Building systems

Building HVAC - complex systems, Building Automation System

Kevin Frost | Slipstream

2024

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Learning Objectives

- Discuss more complex HVAC equipment and system types.
- Name typical control sequences for more complicated equipment and systems.
- Identify the components of a Building Automation System (BAS).
- Highlight trends in modern building automation system.

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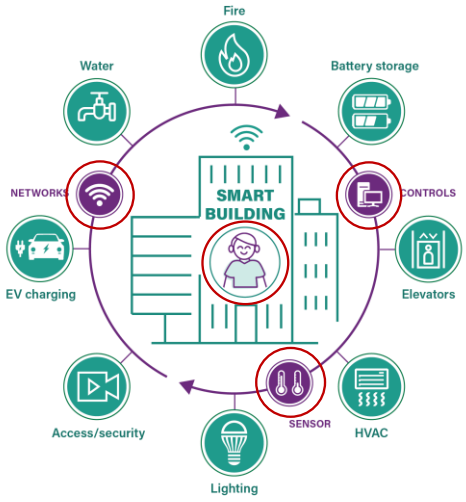
Outline

- **HVAC System Types**
  - Air Handling Units
  - Variable Air Volume Systems
  - Decentralized Systems
  - Hydronic Systems
- **HVAC Control Sequence**
  - Multizone controls
  - Demand Control Ventilation
  - ASHRAE Guideline 36
- **Building Automation System**
  - Architecture
  - Hardware
  - Communication and Software
- **Trends in Modern Building Automation Systems**

Smart Building Elements



1) Building systems
   1) Envelope
   2) HVAC
   3) Lighting
   4) Water
   5) Solar PV + battery energy storage
   6) EV charging
   7) Other (elevator, fire, access/security)
2) Sensors
3) Controls
   1) Platform
   2) Control methods
4) Networks
5) Occupants!

HVAC System Types - Complex Systems

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Air Handling Units

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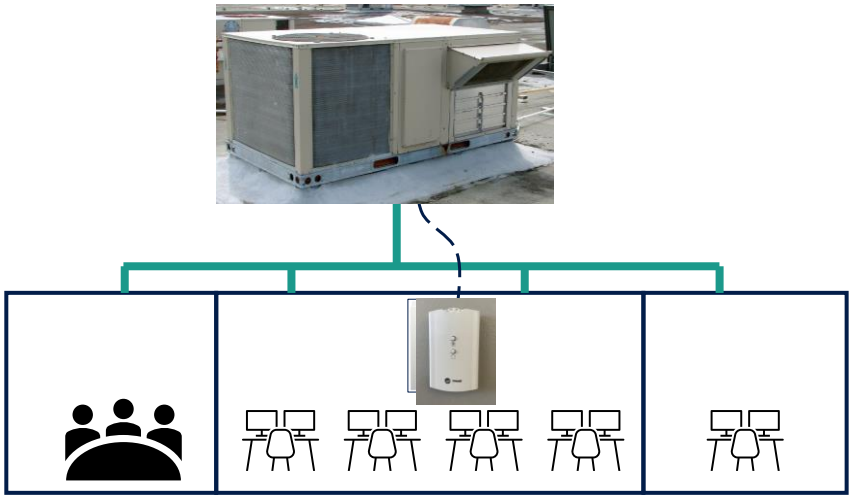
Single Zone Rooftop Unit (RTU)

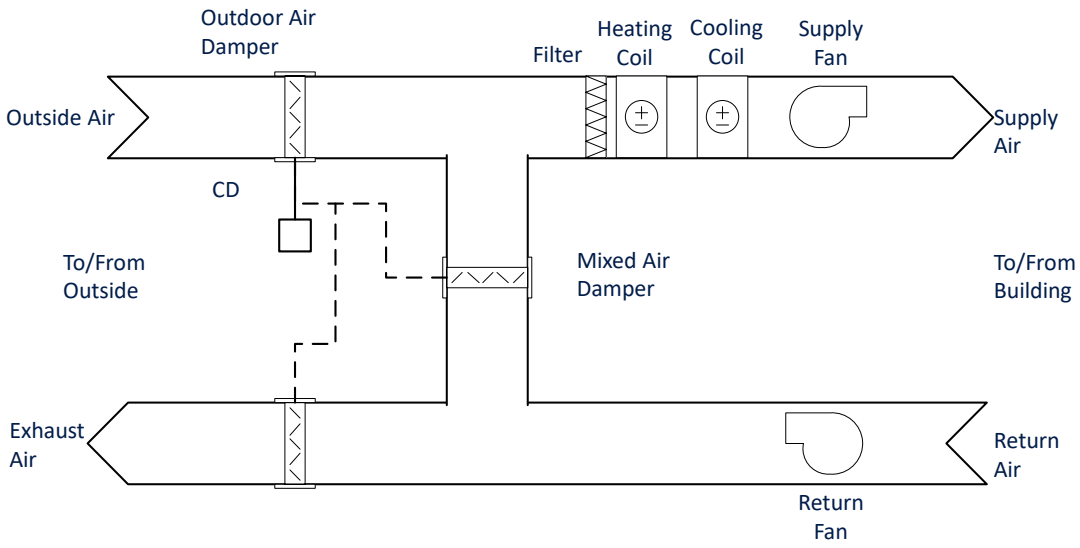


For RTU, see Session #2 Building HVAC – Simple Systems

Air Handling Unit (AHU)

- A larger, built-up unit compared to an RTU.
- Some components may be assembled in the field rather than in the manufacturer.
- More complex sensing and controls
- Often served by chilled water or hot water plants.

Air Handling Unit Schematic



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Variable Air Volume (VAV) Systems

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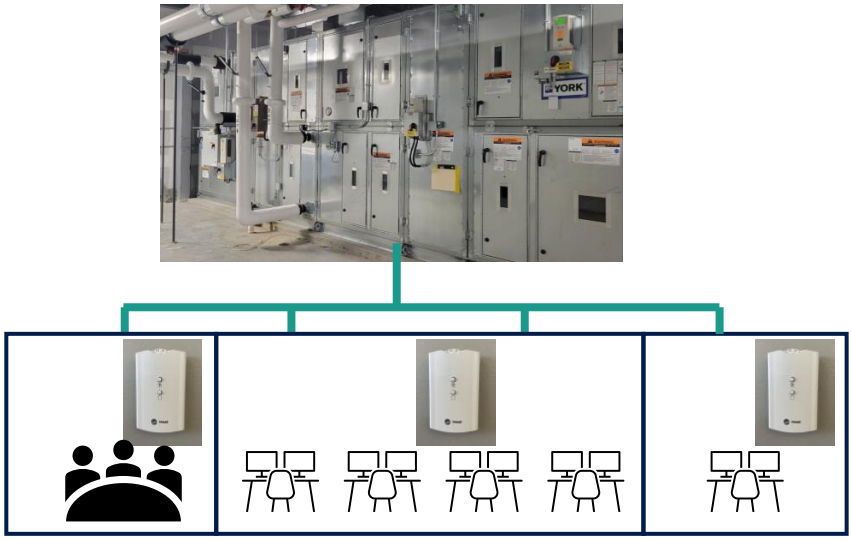
Multi-zone Air Systems



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Variable Air Volume (VAV) System

- Multiple zone system.
- Variable Frequency Drives (VFDs) on the supply and return fans to change fan speeds (and airflow rates).
- The central AHU supplies cool air to air terminal devices at each zone, often called VAV boxes.

Example of VFDs

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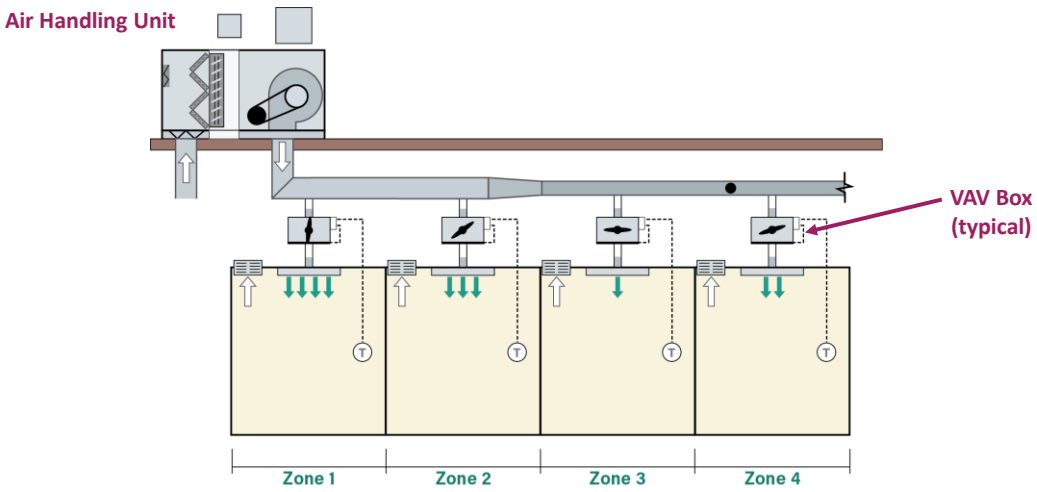
Variable Air Volume (VAV) System – The VAV Box

- Each zone has a VAV box.
- The VAV Box is controlled by a thermostat in the space.
- The VAV Box varies airflow for cooling.
- Reheat devices at the VAV box provide heat.
- Saves more energy than constant volume and old multizone systems.

Variable Air Volume (VAV) System



Decentralized Air Systems

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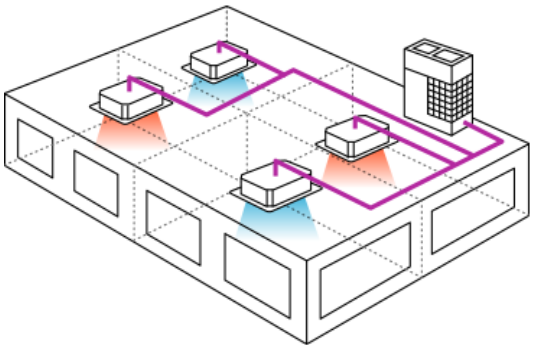
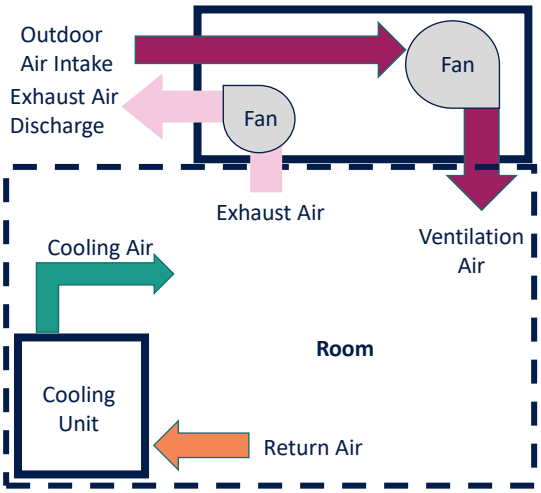
Decentralized Air Systems





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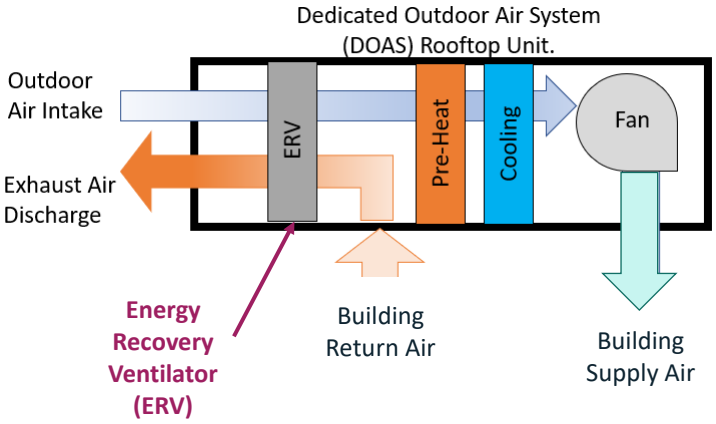
Examples of Decentralized Systems – Heating and Cooling

- Fan Coil Units
- Water Source Heat Pumps (WSHPs)
- Variable Refrigerant Flow (VRF)
- Chilled Beams
- Radiant Heating and Cooling

Makeup Air Unit (MAU) and Dedicated Outside Air System (DOAS)



Hydronic Systems

Hydronic Systems

- Moving air around a large building takes a lot of energy.
- Observe
  - Water can store more energy than air.
  - Water takes less energy to move than air.
  - Piping occupies less space than ducts
- Exploit
  - Heat/cool water centrally
  - Move water around the building efficiently
  - Transfer heat from water to air near the zones
- Downside
  - Piping and hydronic equipment is more expensive and requires more maintenance.

Hydronic Systems – Boilers and Chillers

Natural gas-fired boilers

Air-cooled chiller

Pump set

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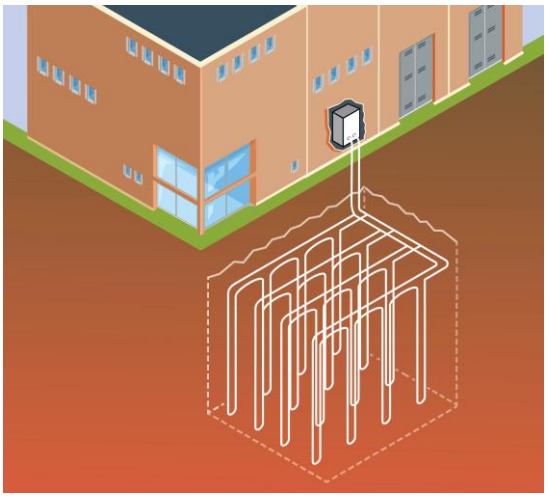
Geothermal Heat Pump Systems

Ground source heat pump bore field



Ground loop pumps

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HVAC Controls Sequences – Complex Systems

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Variable Air Volume (VAV) Controls

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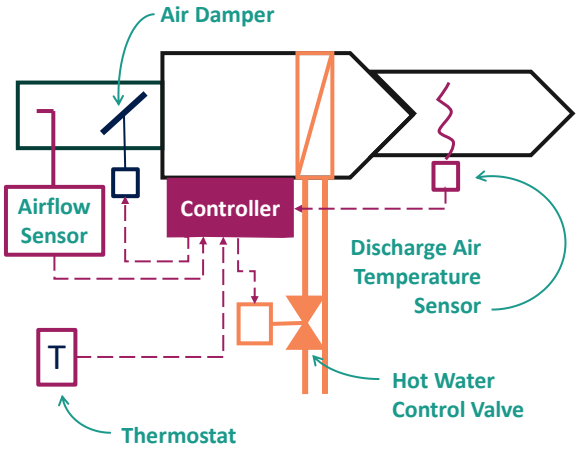
Zone Control – VAV Box



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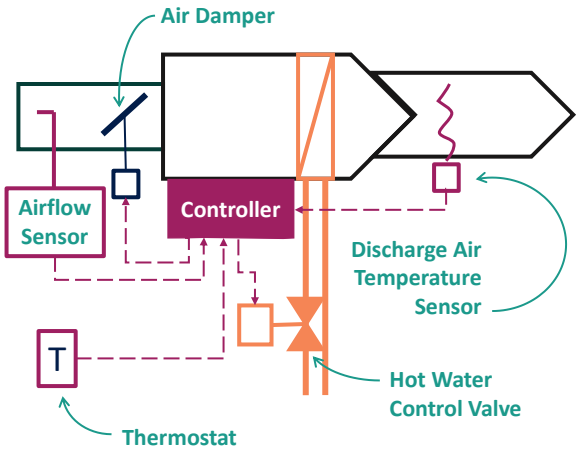
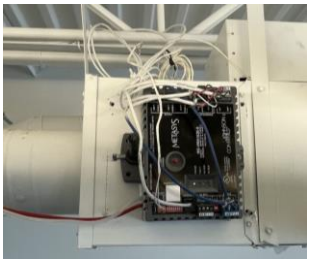
Airflow Sensor

Zone Control





VAV Box Controller

VAV Zone Thermostat

Hot Water Control Valve and Actuator

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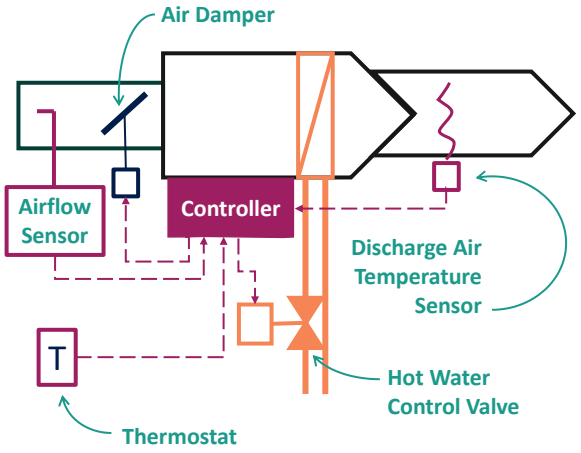
Zone Control – VAV Box Cooling

Controller: Reset the airflow setpoint from 250 cfm to 1,000 cfm

The airflow is still 250 cfm

Controller: Ok. Open the air damper

Damper opens



It's hot in here

It's comfortable in here

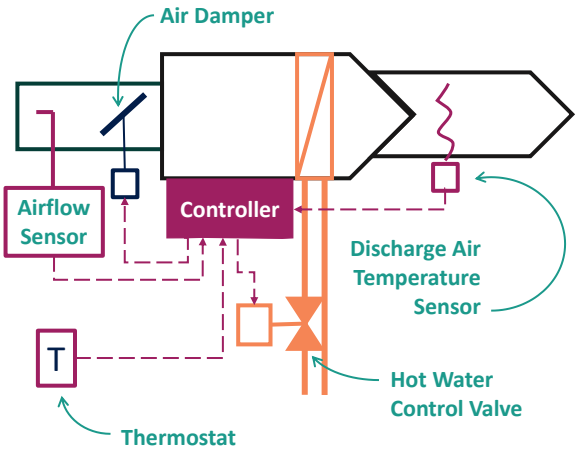
Zone Control – VAV Box Heating

Controller: Reset the airflow setpoint from 1,000 cfm to 250 cfm

The airflow is still 1,000 cfm

Controller: Ok. Close the air damper

Damper Closes



It's cold in here

It's still cold in here

Zone Control – VAV Box Heating

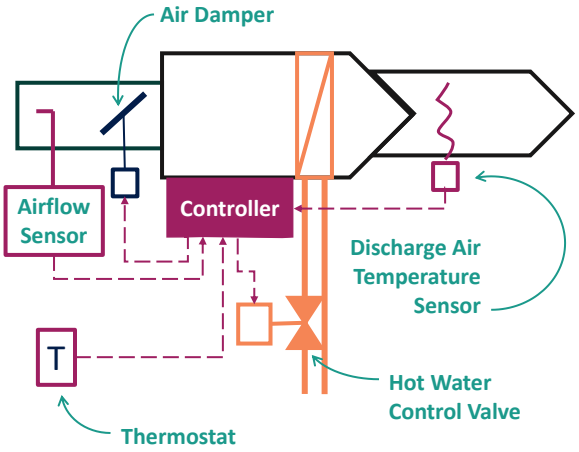
Controller: Open the hot water valve.

Hot water valve open

Controller: Ok, is it still cold?

Discharge air temperature is at 95°F

Controller: That's as high as we can go…



It's still cold in here
It's still cold in here

Zone Control – VAV Box Heating

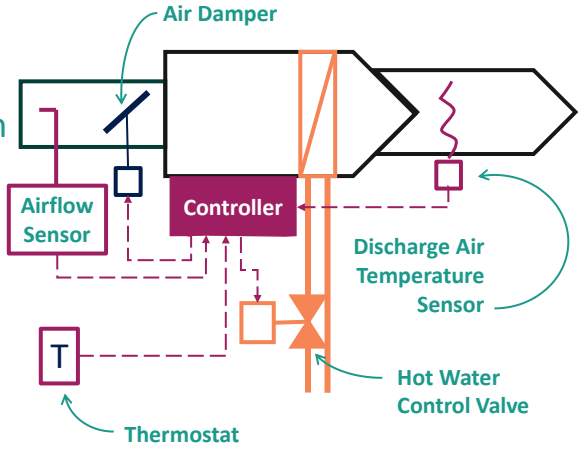
Controller: Ok, reset airflow to 500 cfm.

Airflow is 500 cfm

Controller: Open air damper

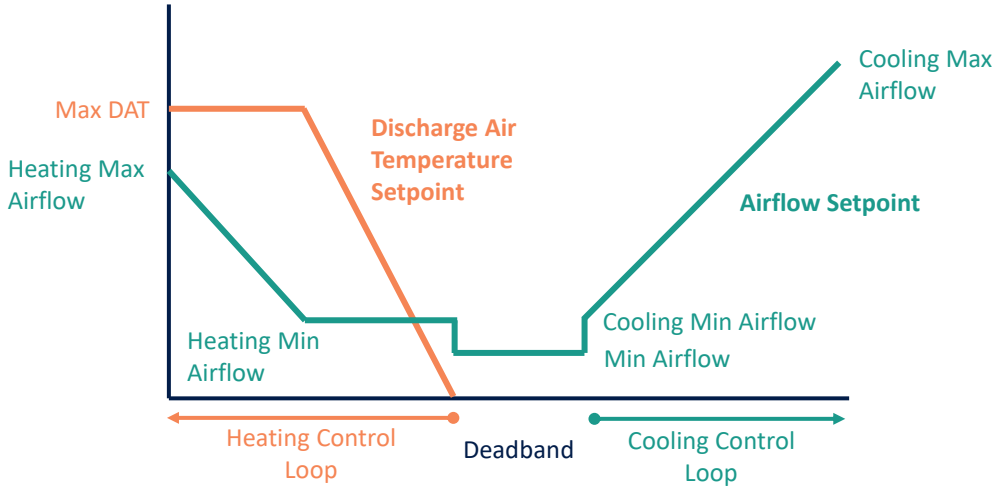
Damper opens

Controller: Ok, what about now?



It's still cold in here
It's comfortable in here

Variable Air Volume (VAV) System – Air Terminal Control



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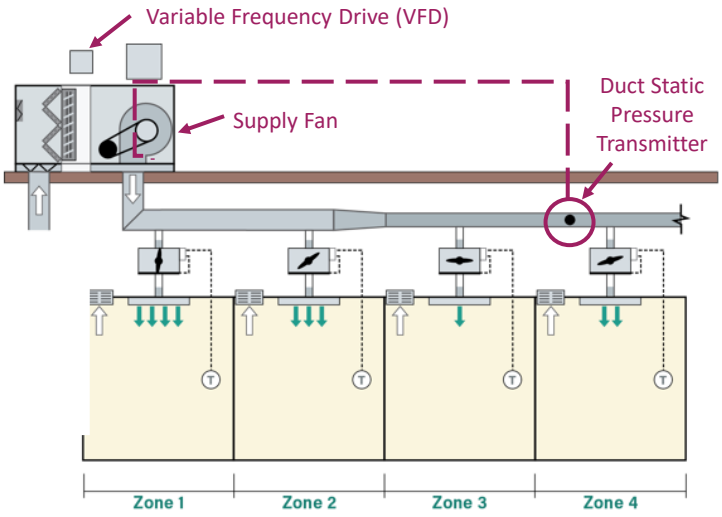
Variable Air Volume (VAV) System – AHU Control



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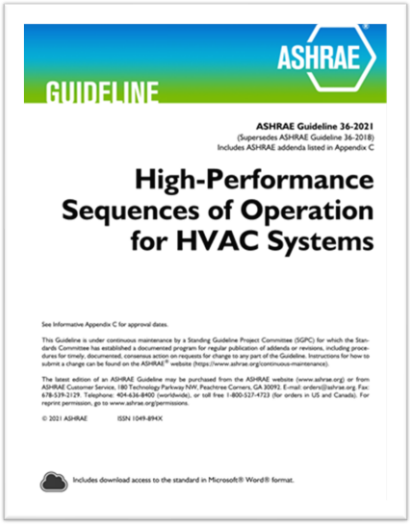
Variable Air Volume (VAV) System – Other Control Loops

- Could be packaged or custom controls.
- Schedule: Occupied, Unoccupied, and Morning Warmup
- Failure sequence - how devices should be commanded in a failure mode
- Preheat Coil and Cooling Coil Control
- Outdoor Air – Economizer Control, Demand-Controlled Ventilation
- Return fan control
- Safeties

ASHRAE Guideline 36

- Guideline of high-performance control sequences to improve occupant comfort and save energy
- Based on Industry Best Practices
- First published in 2018
- Under continuous improvement
- Latest version released in 2021



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Demand-Controlled Ventilation

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Ventilation

- Ventilation is the removal of contaminated building air and it's replacement with clean, fresh, air.
- Introducing outdoor air requires heating and cooling energy to make the air suitable for the indoors.
- We want to provide the minimum outdoor air for a healthy building while limiting energy use.

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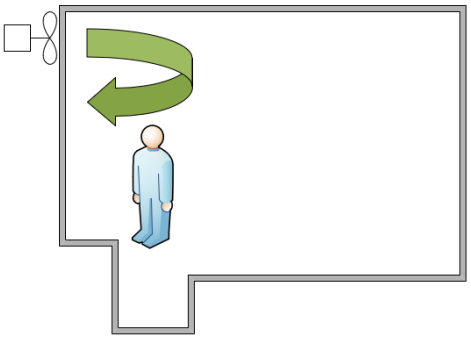
Demand-Controlled Ventilation

- Demand-Controlled Ventilation (DCV) uses the building automation system (BAS) to adjust outdoor airflow to match building occupancy.
- Ideally, we only introduce the most outdoor air when the building is fully occupied or in economizer mode.
- When the building is at partial occupancy and not in economizer mode, we reduce outdoor air intake to try to match the current occupancy.

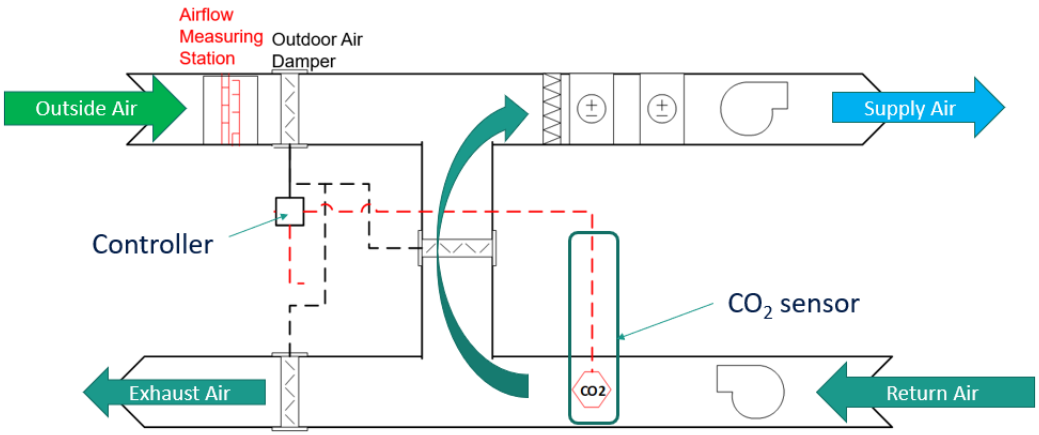


Determining Demand

Detecting Occupancy

- Occupancy Sensors
- Carbon Dioxide (CO_2) Sensors
- Window Switches

Single Zone, Single-duct DCV



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Building Automation System (BAS)

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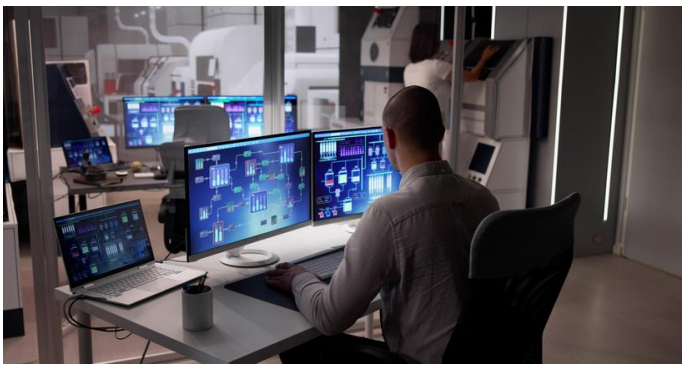
Why Building Automation System (BAS)?

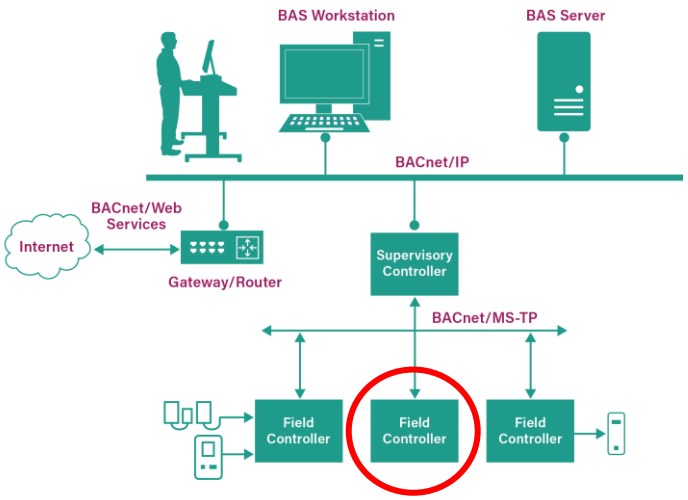
- Also referred to as Building Management System (BMS) or Direct Digital Controls (DDC) System
- For HVAC systems too large or complex to manage using standalone/packaged controls
- Improving energy efficiency
- Insights for operations and maintenance
- Improved comfort
- Better building decision making



Building Automation System

Field Controller

- Local HVAC equipment control
- Run on field control network
- Low-speed Communication
- Fully programmable or configurable
  - AAC (Advanced Application Controller)
  - ASC (Advanced System Controller)



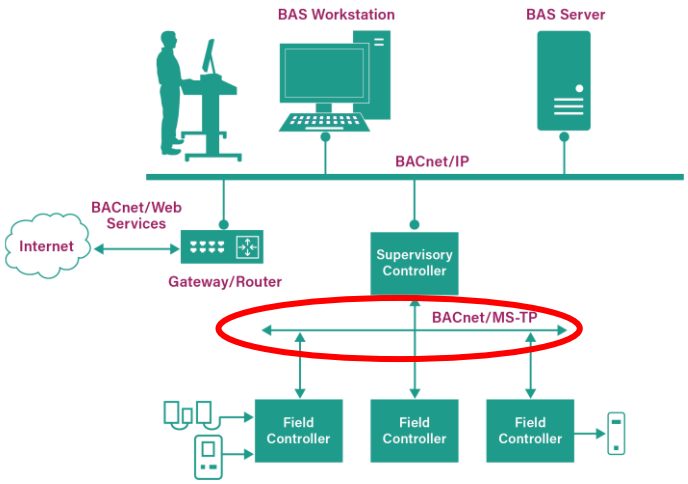
BAS Communications - BACnet

- A data communication protocol for **B**uilding **A**utomation and **C**ontrol **Net**works
- A public, open, international standard
- Intended to improve BAS communication compatibility, interoperability, and encourage fair competitions
- Developed by ASHRAE since 1987
- Supported by ASHRAE Standing Standard Project Committee SSPC 135 – ASHRAE/ANSI Standard 135
- Licensee fee: none

Building Automation System

Field Control Network

- This is the wiring network that connects field controllers to supervisory controllers.
- Most common protocol: BACnet/MS-TP
- Wiring:
  - Stranded, shielded twisted-pair wires,
  - Max length 4000 ft
  - Bused or daisy chained
  - Max 128 controllers
- Low-speed network – 9.6 to 76.8 kbps



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BAS Communications

Proprietary System

- Owned by a specific company
- Could be Open or Closed

Closed System

- Patented, copyrighted
- Not compatible with other systems

Open System

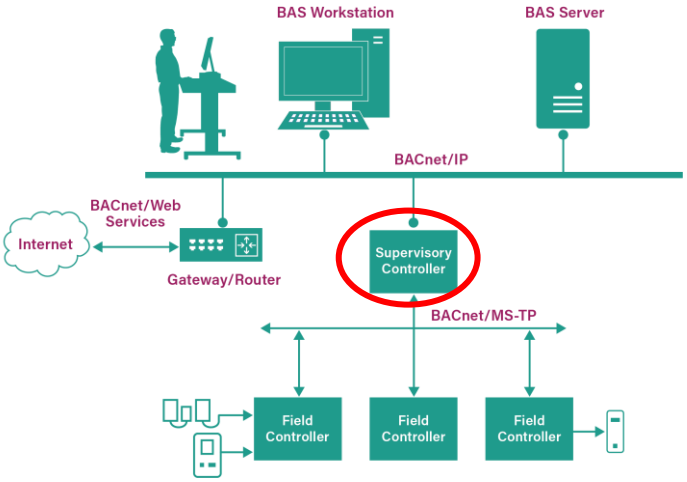
- Codes are disclosed
- Encourage interoperability and competition

	Open System	Closed System
Proprietary	**LonWorks (Echelon)**	**Many BAS Manufacturers**
Non-proprietary	**BACnet (ASHRAE)**	**-**

Building Automation System

Supervisory Controller

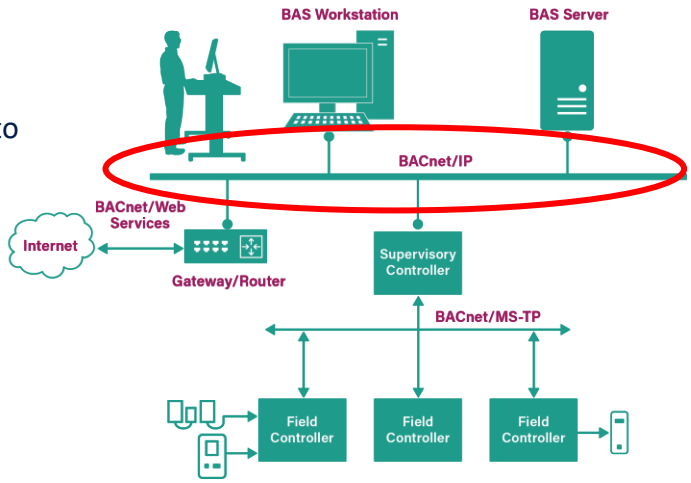
- Also called network controller or building controller (BC)
- Connects field control network to building control network
- Global, networked coordination and controls
- Fully programmable
- Doesn't control equipment directly (no sensors/actuators)



Building Automation System

Building Network

- This is the wiring network that connects supervisory networks to the BAS workstation.
- Most common protocol: BACnet/IP – Internet Protocol
- Wiring:
  - Ethernet
  - Max length 328 ft
  - Star, Chain, Ring, or Mixed
  - Max 254 controllers
- High-Speed Network – 100 to 1,000 Mbps



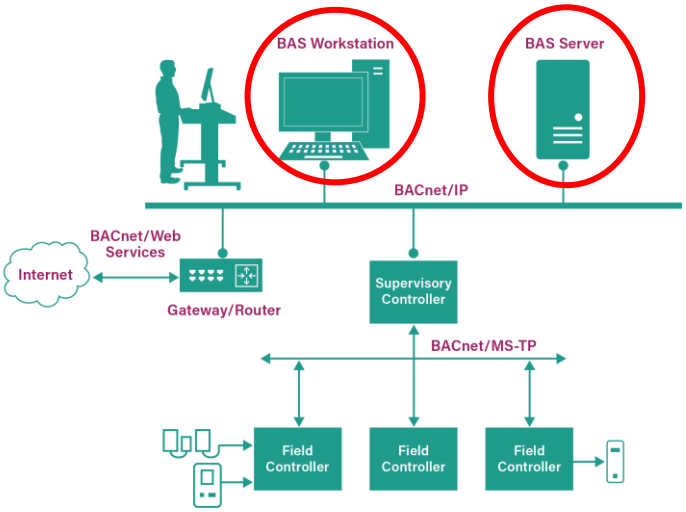
Building Automation System

BAS Workstation

- User interface for monitoring, control, and maintenance
- Web-based interface are common

BAS Server

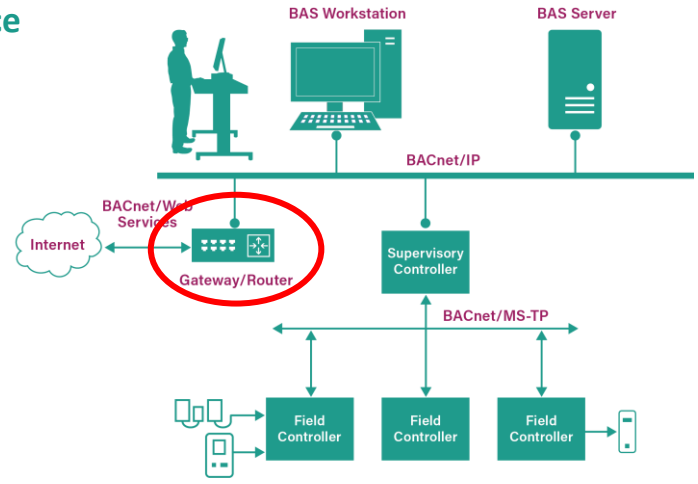
- Collect, store, and serve BAS data and web pages.
- Optional for small systems



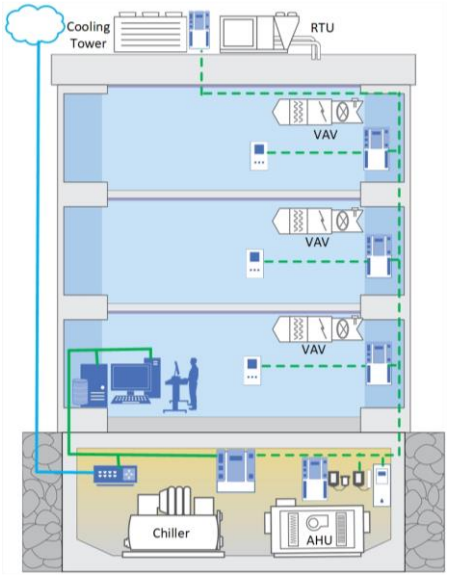
Building Automation System

BAS Communication Interface

- For integration with other systems – Connect to:
  - Other buildings
  - The internet
  - Other BAS Devices
- Translates BAS data from a BAS network protocol to the Internet protocol (IP) or other communication protocols
- Optional – not every BAS needs one



BAS in Commercial Buildings



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BAS components

- Field controller
- Field controller inputs
- Supervisory controller
- Operator workstation
- Server
- Network communication interface

BAS network legend

- Field control network (low speed)
- Building control network (high speed)
- Enterprise IT network (high speed)

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Trends in Modern Building Automation System

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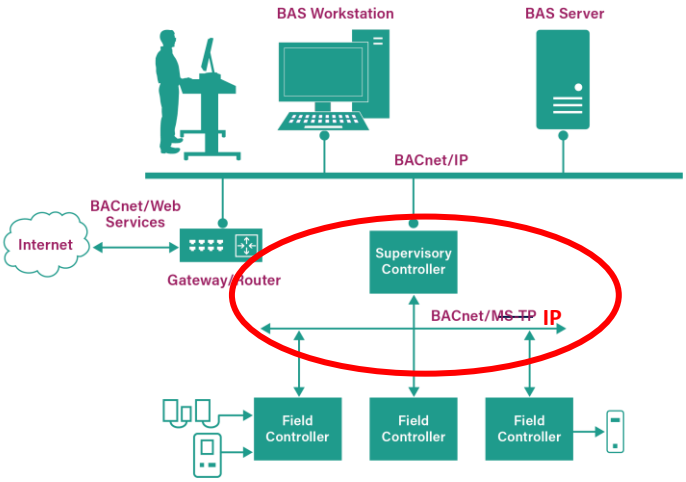
Integration with IoT and Cloud

IP-based controllers

- Easier to integrate with IT networks
- More secure (BACnet is not consider a “secure” protocol)
- Faster (compared to BACnet/MS-TP)

Move advanced monitoring and control functions to the Cloud

- Virtually no limit in computer power and storage space
- Allows the system to run complex algorithms
- Easy access from anywhere



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Advanced Building Monitoring and Controls

- Advanced energy information system and reporting
- Automatic Fault Detection and Diagnostics (AFDD)
- Automated System Optimization (ASO)
- Monitoring-based commissioning

For more information, see Session #9 Advanced Building Monitoring and Controls

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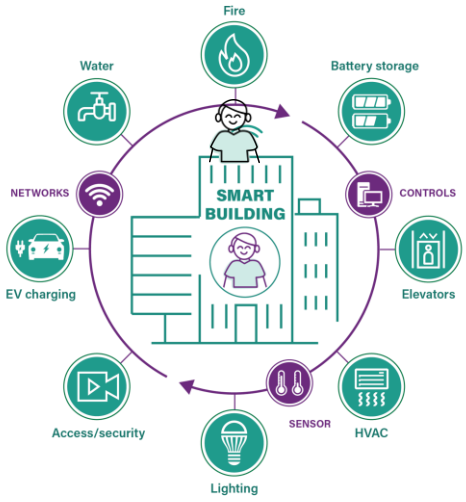
Smart Building Elements – Interoperability



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2) Sensors
3) Controls
   1) Platform
   2) Control methods
4) Networks
5) Occupants!

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- Edge-to-Cloud solution computing
- Integrate with other sensors, devices and building systems
- Enable smart building applications beyond HVAC monitoring and controls
- Open protocols is preferred for better interoperability
- Digital Twin

For more information, see Session #10 Smart Building Control Platform

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BACnet Secure Connect (BACnet/SC)

- Addendum to the BACnet protocol. Secure, encrypted protocol in a professionally managed IP infrastructure.

Important when integrating building systems with the cloud.

For more information, see Session #11 Smart Building Control Platform Cybersecurity

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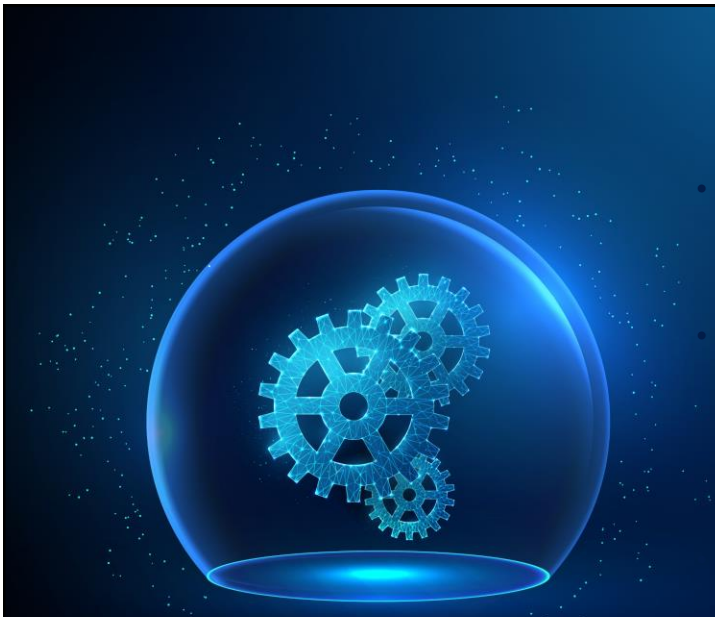

- AI: use computers to mimic human cognitive functions.
- ML: a subset of AI. use computers to analyze data, learn from it, and make decisions.

Self-operating, autonomous building concept.

For more information, see Session #12 Smart Building Control Algorithms

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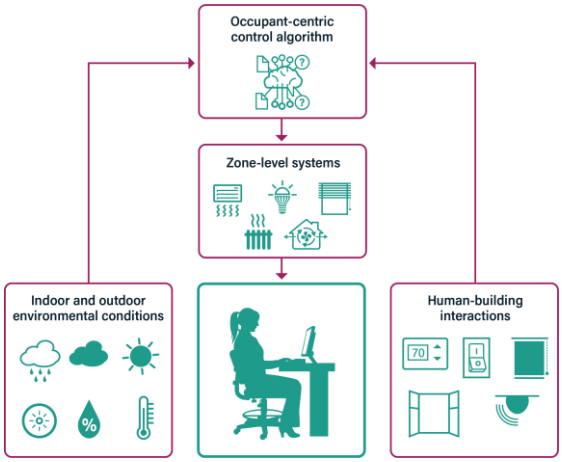
Occupant-Centric Controls



- Rely on real-time occupancy and occupant preference data as inputs
- Can be categorized as either reactive control or predictive control
- May use advanced control algorithm such as machine leaning
- ASHRAE TC 7.10 Occupant Behavior in Building Design and Operation

For more information, see Session #13 Occupant-Centric Controls

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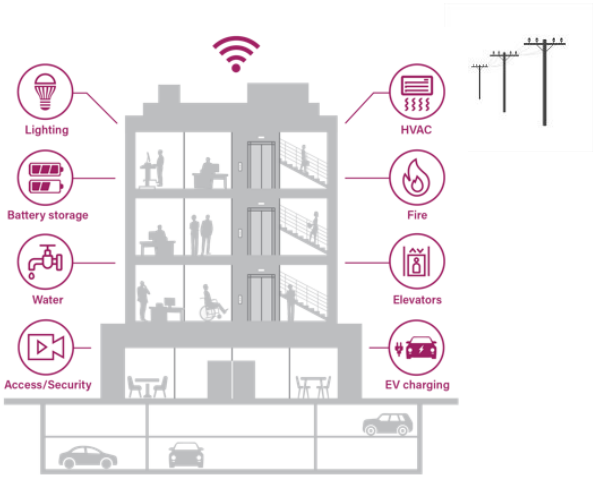
Demand Response and Grid-interactive Efficient Buildings (GEB)

- Growing peak electricity demand
- Increasing share of variable renewable electricity generation
- Available behind-the-meter distributed energy resources (solar PV, battery storage, EV)
- Combined with HVAC, can make buildings much more flexible in controlling building load



For more information, see Session #5 Solar PV, BESS, and EV Charging and #14 GEBs and Connected Communities

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Recap

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Learning Objectives

- Discuss more complex HVAC equipment and system types
- Name typical control sequences of these equipment and systems
- Introduce Building Automation System
- Highlight trends in modern building automation system

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This material is based upon work supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), Building Technologies Office (BTO) Award Number DE-EE0009703.

Thank you!