Small Buildings, Big Impact: Leveraging Controls for Energy Efficiency, Thermal Comfort and Demand Response

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ENERGY TECHNOLOGIES AREA
BERKELEY LAB

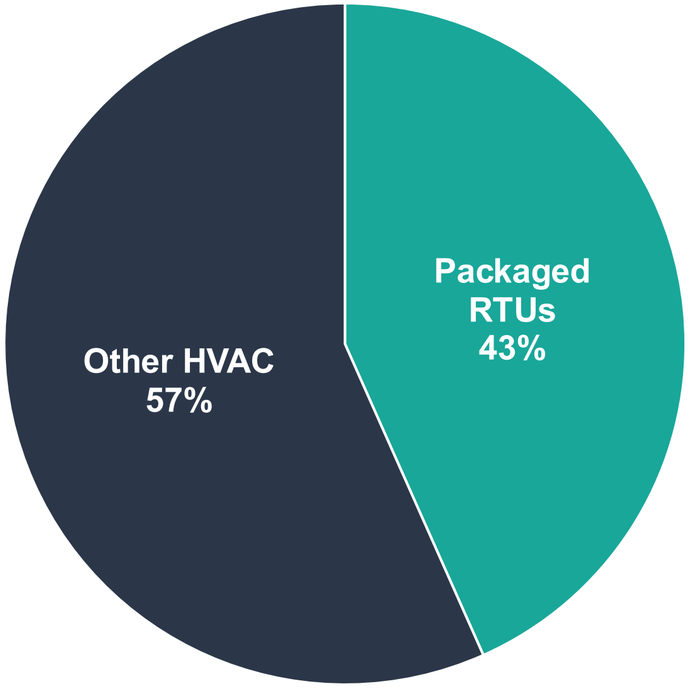
Agenda

1. Background
2. Why Improve Rooftop Unit (RTU) Controls?
3. Different Types of Controls for Small & Medium-Sized Buildings
4. Demand Response and How to Reduce Peak Demand in Small to Medium-Sized Buildings
5. Case Studies
6. Navigating Barriers Related to Control Implementation
7. Resources
8. Q+A

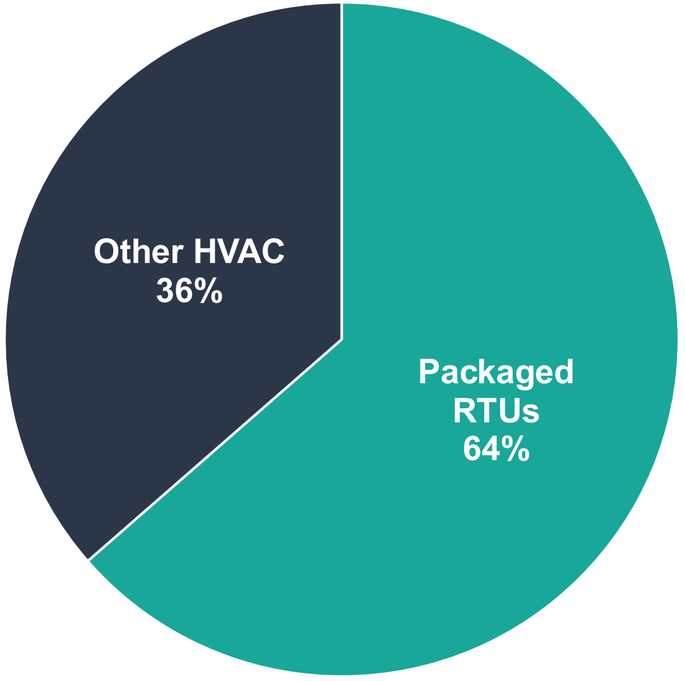
Background

Commercial Buildings

- 94% ≤ 50,000 SQ FT
  - Unlikely to have onsite operations staff
- 16% have a building automation system (BAS)
- 5% have smart thermostats



Distribution of Commercial Buildings with Rooftop Units (RTUs) vs. Other Systems

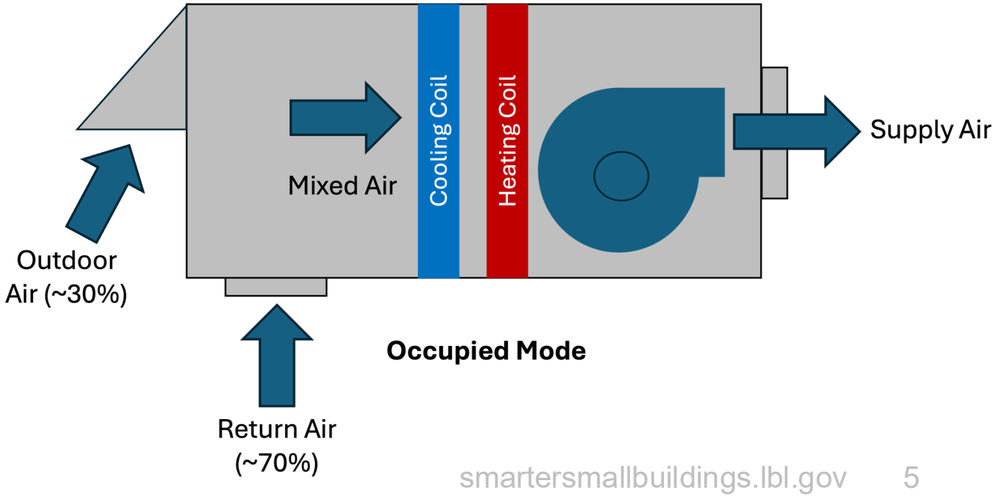


Total Building Energy Consumption in Buildings with RTUs vs. Other Systems

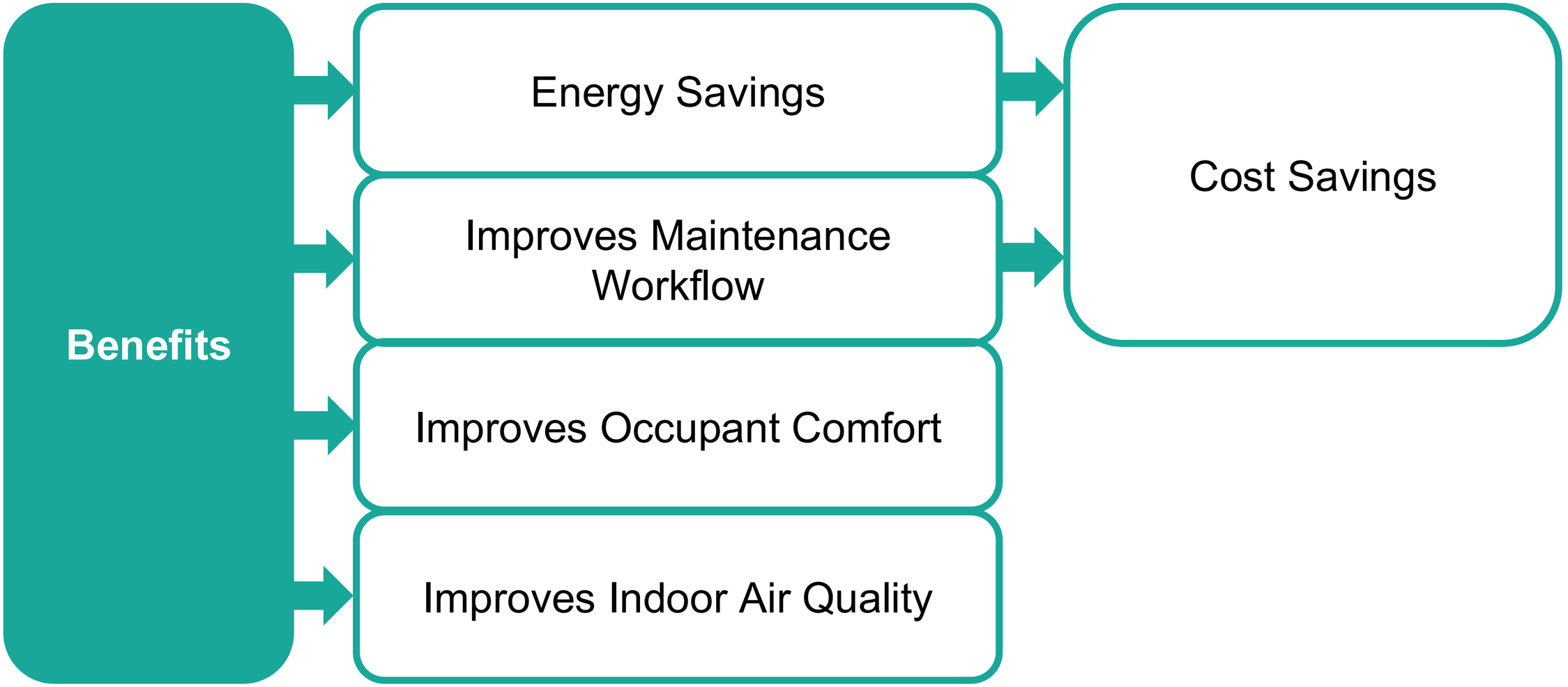
Rooftop Units (RTUs)

- Rooftop Units:
  - All in one system
  - Can provide heating (gas, heat pump, or electric resistance), cooling, and ventilation
  - Commonly used for small to medium-sized offices, retail, restaurants, and warehouses
- Common Issues:
  - Insufficient maintenance/ unit neglect
  - Older units can be inefficient
  - **Lack of control capabilities**

Image Source: DOE (Link)

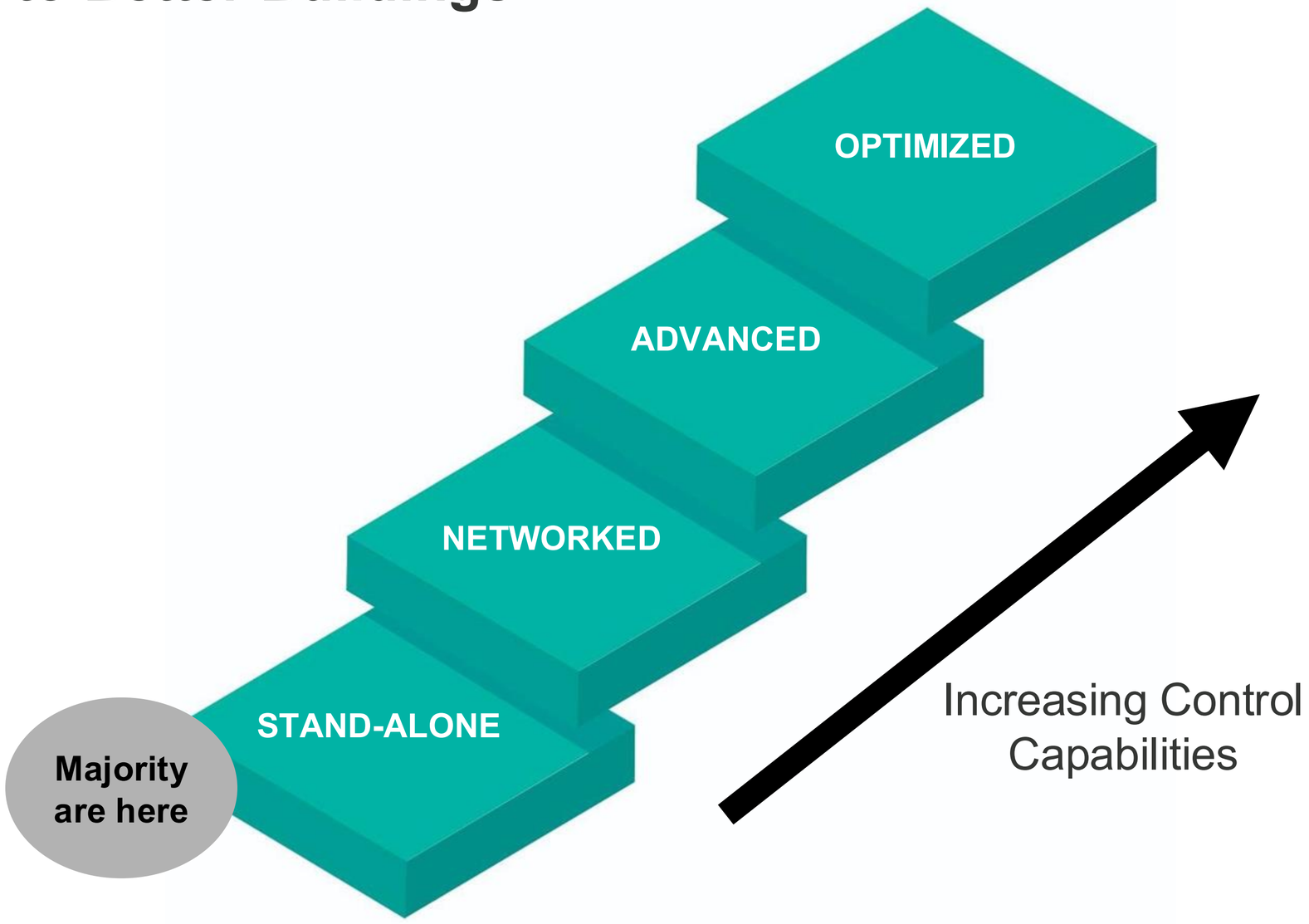


Why Improve RTU Controls?


Benefits
Energy Savings
Improves Maintenance Workflow
Improves Occupant Comfort
Improves Indoor Air Quality
Cost Savings

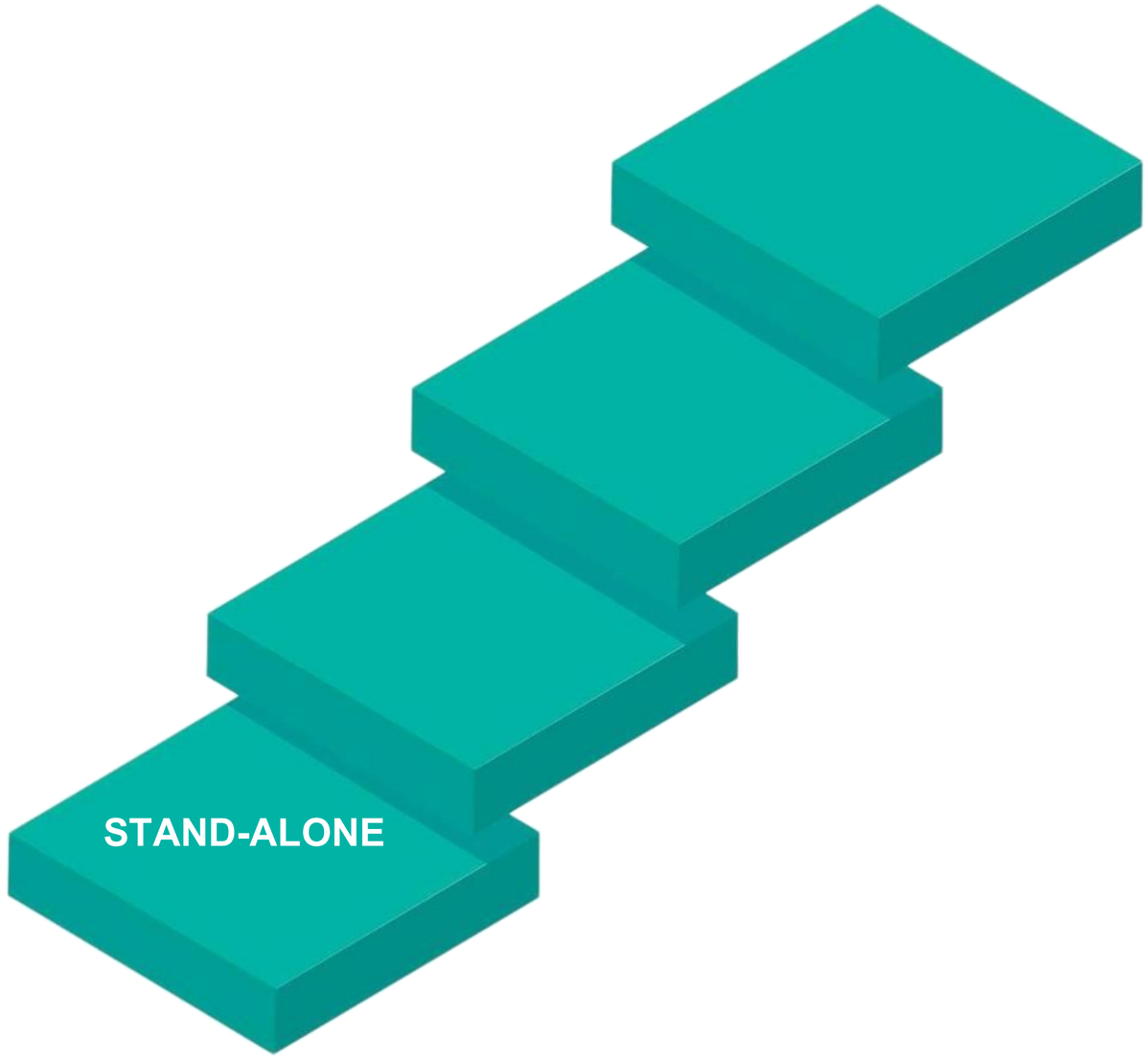
Different Types of Controls for Small & Medium-Sized Buildings

Stairway to Better Buildings



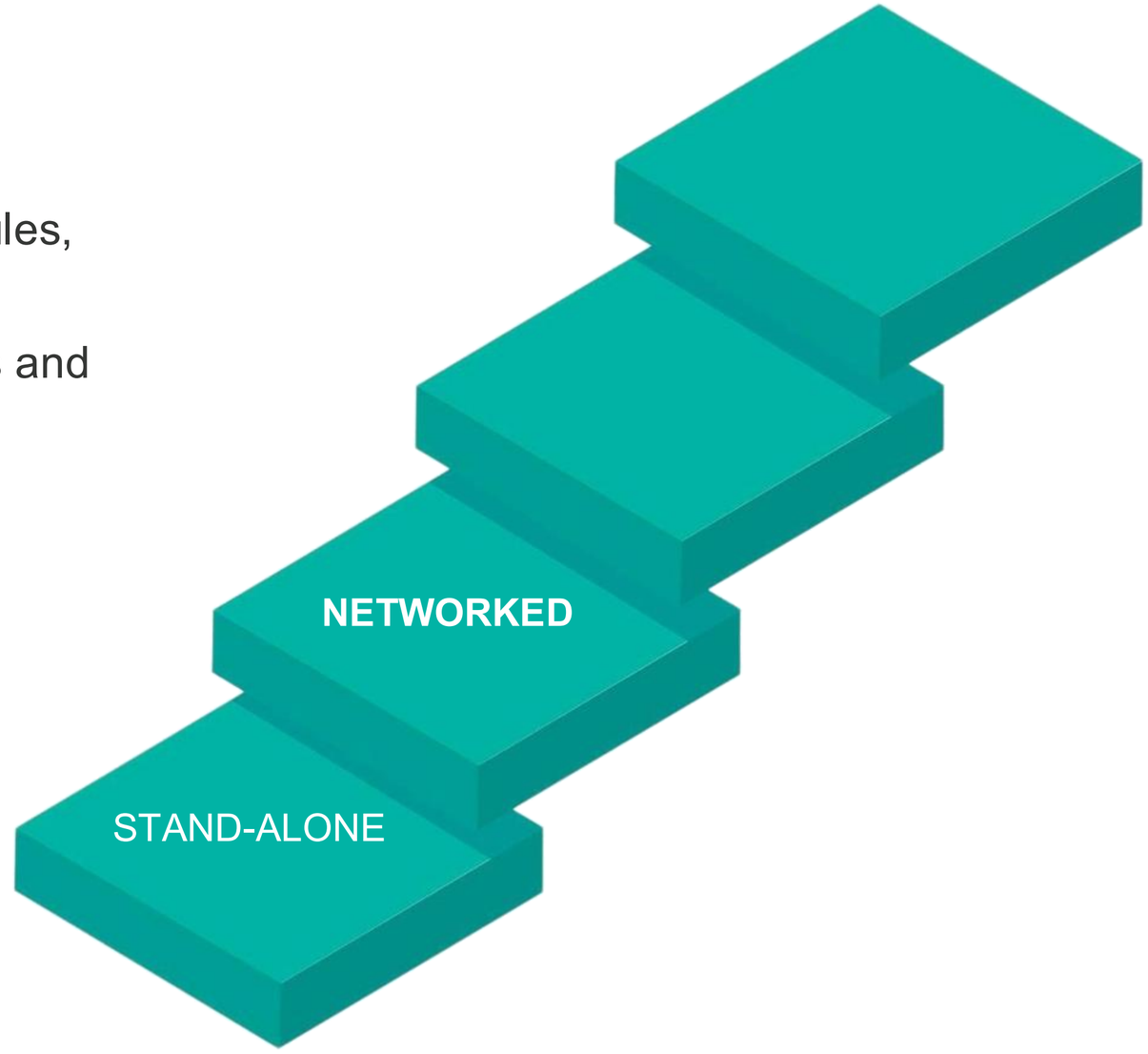
Stand-Alone Controls

- **Status Quo**
- Programmable
- Allows for scheduling and setpoint adjustment
  - Settings to be adjusted at the thermostat
- Non-Communicating Thermostats



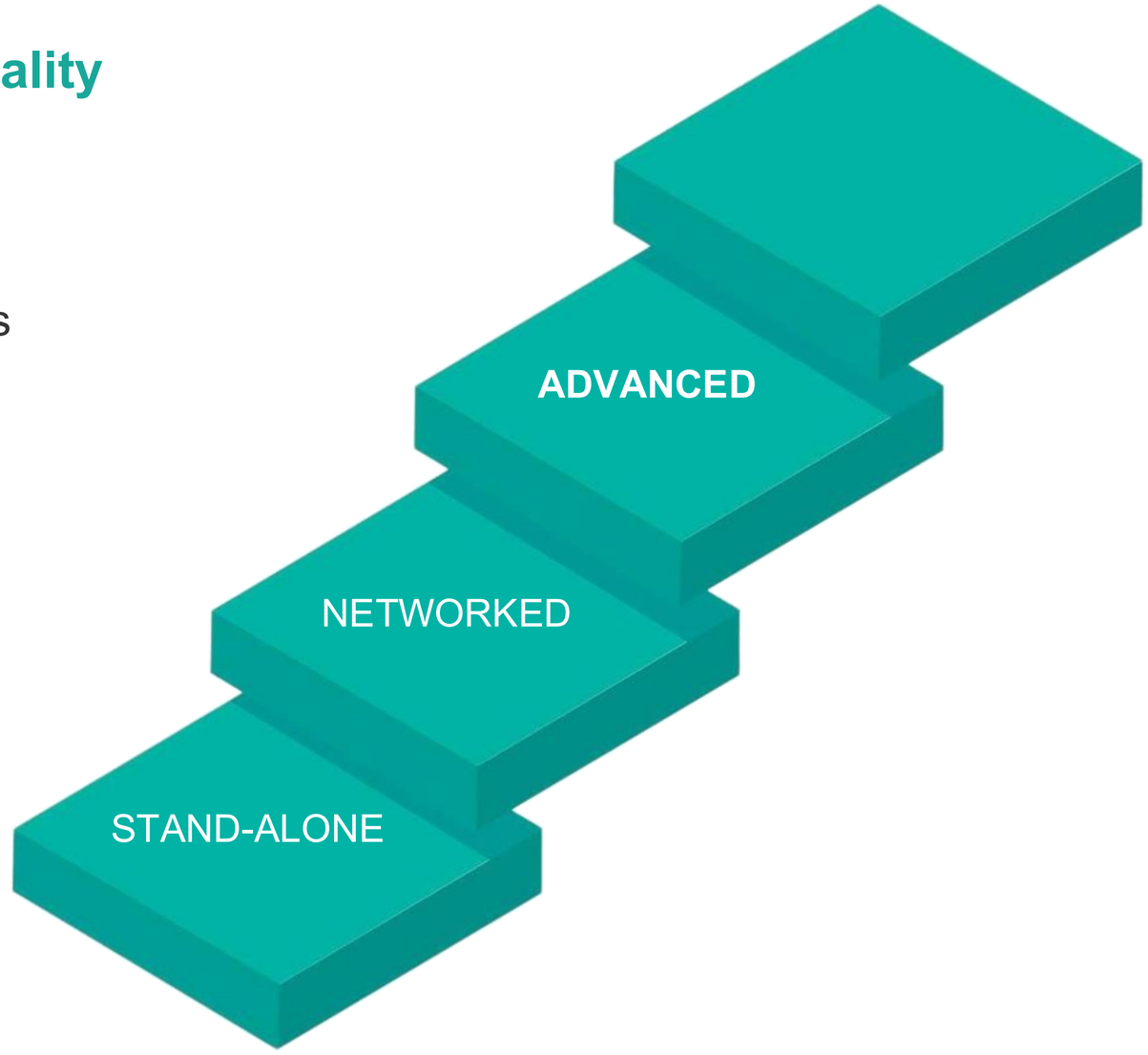
Networked Controls

- **Reduce Energy Waste**
- Allows for:
  - Monitoring of zone temperatures, setpoints, schedules, equipment status, and critical alarms
  - Adjustment of control parameters such as setpoints and schedules
- Great for multiple RTUs and buildings
- **10-20%** whole building energy savings
- Requires communicating thermostats



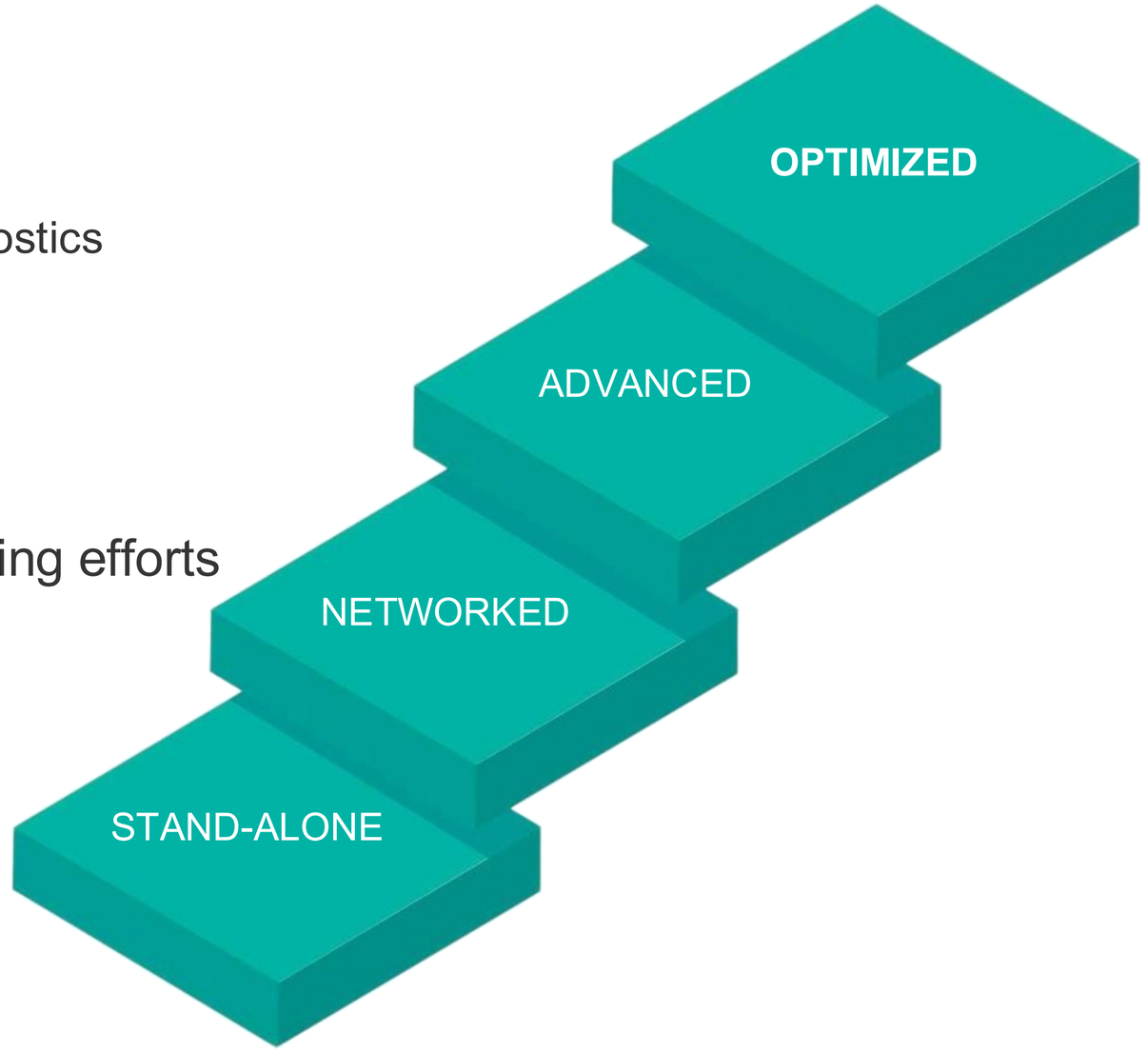
Advanced Controls

- **Improve energy efficiency and indoor air quality**
- Allows for some of the following capabilities:
  - Variable Speed or Multi-Speed Supply Fan Control
  - Economizer Controls, Fault Detection & Diagnostics
  - Occupancy-Based Controls
  - Optimal Start/Stop
  - Demand Control Ventilation
- Average Whole Building Energy Savings of **35%** across 16 locations in 15 climate zones based on a combination of Advanced Control Measures [1]
- Requires additional sensors and control hardware



Optimized Controls

- **Grid-interactive, efficient building control**
- Allows for some of the following capabilities:
  - Vapor Compression Cycle Fault Detection & Diagnostics
  - Coordination of Multiple Units
  - Dynamic Multi-Unit Coordination
  - Facilitation of Automated Grid Response Strategies
- Requires additional commissioning and monitoring efforts



Stairway to Better Buildings

Grid-interactive, efficient building control

- Requires additional commissioning (Cx) and monitoring effort
- Dynamic optimization, automated demand flexibility

Improved energy efficiency and air quality

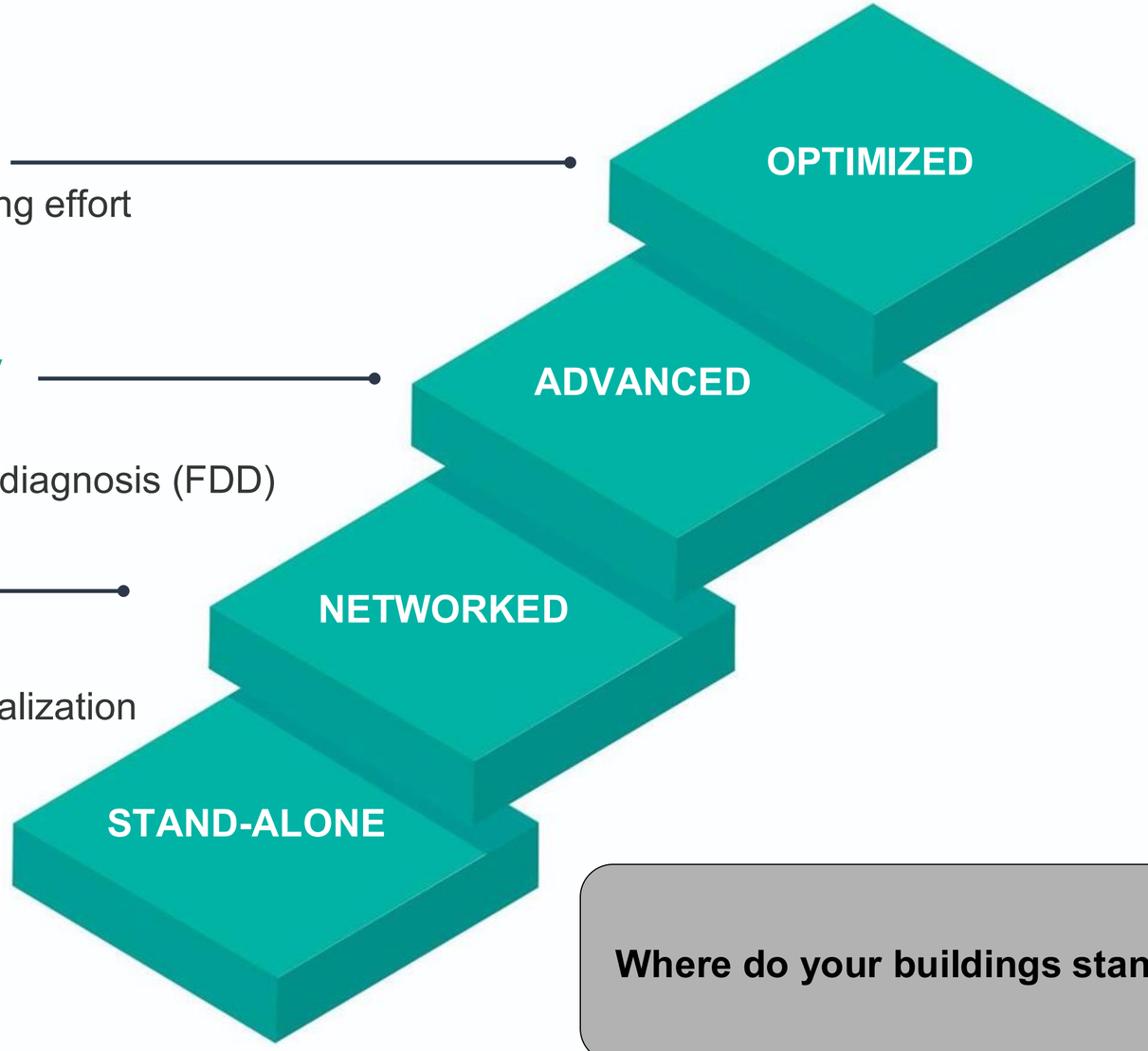
- Requires additional sensors and control hardware
- Advanced component control and fault-detection and diagnosis (FDD) capabilities

Reduced energy waste

- Requires communicating thermostats
- Remotely accessible, centralized data collection, visualization and monitoring

Status quo

- Programmable thermostats
- Scheduling, setpoint adjustment

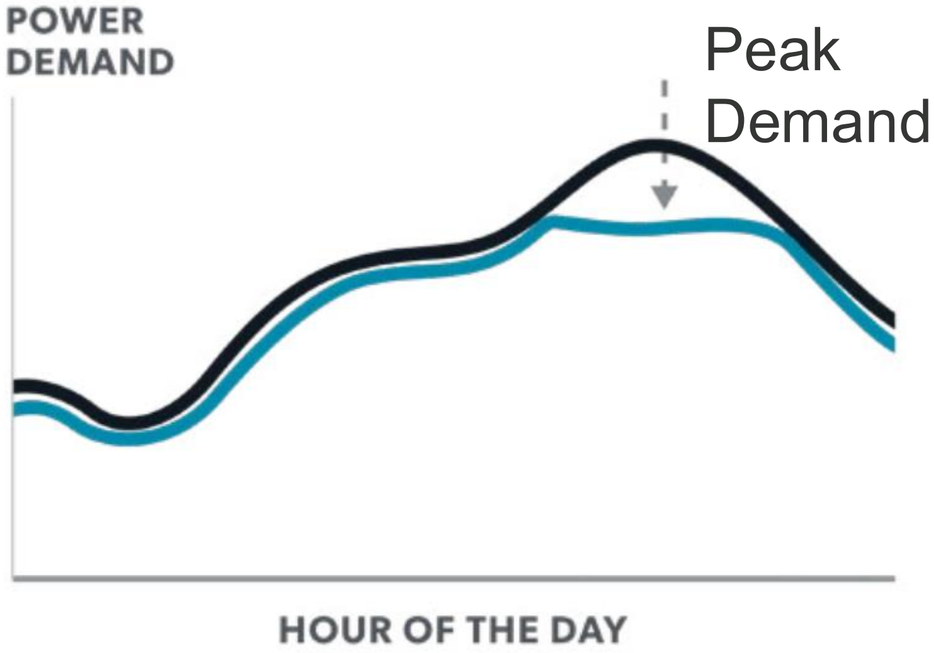


Where do your buildings stand?

Demand Response and How to Reduce Peak Demand in Small to Medium-Sized Buildings

Demand Response (DR)

- Encourages customers to reduce or shift electricity consumption in response to an event signal
  - Incentives
  - Improves Grid Reliability
- The Utility/ Aggregator will send an event signal to the energy management system
  - **Manual** DR operator initiates sequences to reduce building demand
  - **Automated** DR predefined settings automatically initiate sequences to reduce building demand
    - Open ADR2.0 is a common protocol for Auto-DR



Source: Guidehouse

Reducing Building Peak Demand in Small to Medium Sized Buildings

- Common Strategies
  - Temporarily adjust setpoints
  - Cycle the operation of multiple RTUs to avoid simultaneous spikes
    - Such as limiting the number of available cooling stages during a DR event
  - Pre-condition zones
  - Fan speed reduction
  - Lighting Strategies (Zoning and Dimming)
- Possible to configure multiple levels of logic, allowing for different depths of load shedding

Common Controls Incentives

- Smart Thermostats
- VFDs for Fans and Pumps
- Advanced RTU Controls
  - Economizers
  - Demand Control Ventilation
- Lighting and Lighting Controls
- Demand Response & Automated Demand Response

Check with your utility to see what's available!

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Case Studies

Case Study

- Replaced stand-alone thermostats with networked thermostats, referred to as the SWARM Project
- Operational Benefits:
  - Allow users to modify setpoints, and the facilities team can remotely reset temporary changes
  - Reduces equipment wear by minimizing run times through efficient scheduling
  - Enabled participation in demand response programs
  - Transformed maintenance workflow

Building Type	Office, Child Care Center, Lab
Average Building Size	5,000 sq ft
Number of Buildings with Controls	101
Whole Building Energy Savings	28%
Simple Payback	< 3 years

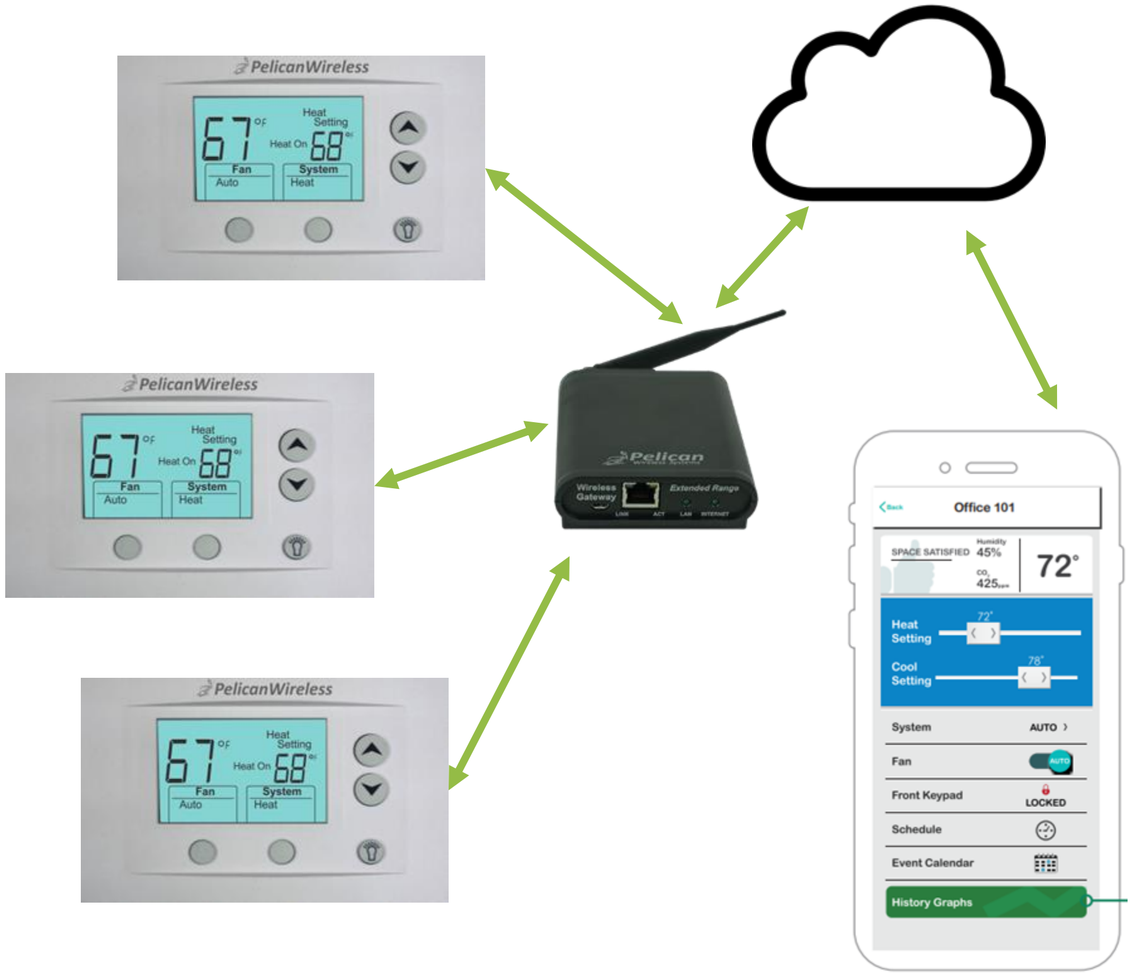
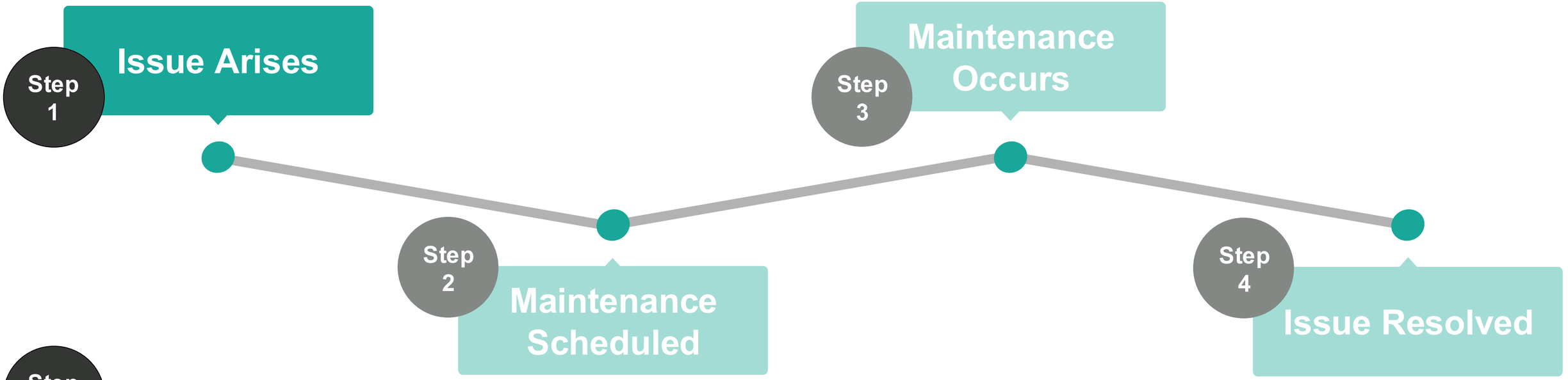


Image Source: UC Davis (Webinar Link)
Note: Other technology providers are available

Source: SSBC UC Davis Case Studies (Link 1 & Link 2)

Improved Maintenance Workflow

Source: SSBC UC Davis Case Study (Link)



Step 1

Stand-Alone Thermostats

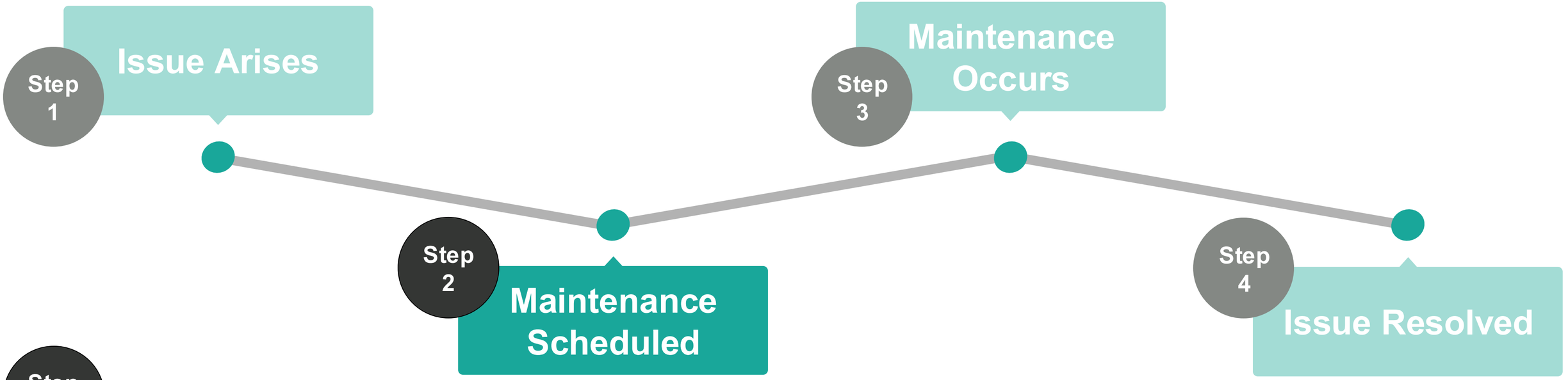
- The occupant submits a complaint to the facilities team

Networked Thermostats

- Deviations from space setpoints trigger an alarm

Improved Maintenance Workflow

Source: SSBC UC Davis Case Study (Link)



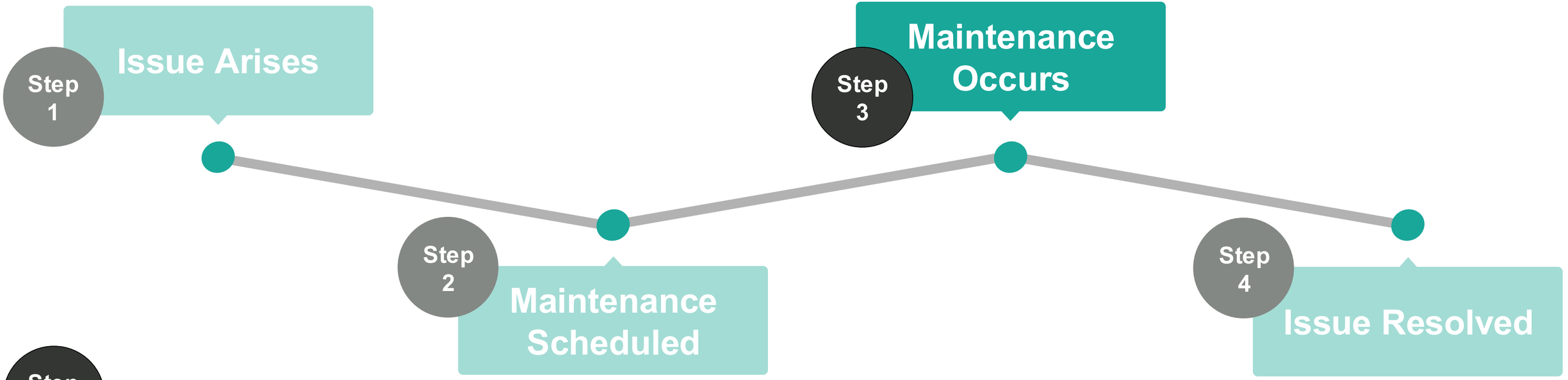
Step 2

Stand-Alone Thermostats
- Site visit scheduled

Networked Thermostats
- Fault and corresponding data reviewed remotely

Improved Maintenance Workflow

Source: SSBC UC Davis Case Study (Link)



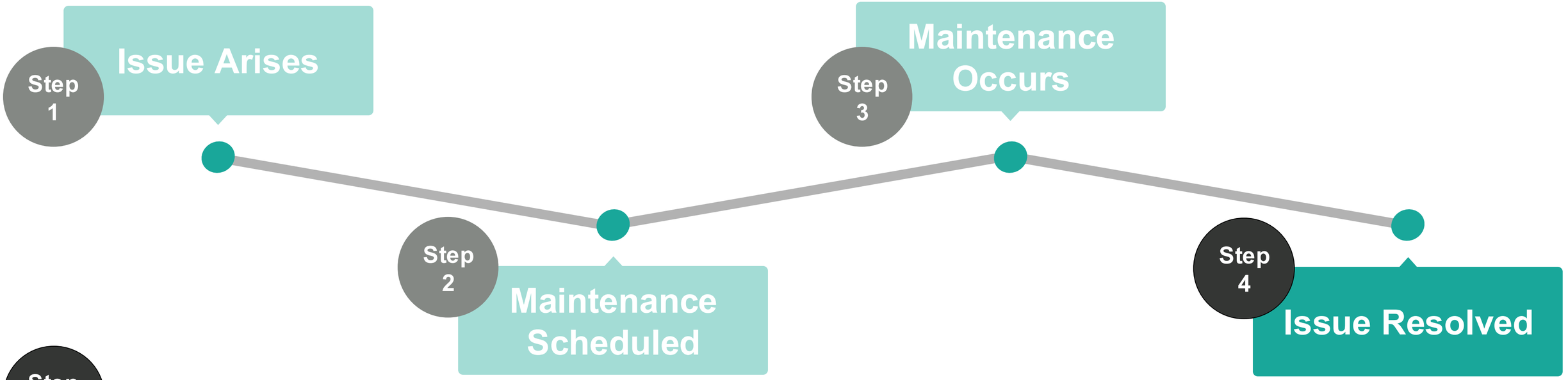
Step 3

Stand-Alone Thermostats
- Fault resolved on-site

Networked Thermostats
- Fault resolved either remotely or on-site

Improved Maintenance Workflow

Source: SSBC UC Davis Case Study (Link)



Step 4

Stand-Alone Thermostats

- Occupants need to verify that the issue has been resolved

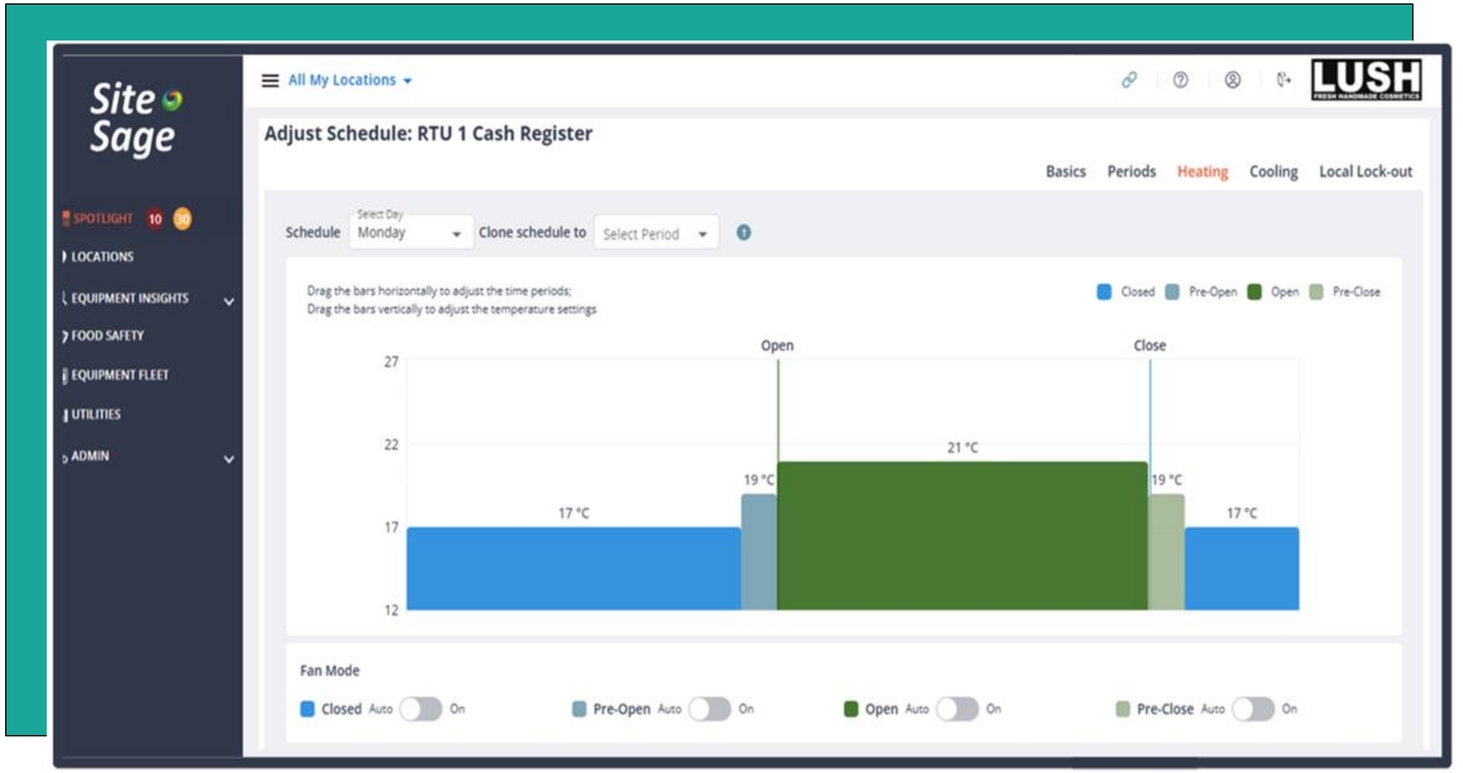
Networked Thermostats

- Fault can be verified remotely through trend data

Case Study

- Installed networked controls across 183 stores
- Were able to
  - Schedule exhaust fans
  - Have better temperature control
  - Improve maintenance workflow
  - Automatically generate a monthly ‘HVAC Fix List’

Building Type	Retail
Average Building Size	1,687 sq ft
Number of Buildings with Controls	183
Whole Building Energy Savings	17%



Source: SSBC Lush Case Study (link)
Note: Other technology providers available

Case Study

- Installed building management systems (BMS)
  - Across 700 stores
- Able to control:
  - HVAC
  - Exterior Lighting
- Able to monitor:
  - Refrigeration
  - Energy Consumption
  - HVAC operating parameters
- Advanced controls have helped
  - Streamline maintenance and reduce truck rolls
  - Provide more insight into the equipment
  - Reduce equipment failures
  - Improve occupant comfort

Building Type	Convenience Store
Average Building Size	6,000 sq ft
Number of Buildings with Controls	700
Whole Building Energy Savings	11%

Source: SSBC Sheetz Case Study (link)

Navigating Barriers Related to Control Implementation

Smarter Small Buildings Campaign

What is the Campaign?

- DOE-sponsored program managed by Berkeley Lab to promote improved HVAC controls for small/medium buildings
- Applicable to all buildings with packaged rooftop units

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Benefits

- 1:1 Technical Support
- Peer-to-Peer Support
- Resources, Webinars, etc.
- Case Study Opportunities

Who can Join?

- Building Owners/Operators
- Product vendors, contractors, industry organizations, utilities

https://smartersmallbuildings.lbl.gov/

Top 5 Most Common Support Topics

"Can you share information on energy meters for small retail spaces where we do not have a dedicated electricity account?"

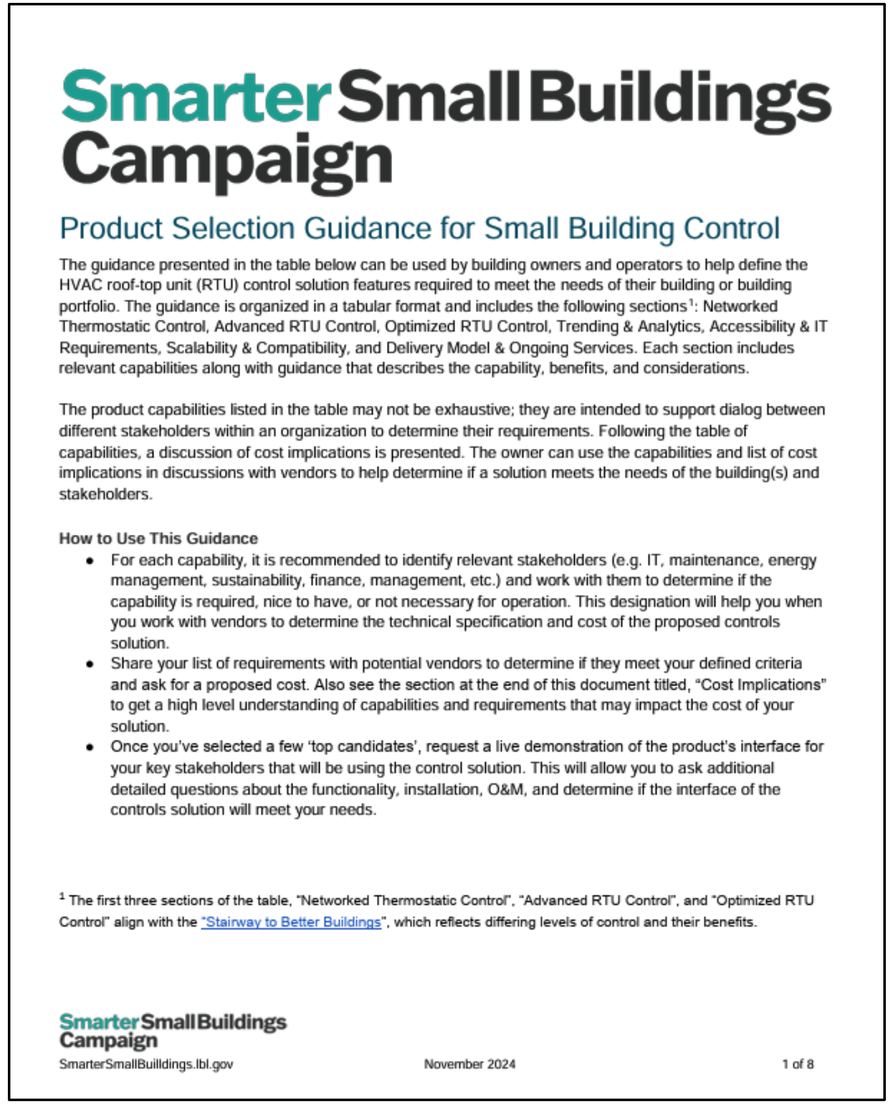
"Can you provide some details on the expected energy savings from controls so I can make the business case to leadership?"

"How can I measure the indoor air quality of my buildings?"

Resources

Product Selection Guidance

- Help define HVAC RTU controls to meet you needs
- Contains Information on:
  - Control Capabilities
    - Networked Thermostatic Control
    - Advanced RTU Control
    - Optimized RTU Control
  - Trending & Analytics
  - Accessibility & IT Requirements
  - Scalability & Compatibility
  - Delivery Model & Ongoing Services



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Product Selection Guidance for Small Building Control

The guidance presented in the table below can be used by building owners and operators to help define the HVAC roof-top unit (RTU) control solution features required to meet the needs of their building or building portfolio. The guidance is organized in a tabular format and includes the following sections[1]: Networked Thermostatic Control, Advanced RTU Control, Optimized RTU Control, Trending & Analytics, Accessibility & IT Requirements, Scalability & Compatibility, and Delivery Model & Ongoing Services. Each section includes relevant capabilities along with guidance that describes the capability, benefits, and considerations.

The product capabilities listed in the table may not be exhaustive; they are intended to support dialog between different stakeholders within an organization to determine their requirements. Following the table of capabilities, a discussion of cost implications is presented. The owner can use the capabilities and list of cost implications in discussions with vendors to help determine if a solution meets the needs of the building(s) and stakeholders.

How to Use This Guidance

- For each capability, it is recommended to identify relevant stakeholders (e.g. IT, maintenance, energy management, sustainability, finance, management, etc.) and work with them to determine if the capability is required, nice to have, or not necessary for operation. This designation will help you when you work with vendors to determine the technical specification and cost of the proposed controls solution.
- Share your list of requirements with potential vendors to determine if they meet your defined criteria and ask for a proposed cost. Also see the section at the end of this document titled, "Cost Implications" to get a high level understanding of capabilities and requirements that may impact the cost of your solution.
- Once you've selected a few 'top candidates', request a live demonstration of the product's interface for your key stakeholders that will be using the control solution. This will allow you to ask additional detailed questions about the functionality, installation, O&M, and determine if the interface of the controls solution will meet your needs.

[1] The first three sections of the table, "Networked Thermostatic Control", "Advanced RTU Control", and "Optimized RTU Control" align with the "Stairway to Better Buildings", which reflects differing levels of control and their benefits.

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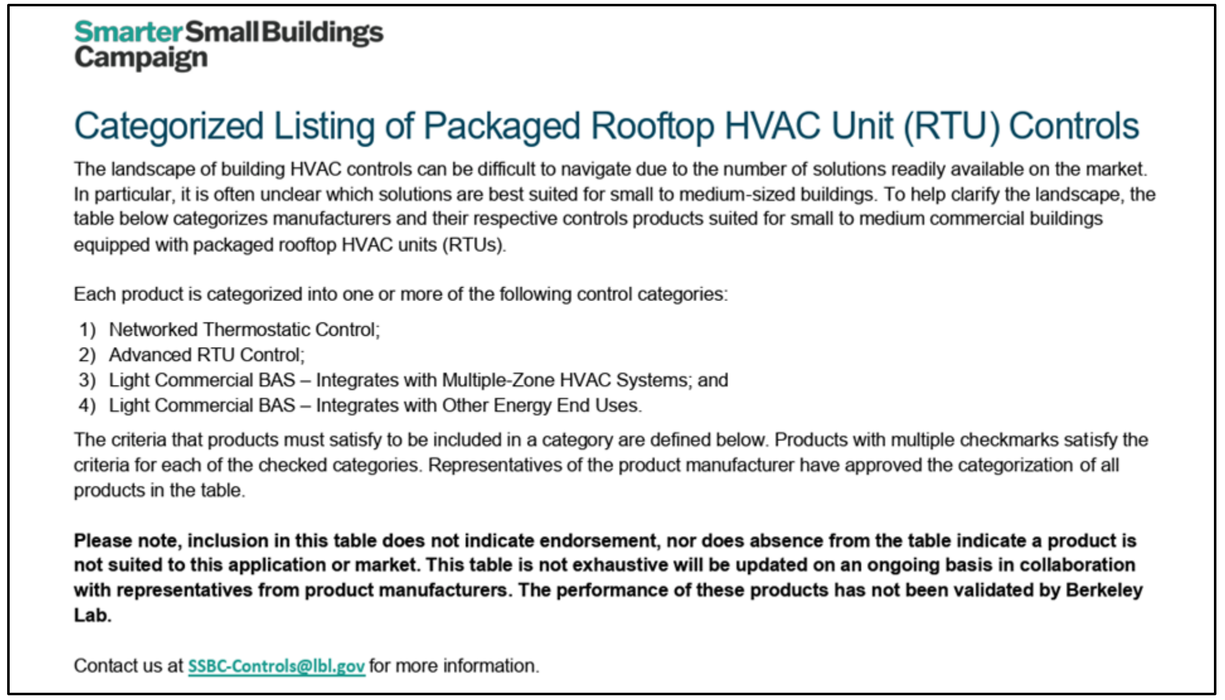
Categorized Listing of Packaged RTU Controls

- Categorizes control manufacturers and their respective products
- Catered to small to medium-sized commercial buildings
- Categorized by:
  - Networked Thermostatic Control
  - Advanced RTU Control
  - Light Commercial BAS
    - Integrates with Multiple Zone HVAC Systems
    - Integrates with Other Energy End Uses



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Categorized Listing of Packaged Rooftop HVAC Unit (RTU) Controls

The landscape of building HVAC controls can be difficult to navigate due to the number of solutions readily available on the market. In particular, it is often unclear which solutions are best suited for small to medium-sized buildings. To help clarify the landscape, the table below categorizes manufacturers and their respective controls products suited for small to medium commercial buildings equipped with packaged rooftop HVAC units (RTUs).

Each product is categorized into one or more of the following control categories:

1) Networked Thermostatic Control;
2) Advanced RTU Control;
3) Light Commercial BAS – Integrates with Multiple-Zone HVAC Systems; and
4) Light Commercial BAS – Integrates with Other Energy End Uses.

The criteria that products must satisfy to be included in a category are defined below. Products with multiple checkmarks satisfy the criteria for each of the checked categories. Representatives of the product manufacturer have approved the categorization of all products in the table.

Please note, inclusion in this table does not indicate endorsement, nor does absence from the table indicate a product is not suited to this application or market. This table is not exhaustive will be updated on an ongoing basis in collaboration with representatives from product manufacturers. The performance of these products has not been validated by Berkeley Lab.

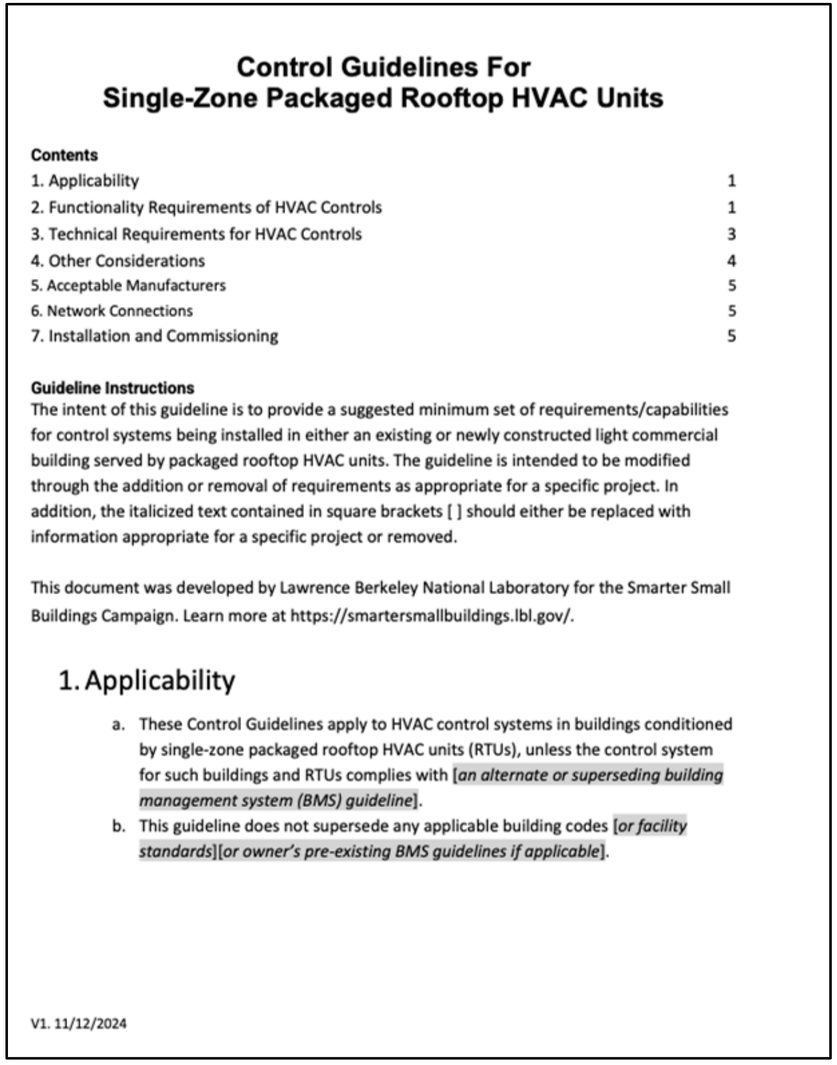
Contact us at SSBC-Controls@lbl.gov for more information.

Setpoints & Scheduling for Packaged RTU Controls

- Setpoints and schedules can have a large impact on energy usage
- Guidance on creating more energy-efficient setpoint schedules and operational policies
  - The Importance of Setpoints and Scheduling
  - Occupant Thermal Comfort
  - Getting Started with an Operational Policy
  - Heating and Cooling Setpoints
  - Deadband
  - Thermostat Placement & Temperature Sensors
  - Thermostat Controls
  - Scheduling Fan Operation

Control Guidelines for Single-Zone RTUs

- Provides a minimum set of requirements and capabilities for RTU control systems
- It's editable and is intended to be adjusted to meet the needs of your project
- Contents:
  - Applicability
  - Functionality Requirements of HVAC Controls
  - Technical Requirements of HVAC Controls
  - Other Considerations
  - Acceptable Manufacturers
  - Network Connections
  - Installation and Commissioning



Control Guidelines For
Single-Zone Packaged Rooftop HVAC Units

Contents

Guideline Instructions

The intent of this guideline is to provide a suggested minimum set of requirements/capabilities for control systems being installed in either an existing or newly constructed light commercial building served by packaged rooftop HVAC units. The guideline is intended to be modified through the addition or removal of requirements as appropriate for a specific project. In addition, the italicized text contained in square brackets [ ] should either be replaced with information appropriate for a specific project or removed.

This document was developed by Lawrence Berkeley National Laboratory for the Smarter Small Buildings Campaign. Learn more at https://smartersmallbuildings.lbl.gov/.

1. Applicability

a. These Control Guidelines apply to HVAC control systems in buildings conditioned by single-zone packaged rooftop HVAC units (RTUs), unless the control system for such buildings and RTUs complies with [*an alternate or superseding building management system (BMS) guideline*].

b. This guideline does not supersede any applicable building codes [*or facility standards*][*or owner's pre-existing BMS guidelines if applicable*].

V1. 11/12/2024

What's Next?

- Performance Metrics
  - Exploring and investigating metrics that would be useful for monitoring purposes
- IT Security Best Practices
  - Defining the minimum requirements for cybersecurity
- Networked Controls Costs
  - Working with our partners to try to answer the common question, "How much do they cost?"

THANK YOU!

Q+A

Contact **SSBC-Controls@lbl.gov** or Ashleigh at **apapakyriakou@lbl.gov**

Our website **SmarterSmallBuildings.lbl.gov**

References

[1] Wang, W., Katipamula, S., Huang, Y., & Brambley, M. R. (2011). *Energy savings and economics of advanced control strategies for packaged air-conditioning units with gas heat* (Report No. PNNL-20955). Pacific Northwest National Laboratory. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20955.pdf