

Transactive Energy: Scalable Coordination of Distributed Grid Assets

Hayden Reeve
Senior Technical Advisor



Acknowledgements

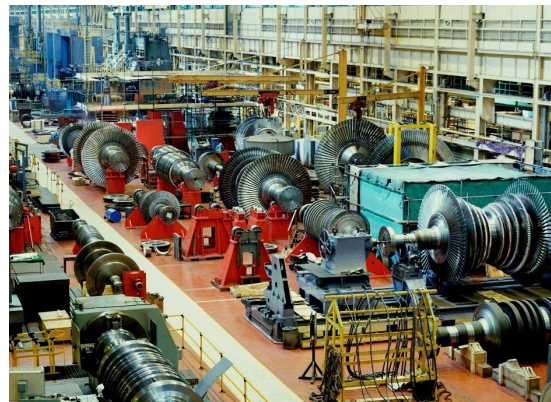
- PNNL greatly appreciates the support of DOE in funding and directing this work, in particular the support of the Office of Electricity (Chris Irwin) and the Building Technology Office (Cecilia Johnson-Walker).
- This work represents the efforts of many current and former PNNL and DOE contributors. Many thanks to all of them!

Key Questions Answered Today

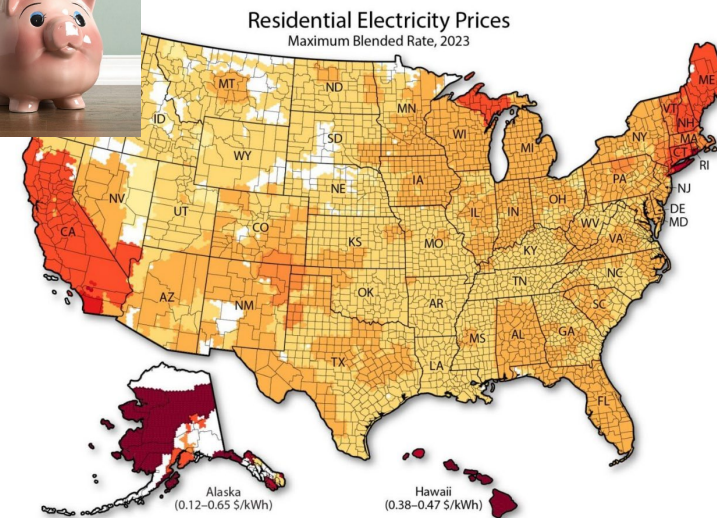
1. Why coordinate distributed grid assets? (And why now?)
2. What is transactive energy?
3. What have been PNNL's contributions in the advancement of transactive energy? (And distribution system coordination in general)
4. What is the current state of progress and deployment?
5. How can you learn more about our work and resources?

Why Coordinate Distributed Grid Assets?

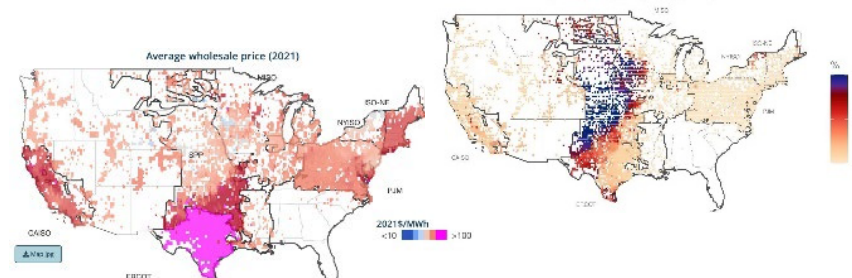
Enabling Growth



Affordability



Greater wholesale price volatility



Resource Adequacy

More high-impact events



Reduced energy use helps avoid load interruption

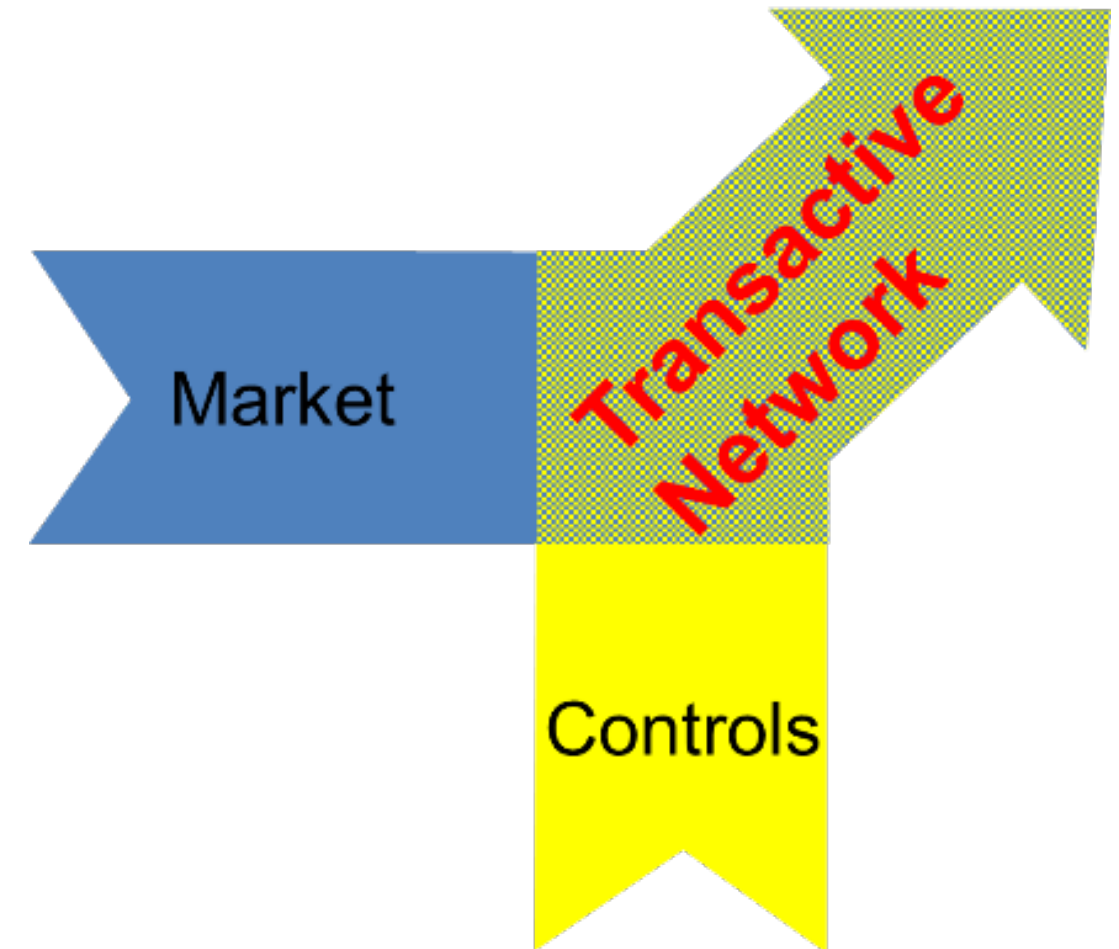


What is Transactive Energy?



Transactive Energy in a Nutshell

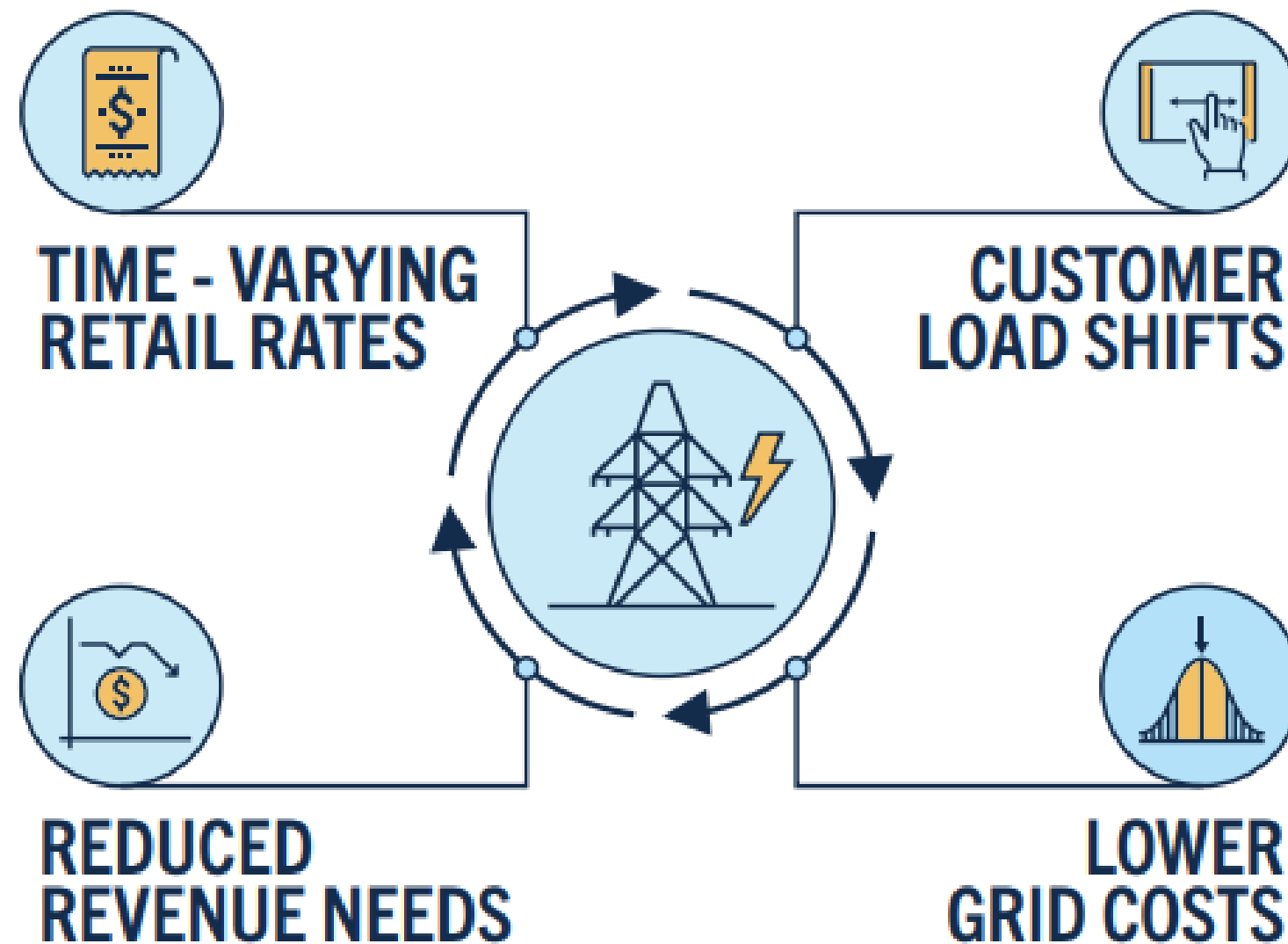
- Use market mechanisms to perform distributed optimization
 - Reflect value in exchangeable terms to effectively allocate available resources and services in real-time and future time periods
- Deploy communications and automation of devices and systems with real-time agents for market interaction
 - Agents convey preferences and perform local control actions, engage in one or more markets to trade for services, e.g., real-time energy, peak-shaving, system reserves



* Schweppe, FC, RD Tabors, JL Kirtley, Jr., HROuthred, FH Pickel, AJ Cox, " Homeostatic Utility Control," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-99, No. 3 May/June 1980

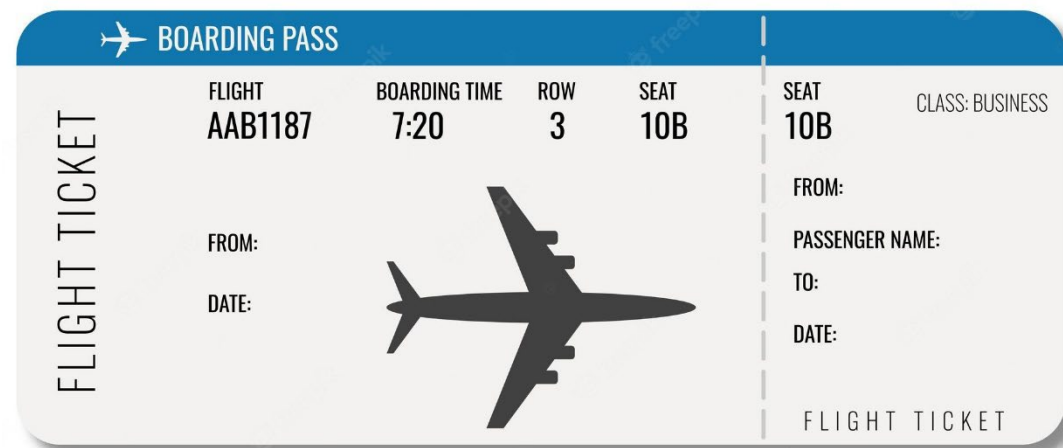
** See GridWise® Architecture Council, "Transactive Energy Framework," https://www.gridwiseac.org/pdfs/te_framework_report_pnnl-22946.pdf

The Core Value Proposition



Market Example: Airline Travel

Forward Market



Correction Market

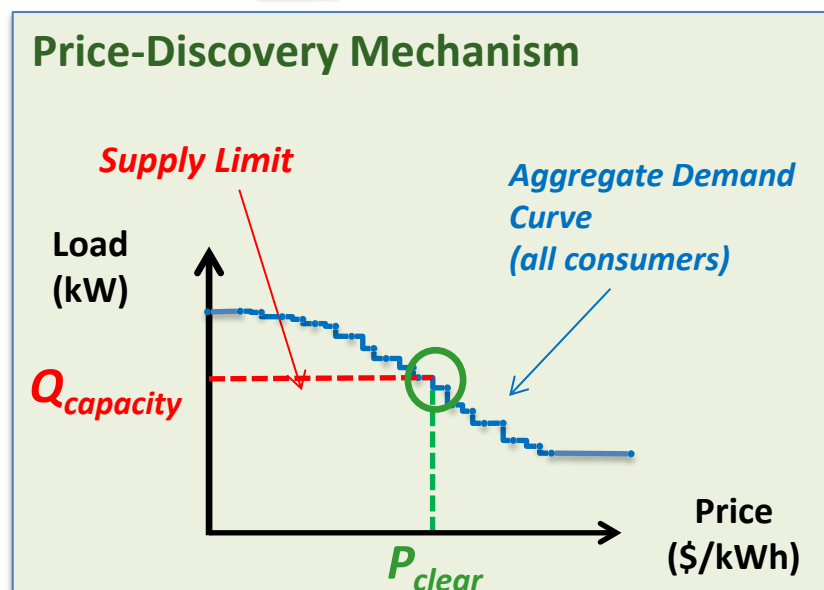
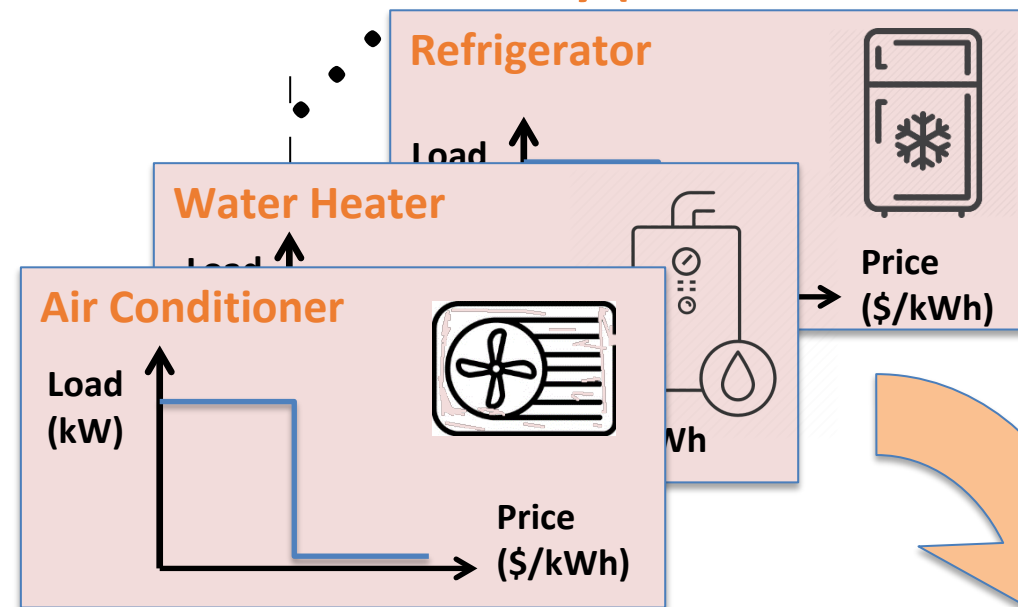


Transactive Energy Interaction Overview

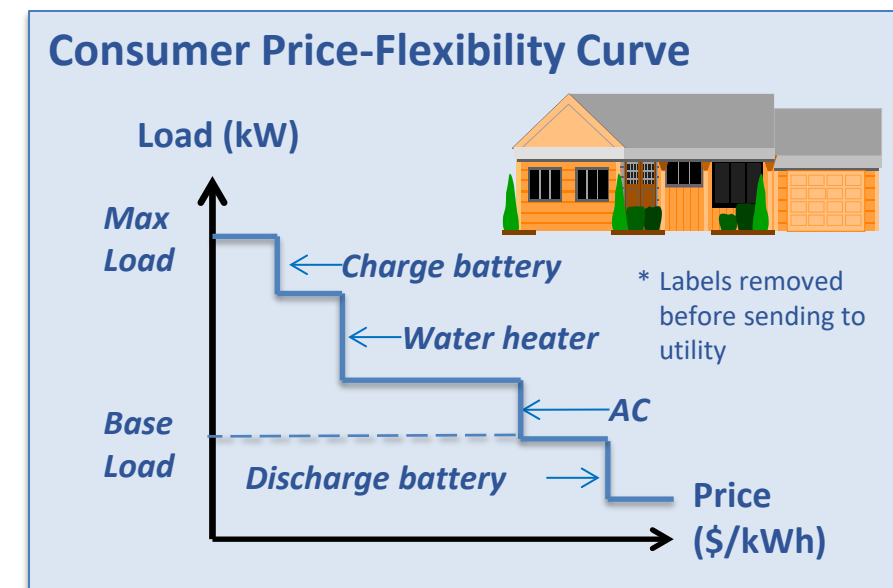
1. Automated, price-responsive device controls express consumer's flexibility (based on current needs)

4. Aggregator determines price at which grid objective achieved, broadcasts to consumers

2. Consumer system aggregates responses to form overall price flexibility curve

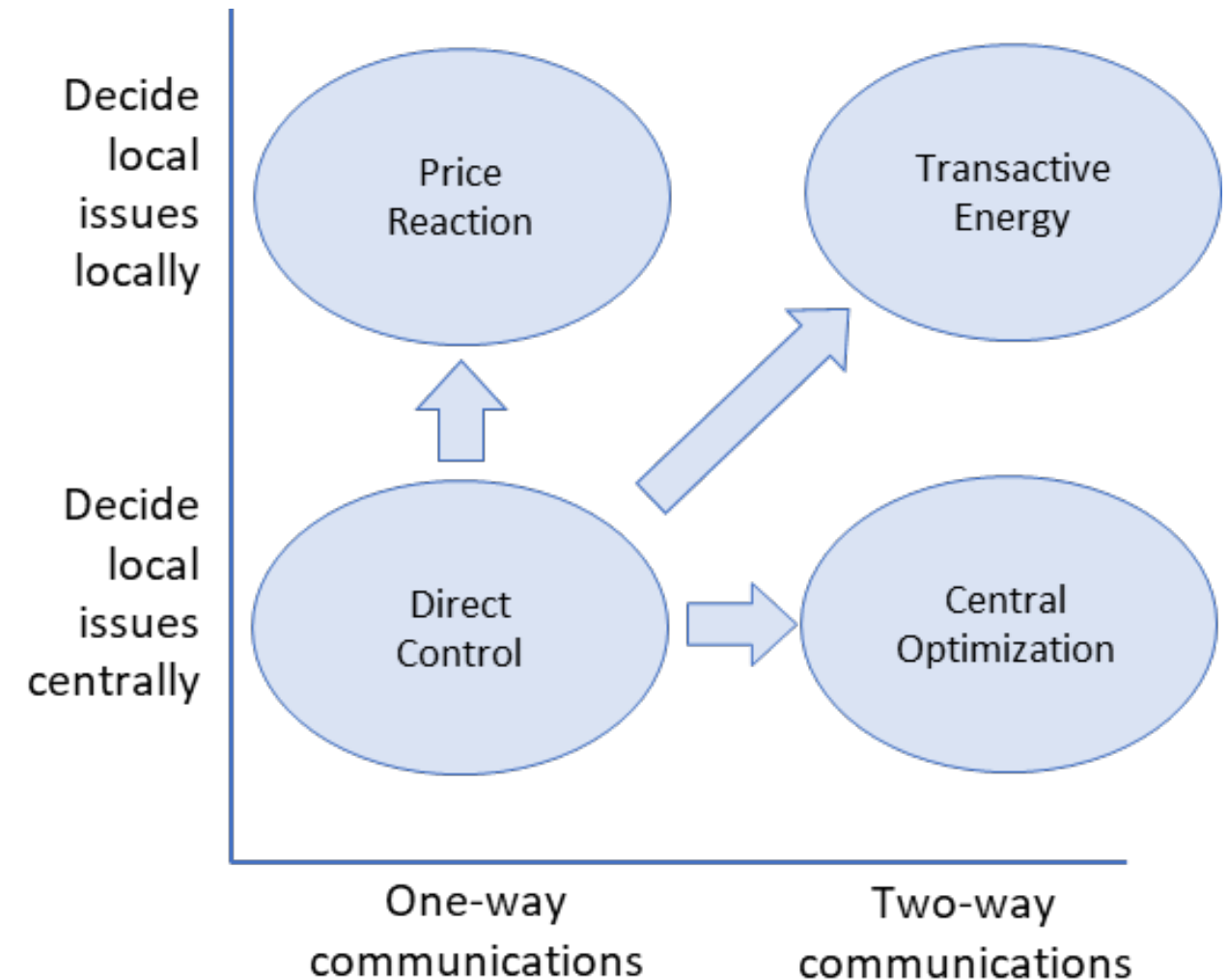


3. Service provider aggregates curves from all consumers

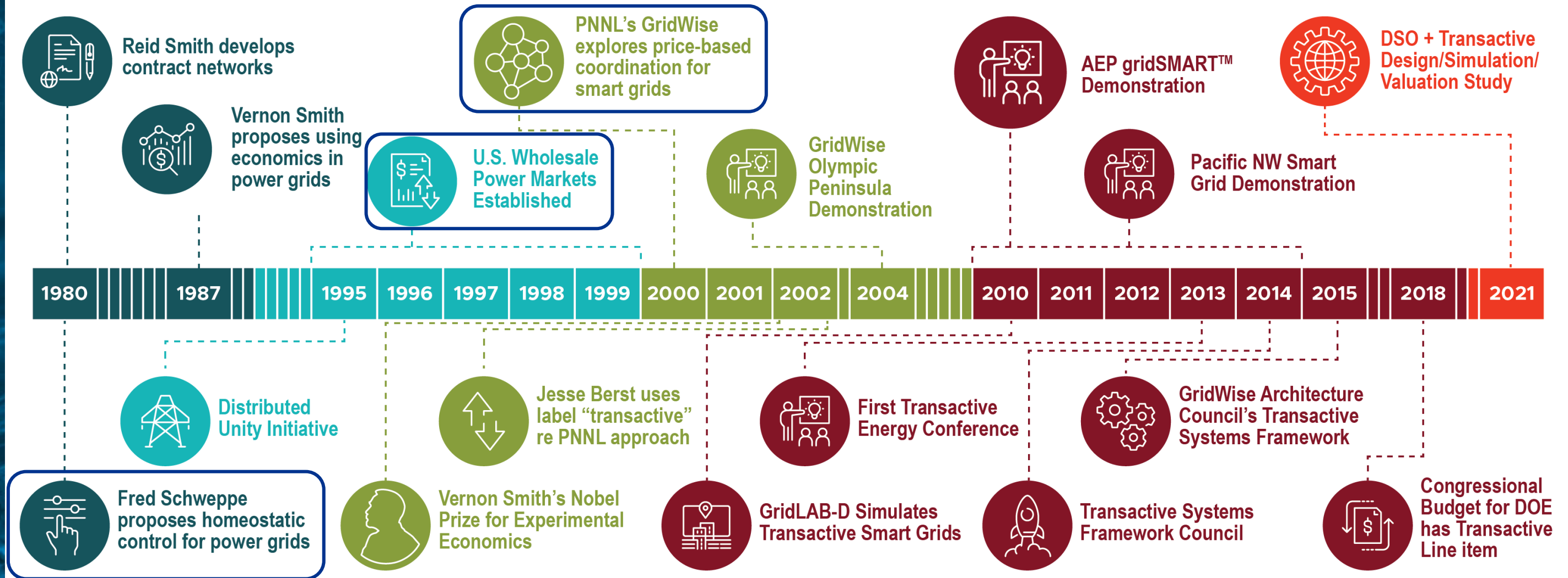


Why Transactive Energy?

- Centralized approaches can have privacy, autonomy, and scalability issues
- One-way coordination can be inefficient and not fully utilize resources
- Distributed, market-based control approaches address these issues



Transactive Energy History



Key PNNL Contributions?



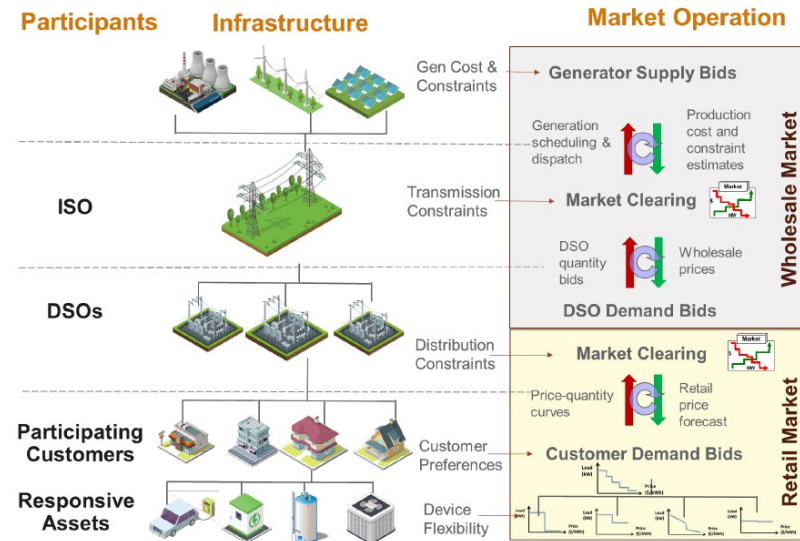
Key Contributions:

Theory & Design

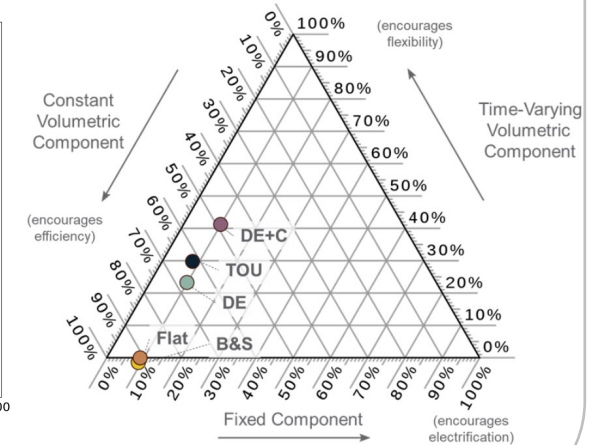
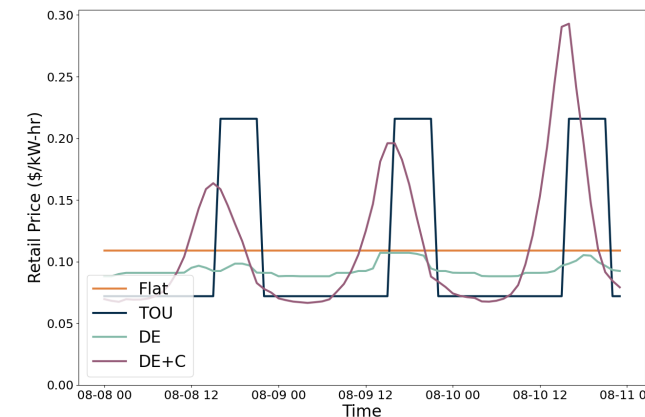


Theory and Design: Key Needs and Contributions

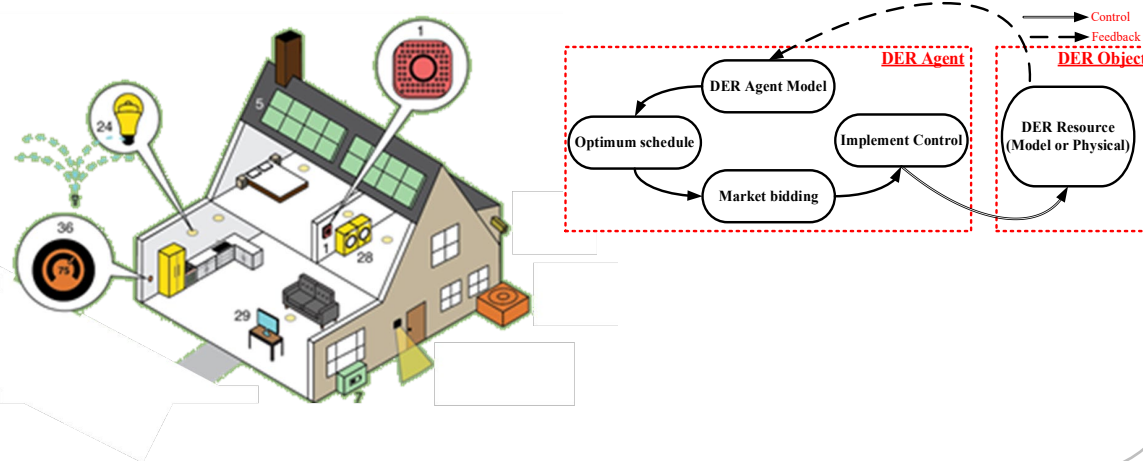
Market Design



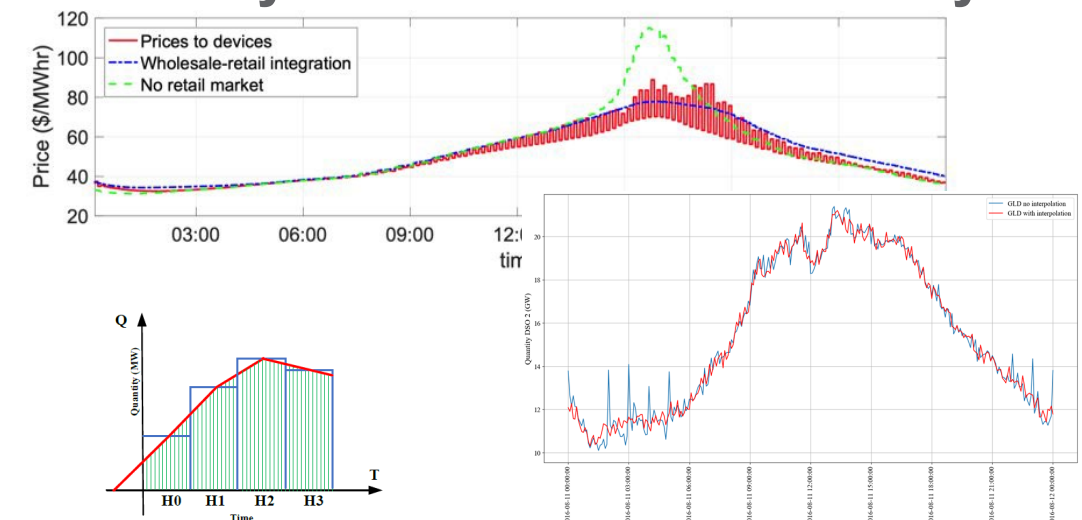
Price and Tariff Design



Device (Agent) Response Optimization



System Behavior & Stability



Key Contributions:

Field Demonstrations

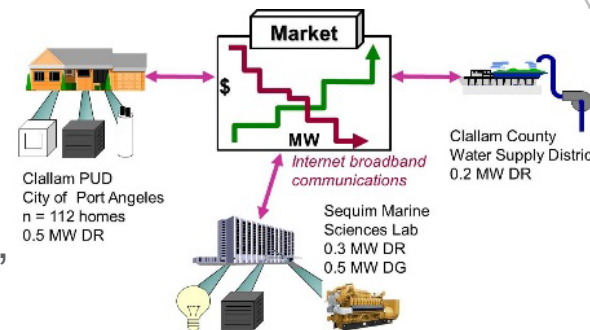


PNNL Transactive Energy Field Experience

Olympic Peninsula, 2006-07

Established viability of transactive, decision-making

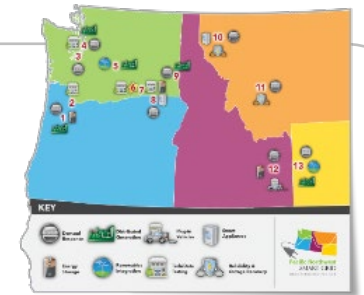
- Peak load, distribution constraints, wholesale prices
- Double auction market
- Residential, commercial, & water pumping loads, DG



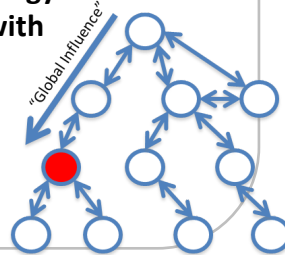
Pacific NW Smart Grid, 2010-15

Key advancements made by PNWSGD

- Wind balancing
- Consensus-based look ahead signals
- Formalized definition of transactive node
- Integrated legacy direct load control systems within a transactive network



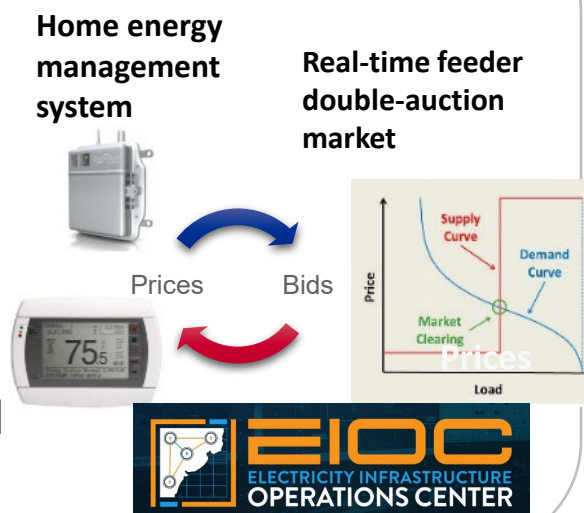
Real-time & forward energy exchange with neighbors



AEP gridSMART®, 2010-14

PUC-approved RTP tariff developed

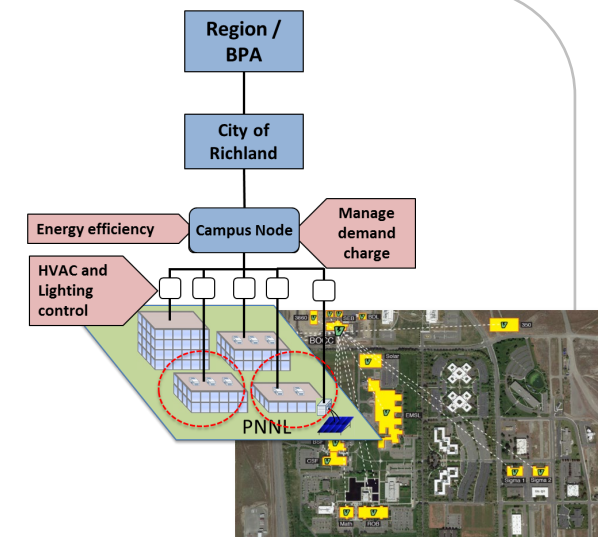
- Dynamic, real-time incentive to respond
- Real-time prices from PJM energy market
- Manages AEP T&D constraints and peak load



Transactive Campus, 2015-2022

Flexibility in buildings, storage, and generation

- Manage peak demand charges, smooth local PV generation
- Enhance energy efficiency
- 3 research locations: PNNL, WA State Univ, Univ of Toledo, OH



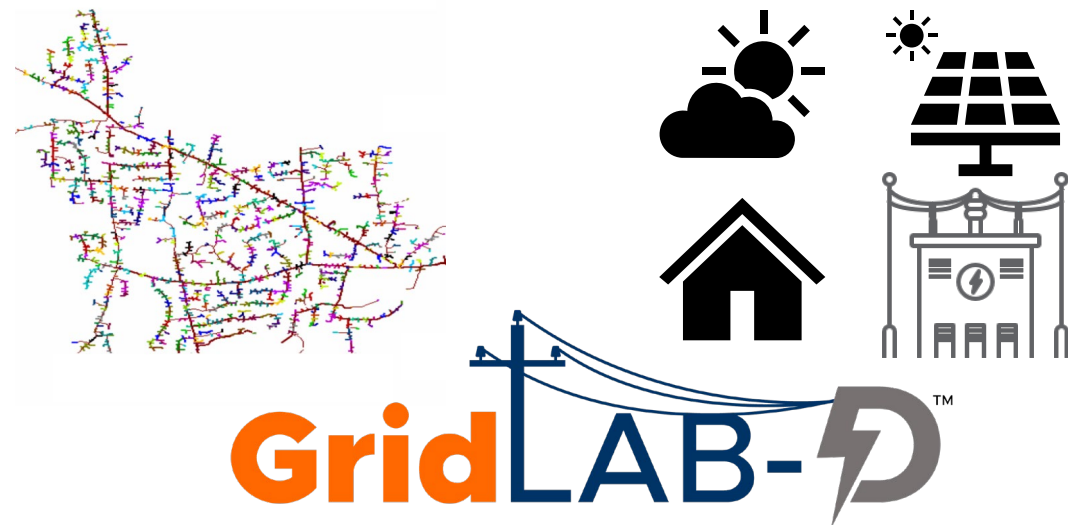
Key Contributions:

Techno-Economic
Analysis



Catalyst for Key Analysis Capability

Distribution System Modeling



Co-simulation

TESP: Transactive Energy Simulation Platform

FNCS

(Framework for Networked
Co-Simulation)



HELICS
Simulations Are Better Together

Value Stream Mapping

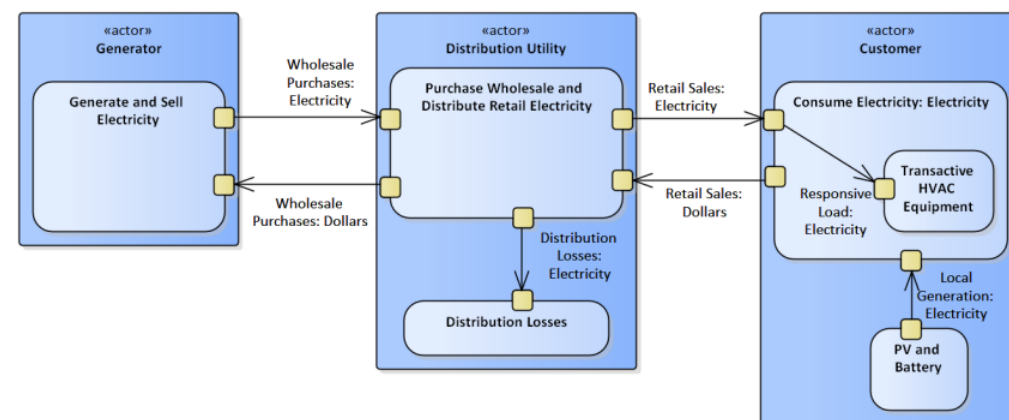
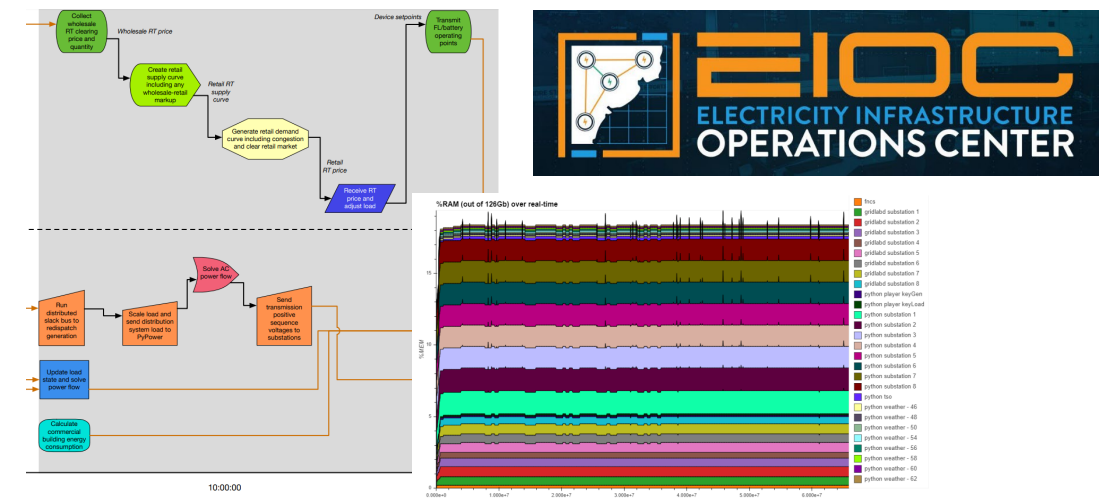


Figure 2. Example Value Model

Large-Scale Computation

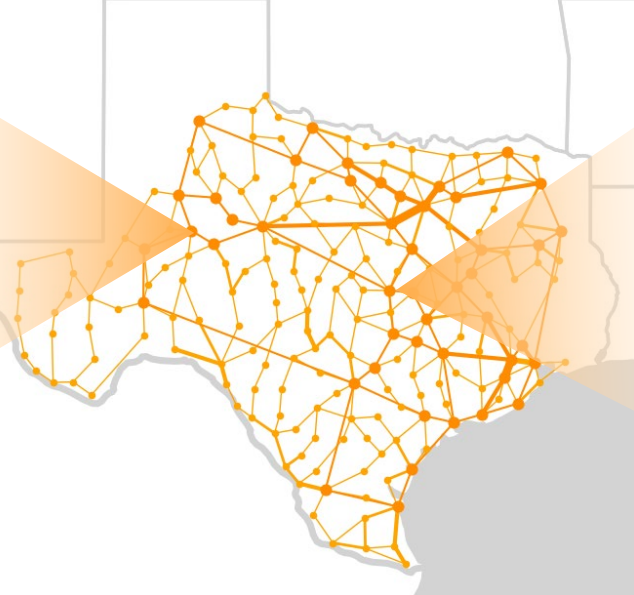


DSO+T Study Overview

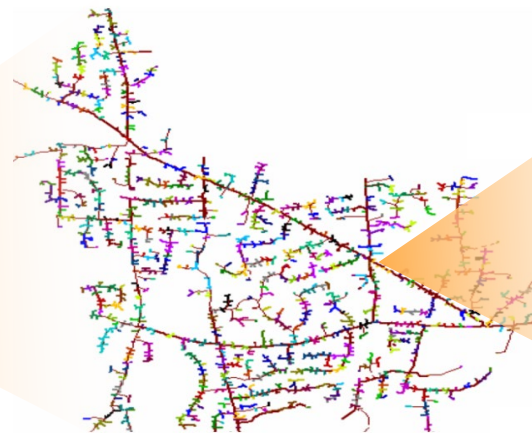
Generation



Transmission



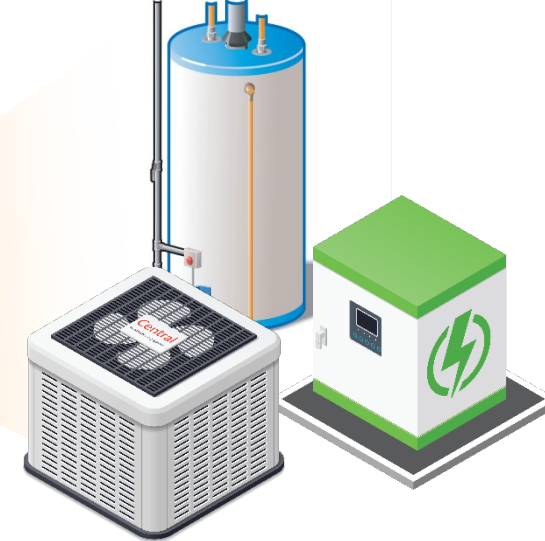
Distribution



Customers



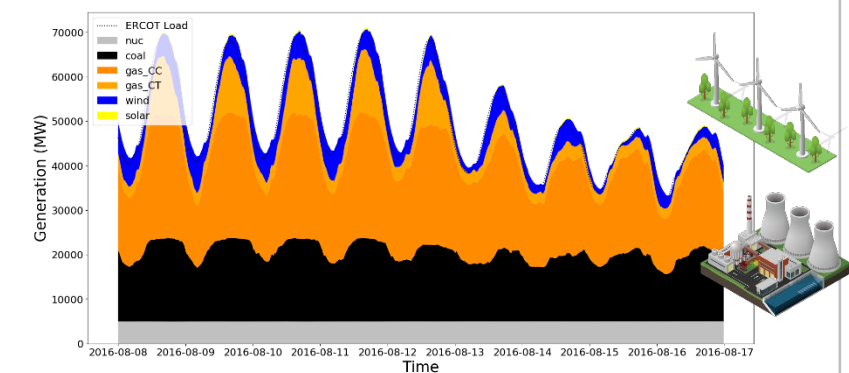
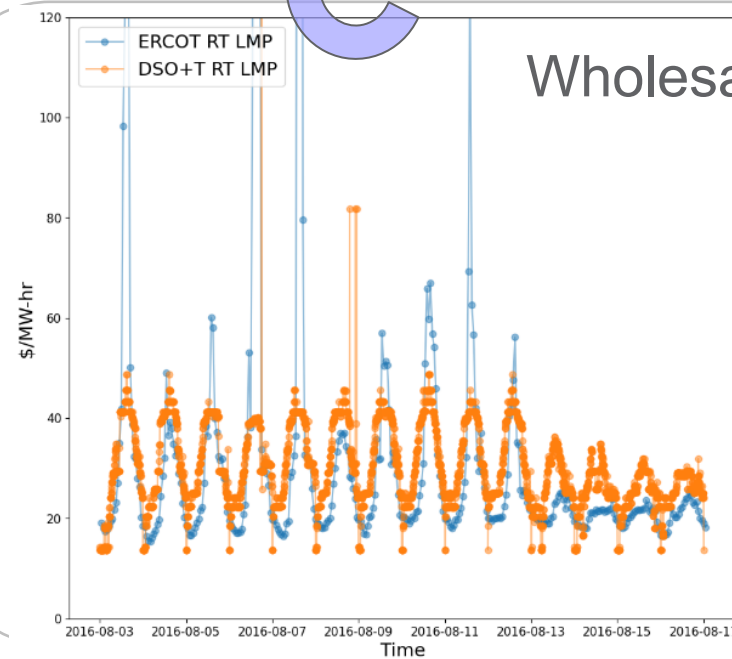
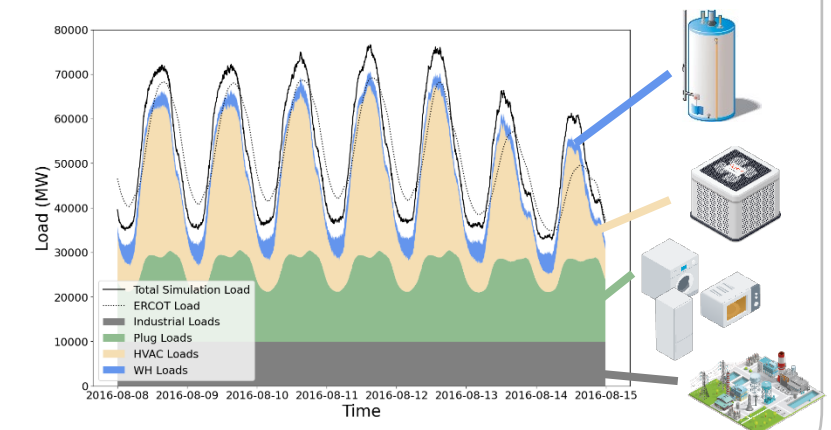
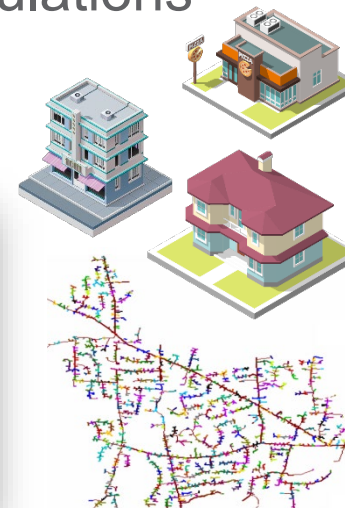
Assets



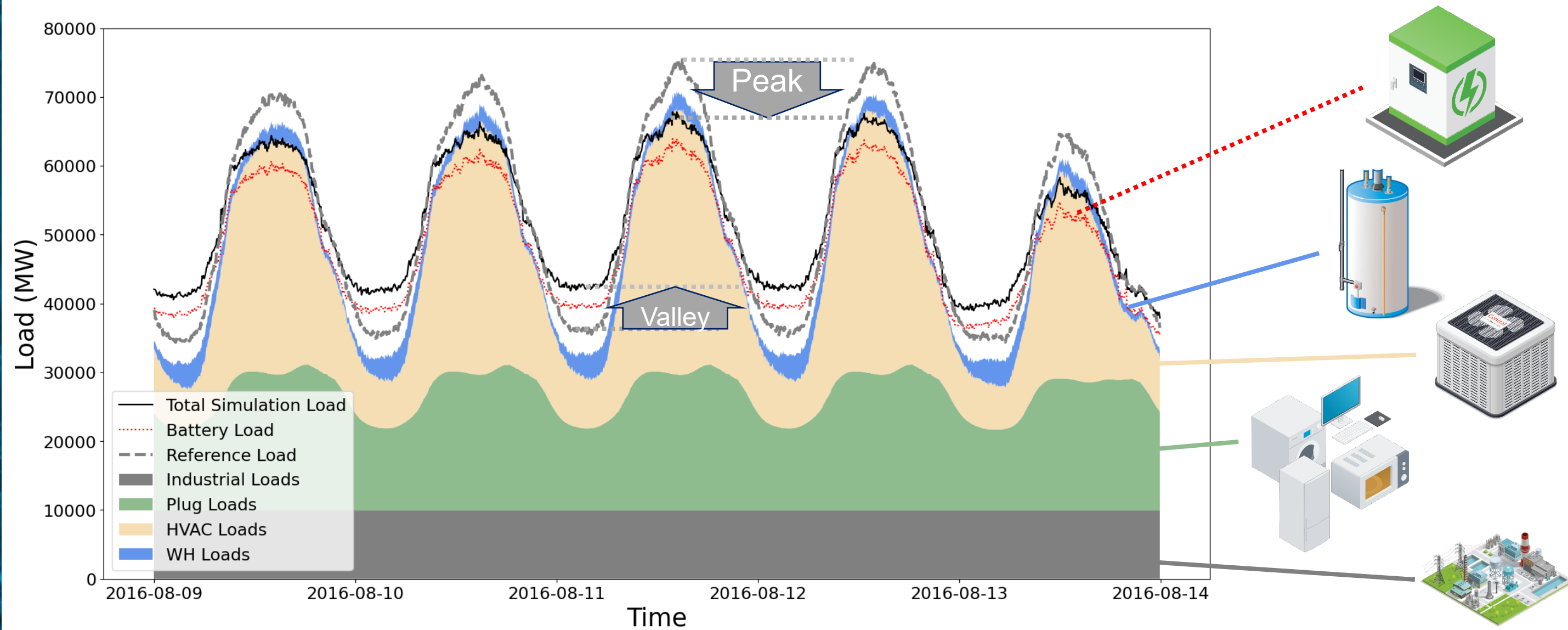
Integrated System Model

Transactive Coordination Framework

Valuation Methodology and Economic Performance

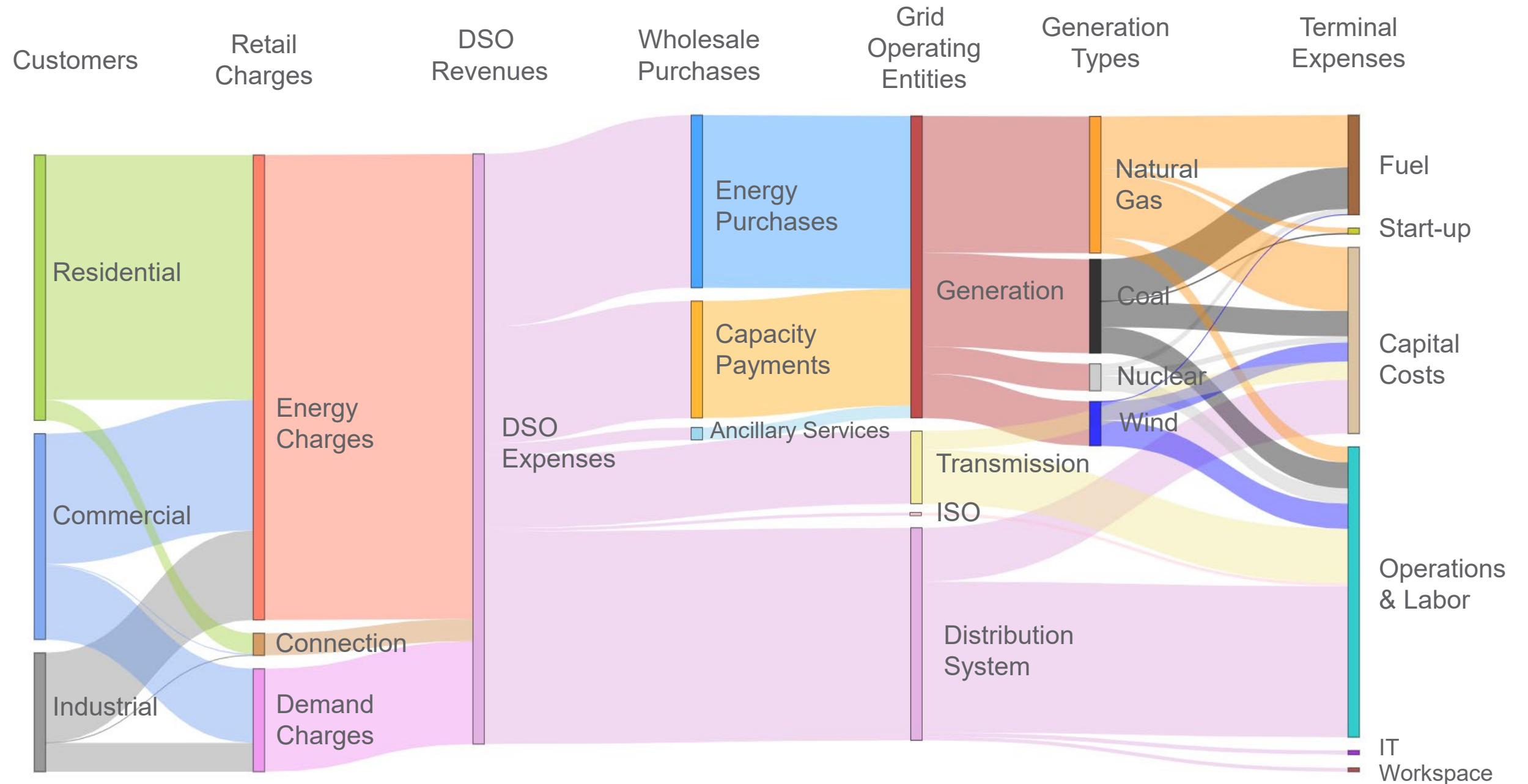


Engineering Performance and Peak Reduction



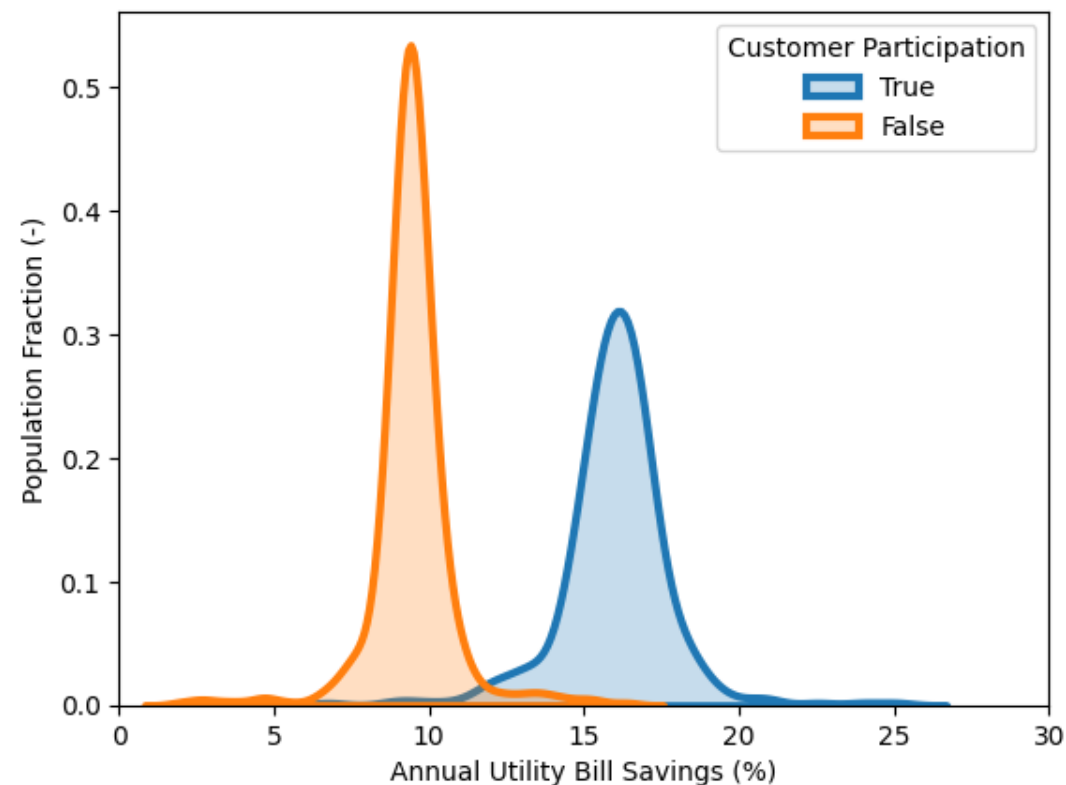
Example battery DER scenario illustrating ~10% reduction in peak load

Mapping of Cash Flow through Grid Ecosystem



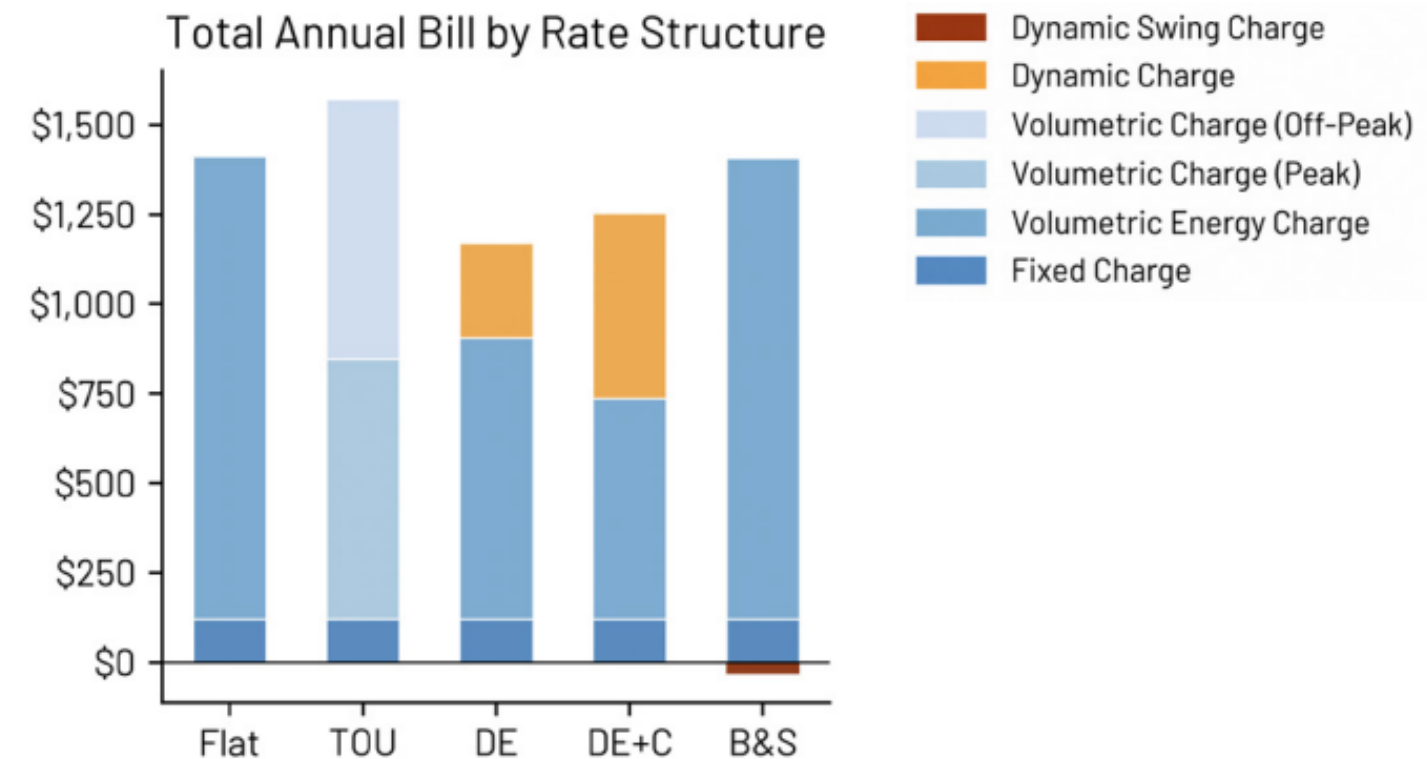
Customer Outcomes – Key Findings

DSO+T Study Key Finding



Participants and non-participants can save money

PAVER Study Key Findings



Customer protections can erode benefits. Care is needed.

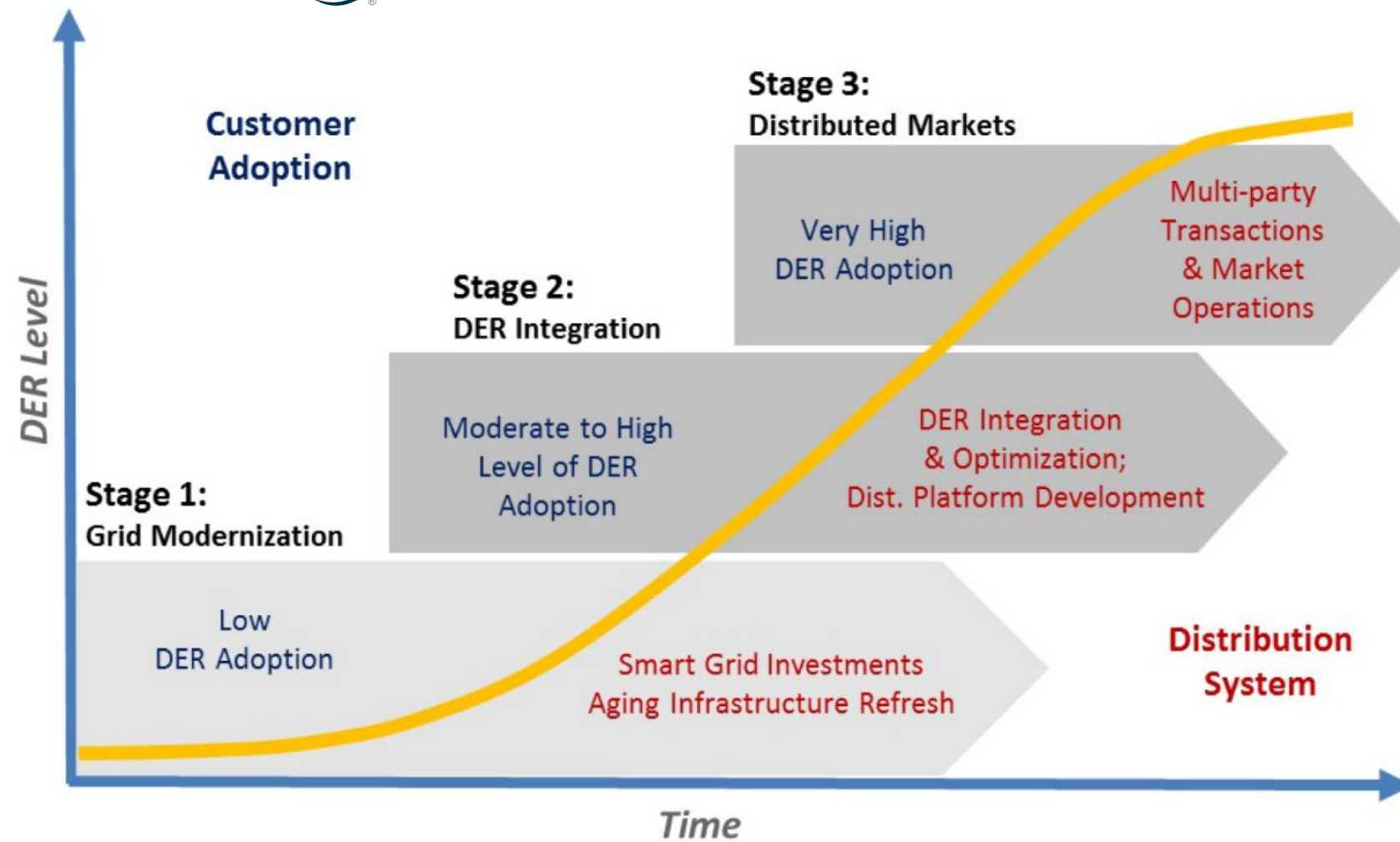
Key Contributions:

Integration and
Interoperability



Grid Architecture and Roadmaps

GRIDWISE Architecture Council



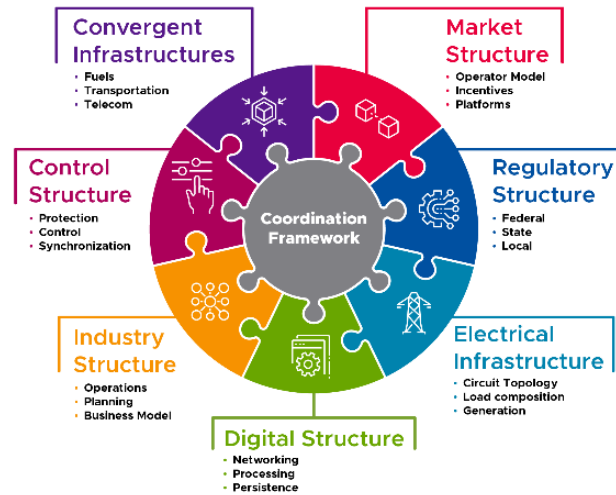
TE Roadmap Stages

<https://gridwiseac.org/>



Integration and Interoperability

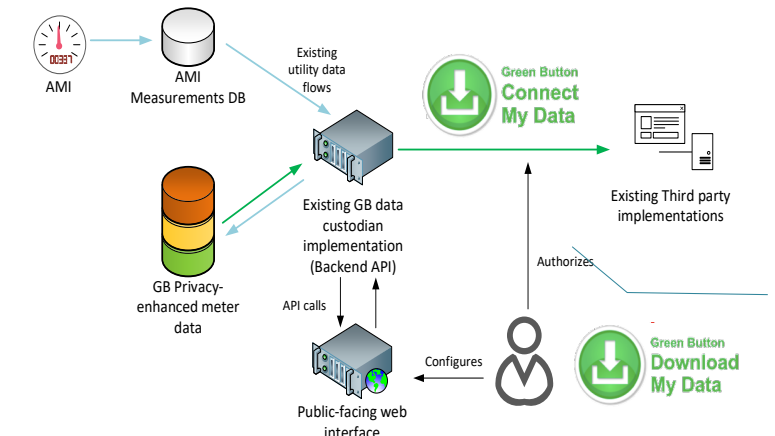
Operational Coordination



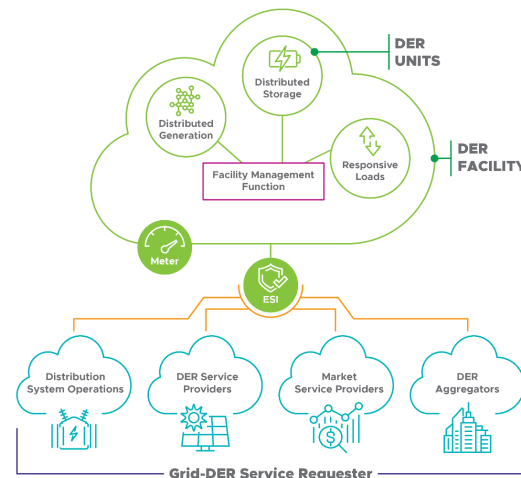
Common Grid Services



Data Services



Energy Services Interface



Standards Engagement



Industry Engagement



What is the Current Status?



International Progress

More Proof Points

A growing number of utility pilots have shown feasibility

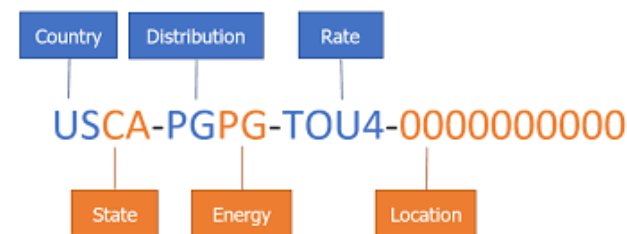


Aggregators and retailers have demonstrated the value in coordinating customer assets in response to grid costs



Regulatory Movement

Migration to TOU and machine-readable dynamic prices

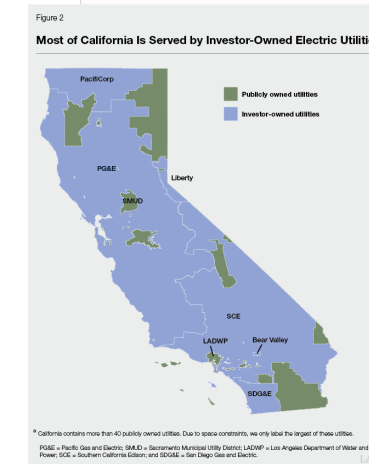
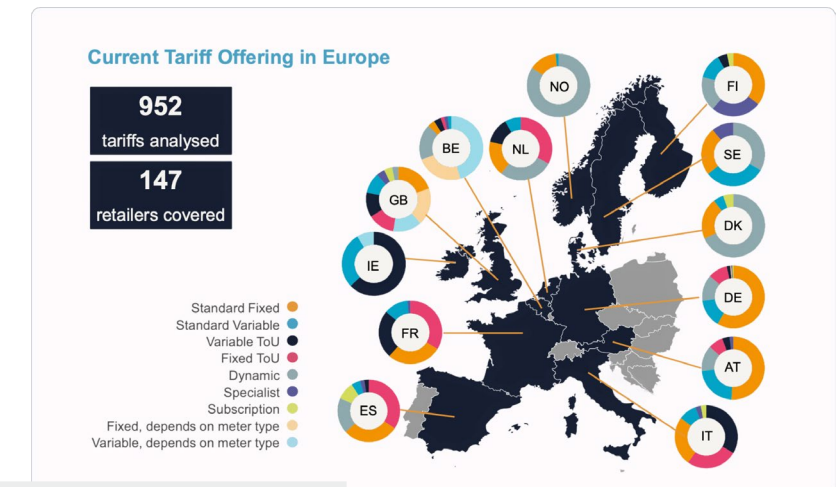


Texas outlaws wholesale indexing of retail rates



Emerging Offerings

Growing adoption of dynamic pricing in Europe



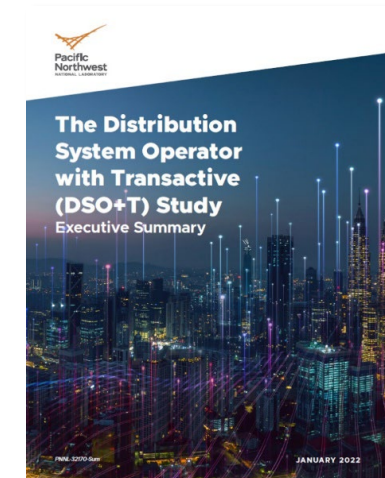
Legacy and emerging options for dynamic-price tariffs in some US jurisdictions

How to Learn More?



Key Resources

- Program website summarizes key capabilities and contributions:
<https://www.pnnl.gov/projects/transactive-systems-program>
- DSO+T and PAVER studies encapsulate the latest techno-economic and rates impact analysis
- The Gridwise Architecture Council (GWAC) has key grid architecture and roadmap resources
- Global Observatory on Peer-to-Peer (GO-P2P) has a catalog of global transactive energy and similar demonstrations



Thank you

