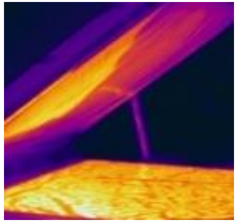
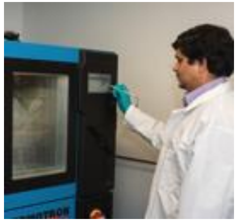
Sundial: Enabling High-Penetration Solar PV with Integrated Energy Storage and Demand Management





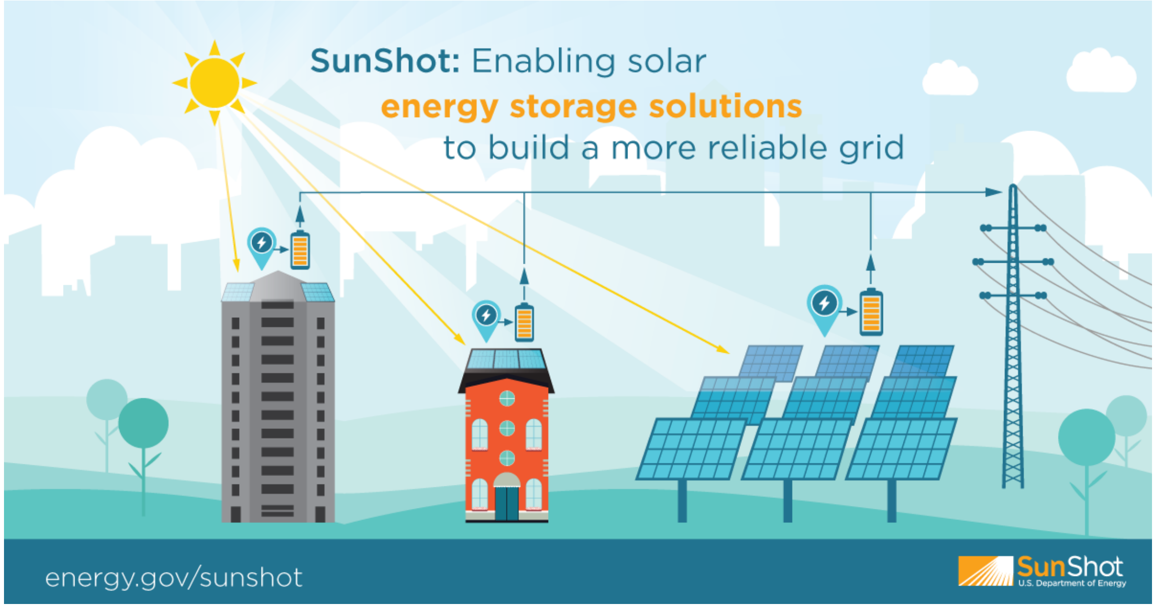
The Right Combination: Solar, Storage, and Demand Response

Matt Kromer
Kurt Roth
Feb 25, 2021

Agenda

- Project Overview
- Highlighted Results from Pilot Deployment
- Key Takeaways

SunDial Project Team



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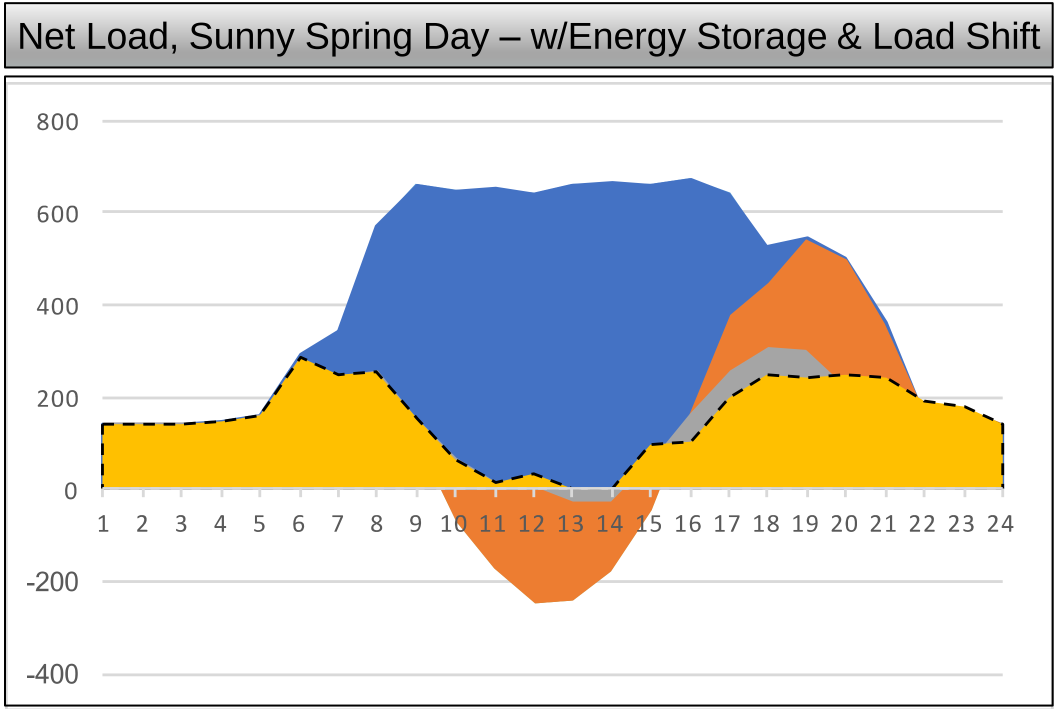
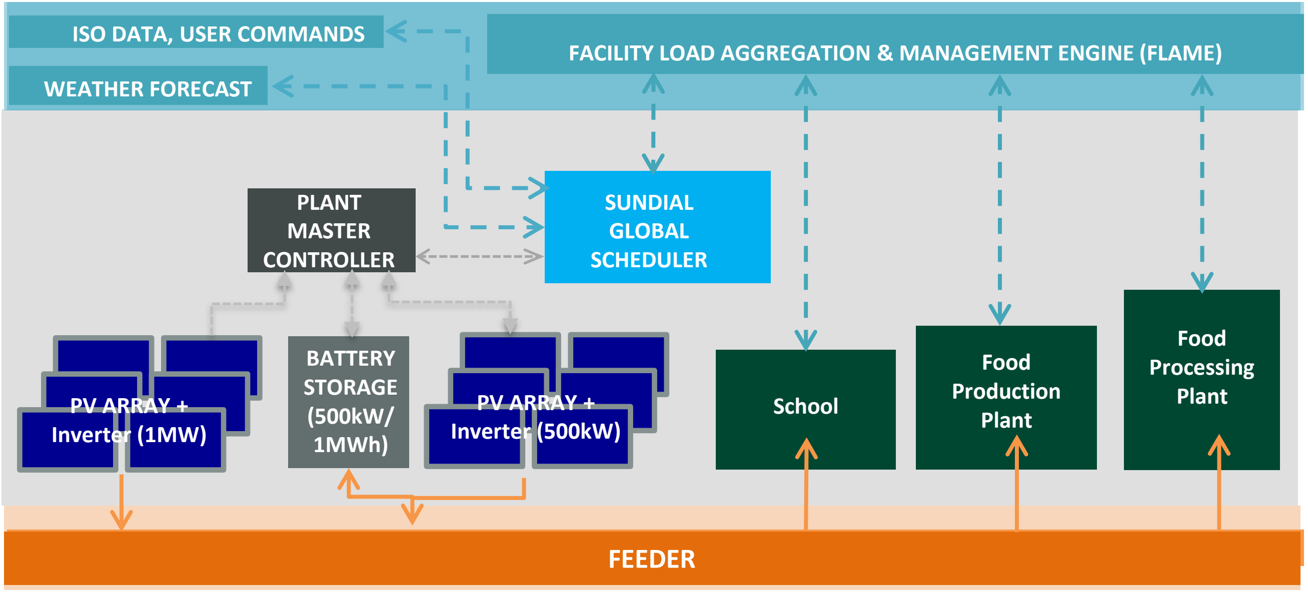
Project Goals



- **Enable coordinated Control of Solar + ESS + Flexible Building Loads:** Use building load shaping and energy storage to support distribution networks with high-penetration of solar
- **Support local distribution grids + wholesale markets:** Test technologies and business models that can facilitate exchange of load-shaping services within local distribution grids
- **Real-World Experience:** Field demonstration on the National Grid distribution system with a portfolio of C&I Customers, derive lessons learned through real-world deployment

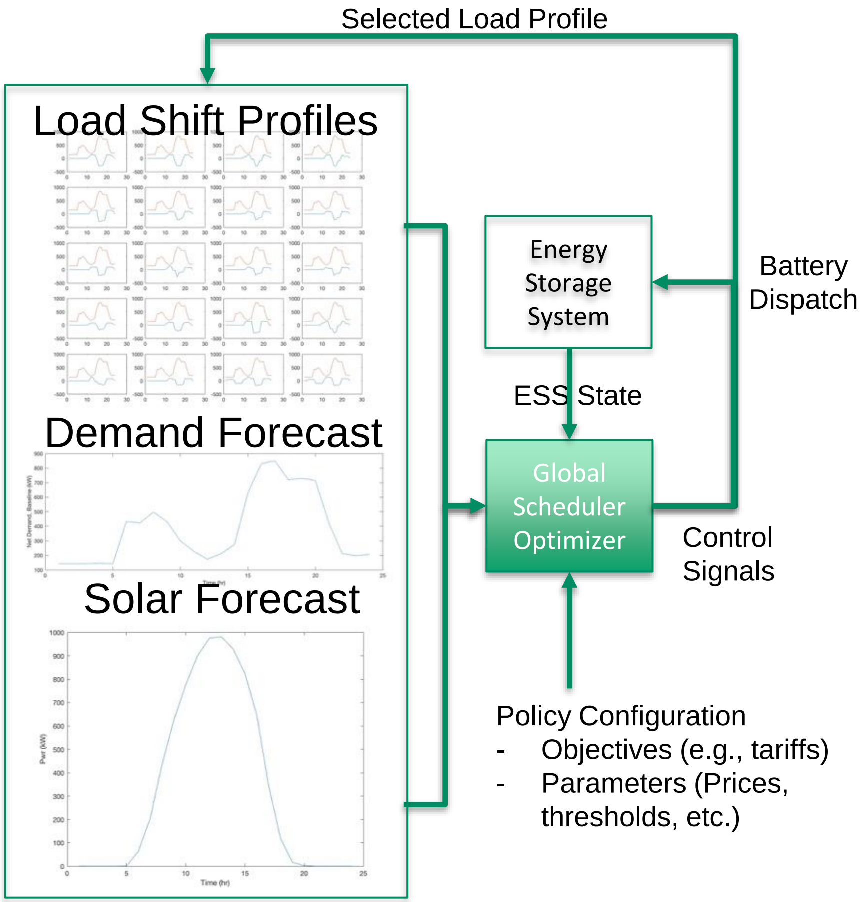
Show that coordinated control of DERs can effectively increase ESS size by 10-20% while optimizing portfolio load shape

System Architecture



Global Scheduler

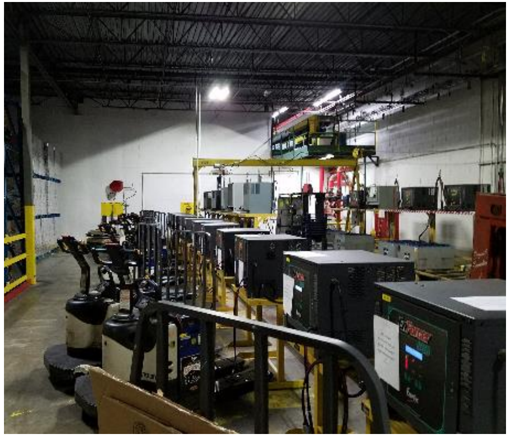
- Vendor agnostic, open-source tool for the control of “Solar + X”
- Generate predictions about future facility loads and PV generation
- Generate optimal dispatch schedules for DERs to satisfy strategic objectives
- Provide dispatch instructions to DERs to simultaneously address short-term intermittency + long-term objectives
  - Charge and Discharge Energy Storage
  - Initiate load-management events
  - Modify PV system set points.
- Real-time data capture and visualization
  - 1-sec data resolution
  - Remotely configurable



Solar + Storage Plant in Shirley, MA

Facility Load Management

Facility	Load Managed	Magnitude	Duration
Food Processing	Drag conveyors	90kWh/h for five hours	Runs 5 hours on weekdays between 7AM and 7PM Default ~9AM-2PM
Food Production	Electric Forklift Charging	67kWh over a four-hour event: 24, 19, 12, 12	EV use ~2PM to midnight Default charging midnight to 4AM Must complete 4-hour charge by 2PM
School	Packaged rooftop unit AC ($T_{zone,set}$) ±3ºF	Varies, maximum ~35kW	Magnitudes and durations vary with T_{out} , during summer vs. school year



"Load Shaping" differs a lot from traditional Demand Response (DR)

Attribute	Traditional DR	Load Shaping to support PV
Frequency of Calls	Order of 5-20 times/year	Majority of days/year
Key Goal	Load shedding	Load sinking and shedding to increase PV and load coincidence
Duration of LM	1 to 4 hours	Up to 8 hours/day
Most Needed	Usually summer or winter peak	Shoulder Seasons – Solar surplus Summer and New England Winter – Peak

- Develop of new algorithms for load sinking over extended periods of time
- Automated load management essential
- Millions of potential load profiles due to temporal path dependence of load management – need techniques to simplify assessment
- Existing standards (e.g., OpenADR) does not readily accommodate communication of potential load profiles

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Pilot Demonstration Overview

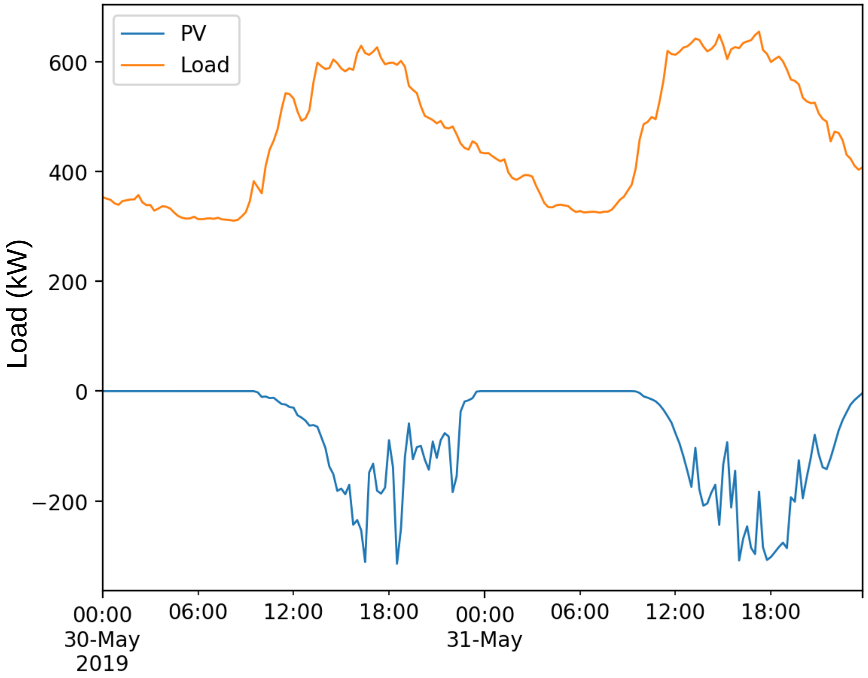
Project Design

- 18-month deployment on National Grid distribution system, ~6 months offline due to switchgear failure at the solar site.
- “Tactical” and “Strategic” dispatch of DERs
  - Tactical: Short-term intermittency of solar production (e.g., due to passing clouds) with ESS
  - Strategic: dispatch ESS + Loads to meet user-defined objectives for different use cases
- Varied use cases throughout the pilot

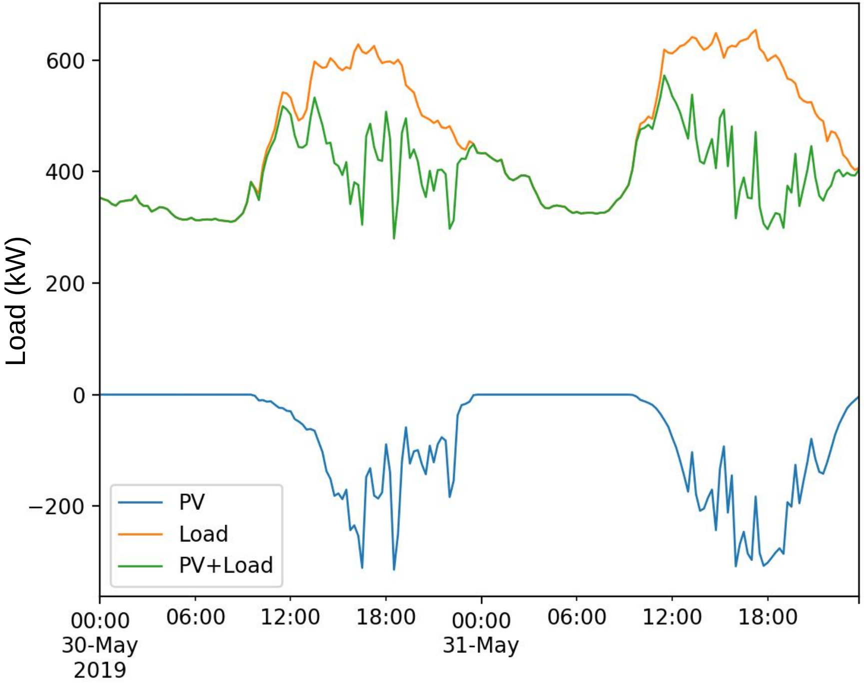
Use Cases

- Peak Minimization + Energy Cost Optimization
- Mitigate Reverse Power Flow
- “Virtual Peaker Plant”
- “Load Shaping”
- “Power Firming”

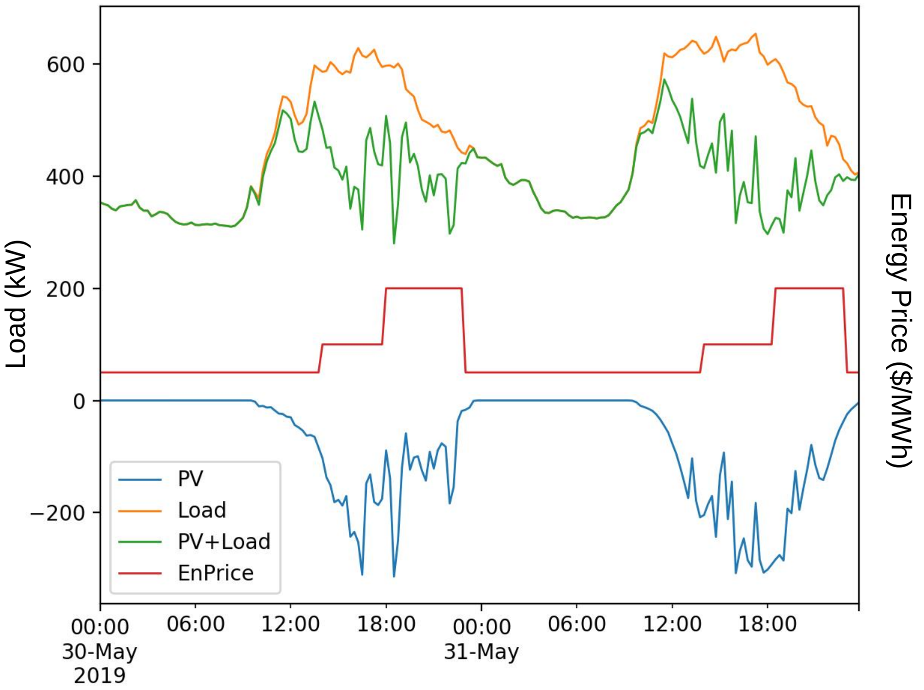
Example – Peak Shaving + Energy Arbitrage



Example – Peak Shaving + Energy Arbitrage



Example – Peak Shaving + Energy Arbitrage



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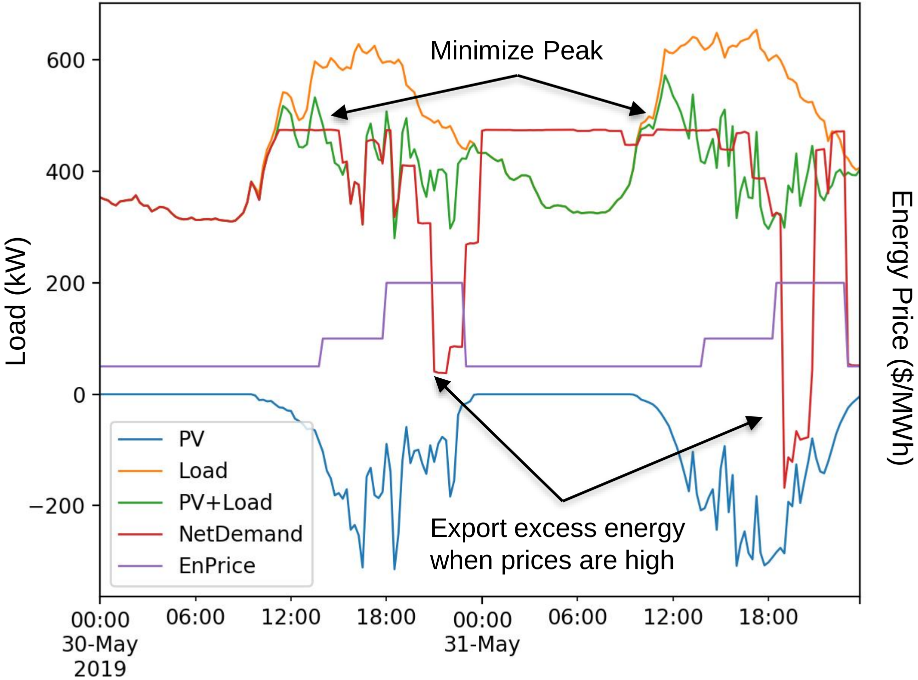
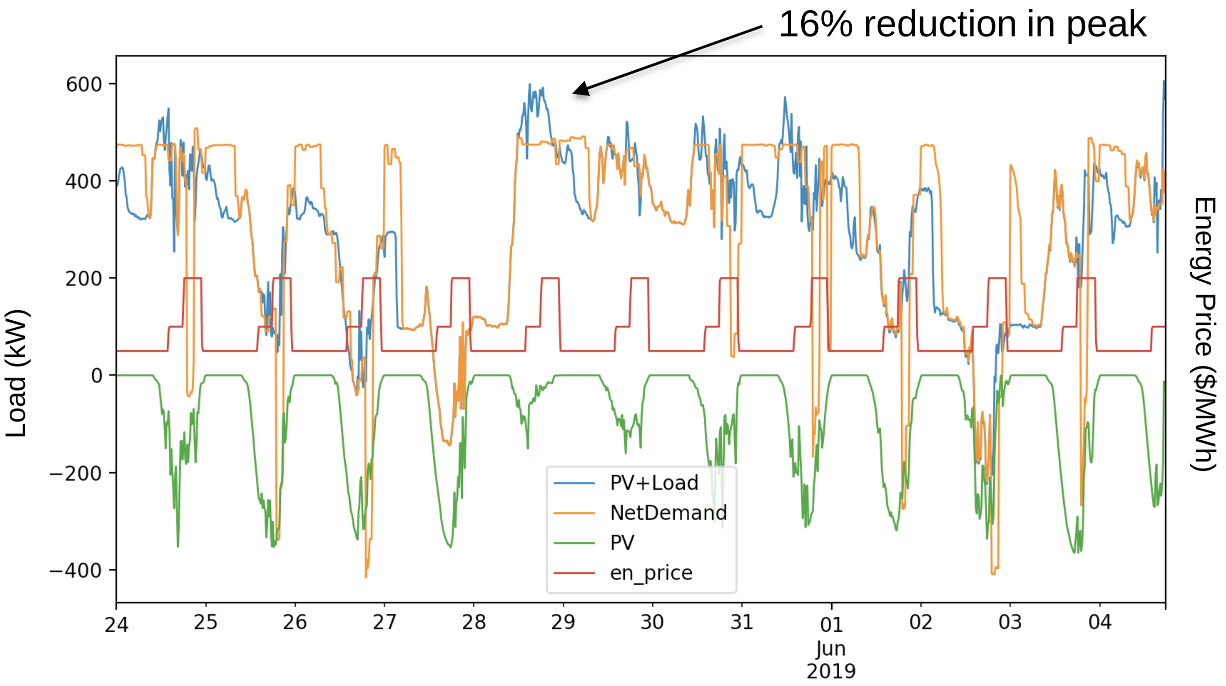
Example – Peak Shaving + Energy Cost Optimization

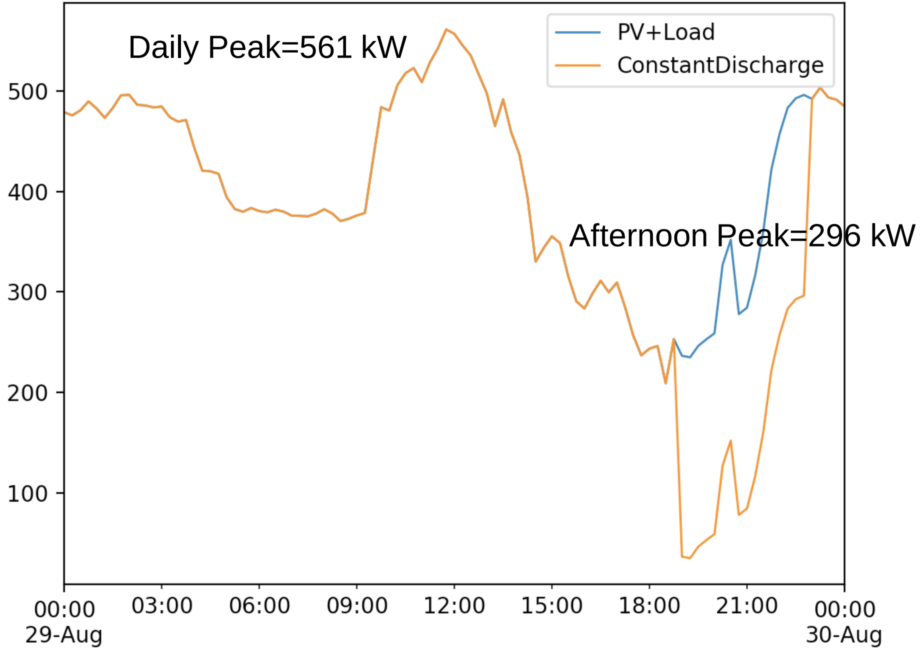


Example - Peak Load Shaving + Energy Cost Optimization

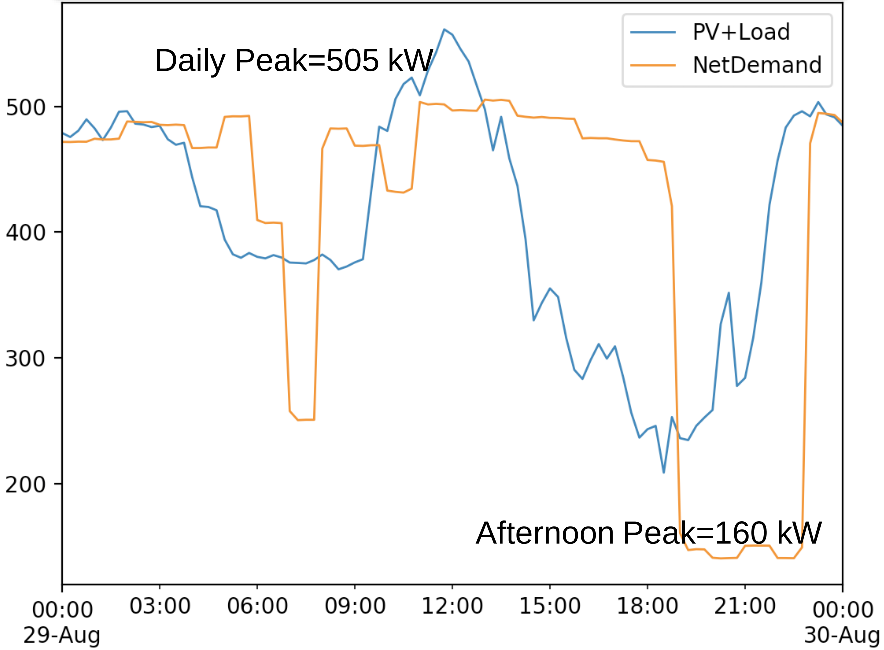


Example - Virtual Peaker Plant

Constant-ESS Discharge Strategy



Adaptive ESS Control Strategy



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Agenda

- Project Overview
- Highlighted Results
  - Strategic Scheduling and Dispatch of DERs
  - Load Flexibility
- Key Takeaways

Figure of Merit -- “ESS Equivalent”

Goal: Optimize load shape using a virtual power plant

How does one evaluate performance?

Approach: Define “efficacy” of optimization in terms of an *ESS-equivalent*: i.e.,

How much more energy storage would I need to accomplish the same goal?

Quantify efficacy of optimization enabled by…

- Improved Prediction Accuracy
- Coordination of building load flexibility and ESS dispatch strategy

Improving Prediction Accuracy

Peak-Load Reduction Cases				
Peak Reduction Period	Avg Reduction in Peak Demand (kW)			ESS Energy-equivalent (kWh)
	Heuristic	Global Scheduler	Perfect Information	
Monthly	80	113	129	400
Daily	30	84	101	145
Afternoon ('Virtual Peaker')	207	255	281	192

- "Heuristic Case" uses a rules-based control strategy and predictions based on historical averages
- Magnitude of effect is ~15 to 40% of the ESS size (145 to 400 kWh)

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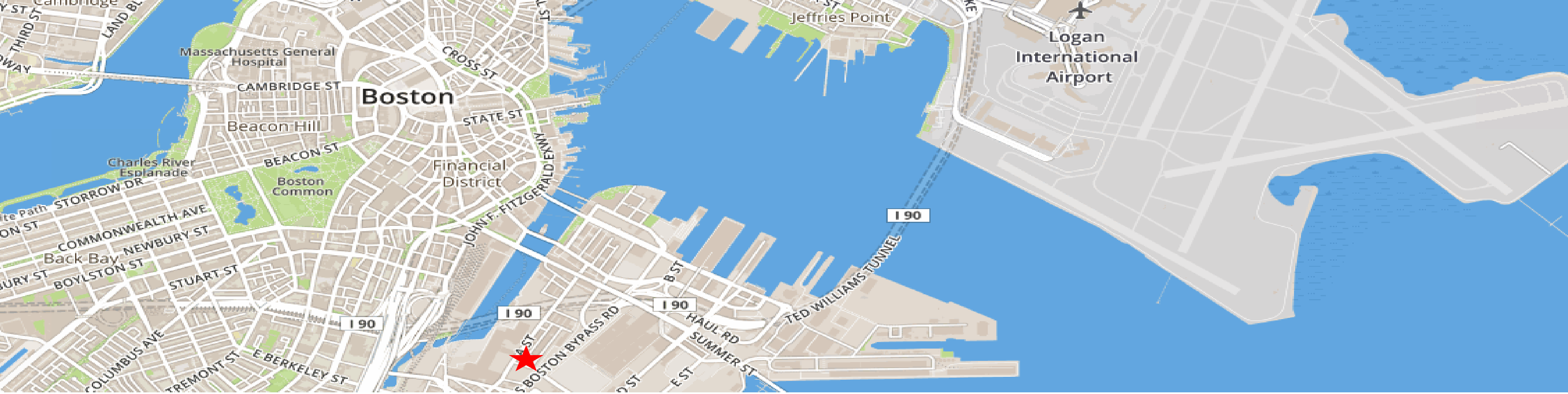
Flexible Loads contribute 85-96 kWh (theoretical) or 40-51 kWh (realized) additional capacity - ~5-10% of the total ESS size

Flexible Load Resource	Total Average Load increase per event (shoulder seasons / backfeed conditions) (kWh)		Total Average Load decrease per event (summer / peak load conditions) (kWh)		Notes
	Raw	Scaled	Raw	Scaled	
EV Charging	54	10.8	0	0	Typical charging pattern is a four hour cycle which peaks in hours 1-2. Baseline operation recharges at night, so load decrease unavailable to support solar.
Conveyor Drag	450	45	-450	-45	Baseline Load is 90kW x 5 hr. Available to be shfited through most of the day. Non-automated asset, relies on customer response.
HVAC	40	40	-40	-40	Highly temperature dependent. Typical summer time (peak events) typically allowed for two hours of load shed at 20kW; typical fall (backfeed-limiting) events typically allowed for two hours of pre-cool at 20kW.
Total (theoretical)	544	95.8	-490	-85	"Realized" load shift incorporates EV and HVAC loads only, as the conveyor was typically non-responsive; "theoretical" load shift includes all three loads
Total (realized)	94	50.8	-40	-40	

Key Enablers for Scalability

- Emerging need in the Northeast e.g., National Grid's Active Resource Integration (ARI) – but toolsets / frameworks do not yet exist
  - Electrification of Heating
  - Electrification of Transportation
- Co-optimizing DERS for *load shaping* (not simple DR) across multiple locations / assets / owners requires new communication protocols
  - Need to balance degree of information exchange with our ability to effectively co-optimize resources
- Auto-calibrating, self-learning techniques for solar and load predictions
- Automation and telemetry are critical for leveraging building load flexibility
- Streamlined process for integrating DERs



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