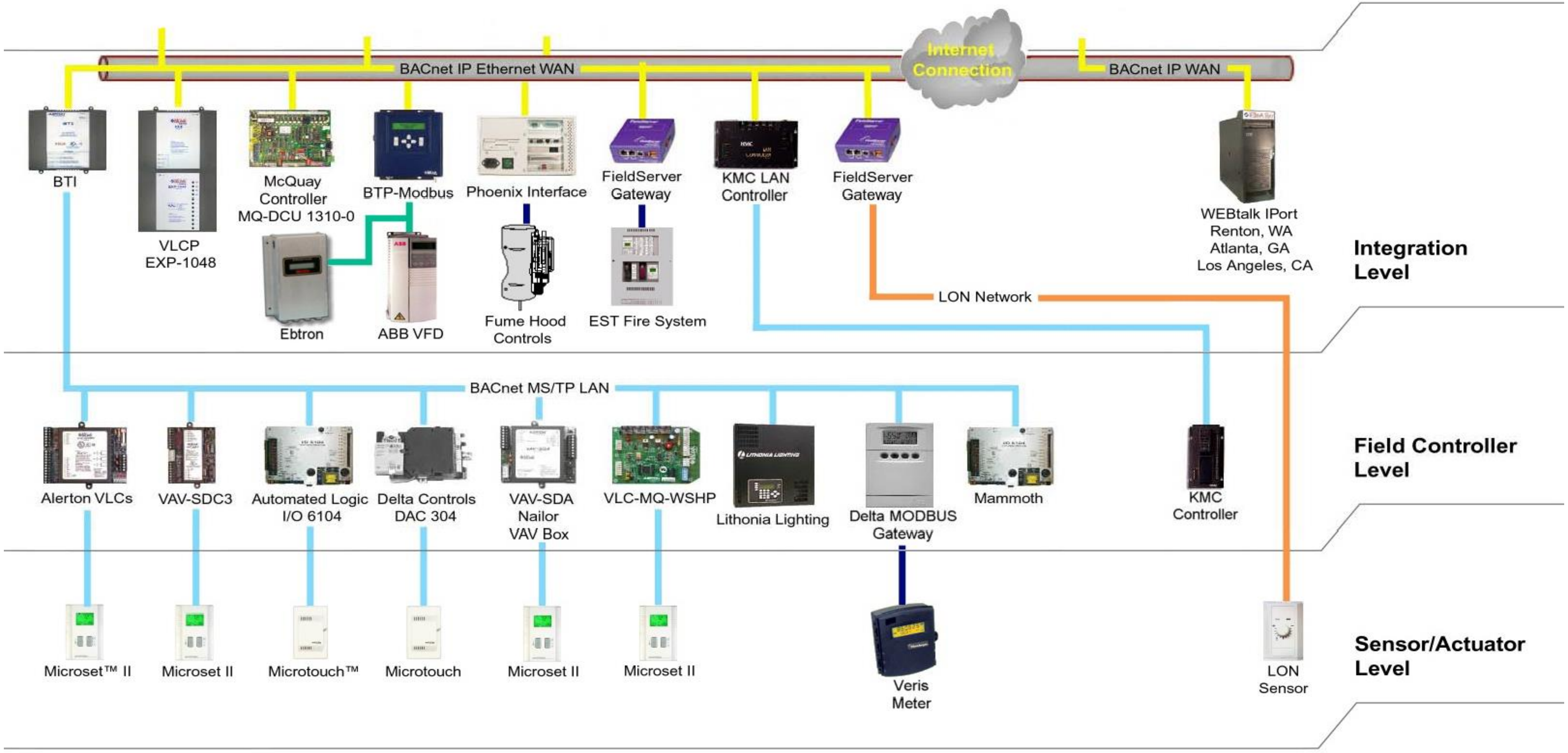
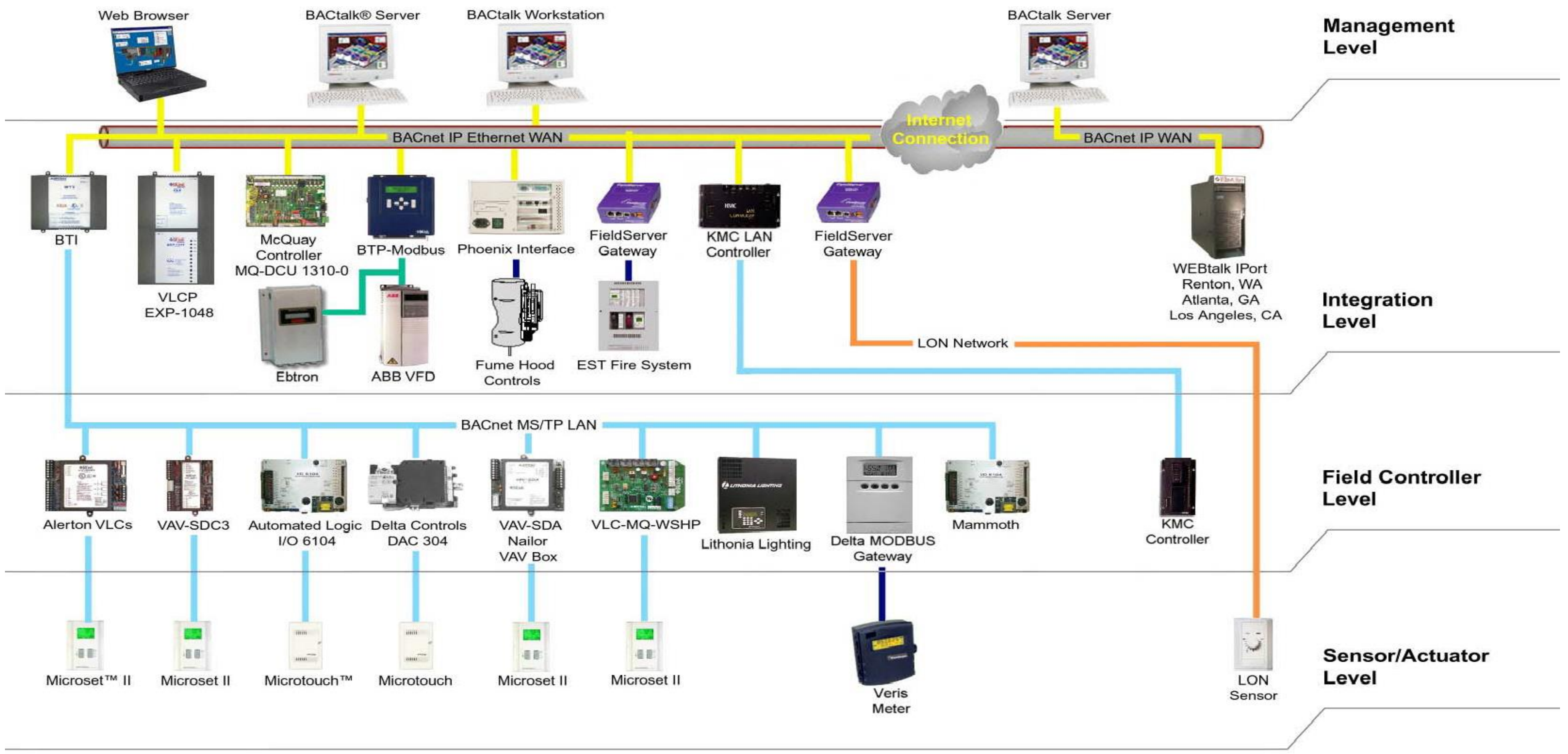


Four Level Architecture Level Four "Management"



Courtesy Alerton Controls

Improving Operations using Building Analytics

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- Important reasons why we must do more to improve building operations
- Current deficiencies in building operations
- Key gaps and best practices in control system deployment and operations
- Common problems with building operations
- Building analytics basics

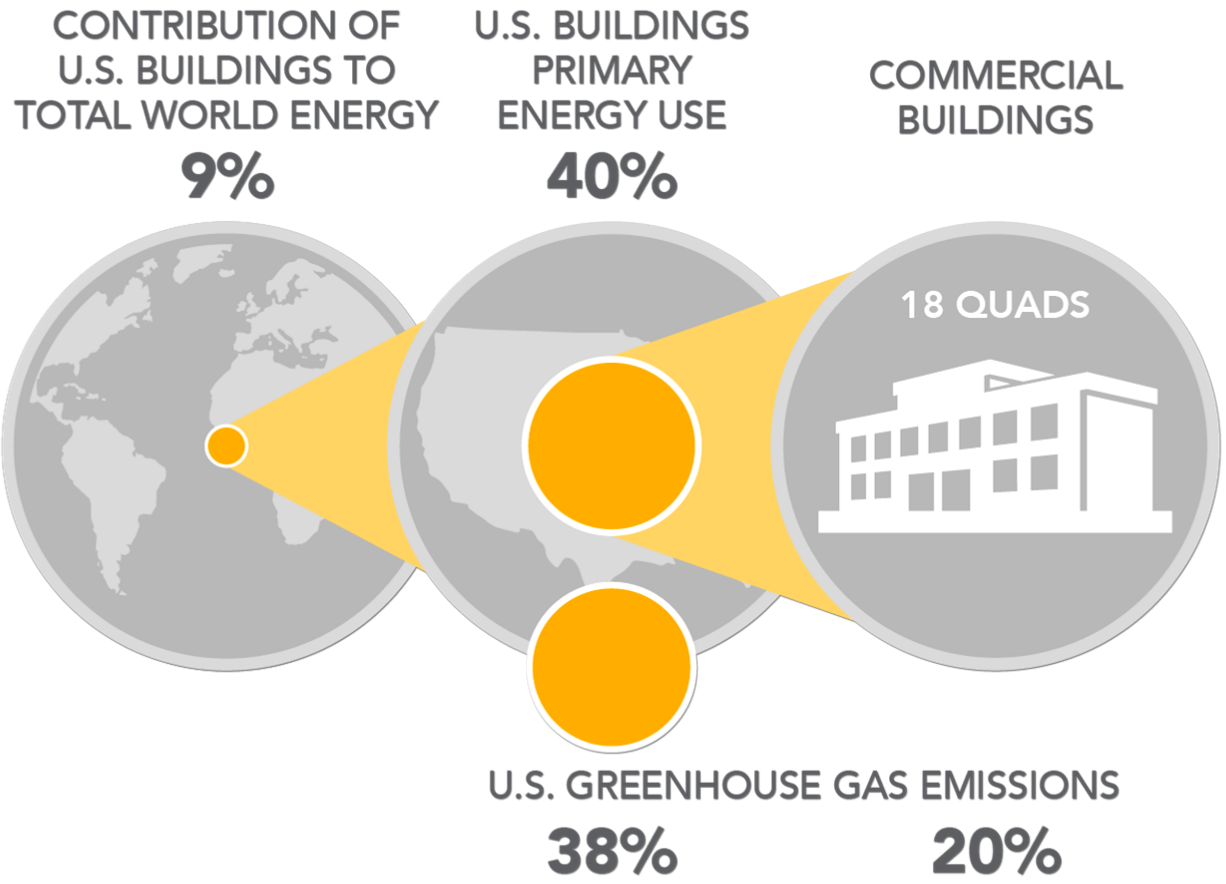
Prevalence of Building Automation Systems

Only 14% (43% of conditioned space) of the building stock has building automation systems

Source: 2012 Commercial Building Energy Consumption Survey

Important reasons why we must do more to improve building operations

State of Building Operations



- U.S. EPA's Clean Power Plan
- City and State "Tune-up" mandates

State of Building Operations (cont.)

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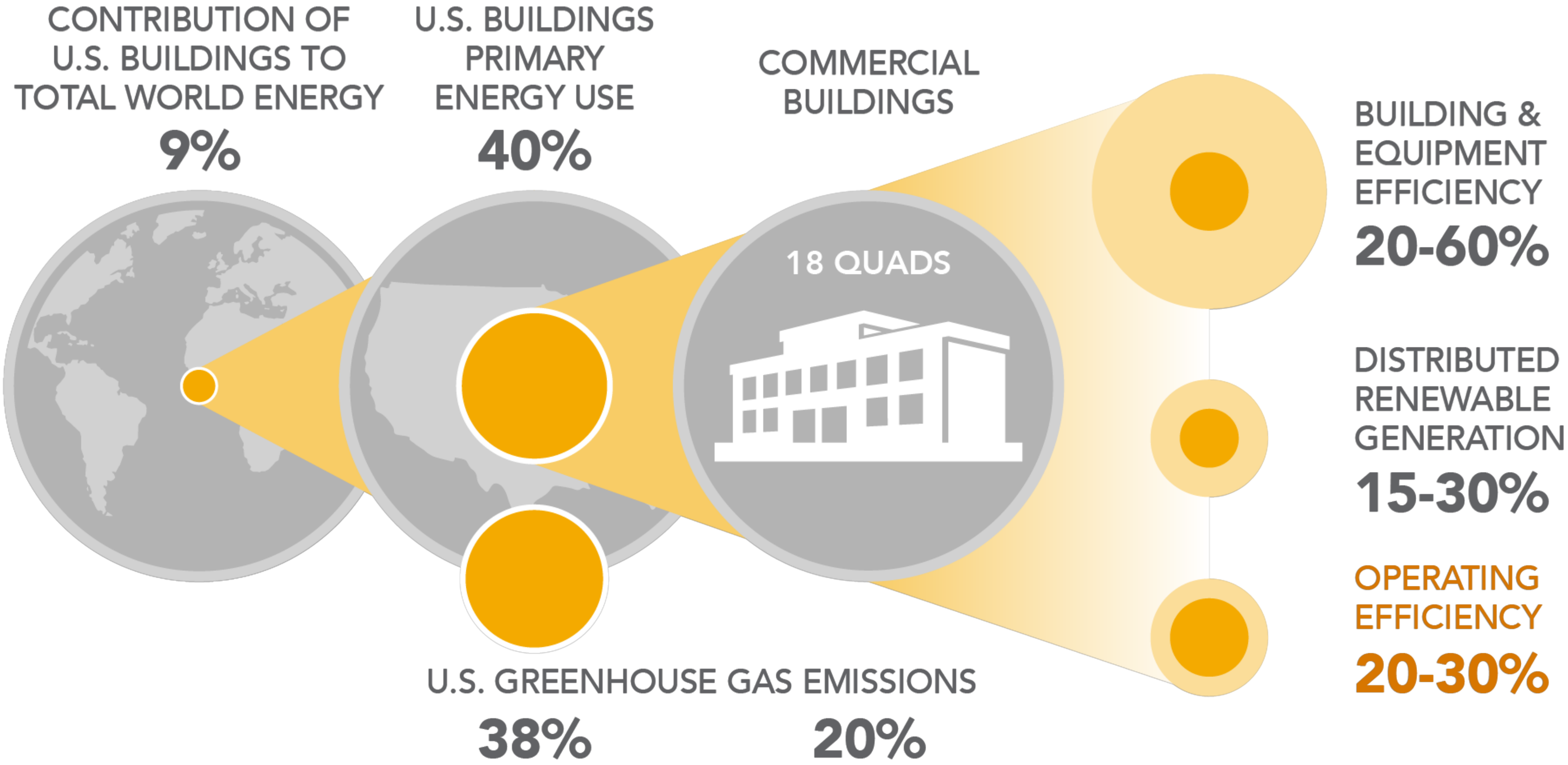
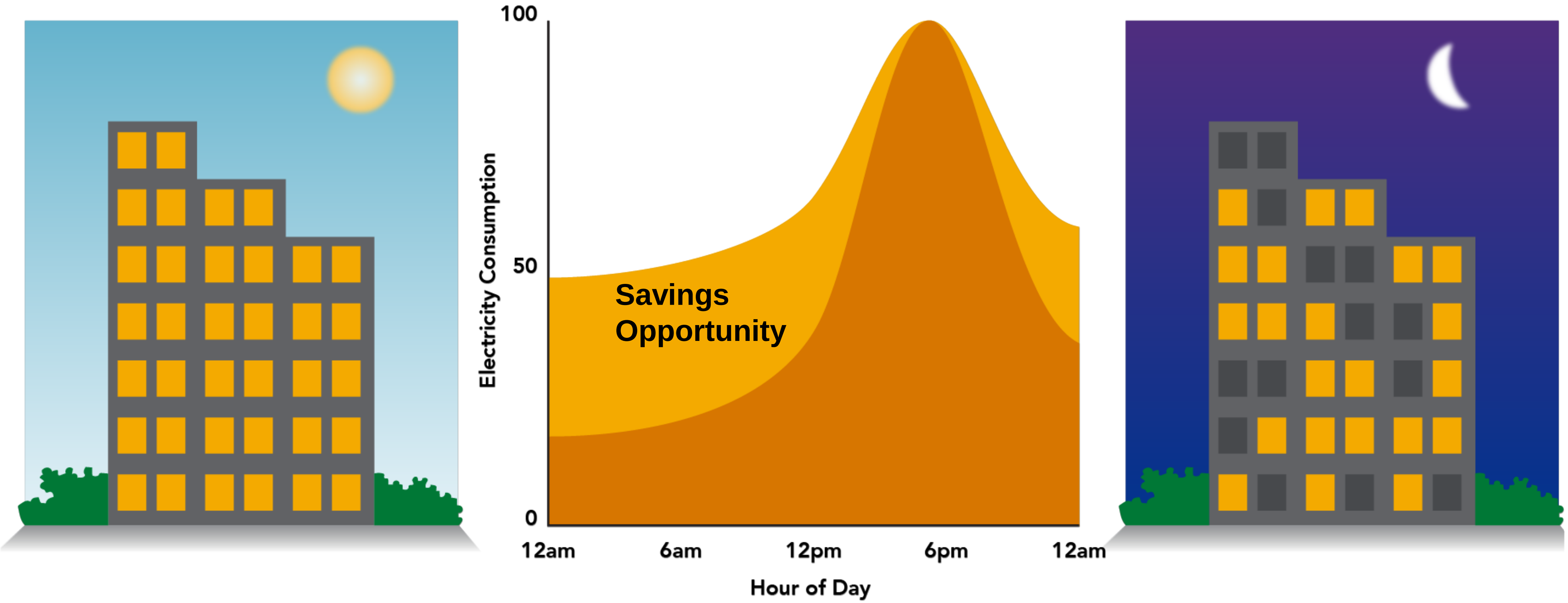


Current deficiencies in building operations

Deficiencies in Building Operations



Building Systems Lack "Self-Awareness"

Systems are designed and sized to provide comfort for a "design" day …

… but they are operated as if every day is a design day…

Operations of Variable-Air-Volume Air-Handling Systems

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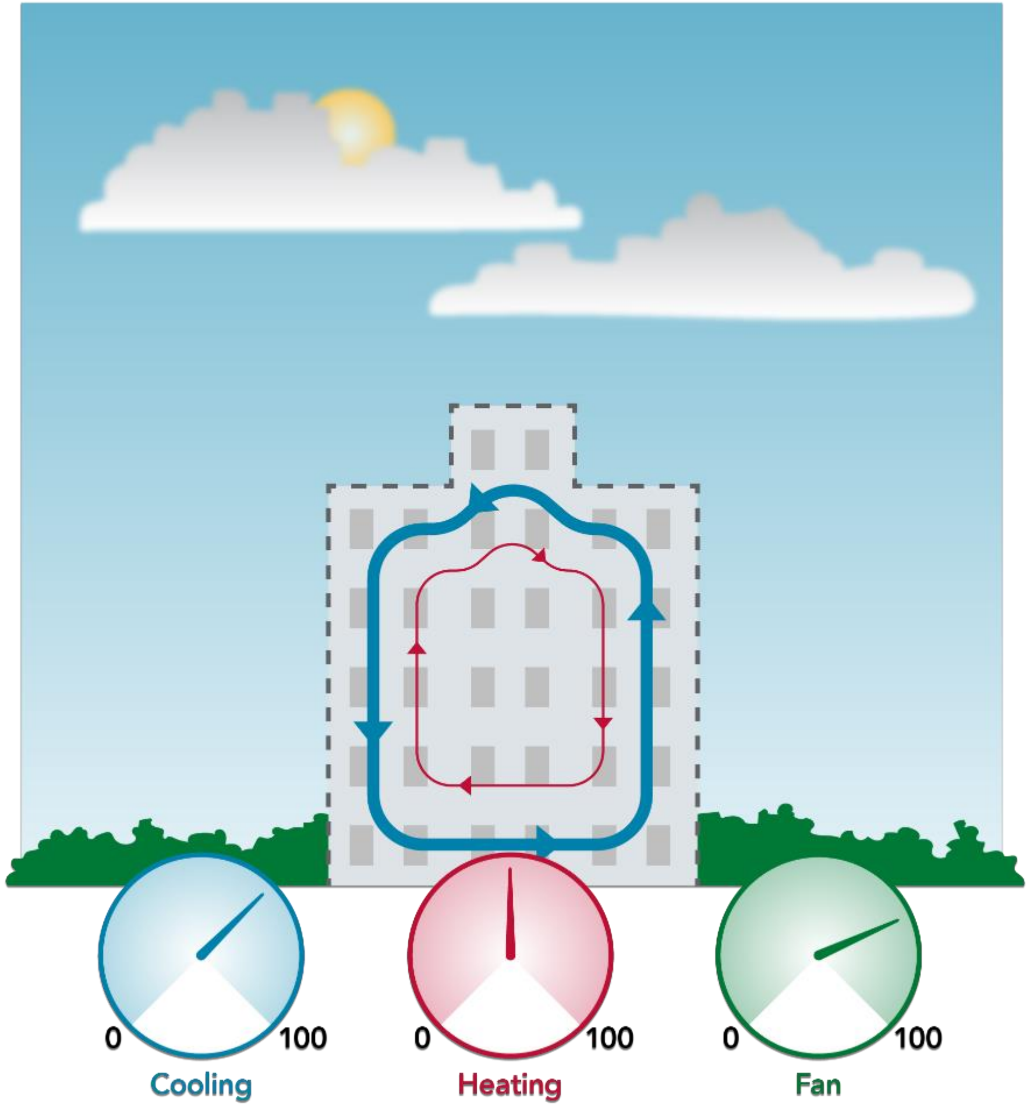
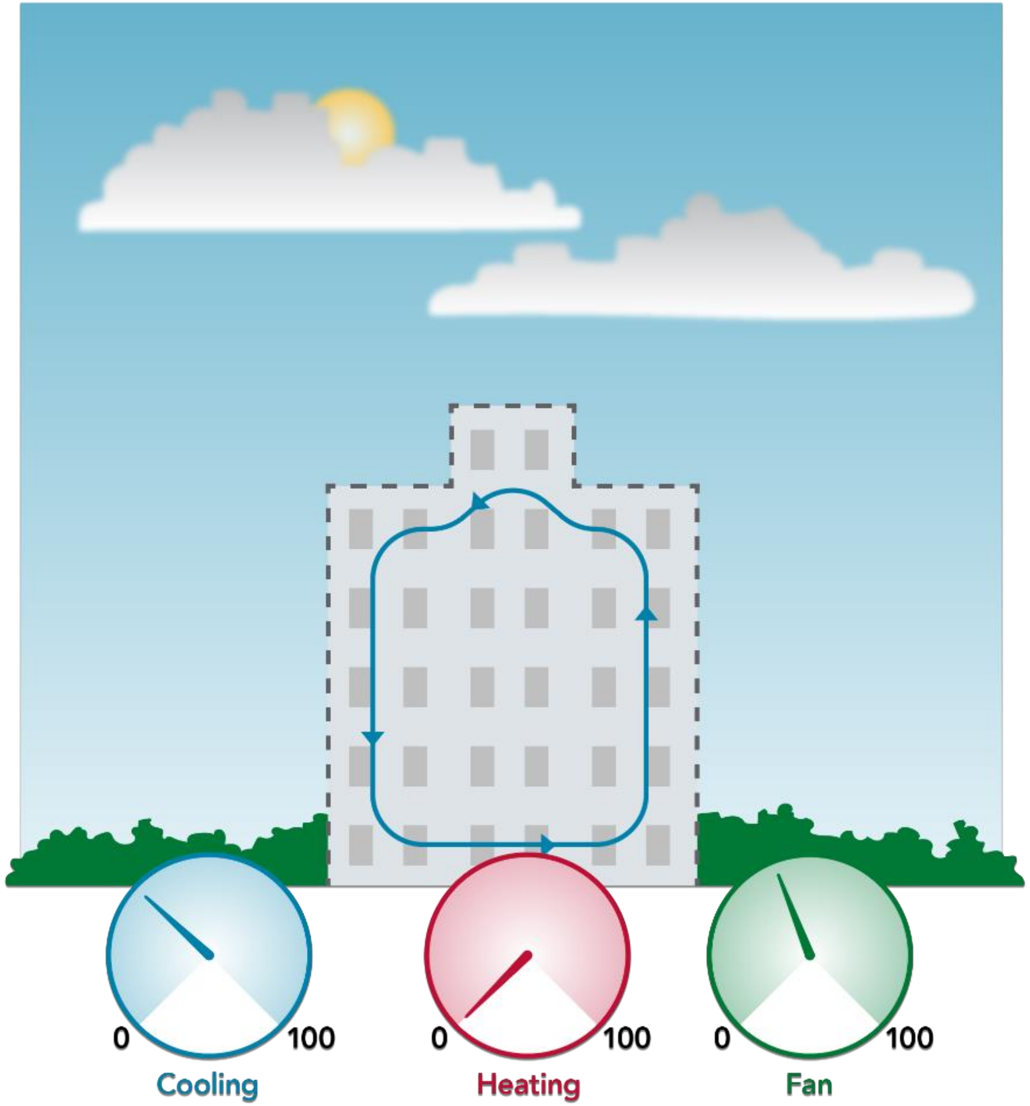
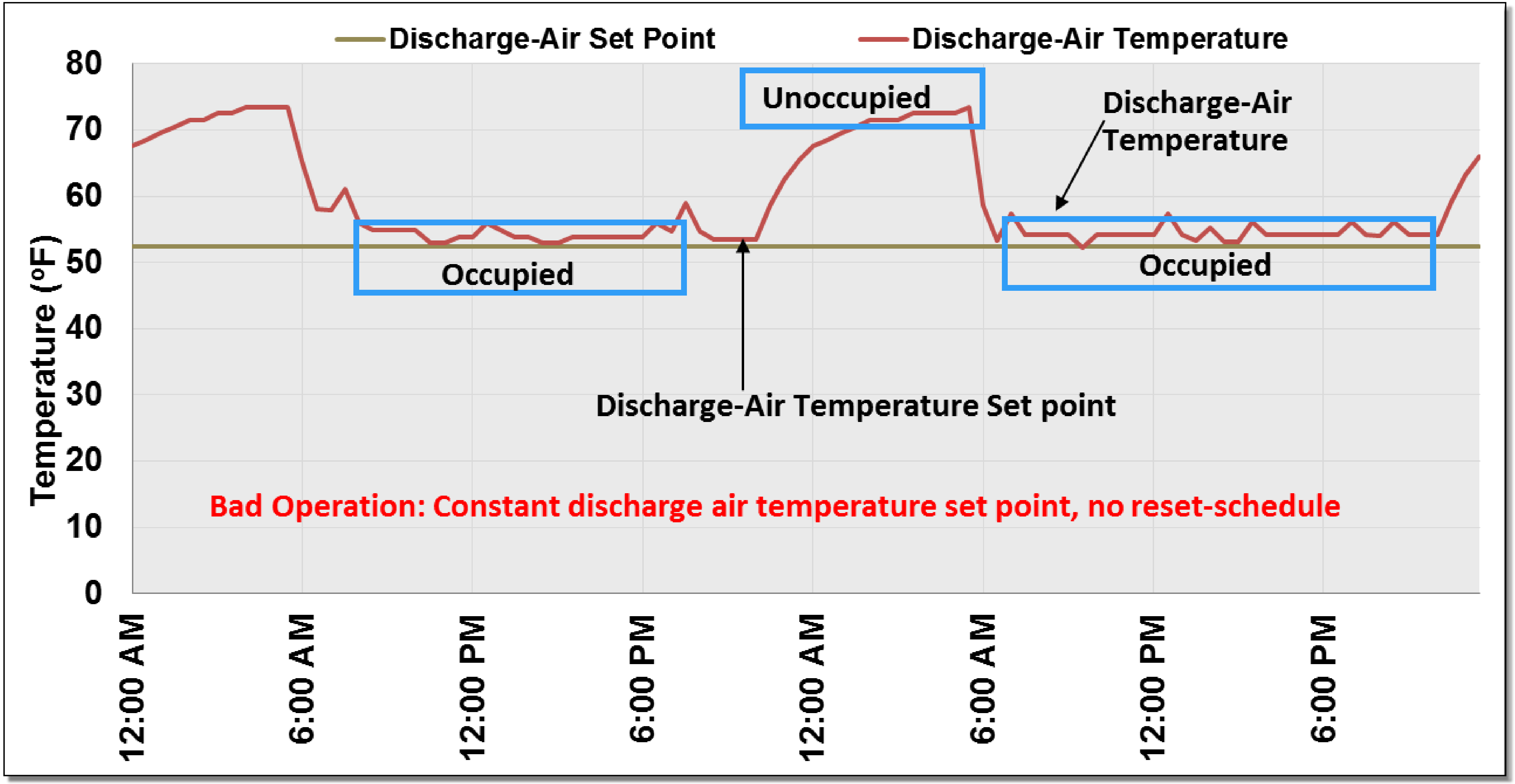
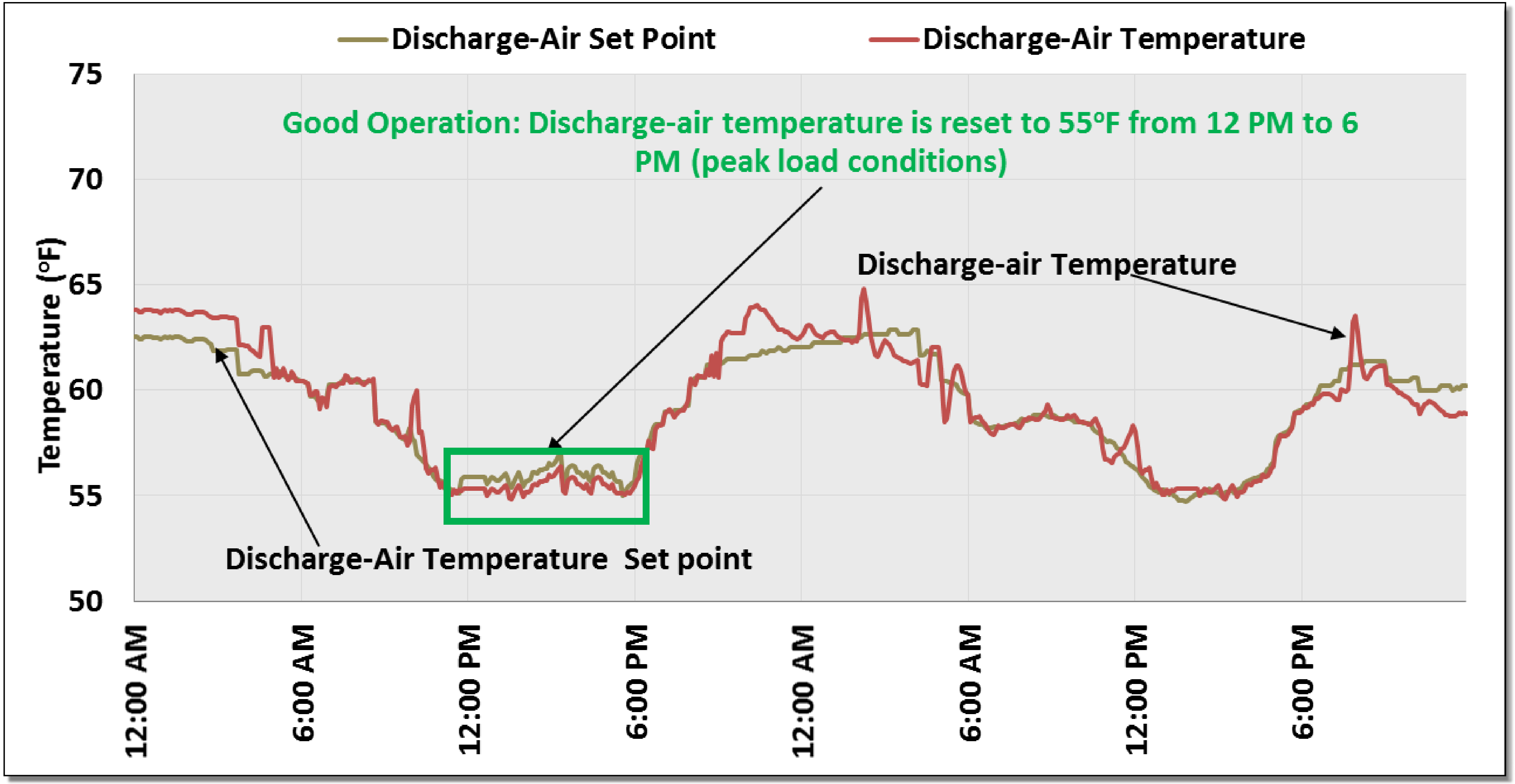




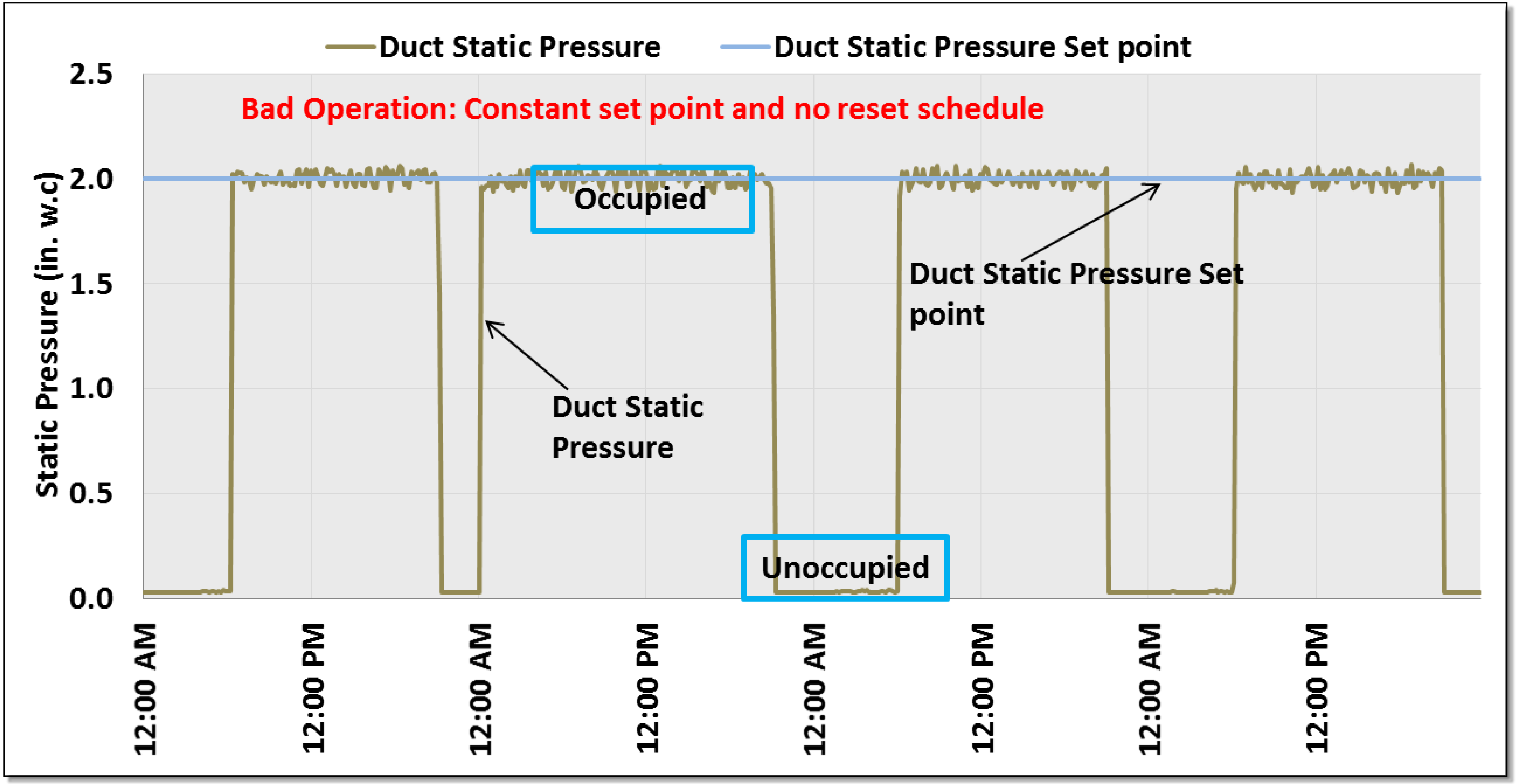
Discharge Air Temperature Control



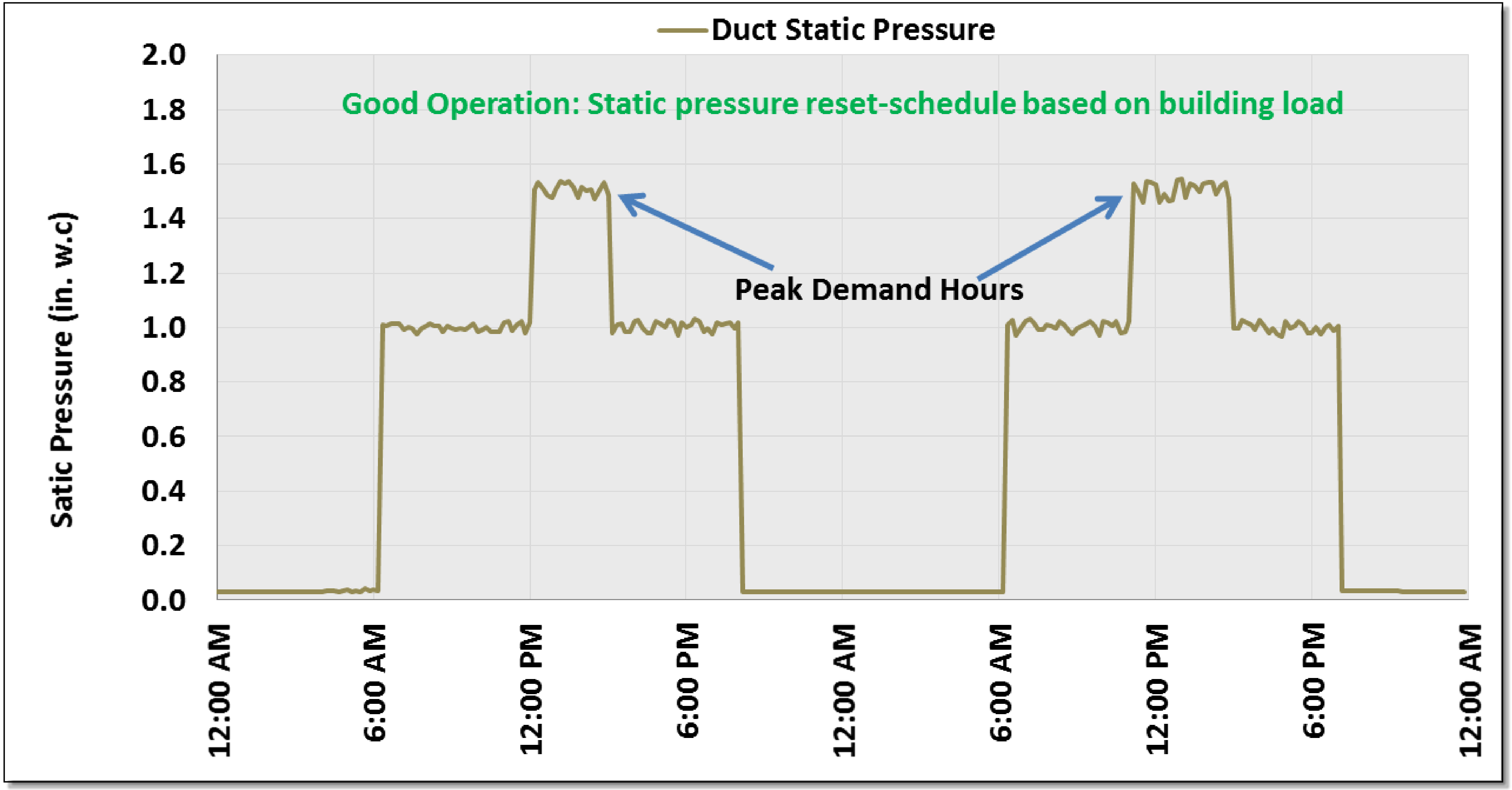
Discharge Air Temperature Control (cont.)



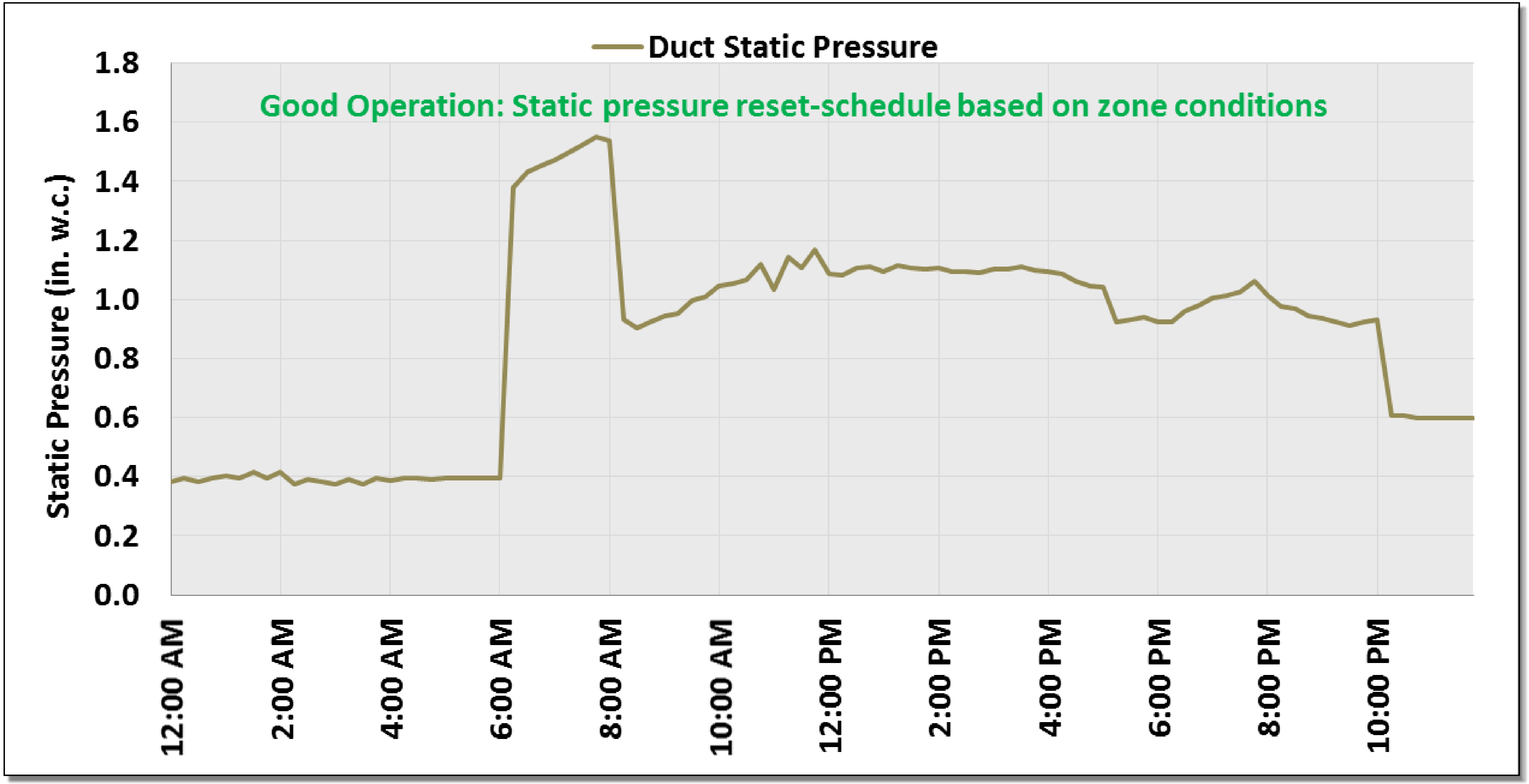
Duct Static Pressure Control



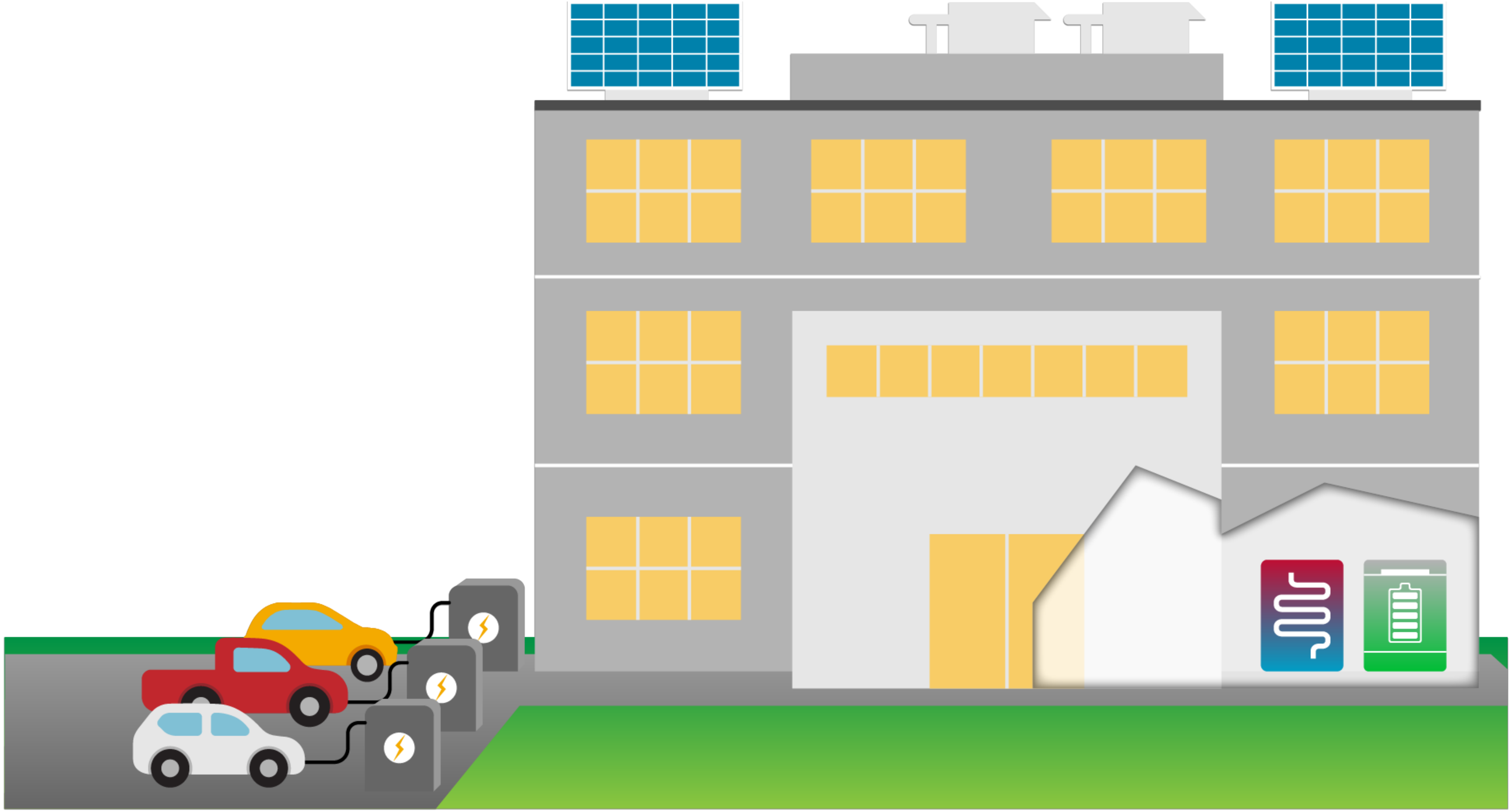
Duct Static Pressure Control (cont.)



Duct Static Pressure Control (cont.)



Integration of Other Systems



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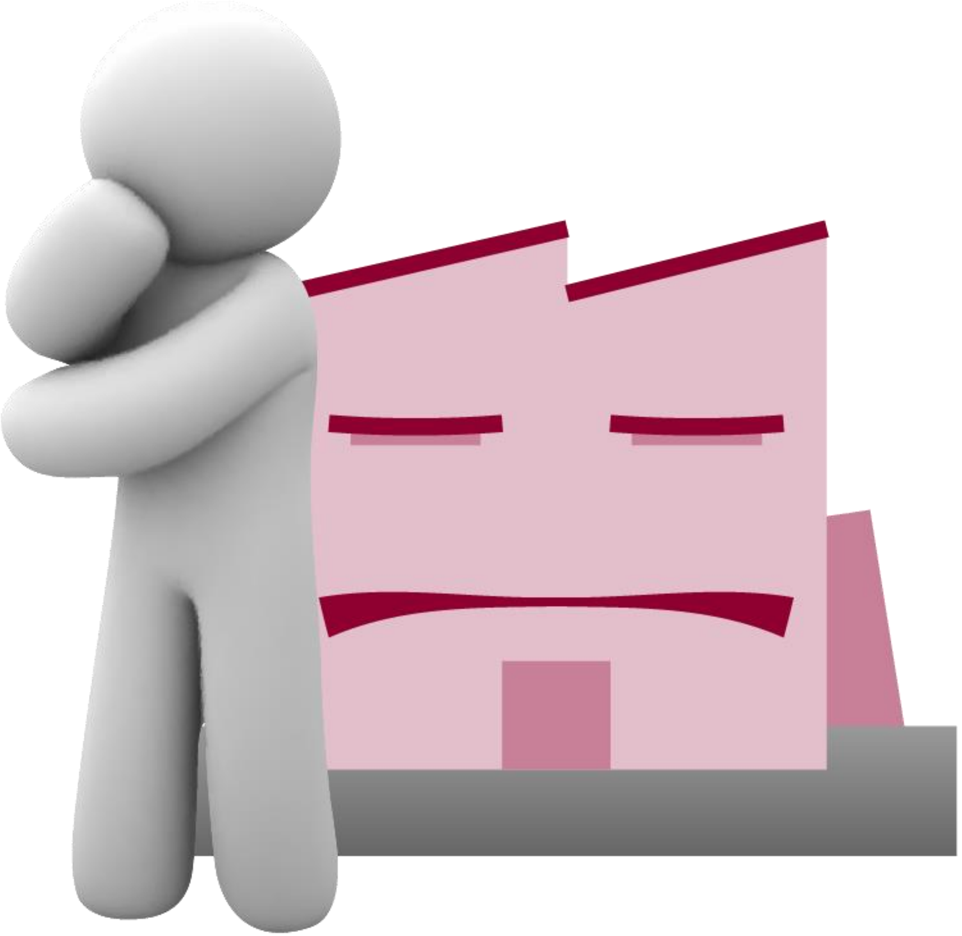
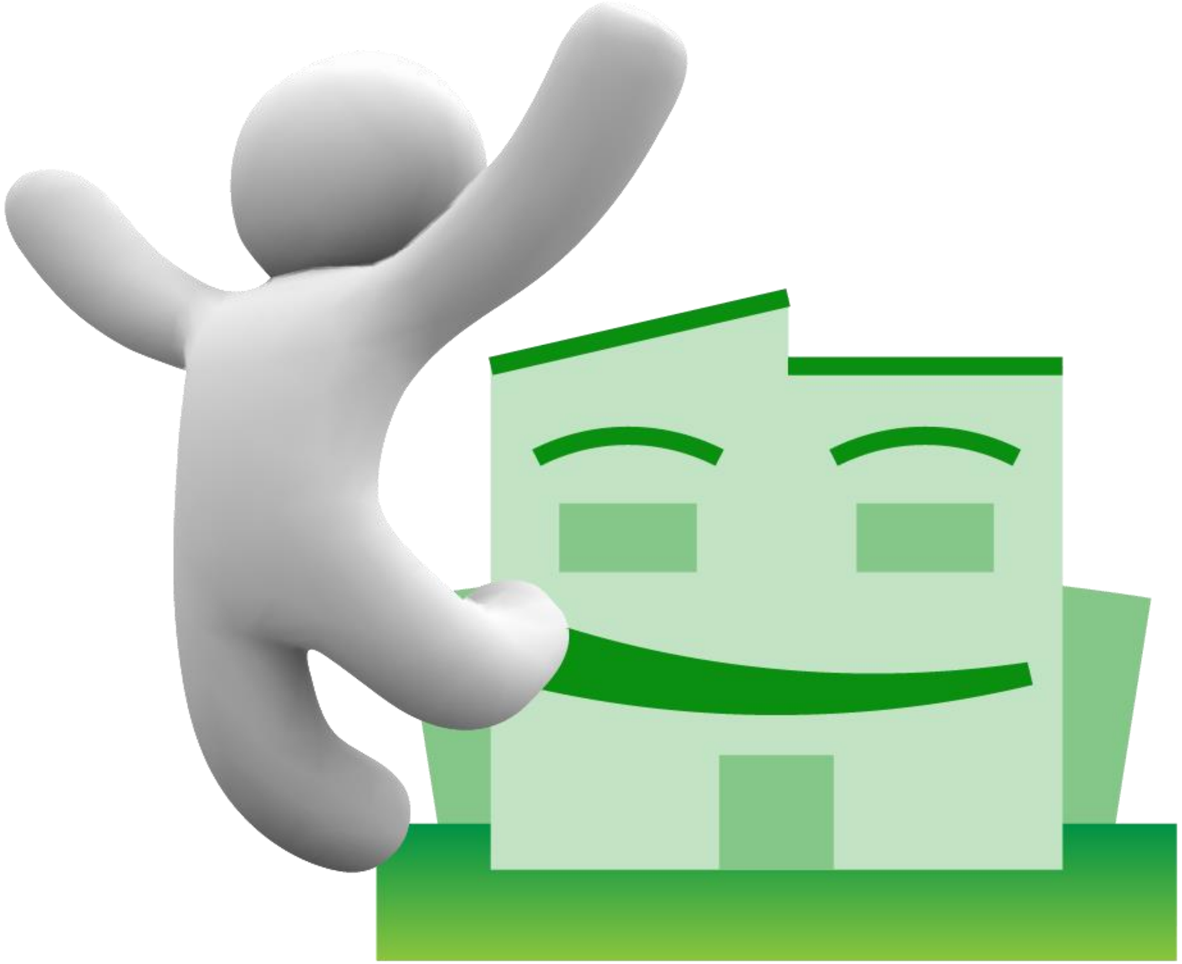
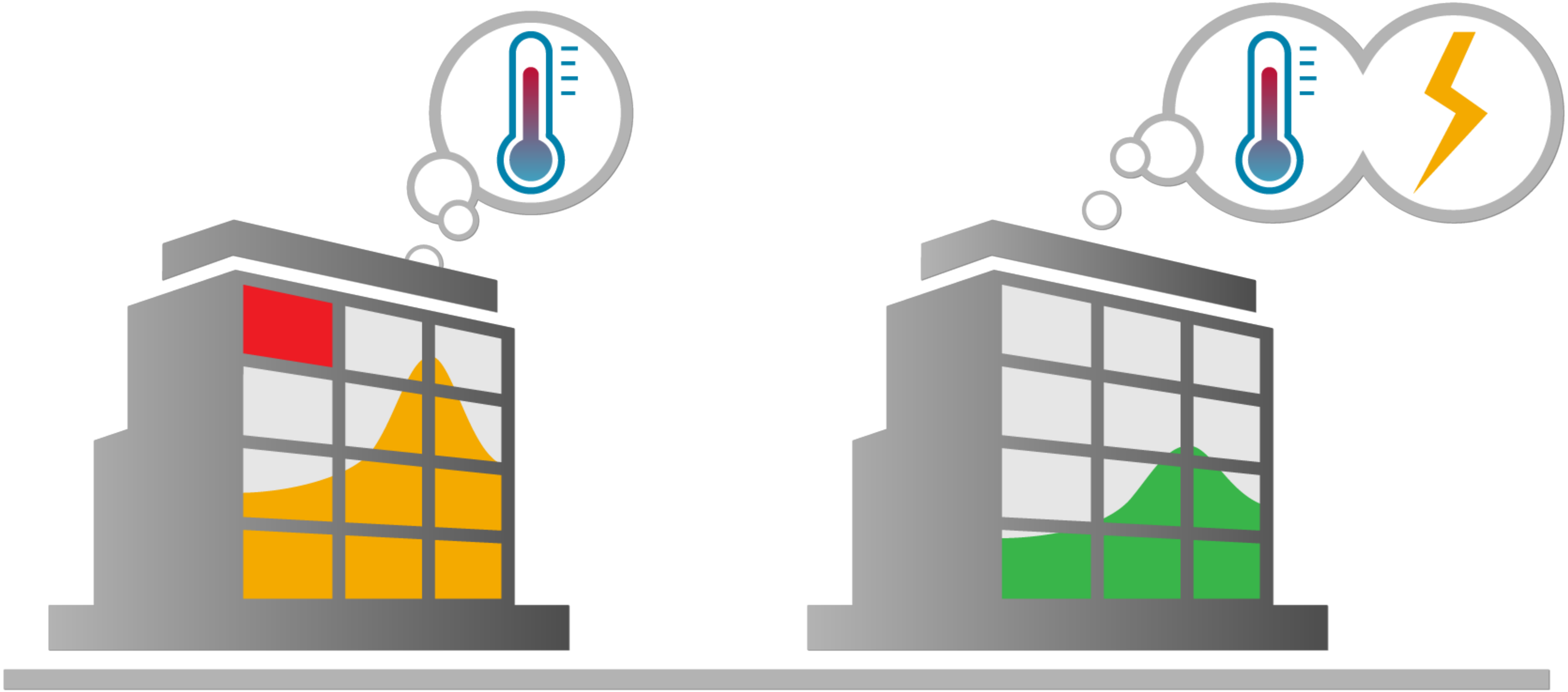
Key gaps and best practices in control system deployment and operations

Goals of Building Operations Staff





True Goals of Building Operations Staff



Other Reasons Why Building Operations Suffer

- Lack of monitoring and self-awareness
- Lack of initial commissioning
- Limited hands-on training options
- Shortage of experienced workforce
- Reduced operating budgets

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Common problems with building operations

Common Opportunities

Lack of Reset Strategies

- Discharge temperature and duct static pressure in AHUs
- Chilled/hot water temperature reset
- Differential pressure reset on chilled/hot water distribution loop

Lack of Use

- Occupancy-based controls for common areas
- One or more faulty sensors or sensors in the wrong location
- Night setbacks
- Photo sensors in the wrong location

Common Opportunities

Improper Settings

- Heating/cooling set points
- Outdoor air during warm-up
- Dead bands
- Automatic lighting controls

Improper Schedules

- AHUs and fans
- Exhaust fans during warm-up

Building analytics basics

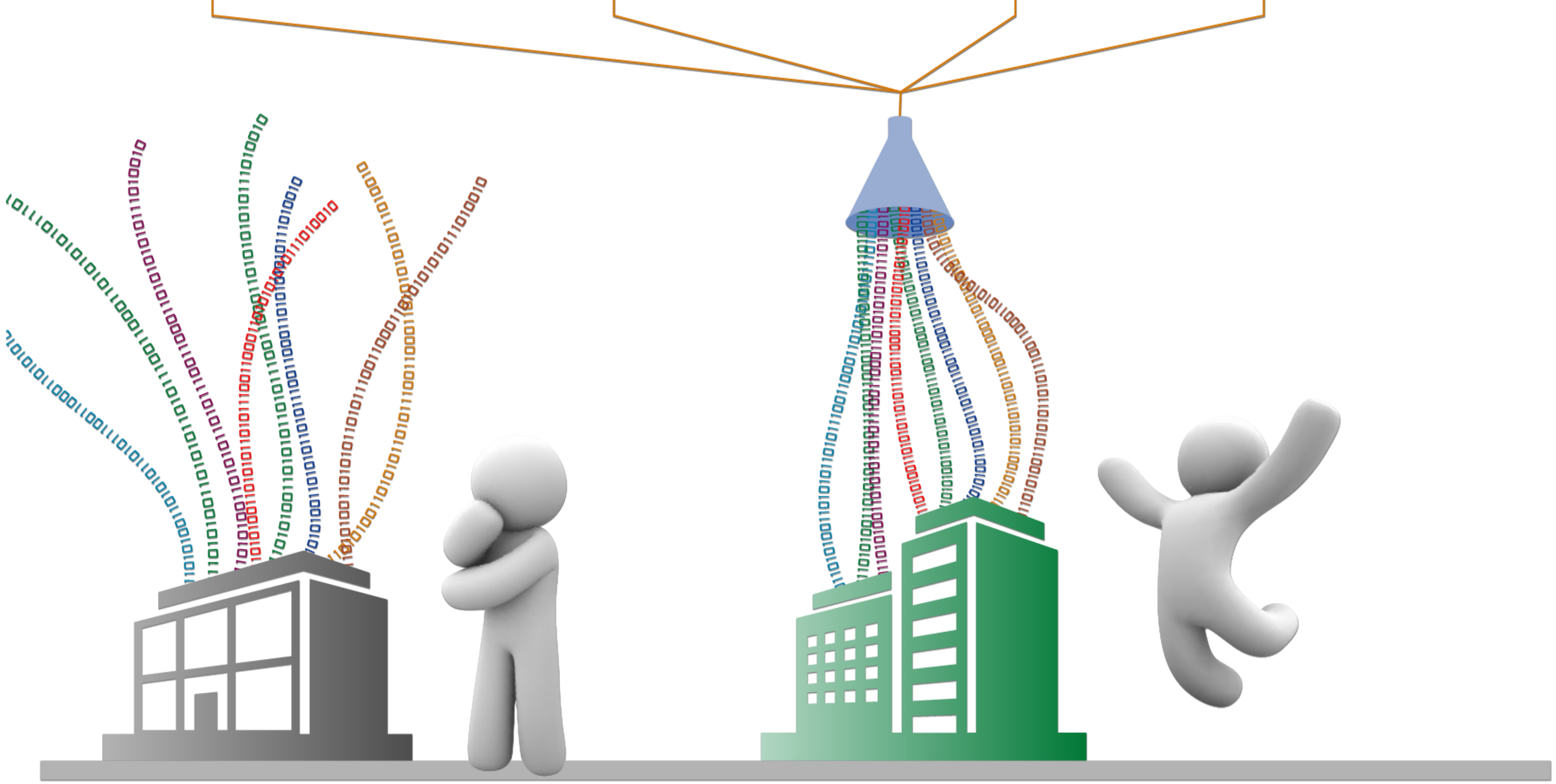
Need of Analytics

Outdoor Air Damper on Air Handling Unit 10 is stuck open (100%)

Economizer Controls are not working on Air Handling Unit 13

Air Handling 1 does not appear to be using Static Pressure Reset

The Delta-T on the Chilled Water Loop is Low (5°F)



First Step - Benchmarking

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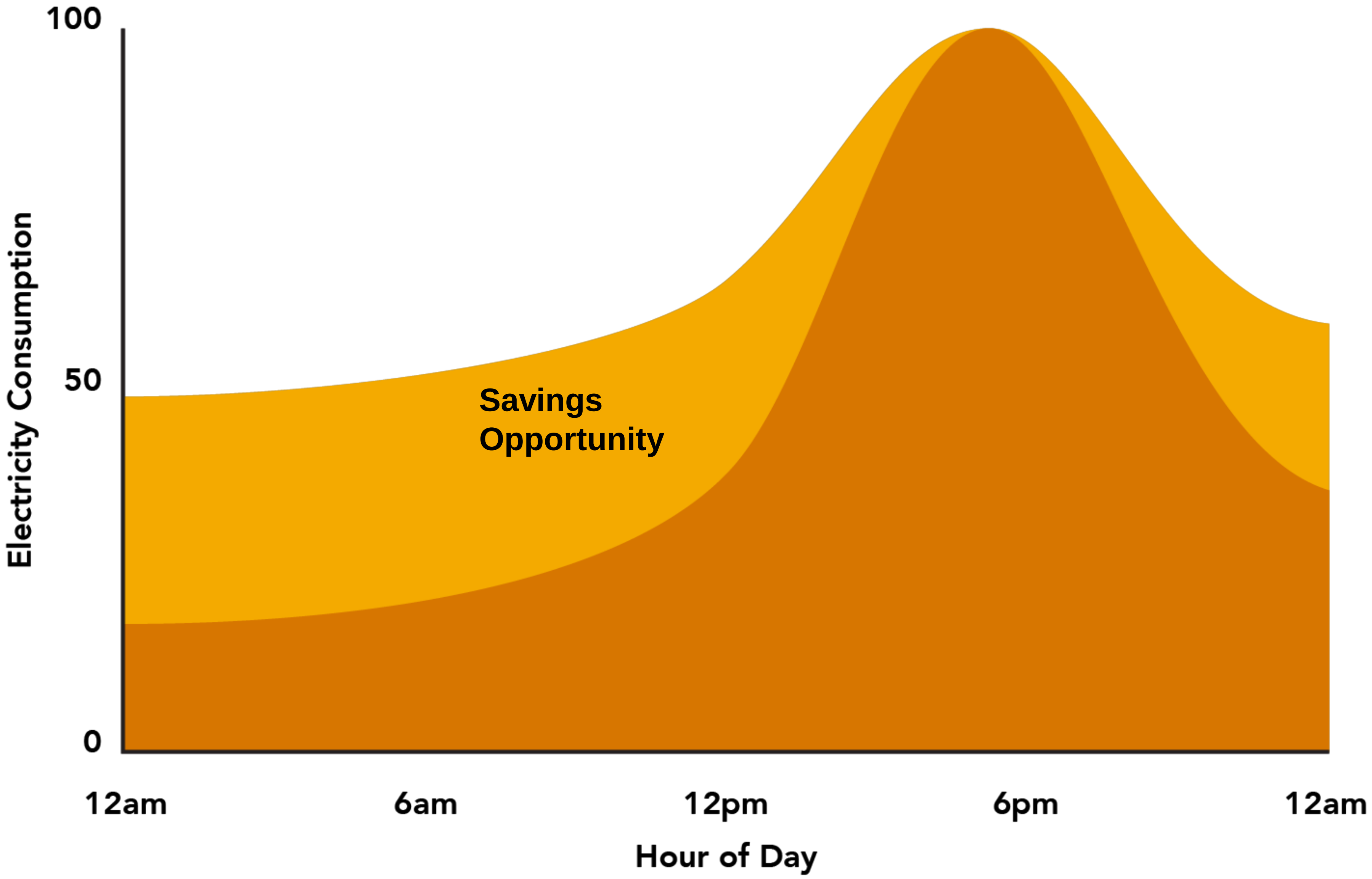
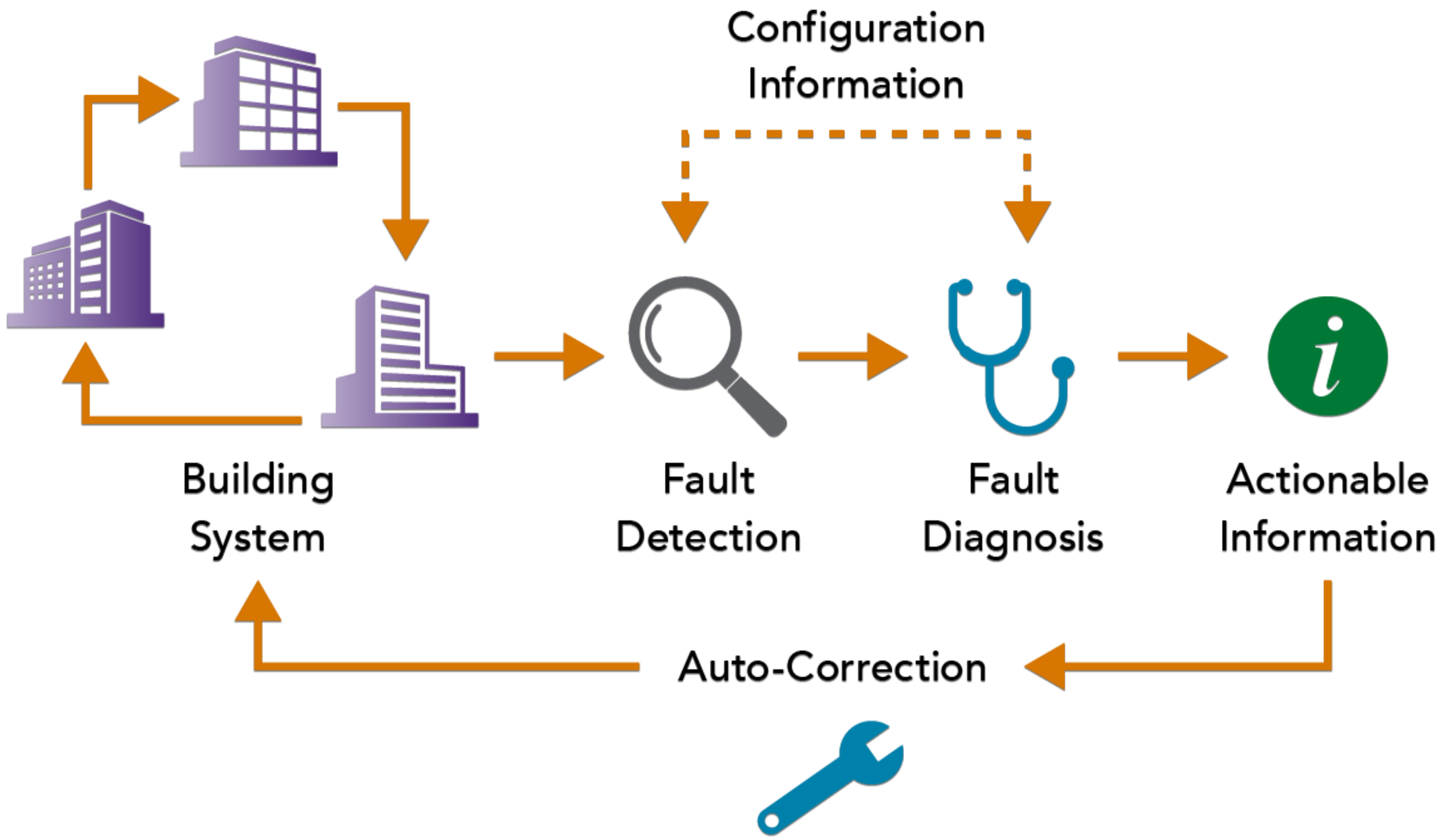


Beyond Benchmarking …

Beyond benchmarking of whole building data, building automation systems provide a rich source of “raw” data that can be used to create:

- Actionable information (i.e., identify operational problems)

Automated Fault Detection, Diagnostics and Self-Correction



Life Cycle of Existing Building-Commissioning

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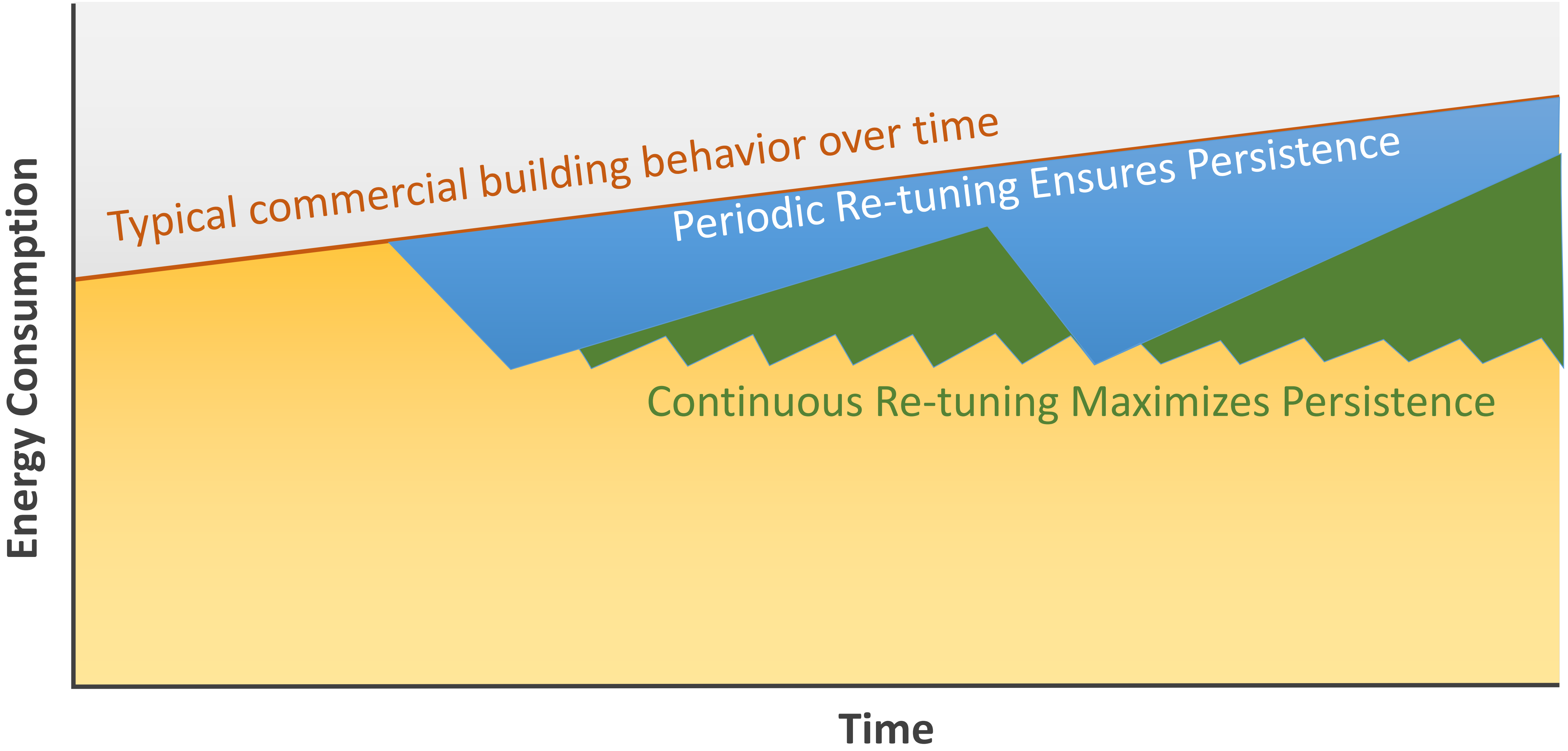
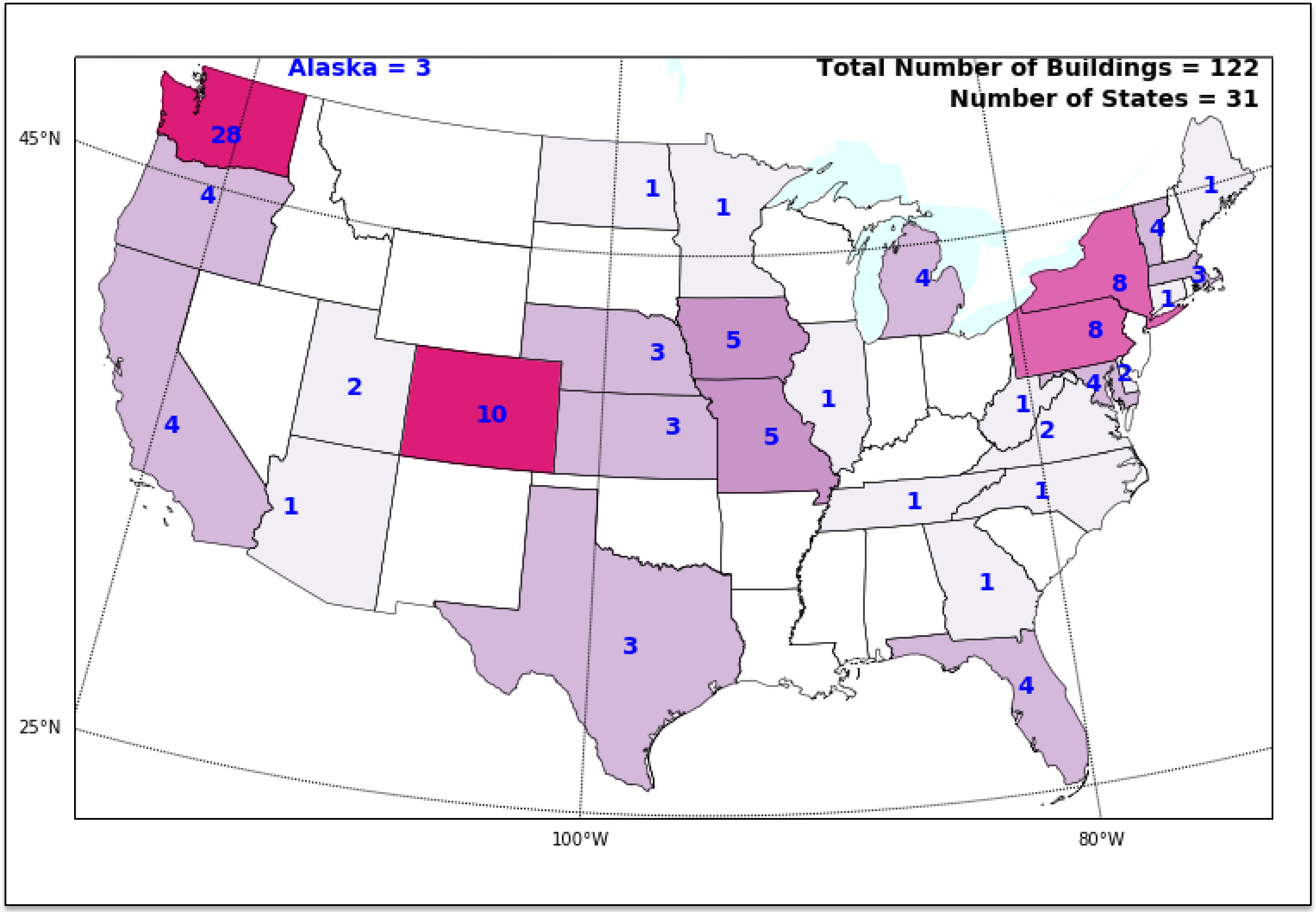
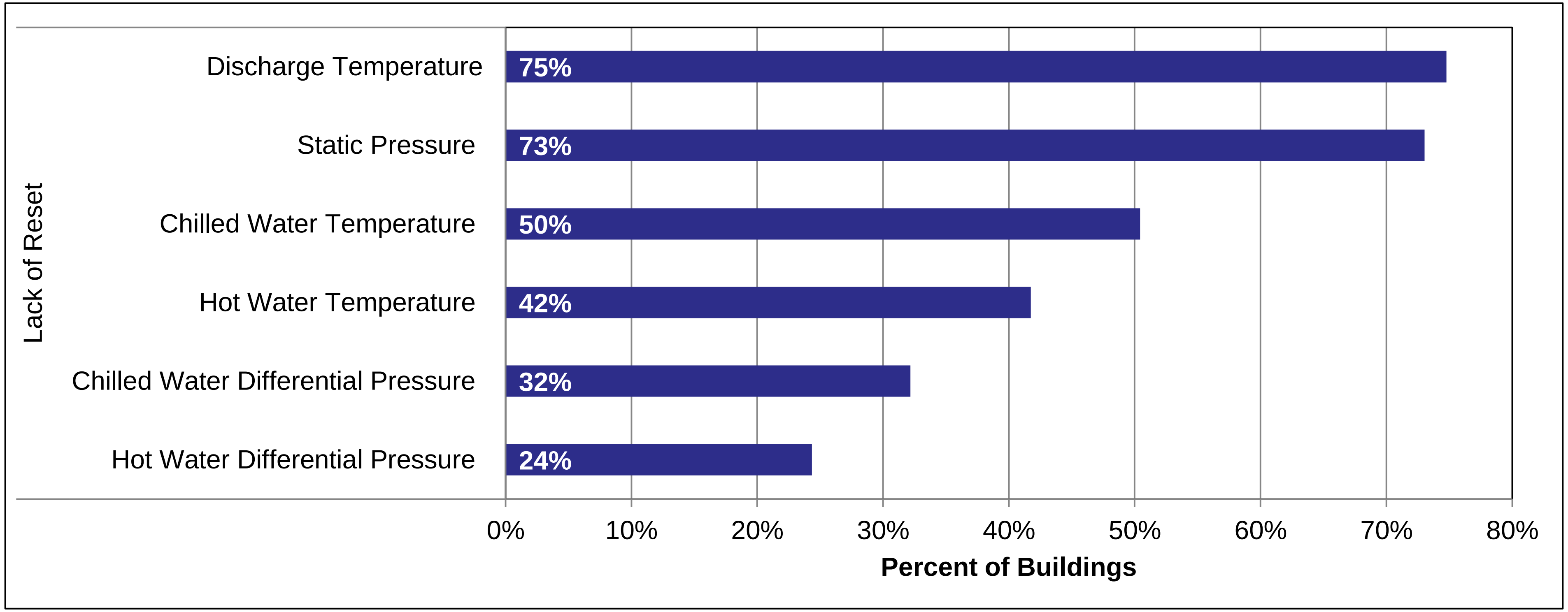


Take Control
Using Analytics to Drive Building Performance:
A Case Study – What to Expect

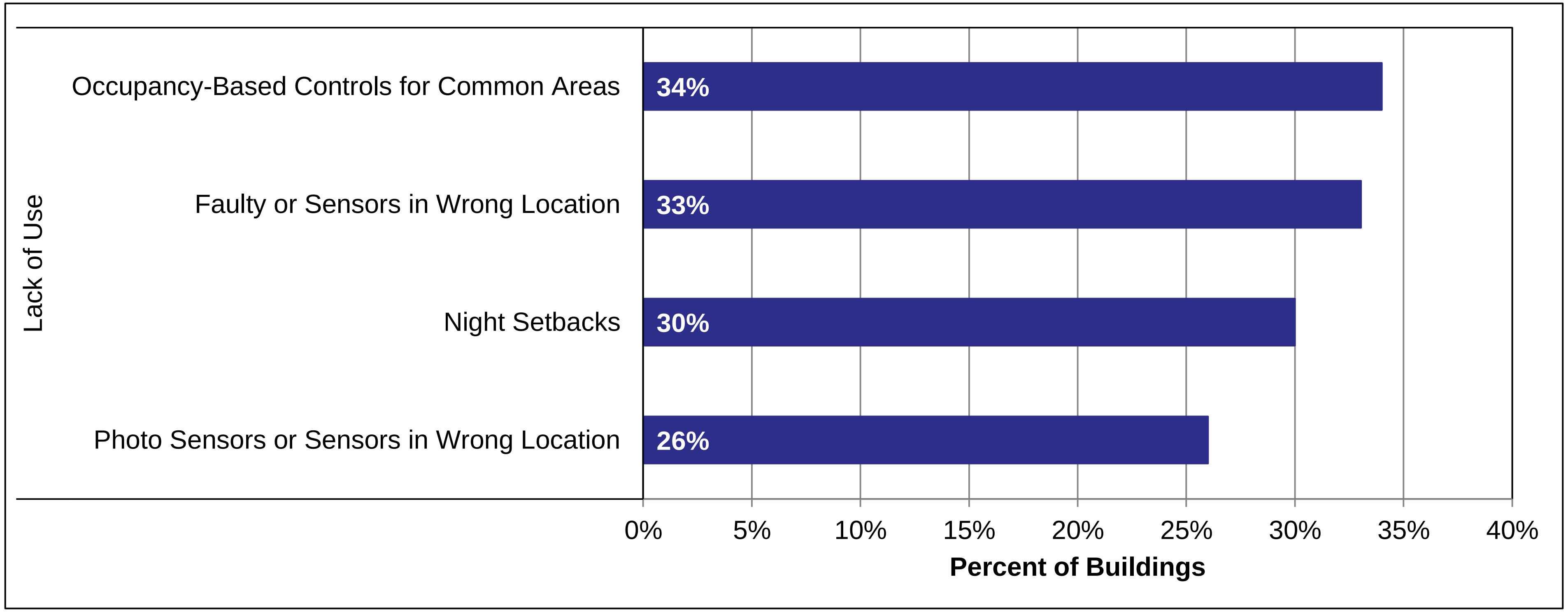
Distribution of Study Buildings by State



Lack of Reset Strategies

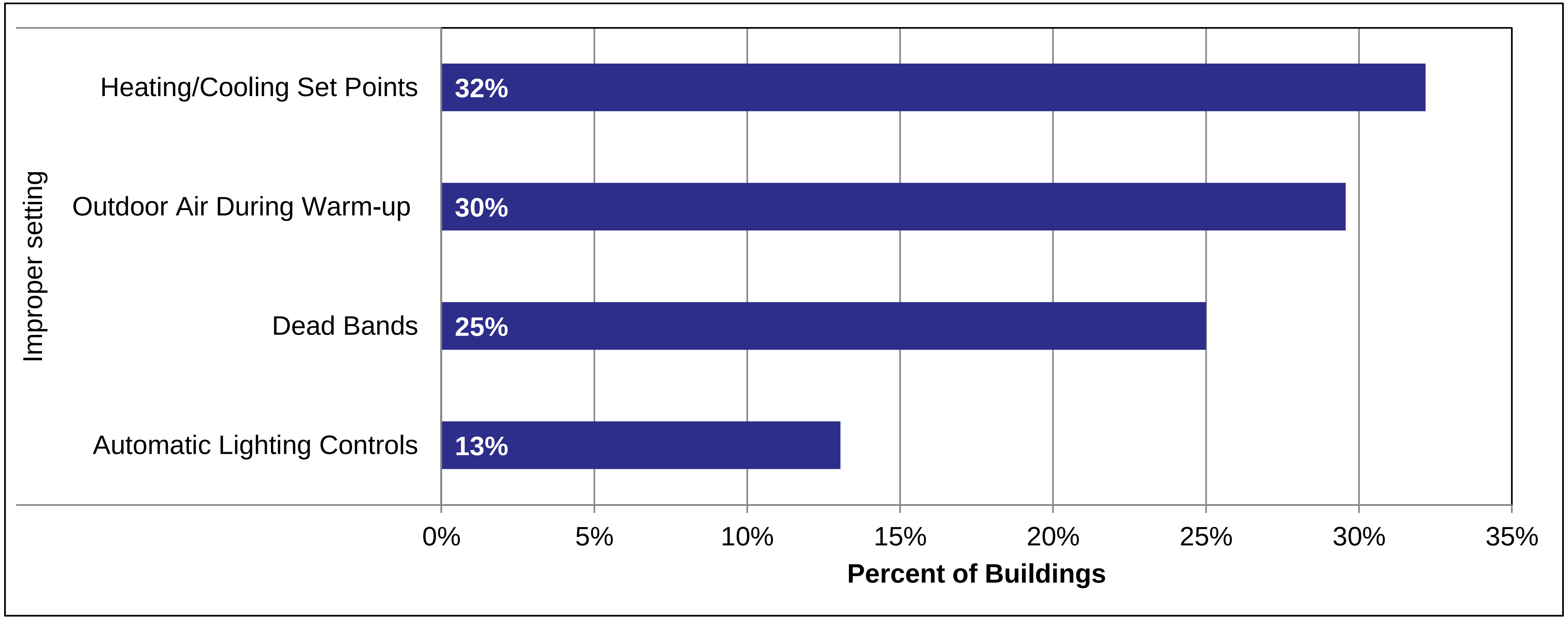


Lack of Use

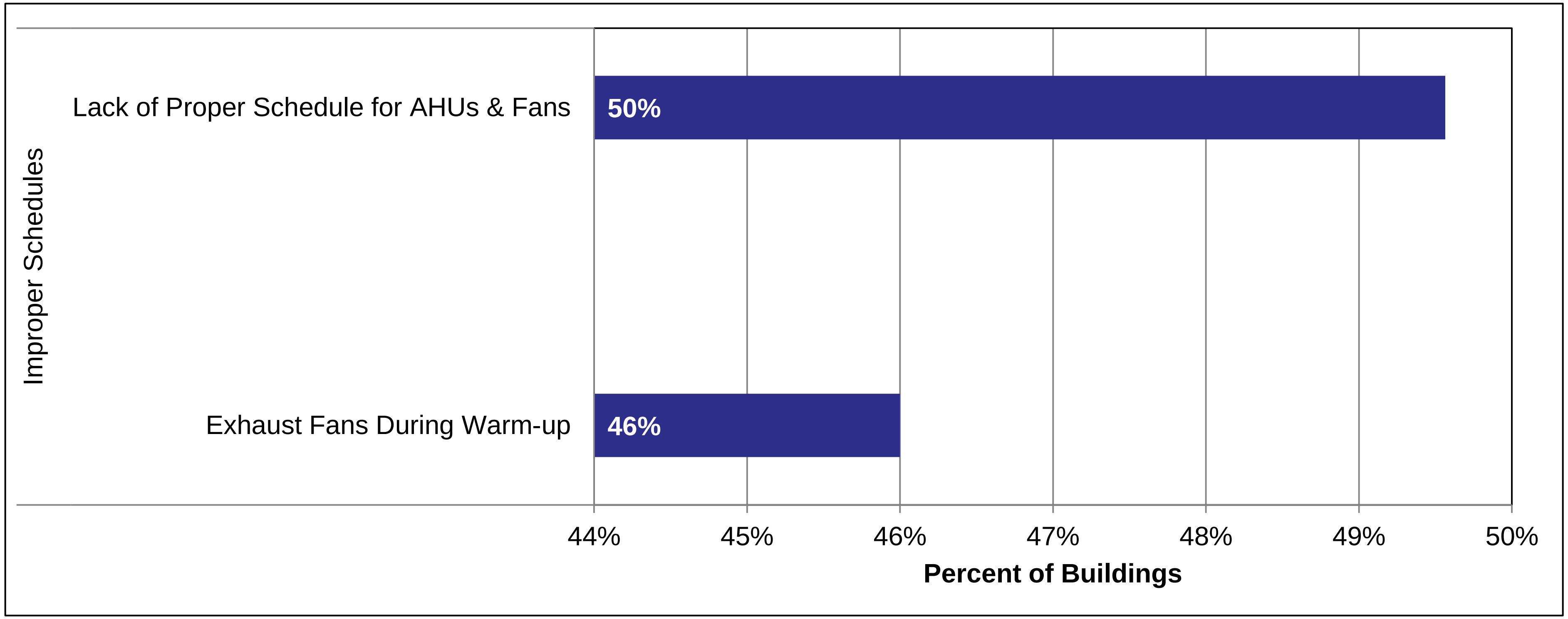


Lack of Use
Occupancy-Based Controls for Common Areas
Faulty or Sensors in Wrong Location
Night Setbacks
Photo Sensors or Sensors in Wrong Location
34%
33%
30%
26%
0%
5%
10%
15%
20%
25%
30%
35%
40%
Percent of Buildings

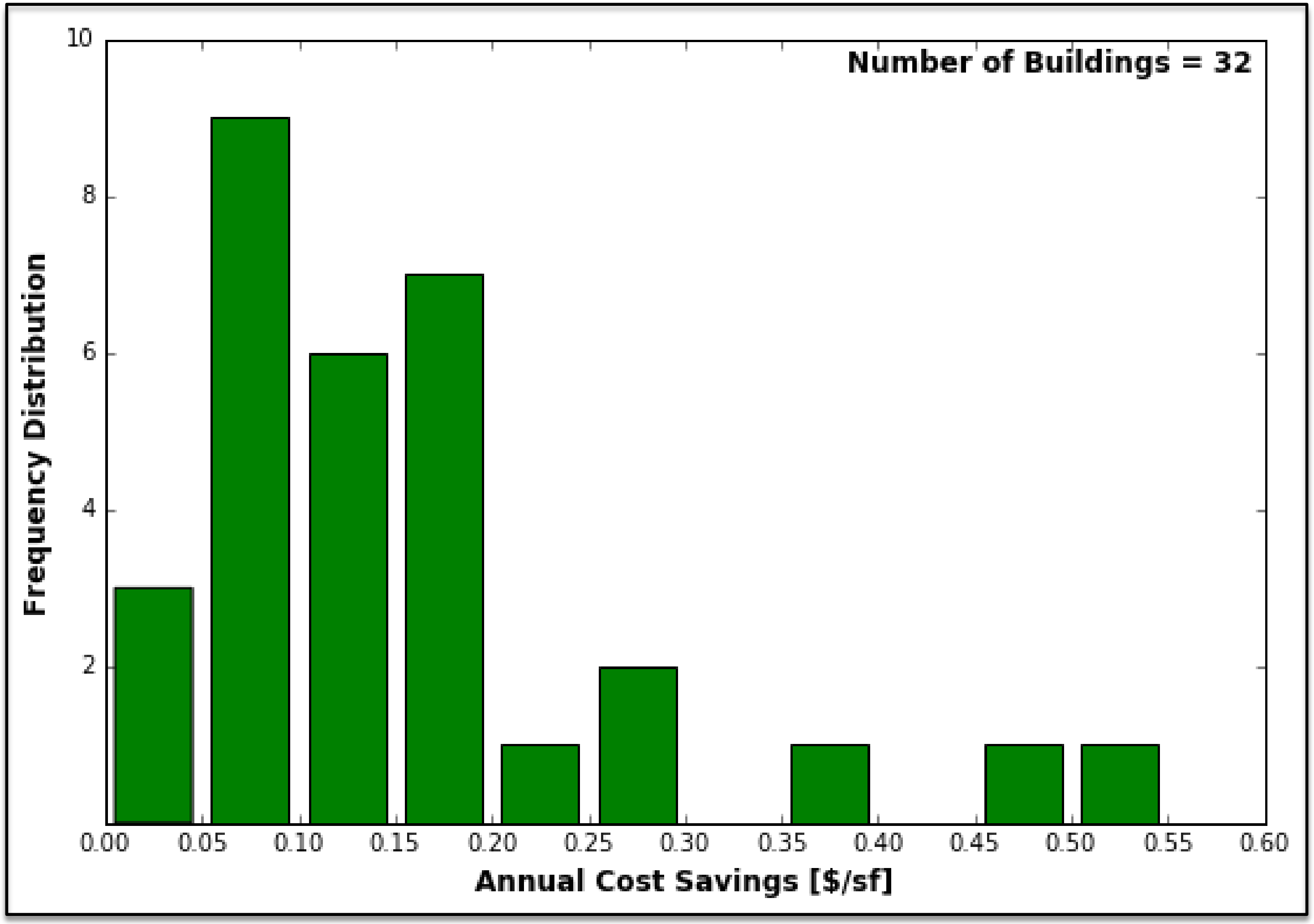
Improper Settings



Lack of Proper Schedules



Distribution of Buildings by State

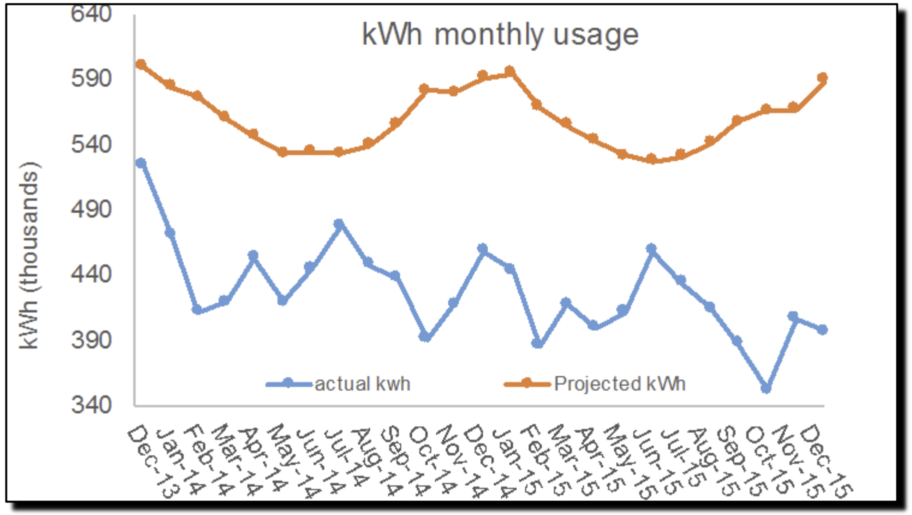


Median Savings 13%

Mean Savings 17%

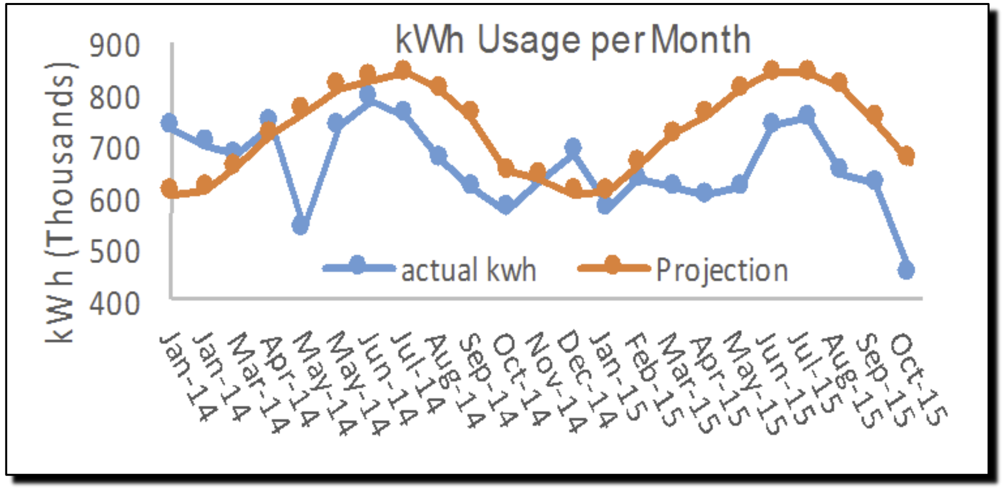
Building in Atlanta, GA

- Implemented night setback for air temperature and pressure
- Reduced interior zone reheat
- Reduced overcooling or overheating
- Reduced reheat during summer/cooling season for exterior zones
- Implemented discharge air reset
- Eliminated zones that were out of control, oscillating between heating and cooling



Building in TX

- Relocated outdoor air temperature
- Reviewed and removed all the overrides
- Recalibrated pneumatic devices
- Replaced gaskets on all dampers
- Implemented discharge air temperature reset
- Updated building automation system code
- “Optimized” the start and stop times
- Adjusted the static pressure of AHUs



Key Lessons Learned

- Many commercial buildings have array of operational problems
- Trained building operations staff can re-tune buildings, if empowered
- Building re-tuning can yield energy savings between 5% and 20% through implementation of no-cost and low-cost measures
- But, the human factor is a real issue in realizing re-tuning benefits in practice
- **In the long run, automation is key to persistence of "optimal" building operation**

Questions?

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http://retuningtraining.labworks.org

Thank you for attending!

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