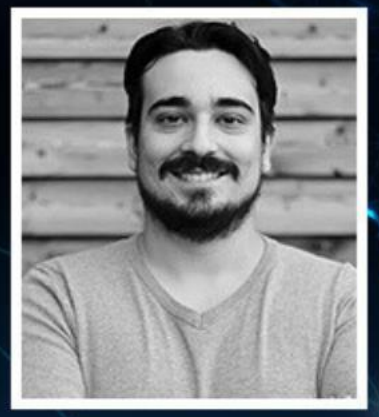
CALFLEXHUB SYMPOSIUM

SEPTEMBER 24 | 8am-6pm PT

DONGHUN KIM

SANG WOO HAM



ETTORE ZANETTI

MARCO PRITONI

PROJECT SHOWCASE: LARGE COMMERCIAL AND CAMPUS

Donghun Kim, Research Scientist, Berkeley Lab
Sang woo Ham, Technology Researcher II, Berkeley Lab
Ettore Zanetti, Postdoctoral Researcher, Berkeley Lab
Marco Pritoni, Research Scientist, Berkeley Lab

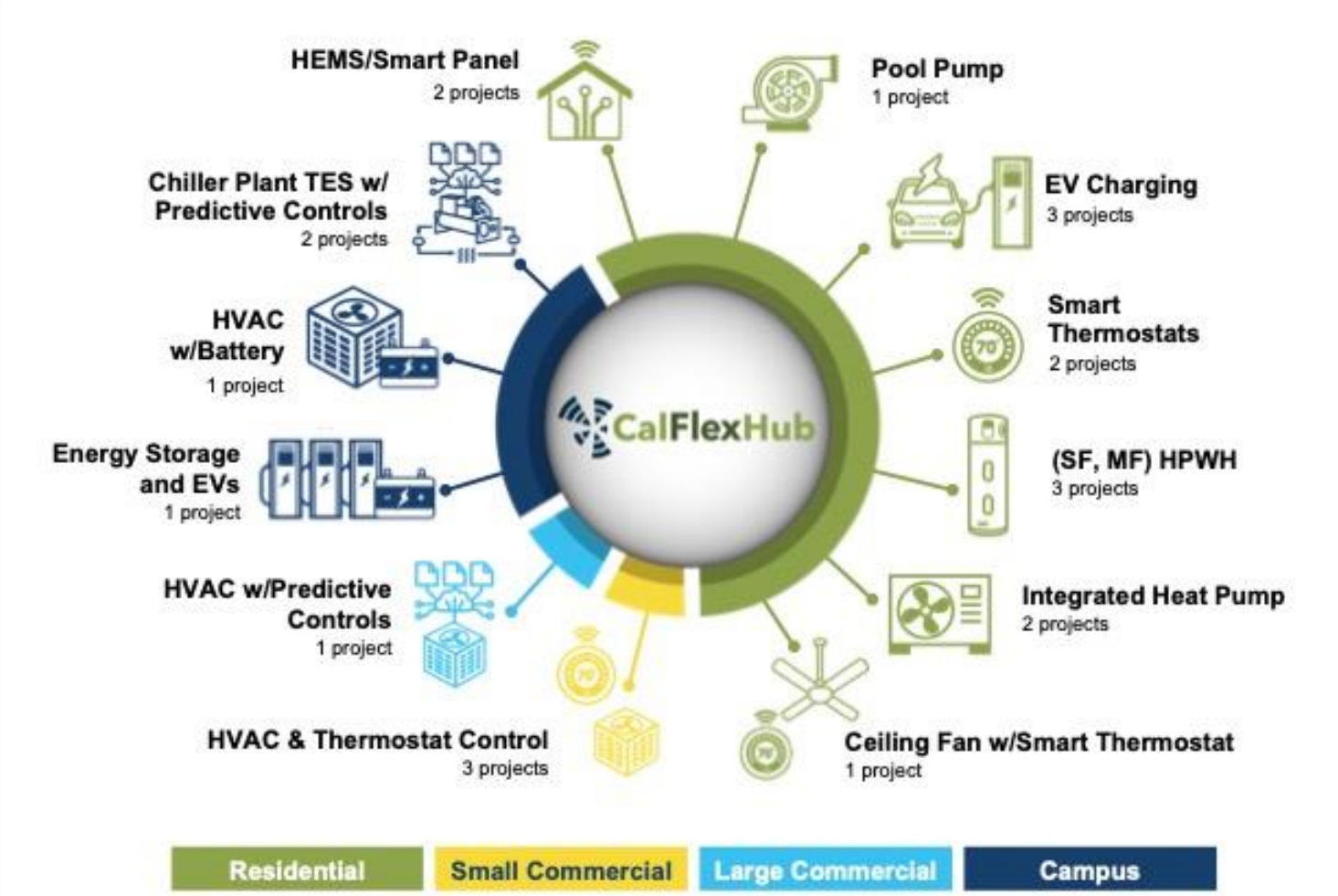
CalFlexHub

BERKELEY LAB

MOMENTUM

2024

CalFlexHub Technology Portfolio



- **21 demo projects**
- **106 existing** test sites
- **40 DAC / 21 LI** sites
- **3 new** sites (SF, SC)
- **hundreds** of **EVs (new)**

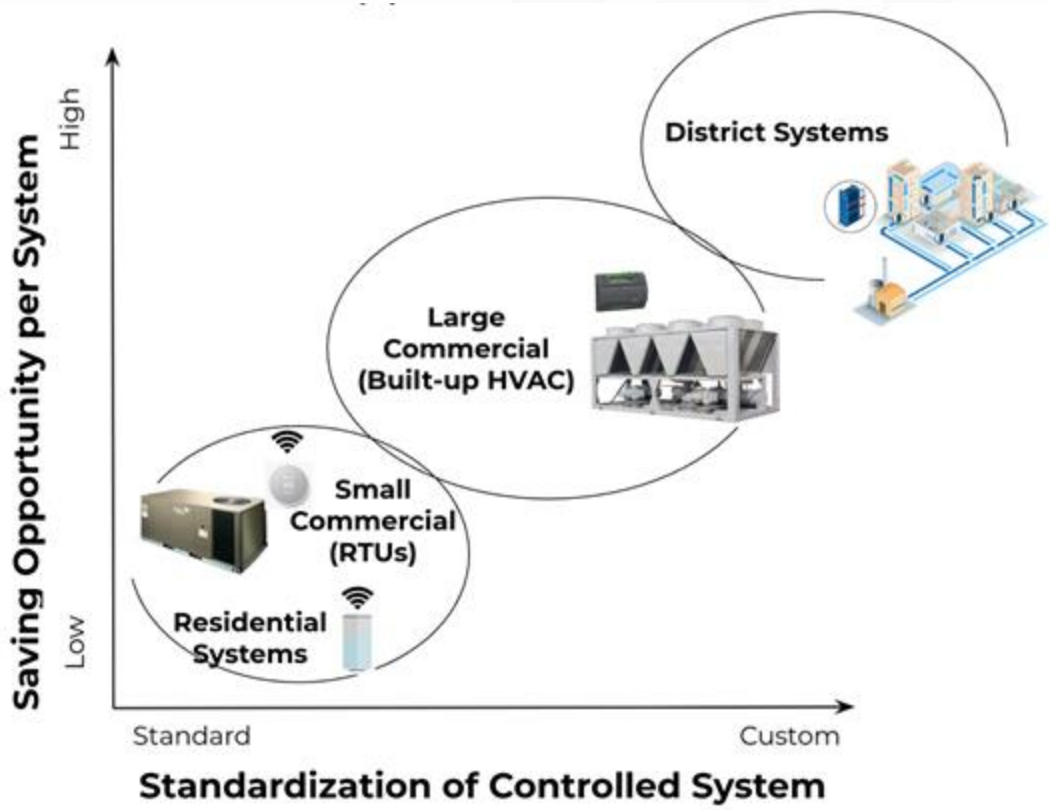
Breakdown of Existing Test Sites:

Single Family	**68**
Multifamily	**25**
Small Commercial	**8**
Large Commercial	**1**
Campus	**4**
EVSE	**28**

Technology Performance

- **EV charging** and **integrated heat pump systems** with hot water storage can **shift load for several hours** to access lowest electricity prices
- **Model Predictive Controls (MPC)** can shift significant load and reduce energy cost in **large buildings and campus central plants**
- **Residential and small commercial HVAC** can provide significant load shed during **short periods**

Types of MPC



Sang woo Ham, Technology Researcher

Contact: sham@lbl.gov

Dynamic Heat Pump Design and Control for Small Commercial HVAC

- Supervisory MPC control system for small commercial systems w/ rooftop units or other small systems
- Can coordinate operation of multiple units
- Can optimize for cost, energy, CO_2 emissions
- Can be integrated with the off-the-shelf controllers.

Office↑ Church↓

School↑ Residential↓

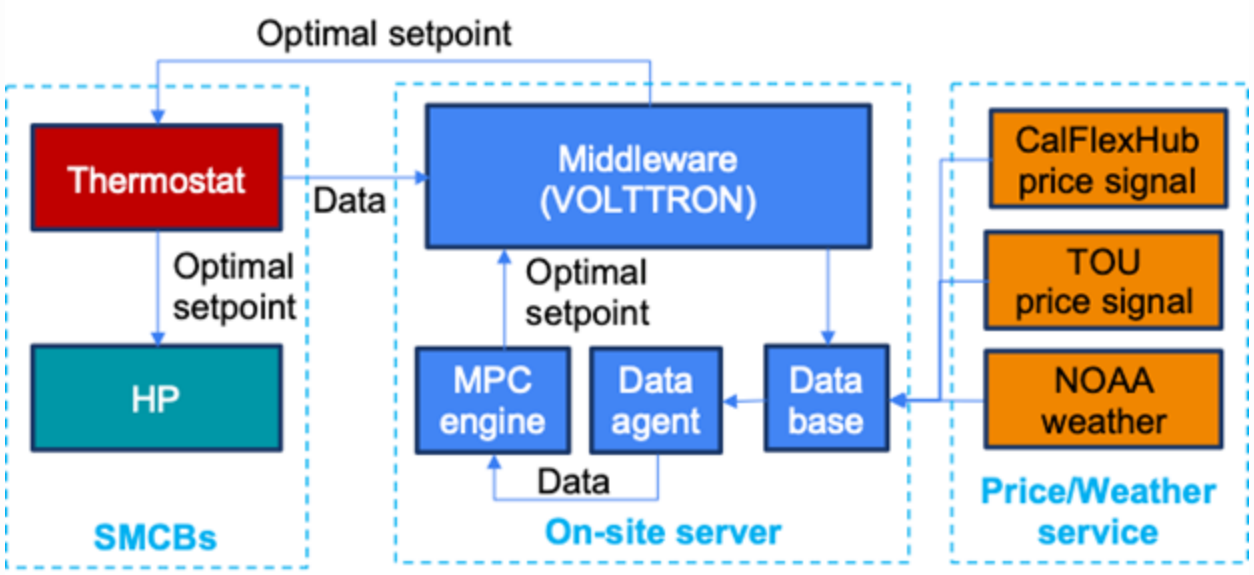
Church↑ Library↓

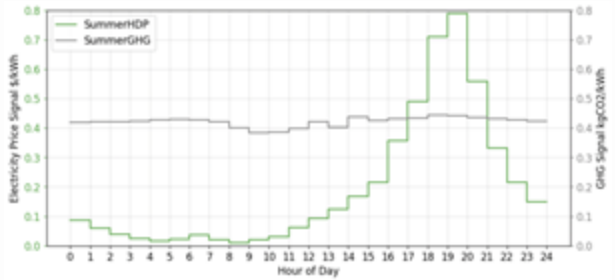
Test Sites:

- VRF system // Office building (13 zones) in Davis
- HP-RTU // School building (2 zones) in Bakersfield
- HP-RTU // Library building (2 zones) in LA
- Split system // Multi-family (2 zones) in San Bernardino
- HP-RTU // Church building (1 zone) in Menlo Park
- HP-RTU // Church building (4 zones) in San Leandro

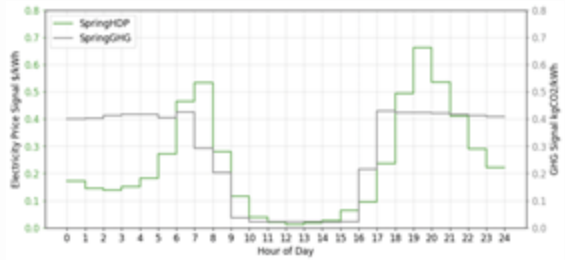
Sector/Building Type	Small Commercial
Technology & End Use	Rooftop units & thermal storage for space and water heating
Communications Pathway	Research Cloud-> OEM Cloud -> Thermostat via Cellular & Wi-Fi LAN
Testing Status/Timeline	In Progress

Communication Architecture





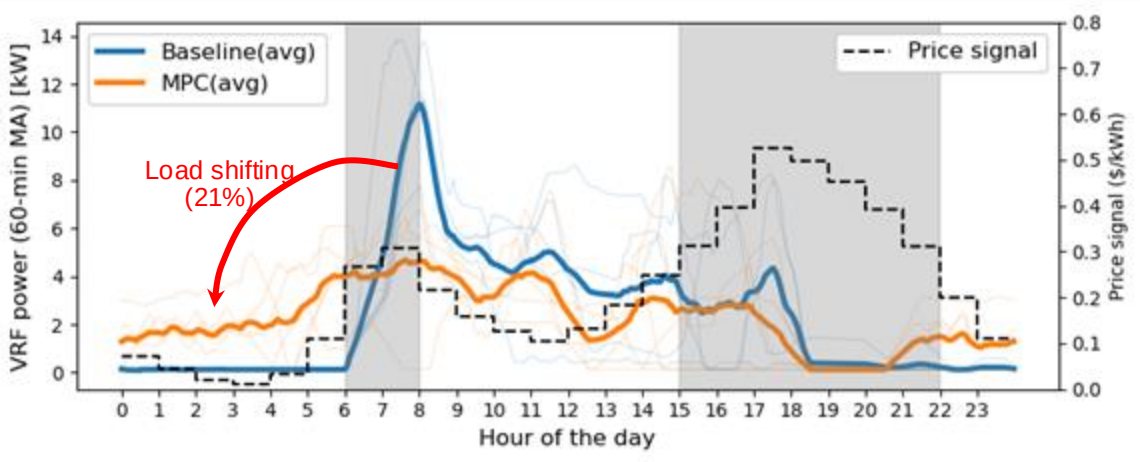
Summer CalFlexHub signal



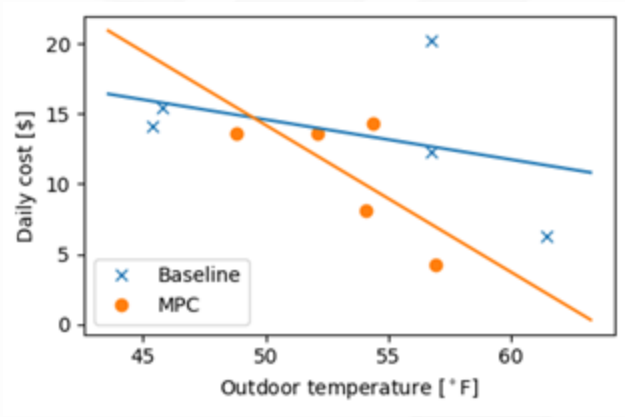
Spring CalFlexHub signal

- Integration of price, weather, and thermostat drivers using VOLTTRON.
- Ability to shift price signal (CalFlexHub signal, TOU).
- Deployment without hardware retrofit in SMCBs.

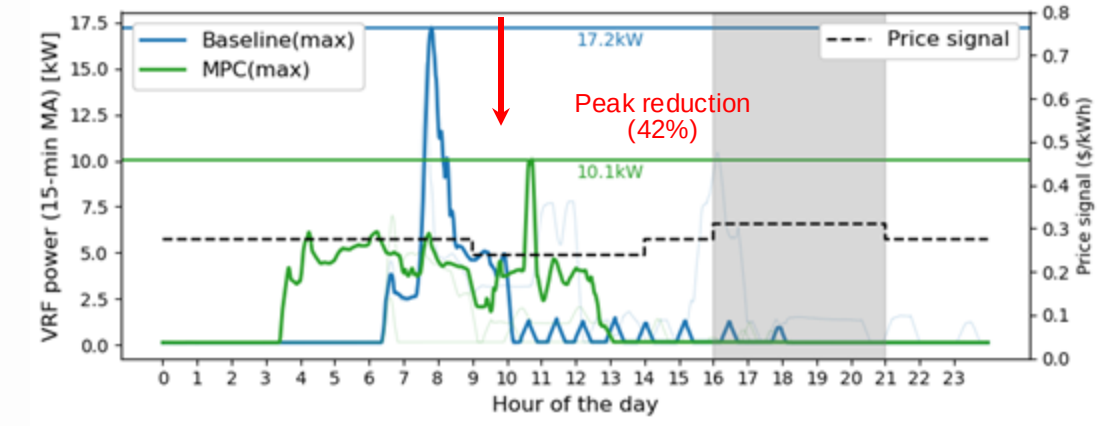
Winter Test Results (VRF for 13 office zones)



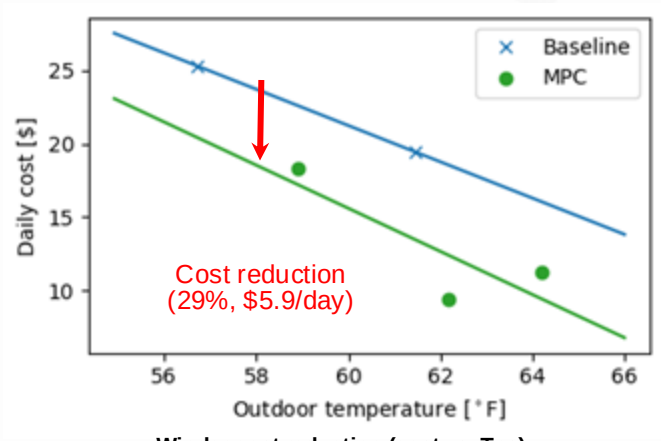
Winter load shifting (dynamic rate)



Winter load shifting (cost vs. Toa)

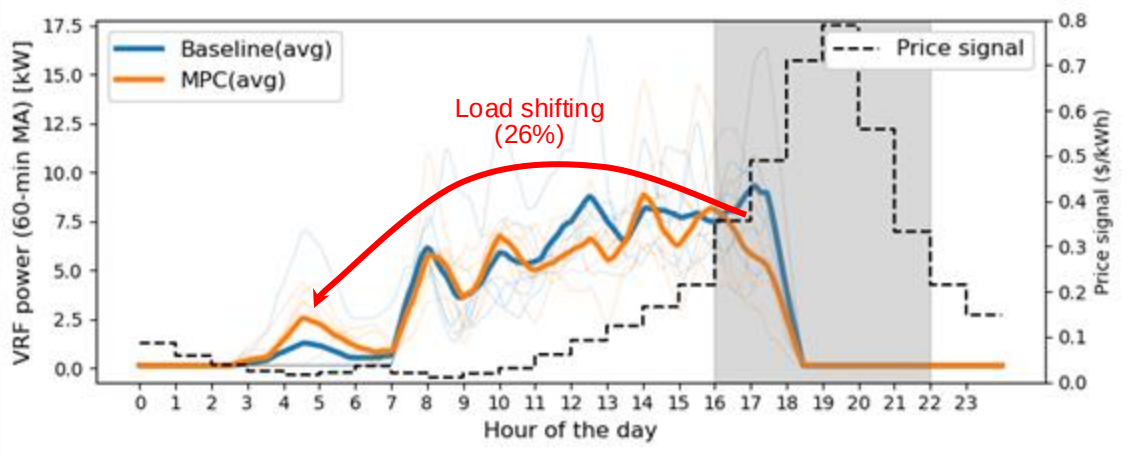


Winter cost reduction (TOU+demand charge)

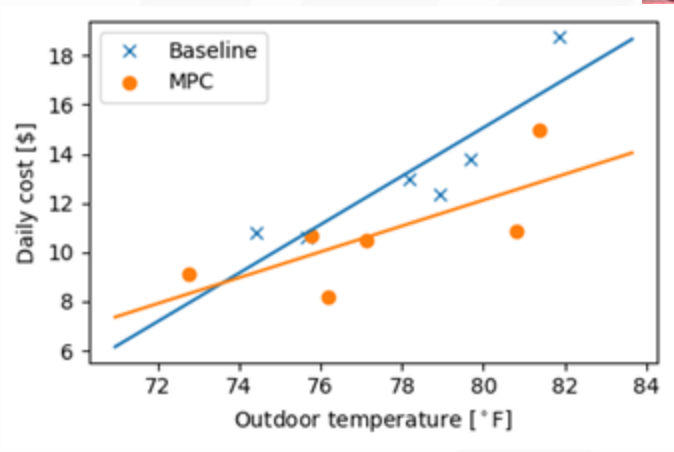


Winder cost reduction (cost vs. Toa)

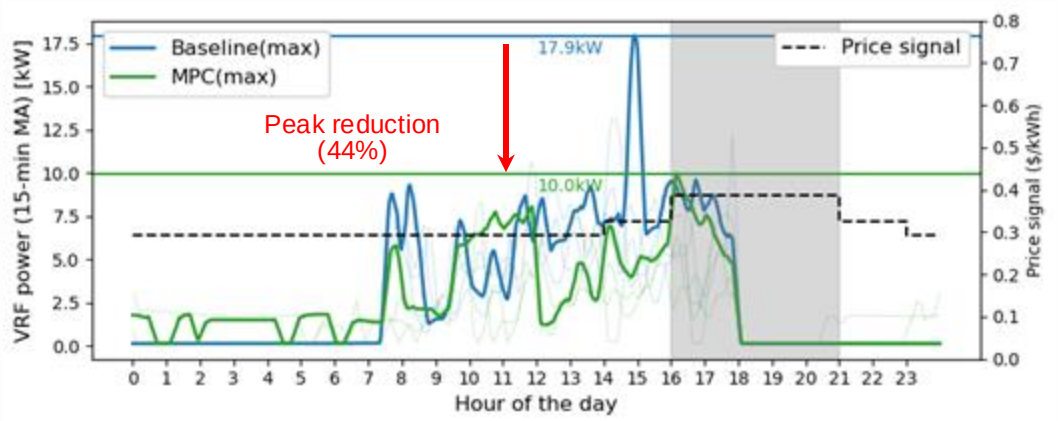
Summer Test Results (VRF for 13 office zones)



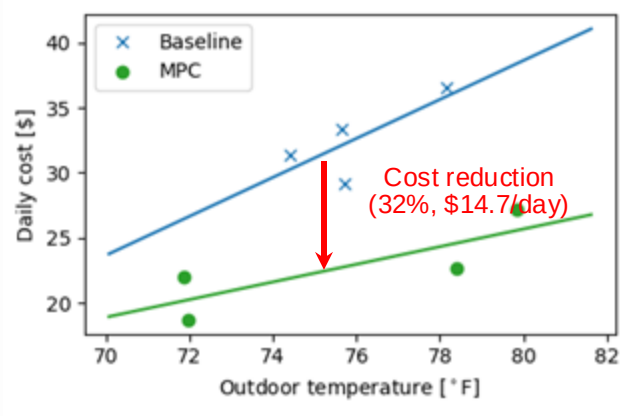
Summer load shifting (dynamic rate)



Summer load shifting (cost vs. Toa)

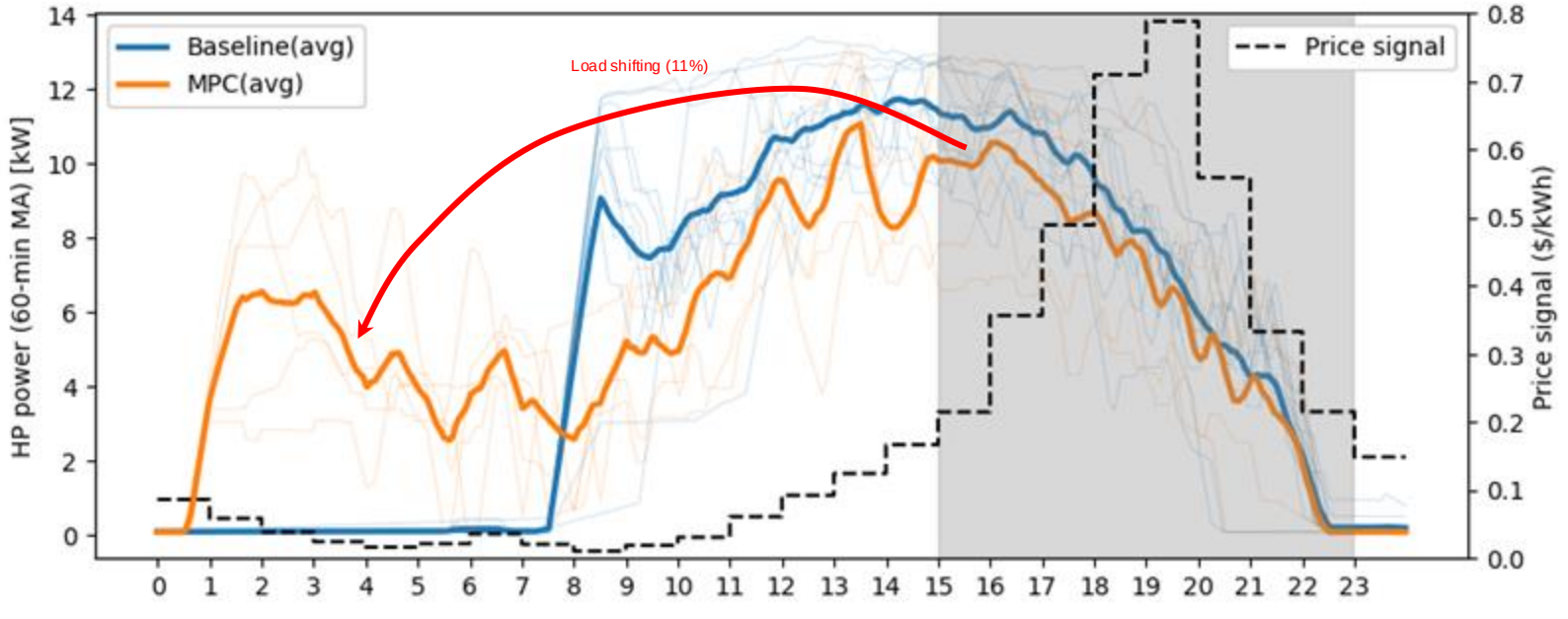


Summer cost reduction (TOU+demand charge)



Summer cost reduction (cost vs. Toa)

Test Results (HPs for 2 library spaces)



Summer load shifting

- 11% load shifted, despite:
  - (a) tight deadband (70-72F),
  - (b) load characteristics (all-day cooling),
  - (c) limited number of devices (2 HPs).

Key Learnings

- HP-Flex is applicable to **various types of SMCBs and HPs including VRF** system and does **not need hardware retrofits** (with networked equipment/thermostats)
- MPC's performance depends on price/building/load characteristics,
  - A screening tool to select sites with high potential would be beneficial
- Deployment process is automated, but still discovering site-specific control conflicts between MPC and local controller.
  - We will keep upgrading the software to handle the unexpected situations.
- Relationship with facility operators and occupants are important.
  - MPC can be easily blamed for any (unrelated) malfunctions.

Ettore Zanetti, Postdoctoral Researcher

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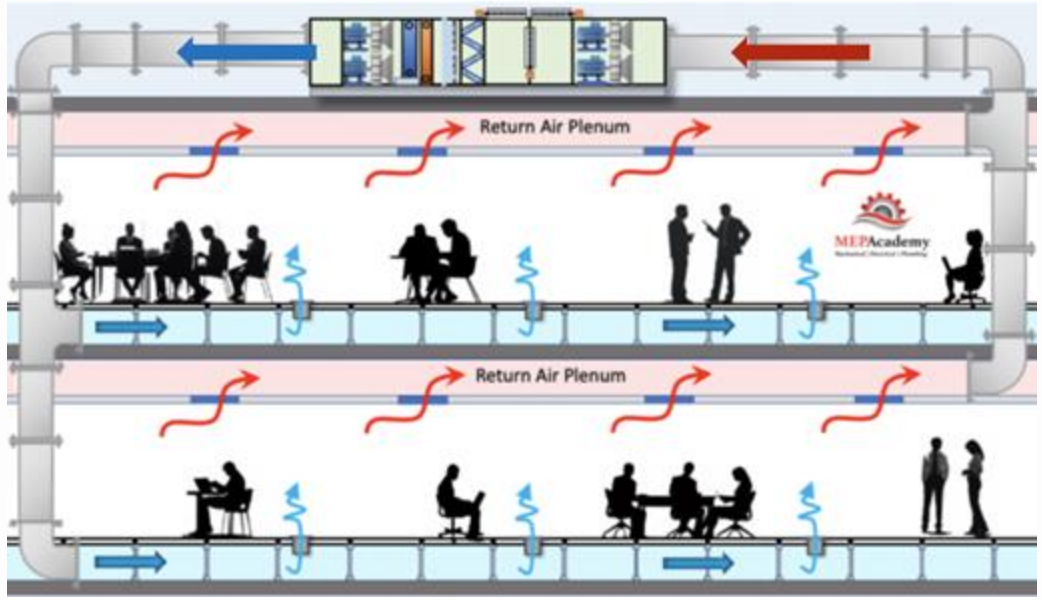
Large Commercial Building Dynamic HVAC Predictive Controls

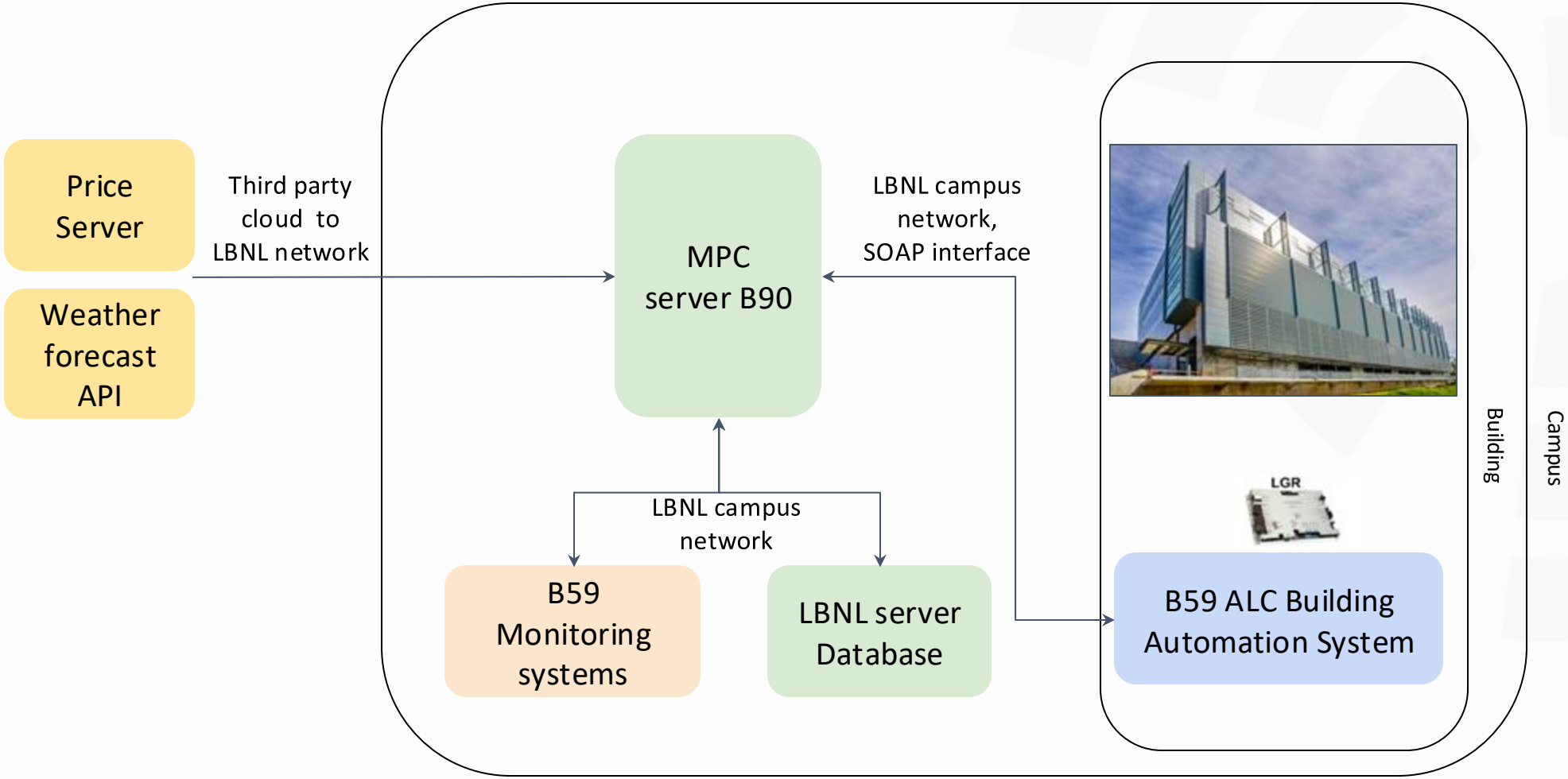
- Supervisory MPC control system
- Coordinates with Building Automation System
- Can optimize for cost, energy, CO_2 emissions



Test Sites: LBNL, Building 59

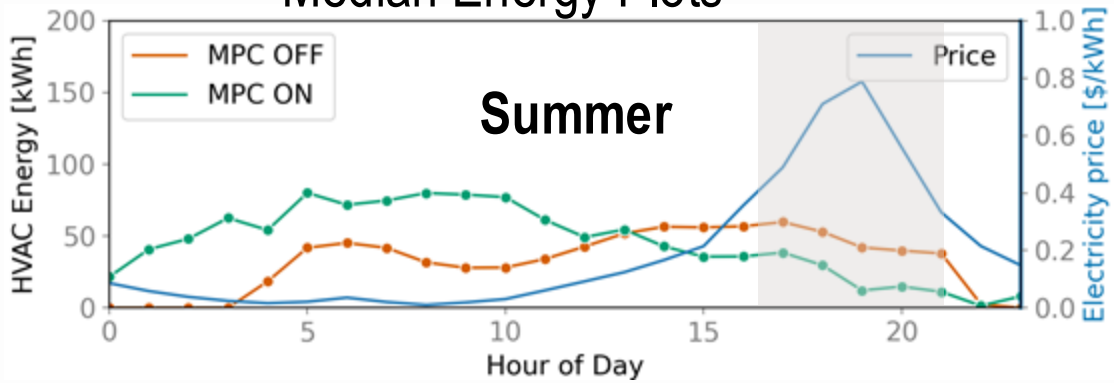
Sector/Building Type	Large Commercial
Technology & End Use	Underfloor Air Distribution (UFAD) w/ Reheat from AWHP, 4 Water-Cooled DX RTUs
Communications Pathway	3rd party cloud -> LBNL cloud <-> B59 ALC <-> HVAC
Testing Status/Timeline	four field tests in Aug/23, Oct/23, Feb/24, and Apr/24. New tests planned with new price profiles

Communication Architecture



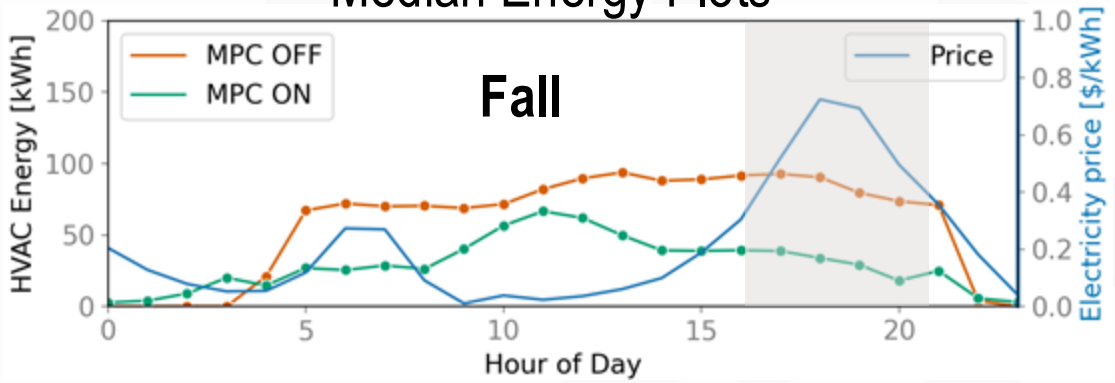
MPC is able to shift load with different prices and seasons

Median Energy Plots

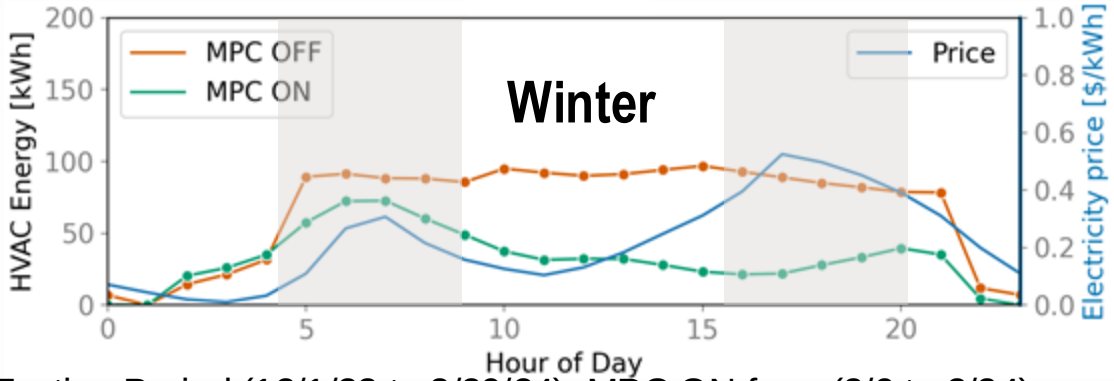


Testing Period (7/1/23 to 8/26/23), MPC ON from (8/21 to 8/26), excluding weekends

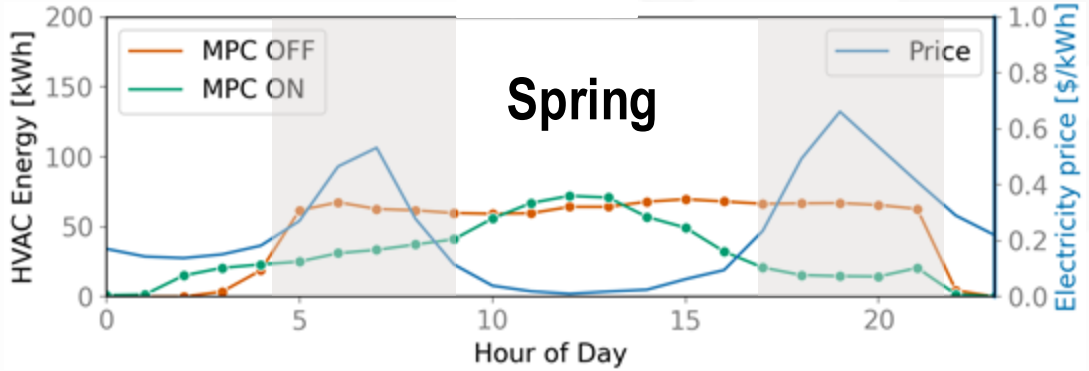
Median Energy Plots



Testing Period (9/5/23 to 10/19/23), MPC ON from (9/27 to 10/6), excluding weekends

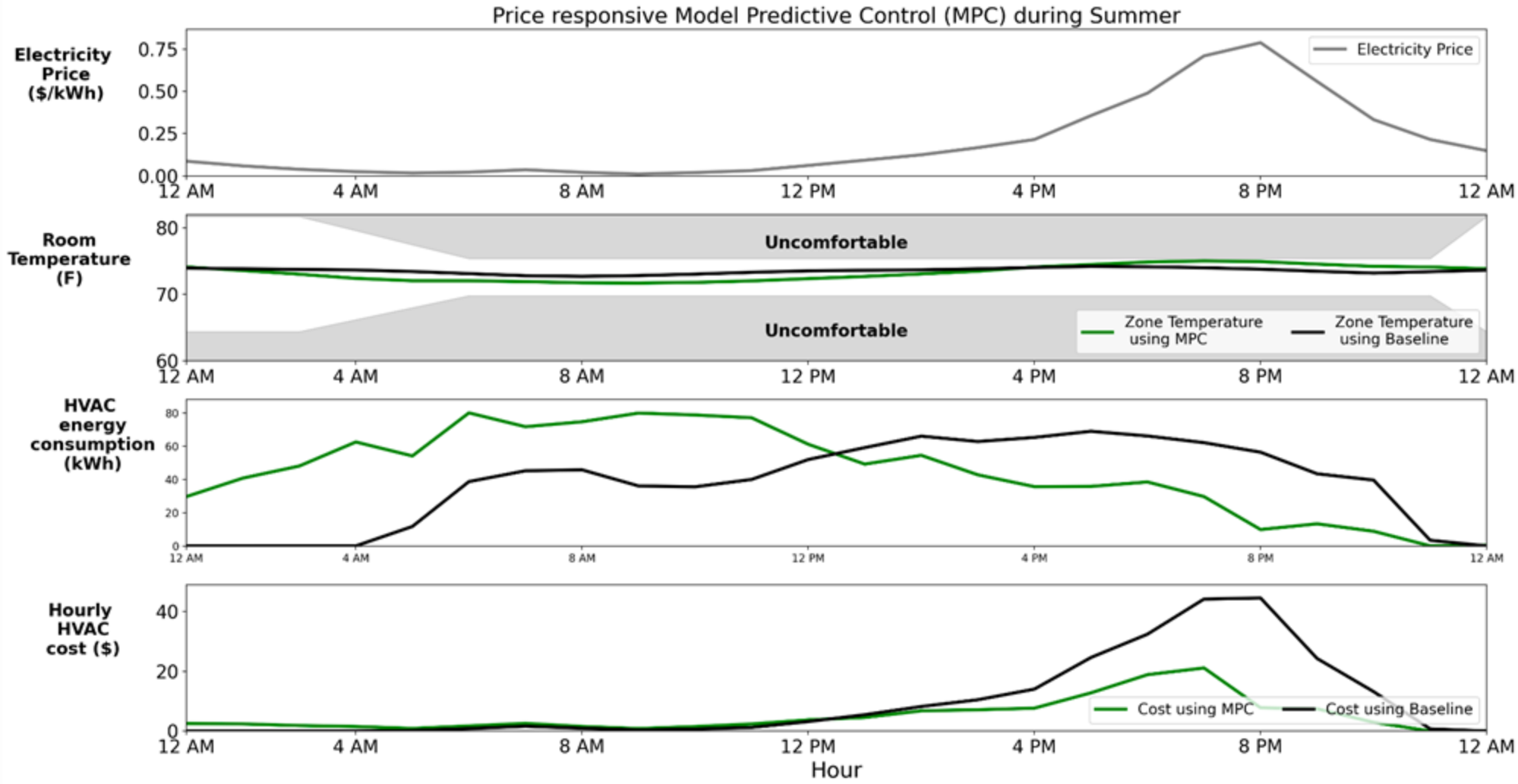


Testing Period (12/1/23 to 2/29/24), MPC ON from (2/9 to 2/24), excluding weekends

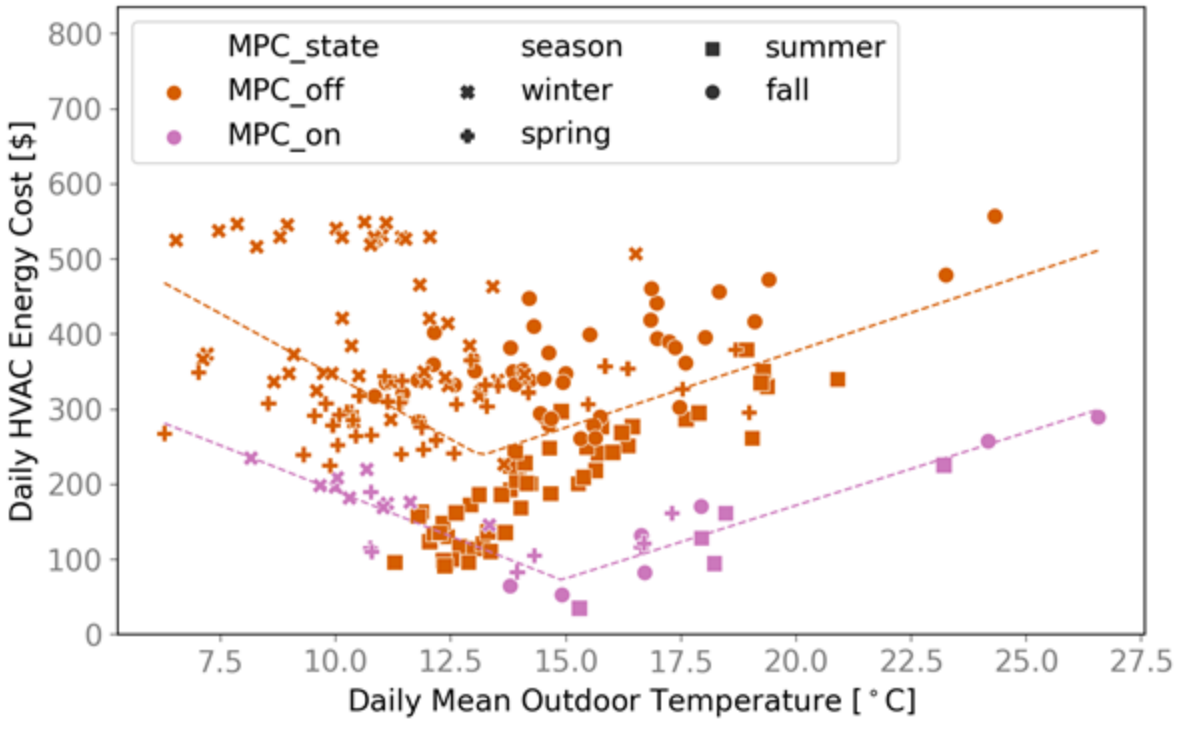


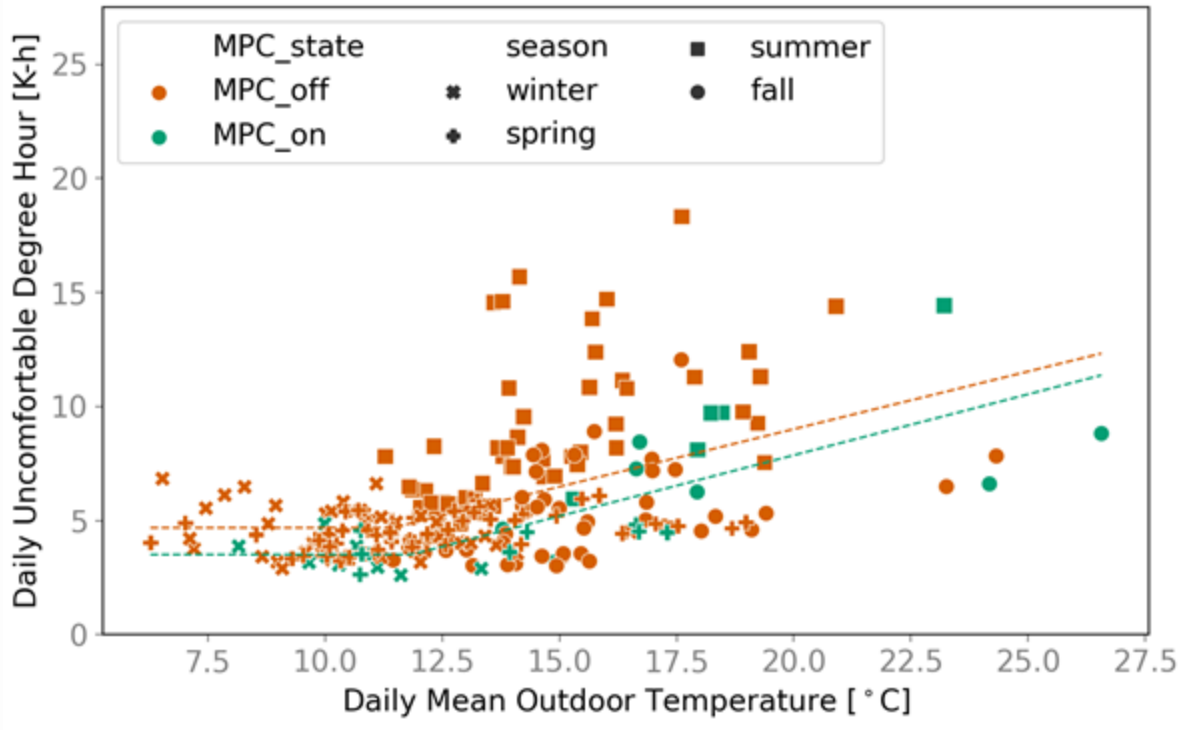
Testing Period (3/1/24 to 4/30/24), MPC ON from (4/9 to 4/19), excluding weekends

MPC load shifting leads to cost savings while maintaining



Test Results: MPC leads to cost savings and keeps comfort





MPC is able to save more 50% runnings costs, while maintaining similar comfort levels

Key Learnings

- **MPC can shift load but makes data management more critical**
- MPC can respond to **four different dynamic price** profiles in f**our seasons using the same code**
- **Thermal comfort was not compromised**: temperature range in zones was tighter & no complaints by occupants
- **MPC maintenance required significant continuous effort** (data stream interruptions, server restarts, and software updates)
- MPC should have basic understanding of underlying control logic: e.g. “Smoke Mode” imposed by operators to constrain outside air intake when wildfires active, or BMS logic to allow MPC to turn on RTUs during unoccupied times.

Donghun Kim, Research Scientist

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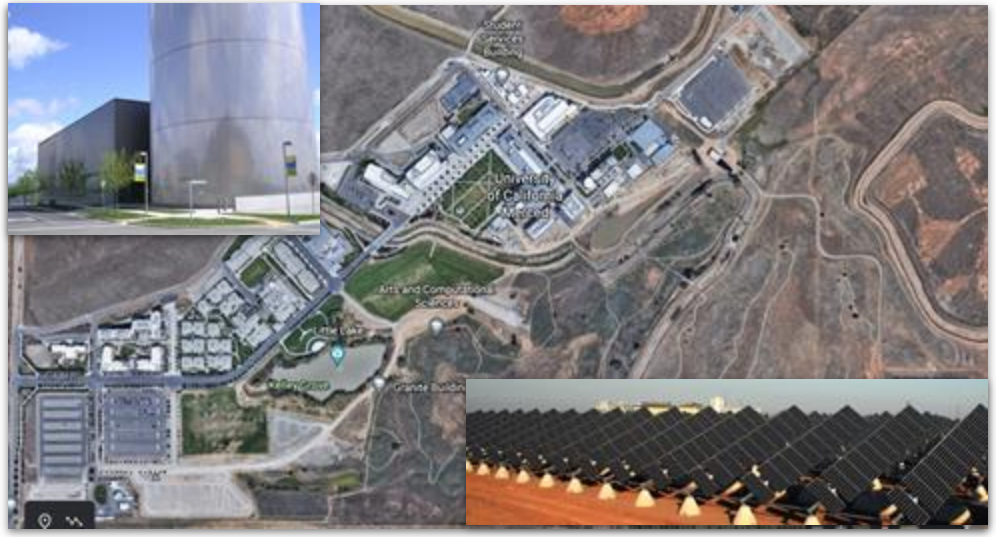
Campus-wide Field Demonstration of Load-shifting, Peak Reduction, and Full Renewable Utilization



UCMERCED
UNIVERSITY OF CALIFORNIA

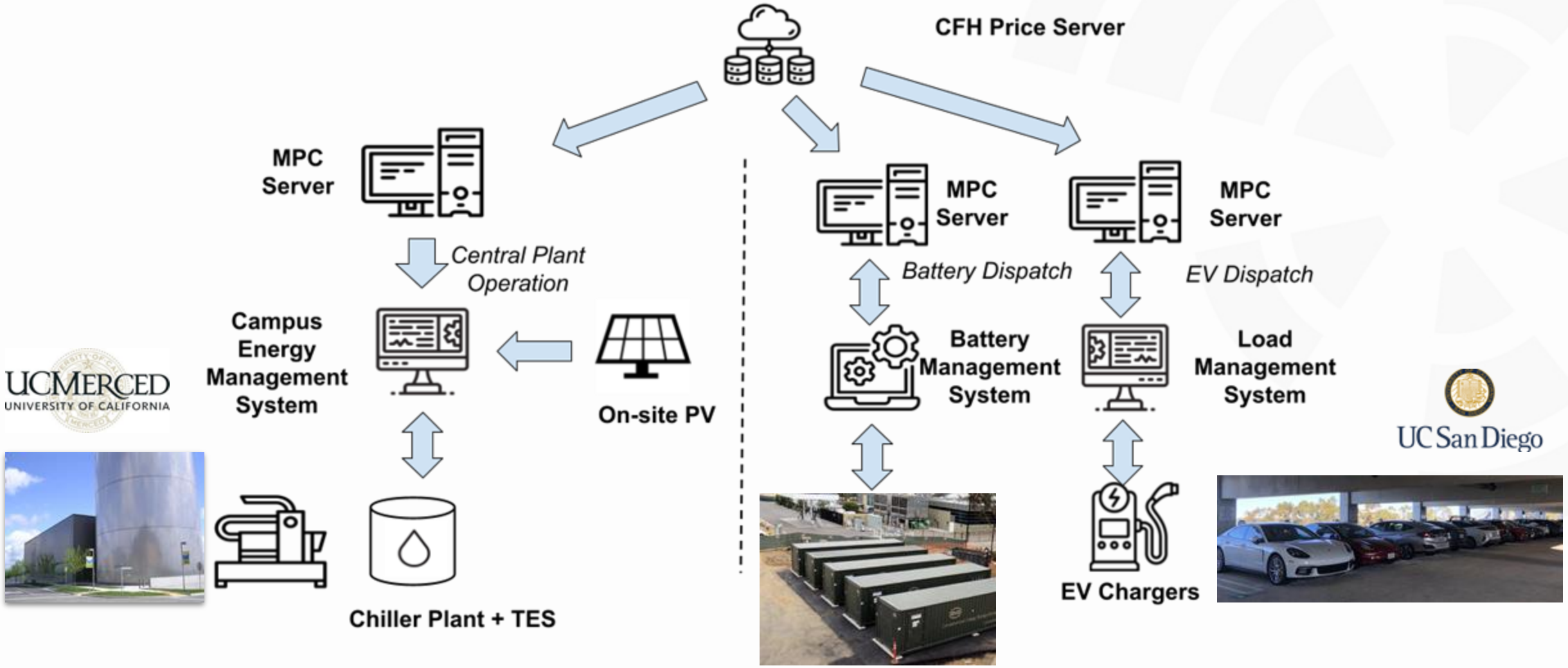
UC San Diego

Test Sites:

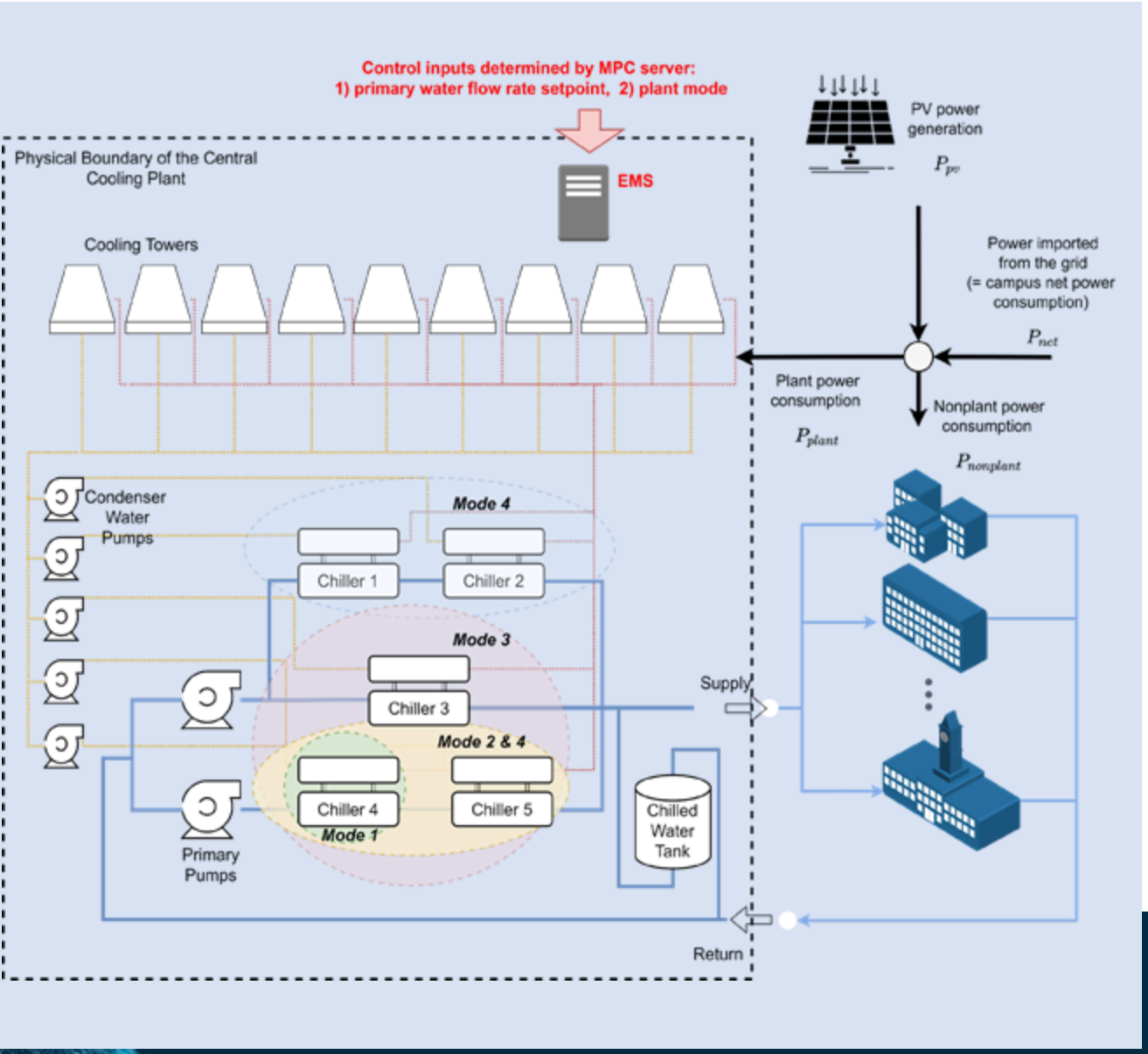
- UC-Merced Campus
- UC-San Diego Campus

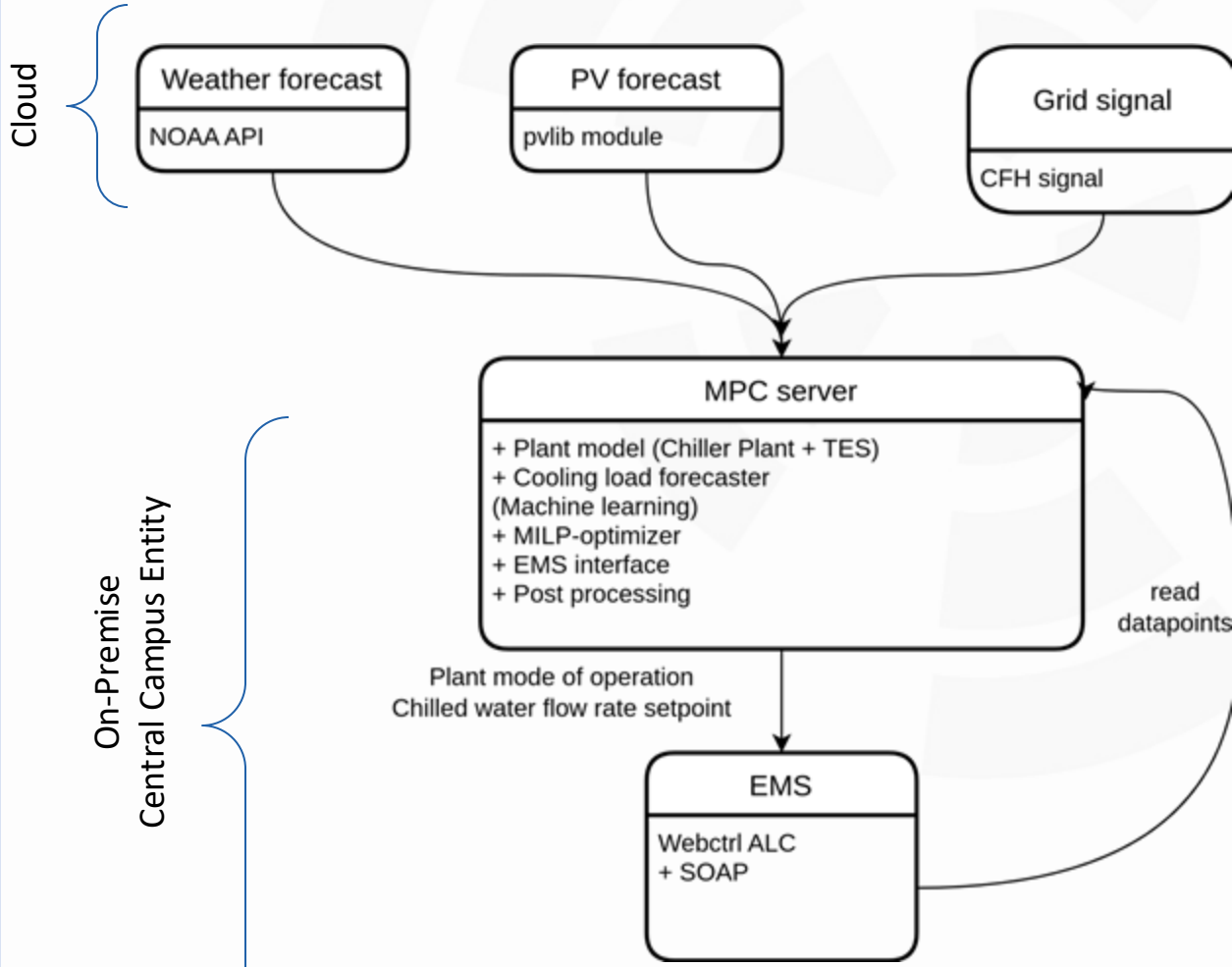
Sector/Building Type	District Energy Systems	
Technology & End Use	5000 ton Chiller plants + 2M gallan Chilled water tank + 4 MW PVs	- 1.5 MW / 1.9 MWh BESS - 27 EV charging stations
Communications Pathway	CFH signal or other signals -> MPC server <-> ALC <-> HVAC	- MPC server <-> PowerFlex Controller <-> EVs - Local MPC server <-> BESS control <-> BESS
Testing Status/Timeline	Four week-long tests in summer 2022 and 2023	Several (>10) daily tests in summer 2022 and 2023

Control and Communication Architecture



Control: Central Chiller Plant + TES + On-site PVs

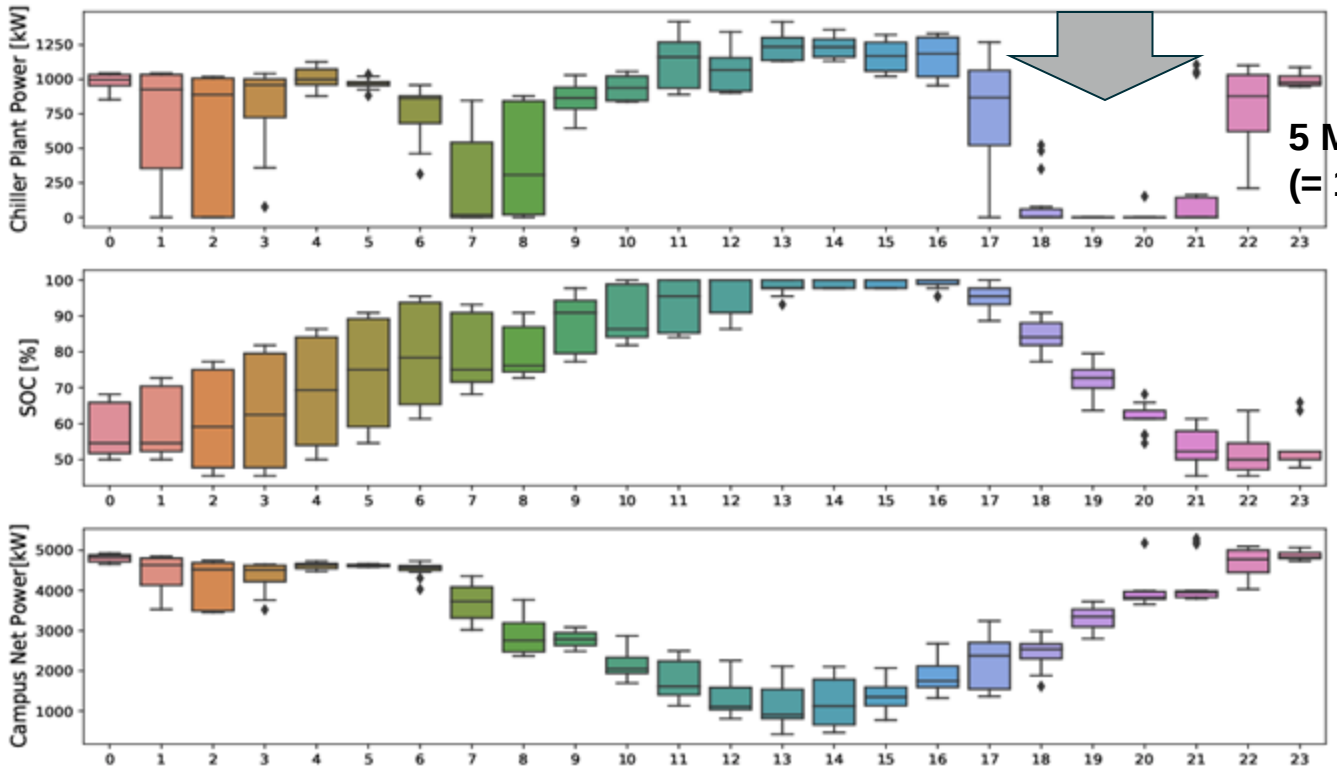




Field Test Result Summary & Takeaways (I) : District Cooling Systems

Field test results with a highly dynamic pricing signal

When the price rate is high

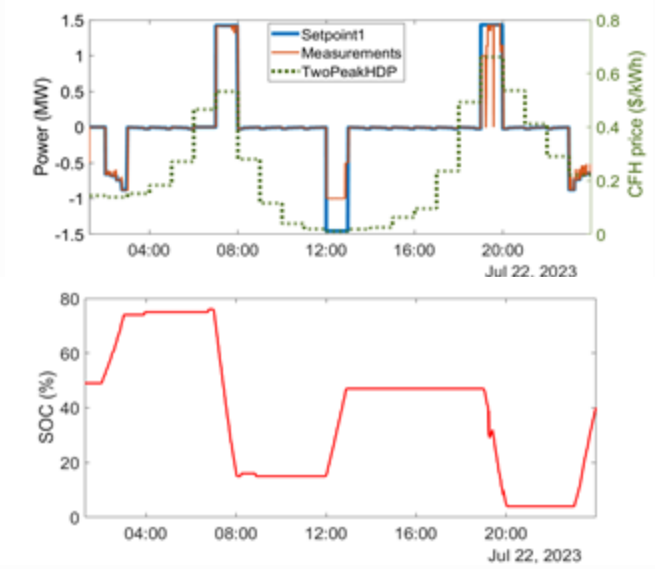


5 MWh Load Shift (= 1.25 MW X 4h)!!

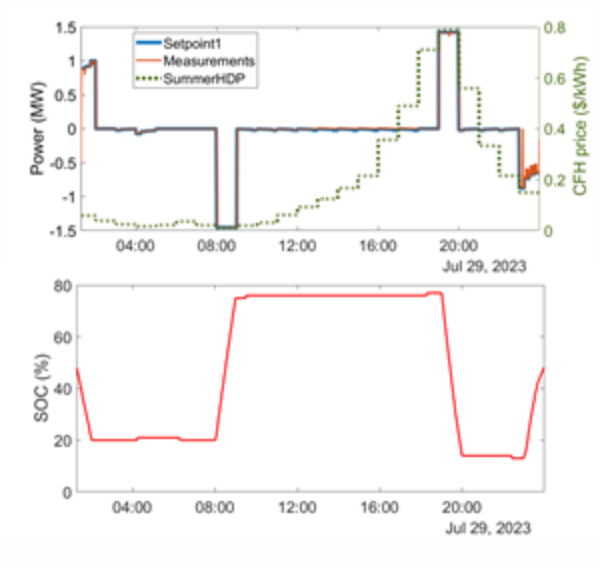
- The single control deployment achieved a 5 MWh load shift (1.25 MW x 4 hours), which demonstrates great effectiveness.
- District Energy Systems would provide a highly cost-effective solution to economically securing demand response (DR) capacity and load flexibility for the grid.

Field Test Result Summary & Takeaways (II) : BESS

Result wlth Two Peak Highly Dynamic Price



Result wlth One Peak Dynamic Price

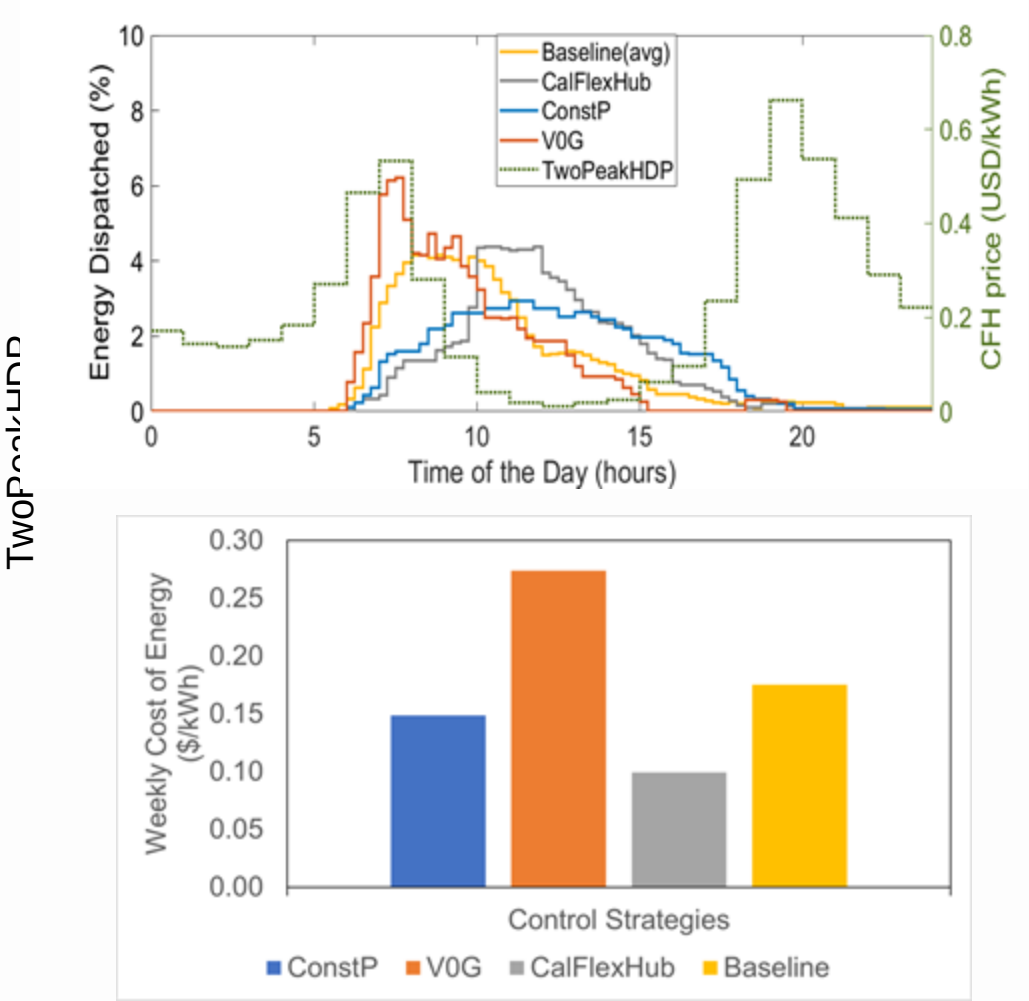


Summary of daily revenue from BESS field tests

Test Date	Price Curve	Daily Revenue
07/22/2023	TwoPeakHDP	$1,226
07/23/2023	TwoPeakHDP	$1,347
07/29/2023	SummerHDP	$1,018
07/30/2023	SummerHDP	$1,023
08/06/2023	SummerLDTOU	$893

- BESS discharges at peak prices and charges at minimum prices
- ~$1,000 daily revenue opportunity from arbitrage
- Higher arbitrage opportunity with two peak pricing

Field Test Result Summary & Takeaways (III) : EV Charging Stations



- Benchmark cases:
  - **Baseline** (tests run May 1-7, 2022):
    - EV charging schedule optimized without price signal.
  - **ConstP** (simulated):
    - Constant power for the entire plug duration.
  - **V0G** (simulated):
    - Maximum charging power until energy demand is satisfied.
- Optimized with price signal:
  - **CalFlexHub** (tests run June 26 - July 2, 2022):
    - EV charging schedule optimized.

- More than 50% reduction in cost compared to benchmark cases
- Optimized (delayed) workplace charging is well-suited for carbon emission reductions

Key Learning & Vision

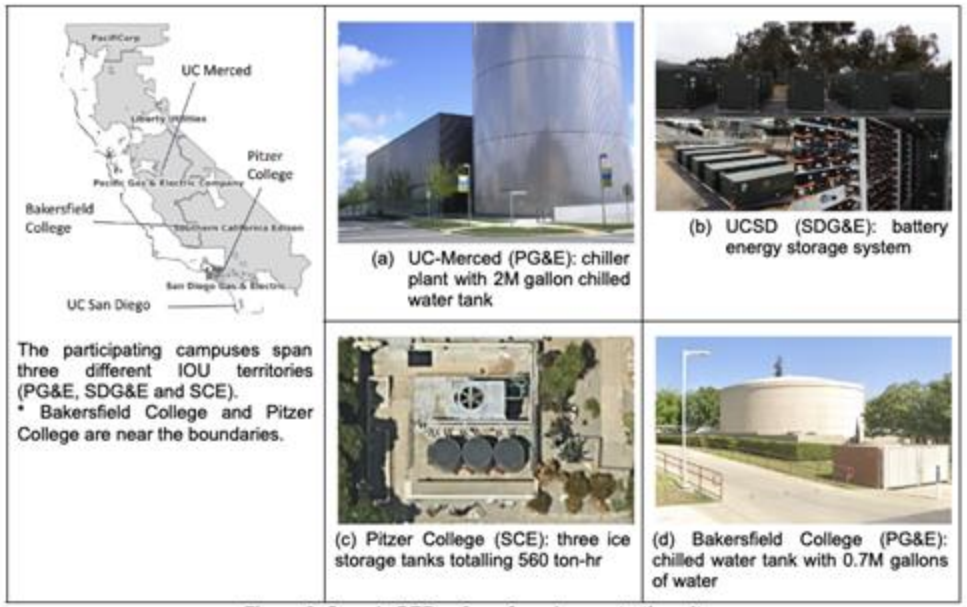
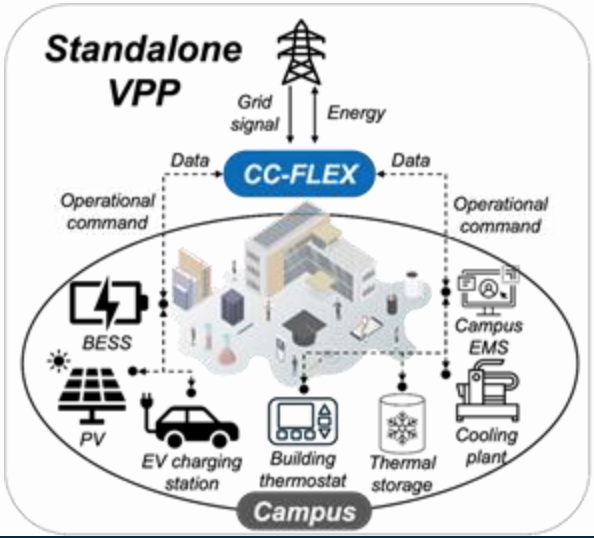


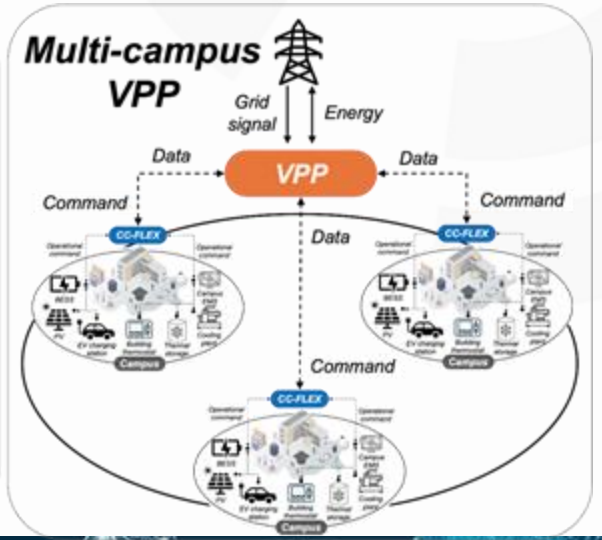
Figure 2: Sample DERs of our four demonstration sites

Table 3: DER descriptions and conservative estimates of maximum DR capacities for this project at the demonstration sites

Metric	Target specification			
	UC Merced	UC San Diego	Bakersfield College	Pitzer College
Types of DERs for this project	- 5000 ton chiller plant - 2M gallon chilled water tank - 4 MW PV - 30 EV charging stations - optional[9]: around 40 campus buildings all connected to central plant EMS	- 10 MW/40 MWh BESS - 969 EV charging stations equipped with Adaptive Load Management (ALM), - 3 MW PV - optional: 11 campus buildings with plug load controllers and connected lighting systems	- 1800 ton chiller plant - 0.7M gallons of chilled water - 3.6 MW PV - optional: 35 campus buildings with > 0.7M sq. ft.	- Two chiller plants totalling 285 ton - Six ice storage tanks (1000 ton-hr in total) - < 1MW PV
A conservative estimation of site DR capacity (not target)	1.25 MW (only from chiller + TES plant)	8 MW (only from BESS)	0.5 MW (only from chiller + TES plant)	0.1 MW (only from chiller + TES plant)

- Many higher education campuses **already** have MW-scale central chiller plants, MW-hr scale thermal energy storage, and rapidly expanding EV charging stations, along with other large distributed energy resources (DERs).
- Significantly greater effectiveness (i.e., $ savings or load shifting capacity per deployment) can be achieved for district energy systems compared to SMCBs if MPC is successfully deployed.
- Proposed Campus-VPP





PANEL DISCUSSION