Price- and Load-Responsive CTA-2045 Controls for HPWHs
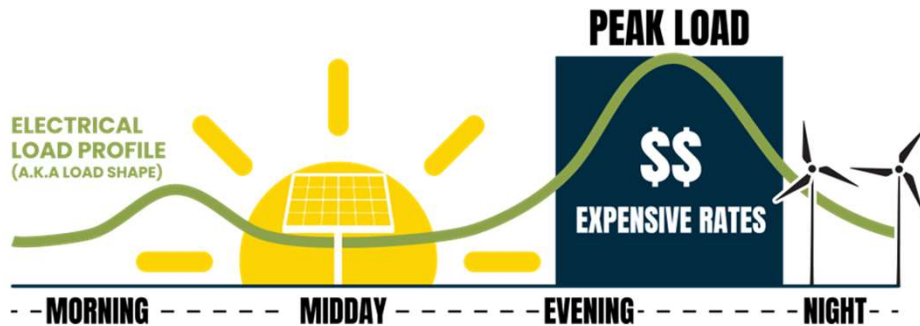
Leveraging CTA-2045 to Reduce HPWH Operating Costs

Peter Grant

Presented at the 2023 ACEEE Hot Water/Hot Air Forums

CalFlexHub Overview

## Advancing Dynamic Energy Management

Goals

- Identify, evaluate, develop, and demonstrate pre-commercial, load flexible technologies
- **Standardize the signals** used to communicate dynamic price and GHG information to devices
- Emphasis on **Load Shaping**

CalFlexHub – "Prices to Devices"

The California Load Flexibility Research and Development Hub (CalFlexHub) is the innovation hub supporting the scaled adoption of affordable, equitable, and reliable load flexible technologies. A future where building loads receive **real-time price information** and adjust their electricity consumption **automatically** for affordable energy cost and reduced carbon content.
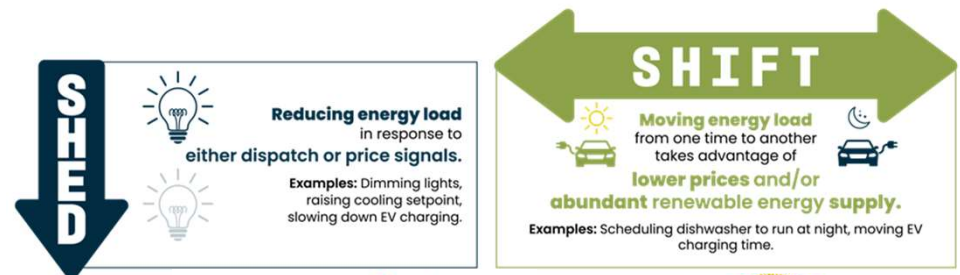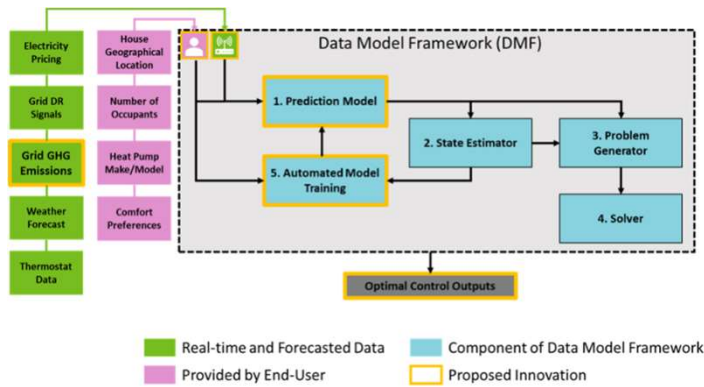
Hot Water-Based CalFlexHub Projects
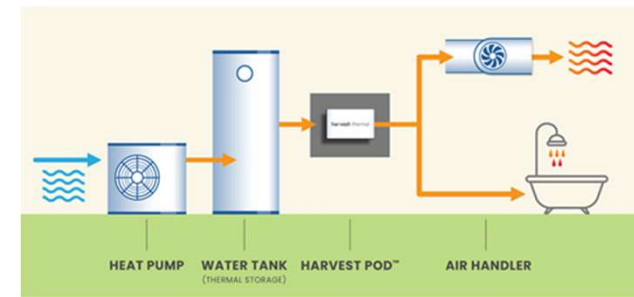
UC Davis
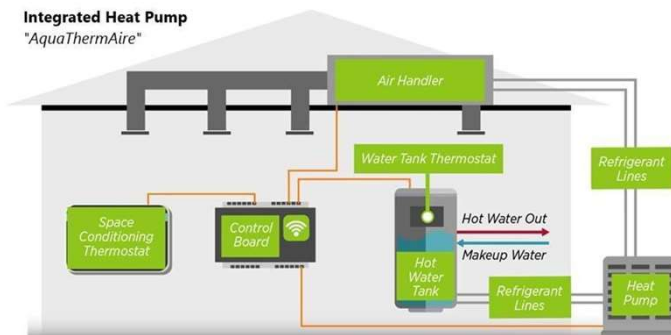## Model Predictive Control HPWH

Harvest Thermal
Price-Responsive Combi Systems
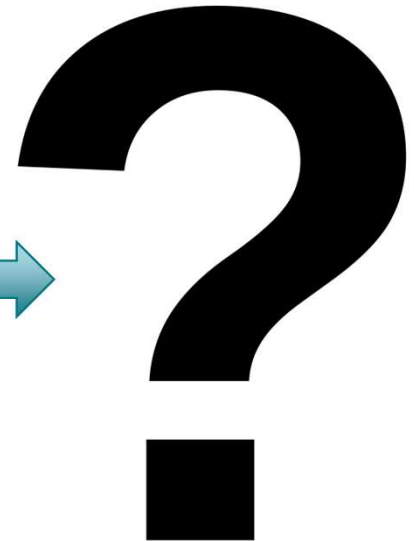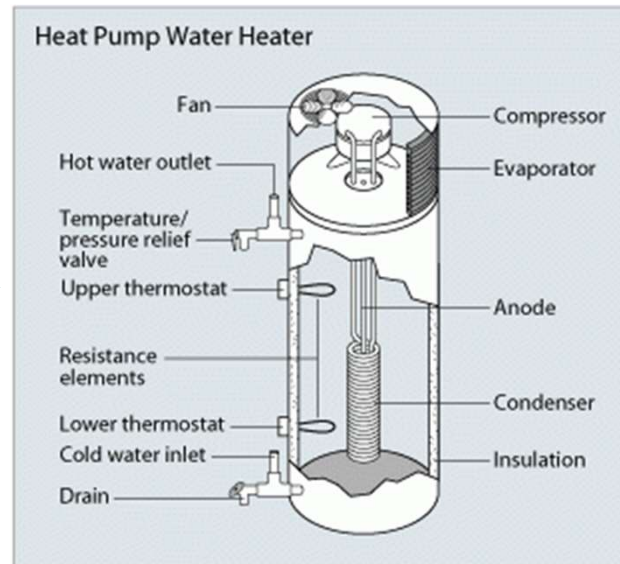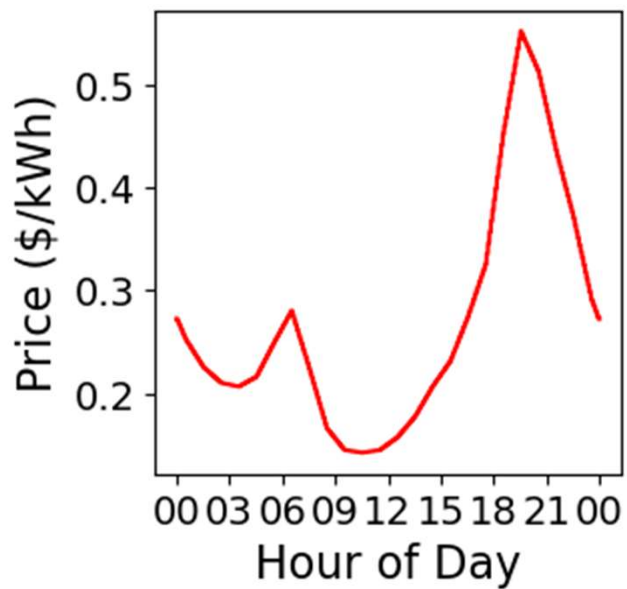

SkyCentrics
Price-Responsive HPWHs

UC Davis
Integrated Tri-Gen HP System
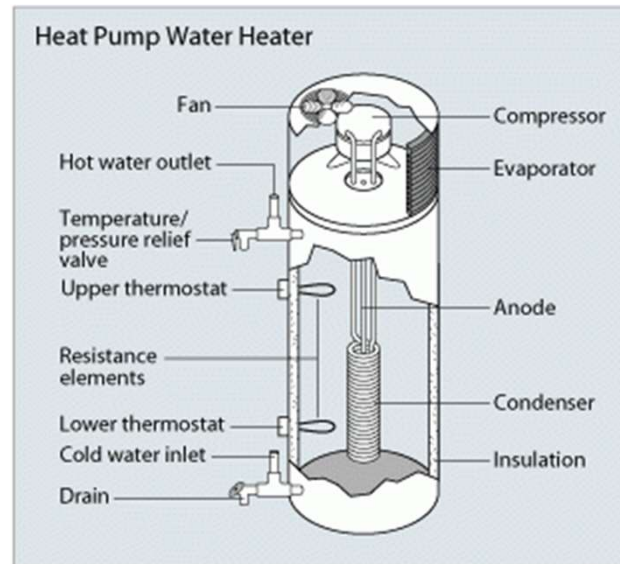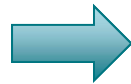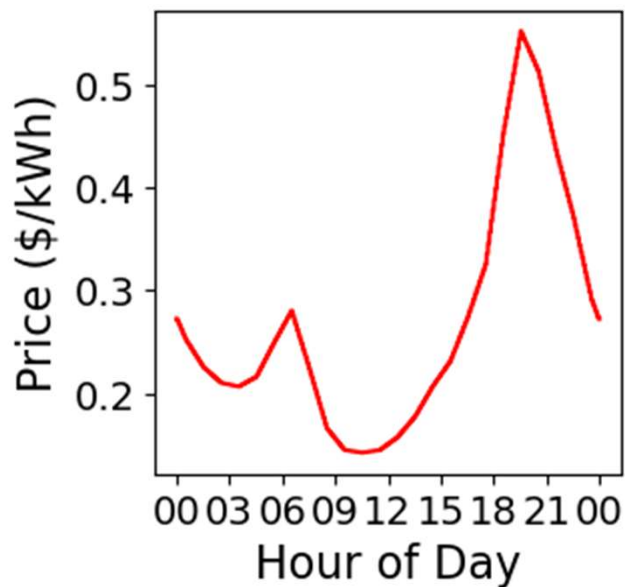
The Problem

Response to prices

- Prices to devices
  - Provide electricity cost metric to devices
  - On-board controls minimize operating cost

The Problem

Response to prices

- Prices to devices
  - Provide electricity cost metric to devices
  - On-board controls minimize operating cost

HPWHs do not know how to respond to price schedules

State of the Art

Current load shifting control approaches

- Hoeschele, Haile, Grant
  - Used manufacturer API to directly change set temperature
  - Increased set temperature gradually to avoid resistance element operation
  - Identical control for all HPWHs, and all days

- Carew, Larson, Piepmeier, Logsdon
  - Created several set temperature algorithms
  - One responds to price schedules
  - Performed well in some cases, not others

- Manasseh, Metzger, Ebony, Ashley, Hunt
  - Varied timing of signals based on typical morning/evening behavior
  - Improved load shifting performance

The Requirements – Sensitive to Local Use Patterns

Controls must be customized to local load curves

- 148 monitored daily draw profiles
- Yield different electric load curves
- Present different load shifting possibilities

|	Water (L)	Electricity (kWh)
5E1	553	9.8
5H0	507	10.2
3H0	0.1	0.7

High morning consumption

High peak consumption

Very little load!

Price- and Load-Responsive CTA-2045 Controls for HPWHs | BERKELEY LAB
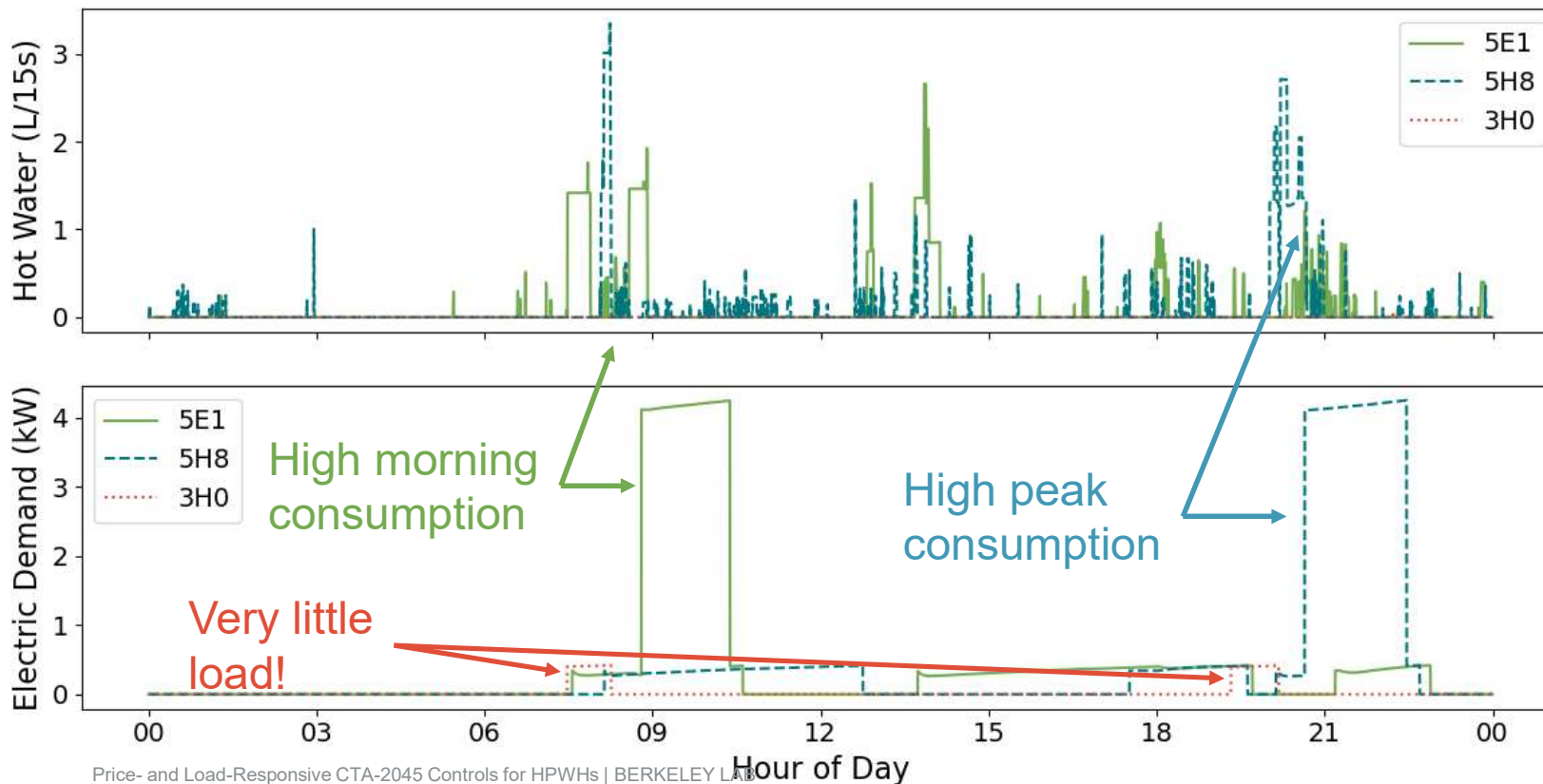
The Requirements – Sensitive to Price Schedules

Controls must identify times to activate/deactivate heat pump

Load tank before high-price period
Shed load during high-price period
Where does the high-price period start/end?

Save more by using
loading earlier/later?
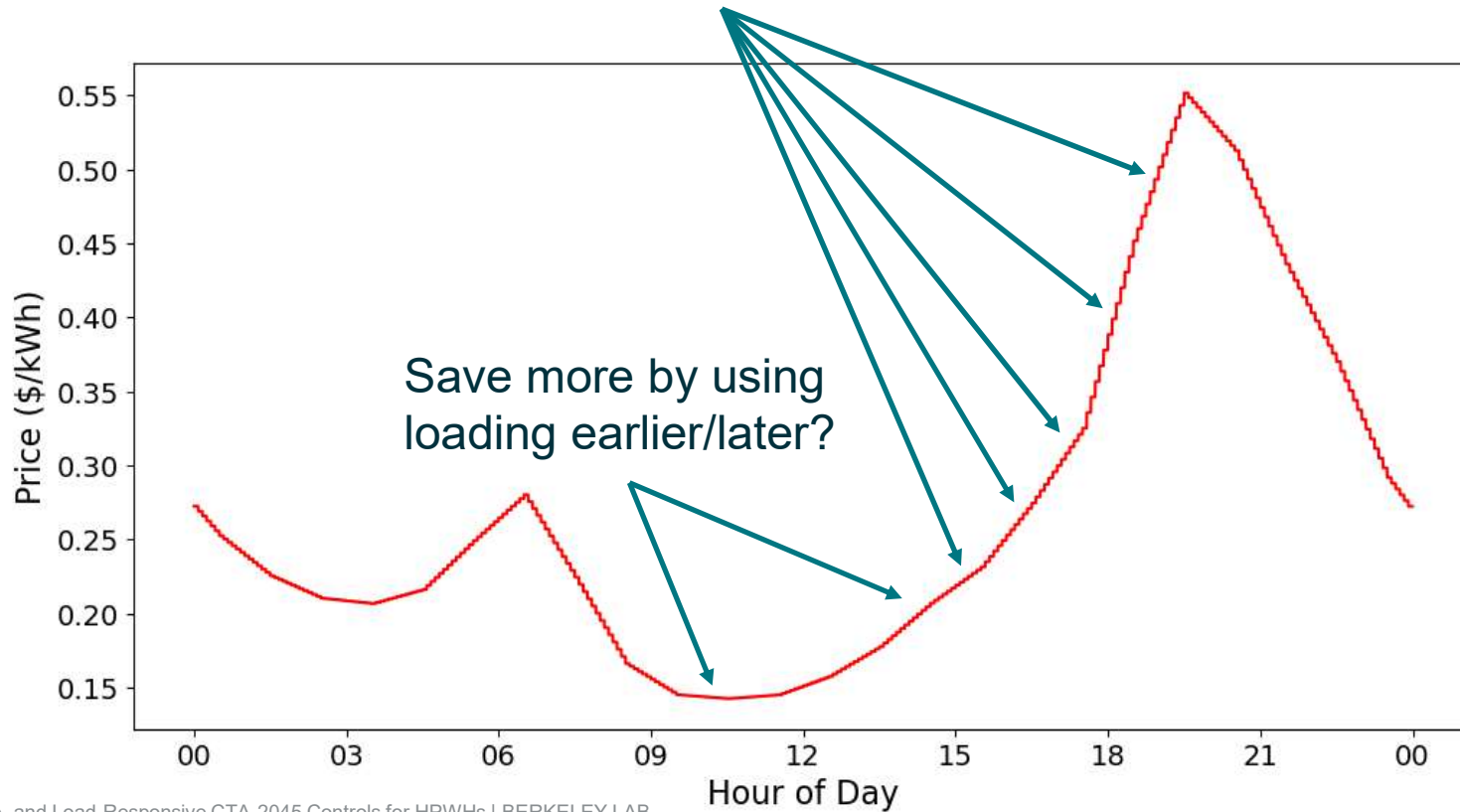
The Tools – CTA-2045

Powerful Communication Capabilities

The Socket Interface is the Standard

GRID CONNECTED

OVERRIDE

CEA

- Can:
  - Report electricity consumption
  - Load-Up
    - Activate HP, deadband = 2 °F
  - Advanced Load-Up
    - T_Set + 15 °F, activate HP, deadband = 2 °F
  - Shed
    - Deactivacte HP, deadband + 50%

- Can't
  - Report or forecast hot water consumption
  - Directly change set temperature

- Color-code legend
  - Is possible
  - Is not possible
  - Varies across manufacturers, assumption

# The Tools - Flexible HPWH Performance Predictor

Features and Performance

- Features
  - Emulates manufacturer control logic
  - Stratified tank
  - Performance map representing heat pump
  - Includes CTA-2045 and Web API communication capabilities

- Performance
  - -0.8% error over 1 week of validation
  - Excellent predictions of resistance element usage
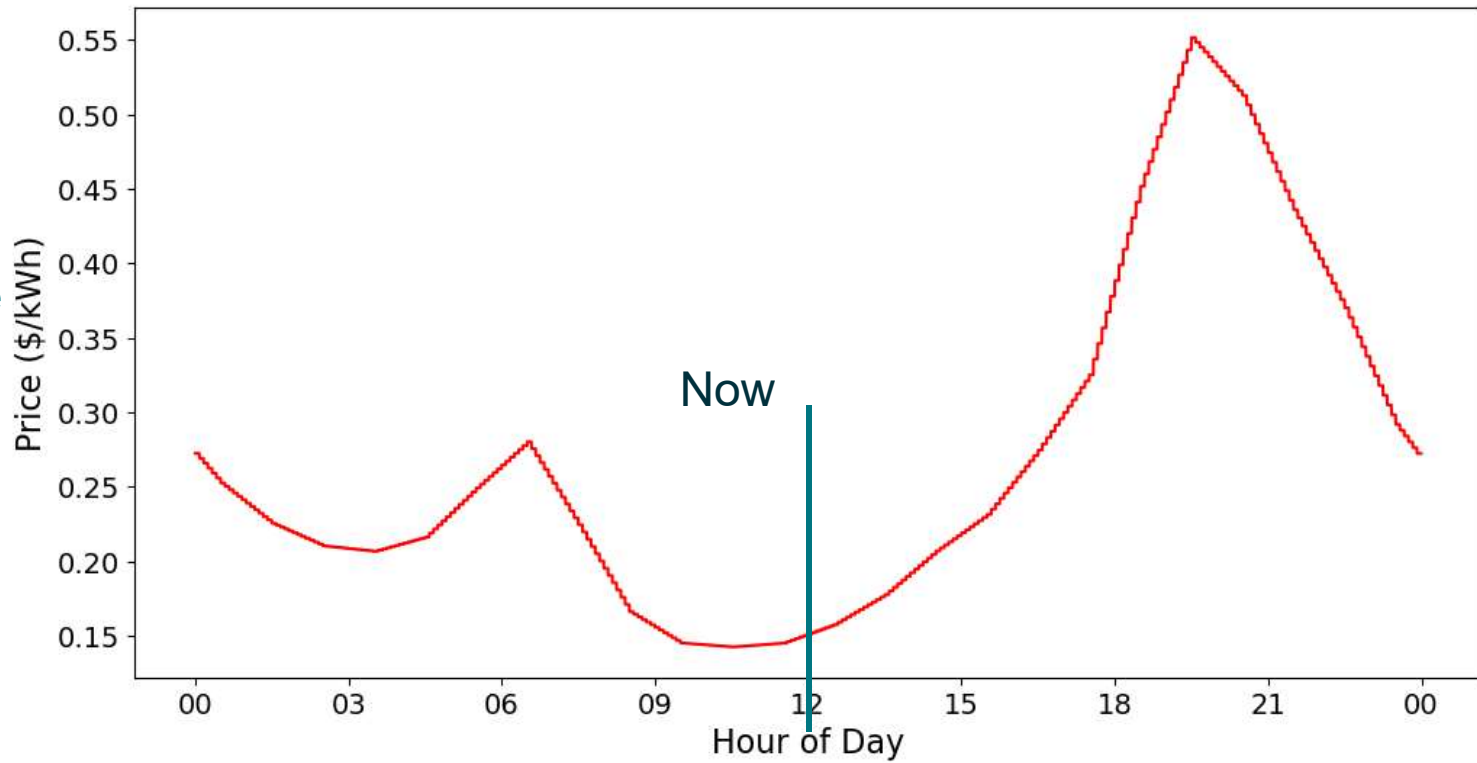 - Accurate prediction of load shifting response
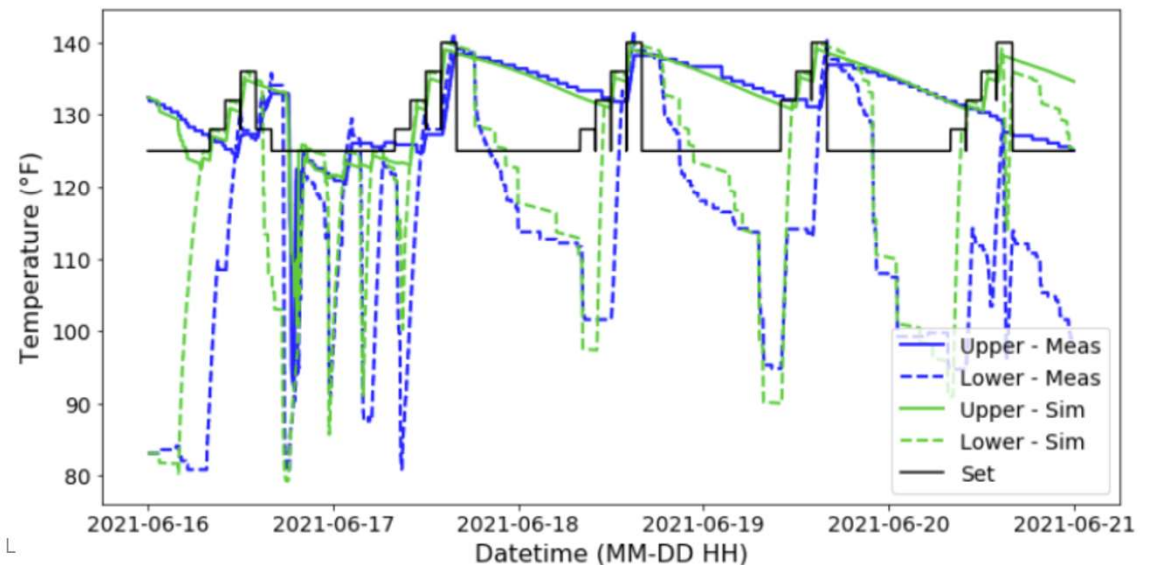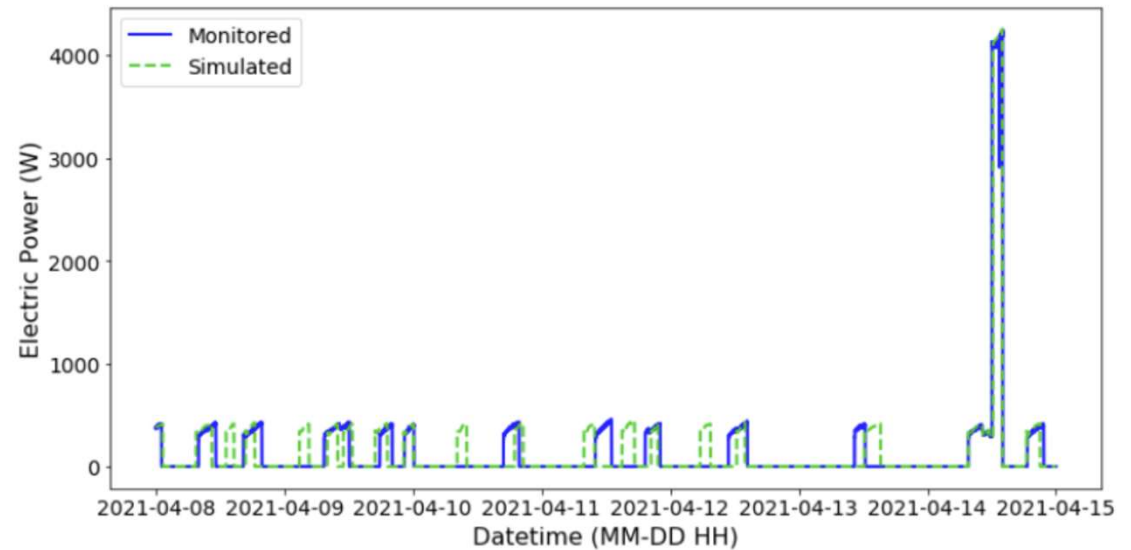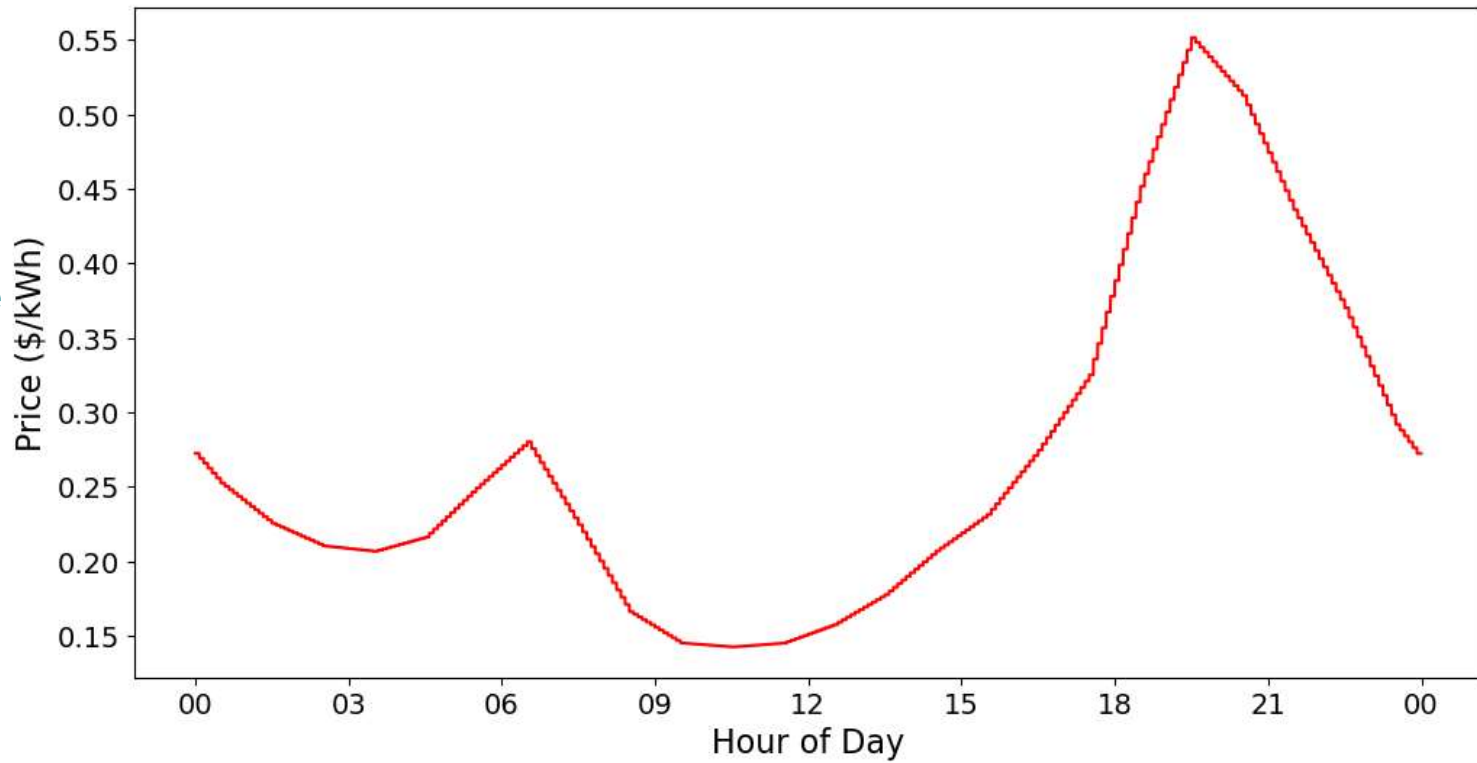
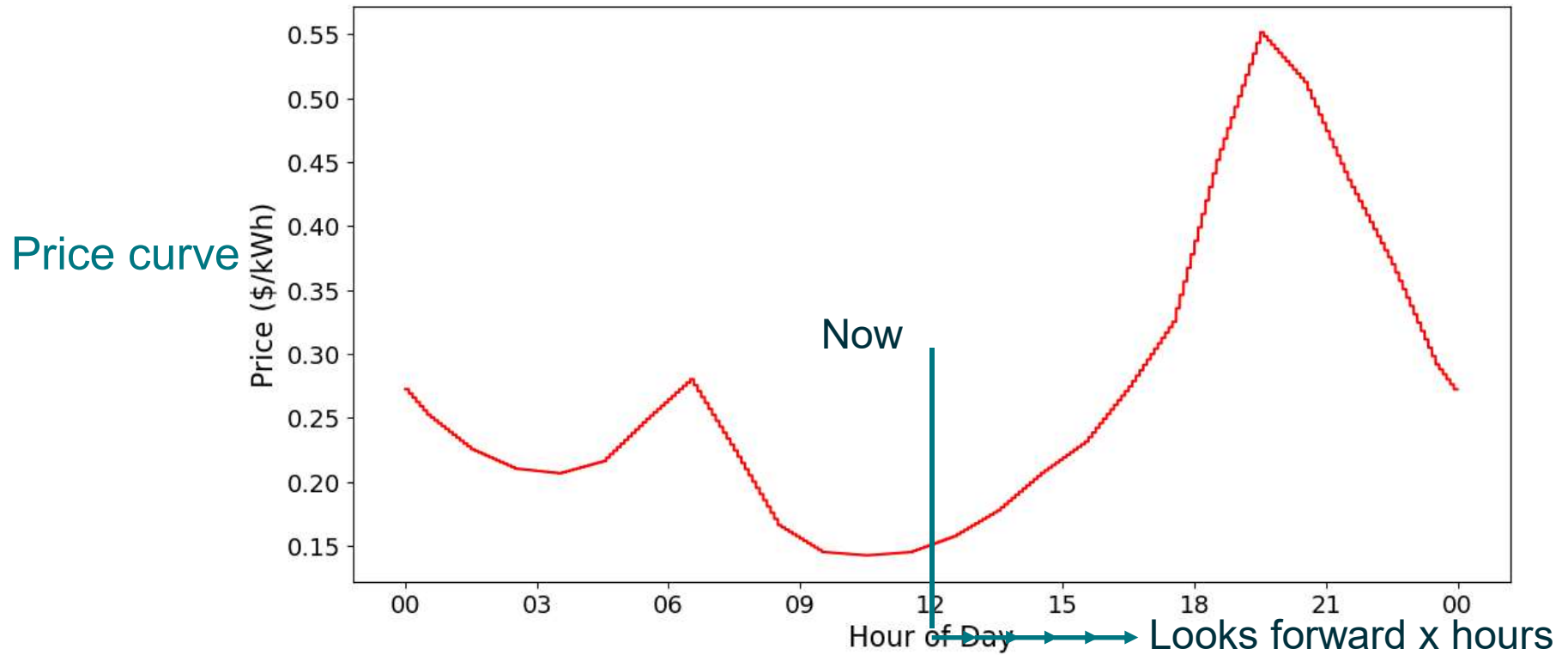# Methods – Control Algorithm
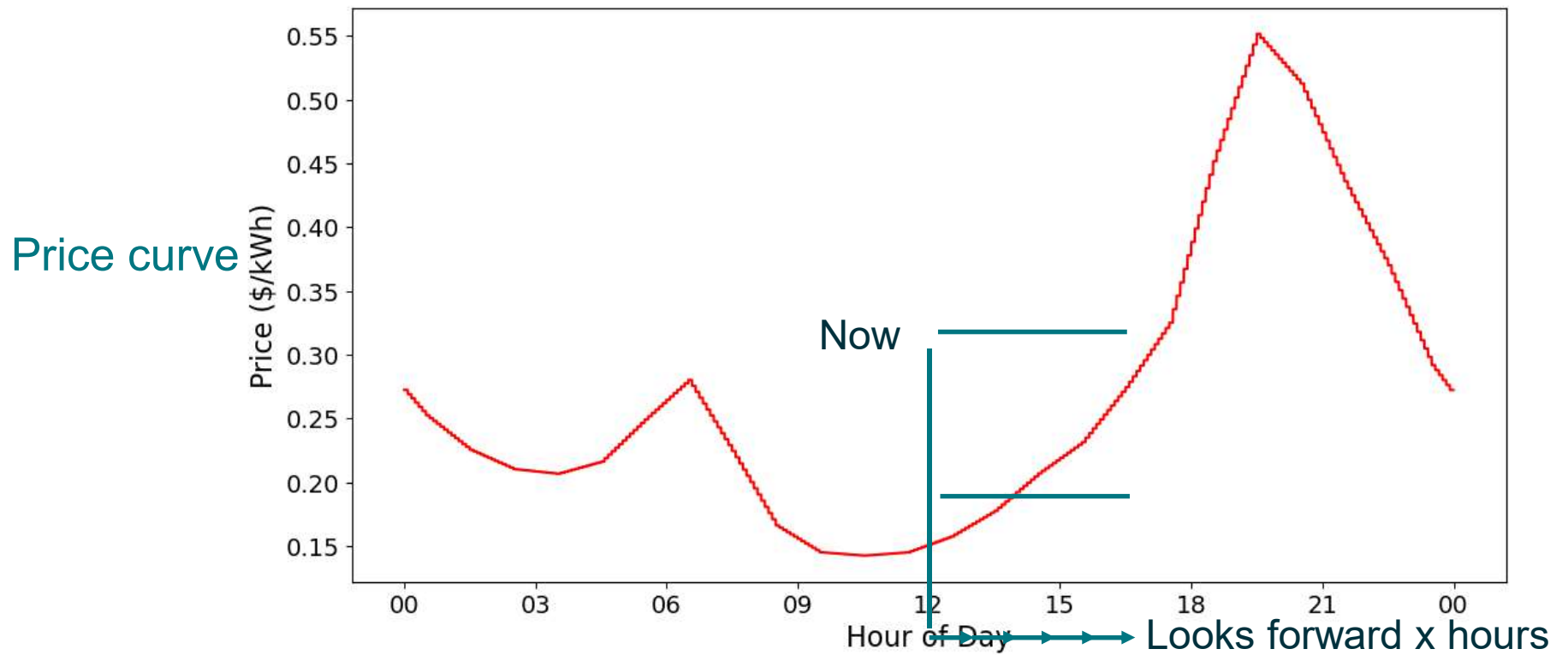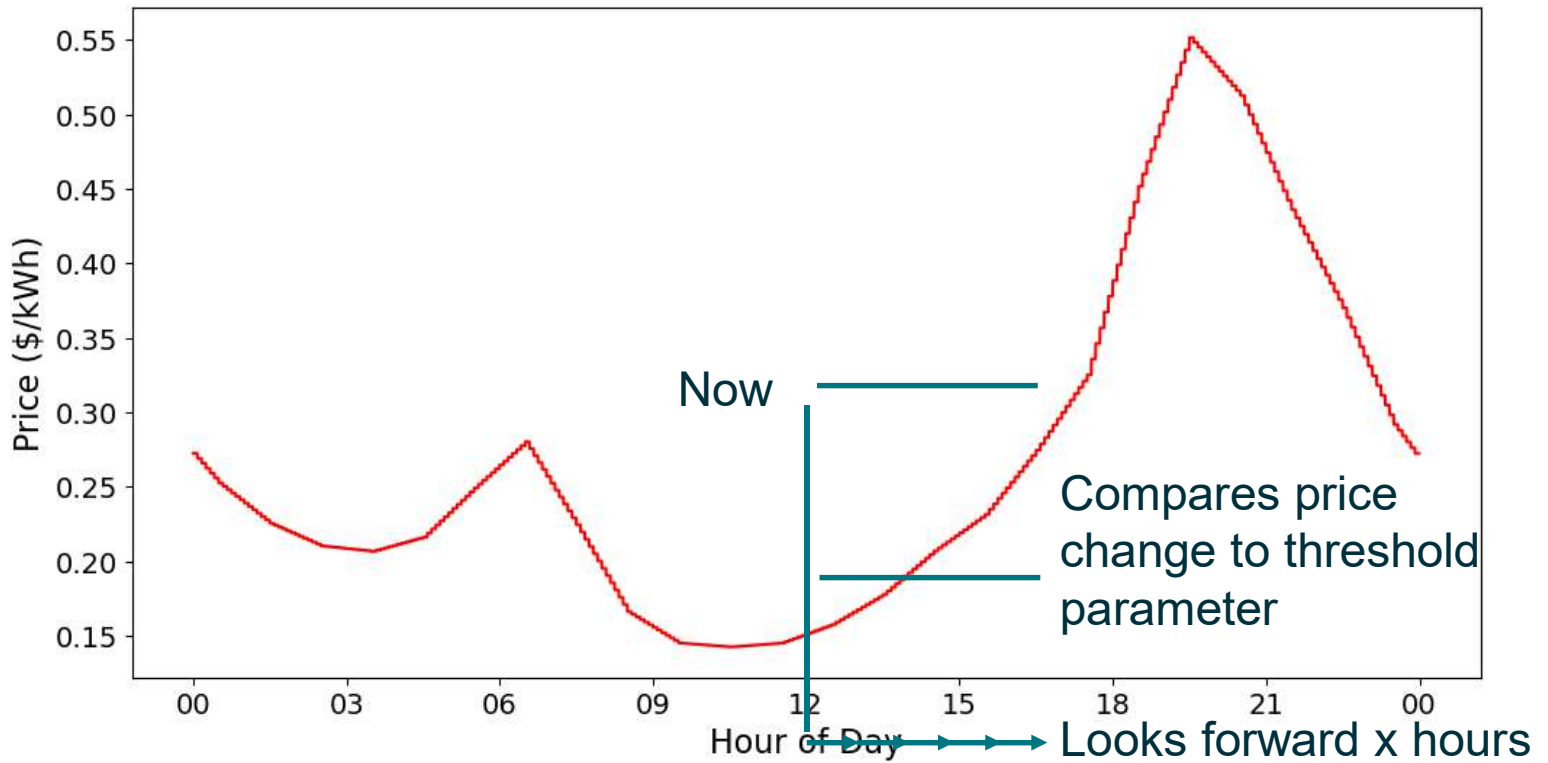
Price curve

Methods – Control Algorithm

Price curve

Now

Methods – Control Algorithm

Price curve

Now

Looks forward x hours

Methods – Control Algorithm

Price curve

Now

Looks forward x hours

Methods – Control Algorithm

Price curve

Now

Compares price
change to threshold
parameter

Looks forward x hours

Methods – Control Algorithm

Price curve

CTA-2045 signal schedule

Now

Compares price change to threshold parameter

Looks forward x hours

Price- and Load
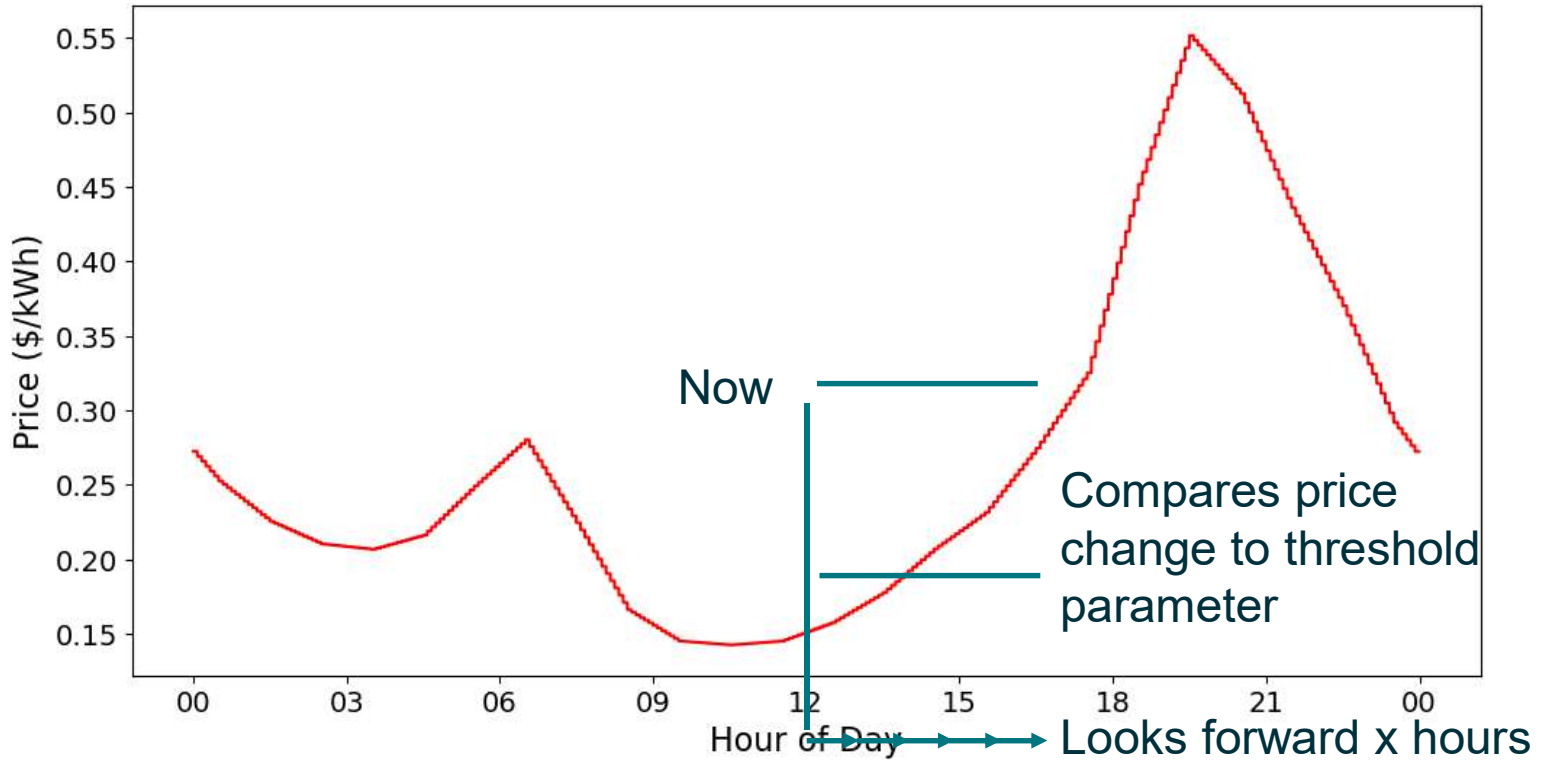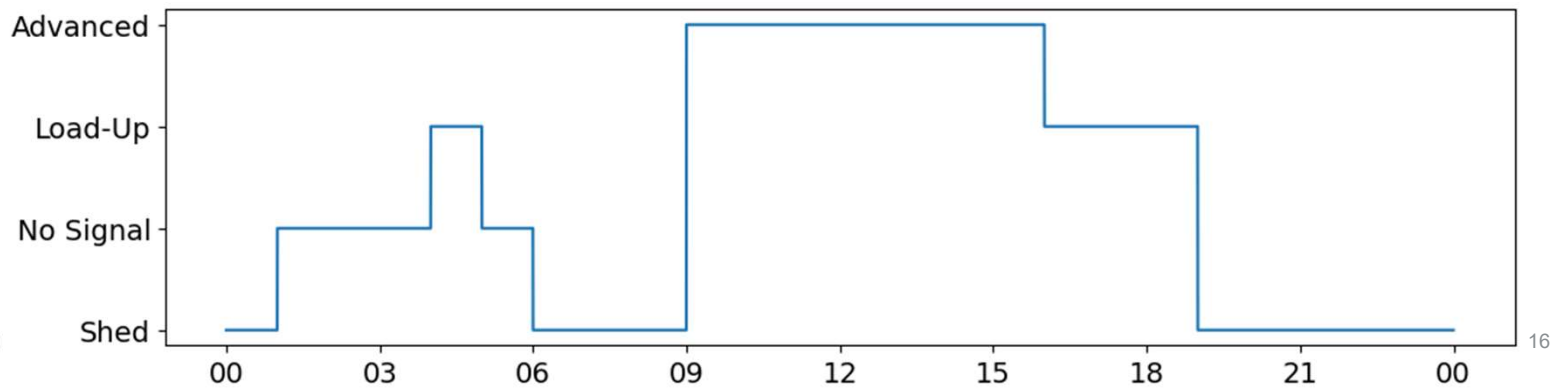
Methods - Grouping HPWHs

Treating HPWHs with similar loads similarly

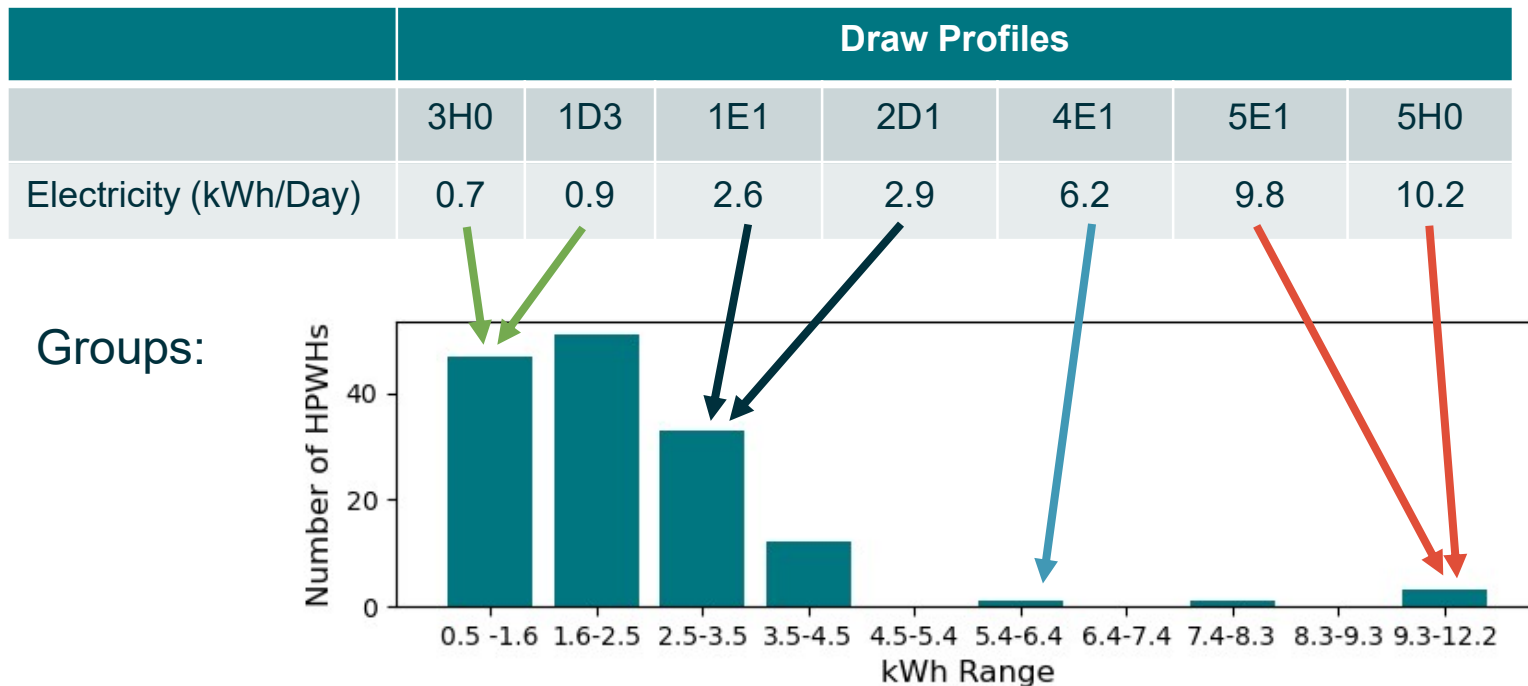- Simulate 148 profiles using manufacturer control
- Obtain kWh/day, split into 10 groups (4 shown)
  - Cannot use hot water consumption because that is not known in deployment

	Draw Profiles						
	3H0	1D3	1E1	2D1	4E1	5E1	5H0
Electricity (kWh/Day)	0.7	0.9	2.6	2.9	6.2	9.8	10.2

Groups:

- Create customized control strategy for each group

Methods – Parametrics Study

Identify the lowest operating cost for each group

- Six parameters to customize CTA-2045 signal schedule
  - Search window: Load-Up, Advanced Load-Up, Shed
  - Price change threshold: Load-Up, Advanced Load-Up, Shed
- Perform parametric study evaluating all combinations

CTA-2045 Command	Search Window (hours)	Price Threshold ($/kWh)
Load-Up	1, 2, 3, 4	0.05, 0.1, 0.15
Advanced Load-Up	3, 4, 5, 6, 7, 8, 9, 10	0.25, 0.3, 0.35, 10
Shed	1, 2, 3, 4	-0.05, -0.1, -0.15

- Evaluations:
  - Operating cost **reduction**
  - Peak period electricity consumption **reduction**
  - Mid-day electricity consumption **increase**

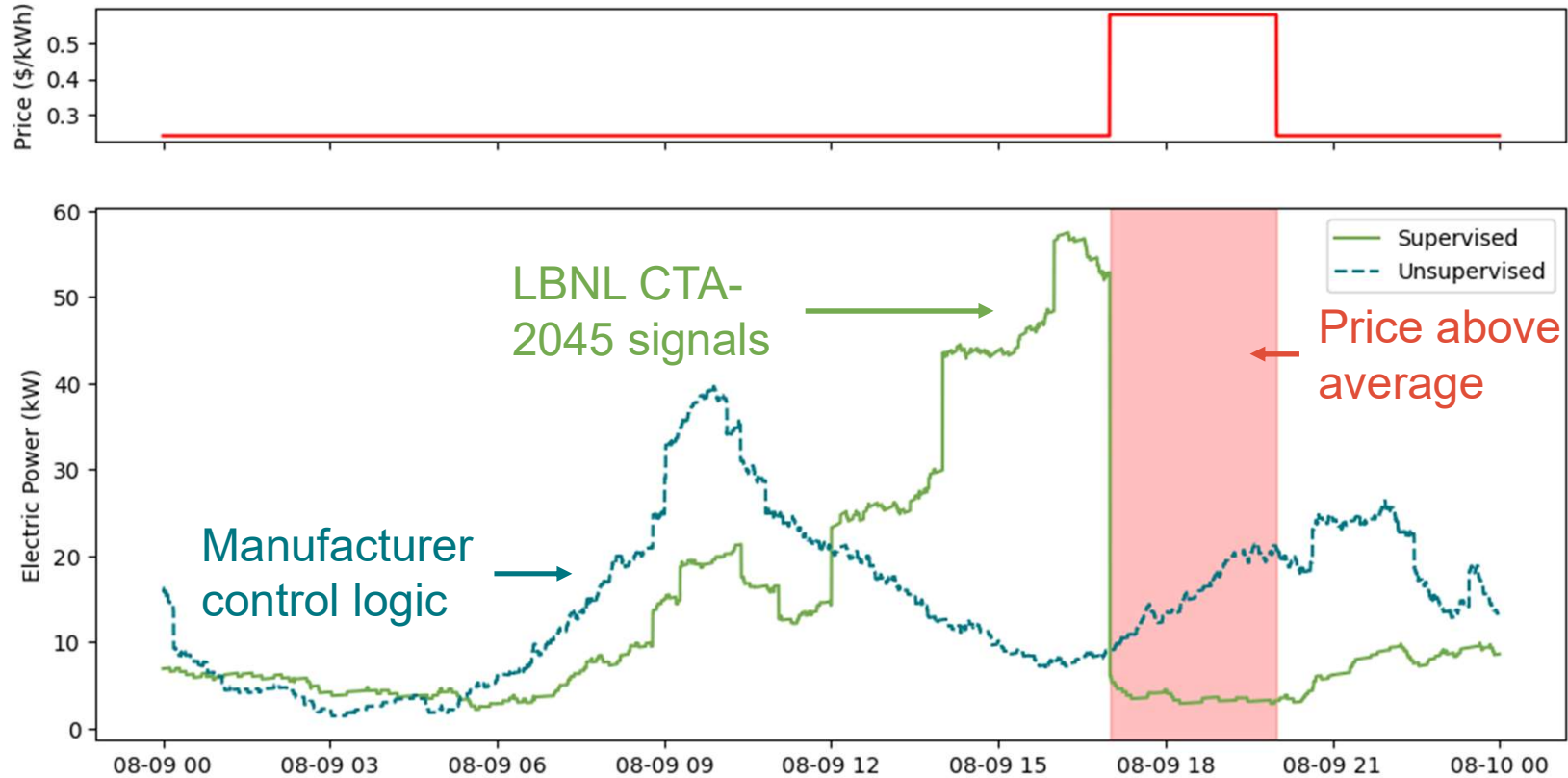# Results – Highly Dynamic Prices

Load Curve Impacts

- Impacts
  - 29% cost savings
  - 75% peak period kWh reduction
  - 102% mid-day kWh increase

Price above average

LBNL CTA-2045 signals

Manufacturer control logic
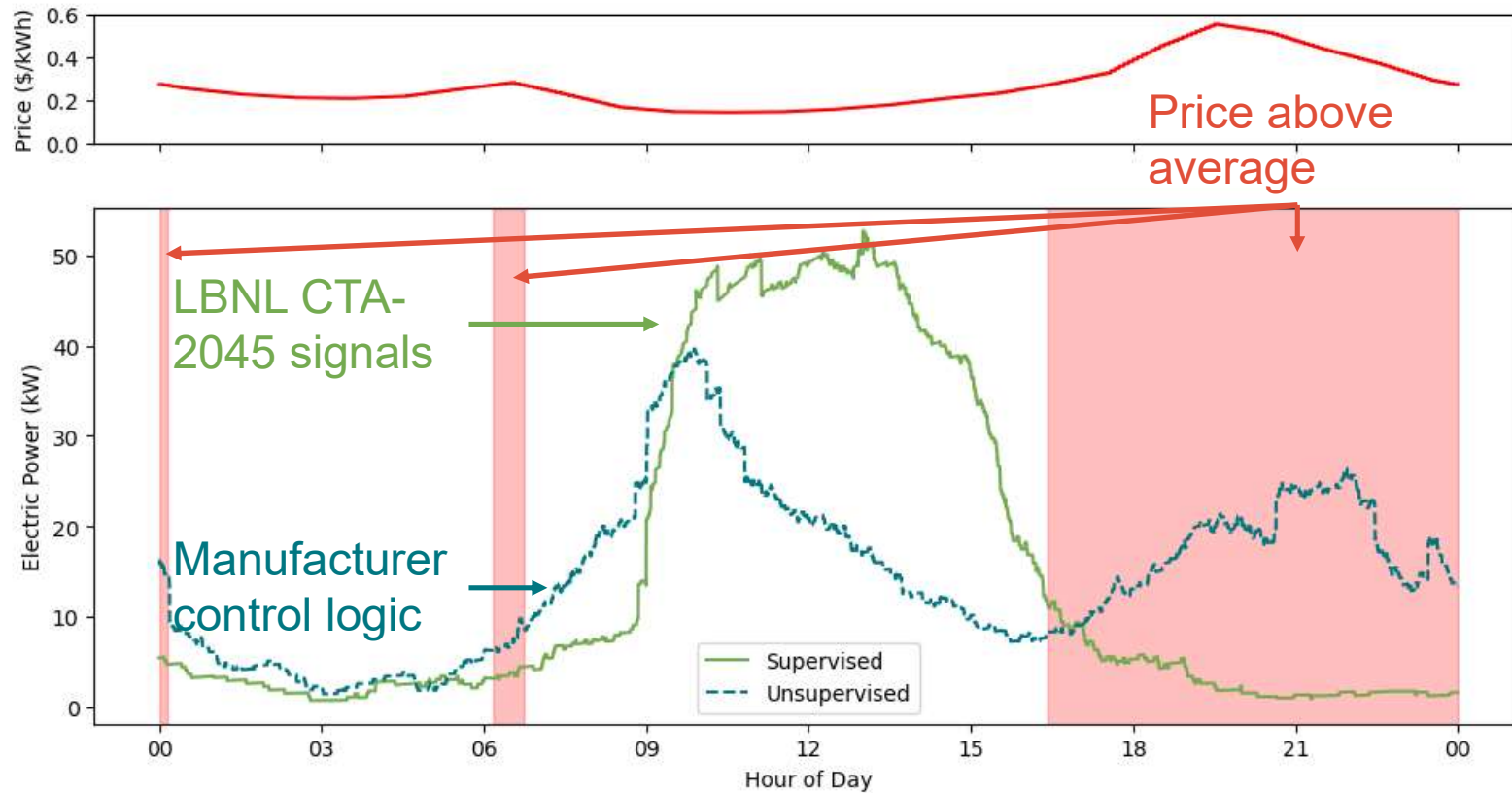
Results – SCE TOU-D-5-8PM

Load Curve Impacts

- Impacts
  - 15% cost savings
  - 77% peak period kWh reduction
  - 63% mid-day kWh increase

Future Work - Path to Market

Easily Accessible to Program Implementers

- Price server releases prices

- Cloud control server delivers CTA-2045 schedules for each group to program implementers

- Program implementers send CTA-2045 signals to HPWHs

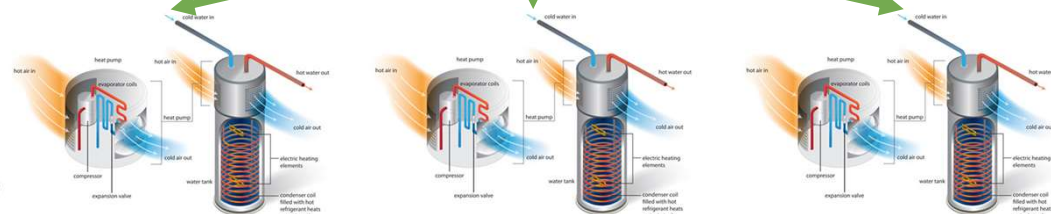**CALIFORNIA ENERGY COMMISSION**

2. Price

3. Receive CTA-2045 schedules

1. API call

4. Signals to HPWHs

Legend:
- 0.62-1.58
- 2.54-3.5
- 5.42-6.39
- 9.27-10.23
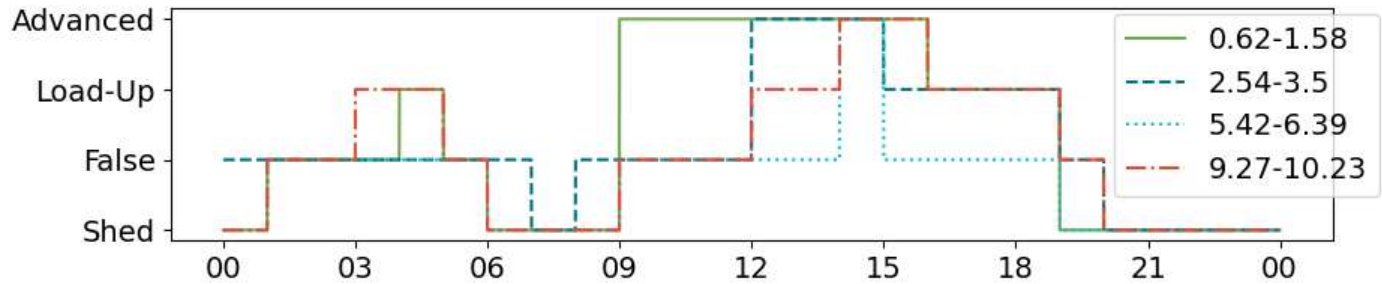
olivine   OhmConnect   SkyCentrics

Key Takeaways

Optimized load shifting under development

- Numerous engineers are still working to solve this problems

LBNL has developed a toolchain

- Generates cost-reducing CTA-2045 signal schedules
- Responds to any price structure

Goal: Can be leveraged for utility programs

- Developing an API
- Enable third parties to easily obtain signal schedules
- Facilitate deployment to real fleets

Goal: Open-source

- LBNL will make the toolchain publicly available
- Manufacturers will be able to leverage the toolchain
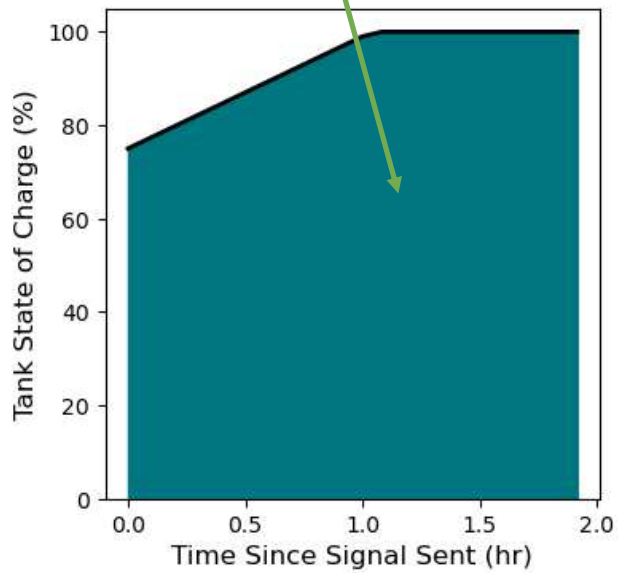
Let's innovate together
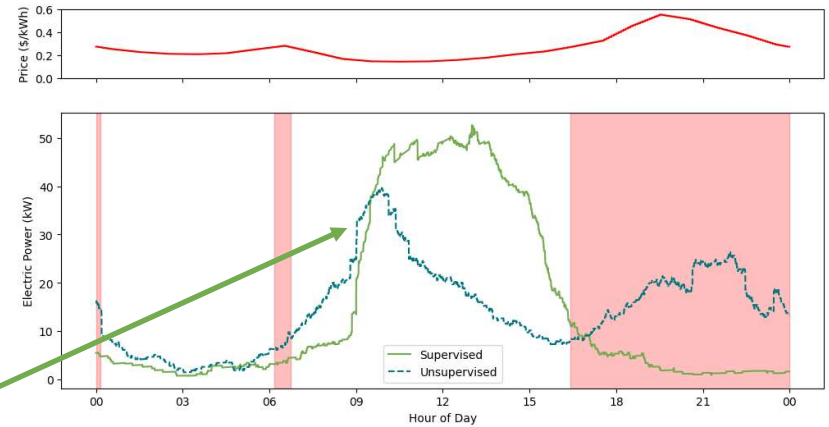
Thank You

pgrant@lbl.gov

Backup Slides

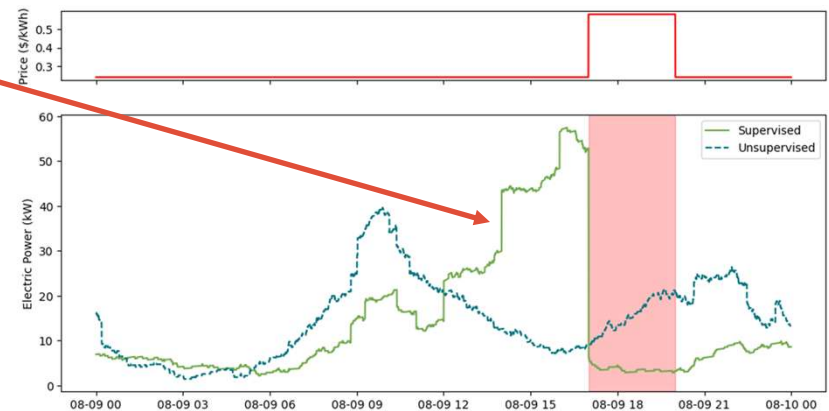# State of Charge Algorithm

Smoothing the Load Up Curve

With algorithm: Smooth curve

Signal sent to all HPWH
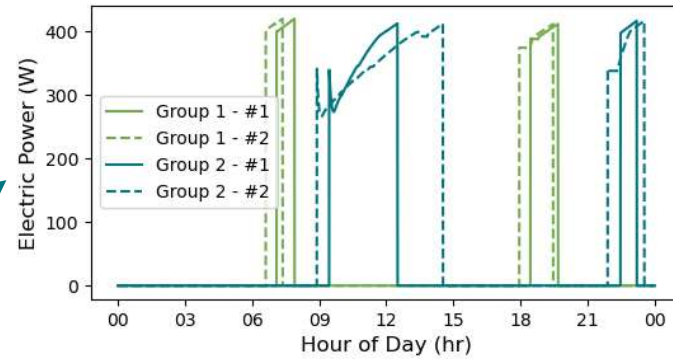with state of charge < threshold
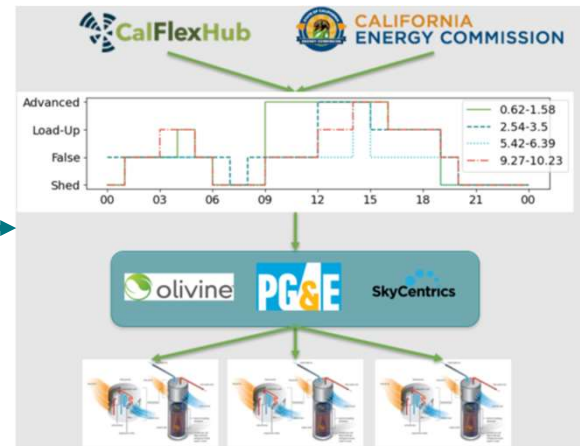

Without algorithm: Sudden increase

Future Work

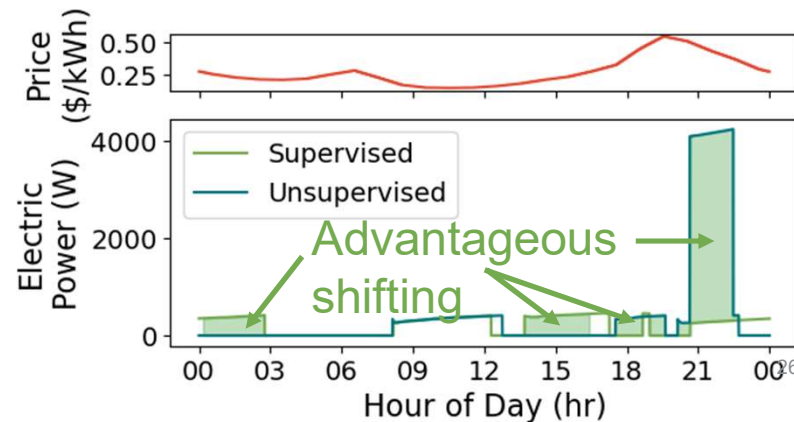Overcoming real-world challenges

1. Refine HPWH grouping strategy
   – Base on monitored data variation

2. Establish price server to controls
   to HPWH communication

3. Evaluate field performance

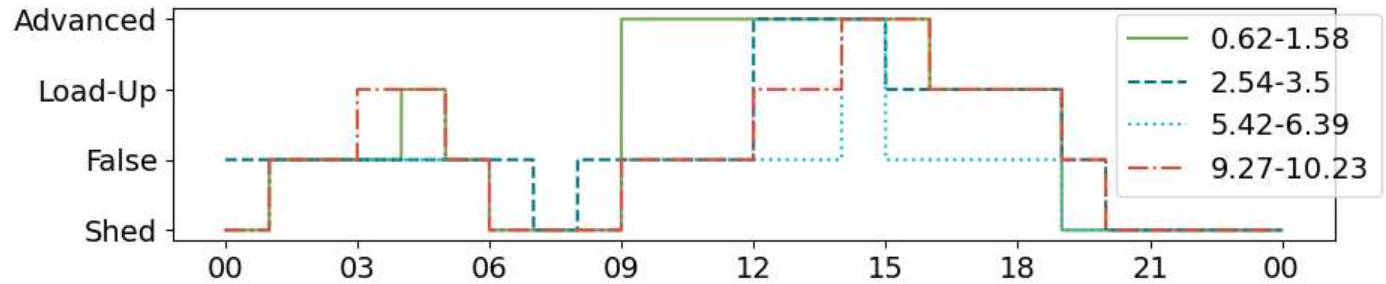4. Establish partnership with industry

Future Work - Path to Market

Easily Accessible to Program Implementers

- Price server releases prices

- Cloud control server delivers CTA-2045 schedules for each group to program implementers

- Program implementers send CTA-2045 signals to HPWHs

2. Price schedules

3. Receive CTA-2045 schedules

1. API call

4. Signals to HPWHs

Legend:
- 0.62-1.58
- 2.54-3.5
- 5.42-6.39
- 9.27-10.23