The Grid is Flat: Implications for Demand-side Modeling, Control, and Optimization

Tariq Samad

Corporate Fellow

Honeywell Automation and Control Solutions

Honeywell

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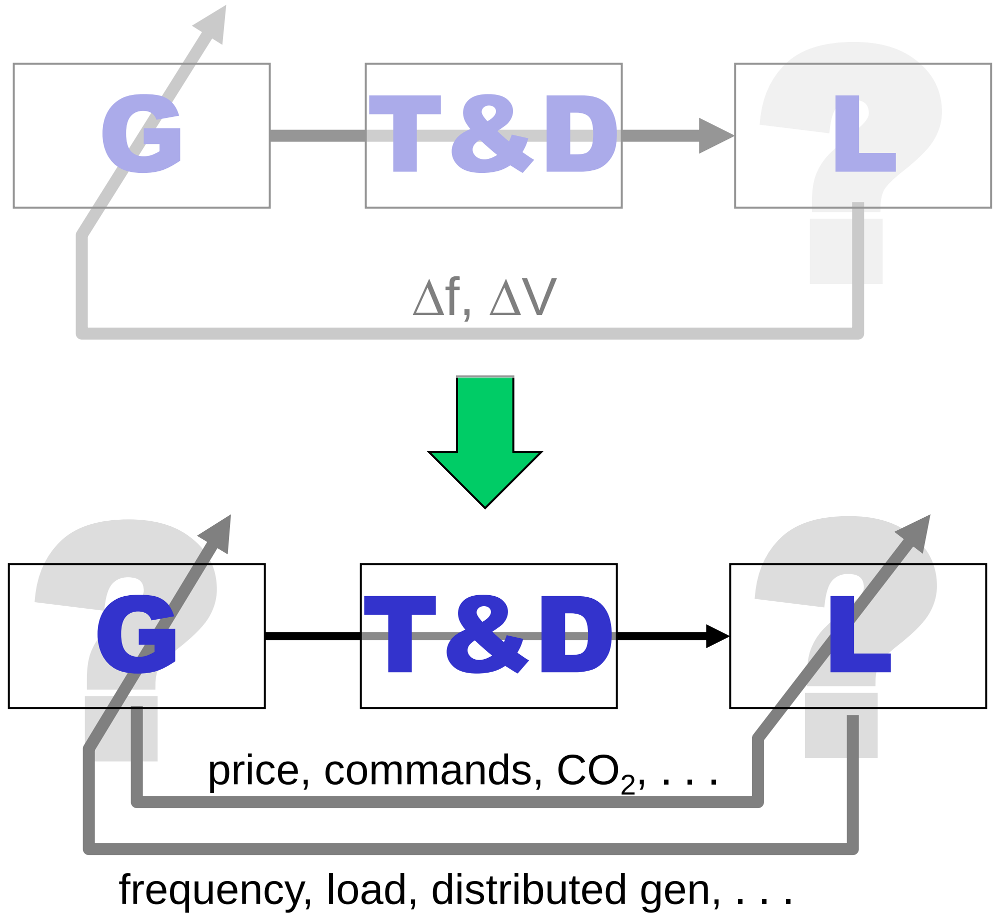
Outline

- Motivation
- The state-of-the-art and -practice
- Research imperatives

Evolution of the Flat Grid

Traditional power system

Grid of the Future (high renewables penetration)



Demand-side management defines the "flat grid"!

“Flat Grid” Research Topics

Energy efficiency

Automated demand response

Distributed generation

Microgrids

Thermal storage

Electrical storage

Combined heat and power

Home energy management systems

Electric vehicles

Connected homes and buildings

Building automation

Dynamic pricing

Measurement & validation

Interoperability and standards

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- The state-of-the-art and –practice
  - the flattening of the grid has begun . . .
- Research imperatives

DOE Smart Grid Investment Grant Award

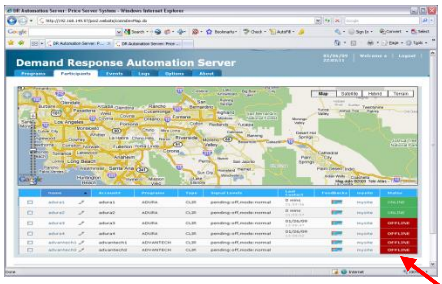
U.S. Department of Energy

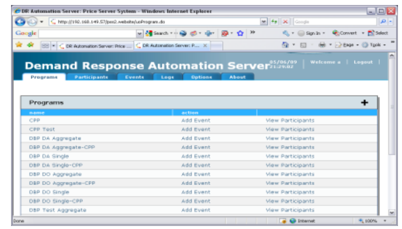
2009 American Recovery & Reinvestment Act (ARRA) Smart Grid Grant

$11.4M DOE-funded; $22.8M total project

Southern California Edison (SCE)

- CPP Tariff Creation
- System Planning
- Event Notification
- Incentive Payment
- Regulatory Reporting





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- Project Implementation
- Operating Center
- Customer Acquisition and Deployment
- Reporting

Akuacom

DR Automation System (DRAS)

- Event Control
- Information Dashboards
- Reporting

JACE Controllers

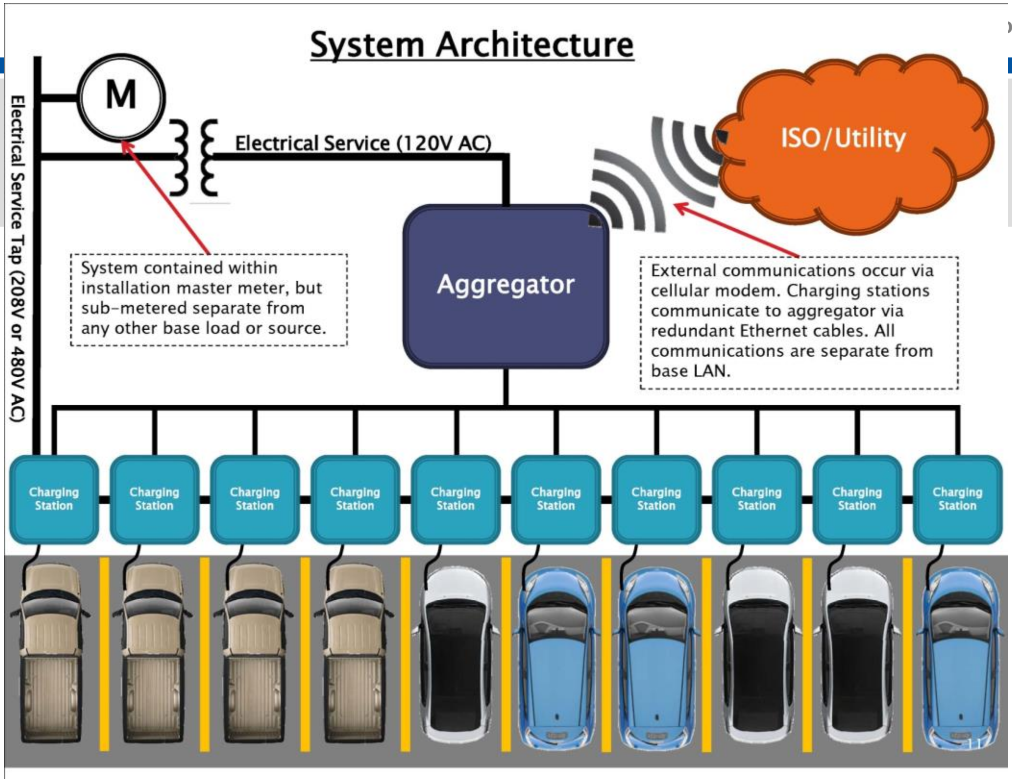
- Integration with Existing BAS
- Customer Dashboard

TRIDIUM Connecting minds and machines

700 SCE Customers (80 MW – Auto-DR)

- > 200KW Use
- Program Participation Agreement
- DR Specific Programming Change to BAS
- Individual Event Participation or Opt Out

Automated Demand Response for Ancillary Services:
LA AFB Vehicle-to-Grid Project



- First federal installation to replace all general purpose fleet vehicles with plug-in electric counterparts
  - 41 plug-in EVs with charging stations, V2G-capable, ~15kW per vehicle
  - tools for scheduling and dispatching of PEVs
- V2G market participation: monthly frequency regulation revenues in CAISO: ~$15/kW (2011)
- First of several anticipated installations for DoD V2G systems

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Microgrid Case Study

US Food and Drug Administration (FDA) campus, White Oak, Maryland

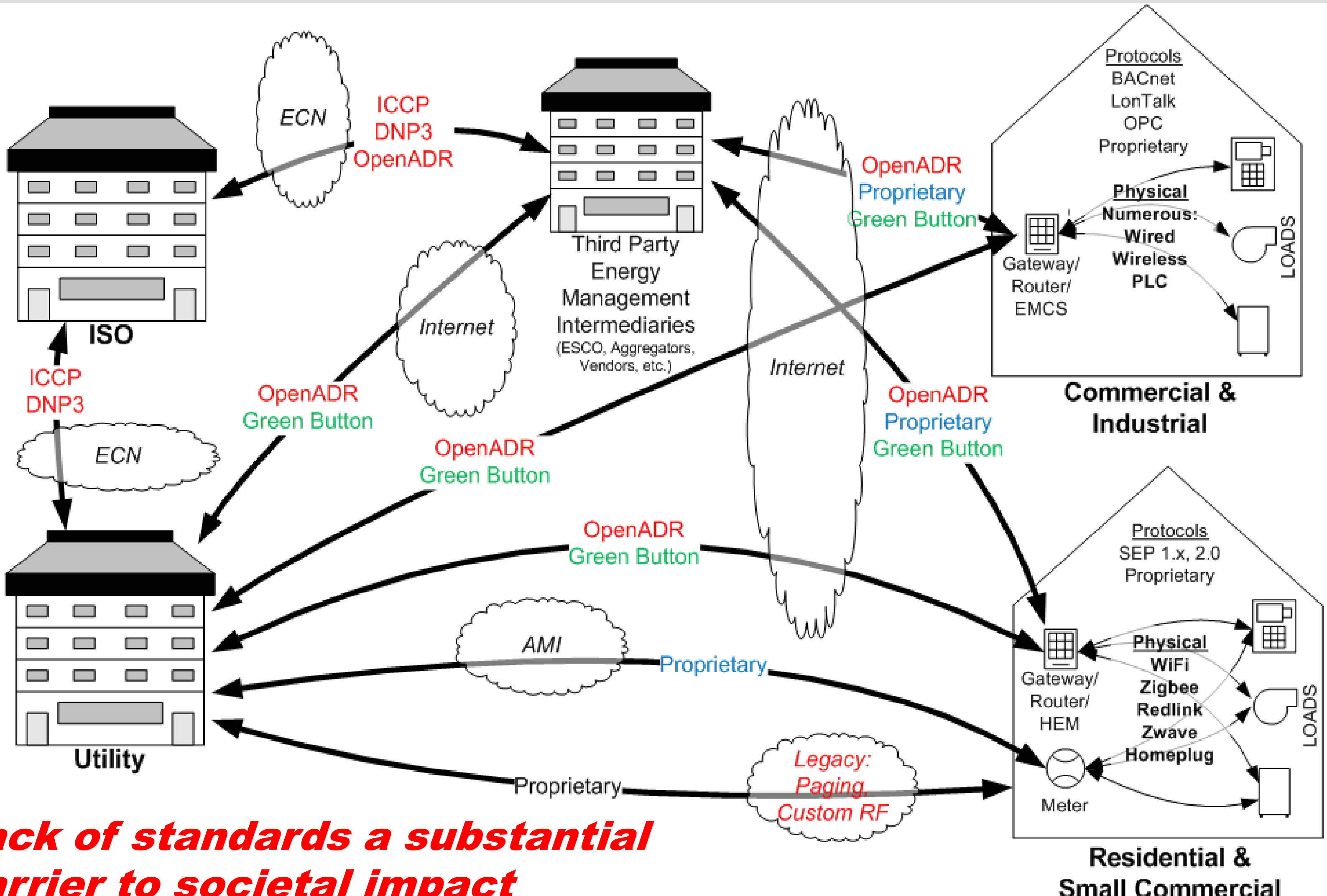
- 9,000 employees
- 362,000 m^2
- Islanding capability required

Current energy assets

- 27,000 ft^2 central plant
- Electrical generation
  - 5.8 MW reciprocating engine (dual fuel)
  - 4 X 4.5 MW turbine-generator (nat. gas)
  - 2.0 MW diesel black-start gen
- Chilled water
  - 2 X 1,100-ton absorption chillers
  - centrifugals (5 for 8,000 tons total)
- Dual-fuel hot water back-up boilers
  - 3 X 10 MMBtu/Hr
- 25KW fixed & 5KW tracking PV array
- Significant expansion under way

Uptime	Uptime over the last 12 months is > 99.999%.
Islanding	Islanded, automatically or manually, 47 times over the past 18 months. No weather-related interruptions.
Power Export	More power is supplied to utility per year than the utility supplies to the White Oak campus.
Energy Conservation	30% reduction in energy use from baseline
CO_2 Mitigation	50,000 metric tons CO_2-equivalent; 15,000 cars' worth. In construction: additional 22,000 metric tons.

Standards Summary



Lack of standards a substantial barrier to societal impact

Outline

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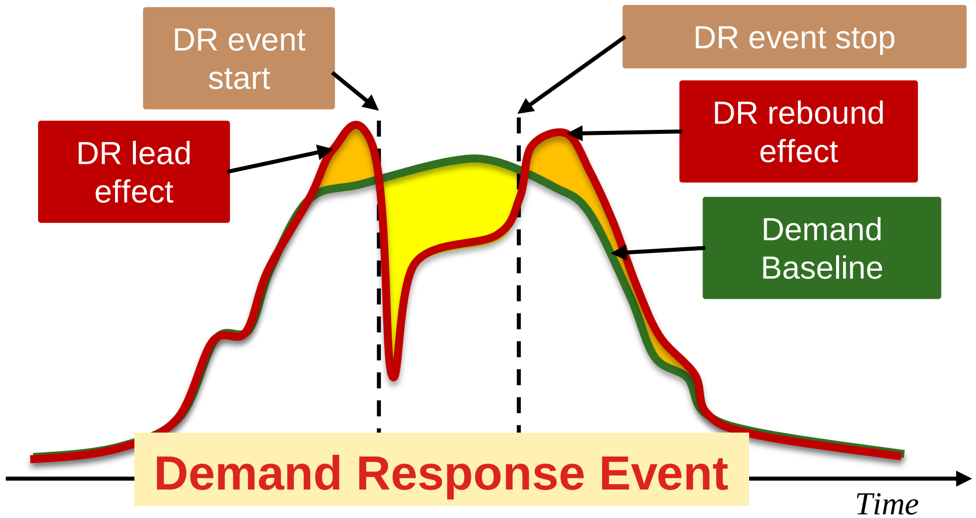
- Research imperatives
  - advances in demand-side intelligence that will enable the flat grid . . . and challenges to their realization

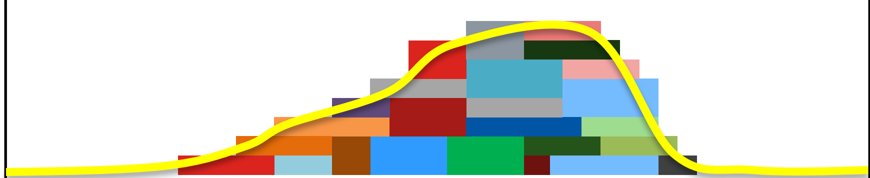
Research Challenge: DR Modeling and Optimization



To fully avail of demand-side assets for renewables integration, higher-fidelity and higher-resolution DR models are required . . . data analytics can help meet the challenge

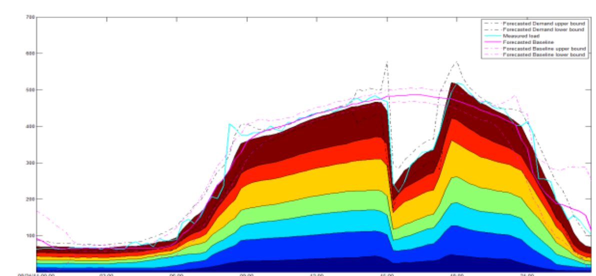
Current approach

Desired load reduction is accomplished by approximate combination of DR bids of individual participants

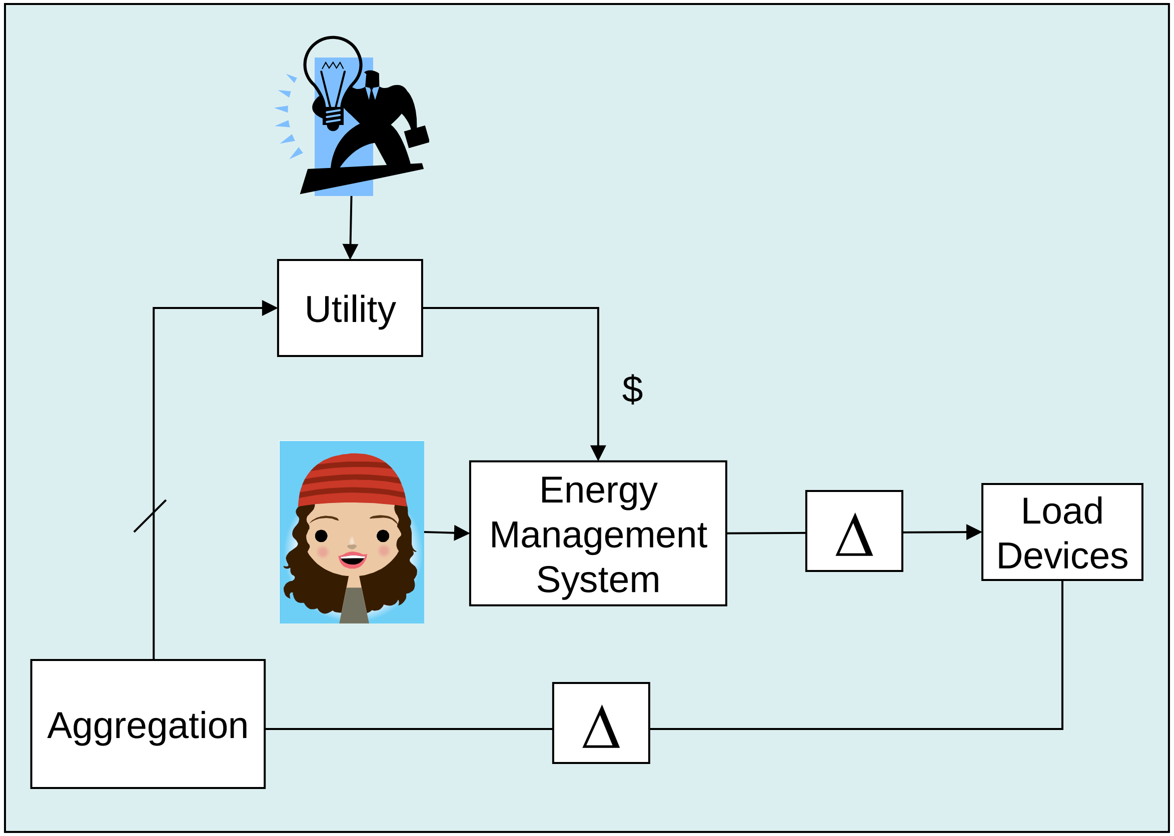


Forecasting based approach

Effect of a specific DR event (including lead and rebound effects) is accurately predicted by combination of forecasts for individual loads



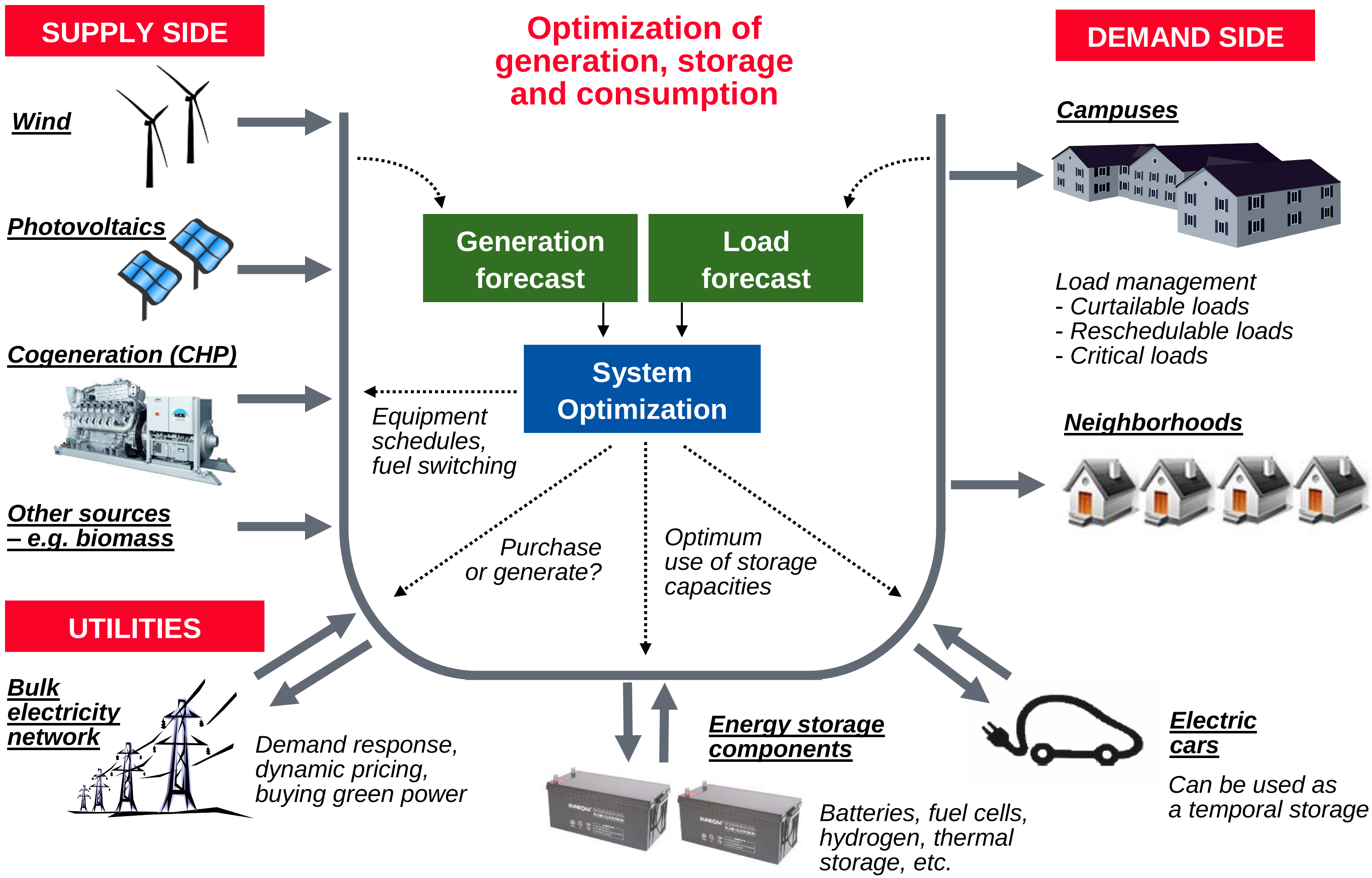
Research Challenge: Human-in-the-loop Automated Demand Response



- *What are appropriate demand response signals?*
  - price signals? load reduction commands?
- *When and how should DR signals be issued?*
  - frequency, timing, variation
- *How can we model consumer response?*
  - delays, learning, fatigue, ...
- *What are the performance and stability implications of coupling markets and power systems?*
  - real-time automated DR

Consumer engagement required—the "direct load control" model isn't sustainable at scale

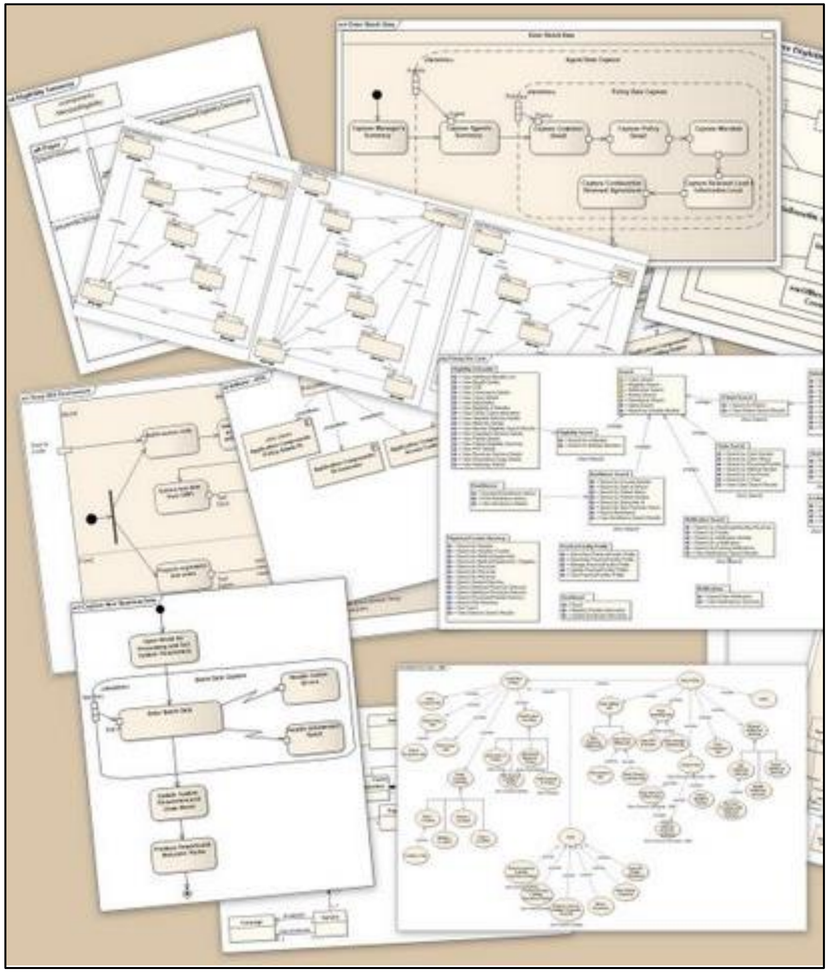
Research Challenge: Integrated Microgrid Optimization



More flexibility for grid balancing with distributed solutions

Research Challenge: Standardized, Interoperable Information and Control Models

- Standards lower the bar for application of research results
  - interoperable, plug-and-play models and algorithms
- Formally capturing the full complexity of energy assets
  - specification of appliances, building loads, storage, distributed generation, and much else
- More than semantic models and ontologies, but these are a starting point
  - cf. CIM, BIM, OpenADR, SPC 201P
  - dynamics of assets, optimization and control models
  - composability and abstraction



How do we develop composable, interoperable energy models of assets for control and optimization?

Research Challenge: New Architectural Paradigm

- Distributed control and optimization of networked, “flat” architectures
  - distributed control with limited information
- Dramatic increase of smaller more intelligent assets
  - highly interactive and responsive to grid conditions
- Addressing conservation, emissions, and renewable integration needs by demand-side modeling, control, and optimization
  - multiple time-scales, including full spectrum of ancillary services
- Further issues for research:
  - formation of virtual resources by aggregators and third parties—how does the physical grid constrain the information and control architecture?
  - development of M&V methods that do not require metering everything
  - modeling and control of distributed and dynamic asset aggregations
  - reliability and resilience to communication failures
  - new market designs that are acceptable from regulatory perspectives

Conclusion

- Next-generation advances in demand response, microgrids, and other demand-side innovations will enable the realization of national and societal goals for energy and the environment
  - numerous opportunities for impact, across all R&D horizons
- The systems and control community is the standard-bearer for rigor in research . . .
  - relevant applied math advances continue to be needed
- . . . but for societal impact deep understanding of the state-of-the-practice and -art in the application domain is essential
  - many exciting demonstration and deployment projects already
  - constraints of industry structures, product roadmaps, system architectures, value chains, market mechanisms, business models, etc., won’t be undone in one fell swoop . . .