Maximizing Smart Building Infrastructure to Scale Grid-Interactive Buildings

UT Austin Guest Lecture
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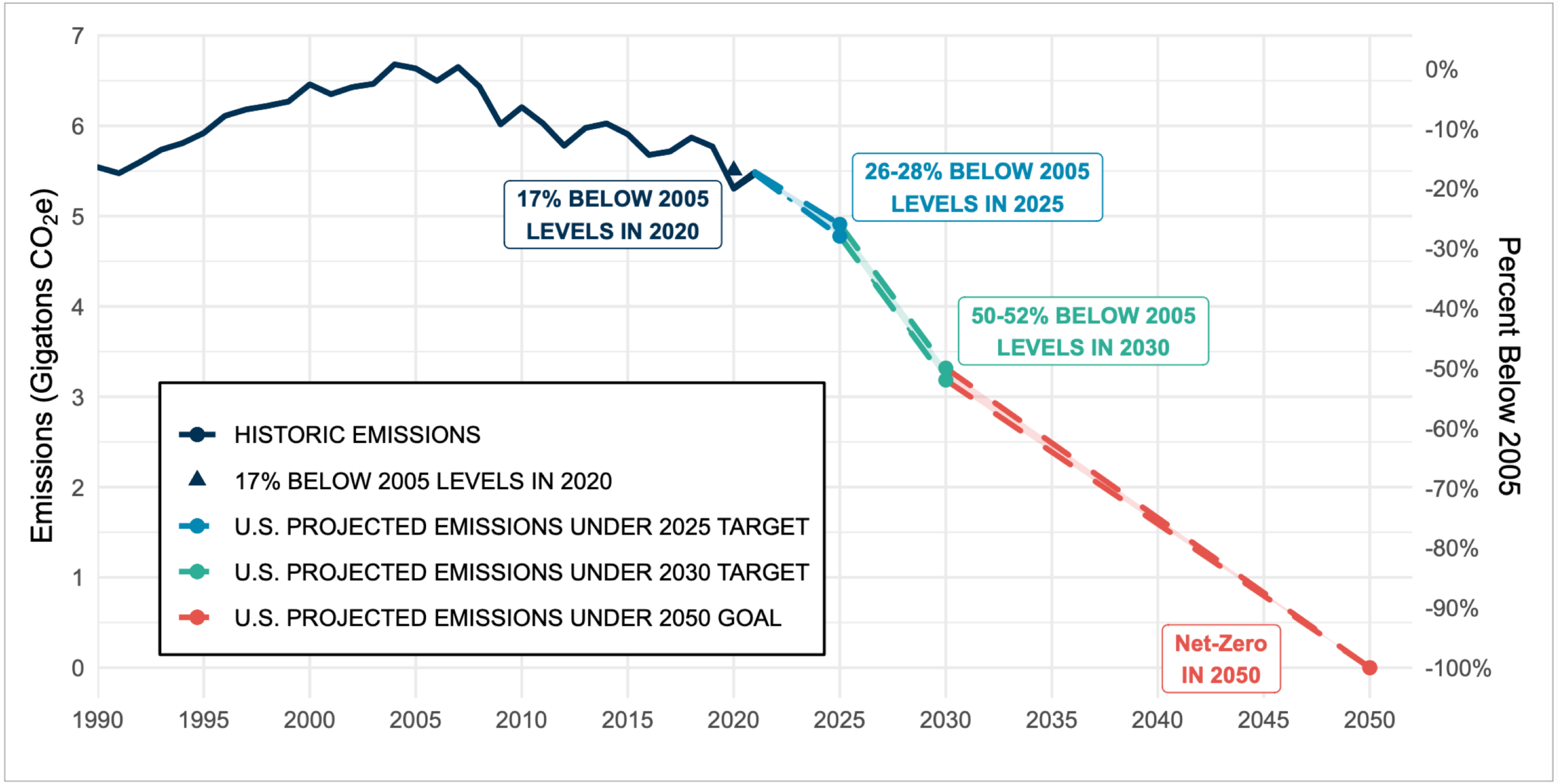
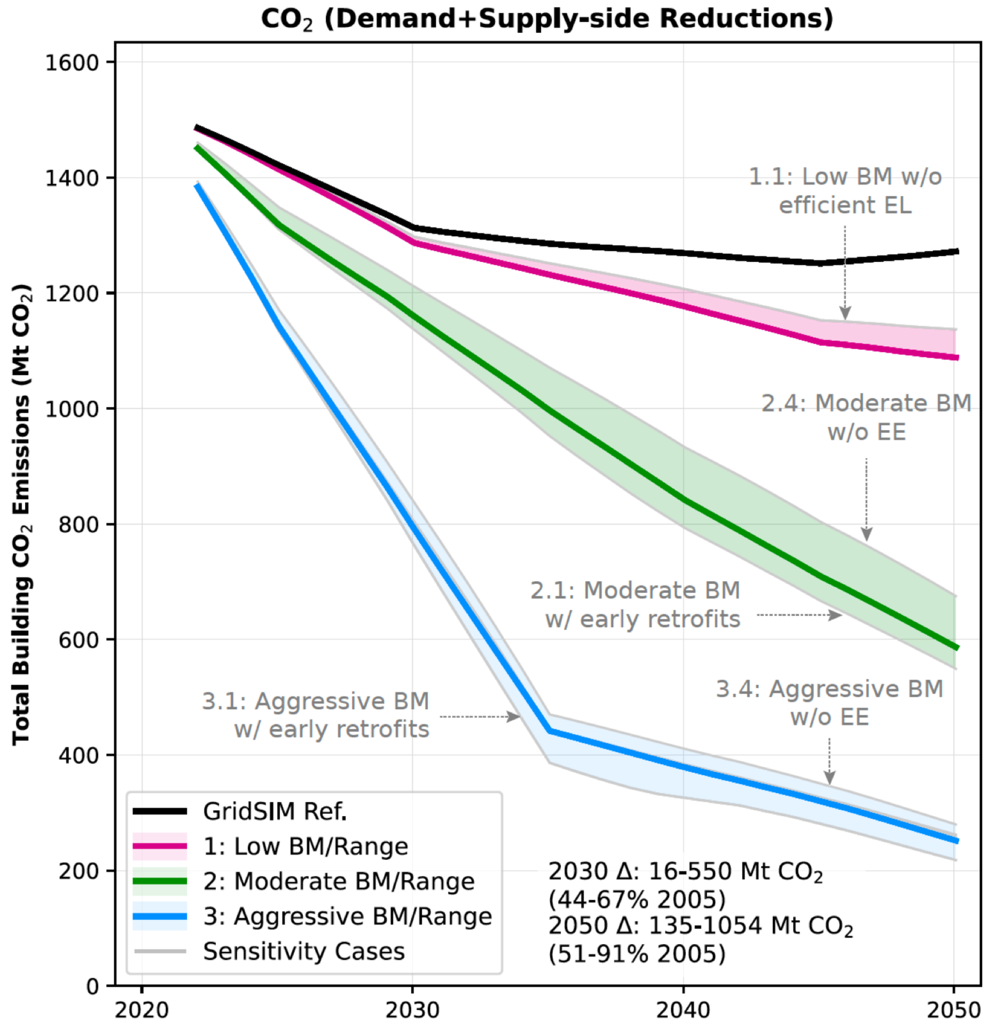
ENERGY TECHNOLOGIES AREA
BERKELEY LAB

Efficient demand-side flexibility is critical to a reliable and affordable energy transition

We have aggressive national goals for economy-wide emissions – 50% by 2030, net-zero by 2050



Here’s what getting there looks like for the buildings sector



Business as usual reference case

High rate of electrification

Moderate electrification, grid decarb, and efficiency, ~50% range by 2050

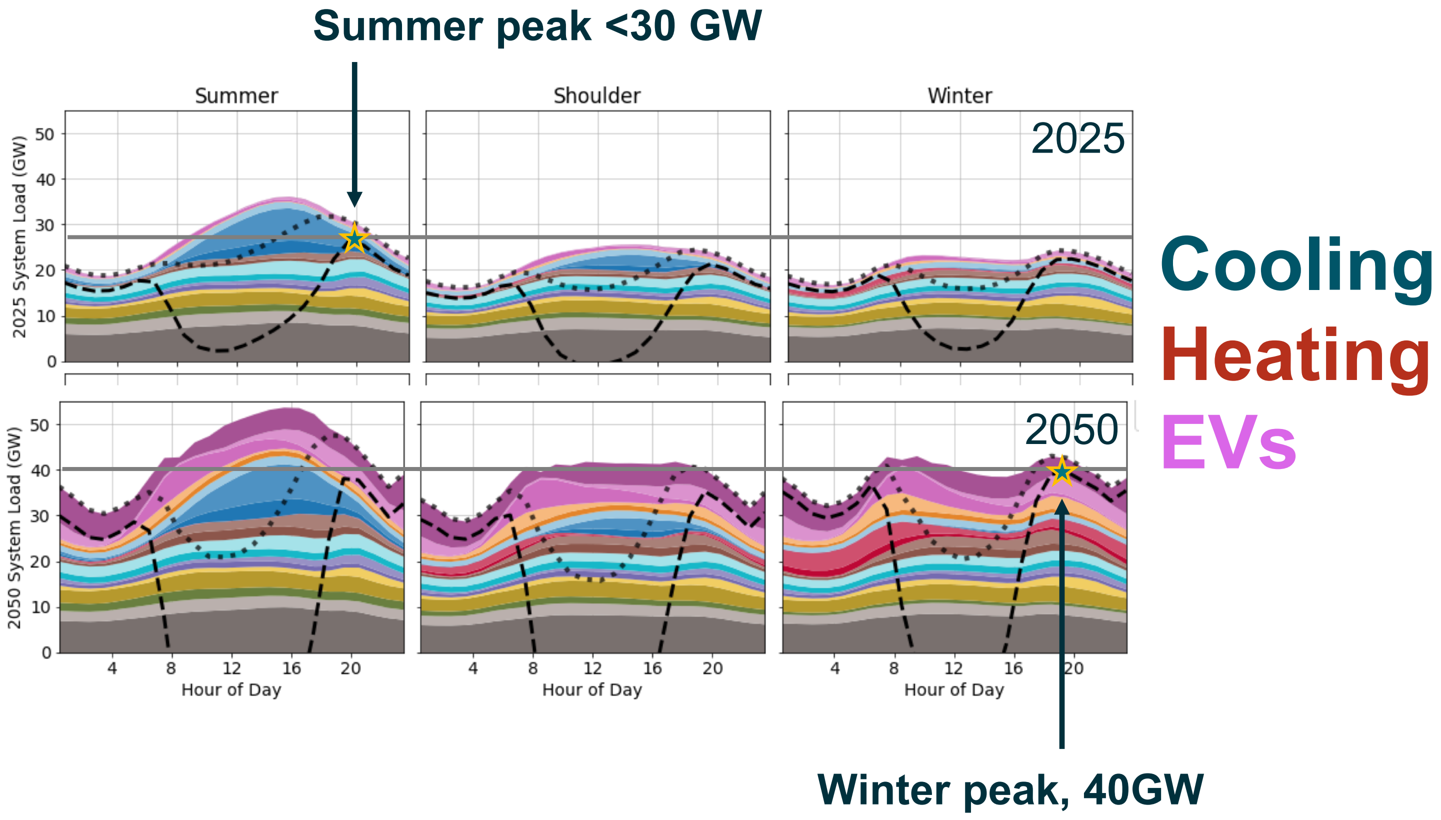
Most aggressive electrification, grid decarb, and efficiency, ~90% range by 2050

Electrified buildings and vehicles will increase electricity loads and the timing of the peak

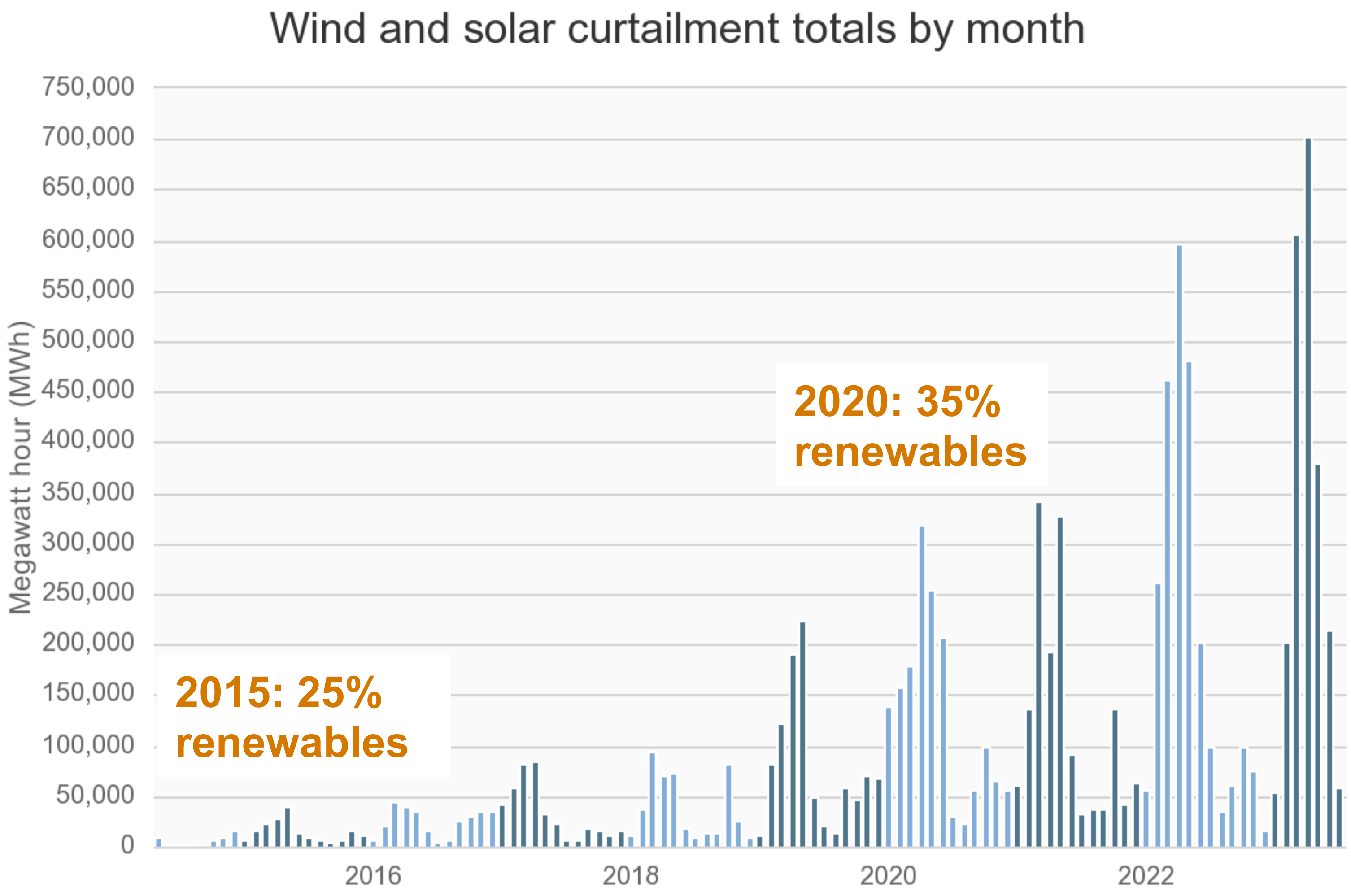
--- is system net, after removing distributed PV, utility wind and solar

CA peak increases by 10+ GW

Moves from summer to winter when there is less renewable generation



With increased renewables we are seeing a mismatch between supply and demand

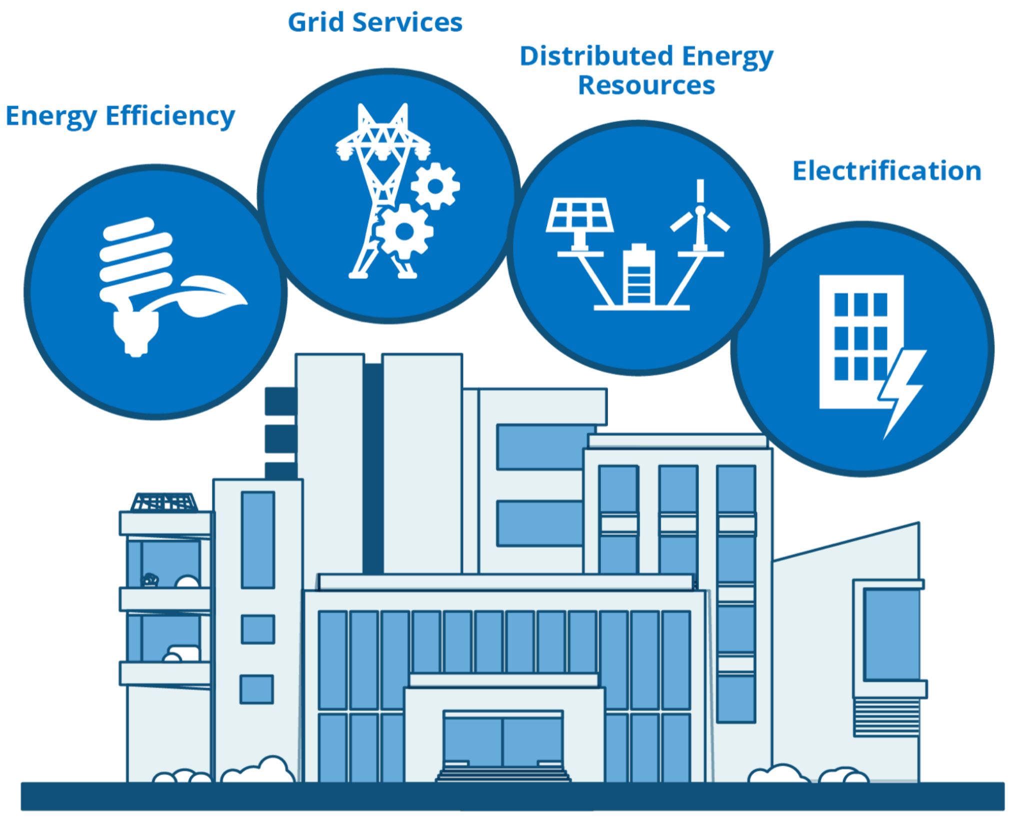


Order of magnitude increases in curtailments

All-time high 700,000 MWh spring 2023

Accelerating toward 2045 goal: 100% clean electricity by 2045

Buildings and vehicles can provide critical grid services in support of the energy transition

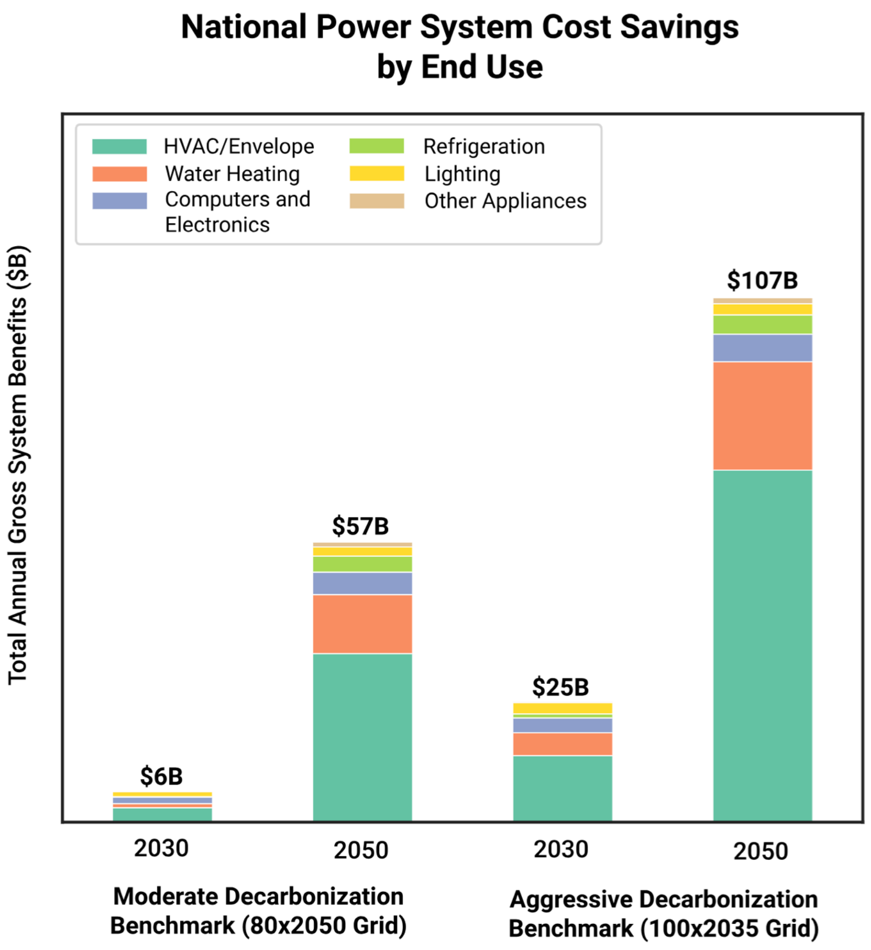


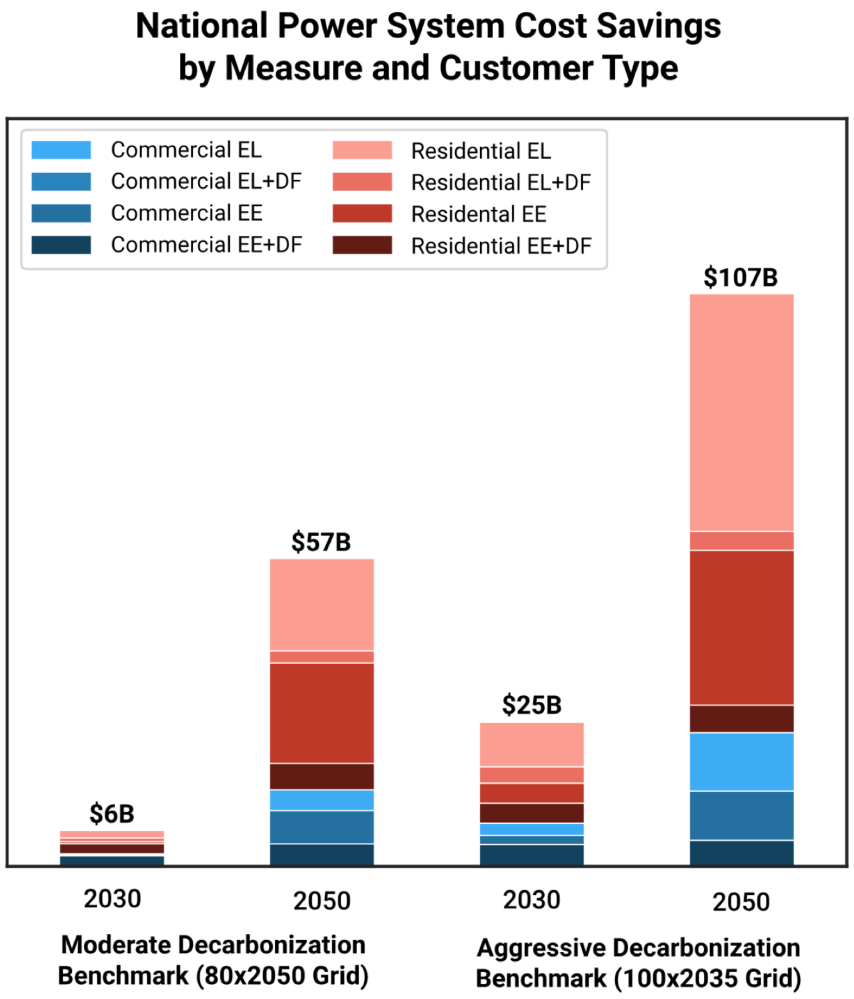
Efficiency: reduce overall loads

Storage: shift use to times when electrons are clean, cheap, and abundant

Control: reduce the peak, lower investment in generation and transmission capacity

Building measures alone could save up to $107B in bulk power system investments by 2050



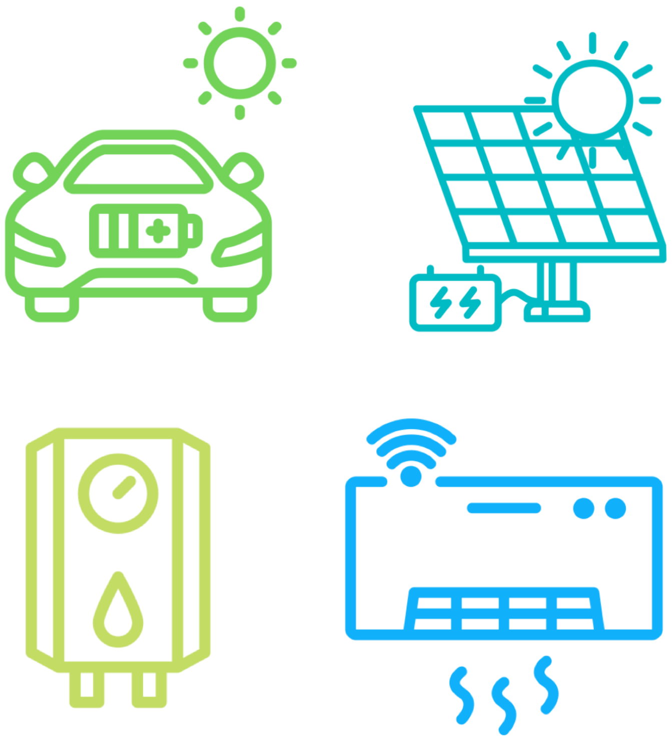


Avoided costs cover >80% of measure costs

Mostly HVAC, envelope, water heating

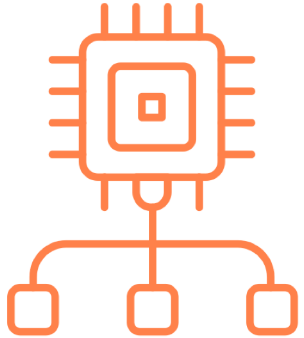
Not accounting for distribution level benefits

Integrated use of DERs can capture this value and provide resilience and bottom-line benefits



Flexible assets

Standardized communications



Responsive control

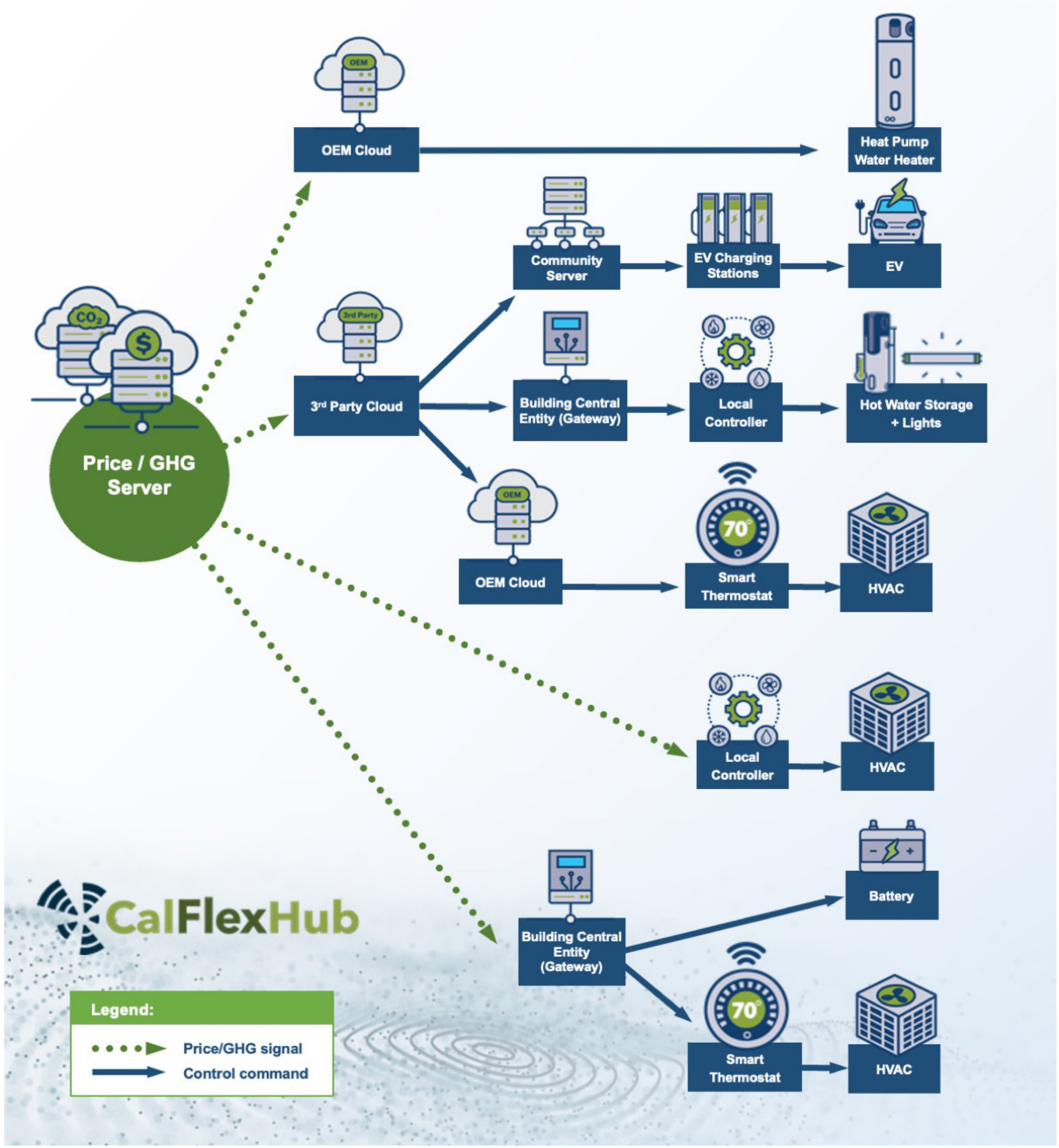
There are many architectures to convey grid signals to building loads

Most common are:

1) OEM cloud to device, e.g., smart grid responsive water heater or thermostat

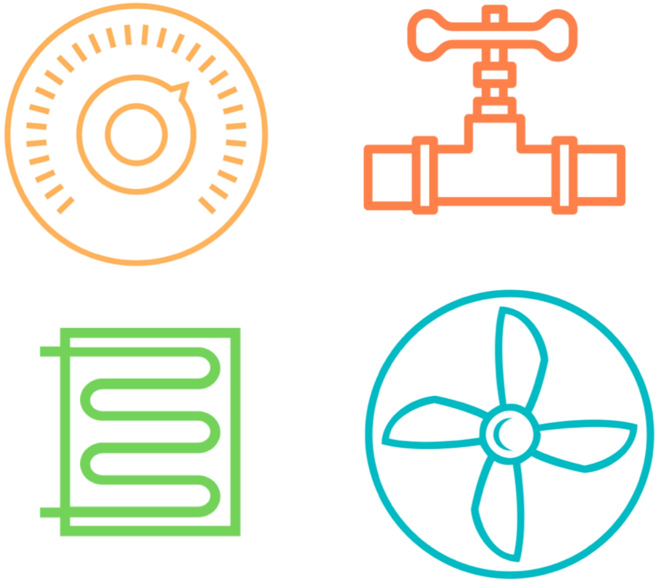
2) Building central entity, e.g. BAS

3) 3rd party cloud, e.g., EMIS



Common, proven HVAC strategies for demand flexibility can be delivered via BAS, smart devices

- Zone temperature setpoint adjustment
- Pre-cooling to shift load, deepen or extend shed
- Chilled water temperature reset
- Fan speed, coil valve limiting
- Controlled charging of chilled/hot water storage



Grid services and demand side management

Typical duration, response time, and event frequency depend on the service provided

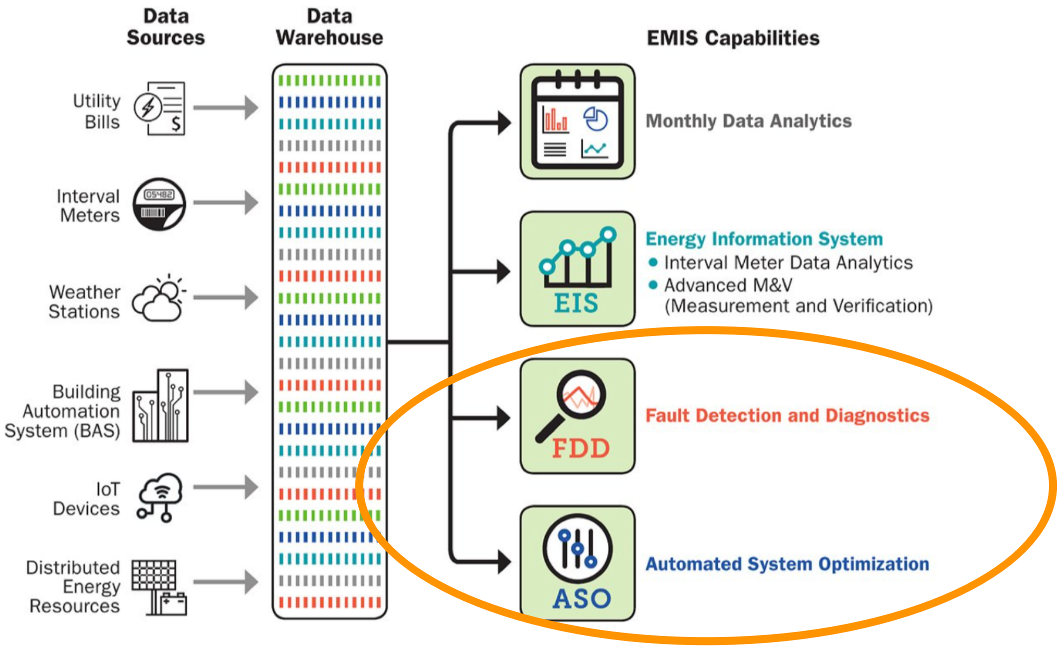
Programs that incentivize load shed are available in many territories

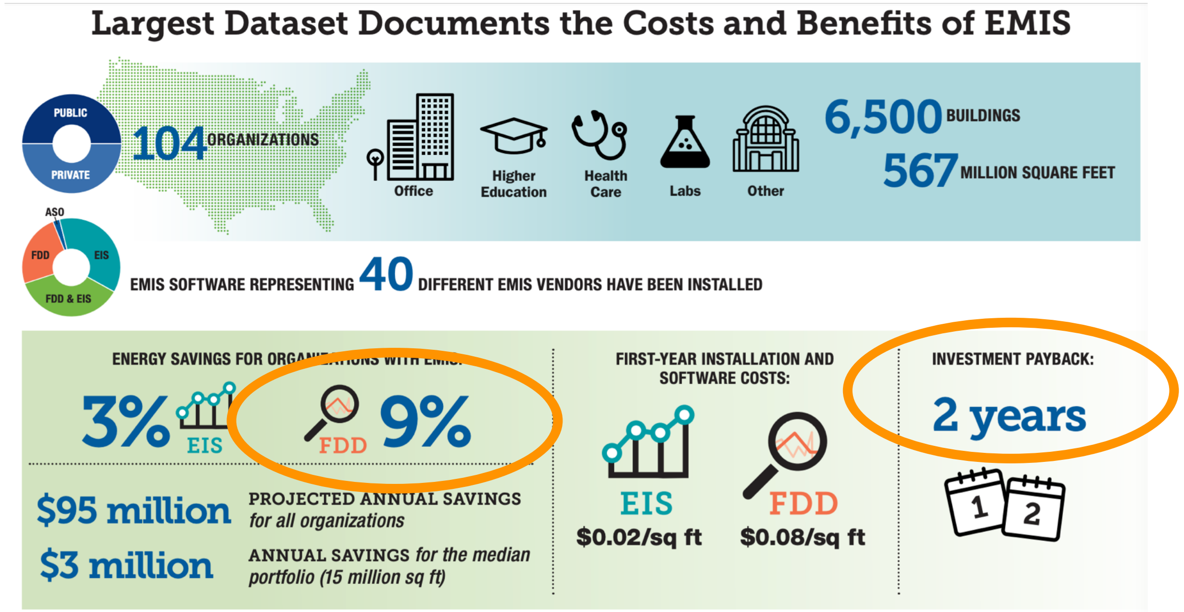
TOU rates encourage load shift

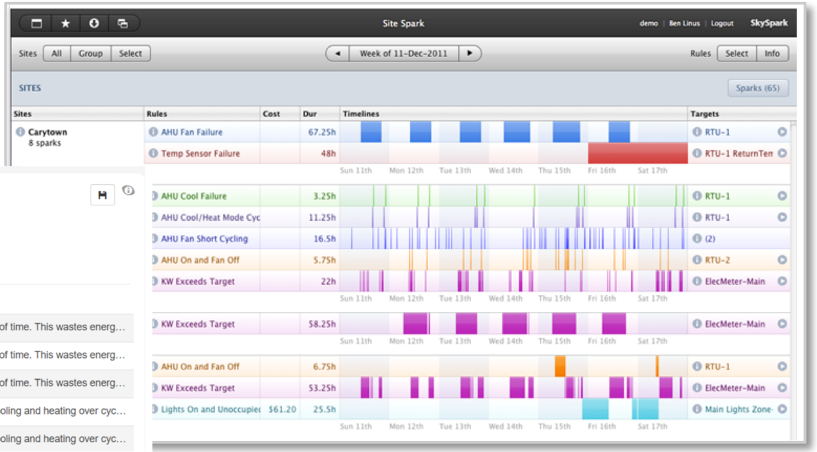
Peak demand charges encourage demand limiting (not a grid service)

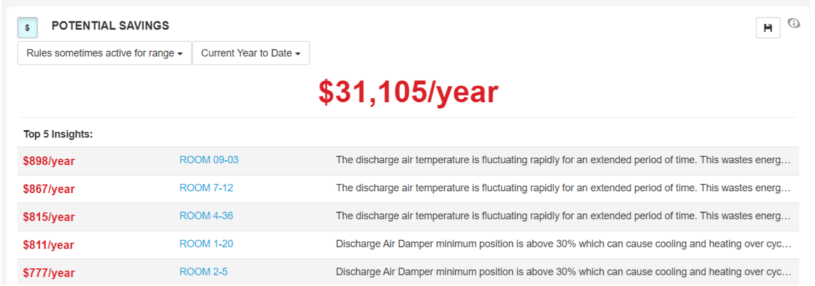
Demand-Side Management Strategies	Grid Services	Description of Building Change	Key Characteristics	
Efficiency	Generation: Energy Generation: Capacity T&D: Non-Wires Solutions	Persistent reduction in load. Interval data may be needed for measurement and verification purposes. This is not a dispatchable service.	Typical duration	Continuous
			Load change	Long-term decrease
			Response time	N/A
			Event frequency	Lifetime of equipment
Shed Load	Contingency Reserves	Load reduction for a short time to make up for a shortfall in generation.	Typical duration	Up to 1 hr
			Load change	Short-term decrease
			Response time	<15 min
			Event frequency	20 times per year
	Generation: Energy Generation: Capacity T&D: Non-Wires Solutions	Load reduction during peak periods in response to grid constraints or based on TOU pricing structures.	Typical duration	30 mins to 4 hrs
			Load change	Short-term decrease
			Response time	30 min to 2 hrs
			Event frequency	<100 hrs per yr/seasonal
Shift Load	Generation: Capacity T&D: Non-Wires Solutions	Load shifting from peak to off-peak periods in response to grid constraints or based on TOU pricing structures.	Typical duration	30 mins to 4 hrs
			Load change	Short-term shift
			Response time	<1 hour
			Event frequency	<100 hrs per yr/seasonal
	Contingency Reserves	Load shift for a short time to make up for a shortfall in generation.	Typical duration	Up to 1 hr
			Load change	Short-term shift
			Response time	<15 min
			Event frequency	20 times per year
	Avoid Renewable Curtailment	Load shifting to increase energy consumption at times of excess renewable generation output. This is not a dispatchable service but can be reflected through TOU pricing.	Typical duration	2 to 4 hrs
			Load change	Short-term shift
			Response time	N/A
			Event frequency	Daily
			Typical duration	Seconds to minutes

Smart building software (EMIS) are unlocking scaled EE+ demand flexibility in commercial buildings



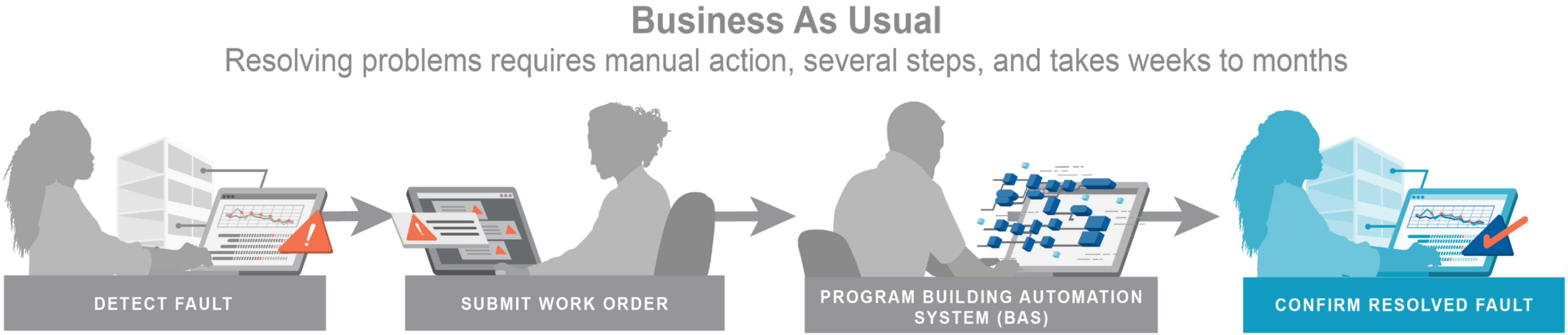




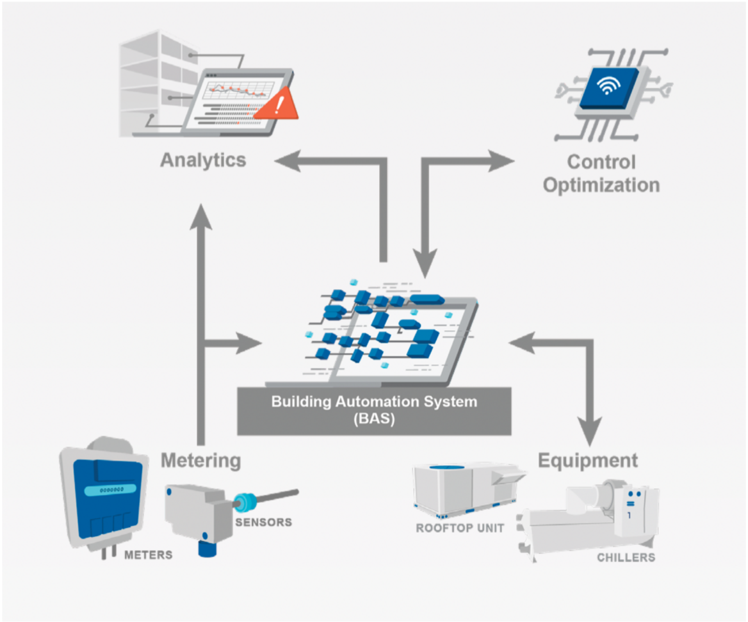


Right: SkyFoundry SkySpark
Left: CopperTree Kaizen

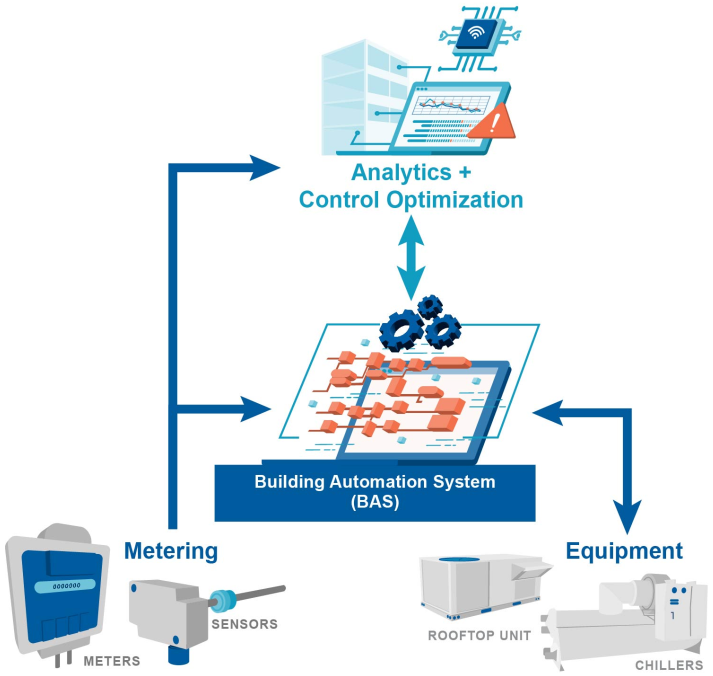
Technologies are saving impressively, but getting faults fixed, and base controls working limits potential



We are integrating fault diagnostics and control optimization for the first time



Historically analytics and optimization were delivered in separate products



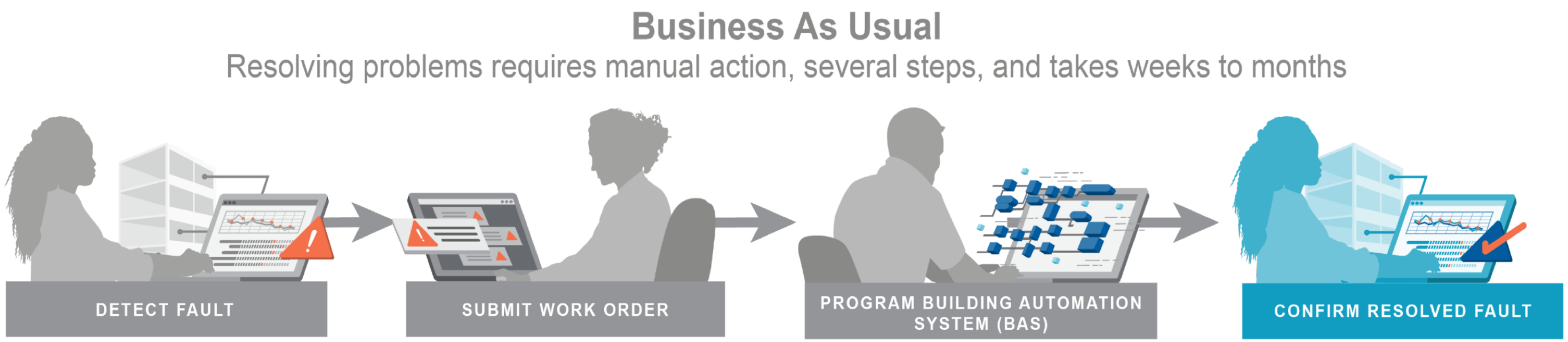
Today we have integrated these capabilities

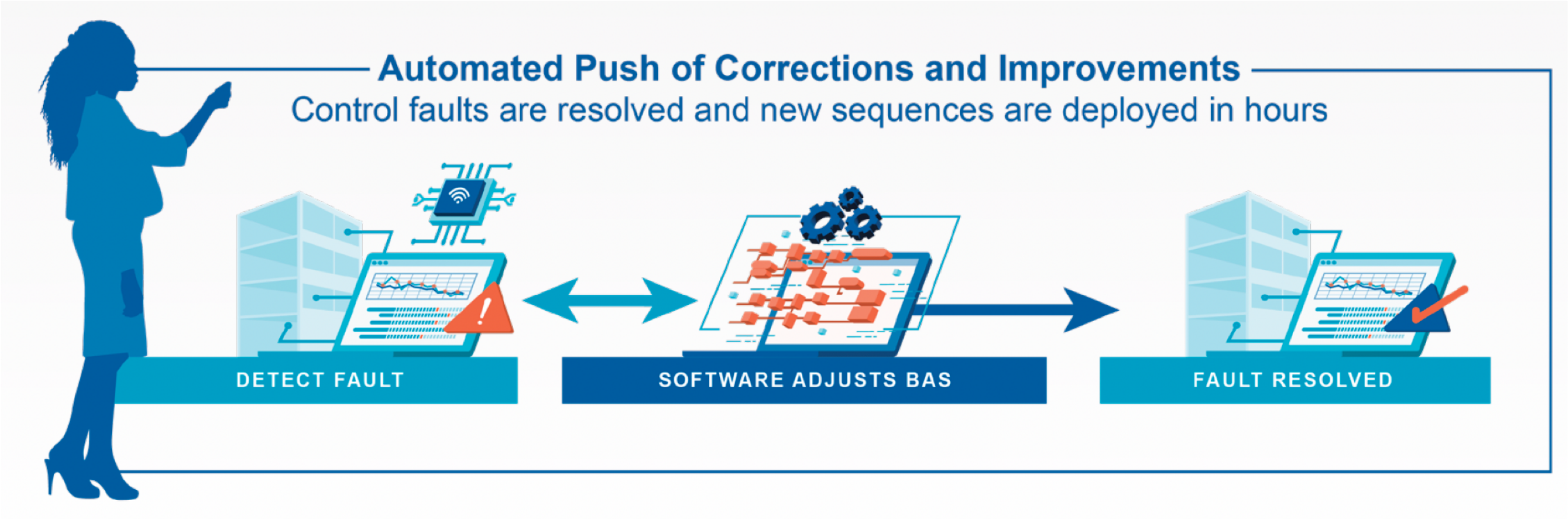
1) Add BAS 'write' capability to FDD

2) Add FDD logic to ASO

3) Add complementary logic to correct problems and implement best practice control

A fix it and easy button for operators to authorize improvements

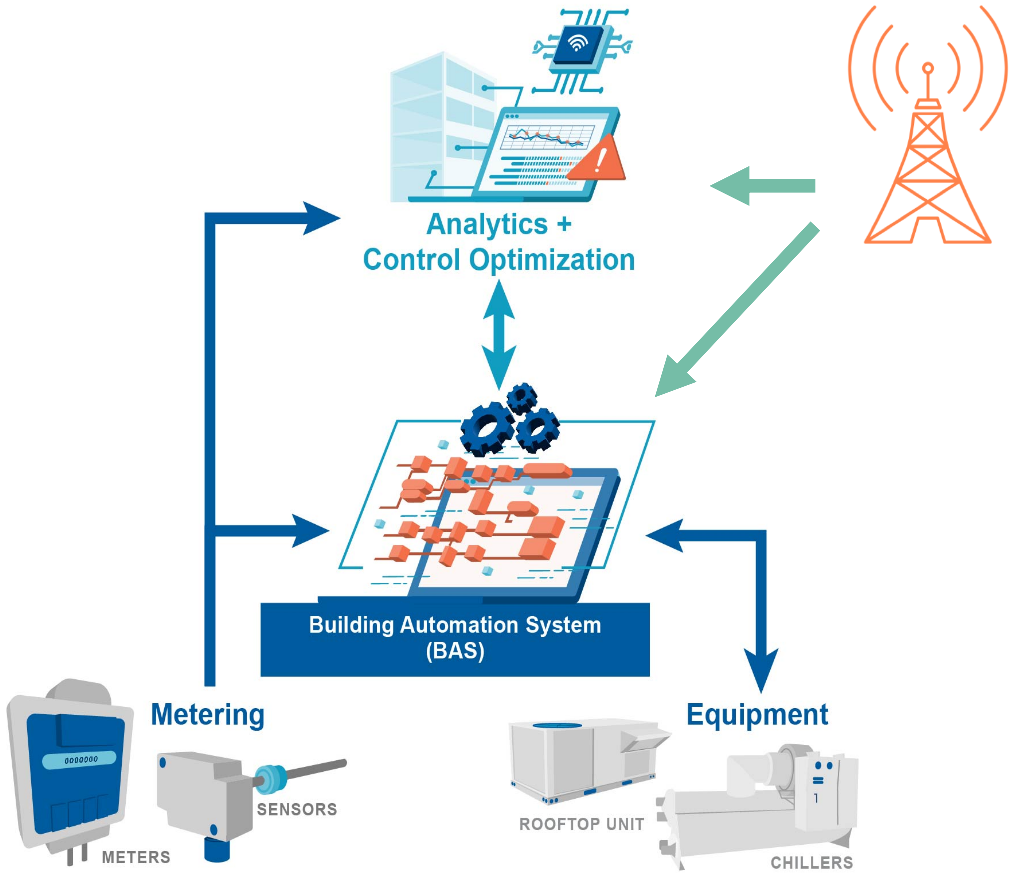




Automatically **correct** faults, overcoming workforce constraints

Optimize control – resets, PID loop tuning

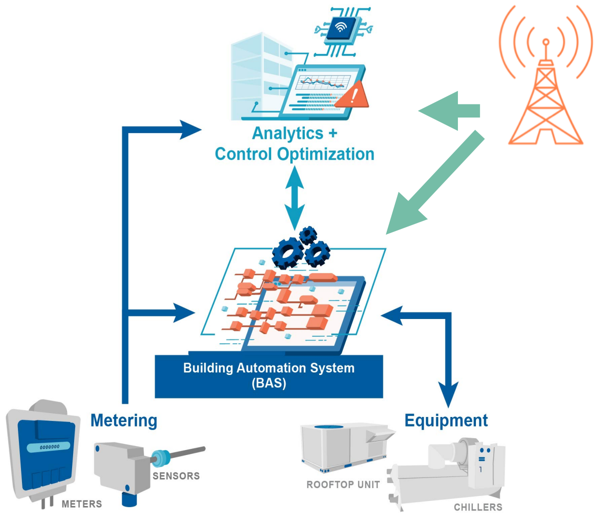
Push fault-free demand-flexible control, without having to bottom-up reprogram the BAS

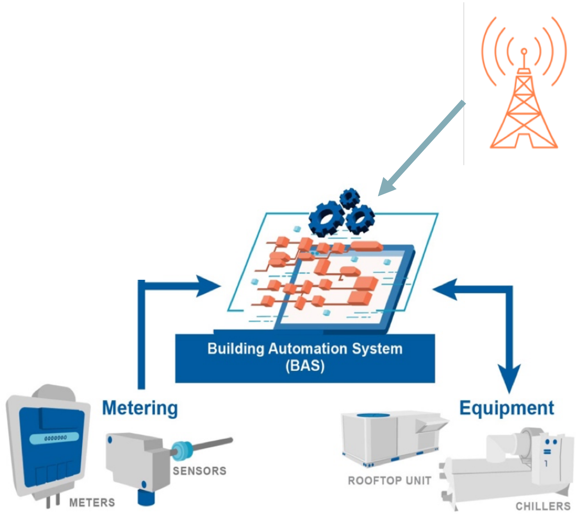


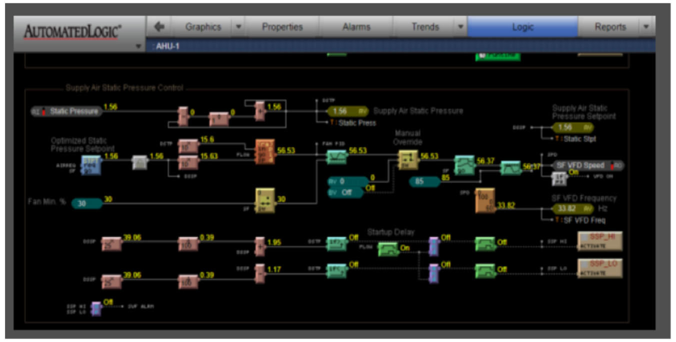
<u>Automate demand flexibility</u> –
demand limiting, shed, shift

Key to scale: EMIS already do the hard work of integrating across BAS, protocols, HVAC configurations

Automation infrastructure for medium and large buildings delivers reliably, but is clunky







Future:
Utilize EMIS' modern software environments for more nuanced control optimization and demand-flexibility (in addition to analytics)

Today:
Limited programming environments
Time consuming, expensive
Operator caretaking

A growing set of providers is beginning to bring enhanced control correction and DF capabilities

Advancing Market Solutions for Self-Correcting, Optimized Controls

Leapfrogging the status quo, the U.S. Department of Energy and Berkeley Lab have joined forces with the smart buildings industry to deliver the first-ever technology to automatically find and correct controls problems.

CopperTree Analytics

CLOCKWORKS ANALYTICS

buildingsIOT

SWITCH AUTOMATION

SkyFoundry + SUSTAINABLE BERKELEY LAB

GSA + CBRE | ESI

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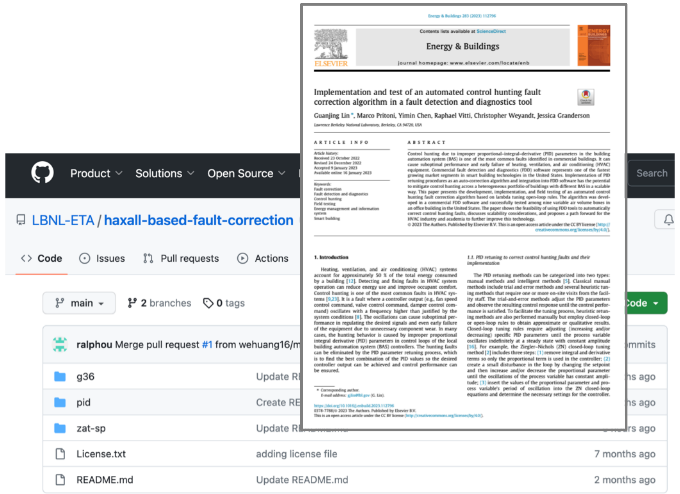
Partnership, IP model



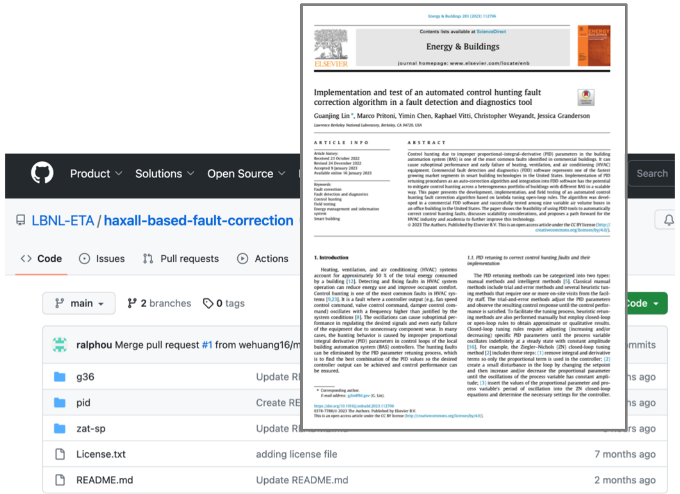
DOE and Lab develop open specification and reference code (for SkySpark users)

Lab transfers to partners to instantiate in products, who refine as needed, keep their IP

Partners share field test data, lab documents efficacy

Partnership, IP model

Inaugural partners ‘go first’, generate field results Industry TAG advises, may be 2nd wave adopters



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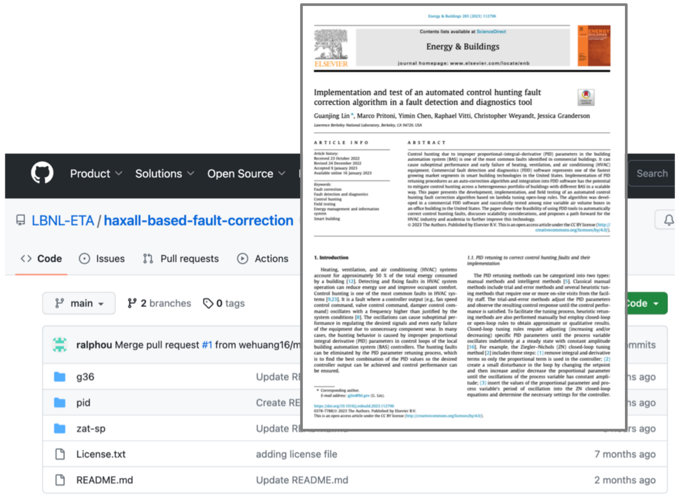

With field results open specs and open code, additional partners are engaged:

+ Several more in progress

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CLOCKWORKS ANALYTICS
CopperTree Analytics
BERKELEY LAB
SkySpark EVERYWHERE

buildingsIOT
riptide
ALTURA
ECOVOX ENERGY ANALYTICS
cimetrics
Group 14 ENGINEERING
MelRok Energy IoT

With field results open specs and open code, additional partners are engaged:

CIM cim.io
SWITCH
GSA
+ Several more in progress
buildingsIOT
CBRE | ESI

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As ecosystem of product/service providers matures we support owners, existing EMIS users to pilot, specify, procure

Better Buildings U.S. DEPARTMENT OF ENERGY

Load shed example, zone temperature adjustment

Traditional BAS-based approach:

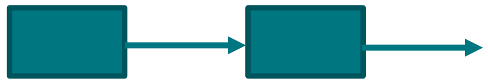
- Use ‘global’ zone temperature point to adjust multiple setpoints at once, or go one by one (!)
- Operator can adjust further during event to deepen shed based on observed effect

EMIS software-based approach:

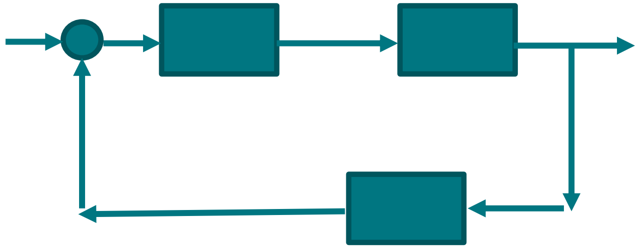
- Leverage programming capabilities for a more nuanced, careful zone-by zone approach

Four flavors for partner consideration

1. Adjust towards a max zone temp setpoint limit
    a. Single adjustment to increase setpoints to maximum that will be permitted
    b. Ratchet - begin with a more conservative adjustment, operator-in-the loop can deepen shed via ratchet towards max permissible



2. Adjust towards performance target (% reduction, kW)
    a. Single-value target based on metered building load prior to the shed
    b. Time-series target based on a program-defined baseline

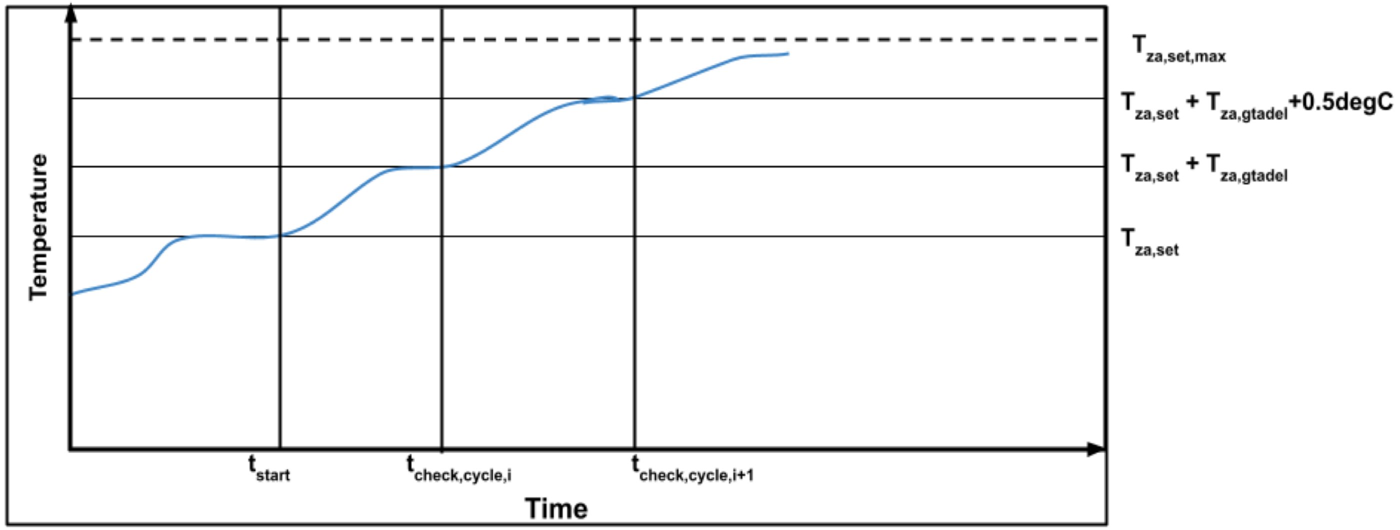


Additional best-practice details, partner customization

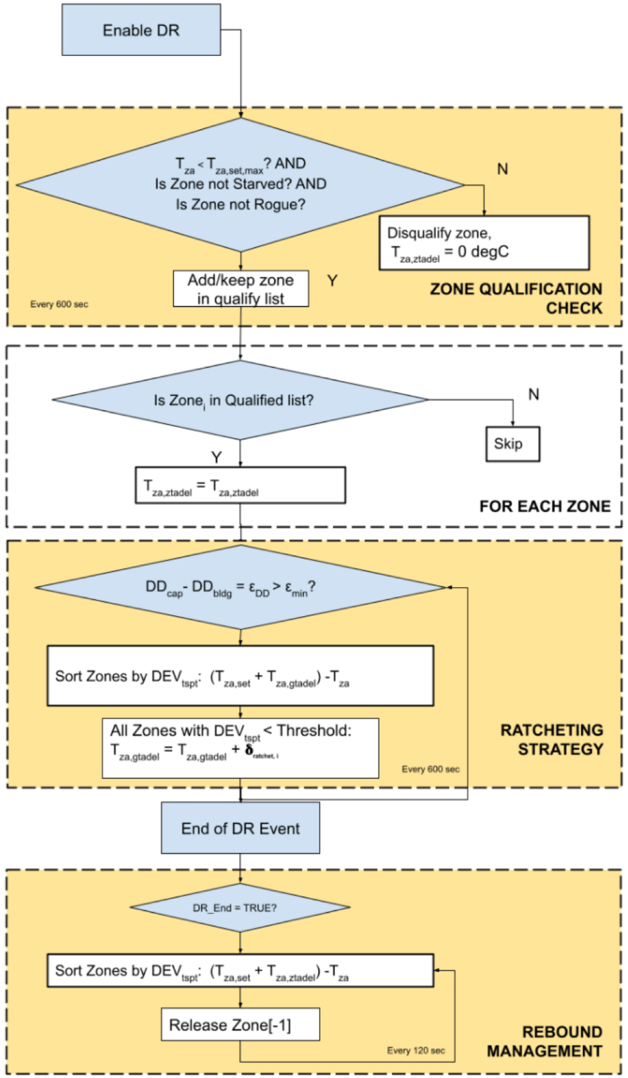
Within each strategy 'checks' qualify zones for adjustment, and re-qualify them prior to a ratchet – e.g., setpoint is being met, not starved for air, etc.

Definition of wait time prior to ratchet, and step size of ratchet is partner-defined

Staggered return of zones to their standard pre-shed setpoints is implemented to avoid post-shed rebound



Specification excerpts

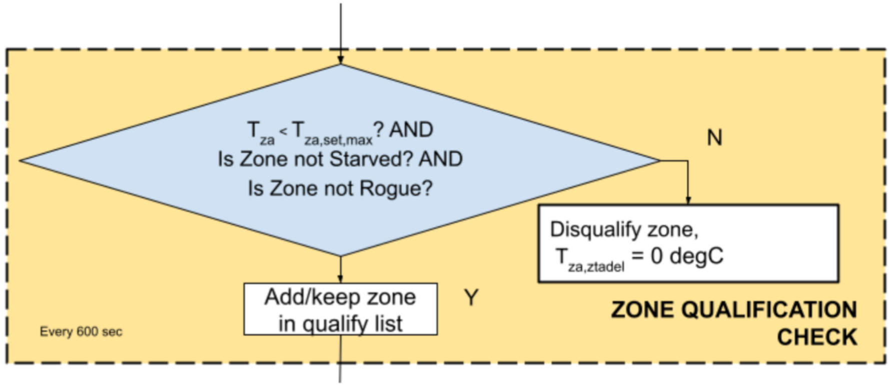


English language descriptions, logical flow diagrams, pseudocode snippets

2.2 Zone qualification check

At each logical cycle, the zone qualification check examines each zone for current disqualifying zone conditions such as thermal runaway and VAV starving conditions, and releases the zone temperature adjustment for zones that are approaching uncomfortable conditions for occupants. The thermal runaway check will examine values for T_{za} for instances of thermal runaway: determining whether or not T_{za} is above the comfort threshold $T_{za,set,max}$. The sequence will also check VAV damper command values and VAV airflow for starving zones. Finally, other disqualifying conditions may be factored in such as rogue zone classification. Zones that are in the occupied list and pass the qualification checks are appended to the qualified list of zones for the current iteration of the logical cycle:

```
#Read all T_za,i from zone_i in zone_list:
     # If T_za,i < T_za,set,max &
     #(u_vdm<uvdm,max) &
     # zone_i  not {Rogue Zone}:
          # qualify_list.append(zone_i)
     #else Continue
```



Other specified strategies: temperature adjustment for precooling, chilled water temperature setpoint reset

Next up?: fan speed and coil valve limiting, incorporation of storage, …

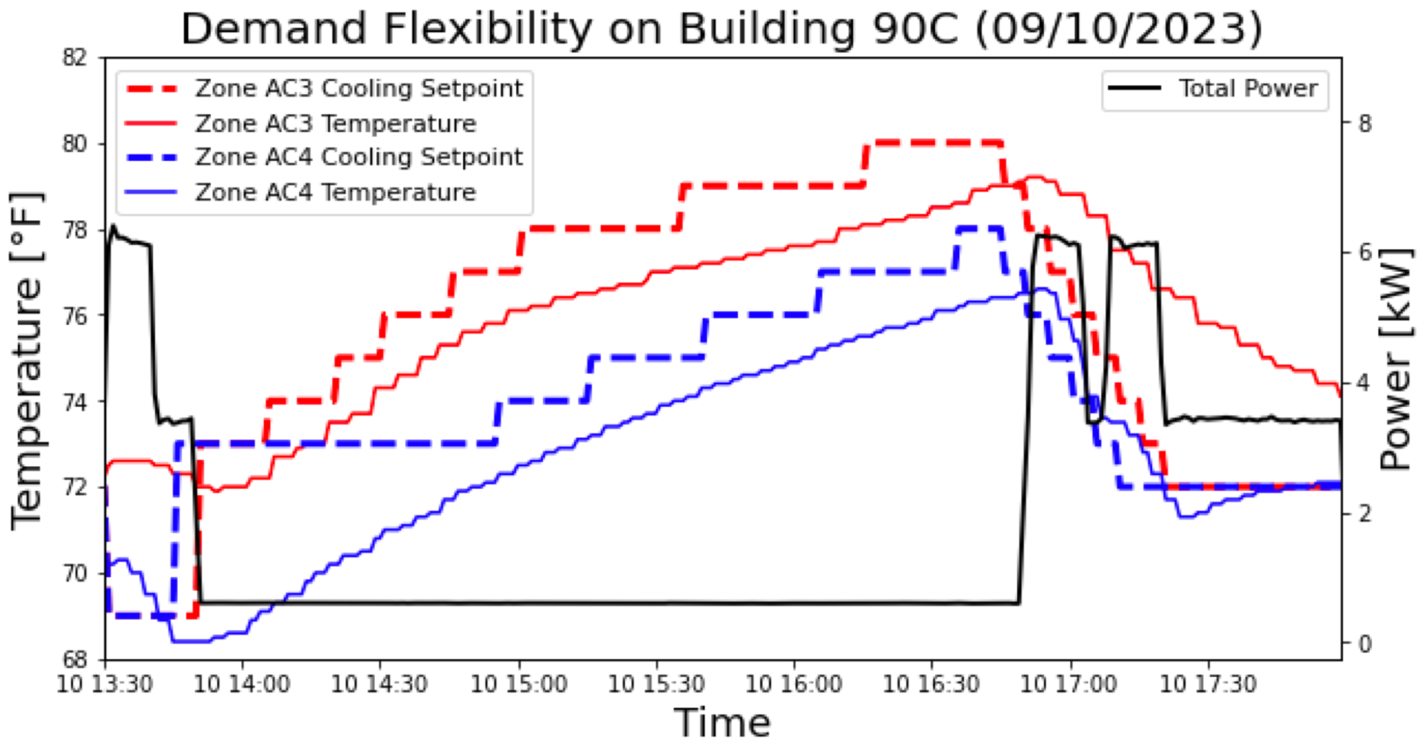
Demand shed + precooling, FLEXLAB ops. office

Controlled 2 HVAC units via smart thermostat cooling setpoint

Load target and real time feedback for sequential shedding of units

Setpoint ratchet tracked the rooms temperature for ”shed preservation”

Setpoints gradually returned to original value to reduce rebound



Demand shed, VA, partner’s product

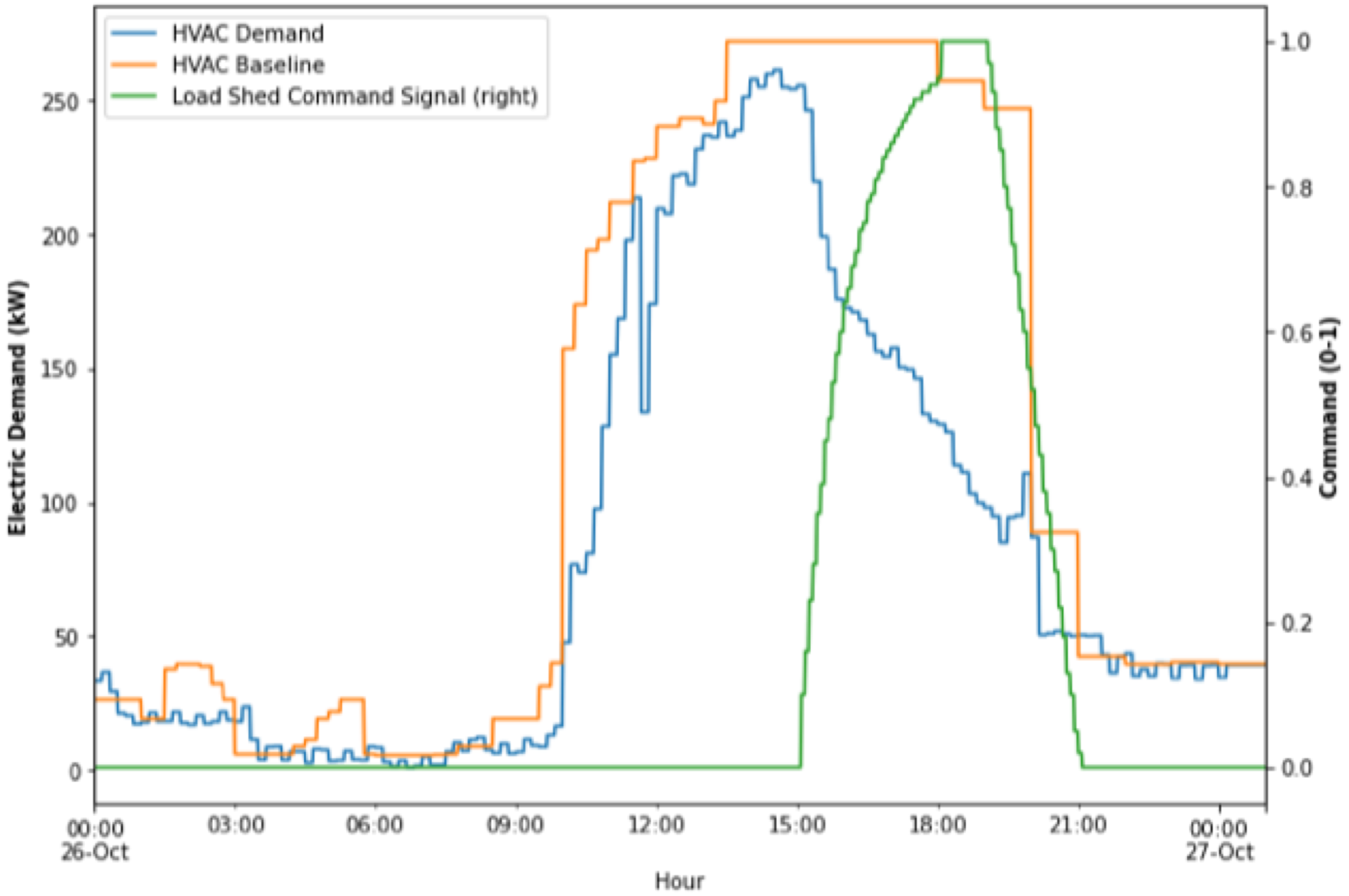
Industry partner tested at retail site

18 RTUs via Niagara BMS, by gradually adjusting zone temp setpoints

Units prioritized based on zone temp at event start

Use of virtual meter calcs, from RTU capacities

Setpoints gradually returned to original value to reduce rebound

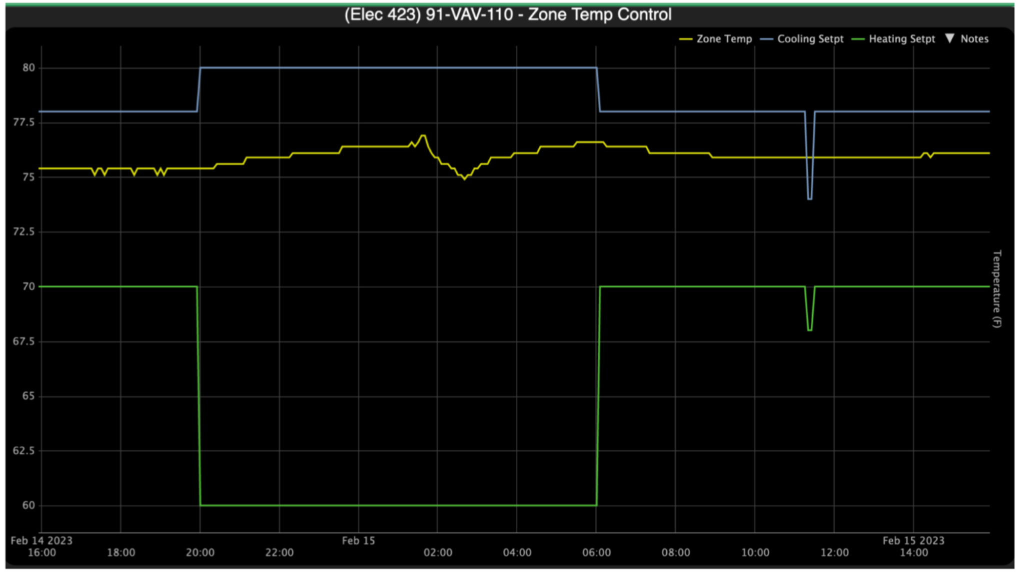


Zone temperature setpoint correction

Setpoint View | Temperature Setpoints

Select ▼ | Edit Reference Temperatures | Push Reference Temperatures

equipRef	curOccHtg	curOccClg	curUnoccHtg	curUnoccClg	refOccHtg	refOccClg	refUnoccHtg	refUnoccClg
B91 Rm 423 SVAV-110	70°F	78°F	60°F	80°F	68°F	74°F	64°F	80°F

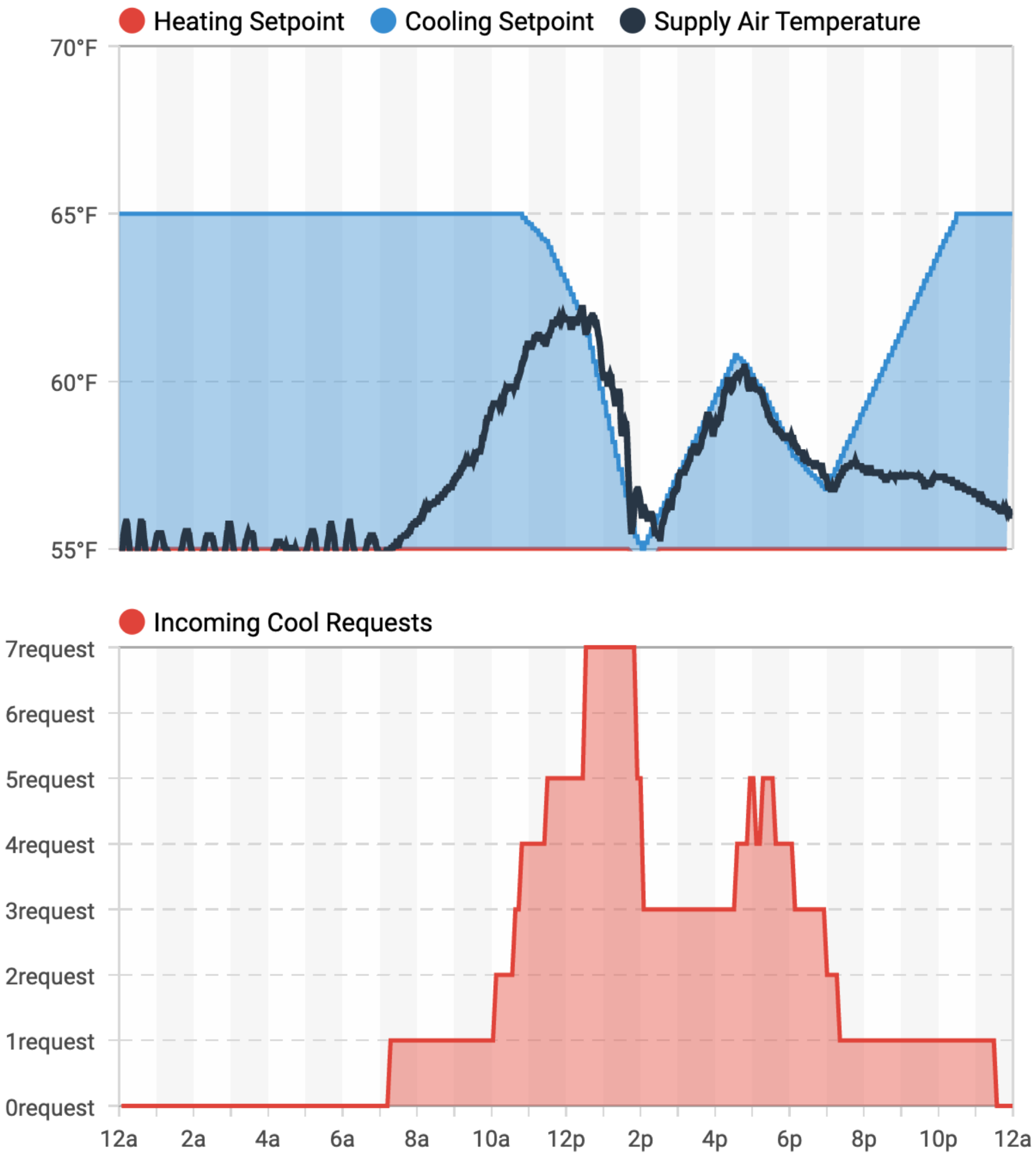


Define operational intent in reference setpoints
Compare actual setpoints to 'reference'
Enable operator to 'push' automated
corrections when divergence is detected

Supply air temperature and pressure resets

Optimizes air handling unit (AHU) supply air temperature and pressure setpoints based on zone-level equipment operating conditions

Implements ASHRAE Guideline 36 standardized Trim and Respond calculations with minimal modification to existing BAS logic

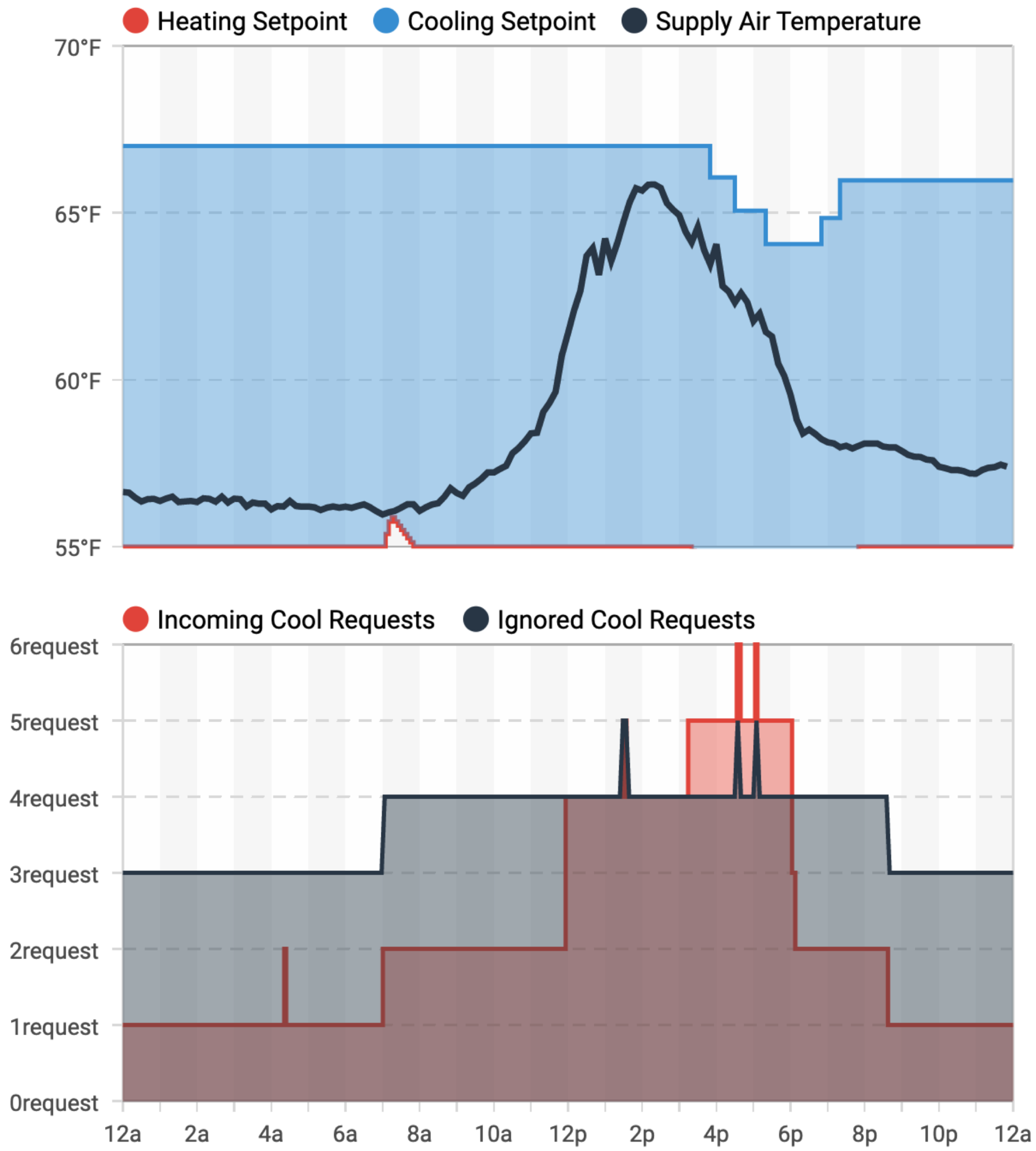


Identify and ignore rogue z

Instructs the BAS to ignore requests (i.e. for colder supply air) from zones that are unsatisfied due to local equipment issues

Faults causing disqualification:

1. Leaky reheat valve
2. Airflow setpoint not met
3. Cooling setpoint too low



transformingbuildingcontrols.lbl.gov

Success stories, algorithm specifications and field test results

Transforming Commercial Building Operations with SkySpark

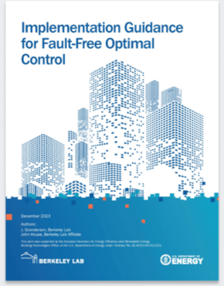
Lawrence Berkeley National Laboratory, 2023

Read More

CopperTree Analytics and Berkeley Lab Partner to Drive Innovation in Smart Buildings

Lawrence Berkeley National Laboratory, 2023

Read More



Implementation guidance for fault-free optimal control

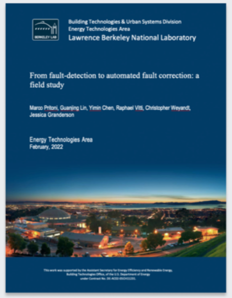
Lawrence Berkeley National Laboratory 2023

Read More

Development and Implementation of Fault-Correction Algorithms in Fault Detection and Diagnostics Tools

Energies 13(10), 2020

Read More



From fault-detection to automated fault correction: A field study

Building and Environment 214, 2022

Read More

Implementation and test of an automated control hunting fault correction algorithm

Energy and Buildings 283, 2023

Read More

Growing set of documentation: success stories, field test publications, owner-facing implementation guide, reference code

SkySpark User?

In addition to the algorithm specifications provided in the above publications, we have released open-source Haxall/Axon reference code to assist SkySpark users in implementing a subset of the fault-free optimal control strategies.

Access the Code

Work continues!

More field testing and transfer to partner cohort

Expand spec to additional demand flex strategies

Codify DF strategies in python library, with semantic features to facilitate application portability and auto-config

Support to owners to pilot and procure capabilities

This technology is core to the future of buildings

- Historic investments in retrofits and electrification

- Persistent performance, enduring value

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- Retiring workforce, next gen. expects networked intelligent systems
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- Automation and modern tools for building O&M

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- Automation and modern tools for building O&M
- Mechanism to scale across systems, data models, equipt configurations
- Growing footprint of software-based infrastructure to rapidly deploy

Thank you