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Managing Uncertainty and Flexibility in Day-ahead Electricity Markets

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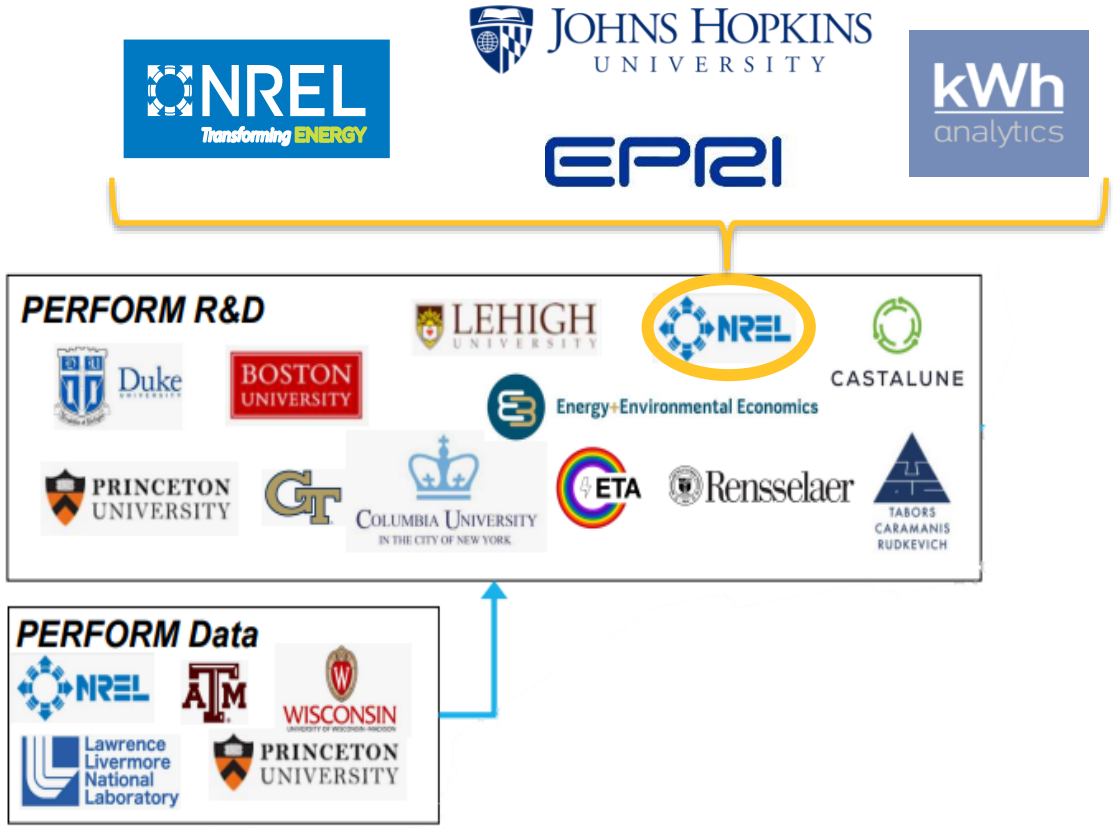
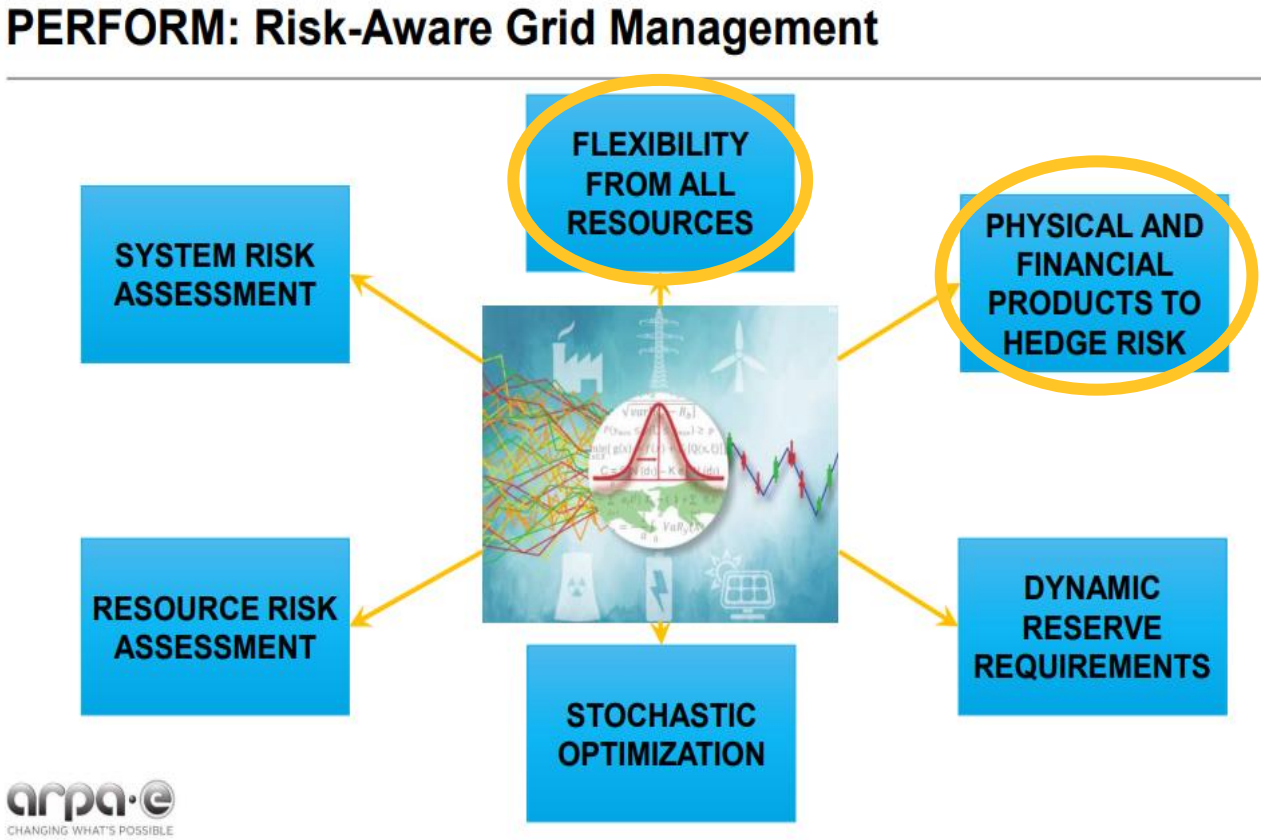
2023 ESIG Meteorology & Market Design for Grid Services Workshop

- Background
- Flexibility Options
- DER Market Participation
- Preliminary Results





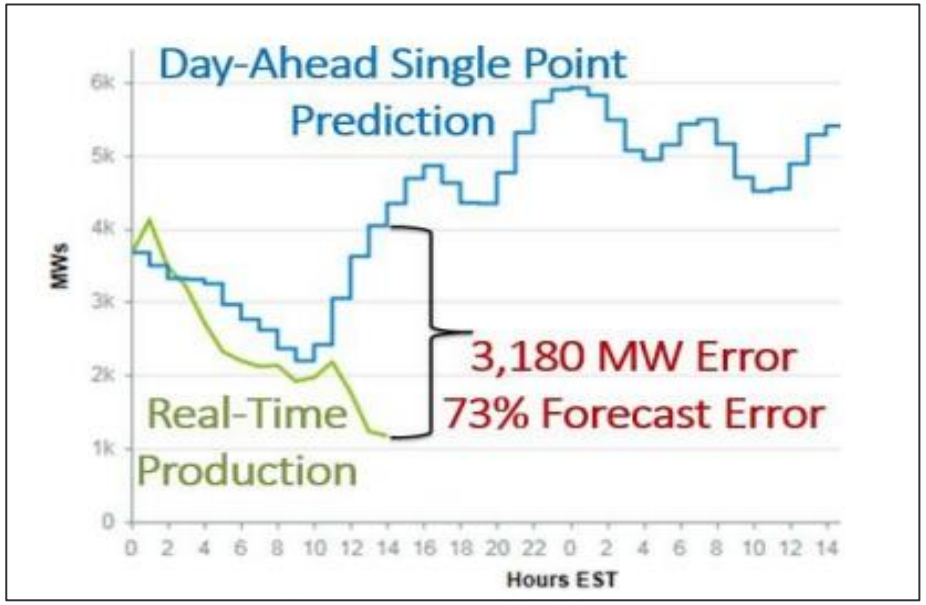
Source: https://arpa-e.energy.gov/sites/default/files/2021-02/ARPA-E%20Intro_PERFORM%20Kickoff_Final.pdf

ARPA-E PERFORM Program Overview

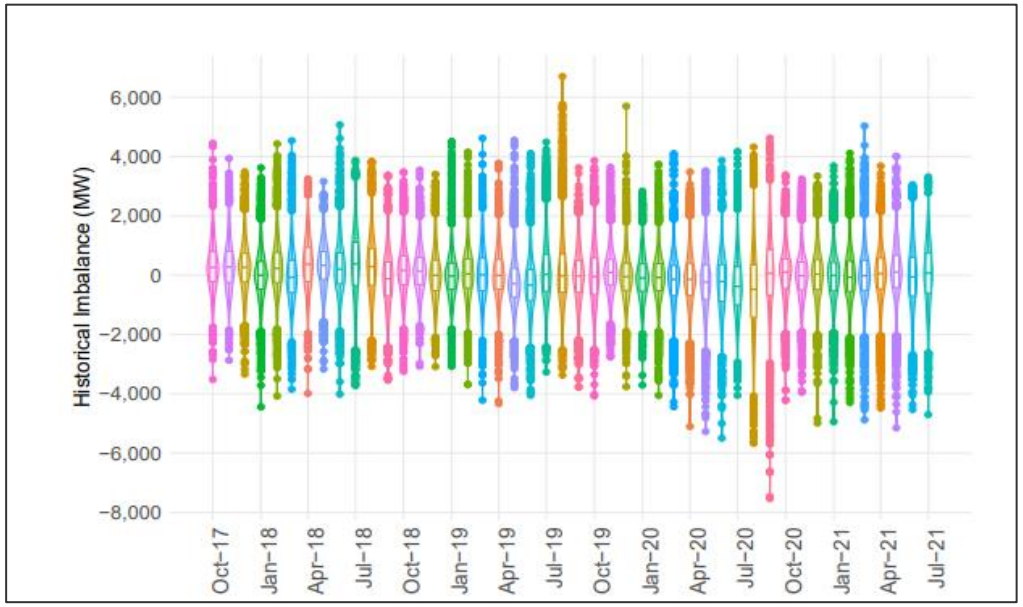
Net Load Imbalance Risk

Net Load = Load – Variable Renewable Generation

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



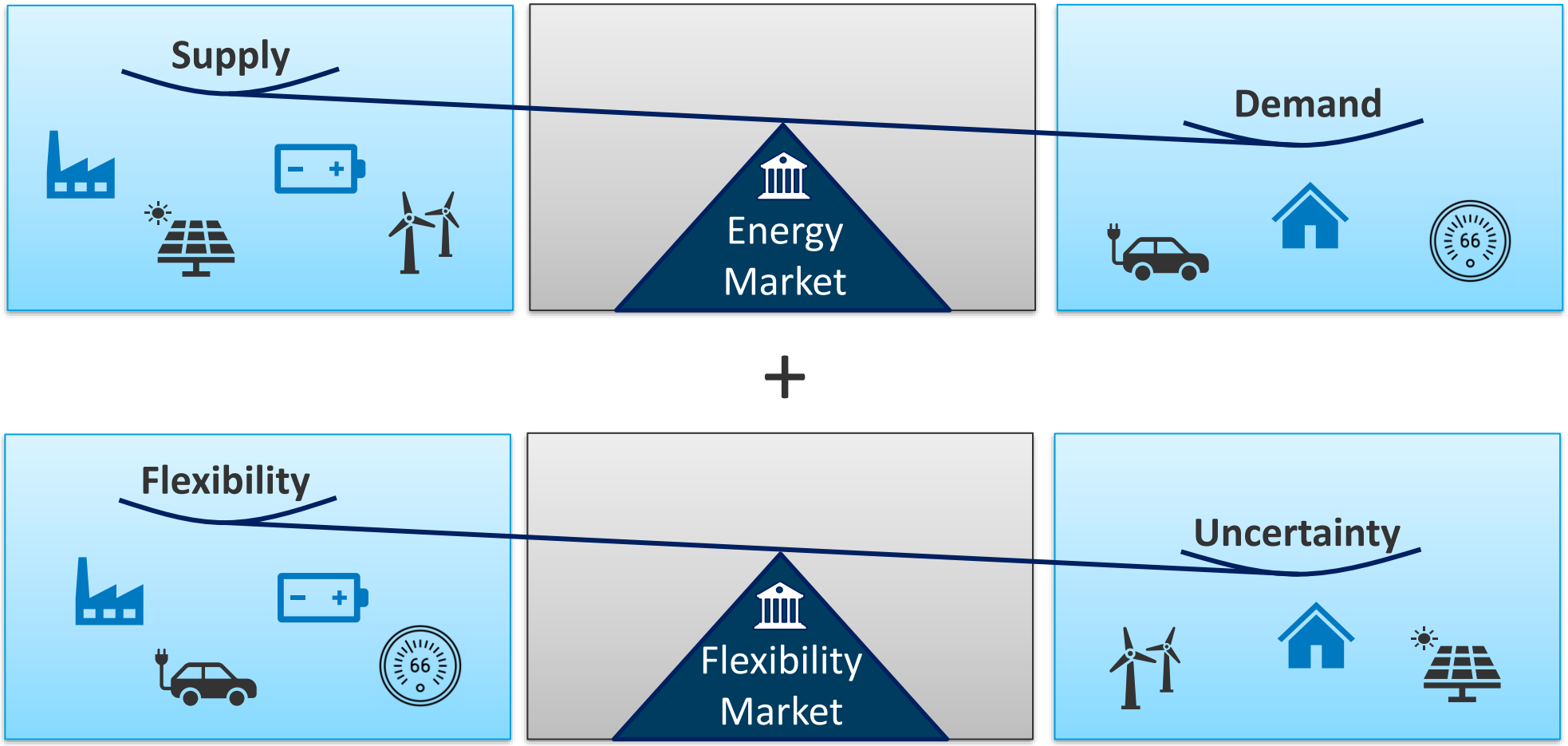
MISO Day-Ahead Renewable Forecast versus Real-Time Production, 6/26/19



CAISO historical net load imbalances within 4 GW range

Source: ARPA-E Performance-based Energy Resource Feedback, Optimization, And Risk Management (PERFORM) FOA; CAISO Day-Ahead Market Enhancements Third Revised Straw Proposal (Apr. 2022); CAISO Energy Markets Price Performance Report (Sep. 2019)

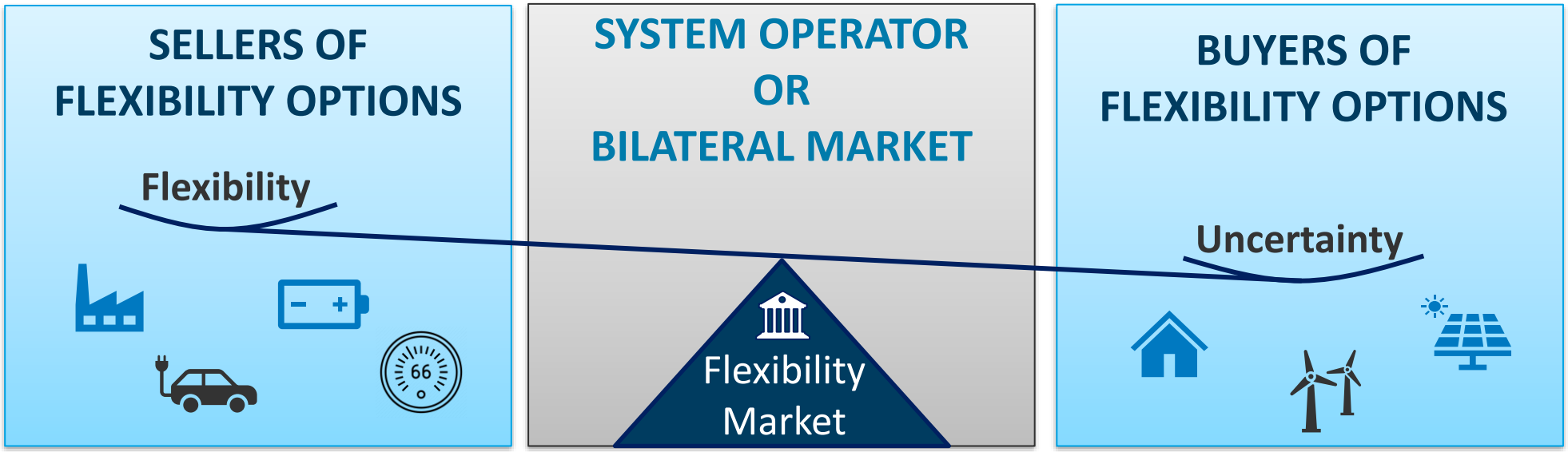
To manage net load imbalance, match **uncertainty** with **flexibility**



Flexibility Options

Flexibility Options

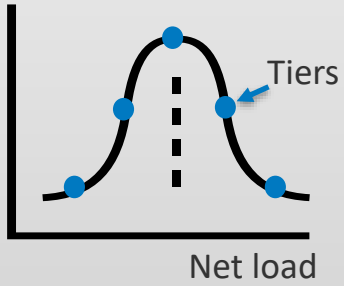
- We propose an ISO market product called **flexibility options**
  - Uses **probabilistic forecasts** to determine flexibility requirements
  - **Strike prices** determine the cost (and value) of flexibility
  - Co-optimized within the **day-ahead market**



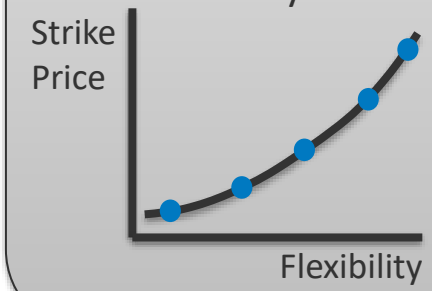
Flexibility Market Process

Day-ahead bidding

Buyers submit **probabilistic** forecast



Sellers submit flexibility curve

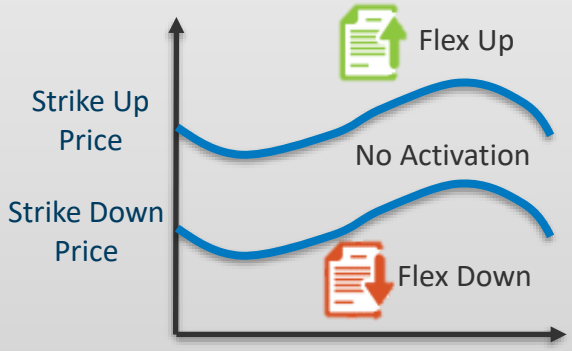


Day-ahead market

- 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

RT price trigger



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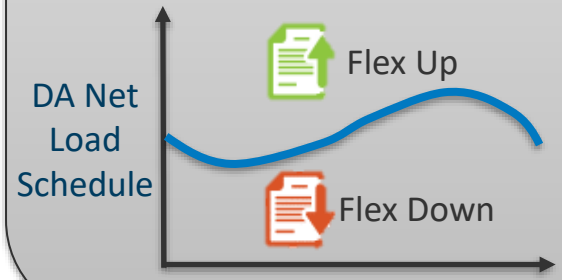
Net load imbalance trigger



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

Why use Flexibility Options?

- Benefits to sellers:
  - Schedule flexible resources in DA market, like energy resources
  - Provide consistent revenue stream from option premium

- Benefits to buyers:
  - Hedge risk from forecast uncertainty
  - Hedge risk from real time price spikes

- Benefits to ISO/system:
  - Commit resources day-ahead based on uncertainty
  - Reduce total system costs
  - Create market-based value of flexibility

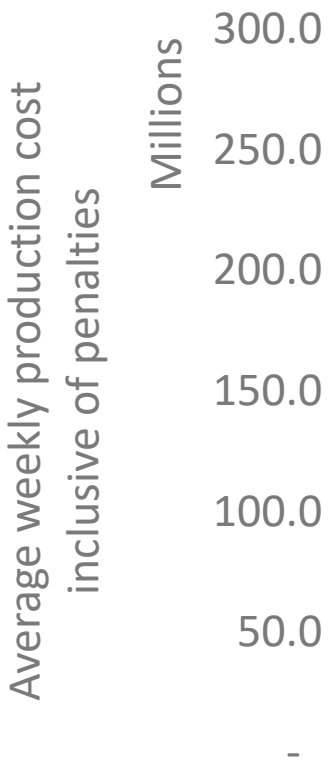
Product Comparison

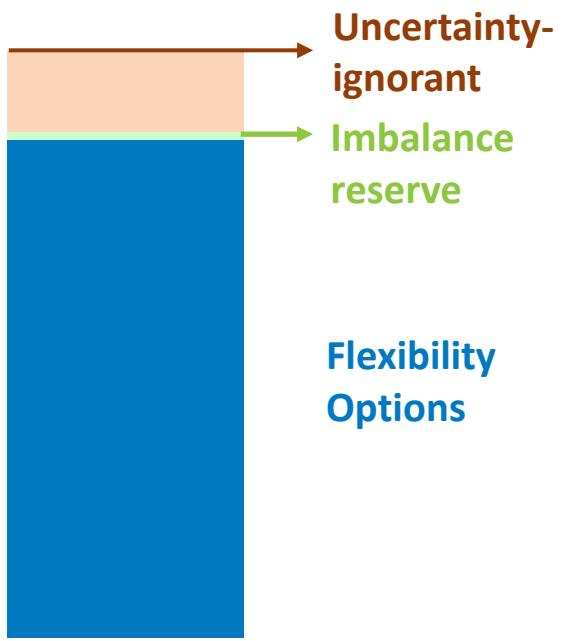
	Hedges real time prices	Creates price on flexibility	Supports flexible commitments	Considers forecast uncertainty	Incorporates cost causation
Virtual Bidding (all ISOs)	✓				
Flexible Ramping Product (CAISO, MISO, SPP)		✓	✓	✓ (RT only)	
Imbalance Reserves (CAISO DAME proposal)		✓	✓	✓	
Flexibility Options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

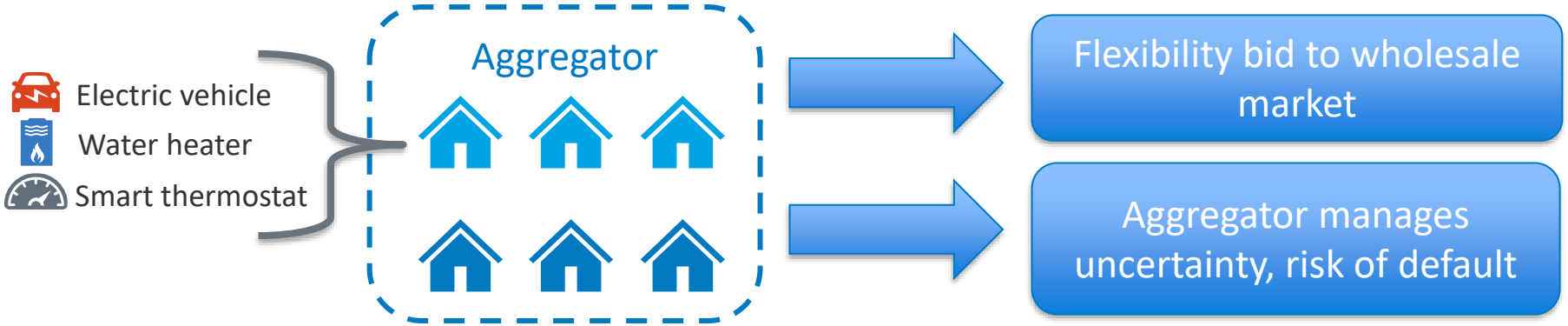




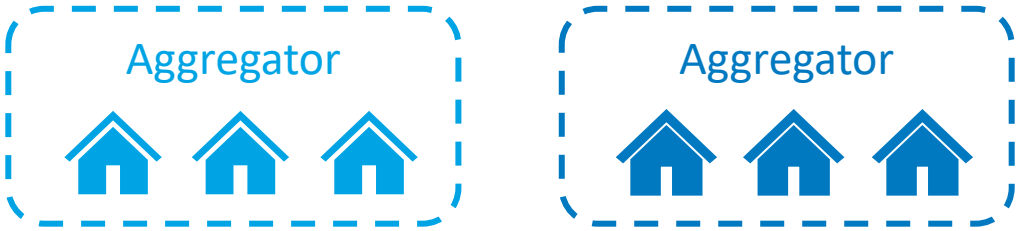
DER Market Participation

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

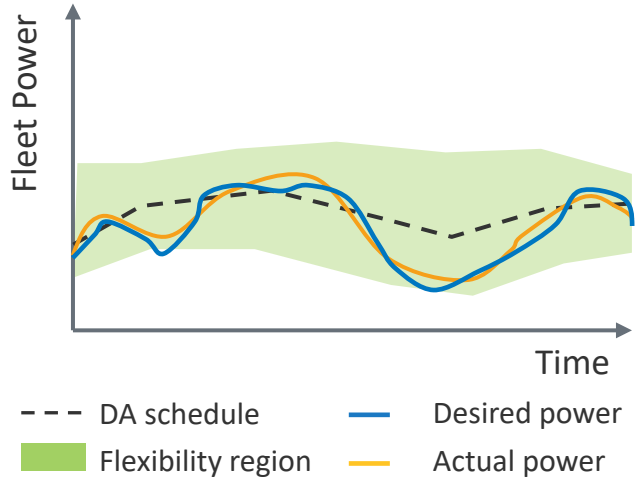


How much flexibility to offer?

- 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



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

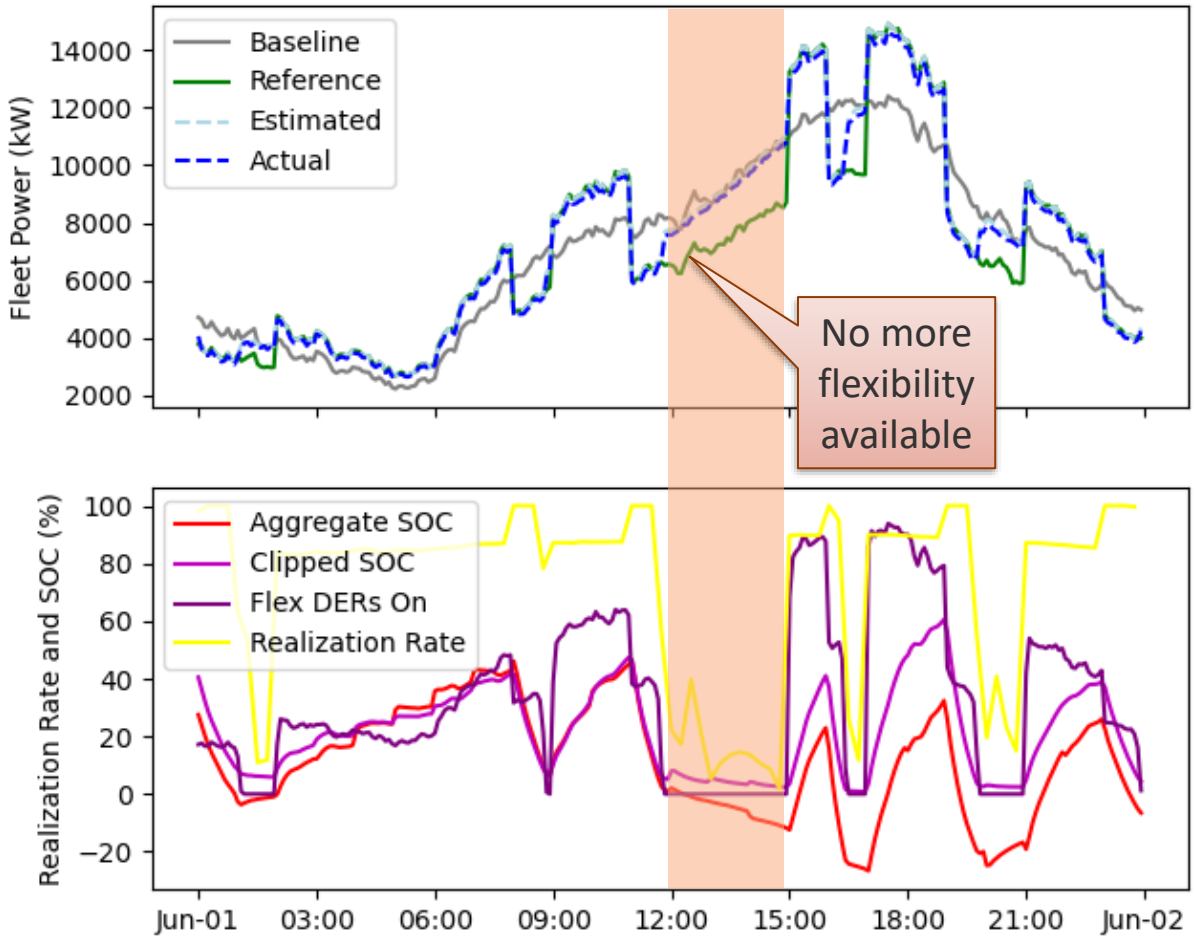
$$E_{min}[t] \leq E[t] \leq E_{max}[t]$$

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

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

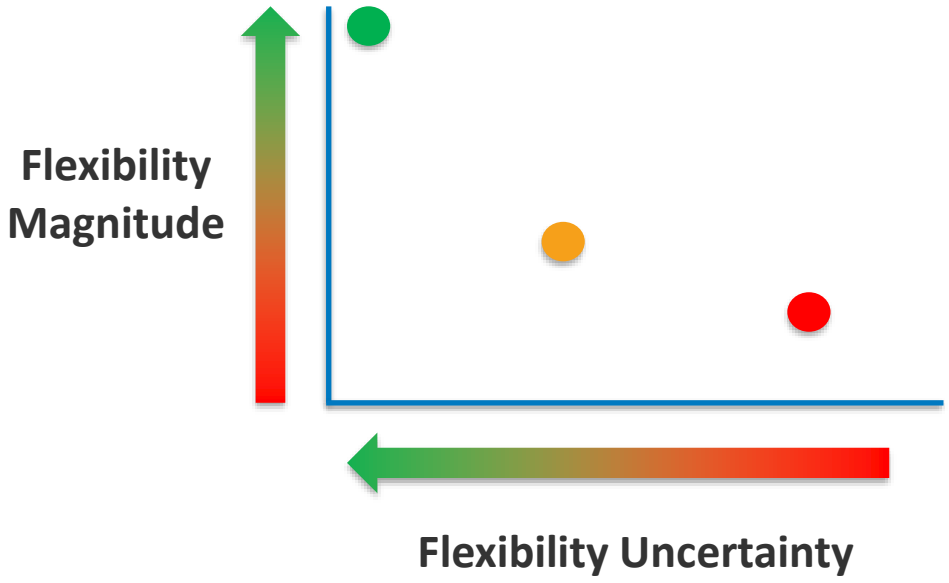
- Simulations model:
  - 2000 representative houses
  - Hot summer day in Dallas, TX
  - Data from NREL's ResStock and OCHRE tools



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

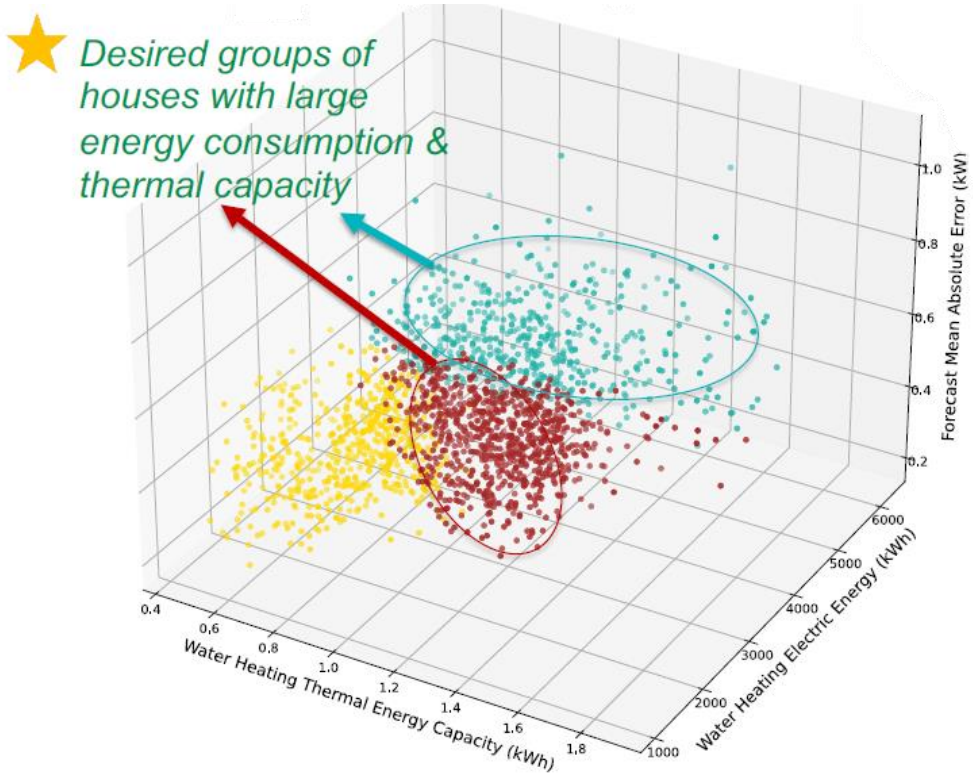
- A DER flexibility score depends on:
  - The **magnitude** of the DER's estimated flexibility
  - The **reliability** of the DER, e.g., probability of delivery



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

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