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Building Automation: Where Is it Today and Where it Should Be

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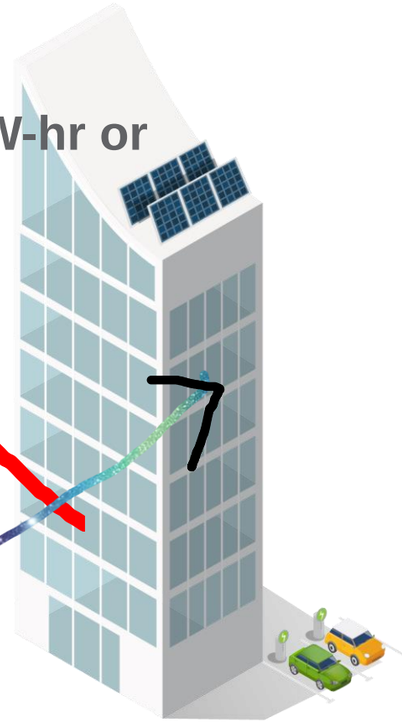
Outline

- Building Automation History and Evolution
- Current State of Building Automation and Building Operation
- Automated Building Control Levels 00 to 05
- Path Toward Autonomous Building Operations
- Closing Remarks

Evolution of Buildings …



~175 Quadrillion W-hr or
~600 Quads

1800 1900 1960 2019 2050

Shelter

Water
Electricity

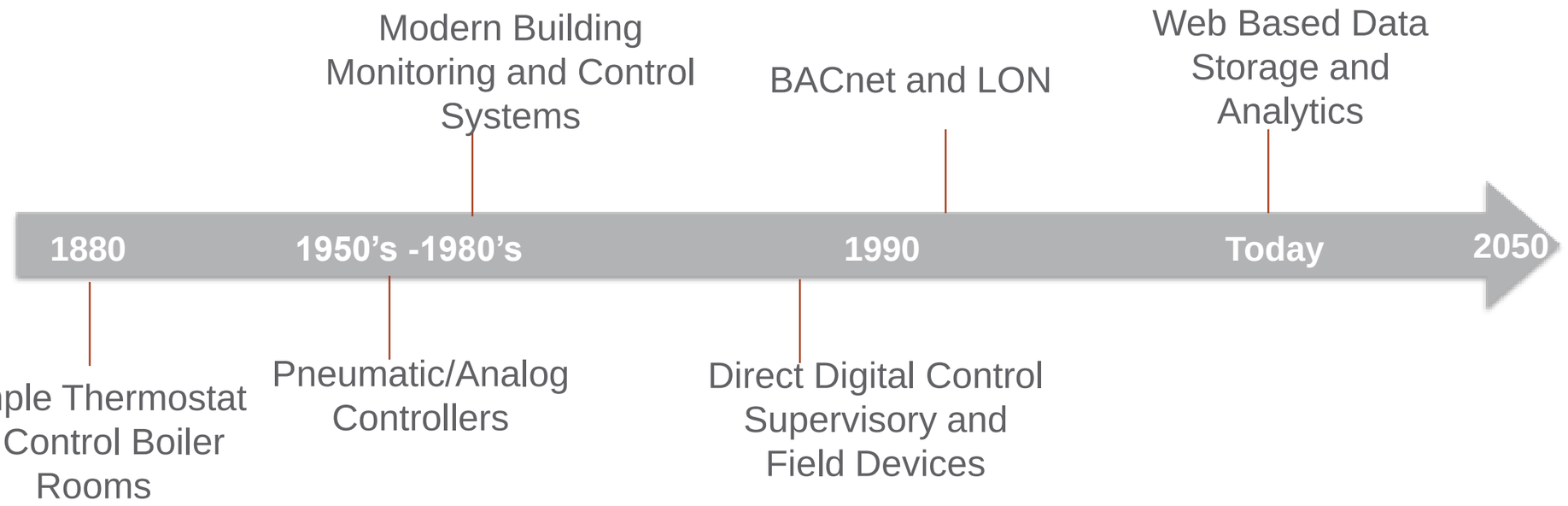
Security
Thermal Comfort
Fire Safety

Ubiquitous Sensing
Connectivity
Artificial
Intelligence
Autonomous
Operation

Cost of Labor and Growth of Technology

Cost of Technology

Evolution of Building Controls …



Autonomous Building Controls: Ubiquitous Sensing, Connectivity, Artificial Intelligence, Autonomous Operations

Fewer Sensors → **Ubiquitous Sensing**

Standalone Systems
Manual Operation
→
Fully Integrated Systems
Autonomous Operation

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Current State of Building Automation and Building Operation

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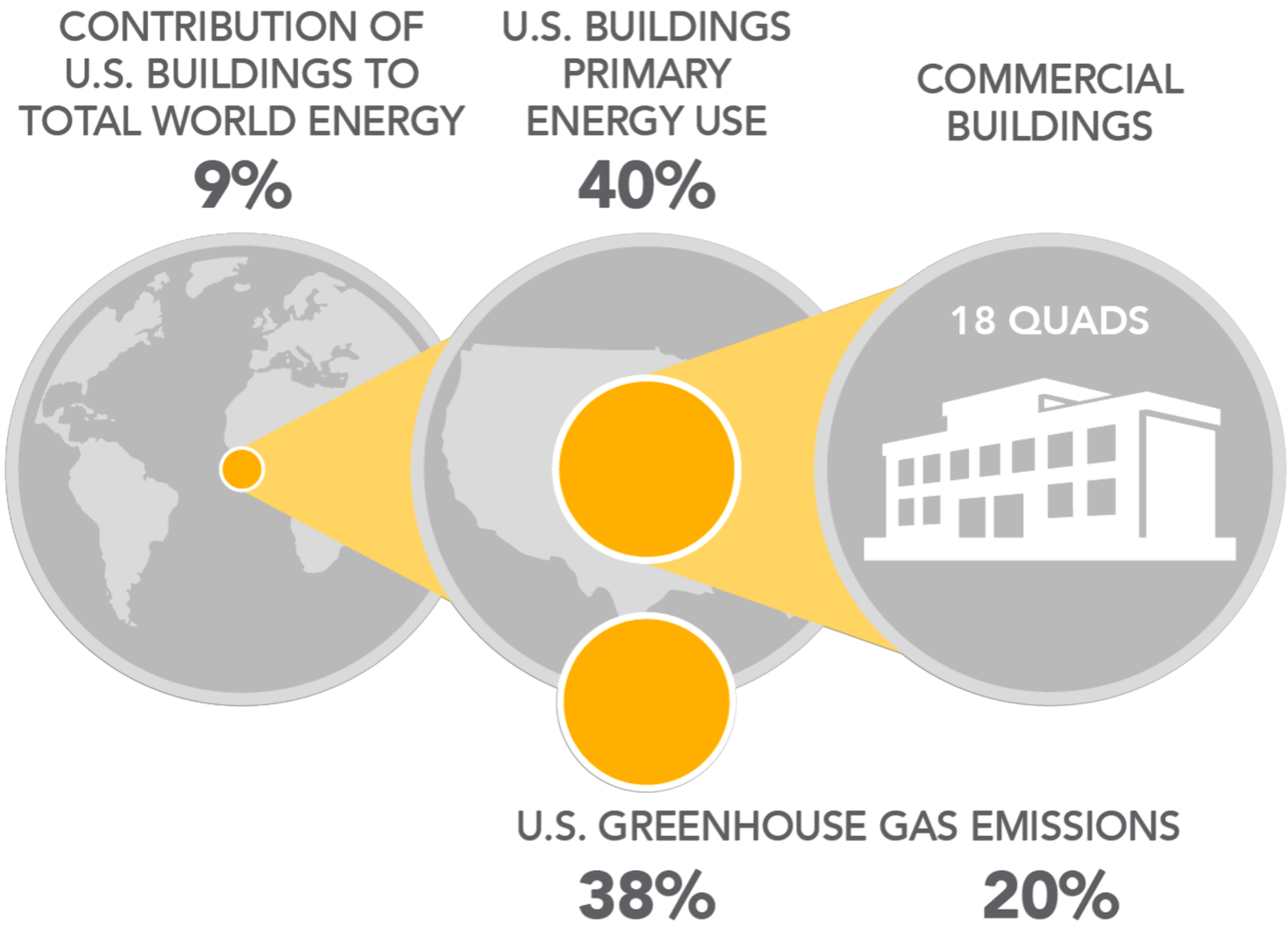
U.S. Building Energy Use



Improving operating efficiency with better building automation will result in energy and cost savings between 10% and 30%

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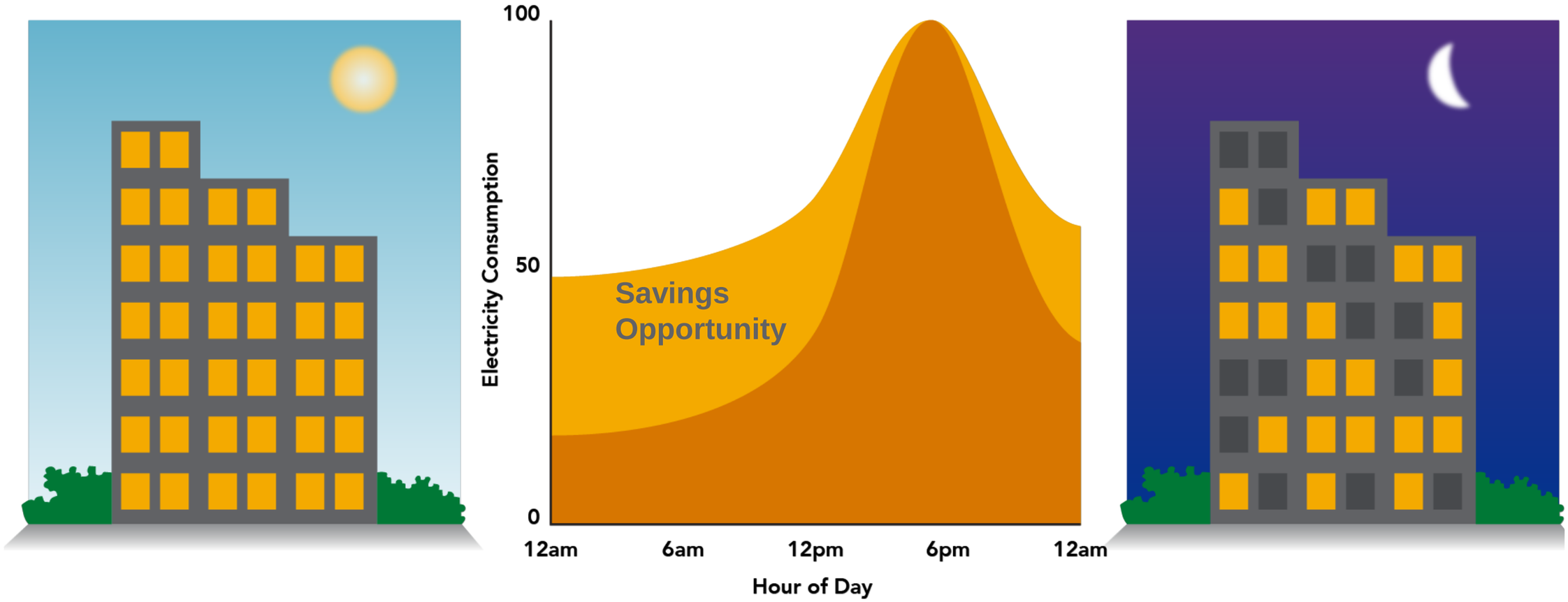
Only 14% (43% of conditioned space) of the building stock has building automation systems (BASs)

Source: 2012 Commercial Building Energy Consumption Survey

Even buildings that have BASs are not managed efficiently, leading to excess energy consumption of between 10% and 30%

State of Building Operations: Occupancy Scheduling



Current State of 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

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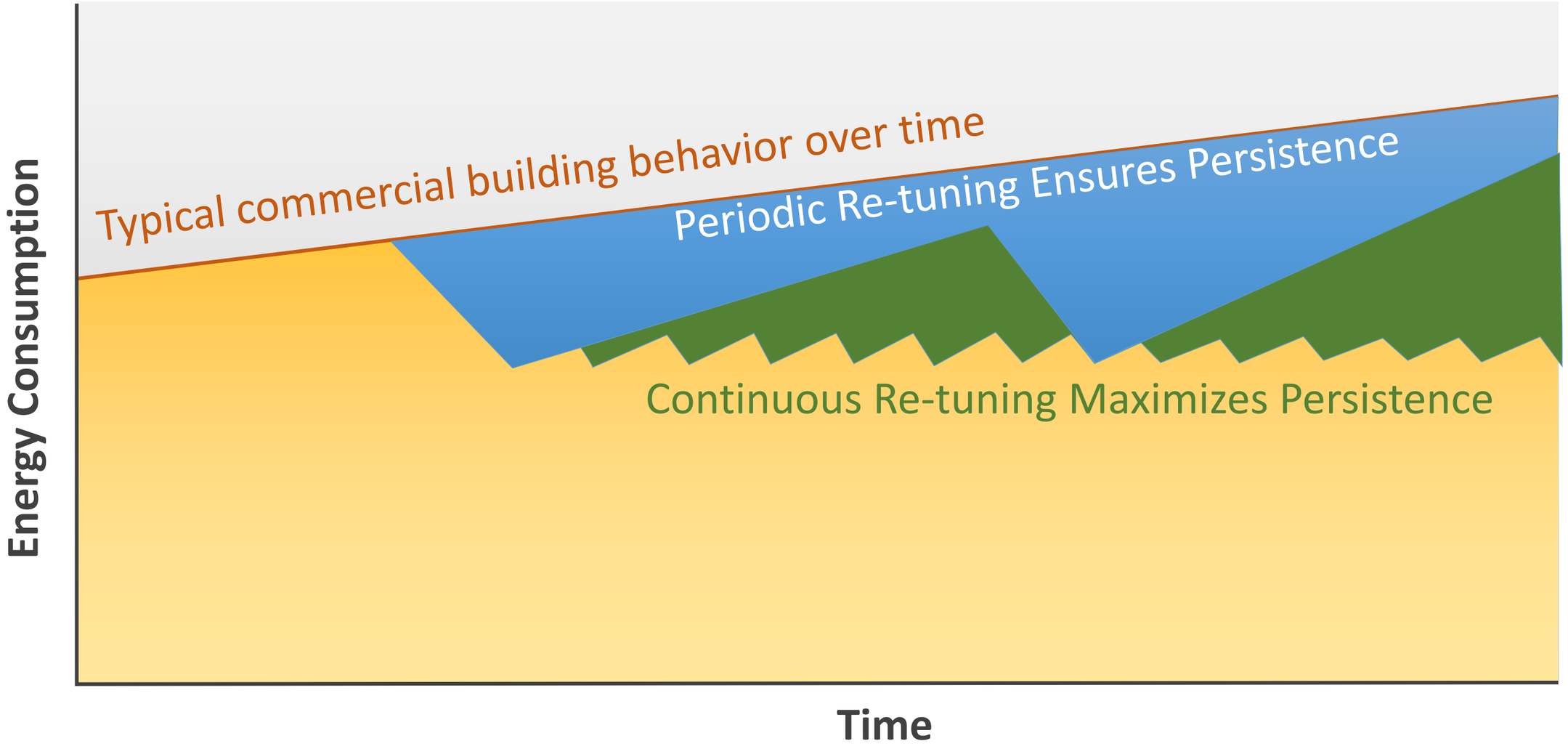
Life Cycle of Existing-Building Operations



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Automated Building Controls: Manual to Autonomous

Six Levels of Automated Building Control (ABC)

- ABC Level 00: Manual Controls
- ABC Level 01: Rudimentary Controls
- ABC Level 02: Central Analog Controls
- ABC Level 03: Central Direct Digital Controls
- ABC Level 04: Self-aware Building Controls
- ABC Level 05: Autonomous Building Controls

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Automated Building Control Levels

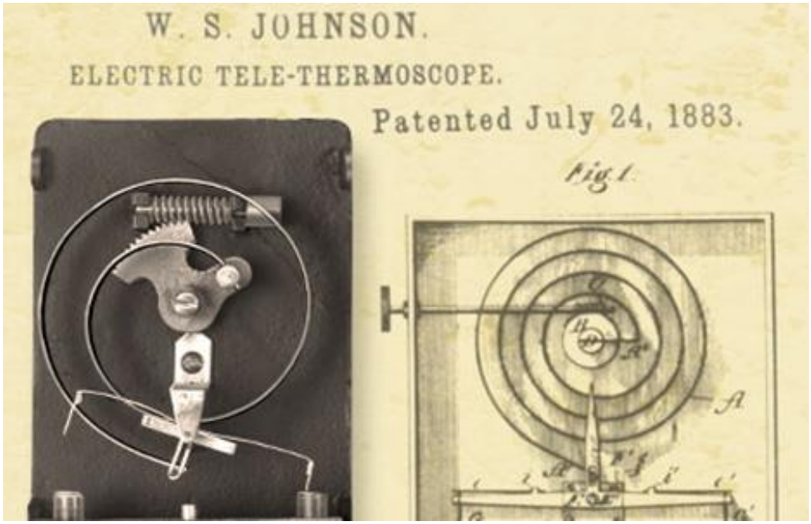
	ABC Level 00	ABC Level 01	ABC Level 02	ABC Level 03	ABC Level 04	ABC Level 05
What does the building operator do?	Building operator will have to make all control decisions and respond to failures		These features will support building operator to make informed decisions, but building operator is still in-charge of making the final decisions		Building operator is not involved in decision making when these automated features are engaged with exception to correcting or replacing failed hardware	
	Operator is the Controller		**Automated Controls with Operator Support Features**		**Automated Operations with Limited Operator Interaction**	**Autonomous Operations**
What do these features do?	These features allow operator to manage systems	These features allow operator to control or make changes to the system operation	These features provide insight into building operation and support integrated operations	These features provide limited local control when there is loss of communication with the central workstation	These features will allow building systems to be "self-aware" and adapt to deliver "optimal" performance to minimize energy and cost and maximize occupant comfort and support grid reliability	These features will allow building systems to operate autonomously to maintain building operations continuously at peak efficiency and seamless integrate with electric grid
Example features	• Manually start/stop systems	• Manually change set points	• Dashboards – alarms, energy/demand consumed • Rudimentary supervisory controls	• Maintain set points locally • Override set points locally • Brute-force demand response	• Fault detection and diagnostics • Model-based controls • Adaptive controls • Beyond demand response	• Interoperate; self-configure; self-diagnose and self-commission; self-correct and self-heal • Transactive control

Automated Building Controls Level 00: Manual Controls

- Manual control (ON/OFF) of building systems
- Inefficient
- No ability to schedule, systems could be running all the time
- Poor comfort
- This approach is adequate when
  - Labor is cheap
  - Energy and is abundant and inexpensive

Automated Building Controls Level 01: Rudimentary Controls

- Use of a thermostat to control heating, ventilation and air-conditioning operations or timeclock to control lighting
- Slightly better comfort
- Non-optimal
- Limited ability to schedule or centrally manage systems
- Many buildings still use this level of controls
  - Especially small commercial and residential buildings



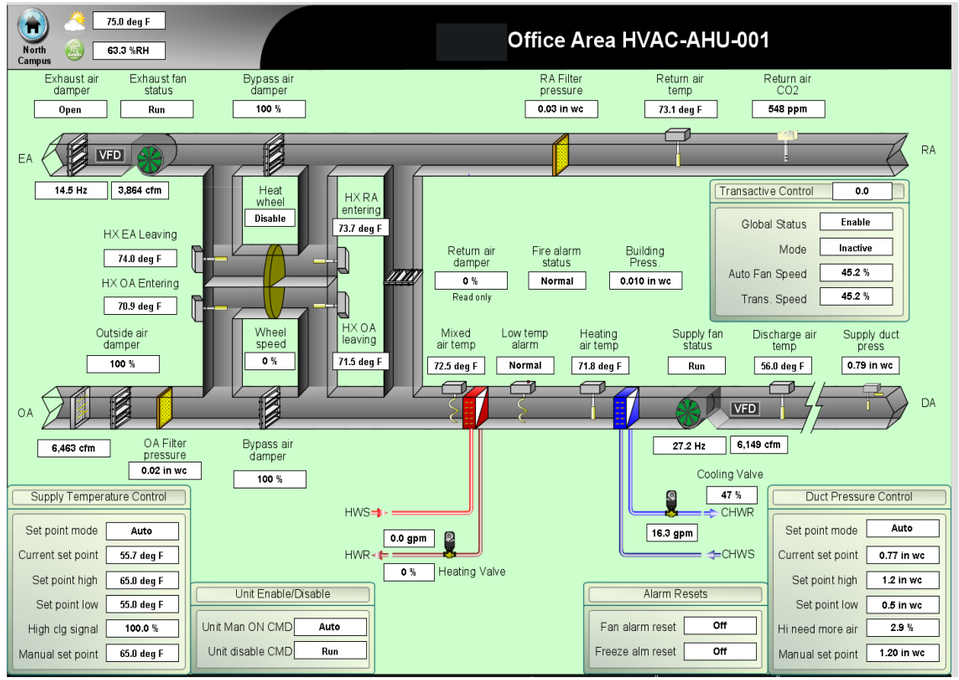
Source: Johnson Controls

Automated Building Controls Level 02: Central Analog Controls

- Central analog control of building systems
- Ability to schedule systems and reset set points, etc.
- Proprietary communication systems, low bandwidth
- Pneumatic actuation of valves and dampers
- Ability to start/stop large systems (air-handling units, boilers, chillers, etc.)
- Simple workstations with operator dashboards
- Rudimentary
  - Supervisory controls
  - Capability to integrate with the grid
- Developed in response to rising energy and labor costs

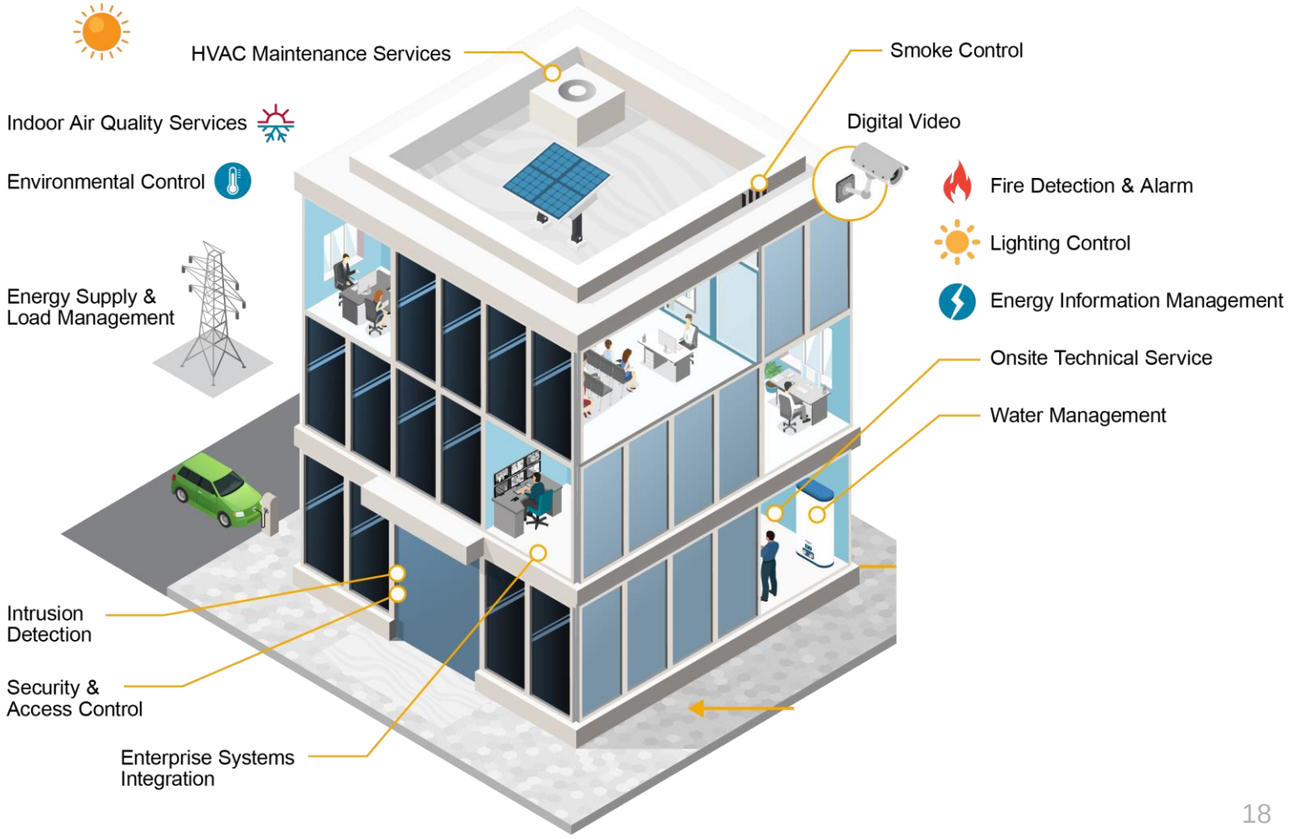
Automated Building Controls Level 03: Direct Digital Controls (DDC)

- DDC systems with central operator workstation and distributed field control devices
- Sophisticated supervisory controls and have the ability to integrate with the electric grid
- Adoption of standard and open communication protocols, such as BACnet
- TCP/IP based
- Support integration of 3rd party equipment (Chillers, boilers, etc.)
- Operator dashboards and extensive use of graphics and graphical programming
- Early development of automated fault detection and diagnostics (AFDD) and integration of lighting, life safety



Automated Building Controls Level 04: Self-aware Building Controls

- The building and its systems are self-aware of the conditions and adapt automatically to ensure “optimal” operation
- Supports seamless integration of building systems with the electric grid to provide grid services
- It also leverages embedded AFDD in equipment and also supports remote monitoring and diagnostics services
- Supports integration of distributed renewable generation
- Full integration of lighting, fire, security, and vertical transport



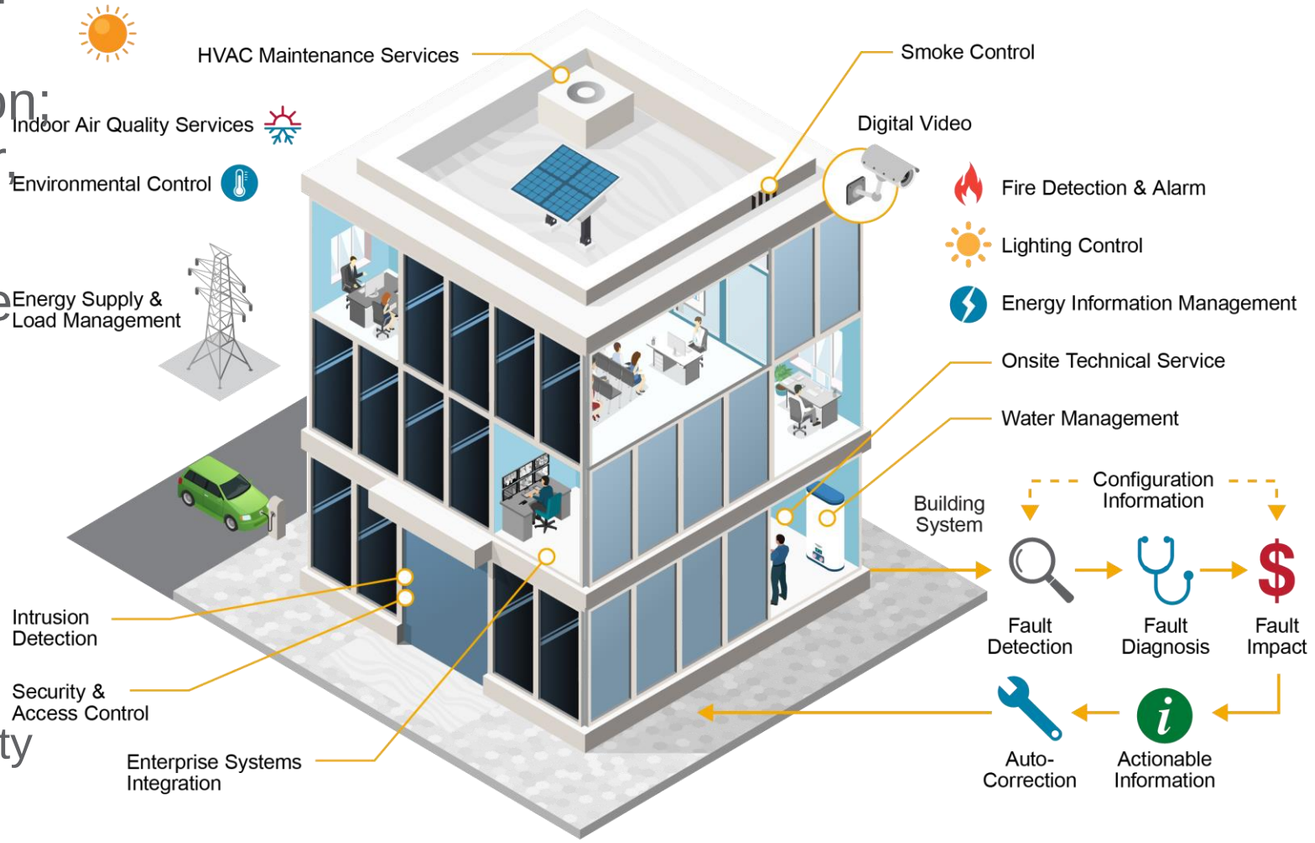
ABC Level 05 Autonomous Building Controls: Autonomous Building Controls

- Building controls are interoperable, self-configuring, self-commissioning and self-diagnosing, self-correcting, and self-healing

- The BAS takes advantage of network of sensors, including wireless; advanced control sequences; intelligent automation; and modern communications to monitor, operate and maintain a building

- The BAS ensures that buildings operate automatically and continuously at peak energy efficiency and cost-effectively over their lifetimes and interoperate seamlessly and effectively with the electric grid

- Finally, the BAS:
  - Provides better indoor environmental quality
  - Supports high-performance and net-zero buildings
  - Results in increased asset valuation



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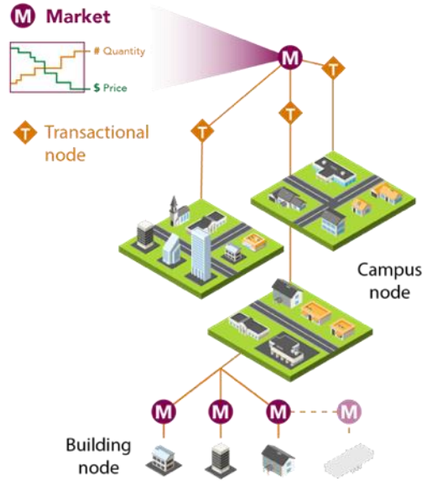
Path Towards “Self-Aware” and Autonomous Building Operations

Making Commercial Building Operations Autonomous

- First, develop and install low cost BAS for 86% of the remaining commercial building stock
- Second, improve operations in all buildings by making buildings and their systems “self-aware”
- Third, create multiple value streams
  - Spreading the cost of technology and on ongoing operations
  - Grid or energy efficiency services alone may not be sufficient
  - Simultaneous deployment of both grid and energy efficiency services are needed
  - Extended equipment life (reduced capital cost)



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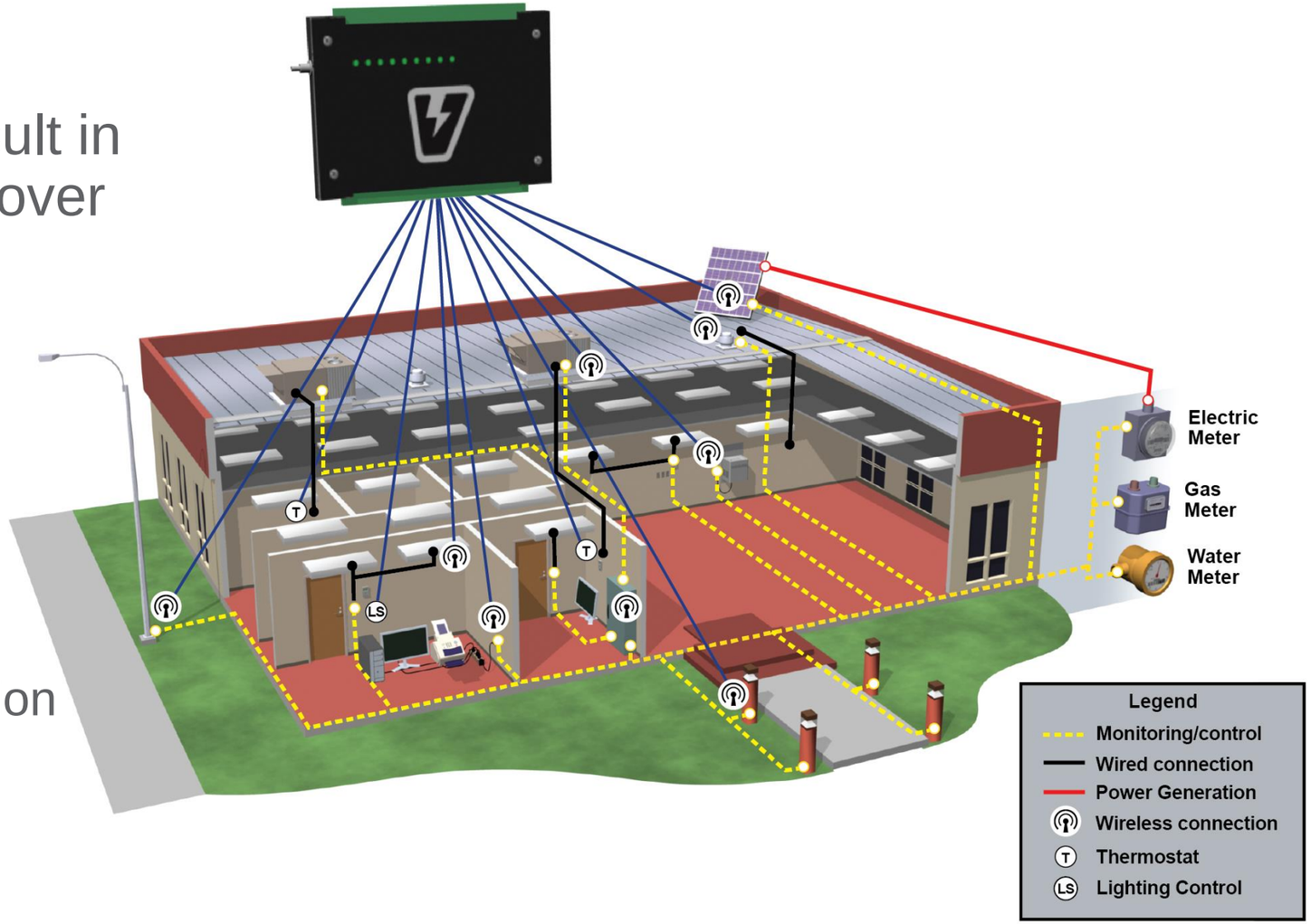
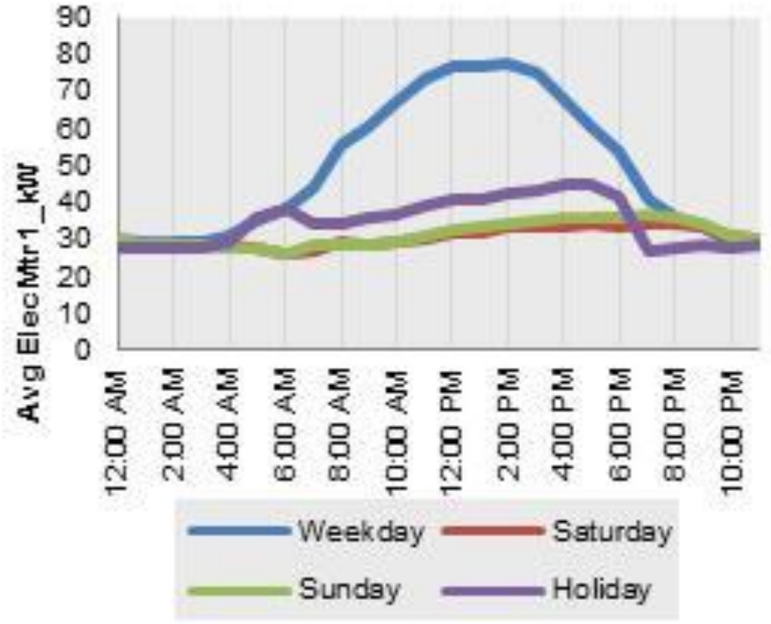
Low-Cost BAS for Small/Medium Size Buildings

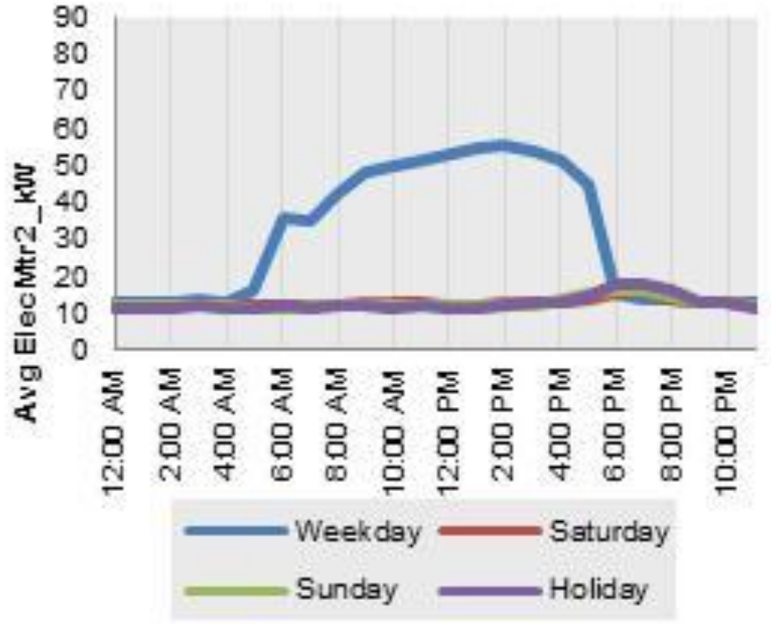
- Enforcing schedules and managing set points will result in energy and cost savings of over 20%
- Beyond demand response
  - Intelligent load controls to support grid reliability
  - Supporting renewable generation technology integration
  - Will result in demand reduction between 10% to 20%



Comparing Consumption from Two Identical Buildings: What Intelligent Controls can do for You!

- Electric load profiles for two identical 20,000 sf office buildings
- The building on the left has about 80+ occupants and one on the right has 90+

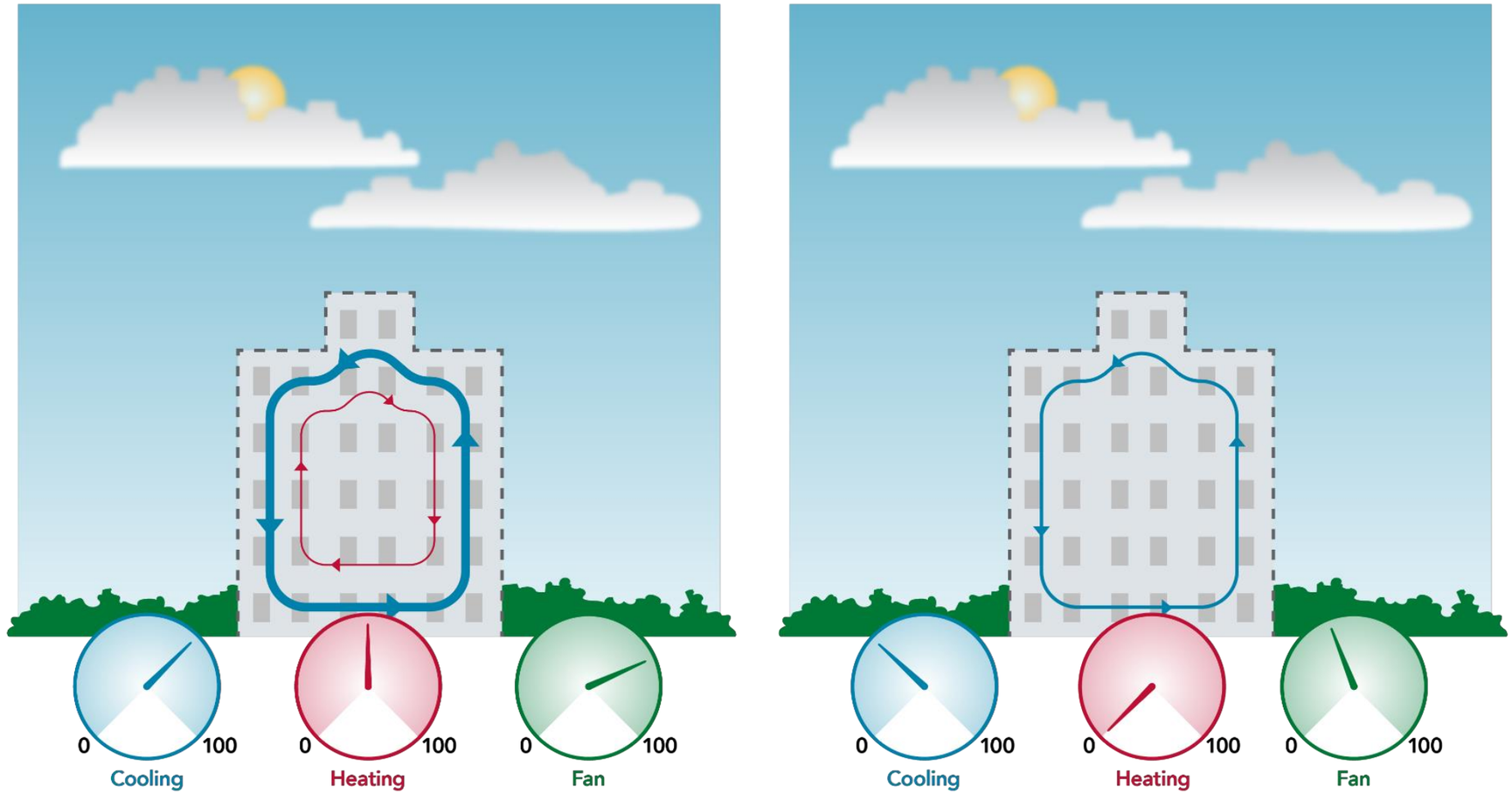




- The building on right also has a central BAS that is managing the operations of the rooftop units and few other equipment (exhaust fans and exterior lighting), it also has good weekend and holiday operational schedules
- The building on the left only has non-integrated thermostats that control the rooftop units, there are no holiday schedules that can be programmed

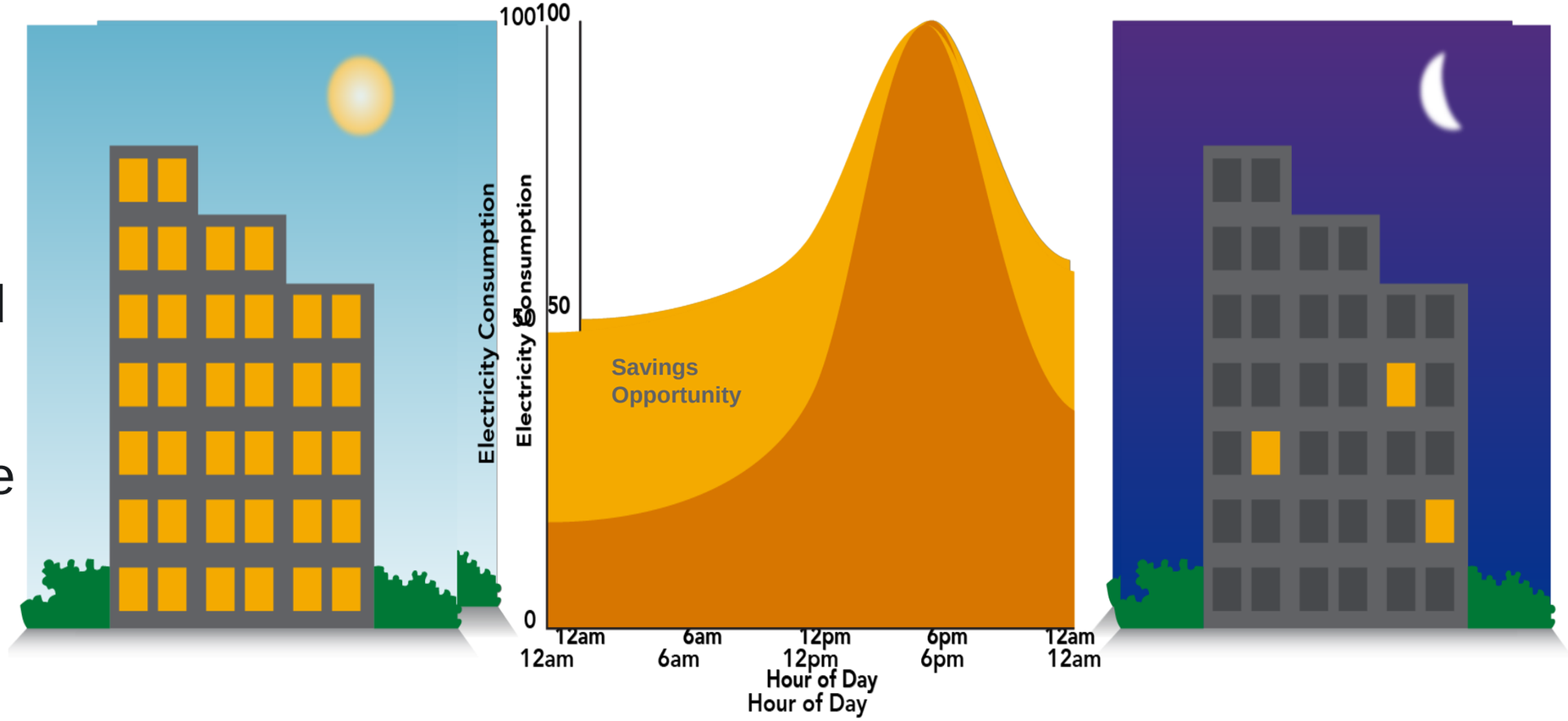
Buildings that are Always Self-Aware

Self-aware buildings detect and learn occupant's needs, respond to changing weather conditions, and automatically make changes to the HVAC and lighting systems to maximize energy efficiency

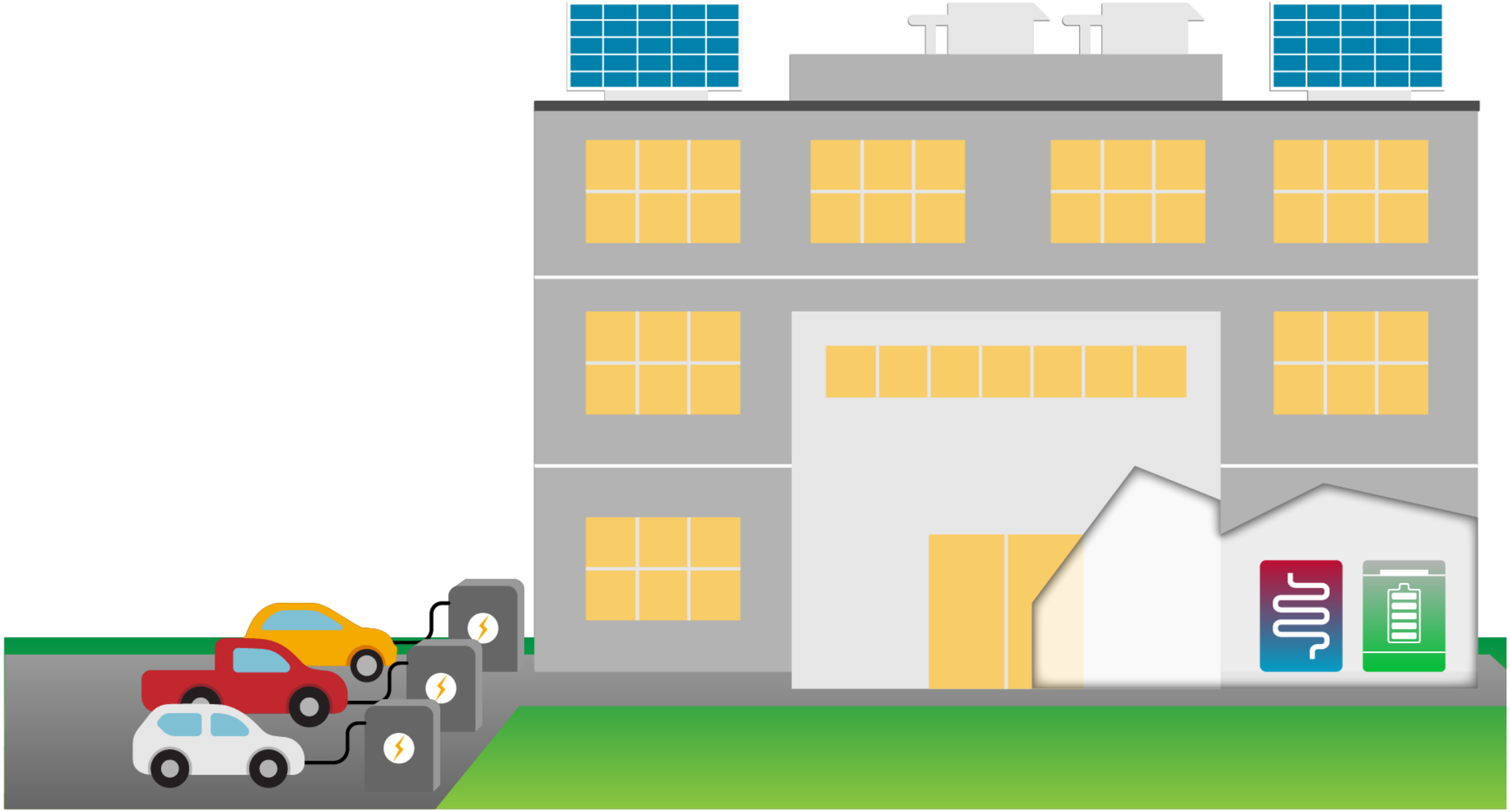


Another Example of Self-Aware Building Operations

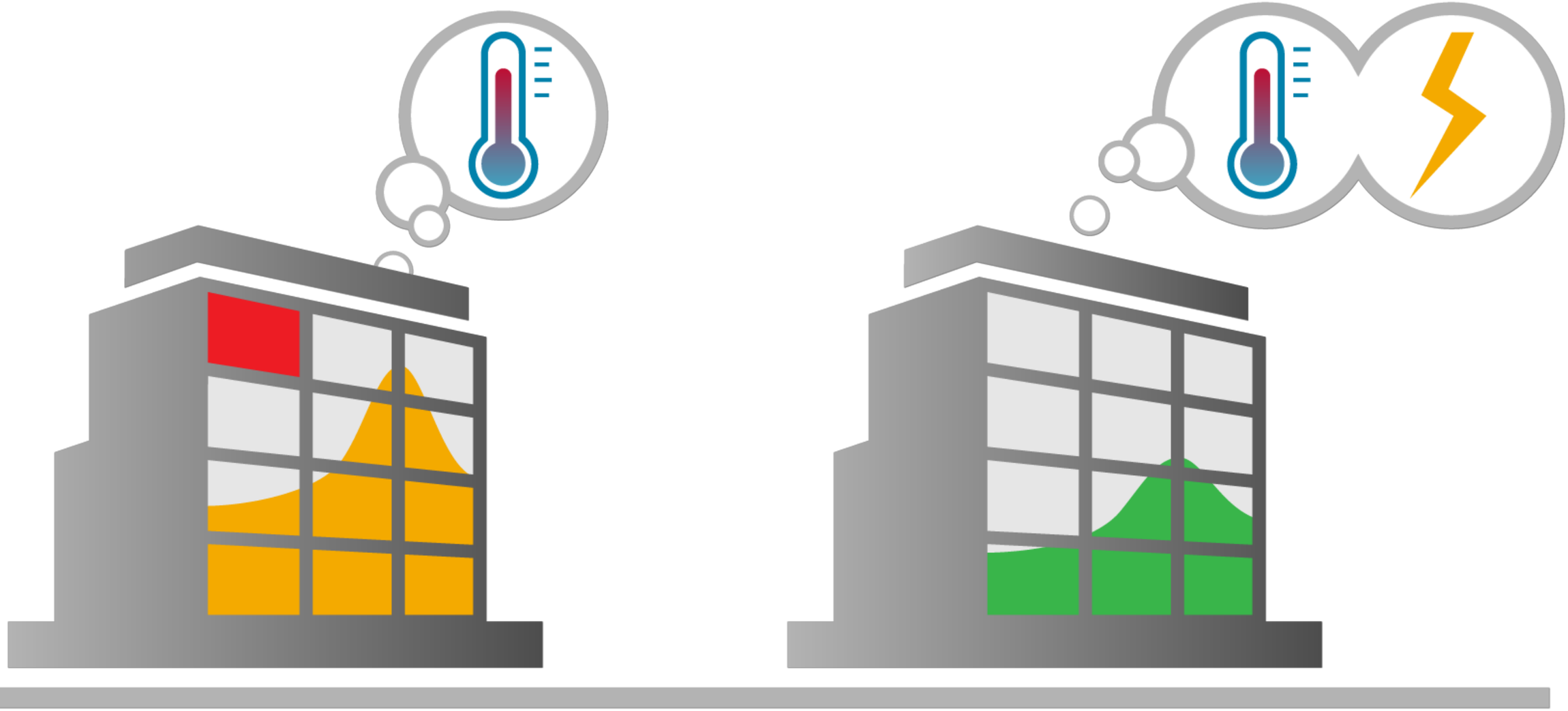
Buildings that detect lack of activity in spaces and automatically adjust lighting and HVAC systems to allocate less resources to these spaces



Autonomous Building Operations will Enable Integration of Additional DERs Easy

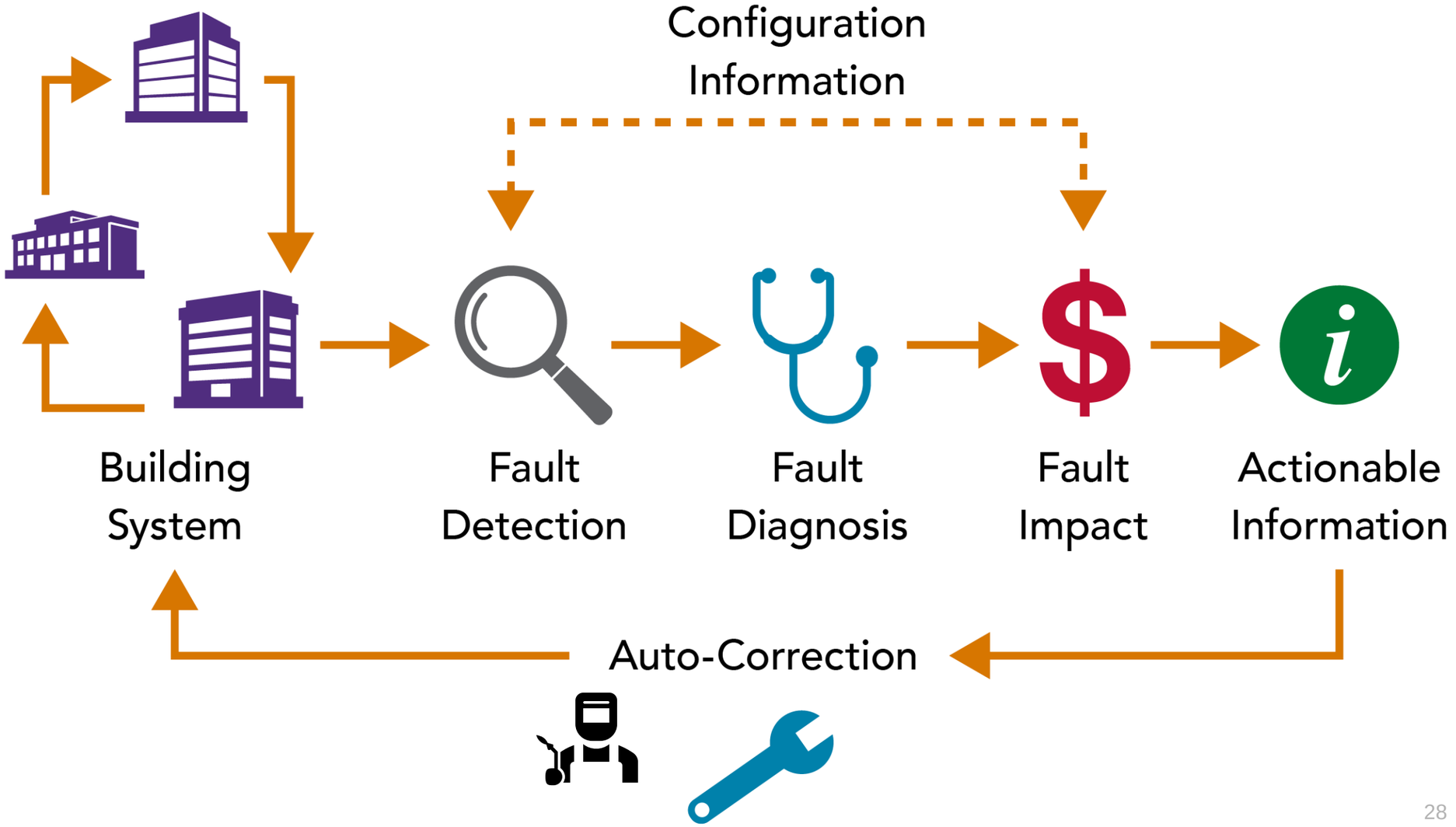


Autonomous Building Operations will Lead to Better Comfort and Lower Cost

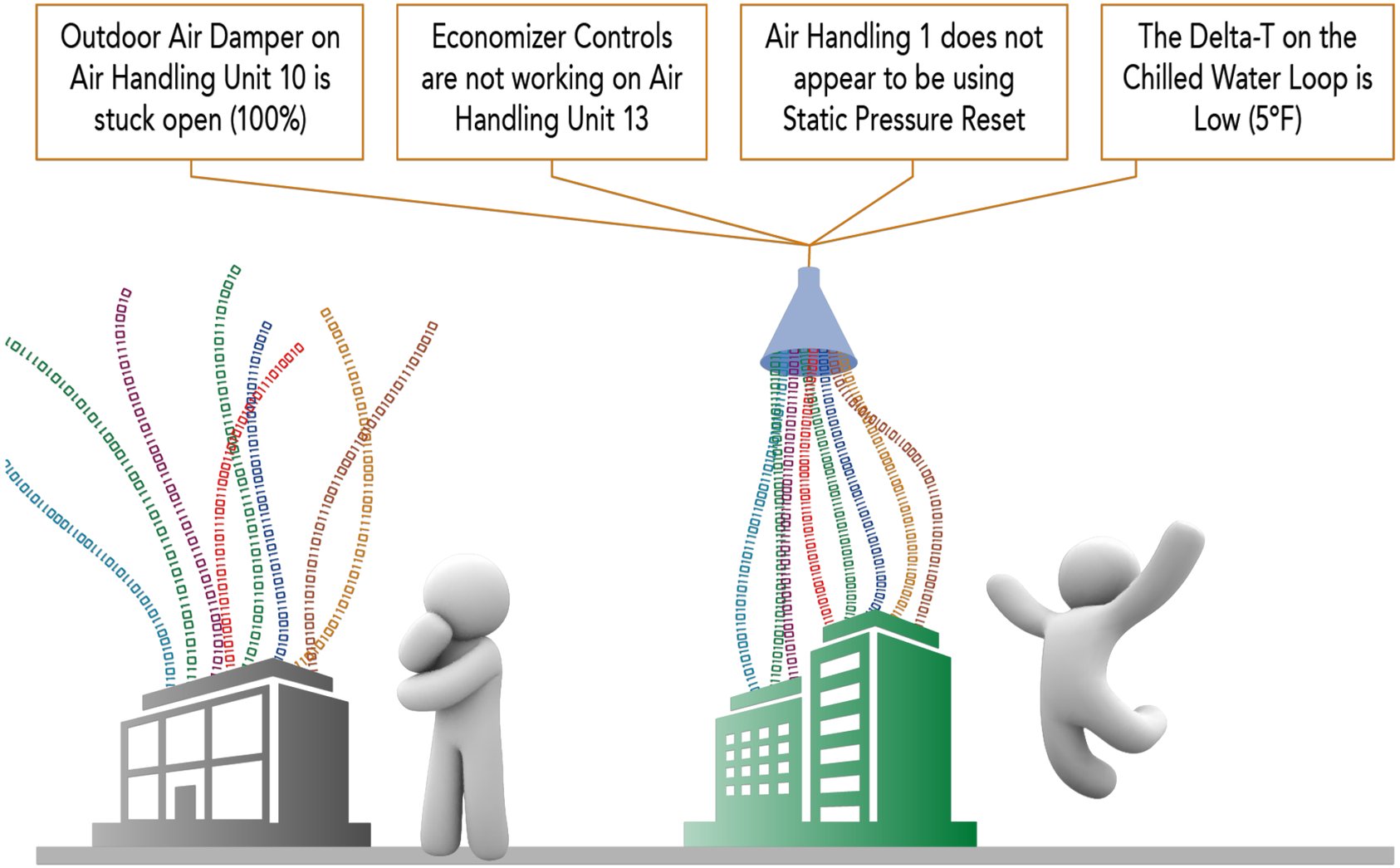


Autonomous Building Operations Means Continuously Self-Diagnosing, Self-Commissioning and Self-Healing

Continuously operating building systems at peak efficiency

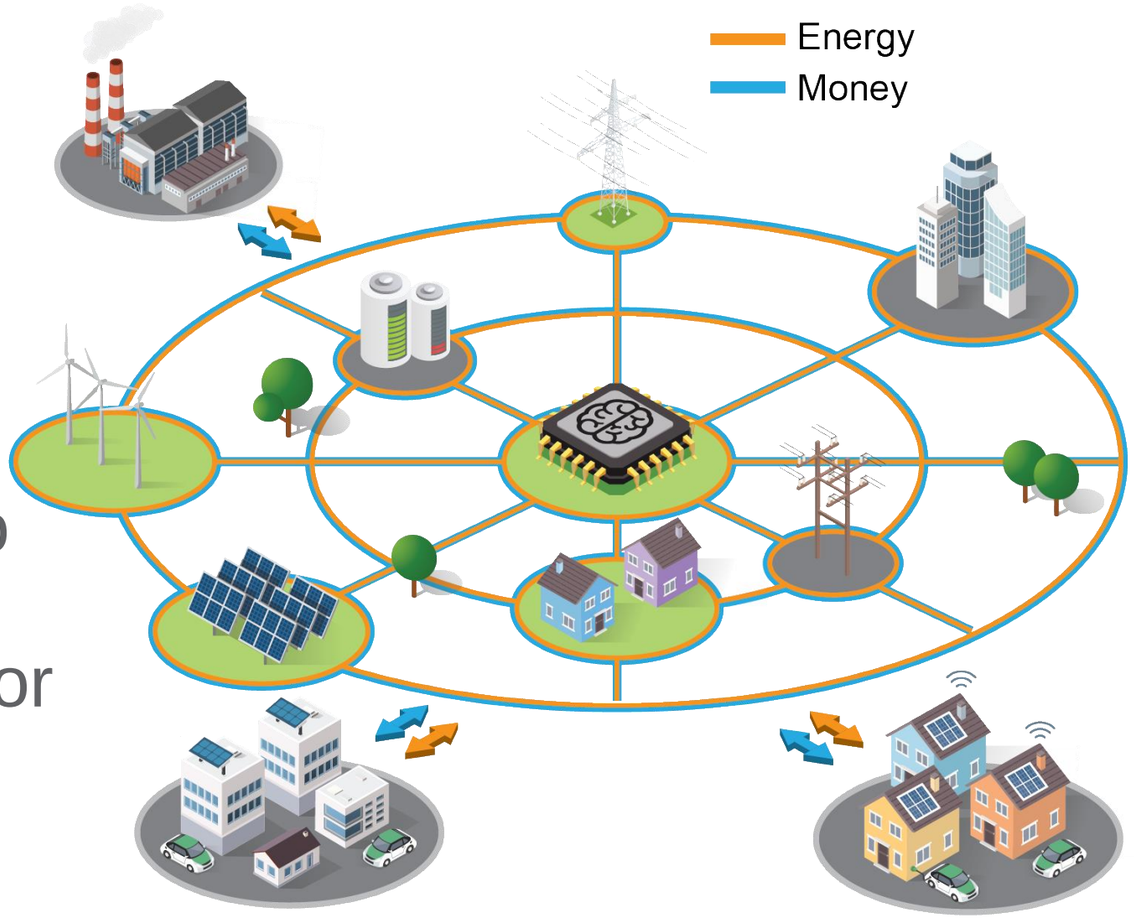


Autonomous Building Operations Go Beyond Actionable Information: Fault Tolerant Operations and Self-Correction



Autonomous Building Operations also Means Seamless Interaction with the Electric Grid

- Dynamic balancing of supply and demand on the grid efficiently and cost-effectively requires the participation of the flexible building end-use loads
- It also means two-way power flow, information, and communications to facilitate management and distributed optimization of the grid for the mutual benefit



Closing Remarks

- Autonomous building operations will result in persistent building operations, significant energy savings, improved occupant comfort and extended equipment life
- Autonomous building operations can also mitigate unintended, negative consequences from the effects from high penetration of renewable generation and mitigate climate change
- Most buildings do not have the necessary infrastructure to make their operations autonomous, but they could
- To make buildings autonomous, investment/infrastructure is needed
- Leveraging multiple value streams will help make investments in infrastructure cost-effective
- Although there are a number of efforts to improve building operations, more work is needed to close the gap, especially to move building controls from ABC Level 03 to ABC Level 05

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Thank you