DESTION 2021 WORKSHOP
MAY 18, 2021

Transactive Energy and Solarization: Assessing the Potential for Demand Curve Management and Cost Savings

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Acknowledgement for Support:

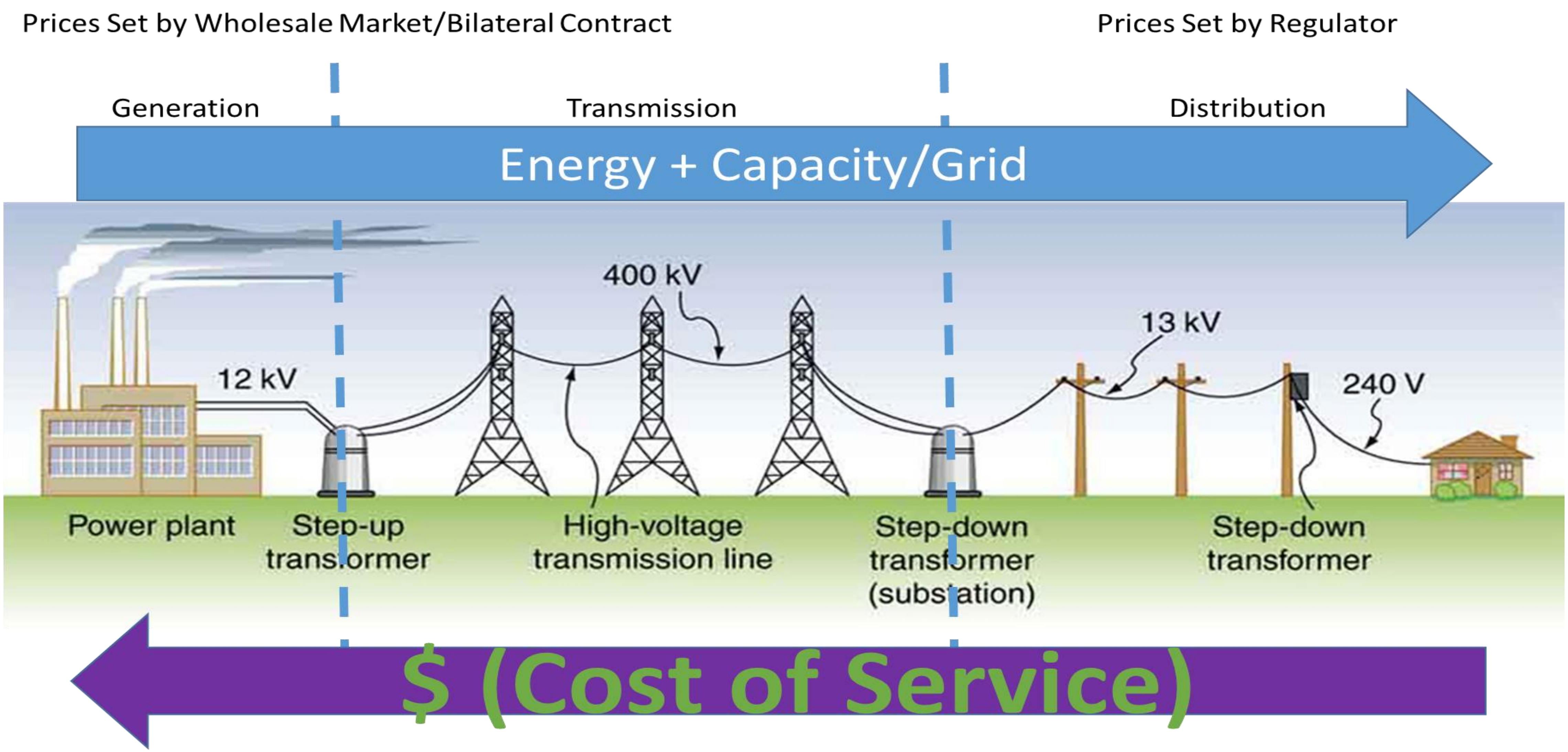
Outline

1. **Overview of Evolving Landscape of Power Distribution**
    - Transactive Energy
    - Community Choice Aggregations
    - Virtual Power Plants
2. **Load Curve Smoothing via Real-Time Pricing**
    - Motivation
    - Experiment Design
    - System Architecture
    - Experiment Results
3. **Conclusions and Future Work**

1. Evolving Landscape of Power Distribution:

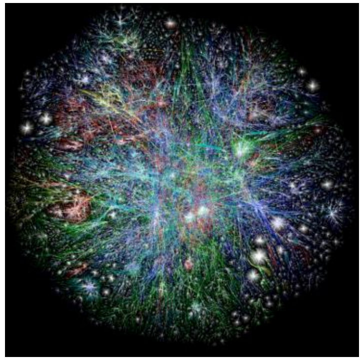
- Transactive Energy (TE)
- Community-Choice Aggregations (CCA)
- Virtual Power Plants (VPP)

Traditional centralized grid operations



Global energy goals cannot be met without changes in how we control complex systems

Our world is getting more complex and growing faster than our control methods can handle.



Modern power grid has become highly complex:

- Highly interconnected
- Heterogeneous device-human participation
- Extreme data
- Pervasive intelligence
- Increasing autonomy

Energy systems

- Potential for substantial efficiencies in end-use systems with new controls
- More data and devices available
- New assets difficult to coordinate
- Existing controls antiquated

Cyber-physical systems

- Growing "edge" computing resources
- Cloud computing becoming paradigm
- Existing security models challenged

Distributed Energy Resources (DERs)

Traditional centralized control approaches are a common weakness

What is Transactive Energy?

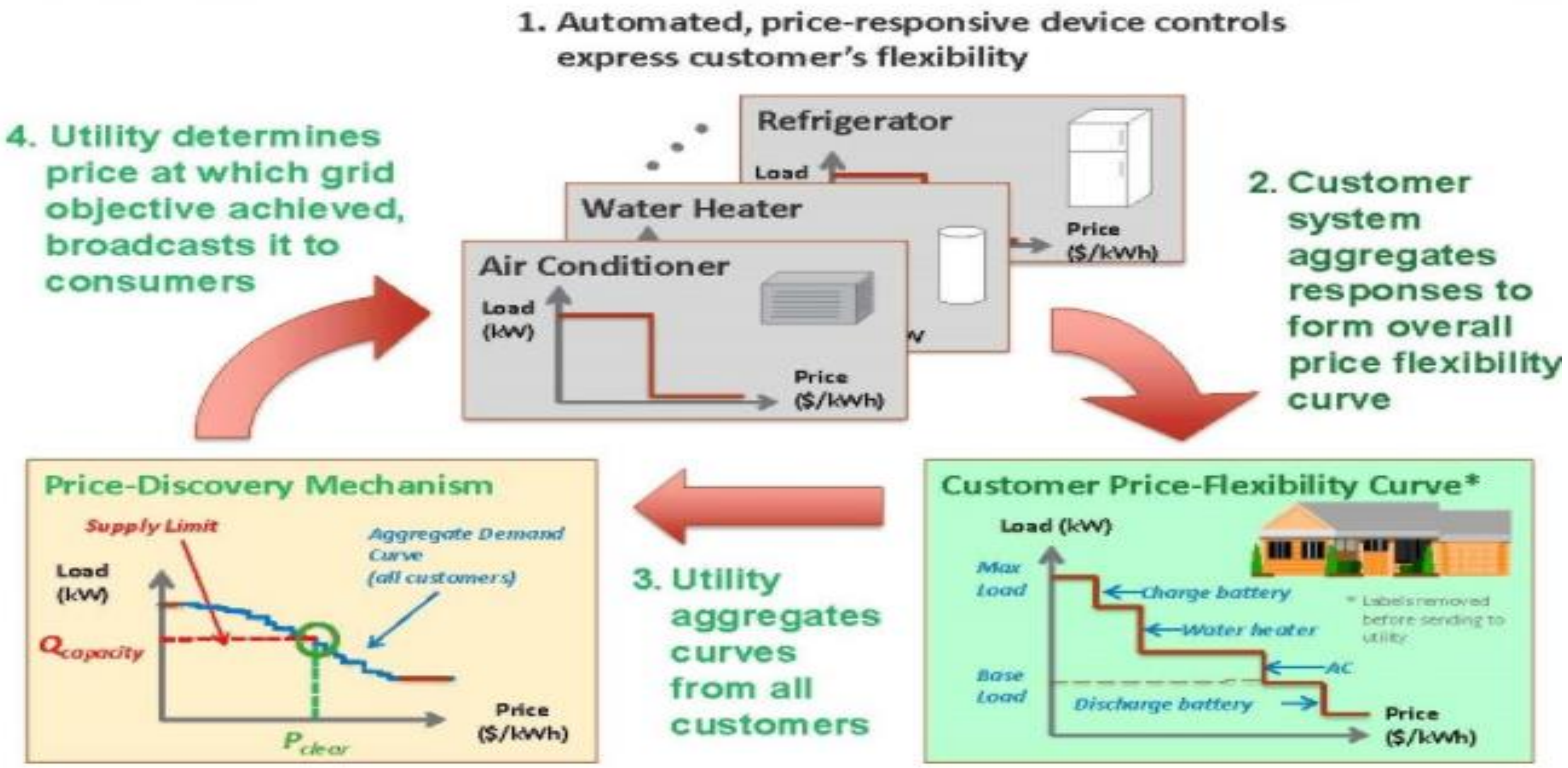
- **Transactive Energy Systems (TESs) involve:**

  "smart devices that communicate with the energy market to make decisions on behalf of the consumer whether to pay higher energy costs during times when power use peaks or delay energy use to pay less and alleviate strain on the power grid".

  - Generally includes both real-time pricing and load management
  - Grid reliability and demand management
  - Integration of renewable and distributed energy sources
  - Environmental benefits such as reduced greenhouse gas emissions
  - Lower energy bills
  - Reduce the need for investment in costly and often politically contentious high voltage power lines

- **Prosumers: Not only the consumers get visibility into power pricing curves to better manage their power consumption, they can even supply excess power back to the grid.**

So, how exactly the TE transactions flow?



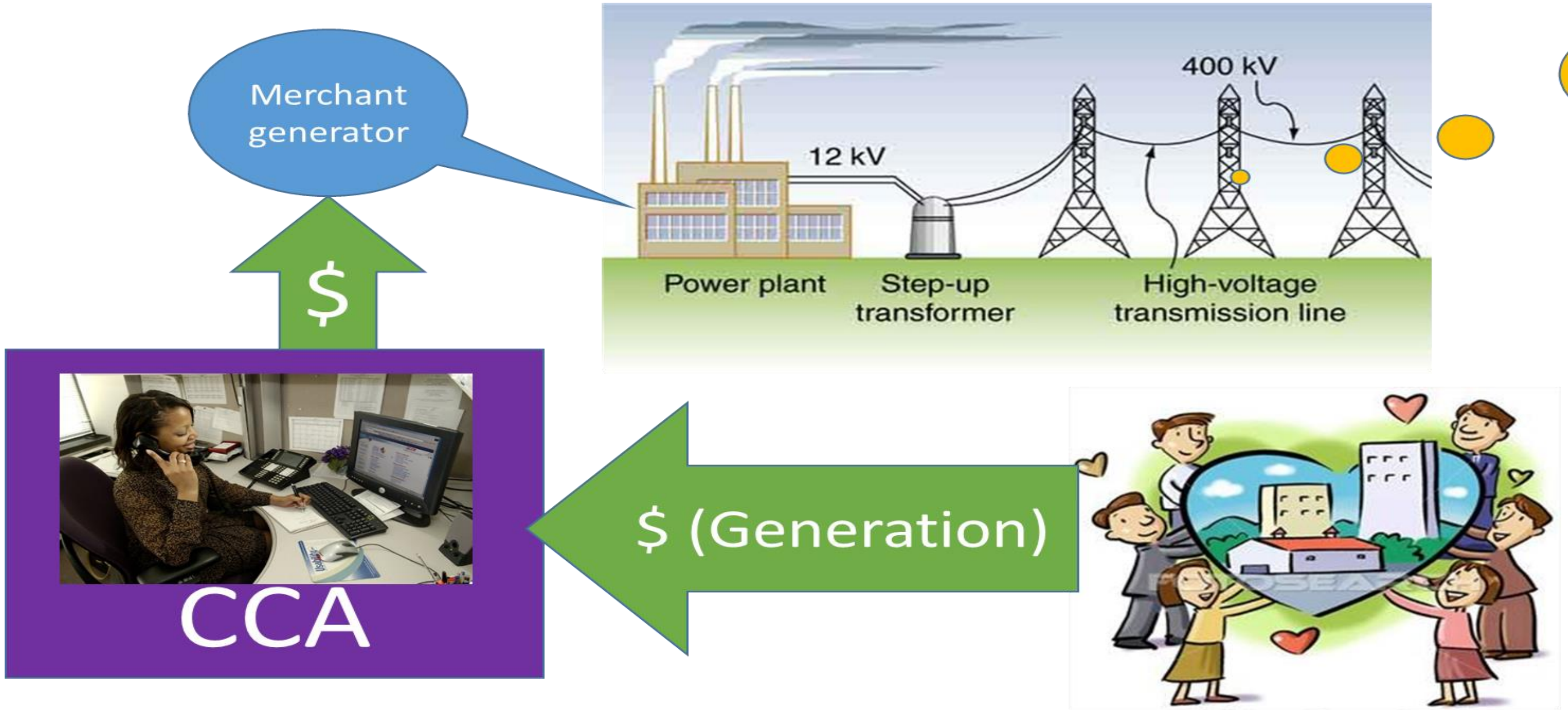
2. Real-World TE Implementation Projects in USA

	GridWise Olympic Peninsula Project	AEP Ohio GridSMART Demonstration Project	Pacific Northwest Smart Grid Demonstration Project
Location	Washington state	Ohio	Idaho, Montana, Oregon, Washington, Wyoming
Time	Started: Late 2004; Data collected: early 2006 until March 2017	2009-2013	2010-2015
Pricing	5 minute intervals based on projected costs and the value of local resources but later adjusted based on a customers' responses	5 minute intervals based on the regional wholesale price	5 minute intervals depended only on price-responsive household technology
Demand	Water pumps from a government facility, commercial building equipped with diesel generators, 112 homes that could alter residential consumption of water and heating	Customers could set preferences for home energy consumption (heating and AC)	Both customer owned distributed generation and management of consumption from residential and non-residential customers

Implementation Challenges Observed:

- **Sometimes TESs were not ready**
  - Hot water heater risk
  - Vendor failures
  - Security issues
- **User readiness**
  - Need for education and greater customer service
  - Recruitment difficulties
  - Participation drop out rates
- **Economic feasibility**
  - Time of use pricing may be better for smaller residential consumers
  - Minimal reduction of residential consumption

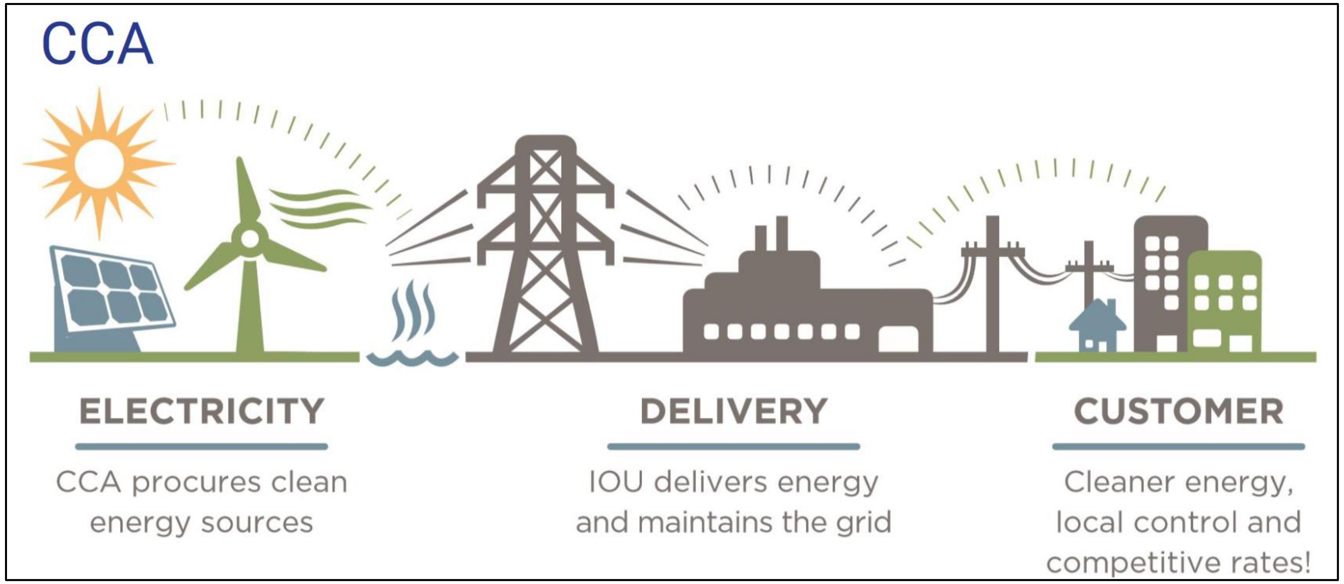
TE brings the Paradigm Shift: Independent System Operator (ISO), Wholesale Market and CCAs

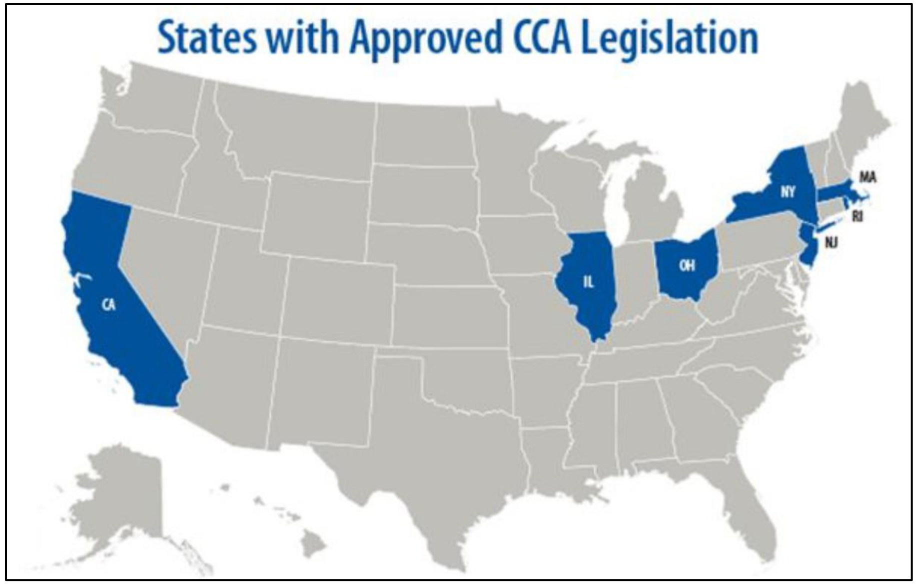


- Balancing
- Frequency Regulation
- System monitoring
- Reserve management
- Outage response
- Emergency Response
- **Operates market and**
- **Dispatches generators**

Community Choice Aggregation (CCA) allows local governments and some special districts to pool (or aggregate) their electricity load in order to purchase and/or develop power on behalf of the residents, businesses, and municipal accounts within their service territory

Community Choice Aggregation (CCA)





CCA 1.0:

- Lowered prices for consumers through collective bargaining
- Slightly reduce emissions through Renewable Energy Credits (RECs)

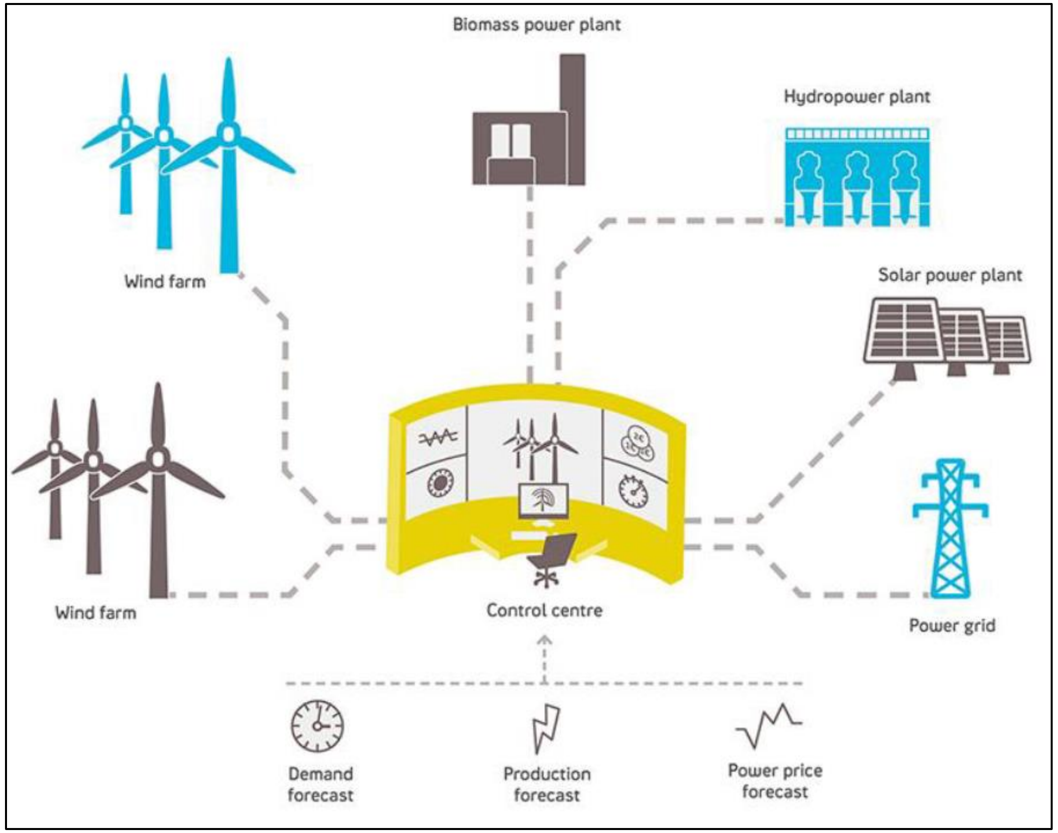
CCA 2.0:

- Long term reduced carbon emissions through large scale investment in renewable energy
- Net metering

CCA 3.0:

- Large focus on the accessibility of Distributed Energy Resources (DERs) to everyone
- Renewably powered microgrids with electric vehicles and HVAC/hot water systems as flexible storage (minimizing importation of energy)
  - Eliminate exportation of onsite power
- Virtual Power Plant
- CCA 3.0 has the potential to lower greenhouse gas emissions by 50-85% in the next 5-10 years

Virtual Power Plants (VPP)



- Virtual Power Plants are collections of energy producing resources (often DERs owned by residents) that serve as a power plant for an area
- Resources are connected to a central control system so that they can be effectively monitored, coordinated, and controlled
- Manage and relieve grid load

2. Load Curve Smoothing via Real-Time Pricing:

- Motivation
- Experiment Design
- System Architecture
- Experiment Results

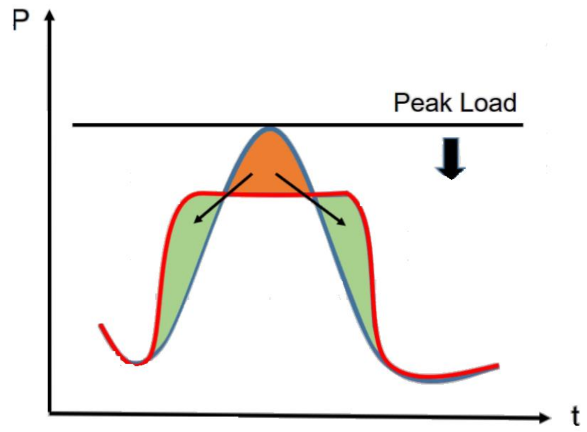
Load Curve Smoothing

Power fluctuations can occur due to the two-way power-flows:

- Sudden cloud cover
- Special mega events
- Storms
- Excessive solar power generation (e.g., in summer)
- Integration of EVs and charging stations

TE can be used in VPPs with variable power pricing and control to efficiently manage this.

But, an interesting question is can TE smooth the daily load curve?

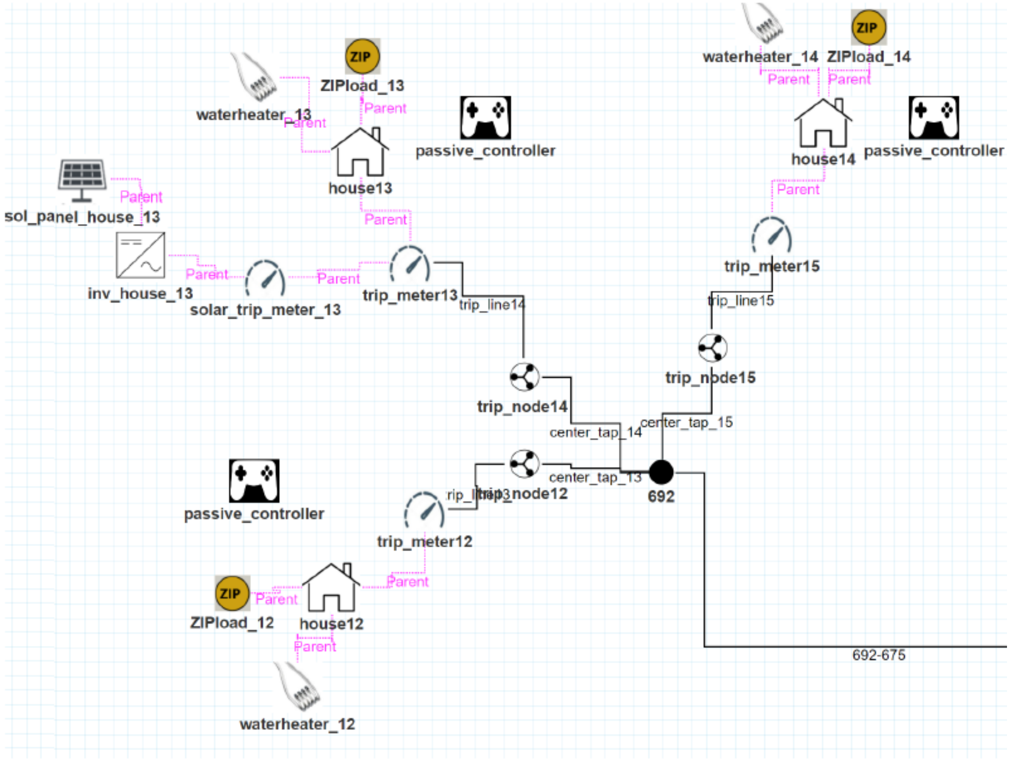


- **What parameters to vary in grid modeling?**
- **What pricing mechanisms to test?**
- **What variations in configuration of pricing mechanisms (TOU/RTP) to try?**

Experiment Design

- **Grid Model:**
  - Sacramento, CA; 544 residential houses; 26 businesses; 2017 weather data; Aug. 1-15, 2017; Heating is ignored due to summer month;
  - Real-world data collected from government websites (546 kWh per home per month; PV efficiency: 19.52%)
- **Outcomes Measured:**
  - Reducing overall utility demand
  - Decrease in community power costs
  - Reduction in peak load on the system
  - Smoothing of the daily load curve

Grid Modeling

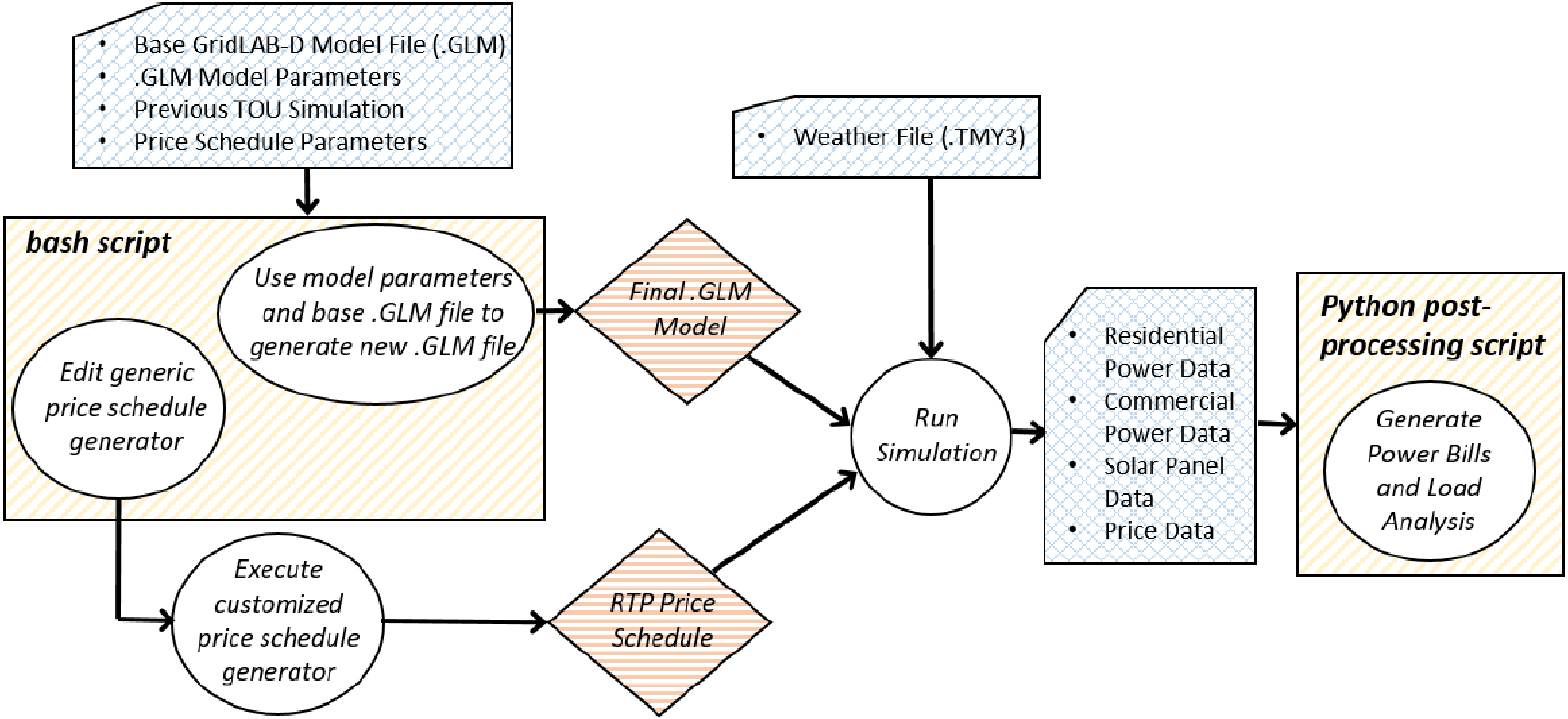


- Updated PNNL's R1-12.47-2 model
- Triplex meters to each house, also to each solar panel and inverter pairs
- Loads responsive/unresponsive to price changes
- GridLAB-D simulation with stub-auction (GridLAB-D auction module for basic demand-response)
- HVACs with transactive control, set-points, a low and high threshold
- RTP pricing every 5 minutes

Power Pricing: TOU and RTP

- CA TOU pricing data:
  - Peak hours (Weekdays: 1-7 pm)
  - Medium (Weekdays: 10 am - 1 pm, 7-9 pm; Weekends: 5-8 pm)
  - Rest are off-peak hours
- TOU price schedule is generated via GridLAB-D simulation
- Two *lookahead* periods:
  - Shorter: Higher demand in TOU → Higher price for RTP
  - Longer: Higher demand in TOU → Lower price for RTP
  - [These two periods were averaged with a weighting]

Experiment Automation



Experiment Parameters and Metrics

Parameters:

- Pricing technique: TOU/RTP
- Rooftop solar system wattage: 5 kW, 7 kW (*)
- Local battery storage (Y/N)
- Solar penetration rates: 0%, 25%, 50%
- Pre-cooling

Metrics:

Many metrics were collected from GridLAB-D simulation for calibrating the RTP pricing such as:

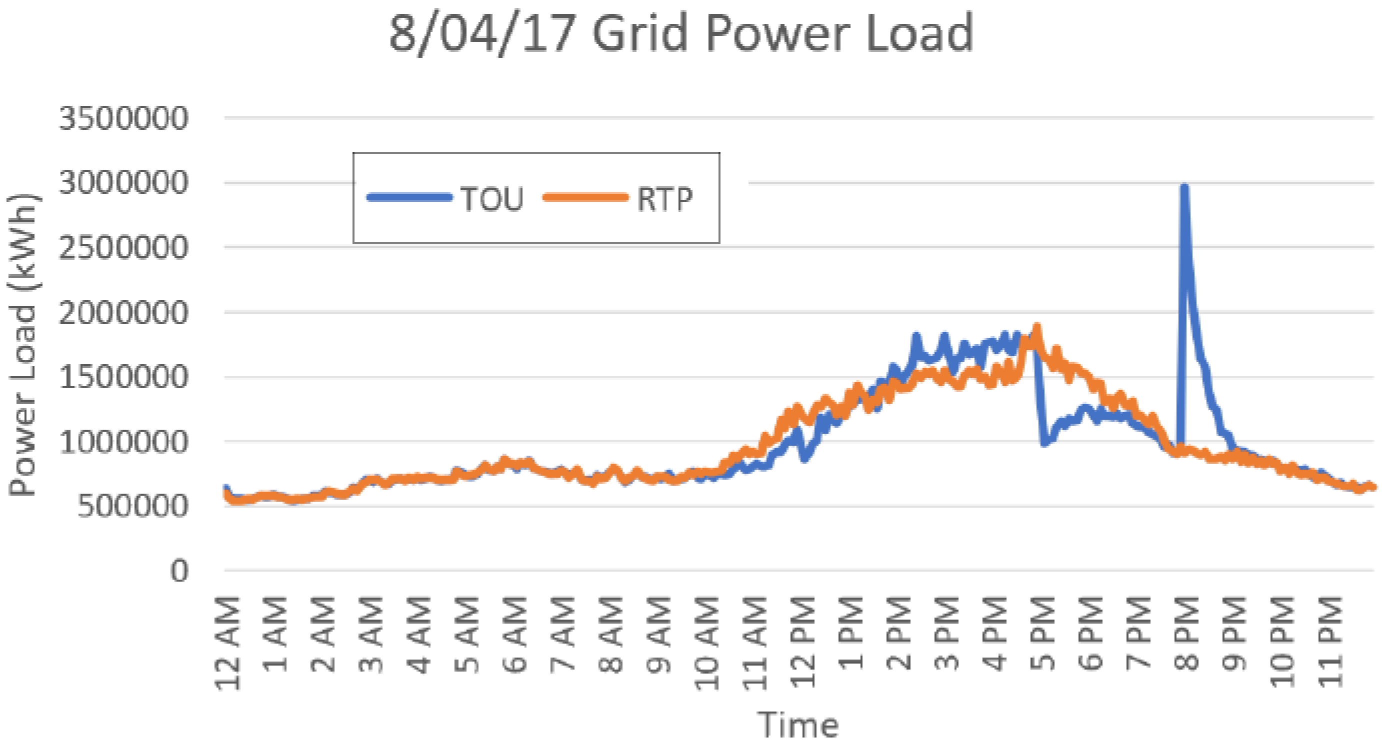
- Peak power demand
- Standard deviation of power demand
- $MaxMin_d$: Difference between avg. of 5 maximum load timeslots with 5 minimum load timeslots over each 6 hour time-periods in the simulation

Effect on Parameters on Power Costs

- **TOU vs RTP Pricing:**
  - In this model/experiment, power costs were not reduced overall (Reduced for those with solar panels and increased for those without)
- **Battery Storage**
  - Reduced some cost for those without solar panels
  - Not much reduction for those with solar panels!
- **Solar panel penetration and generation capacity**
  - Increases in both directly decreased power costs

Effect on Parameters on Daily Load Curve – 1/3

- **TOU vs RTP Pricing:**
  - RTP pricing significantly reduced the daily load curve as compared to TOU



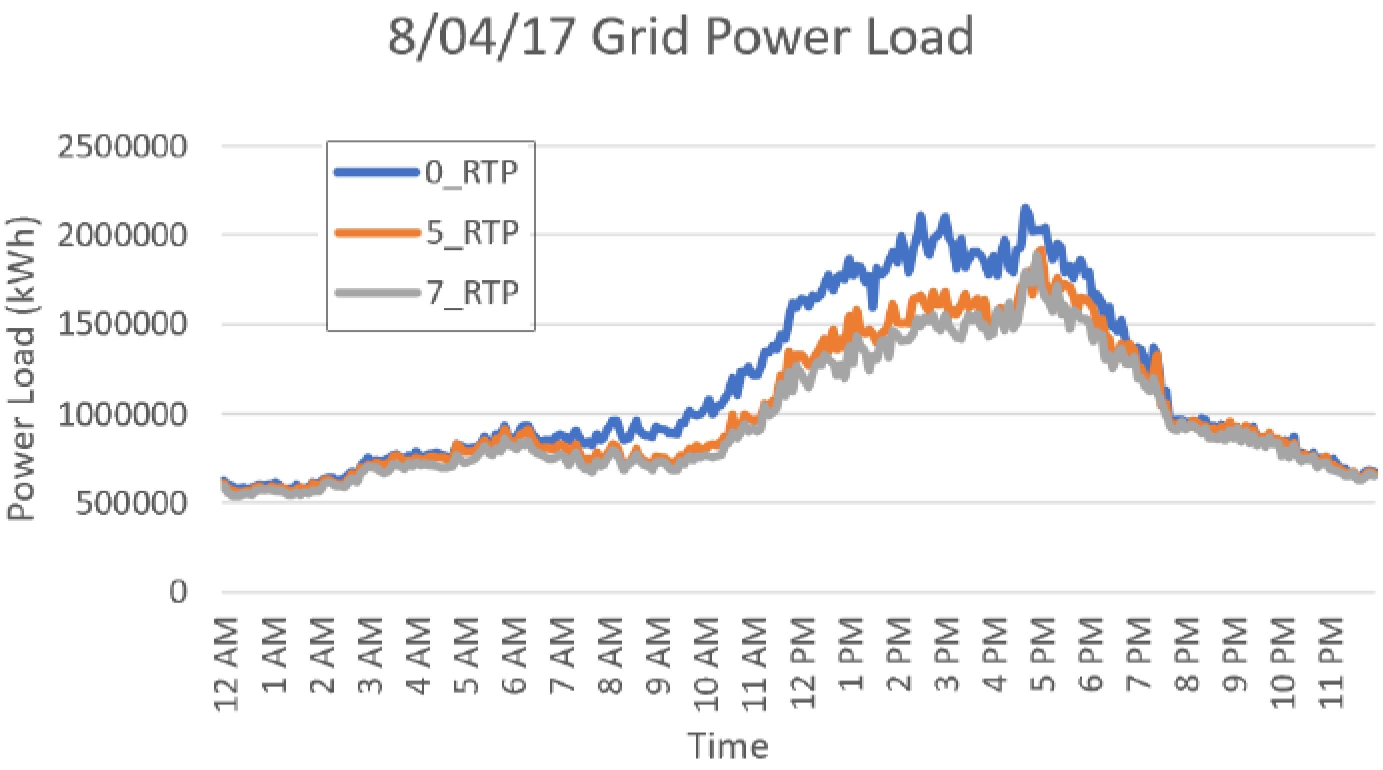
Effect on Parameters on Daily Load Curve – 2/3

- **Battery Storage:**
  - Batteries similarly had a significant impact on smoothing the duck curve
  - Batteries could reduce peaks and troughs

- **Precooling:**
  - Does produce smaller standard deviation in power demand and $MaxMin_d$
  - However, minor impact on duck curve smoothing

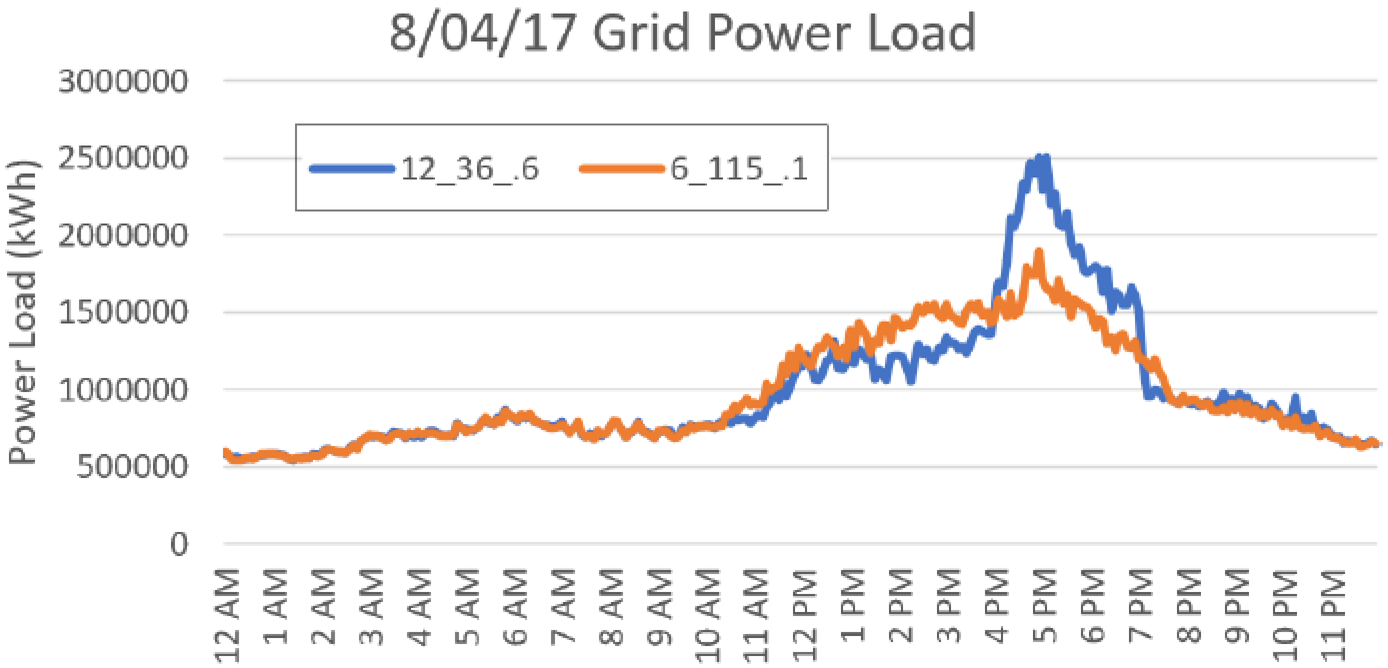
Effect on Parameters on Daily Load Curve – 3/3

- **Solar panel capacity:**
  - Higher capacity leads to more smoothed load curve
  - Increase in solar panel penetration also produced similar effects



Effect on Tuning Price Schedules on Load Curve

- **After running thousands of simulations, produced parameter combinations that significantly smoothed the duck curve!**
  - 12 positively correlated lookahead intervals; 36 negatively correlated; weight of positively correlated = 0.6
  - 6 positively correlated lookahead intervals; 115 negatively correlated; weight of positively correlated = 0.1



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Conclusions and Future Work

- Demonstrated the benefits of TE with RTP in the context of local electricity network with distributed solar energy and virtual power plants.
- Provided a systematic approach to designing RTP pricing to smooth the load curve.
- Showed that the solar panels did not drastically reduced customer power costs (more research can be done here).
- Many configurations were studied, but a lot other variations can, of course, be investigated in future work.
- Current work we are using Machine Learning techniques to automatically discover better RTP pricing schemes that reduces the load curve.
- Characterizing the grid and its configurations
  - Features collected both before and after the simulation
- Training a neural network
  - Testing for accuracy
  - Scenario generation
  - Applying in highly different grid configurations

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ANY QUESTIONS?