



Managing Uncertainty and Flexibility in Day-ahead Electricity Markets

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2023 ESIG Meteorology & Market Design for Grid Services
Workshop

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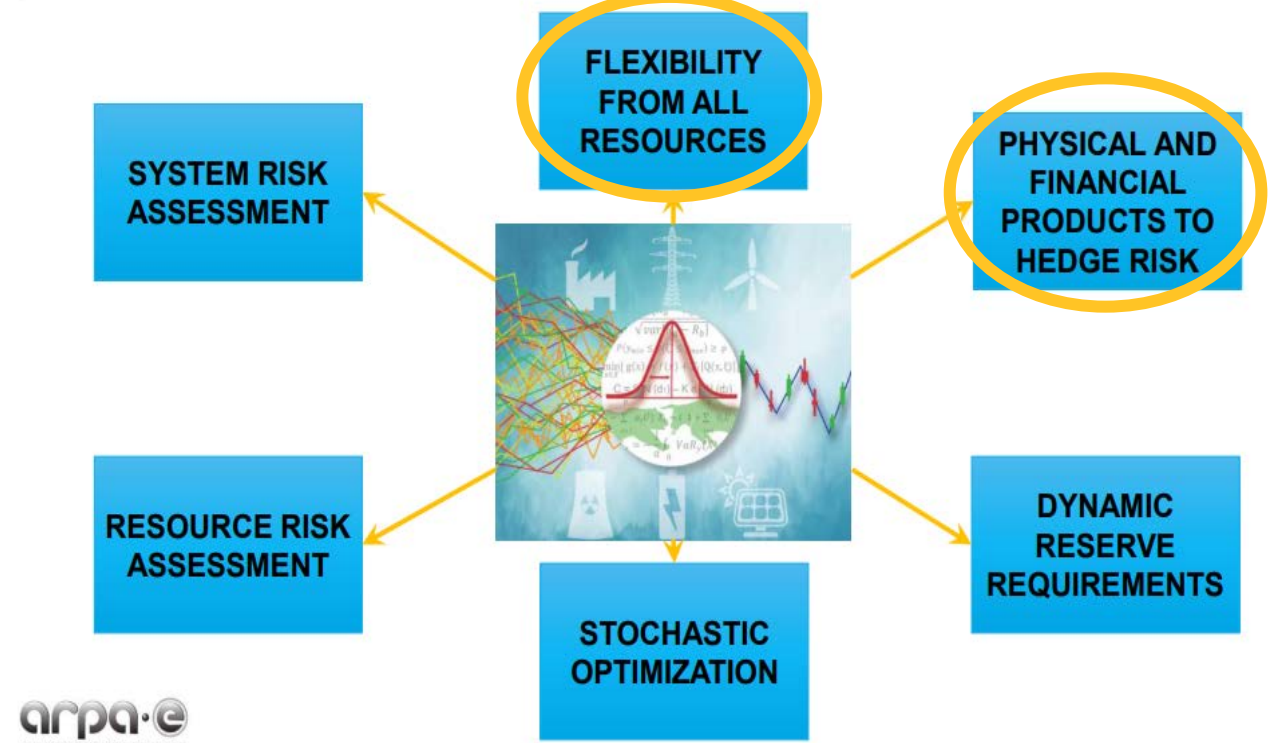
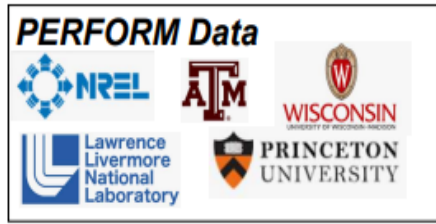
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PERFORM: Risk-Aware Grid Management



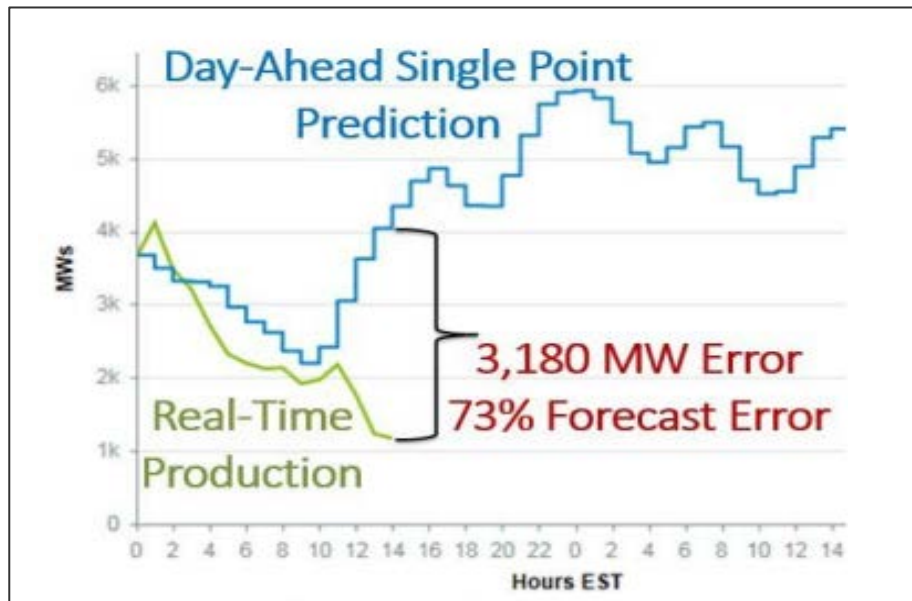
Source: https://arpa-e.energy.gov/sites/default/files/2021-02/ARPA-E%20Intro_PERFORM%20Kickoff_Final.pdf

ARPA-E PERFORM Program Overview

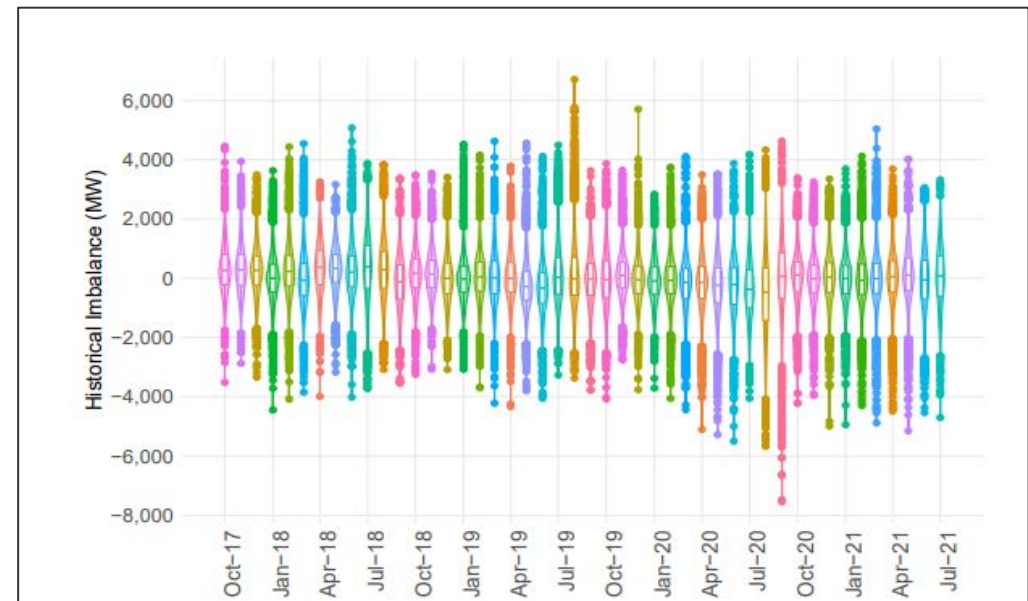
Net Load Imbalance Risk

Net Load = Load – Variable Renewable Generation

Net Load Imbalance = **Real Time** Net Load – **Day-ahead** Net Load

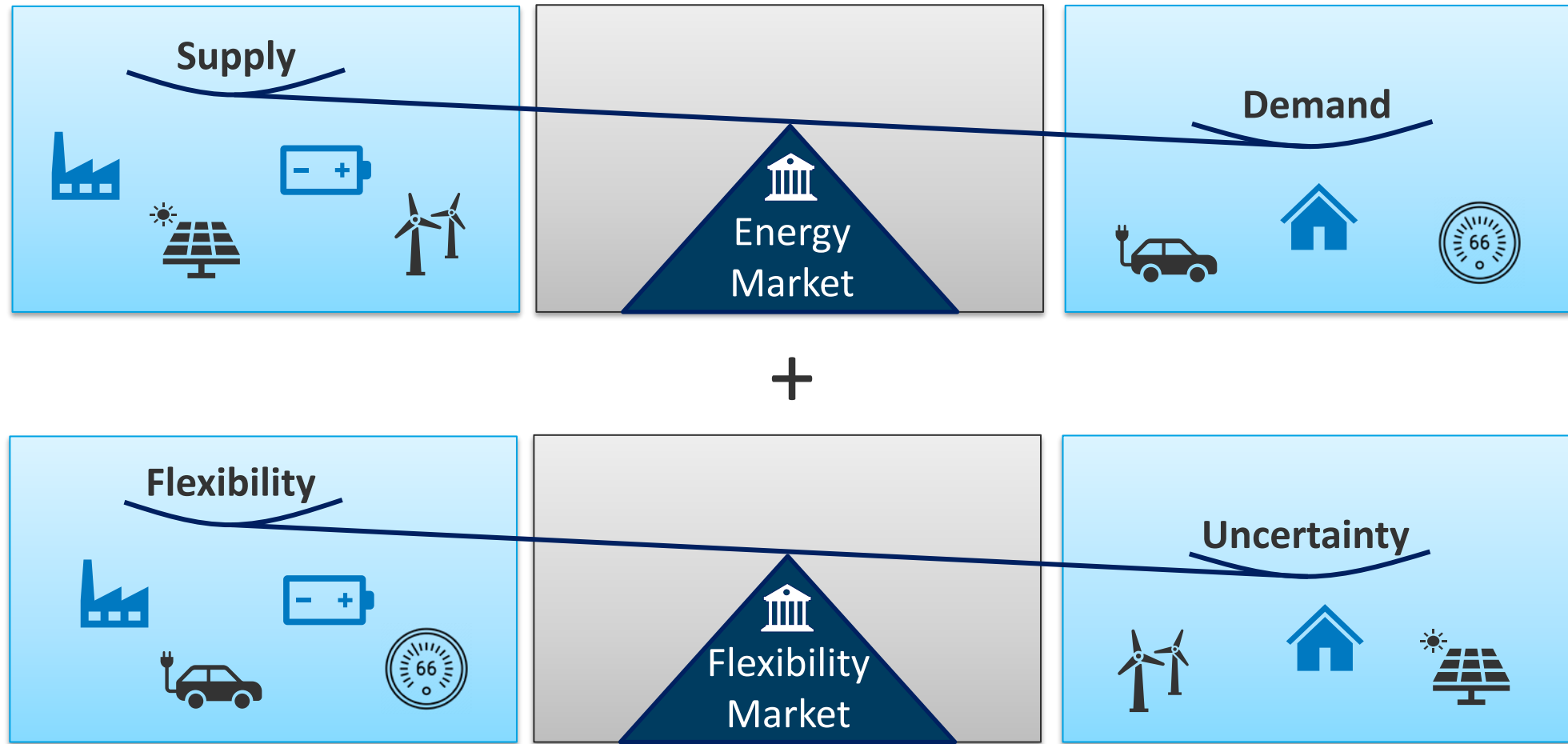


MISO Day-Ahead Renewable Forecast versus Real-Time Production, 6/26/19



CAISO historical net load imbalances within 4 GW range

To manage net load imbalance, match uncertainty with flexibility



Flexibility Options

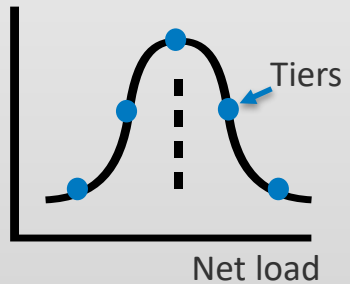
Flexibility Options

- We design an ISO market product called **flexibility options**
 - Uses **probabilistic forecasts** to determine flexibility requirements
 - **Strike prices** determine the cost (and value) of flexibility
 - Co-optimized within the **day-ahead market**

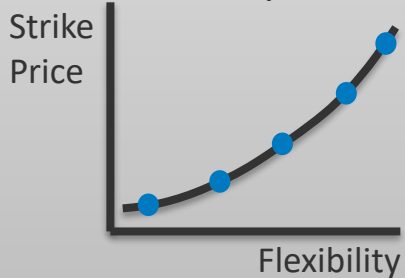


Day-ahead bidding

Buyers submit probabilistic forecast



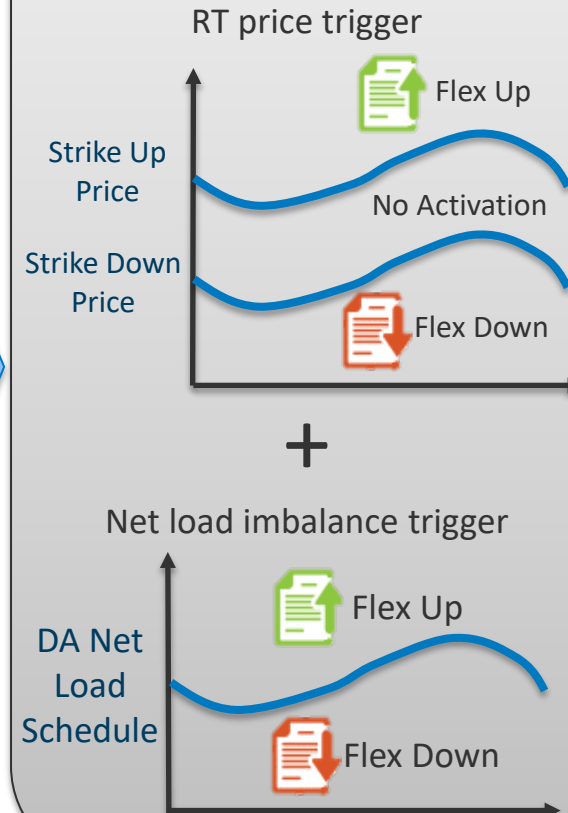
Sellers submit flexibility curve



Day-ahead market

- ISO co-optimizes energy and flexibility products
- Flexibility option outputs:
 - Option premium
 - Option quantity
 - Strike price
- Multiple “tiers” for up and down flexibility

Real time activation



Financial settlement

- Buyer pays option premium
- If activation occurs, seller pays the difference between strike and RT price
- Revenue neutral for ISO
- Lowers revenue volatility for buyers and sellers

Flexibility Market Process

Potential Benefits of Flexibility Options

- Sellers can:
 - Schedule flexible resources in DA market, like energy resources
 - Provide consistent revenue stream from option premium
- Buyers can:
 - Hedge risk from forecast uncertainty
 - Hedge risk from real time price spikes
- The ISO can:
 - Commit resources day-ahead based on uncertainty
 - Reduce total system costs
 - Create market-based value of flexibility

Product Comparison

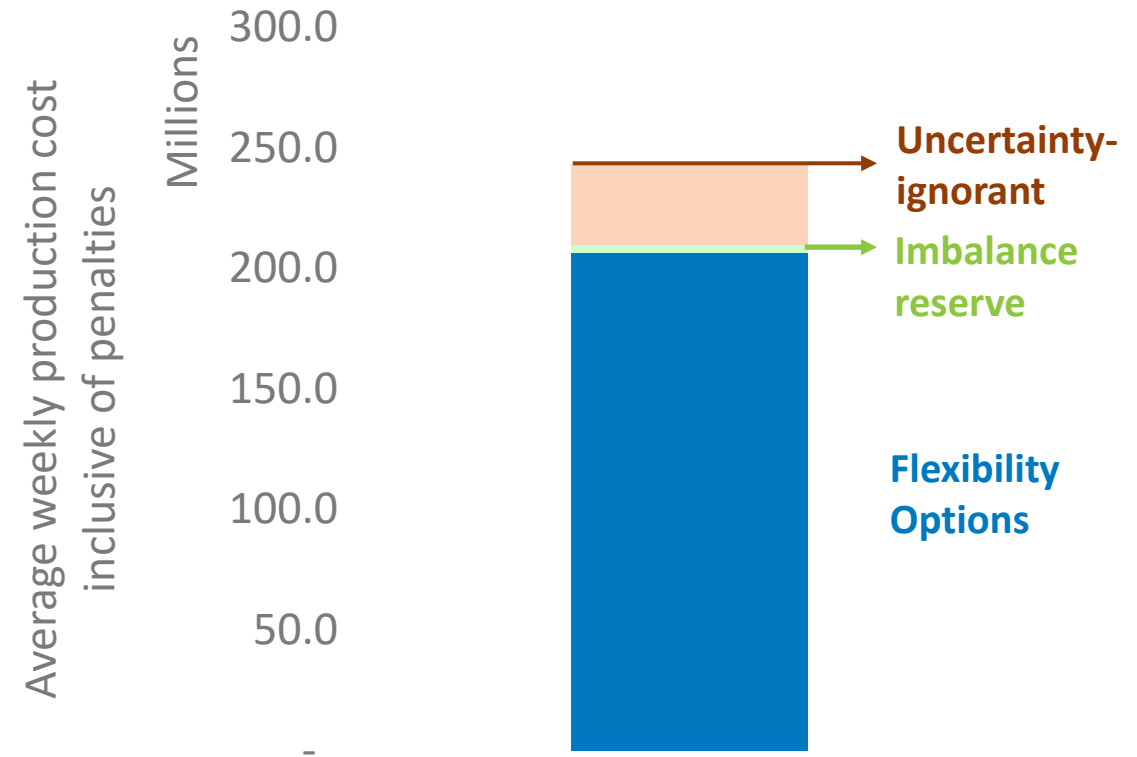
	Hedges real time prices	Creates price on flexibility	Supports flexible commitments	Considers forecast uncertainty	Incorporates cost causation
Virtual Bidding (all ISOs)	✓				
Flexible Ramping Product (CAISO, MISO, SPP)		✓	✓	✓ (RT only)	
Imbalance Reserves (CAISO DAME proposal)		✓	✓	✓	
Flexibility Options (proposed product)	✓	✓	✓	✓	✓

Market Simulation Results

- Simulations with Flexibility Options:
 - Reduced total system costs
 - Increased the number of units committed
 - Reduced redispatch costs compared to Imbalance Reserve case
- Used 7k node ERCOT system model
 - Used FESTIV software
 - 12 characteristic weeks
 - Data from PERFORM partners



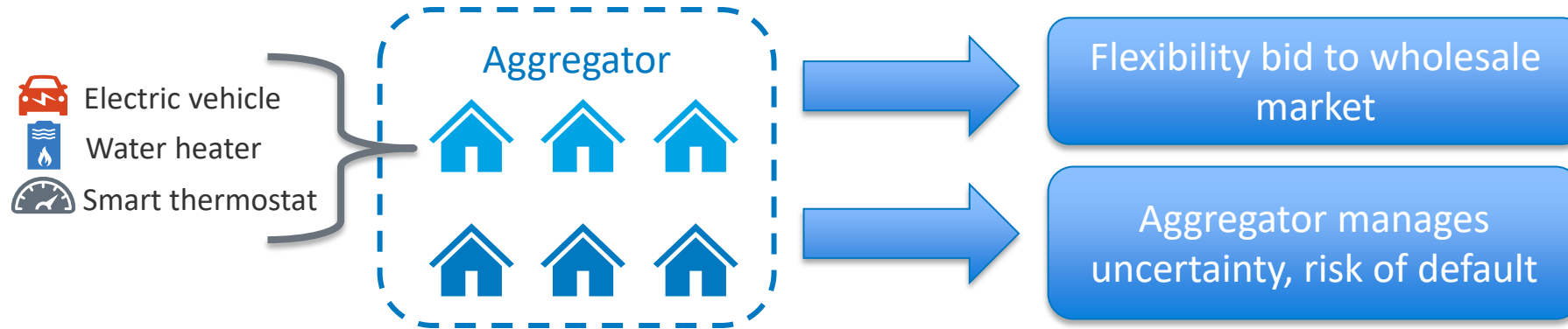
~**1.7%** cost savings when Flexibility Options compared to *Imbalance Reserve-like* framework



DER Market Participation

DER Market Participation

- DER Aggregators can **provide flexibility** to the wholesale market
- Flexibility is reduced due to **uncertainty from occupant behavior and weather**

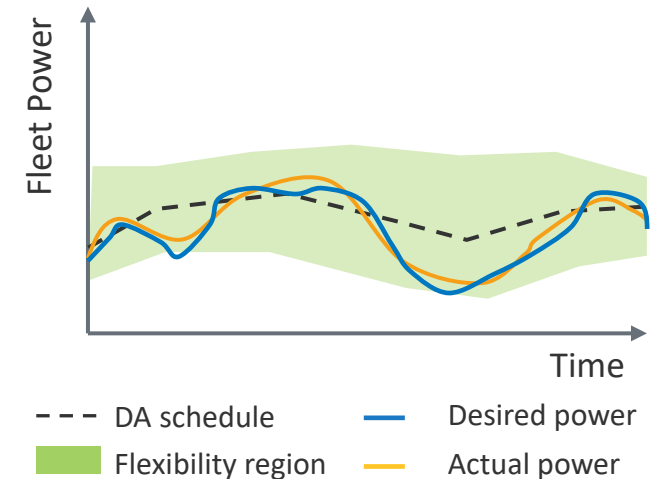


- More efficient flexibility procurement if DERs are aggregated into multiple fleets
- Fleets may have different flexibility profiles or different levels of uncertainty



How much flexibility to offer?

- Maximize market revenue from:
 - Flexibility options
 - Real time market
 - Delivery penalty costs
- 2-stage stochastic optimization problem with uncertainty in:
 - Real time prices (and flexibility activations)
 - Baseline (uncontrolled) energy consumption
- Flexibility constrained by a “Virtual Battery Model”
 - Baseline power based on behavior and weather
 - Energy constraints based on occupant comfort
 - Power constraints based on equipment ratings



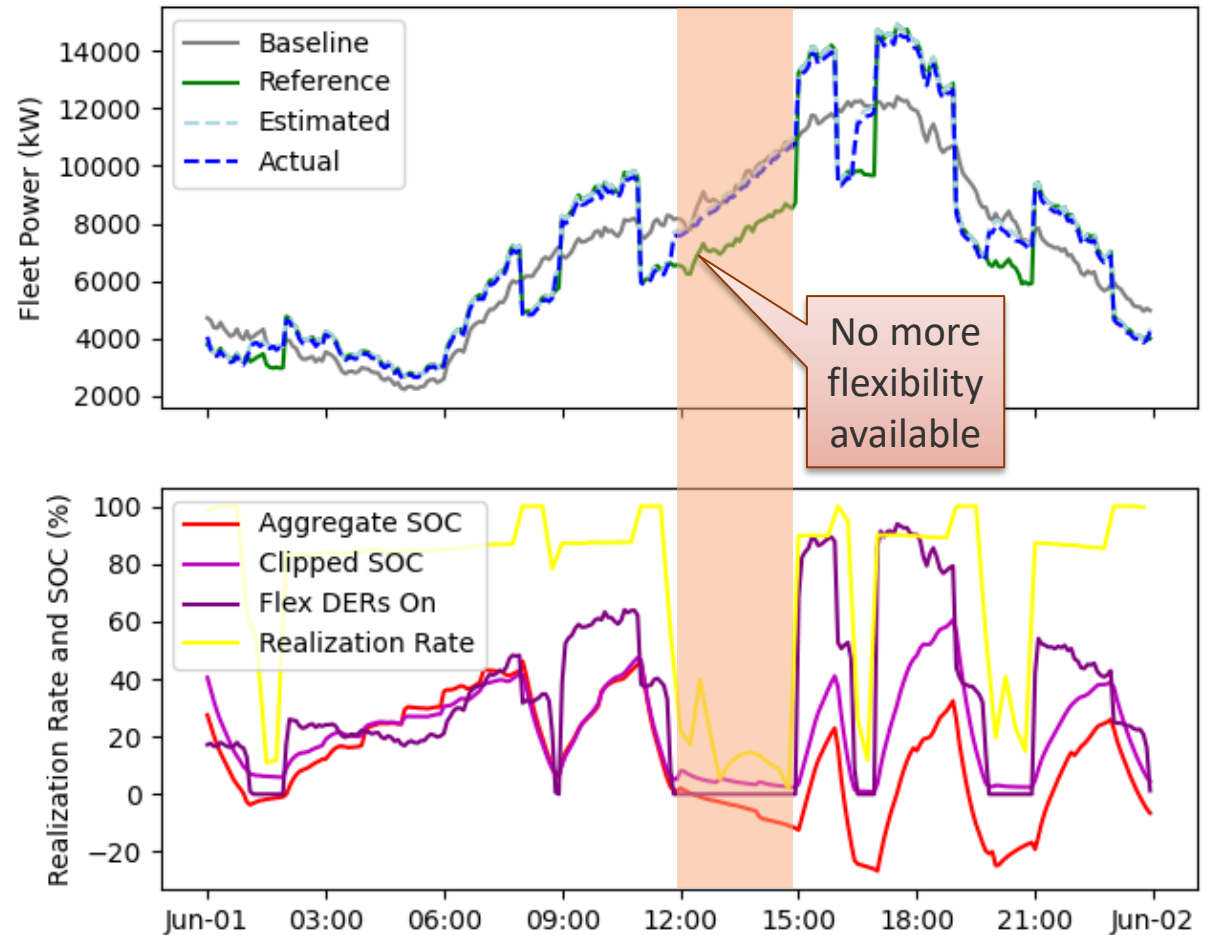
$$E[t + 1] = E[t] + \eta(P[t] - \tilde{P}_{base}[t])\Delta t$$

$$E_{min}[t] \leq E[t] \leq E_{max}[t]$$

$$P_{min}[t] \leq P[t] \leq P_{max}[t]$$

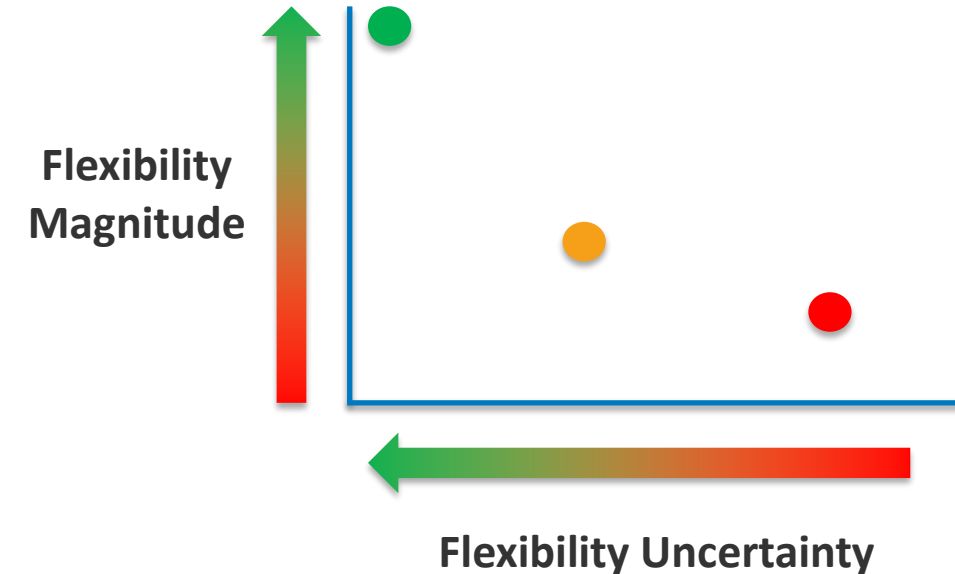
HVAC Fleet Results

- DER aggregator:
 - Determines **desired (reference) fleet power** based on baseline and flexibility activations
 - **Dispatches DERs** to achieve desired power
 - Tracks fleet’s “state of charge”
 - Can’t achieve desired power when **comfort limits** are reached
- Simulations model:
 - 2000 representative houses
 - Hot summer day in Dallas, TX
 - Data from NREL’s ResStock and OCHRE tools



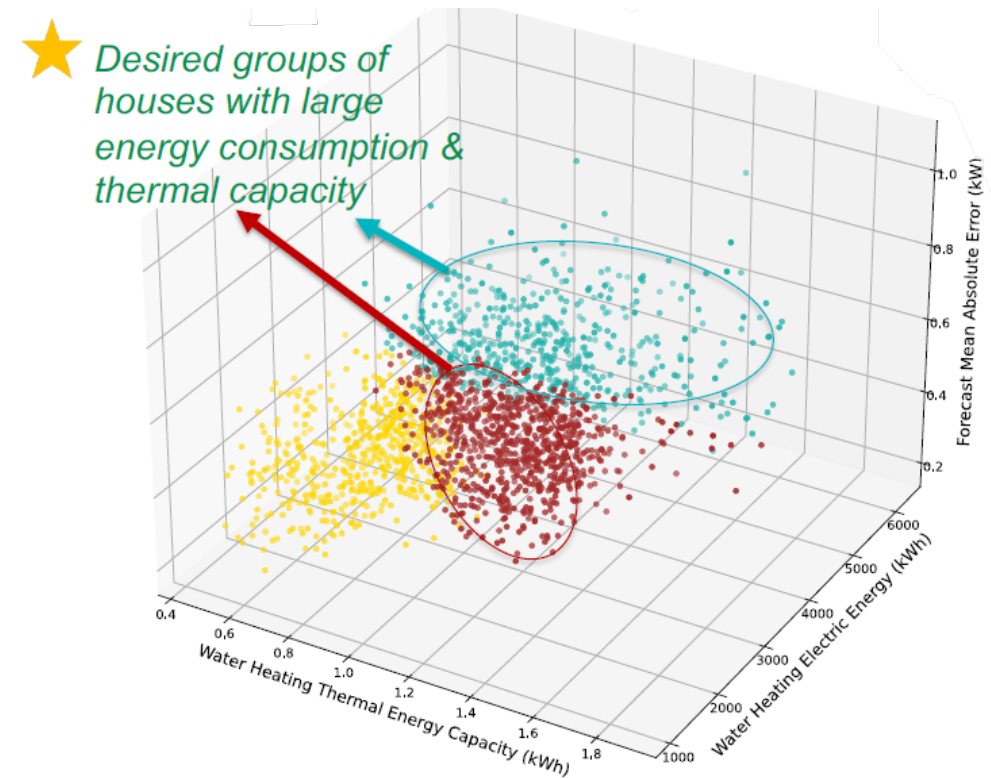
DER Flexibility Score

- Aggregators need a simple method to convey the value of a DER with a customer or occupant
 - For customer outreach/enrollment
 - For calculating incentives/compensation
- A DER flexibility score depends on:
 - The **magnitude** of the DER's estimated flexibility
 - The **reliability** of the DER, e.g., probability of delivery



DER Score Results

- Scores for water heaters based on:
 - Annual energy consumption
 - Thermal capacity (i.e., water tank size)
 - Forecast error (based on day-ahead load forecast)
- Plan to simulate clusters as separate DER fleets and compare:
 - Flexible capacity
 - Realization rate
 - Aggregator revenue



Summary

- Match **Uncertainty** with **Flexibility**
- **Flexibility Options** in day-ahead markets can:
 - Manage net load imbalance risk
 - Hedge risks for buyers and sellers
 - Lower total system costs
- Enabling **DER flexibility** requires:
 - Managing uncertainty from behavior and weather
 - Simple “DER scores” to convey value to customers

Thank you

www.nrel.gov

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