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Transactive Control and Coordination of Demand and Distributed Energy Resources

Presented by:
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Addressing the Need for *Grid Flexibility* from Distributed Assets: Transactive Grid Systems

The Problem:

- Generation is rapidly shifting from centralized to more distributed forms, and from being entirely dispatchable to significantly intermittent and stochastic.
- Operating such a grid with the reliability and affordability society demands, will require new forms and vastly increased amounts of *operational flexibility.*

The Opportunity:

- To provide this flexibility at reasonable cost, much of it is expected to be derived from *distributed energy resources (DERs)*: responsive loads, electrical & thermal storage, smart inverters, electric vehicle chargers, etc.

The Challenge:

- How can we coordinate DERs to provide grid services when they are neither owned nor controlled by the power grid operator?
- *Transactive grid systems* coordinate DERs through transparent, competitive means using real-time transactions involving prices or incentives to provide the feedback to close the “control” loop.

Long-Term Objective: Link All Values/Benefits in Multi-Objective Control

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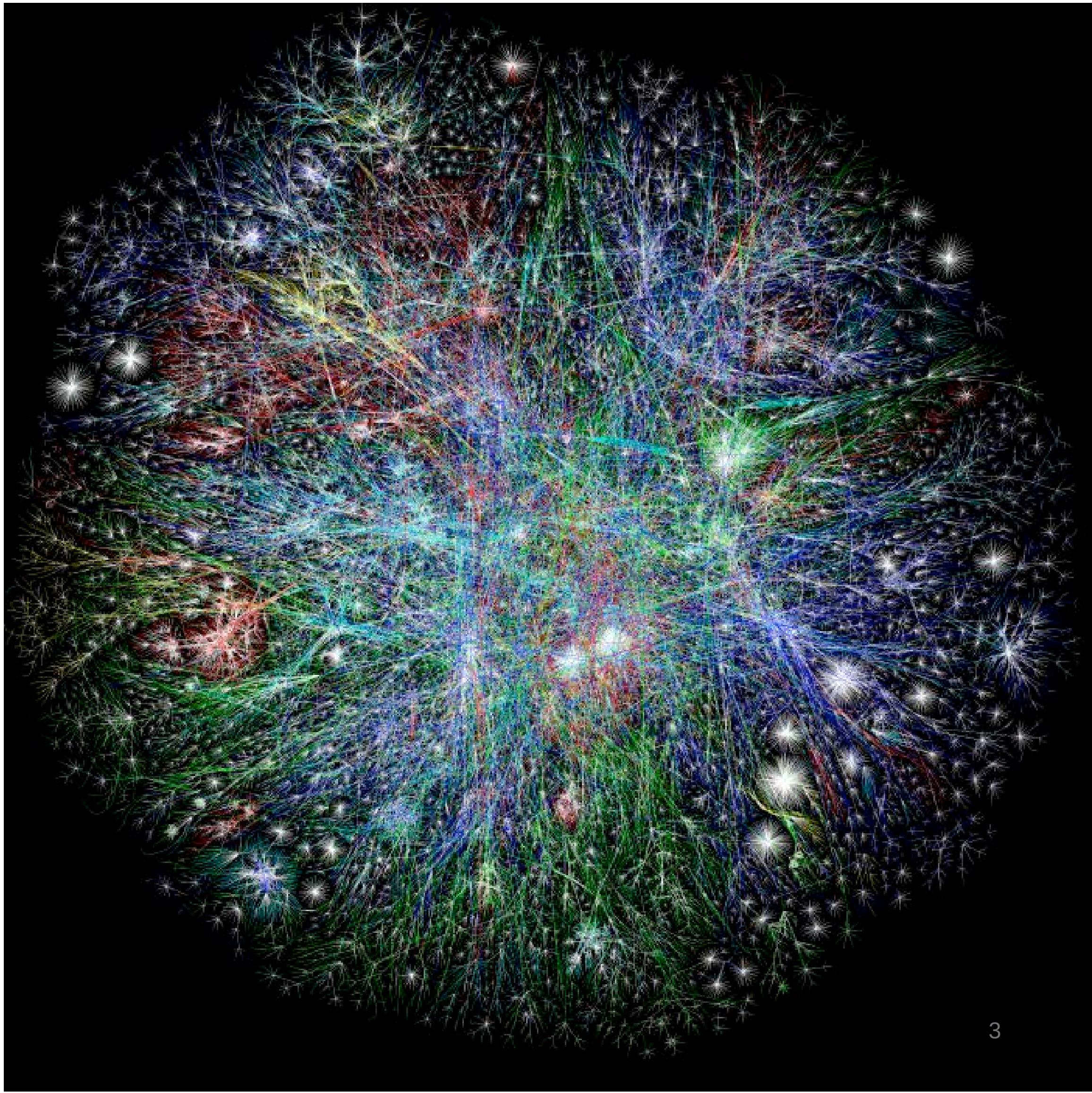
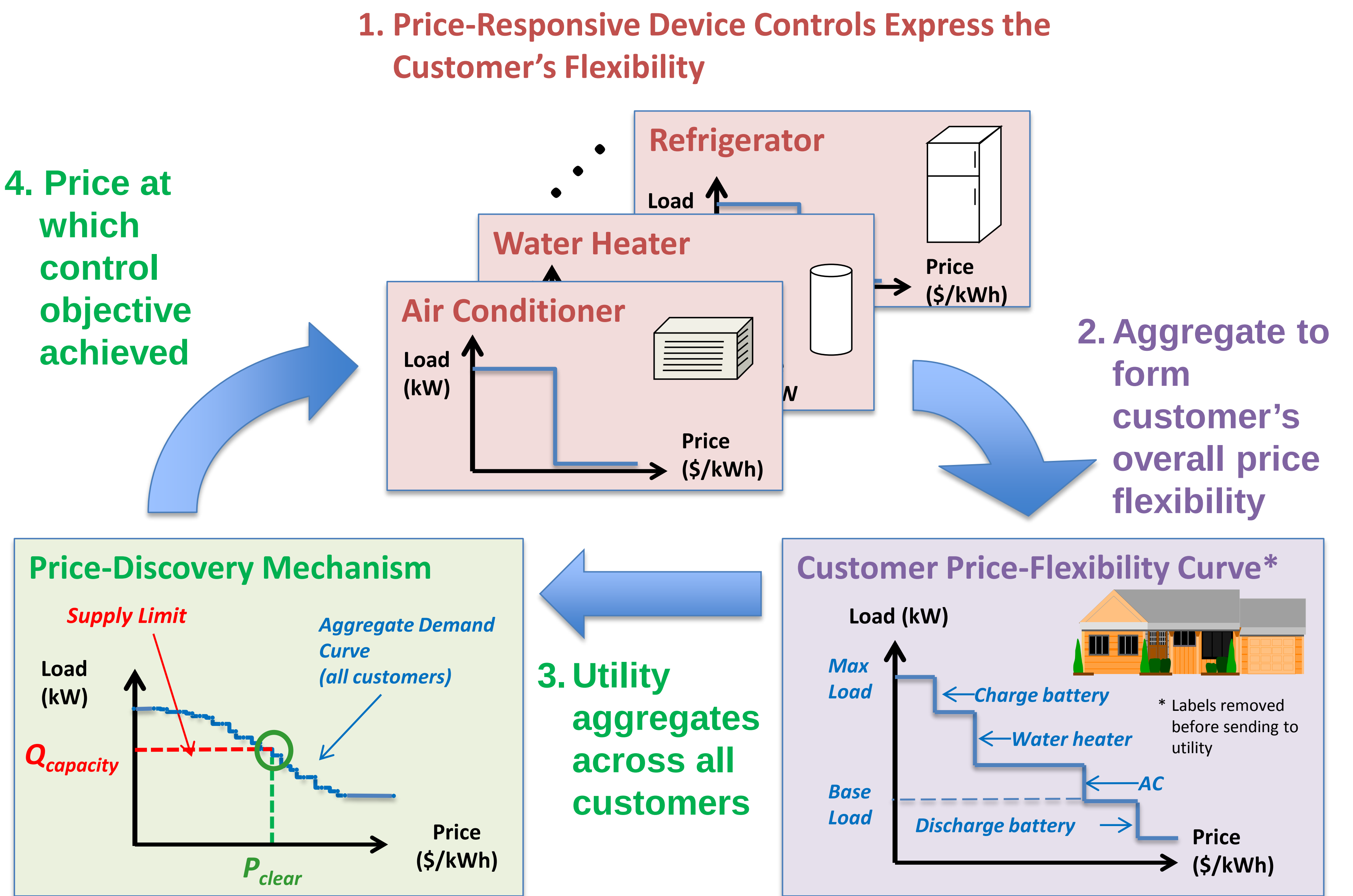
Simultaneously achieve combined benefits:

- Reduce peak loads
- Minimize wholesale prices/production costs
- Reduce transmission congestion costs
- Provide stabilizing services on transmission lines to free up capacity for renewables
- Provide ancillary services, ramping, & balancing
- Manage distribution voltages in light of rapid fluctuations in production from renewables



Feedback from Customer on their Price-Flexibility Provides Closed-Loop Control when Setting Prices



Transactive Thermostat Generates Demand Bid Based on Customer Settings *(Cooling Example)*

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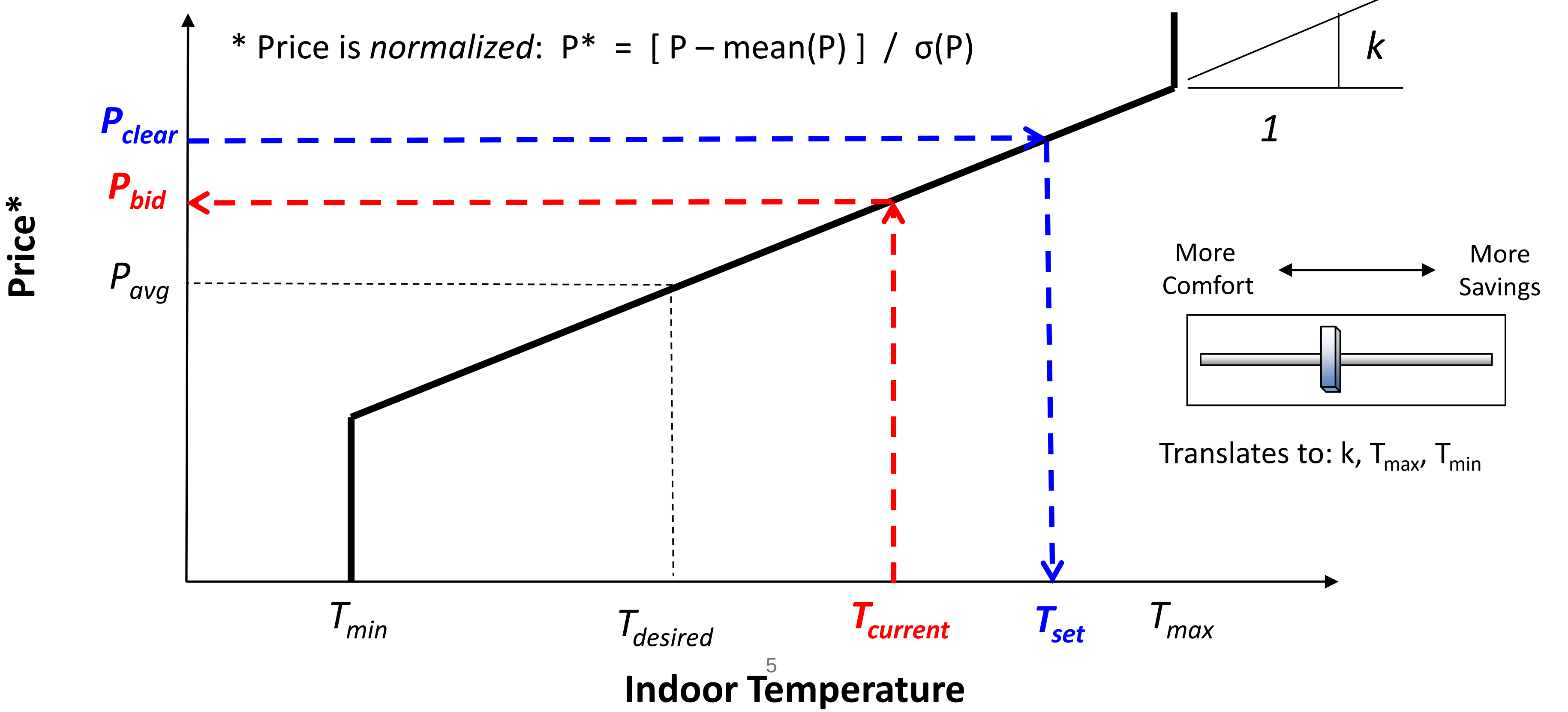
- User's *comfort/savings* setting implies limits around normal setpoint ($T_{desired}$), *temp. elasticity* (*k*)
- Current temperature used to generate bid price at which AC will "run"
- AMI history can be used to estimate bid quantity (AC power)
- Market sorts bids & quantities into demand curve, clears market returns clearing price
- Thermostat adjusts setpoint to reflect clearing price & temperature elasticity



Good Transactive System Designs Address Key Barriers to Deploying & Utilizing DERS

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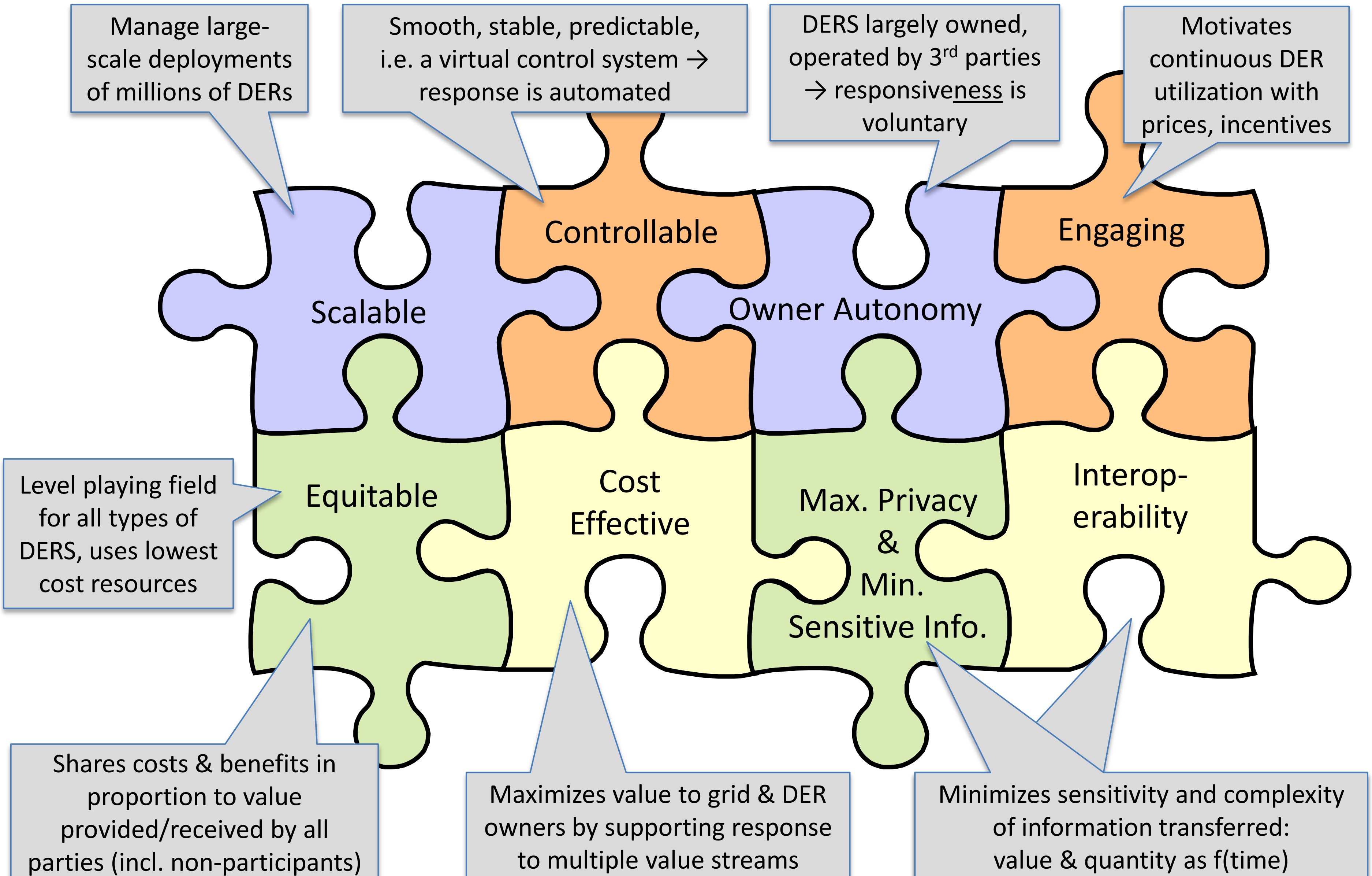

Basics of Transactive Grid Control Systems

- Voluntary coordination of responsive, distributed assets though rates or incentives
- Rates and incentives reflect actual grid values and constraints
- End user offered an equitable portion of the value earned
- Decision-making on if and how to respond is kept at end-user level and automated
- Decentralized decision-making – central command-and-control (~10^9 assets) unworkable, unacceptable re. privacy
- Feedback loop provides smooth, stable, predictable response required by grid operators
- Allows end-user assets to compete with each other and traditional grid assets, to provide grid services at the lowest cost

Supporting Infrastructure Requirements

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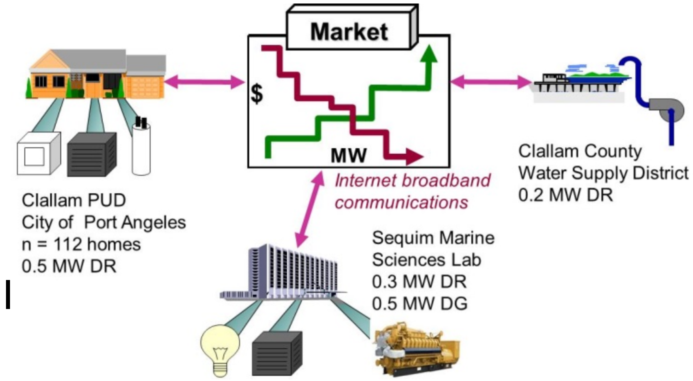
	Residential	Sm./Med. Commercial (Unitary HVAC)	Large Commercial (Built-up HVAC)
End Use Targets	▶ AC / Heat ▶ Water heaters (elec.) ▶ Refrigerators/ freezers?* ▶ Dryers?	▶ AC / Heat (rooftop, unitary) ▶ Lighting?* ▶ Refrigeration	▶ Chillers ▶ Pumps ▶ Fans* ▶ Lighting* ▶ Refrigeration* ▶ Office equipment?*
Platforms	▶ Smart thermostats ▶ Smartphone ▶ On-board appliances ▶ Home PC, cable box ▶ Smart meter ▶ HEM platform?	▶ Smart thermostats ▶ On-board equipment ▶ PC ▶ Smart meter ▶ Lightweight BEM platform?	▶ BMS (SCADA + RTU controllers) ▶ Program response into BMS, or ▶ Add supervisory-level “controllers” managing setpoints, etc.

- * Some resources needed all times of day and year – not just daytime, not just on-peak
- Where are smarts located? Where is the common interface? -- HEMS and BEMS

NW has Led Journey on Transactive Approaches

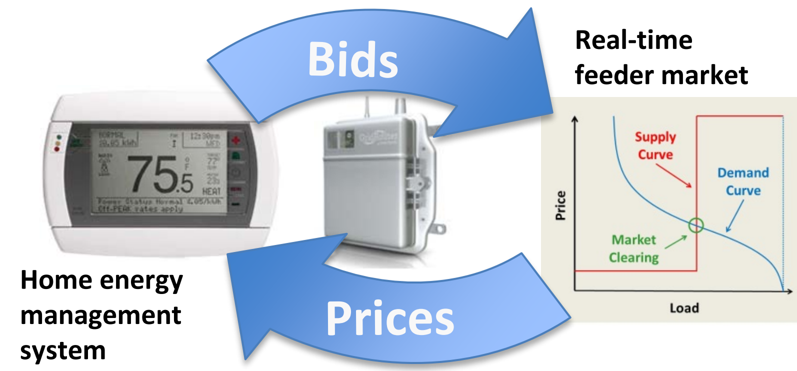
Olympic Peninsula demo, ca. 2006-07

- Established viability of transactive, decision-making to coordinate to achieve multiple objectives
  - Peak load, distribution constraints, wholesale prices
  - Residential, commercial, & municipal water pumping l distributed generation



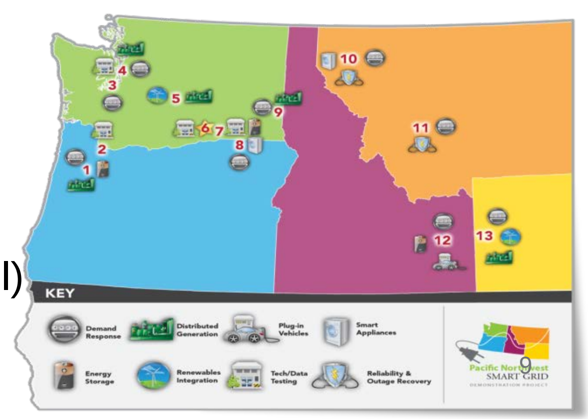
AEP gridSMART demo, ca. 2010-2014

- PUC-approved RTP tariff developed
  - Provides dynamic, real-time incentive to respond
  - Reflects real-time prices in PJM energy market
  - Manages AEP T&D constraints and peak load

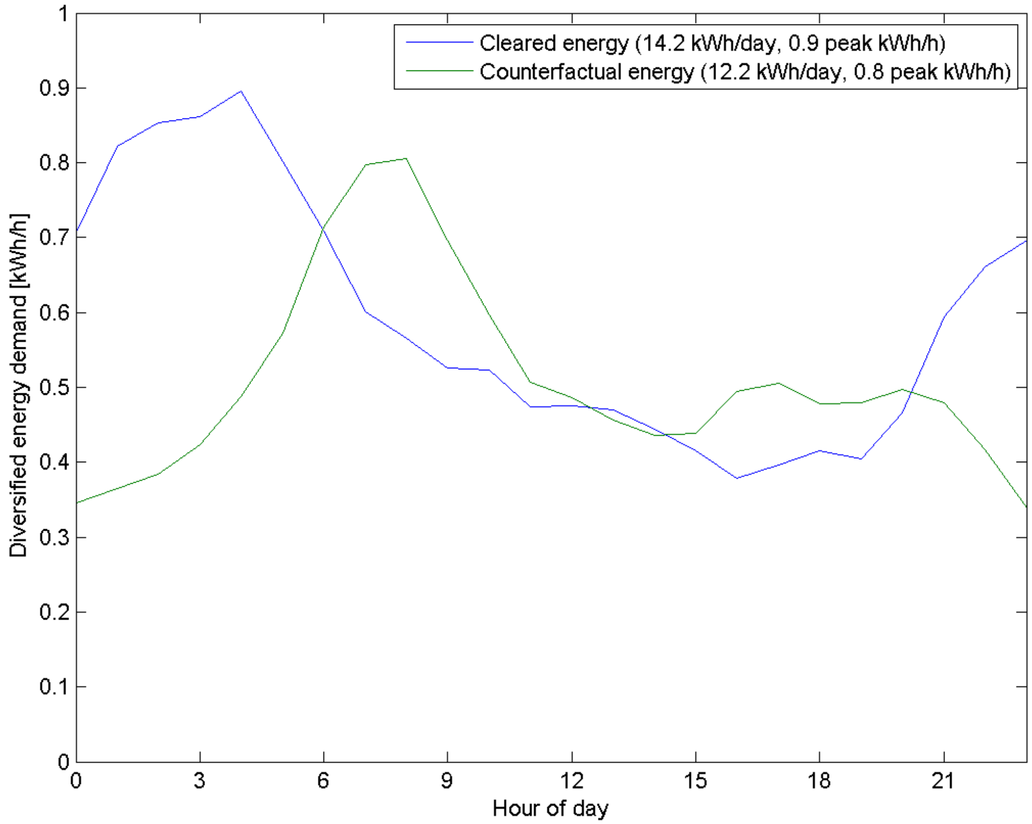


Pacific NW Smart Grid demo, ca. 2010-2015

- Key advancements made by PNWSGD
  - Response to wind balancing needs
  - Developed look ahead signals
  - Formalized, scalable architecture def. transactive node, etc.
  - Showed how "old school" approaches (e.g. direct load control) can be integrated with a transactive schema



Load Shifting Results for RTP Customers in the Olympic Peninsula Demo



- Winter peak load shifted by pre-heating
- Resulting new peak load at 3 AM is non-coincident with system peak at 7 AM
- Illustrates key finding that a portfolio of contract types may be optimal – i.e., we don't want to just create a new peak

Olympic Peninsula Demo: Key

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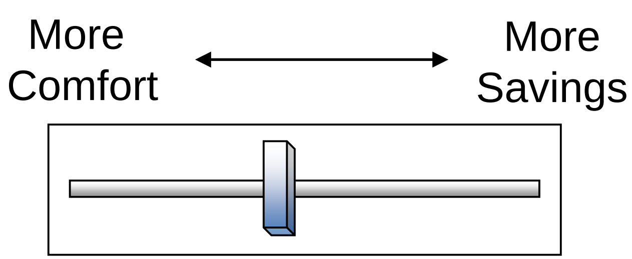
Customers can be recruited, retained, and will respond to *dynamic pricing* schemes **<u>if they are offered</u>**:

- Opportunity for significant savings (~10% was suggested)
- A "no-lose" proposition compared to a fixed rate
- Control over how much they choose to respond, with which end uses, and a 24-hour override
  - prevents fatigue: reduced participation if called upon too often
- Technology that automates their desired level of response
- A simple, intuitive, semantic interface to automate their response



Translates to control parameters:

K, T_{max}, T_{min} (see *Virtual Thermostat*)

Olympic Peninsula Demo: Key

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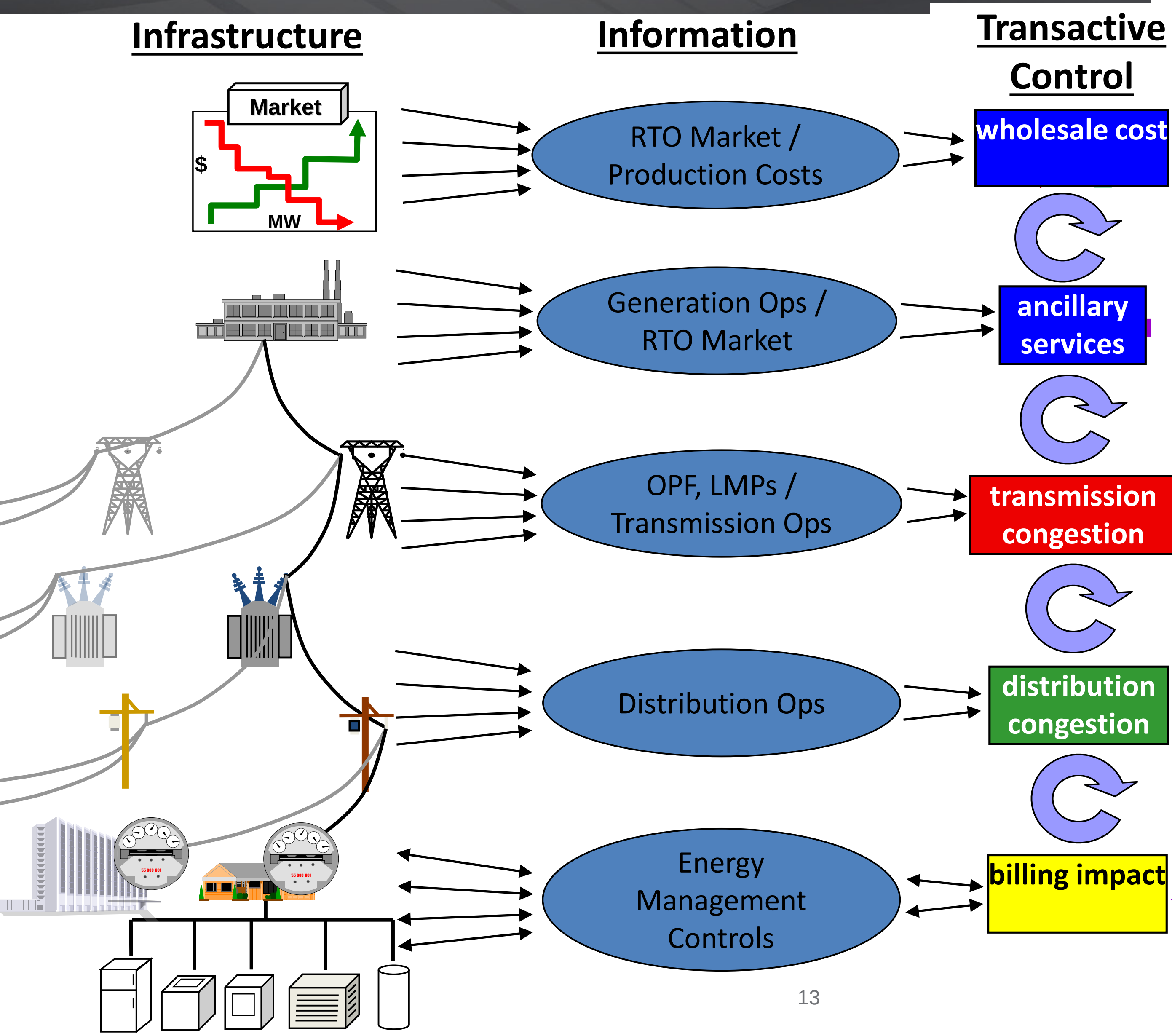
Significant demand response was obtained:

- 15% reduction of peak load
- Up to 50% reduction in total load for several days in a row during shoulder periods
- Response to wholesale prices + transmission congestion + distribution congestion
- Able to cap net demand at an arbitrary level to manage local distribution constraint
- Short-term response capability could provide regulation, other ancillary services adds significant value at very low impact and low cost)
- Same signals integrated commercial & institutional loads, distributed resources (backup generators)

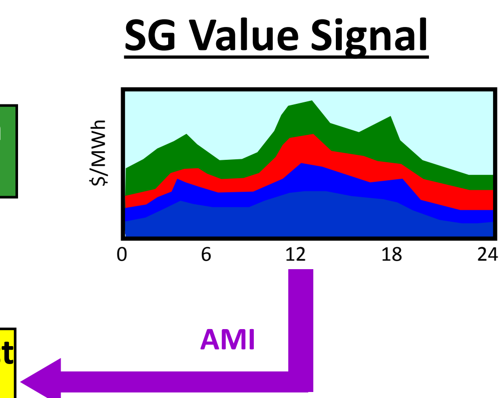
Two-Way, Hierarchical, Transactive Architecture Localizes and Balances Values & Prices



Information for each layer of value signal is <u>entirely local</u>

Honoring <u>natural domains</u> keeps the smart grid simple:

- protocols/standards are mostly quantity, cost, and time (*"KISS"*)
- honoring "need-to-know" enhances cyber security



Opportunities in Large Commercial Building Controls

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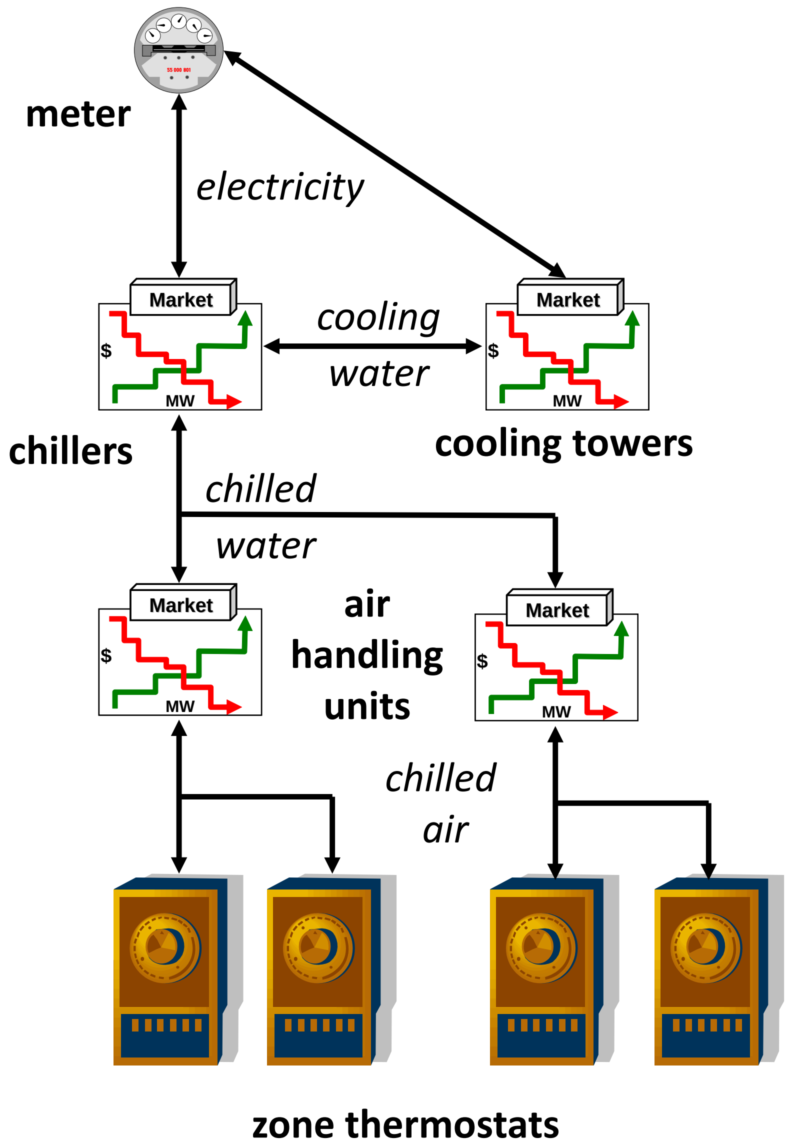
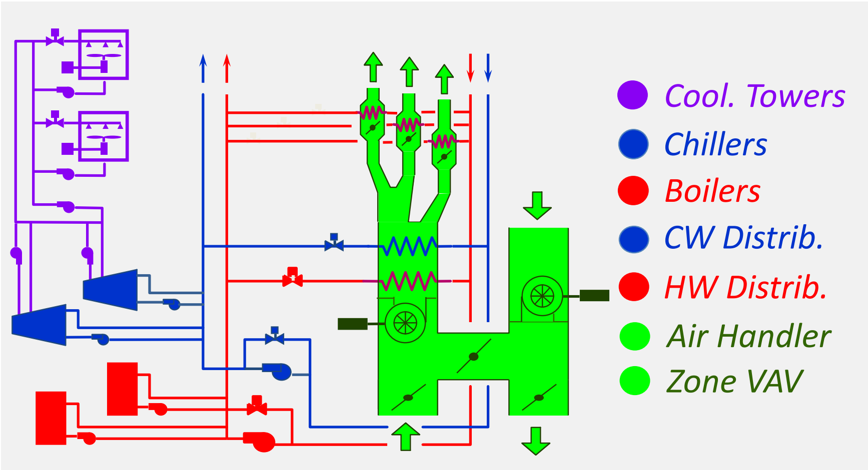
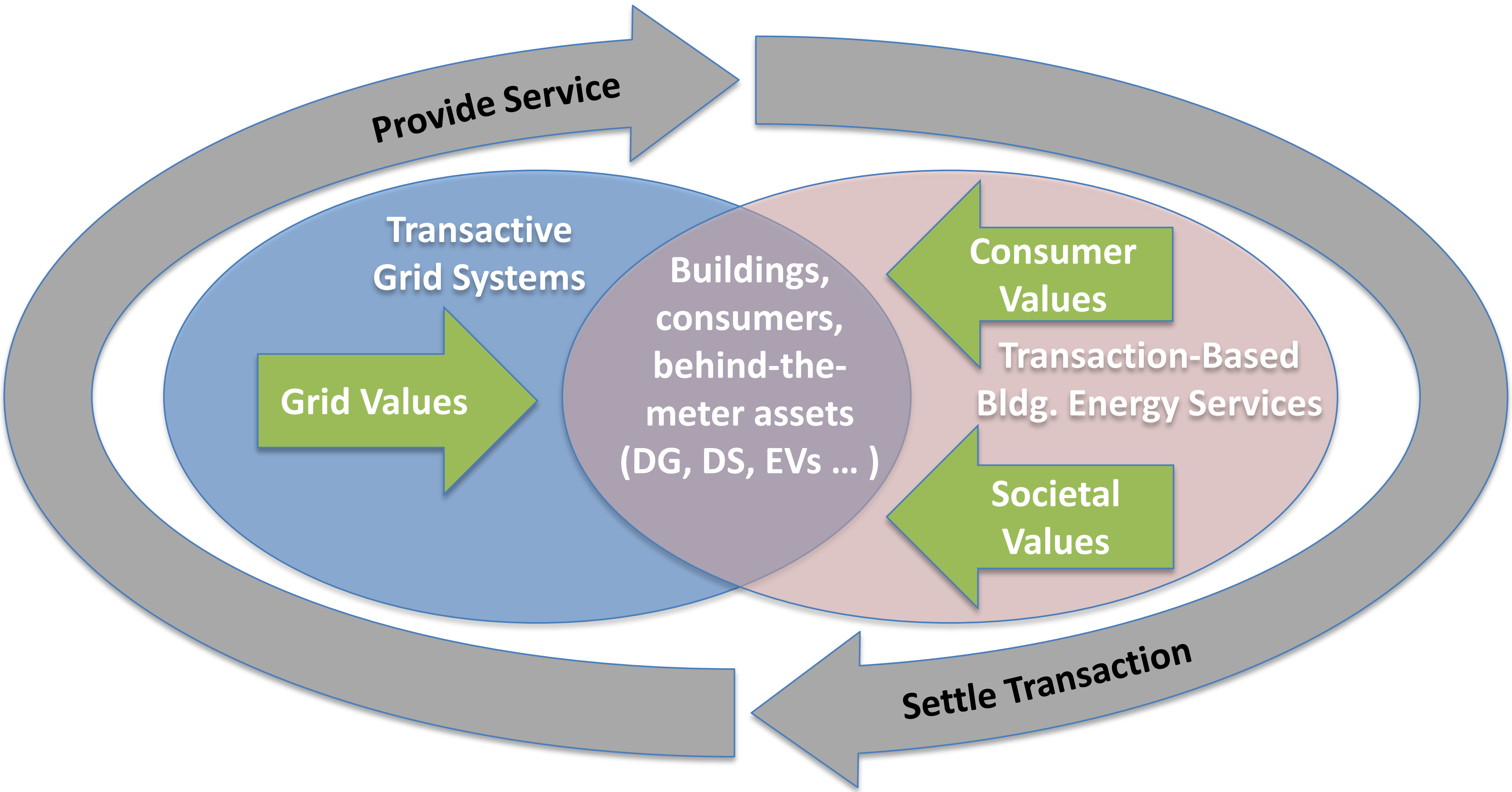




- Commercial HVAC controls can be organized as a transactive network
- In principle, has similar self-organizing, self-optimizing properties
  - Chillers buy electricity, sell chilled water to AHUs, who sell chilled air to zone thermostats, etc.
- Electricity prices seamlessly penetrate, system readjusts automatically
- Efficiency potential from diagnostics potential, chiller/cooling tower optimizations

The Emerging Transactive Energy Ecosystem

Transactive Energy Ecosystem



- Coming soon: transportation, manufacturing

Synergies Between Transactive Systems for Grid Integration and Building Energy Services

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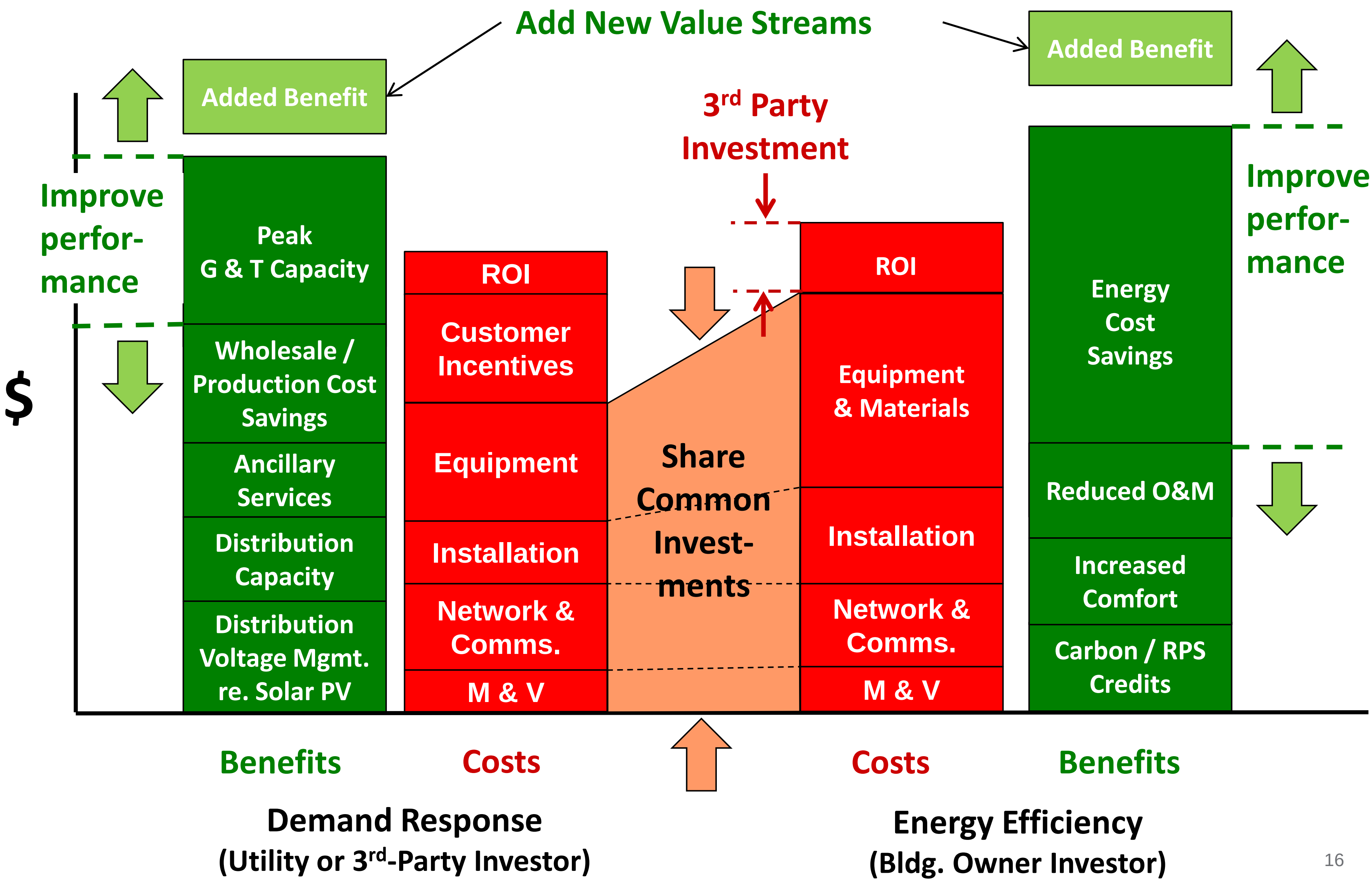

Significant New Drivers for Transactive Systems Have Emerged

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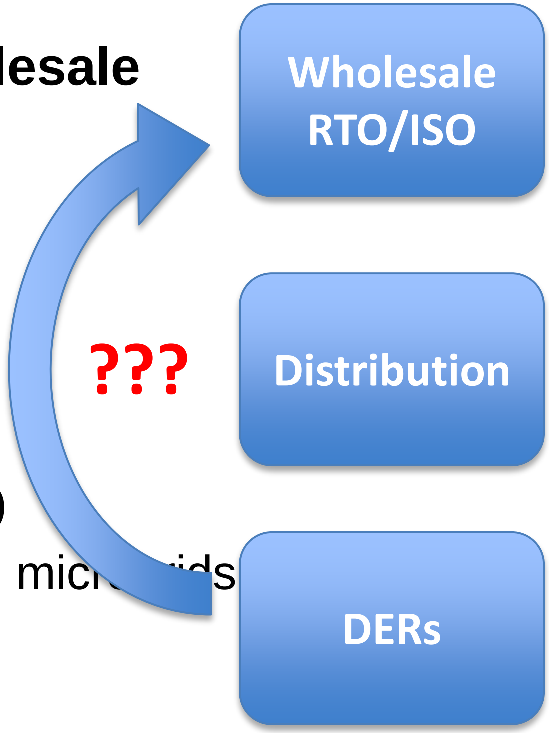
- **Flexibility resources at distribution level are needed**
  - Significant value from distribution capacity
  - More importantly, to manage impacts of PV
- **Bypassing distribution, DERs straight to wholesale**
  - Misses distribution value
  - More importantly, problematic architecturally
    - no observability by distribution
    - no ability to manage conflicting objectives
- **Rise of distribution system operators (DSOs)**
  - Important new trend (6+ states lead by NY, CA, HI)
  - Broad access to distribution networks – DERs, PV, microgrids
  - Market exchange is a core concept
  - DSO as aggregator is a core concept
  - Reinforces foundational elements of transactive approach



Transactive Systems Program

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GOAL: Develop means for engaging and coordinating large populations of customer-owned & 3rd-party distributed assets* through transparent, competitive means, to provide the flexibility required by an adaptive, reliable, and cost-effective future electric system.

To support this goal, the program will:

Develop an environment for developing, testing, refining, and comparing designs for transactive coordination systems, including:

- Analysis framework & performance metrics for developing and comparing transactive designs
- Systematic expression of value & costs from various stakeholders' perspectives
- Scenarios, models & simulation environment to support the analysis

* Distributed assets – DERs – include responsive loads, distributed electrical & thermal storage, smart inverters for solar photovoltaic systems, other distributed generation, electric vehicles, etc.

WA-CEF and DOE - OE & EERE Sponsored Transactive Multi-Campus Project

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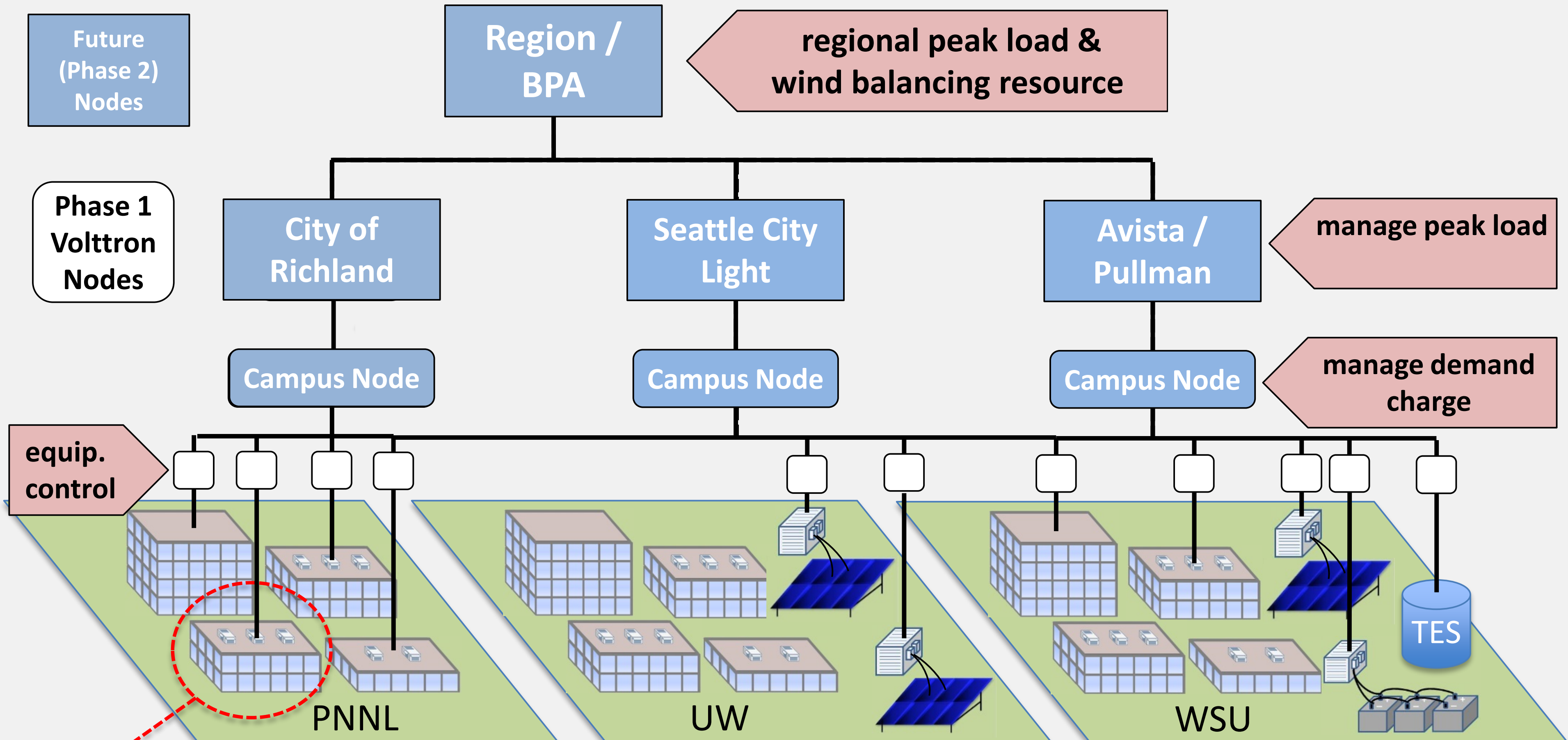

- Multi-campus network operations
- Transactive campus/bldg. responsive applications
- Transactive / advanced bldg. controls testbed (SEB bldg.)

- Energy efficiency applications, leveraging transactive network
- Smart PV inverter integration w/ distribution
- Transactive grid controls

- Microgrids as a resilience resource/smart city w/ Avista
- Solar PV & CEF battery in WSU microgrid operations
- Flexible loads, thermal storage