

CADMUS



Demand Side Analytics
DATA DRIVEN RESEARCH AND INSIGHTS

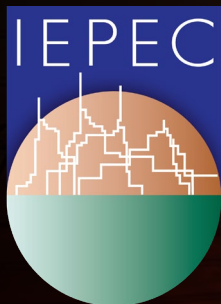


Hawaiian
Electric

IEPEC 2022

Can Residential Water Heaters Provide Reliable Demand Response Grid Services?

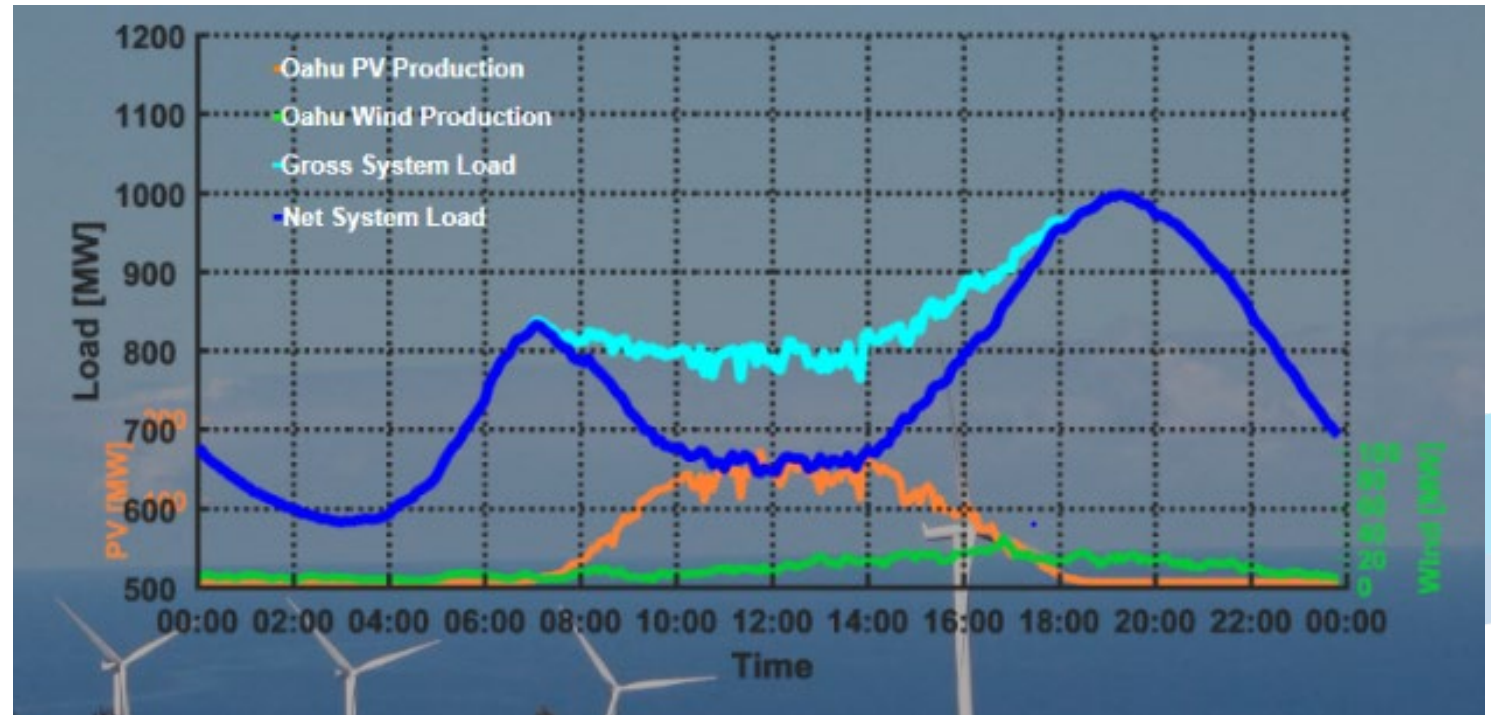
NOVEMBER 3, 2022



Background

- Hawaii has 100% renewable energy goal by 2045
- Renewable energy subject to periods of ramping, intermittency, and over- and under-supply of power
- With retirement of coal and oil generators, Hawaiian Electric Company (HECO) must find new ways to balance its grid

Source: Hawaiian Electric Company.
“Renewable Watch.” Accessed March 14, 2019.



HECO Grid Services Purchase Agreement

- In 2019, HECO reached Grid Services Purchase Agreement (GSPA) #1 with aggregator OATI, Inc.
 - Capacity build (1 MW), capacity reduction (10 MW), and FFR (11 MW) demand response
 - Pay-for-performance
 - Residential water heaters and PV/battery storage systems and commercial battery storage



Water Heater Demand Response

- January 2020 Shifted Energy (subcontractor to OATI) began enrolling customers
 - Low- and middle-income residential customers in MF buildings on O'ahu
 - Participant monthly incentive payment
 - Pandemic slowed enrollment
- Electric resistance water heaters retrofitted with Tempo smart controller
 - Grid interactive
 - Cellular communication capability



Source: Shifted Energy.
<https://www.shiftedenergy.com/technology/tempo-controller/>

Research Questions

1. **Impact Assessment:** What kW impacts did the grid services deliver during demand response events?
2. **Aggregator forecast accuracy:** Did the aggregator accurately forecast the availability of grid services?
3. **Settlement Accuracy:** Do the GSPA #1 baseline calculation methods provide accurate estimates of the delivered capability?

Randomized Controlled Trial Evaluation

- GSPA water heaters on O'ahu randomly assigned to a treatment group (n=733) or control group (n=730)
- Trial ran from January 21, 2021 to June 1, 2021

DR Grid Services Events Summary

Grid Service	Number of Events	Average Length (hr:min:sec)	Event Window
Capacity Build	27	4:00:00	10:00 a.m. - 2:00 p.m.
Capacity Reduction	37	1:17:50	5:00 p.m. - 9:00 p.m.
FFR	1	0:04:53	4:48 a.m. - 4:53 a.m.

- Regression analysis of WH 5 or 15-minute interval kW telemetry data
- Validated accuracy of telemetry data by installing 10 data loggers

Demand Response Impact Estimates

Event Day - March 2, 2021

CB Event, 10:00 a.m. to 2:00 p.m., CR Event, 6:00 p.m. to 8:00 p.m.

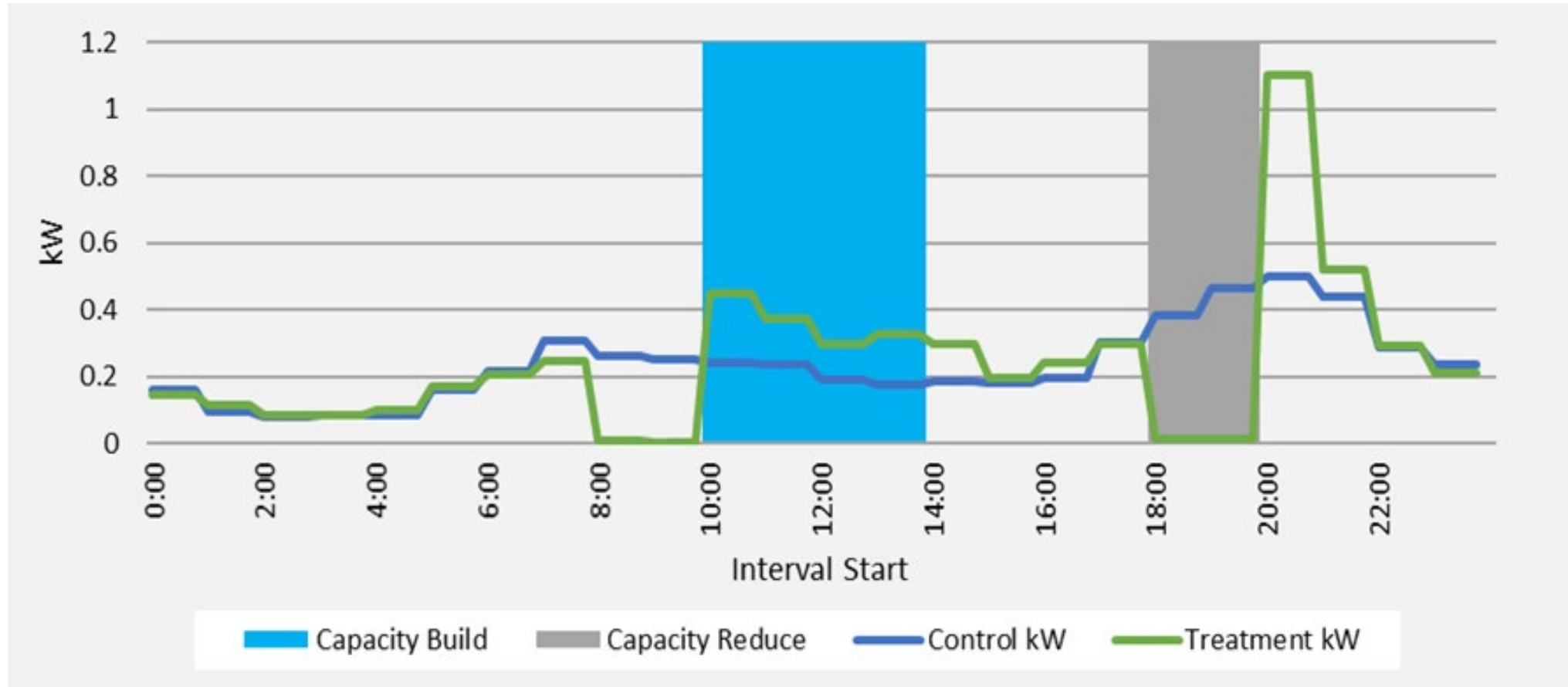
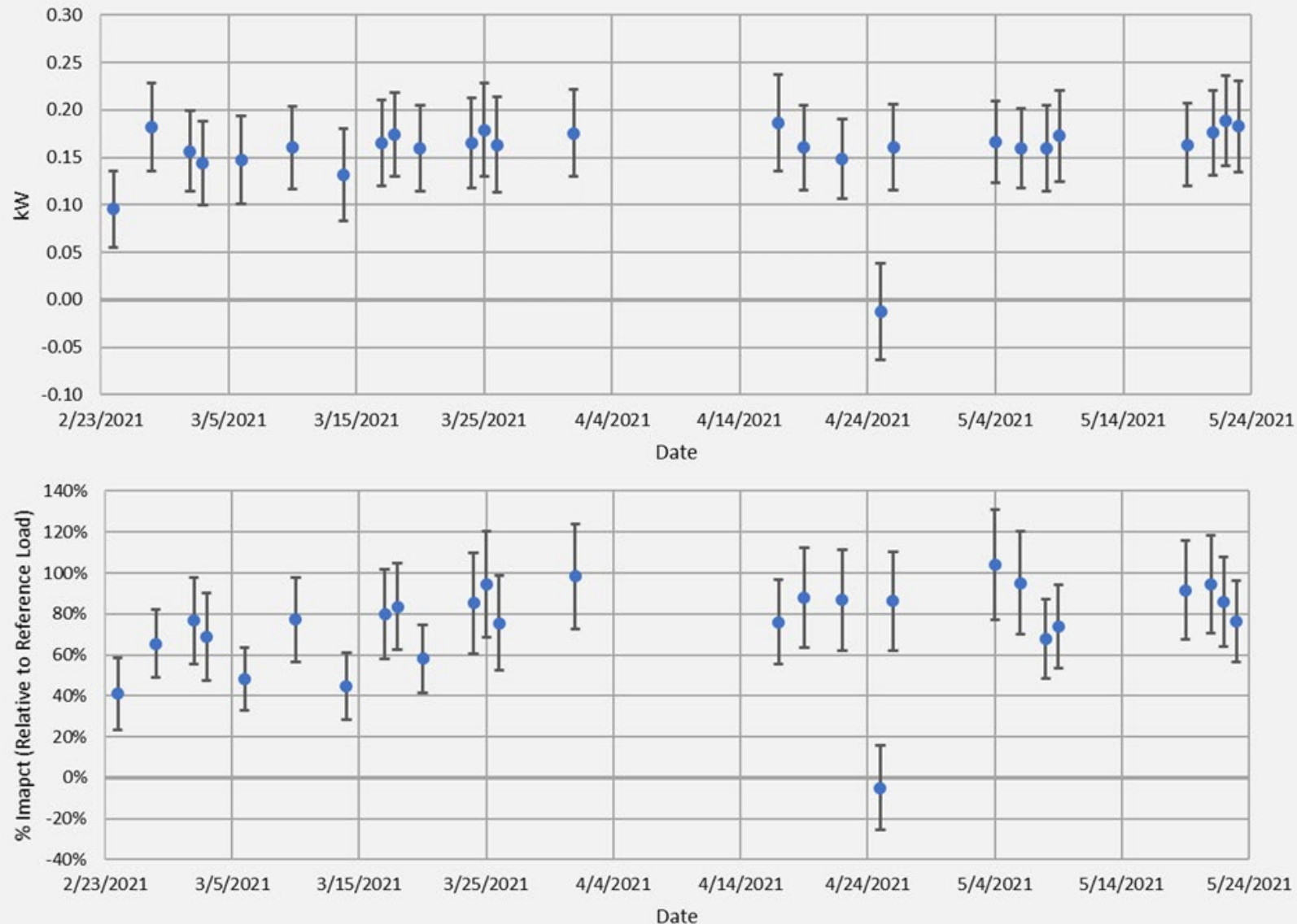


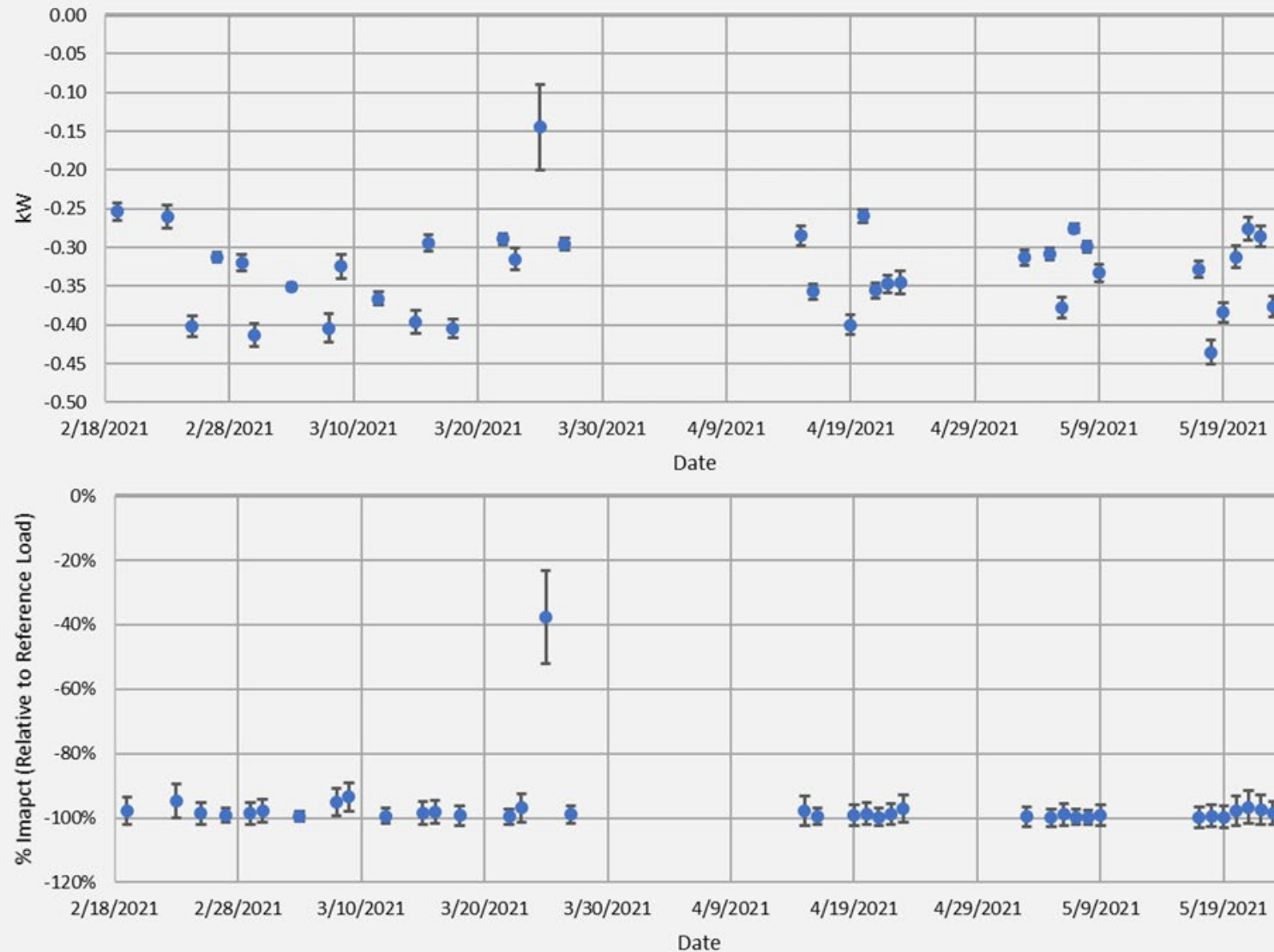
Figure shows unconditional mean electricity demand for water heaters in the RCT treatment and control groups on March 2, 2021. Hourly electricity demand calculated using 15-minute interval water heater electricity demand telemetry data.

Capacity Build Events



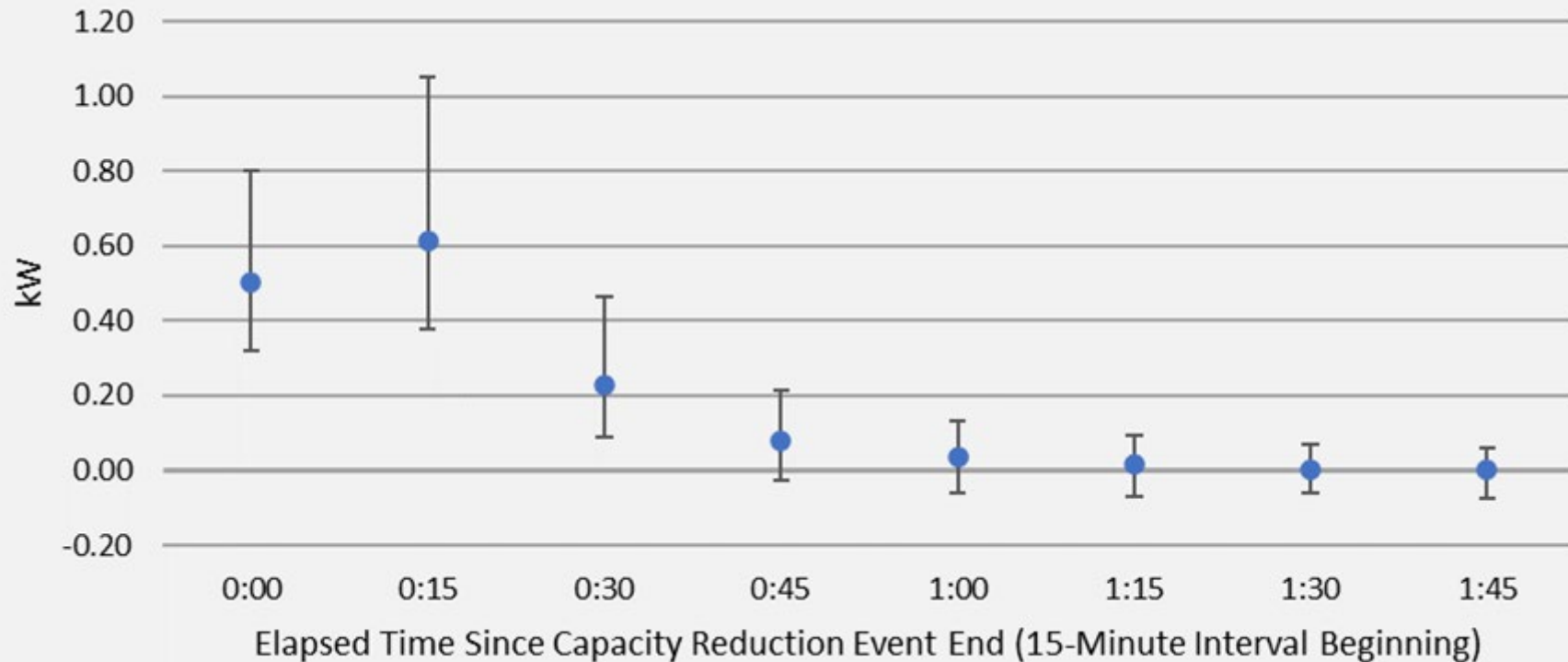
- Average demand impact per WH:
 - 0.159 kW
 - +76% of the reference load
- Consistent delivery
- Some events doubled water heating electricity demand

Capacity Reduction Events



- Average demand impact per WH:
 - -0.321 kW
 - -95% of the reference load
- Consistent delivery
- Reduced electricity demand to near zero

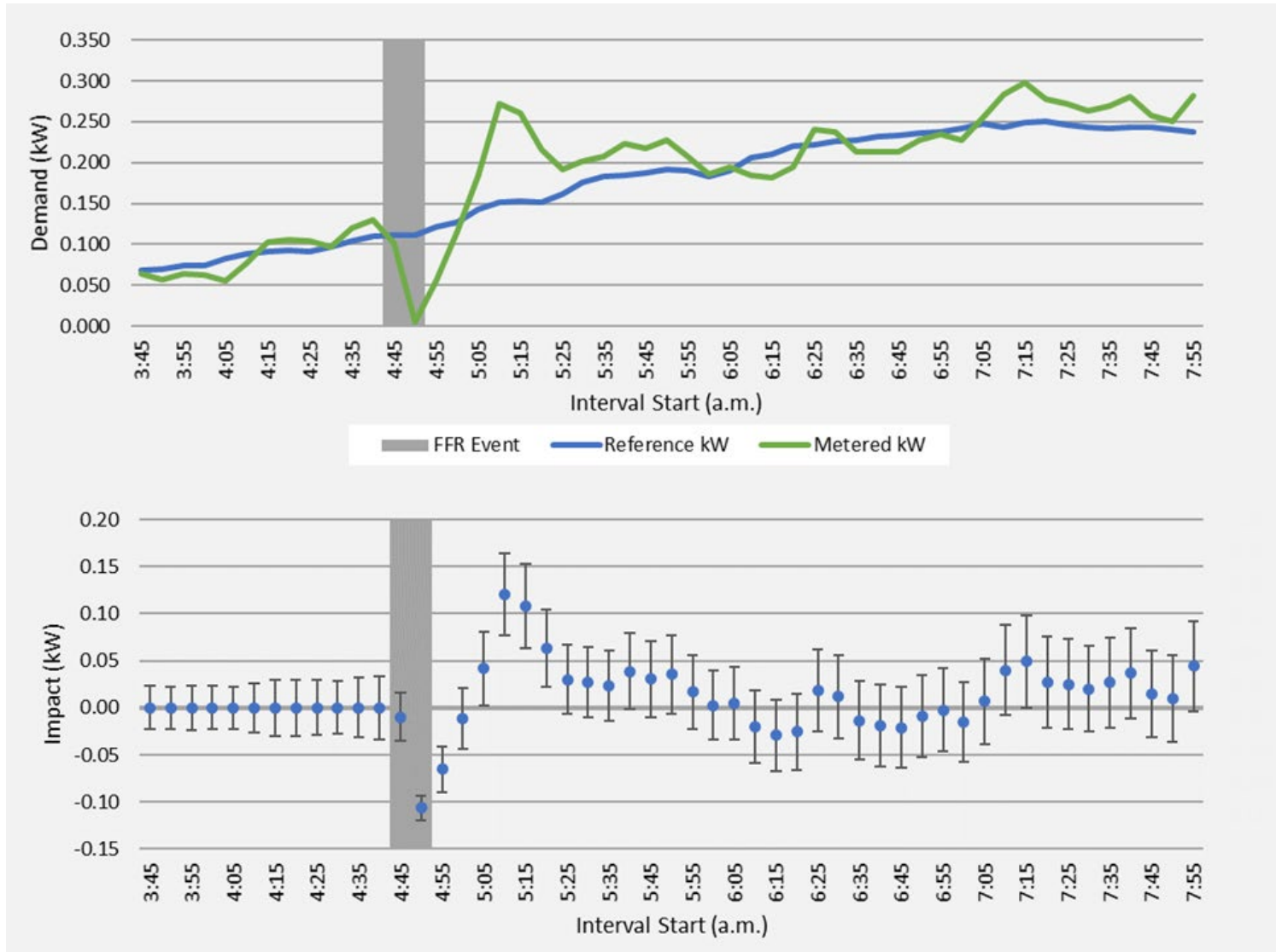
Capacity Reduction Post-Event Snapback



- Average increase in demand per WH in first 30 minutes after event
 - 0.5-0.6 kW
 - >+160% of reference load

Note: Markers show the average increase in electricity demand per water heater after capacity reduction events. The error bars show the 5th and 95th percentiles of the distribution of estimates of snapback across the 37 events.

Fast Frequency Response



- WHs continuously measure frequency of AC
- Event triggered when frequency drops below 59.7 Hz
- Underfrequency event occurred on March 29, 2021 from 4:48:24 a.m. to 4:53:02 a.m.

Forecast Accuracy

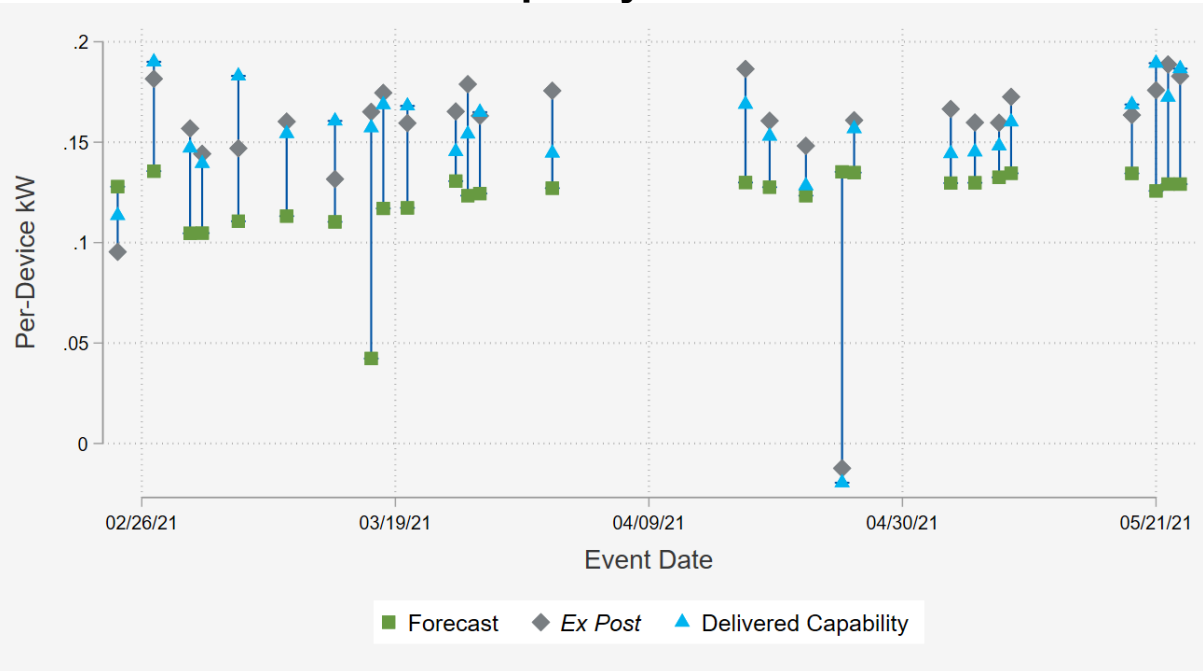
Forecasts of Grid Services Capability

- Aggregator delivers operational forecasts of grid services capability
 - Four-day ahead time horizon
 - 15-minute interval resolution
 - Updated every 12 hours for CB and LR and hourly for FFR
- Proprietary machine-learning algorithms
- Compensation depends on the closeness of delivered to forecasted capability
 - Penalized for errors in forecasting grid services capability

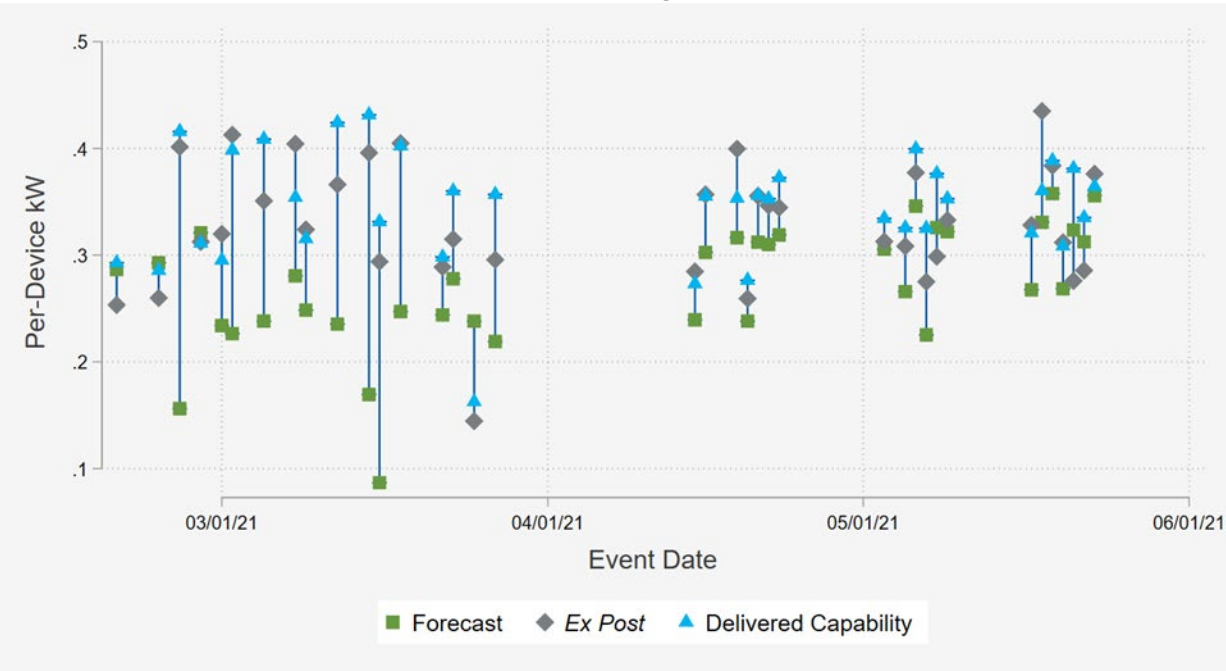
Evaluated Forecast Accuracy

Forecasting accuracy improved during the RCT

Capacity Build



Capacity Reduction



Notes: Forecast is the aggregator forecast of per-device kW capability, ex-post is evaluation estimate of impact based on RCT, delivery capability is the estimate of the kW impact based on the baseline calculation formulas in the GSPA.

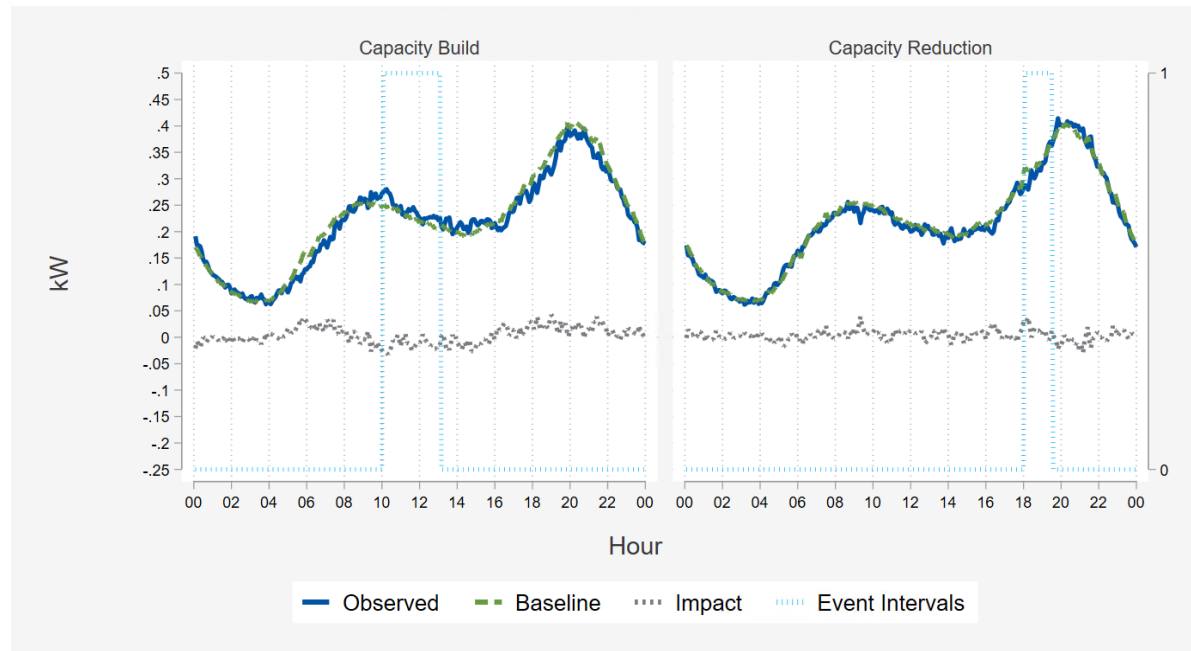
Settlement Calculations Assessment

Accuracy of Settlement Calculations

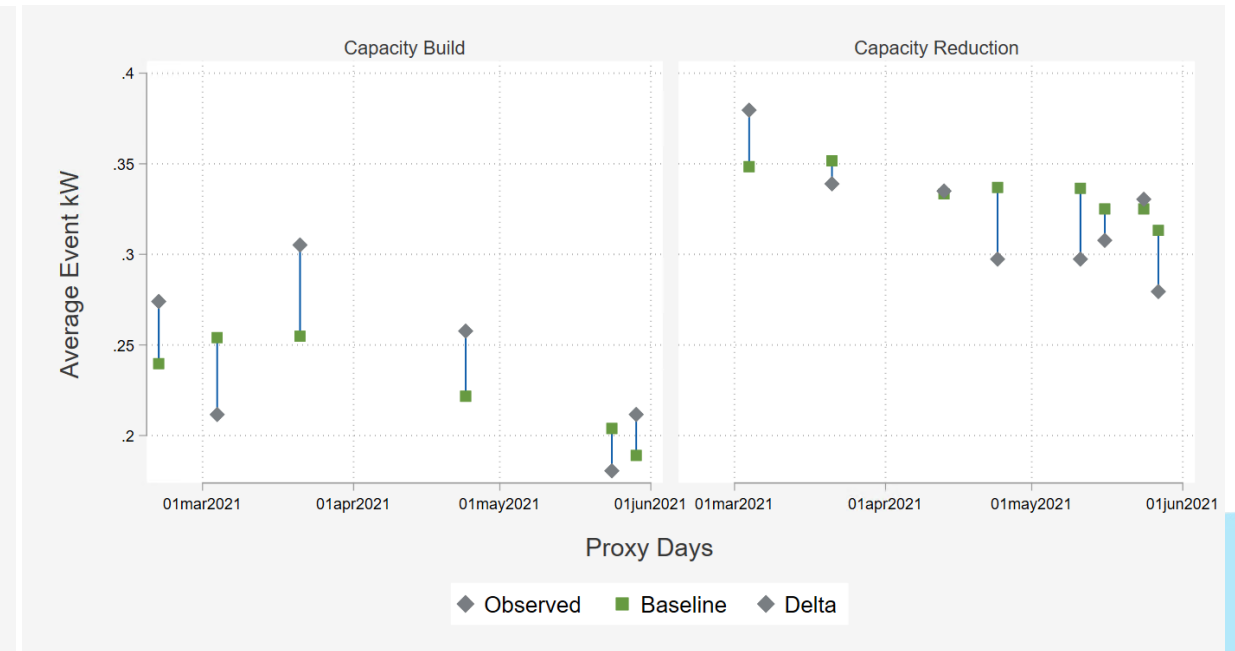
- GSPA #1 specifies methods for calculating baseline demand
 - CB and CR: 10-of-10 similar day baseline
 - FFR: demand in 5-minute interval immediately preceding event
- Do the prescribed methods yield accurate estimates of delivered capability?
- Evaluation approach
 - Simulated events on similar non-event (“pseudo-event”) days
 - Demand impacts expected to be zero if baseline calculation methods are accurate

Settlement Accuracy Simulation

10-of-10 baseline methods work well



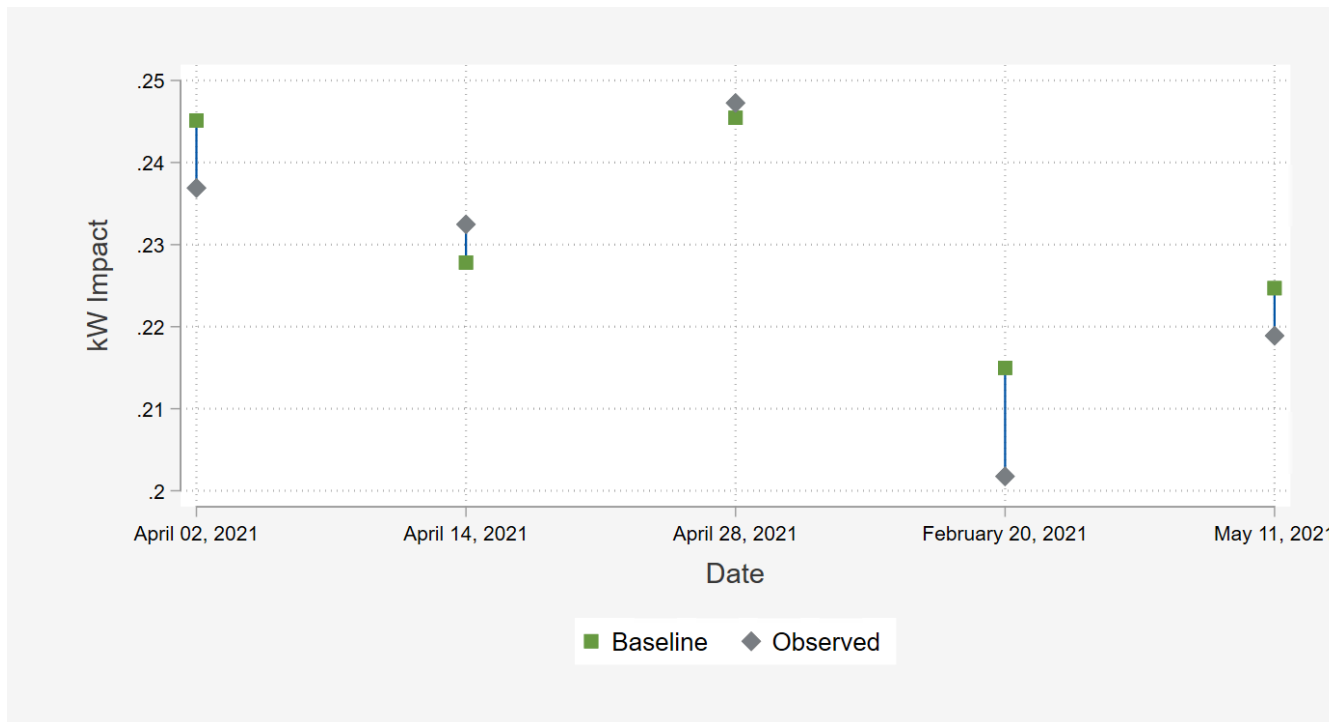
Baselines perform well on the average pseudo-event day



Baselines do not consistently over- or under-predict the loads. Magnitude of errors is relatively consistent

Settlement Accuracy Simulation

Interval-prior baseline methods work well for FFR events



- Slight tendency for the baselines to be biased upward
- Magnitude of these differences are small

Conclusions

Summary of Key Findings

- In general, **capacity build events** greatly increased water heater electricity demand relative to baseline demand
- During most **capacity reduction events**, water heating electricity demand nearly reduced to zero, showing most water heaters that would have been operating remained off
- **FFR** decreased water heating electricity demand in response to detection of an underfrequency event
- Accuracy of **grid services forecasts** improved
- The **baseline calculation methods** prescribed in the GSPA are sufficiently accurate for the measurement of grid service impacts

Scaling DR Grid Services

- Due to pandemic, HECO DR grid services enrollment and capability were and remain lower than expected. But...
- The forecasting, delivery, and settlements for O'ahu WH demand response grid services largely went as expected
- Question: Can aggregators acquire enough capacity to meet their commitments under this and future GSPAs while keeping the DR grid services cost-effective?

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Thank You

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2021 Impact Evaluation Report:

<https://dms.puc.hawaii.gov/dms/DocumentViewer?pid=A1001001A21K24B43239G03480>