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Transactive Energy for Distributed Resource Integration

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

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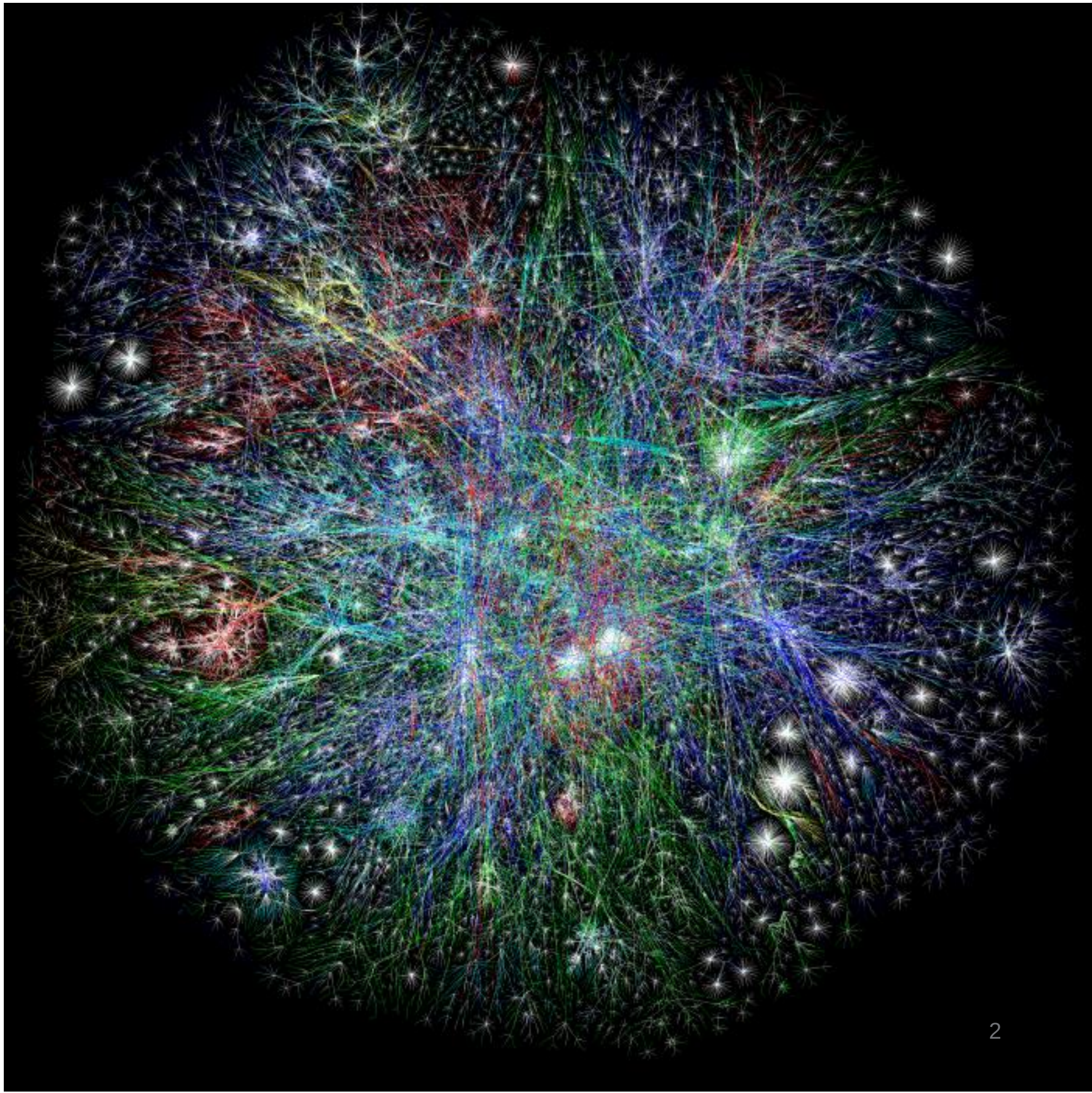
Complex systems

- Highly interconnected
- Heterogeneous device-human participation
- Extreme data
- Pervasive intelligence
- Autonomous decision-making
- Diverse and often competing objectives



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

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Energy systems offer

- Potential for substantial efficiencies in end-use systems with new controls
- More data and devices available

But

- New asset behaviors difficult to coordinate
- Existing controls antiquated to changes

Cyber-physical systems offer

- Growing “edge” computing resources
- Cloud computing scaling paradigm

But

- Existing security models challenged

Traditional centralized control approaches are a common weakness

Transactive Energy – an approach to responding to our changing world…

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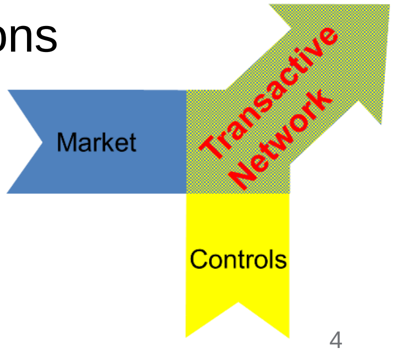
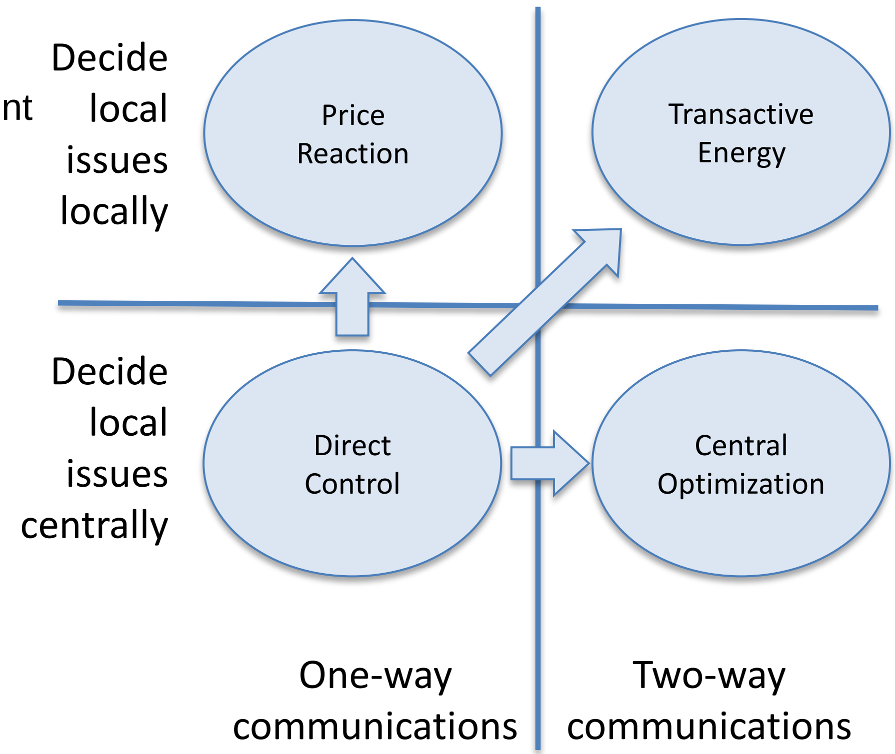
> *"A set of economic and control mechanisms that allows the dynamic balance of supply and demand across the entire electrical infrastructure using value as a key operational parameter."*
>
> GridWise® Architecture Council, Transactive Energy Framework

- Use market mechanisms to perform distributed optimization
  - Reflect value in exchangeable terms (price)
  - Effectively allocate available resources and services in real-time
  - Provide incentive for investment on longer time horizon
- Use communications and automation of devices and systems as 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



Types of Smart Grid Coordination

- **Direct (Top-Down) Control**
  - Utility switches devices on/off remotely
  - No local information considered
- **Central Control/Optimization**
  - Optimization and control from a central point
  - Relevant local information must be communicated to central point
- **Price Reaction Control**
  - Prices signalled to customers and/or their automated devices
  - No communication of local information
- **Transactive Energy (TE)**
  - Automated devices engage in market interactions
  - Information exchange includes quantity (e.g., power, energy) and price



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Smart Energy Management Matrix

	One-way communications	Two-way communications
Decide local issues locally	**Price Reaction** ↑ Full use of response potential ↓ Uncertain system reaction ↓ Market inefficiency ↑ Mitigates privacy issues	**Transactive Energy** ↑ Full use of response potential ↑ Predictable system reaction ↑ Efficient market ↑ Mitigates privacy issues
Decide local issues centrally	**Direct Control** ↓ Partial use of response potential ↓ Uncertain system reaction ↓ Autonomy issues	**Central Optimization** ↑ Full use of response potential ↑ Predictable system reaction ↓ Privacy & autonomy issues ↓ Scalability issues

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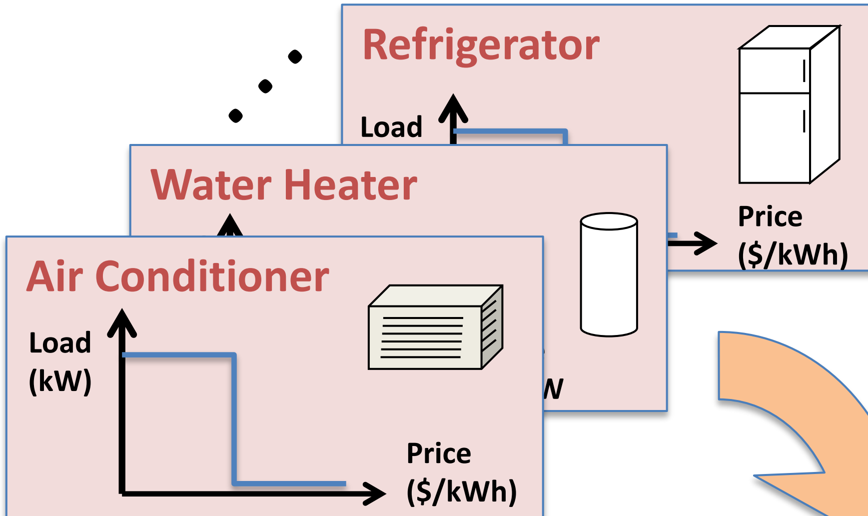
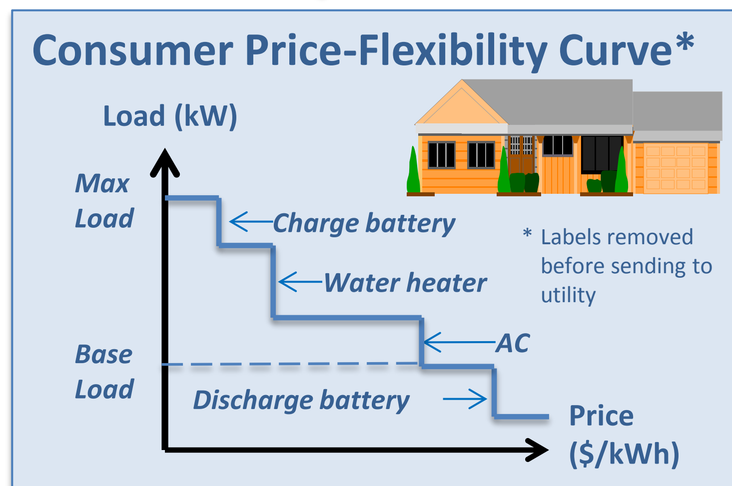
Transactive Grid Overview

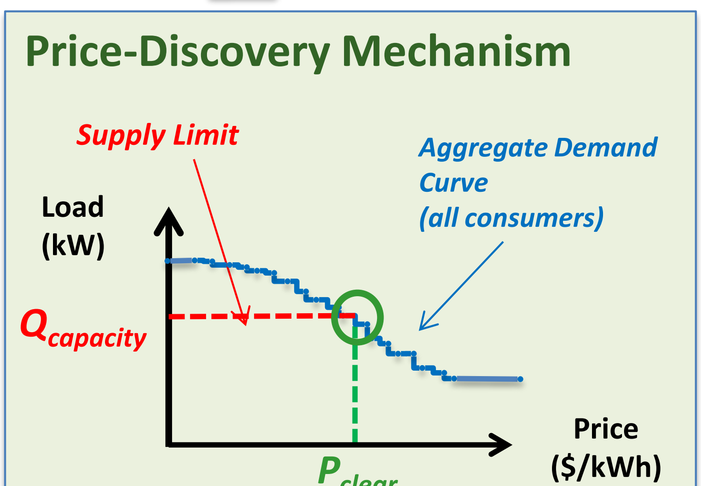
1. Automated, price-responsive device controls express consumer's flexibility (based on current needs)



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



3. Service provider aggregates curves from all consumers



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

Transactive Energy Principles

Highly automated, coordinated self-optimization	Provide non-discriminatory participation by qualified participants
Transacting parties are accountable for standards of performance	Observable and auditable at interfaces
Maintain system reliability and control while enabling optimal integration of distributed energy resources	Scalable, adaptable, and extensible across a number of devices, participants, and geographic extents

Principles: High-level requirements for TE systems that provide an additional point of reference for communicating with stakeholders and identifying common ground within the transactive energy community.

From GridWise Architecture Council's Transactive Energy Framework
http://www.gridwiseac.org/about/transactive_energy.aspx

Transactive Interaction Model

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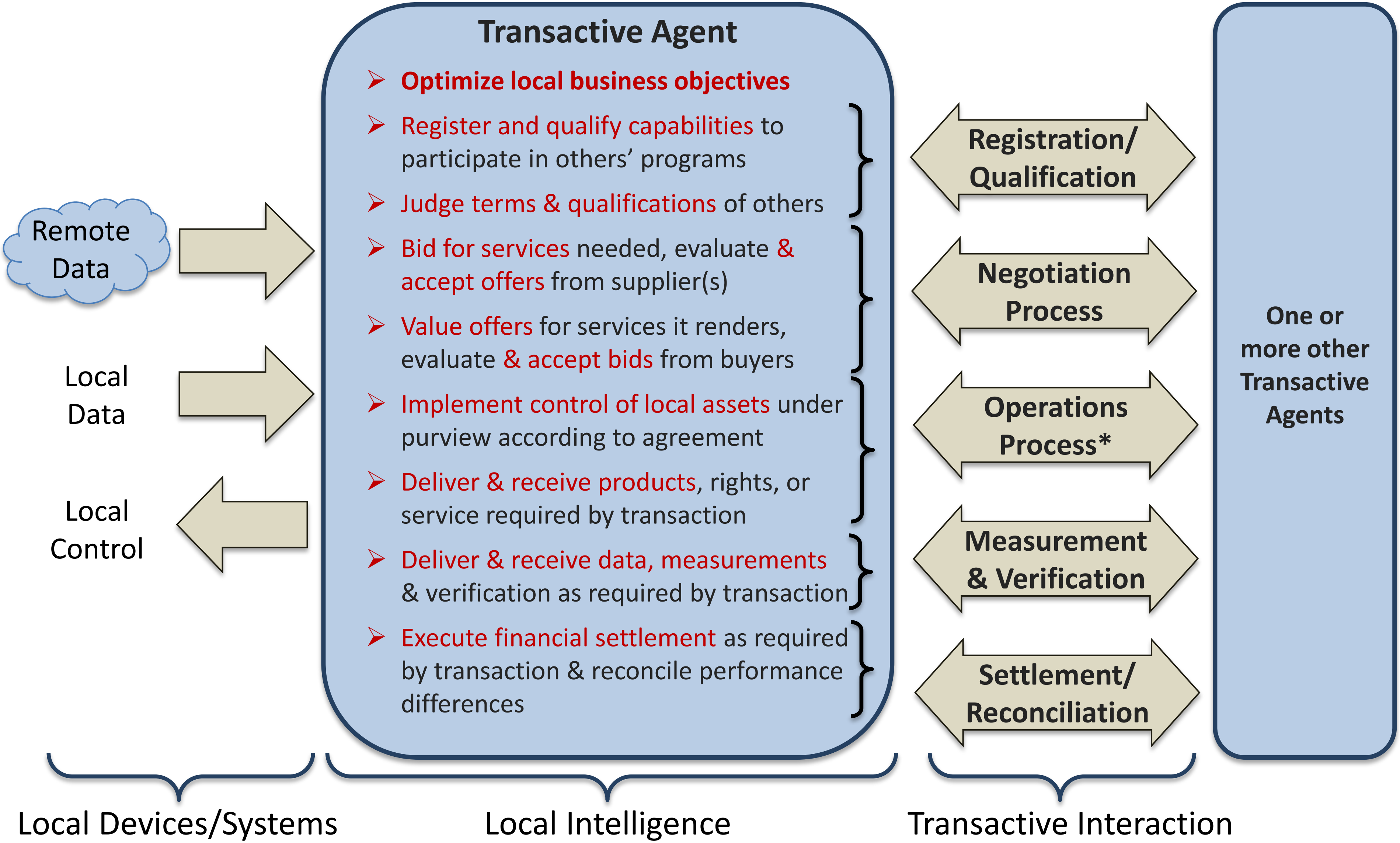

* E.g., operations signals or e-product exchange

Some US Transactive Energy Demonstrations

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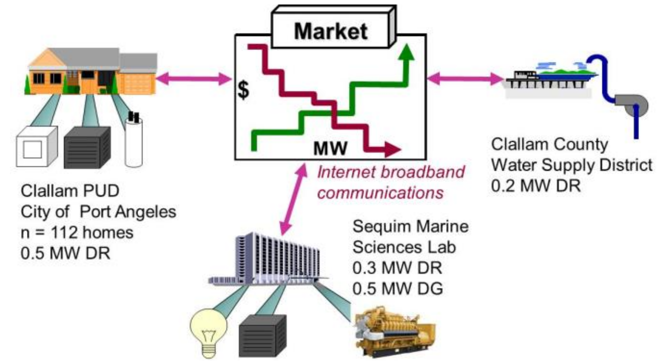
Olympic Peninsula demo, ca. 2006-07

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

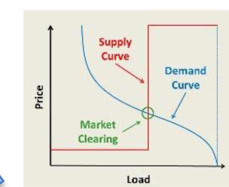


AEP gridSMART® demo, ca. 2010-2014

- PUC-approved real-time price 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

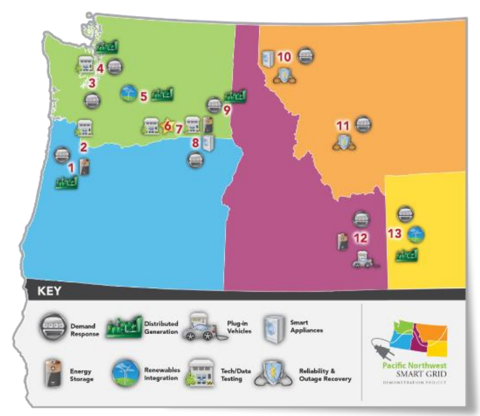
Home energy management system

Real-time feeder double-auction market

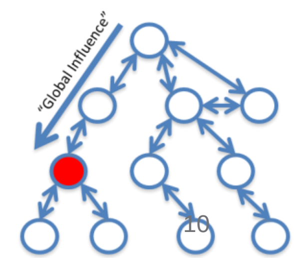


Pacific NW Smart Grid demo, ca. 2010-2015

- Key advancements made by PNWSGD
  - Wind balancing
  - Developed look ahead signals
  - Standardized definition of transactive node and formalized agent testing
  - Showed how “old school” approaches (e.g., direct load control) can be integrated with a transactive schema



Real-time & forward energy exchange with neighbors



PowerMatcher Demonstrations in Europe

Project/Demo	Description	Results	Year
Crisp field experiment	Flexibility sourced from industrial and household sites reacting to fluctuations in wind energy generation.	Electricity market related gain: wind imbalance reduction of 40%.	2005–2006
Microcogeneration field experiment	Flexibility from microcogeneration units at households used to perform peak-load reduction in a distribution grid.	Distribution grid peak-load-reduction of 30% (during summer) to 50% (during winter).	2006–2007
PowerMatching City	Demonstration of simultaneous optimization for energy trade and active distribution management. It included a value assessment of end user flexibility.	Based on the demo's outcomes, the value of end user flexibility in The Netherlands may reach an estimated €3.5 billion (US$2.8 billion). The Netherlands has a population of 17 million people.	2009–2015
Smart-charging electrical vehicles (EVs)	A series of tests with smart-charging EVs coordinated using PowerMatcher, backed by large-scale simulation study (Grid4Vehicles project).	Active network management: distribution grid peak-load-reductions of 30–35%.	First EV test: about 2007; Grid4Vehicles simulation: 2010
SmartHouse/ SmartGrid scalability field experiment	Scalability stress test of large-scale information communications technology (ICT) architecture connected to a cluster of real households.	Scalability beyond 1 million customers is feasible.	2010
EcoGrid EU demonstration	Large-scale demonstration of a novel real-time market involving 5-min electricity prices communicated to about 1,800 households, of which a subset ran PowerMatcher's ICT architecture.	Large-scale roll-out experience for price-based and transactive smart grid technologies. Unleashed flexibility from a large number of heat pumps, making 20% of their power consumption shiftable in time.	2011–2015
Couperus	Approximately 300 apartments with heat pumps (HPs) involved in simultaneous optimization for energy trade and active distribution management.	Electricity market related gain: wind imbalance reduction of 80%. Active network management: proof of principle of locational-price based congestion management. Operation of HPs shiftable up to eight hours.	2011–2015

K Kok, S Widergren, “A Society of Devices,” *IEEE Power & Energy Magazine*, May/June 2016.

Thank you!

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