Advanced Distribution Simulation (a PNNL Lab-Directed R&D Project)

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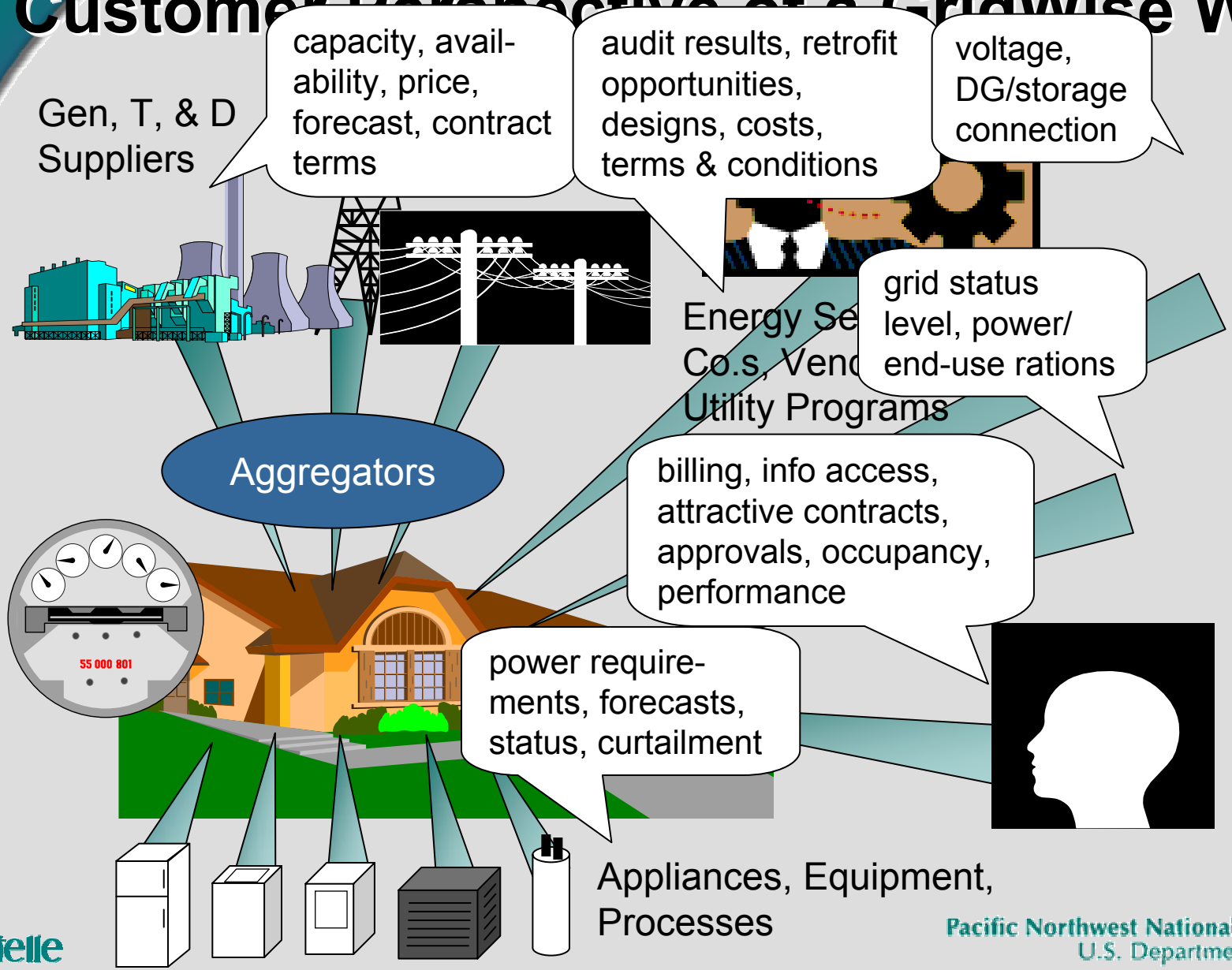
Pacific Northwest National Laboratory

Electric Distribution Transmission Program Review

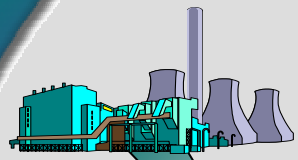
October 28, 2003

Coronado CA

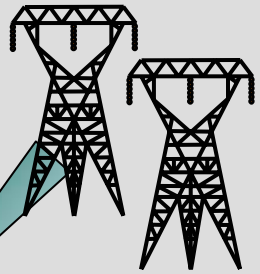
Communicate – With Whom? About What? Customer Perspective of a GridWise World



Communicate – With Whom? About What? DisCo Perspective of a GridWise World



GenCo

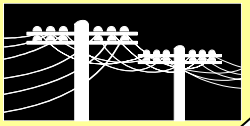


ISO/RTO

Capacity upgrade costs

Load data

Dist ility



Planning

Operations

Localized Retail Markets

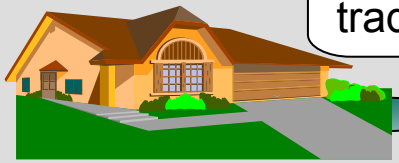
Congestion

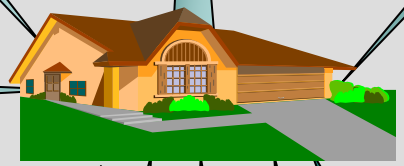
Forecast long-term loads

Capacity trading

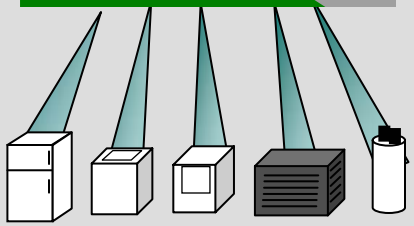
Long-term fixed/ spot/TOD prices, demand response

l-time loads, ct curtailment





Customer



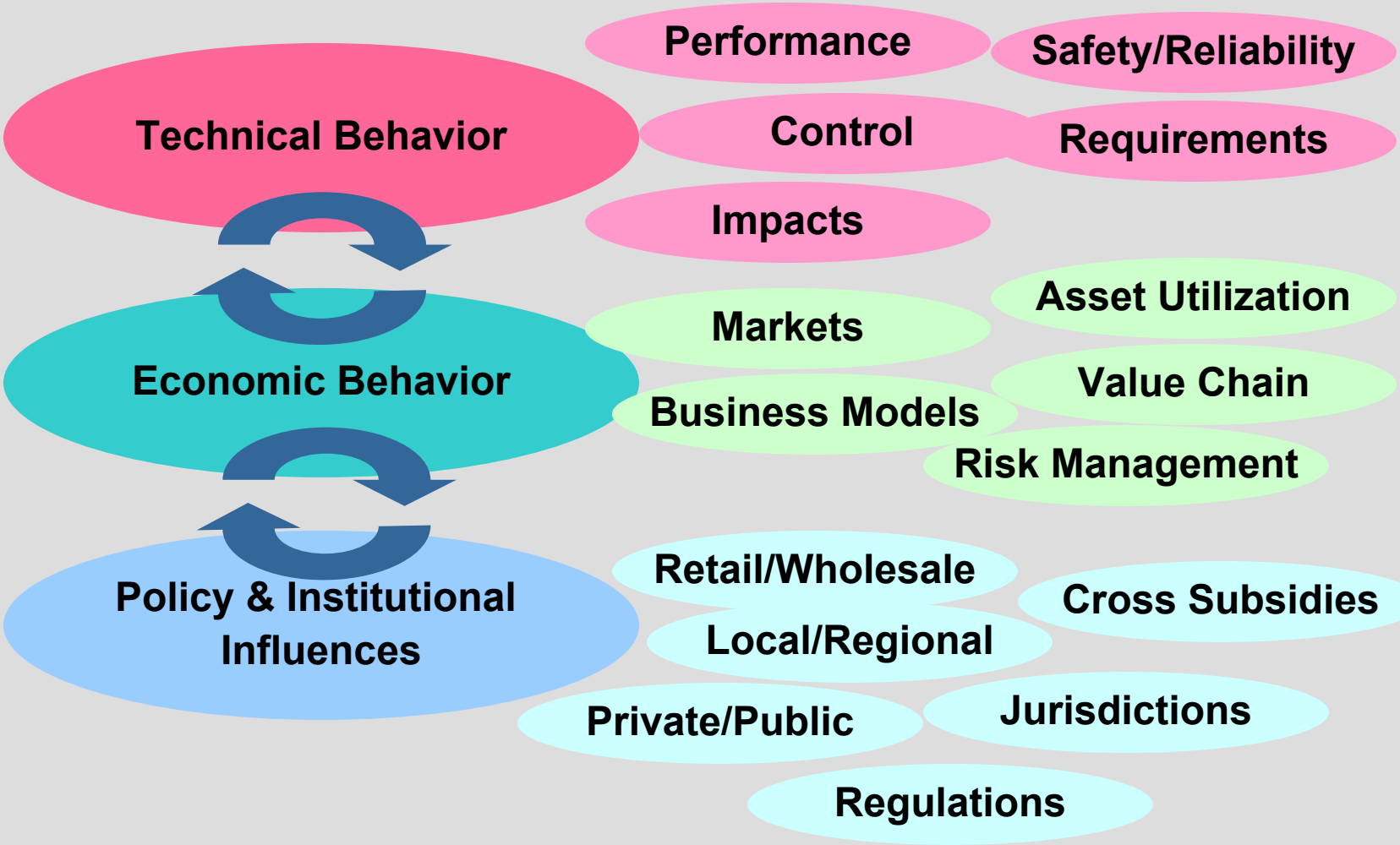
Appliances, Equipment, Processes

Problem and Need

- ***Goal:*** **Understand and shape the nature of the energy system as it evolves to an information-rich network of devices marked by autonomous, value-based decision-making.**

- ***Importance:*** **Fashion the behavior of transactive energy networks through analyses and simulation**
  - quantify benefits while ensuring feasibility and stability
  - enable policy, regulatory, and market design analyses
  - identify key technology targets
  - virtual testbed for development of technologies and applications

Key Technical Challenge: Interactions of Grid, Economic Behavior, & Policy/Regulation



Objectives/Basic Requirements

- Accurately represent "slow" dynamic interactions of load, supply, T&D, and market operations
- Represent rational behavior of market participants
  - generators, brokers, customers, system management
  - system management ≡ planning, operations, market ops, regulation
- Couple markets, loads, supply, & system management with *transactive control*
- Multi-time scales:

	Phenomena	Sim. Duration	Benefits Integration
passive GFAs*:	~1 sec	~10 min	~1 year
transactive controls:	~1 min	~1 week	~1 year
planning/markets:	~1 hr	~1 month	~10 years

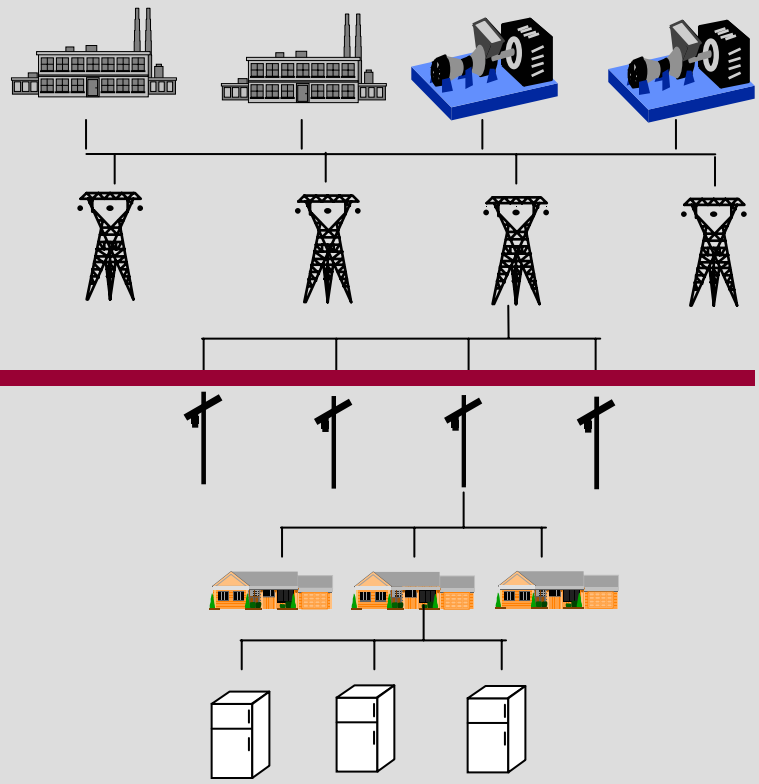
* Grid-Friendly Appliances™

A Key Challenge – Topological Resolution
Proposed Multi-Resolution Approach

Element		Nodes*
Generation		~10^2
Transmission	~10^4	~10^3
Substations		~10^4
Distribution Feeders		~5×10^4
Customer Meters	~10^4	~10^7
Appliances/Equipment		~5×10^8

Transmission-level Model

Distribution-level Model



*Western U.S.

Technical Approach

- Built around MATLAB Power Systems Toolkit
- Add detailed end-use appliance/equipment/process loads
  - *Ultra-fast* simulation of power usage in a distribution system
  - Minutes of processing simulates months of response from hundreds of residences
  - Match utility end-use load shapes as control totals
  - Equivalent thermal parameters model for thermal loads (e.g., HVAC, hot water) instead of estimating a statistical response
  - Statistical event/queue approaches used for non-thermal loads (e.g. washer/dryer, lights)
- Add customer and retail behaviors using agent-based economics modeling approach
  - Simulates load curtailment as a response to price increase
  - Simulates contract selection

Distribution Level Interactions

- Distribution system simulator analysis tool
  - Building appliance & human behavior models
  - Distributed generation models
    - Reciprocating engines, fuel cells, micro-turbines, storage systems, etc.
  - Price responsive demand to retail markets
  - Load serving entity & distribution system operator agents
  - Contract choice by customers
- Price sensitive demand feeder equivalent for bulk grid simulation
  - Load: function(time, weather, voltage, frequency, price)
  - Traditional “averaged” load shapes won’t do

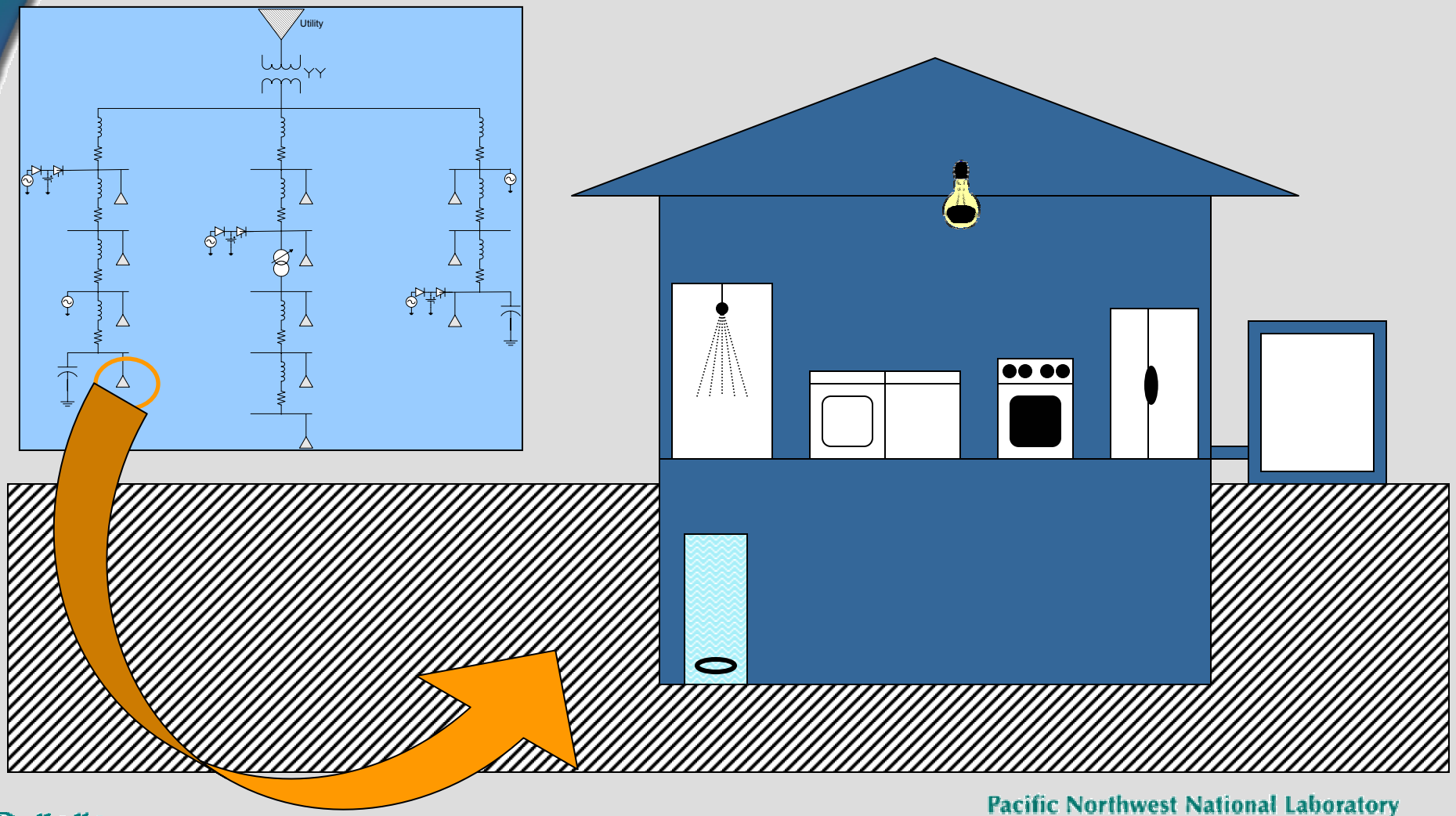
Life-Cycle Project Timeline with Milestones and Budget, by FY

- FY02/03: PNNL Laboratory-Directed R&D project
- Budget and scope TBD
- Proposed multi-year development effort:
  - Add GFA* and longer-duration voluntary load curtailment based on individual end-use load elasticities (price response).
  - Adapt commercial sector loads from residential load models, including major building types
  - Provide for arbitrary industrial time series loads from exogenous sources, such as utility meters, to be read into the model.
  - Add distributed generation (DG) and energy storage system models.
  - Validation testing and user documentation
  - Open source release, collaborative module developments
  - Bug fixes, maintenance

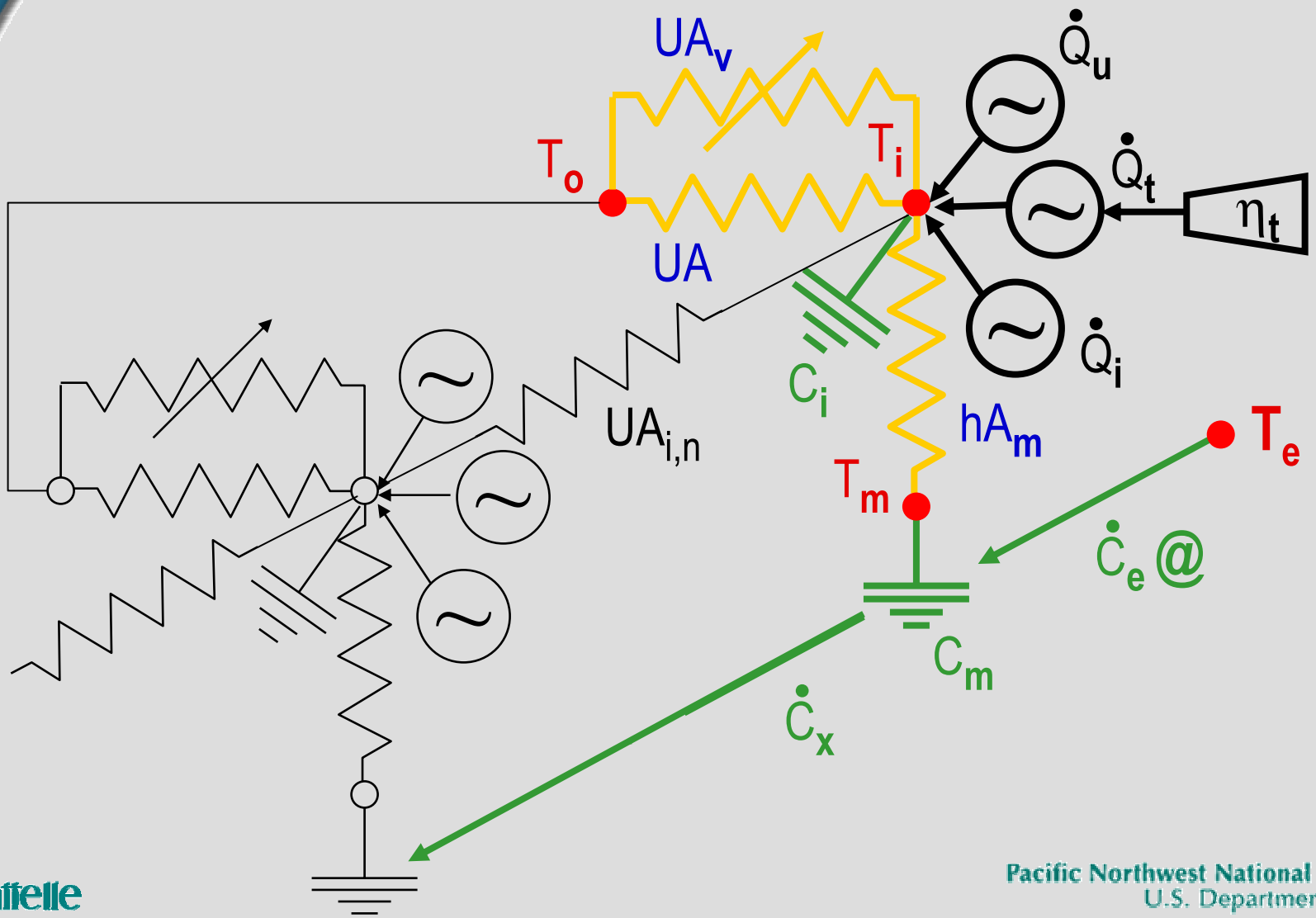
* Grid-Friendly Appliances™

Progress and Accomplishments to Date

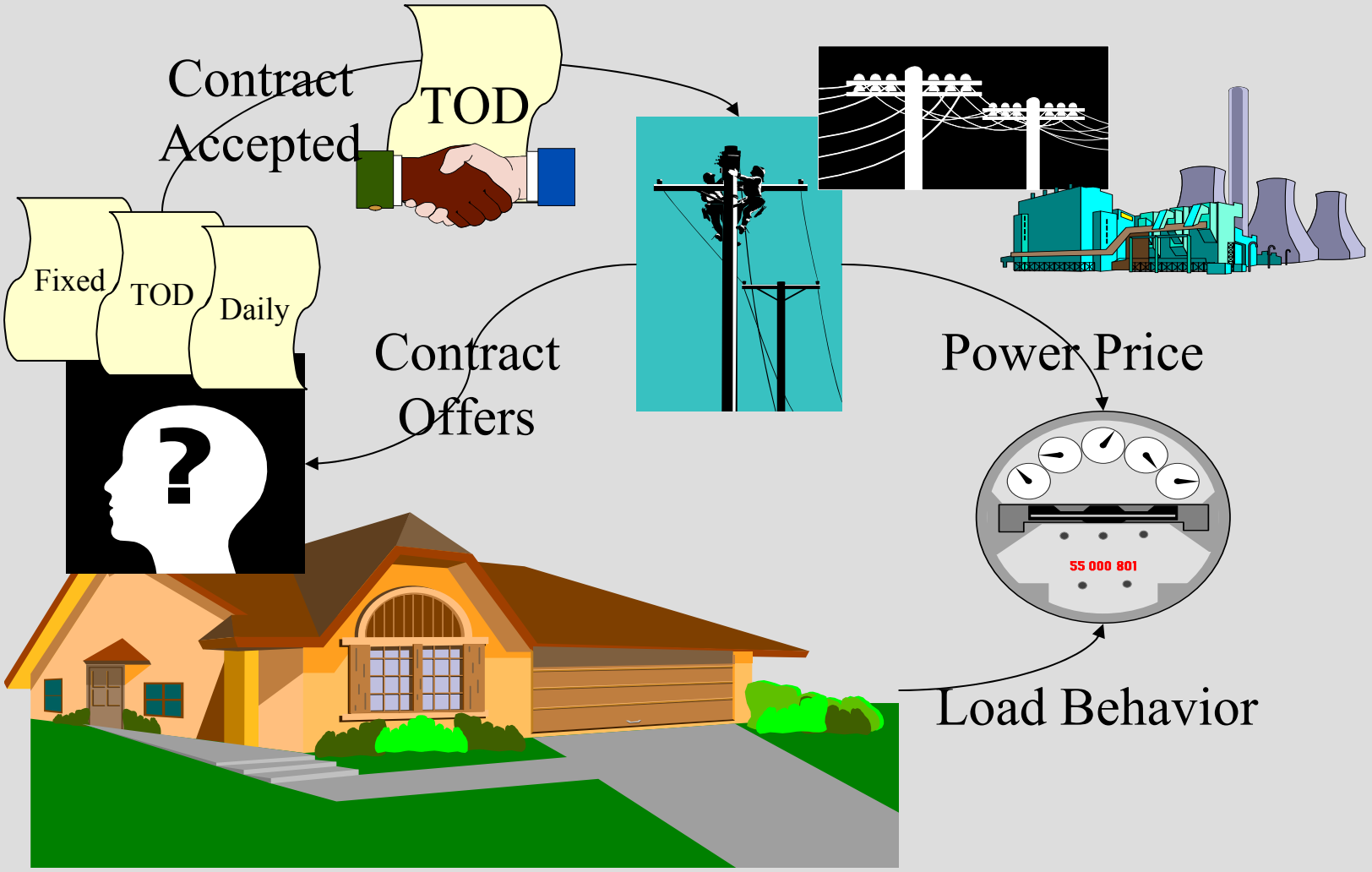
How Does the Residential Model Work?



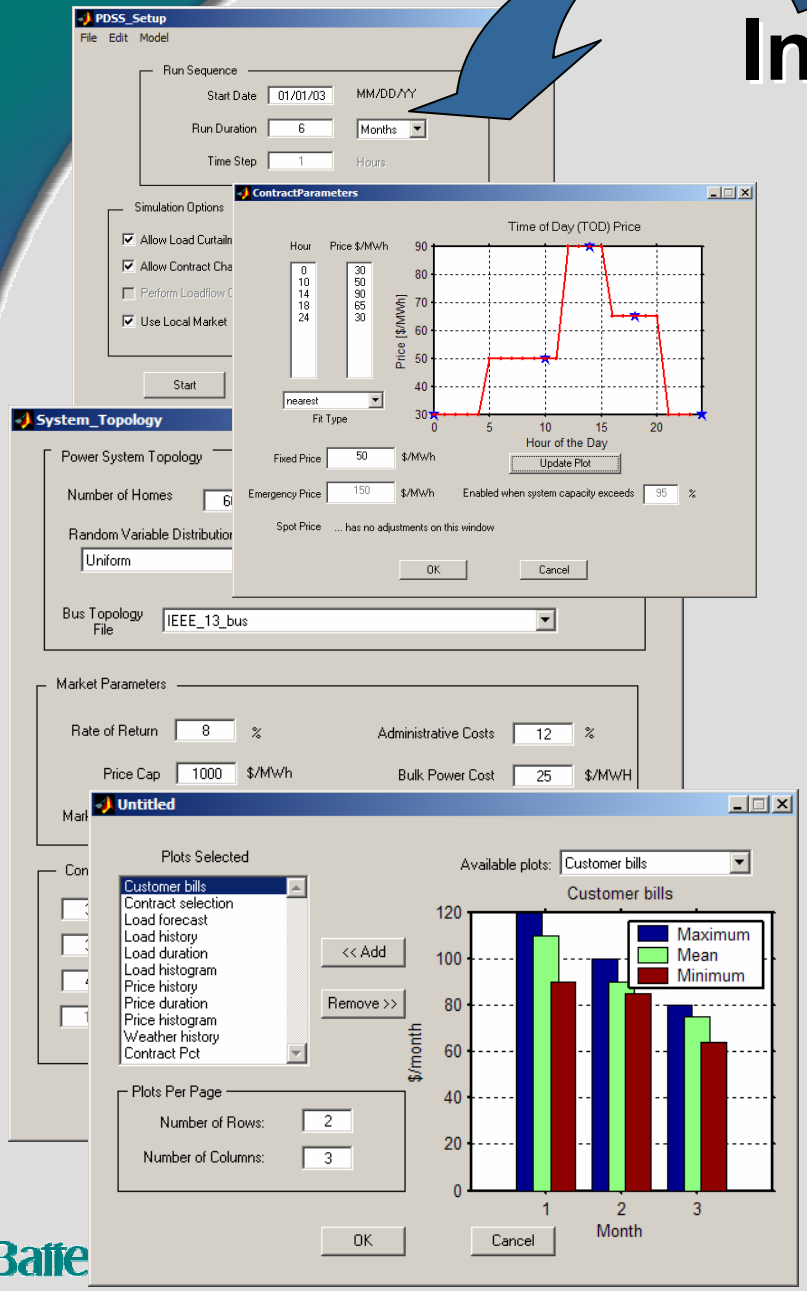
Equivalent Thermal Parameters
Model of Thermal Loads

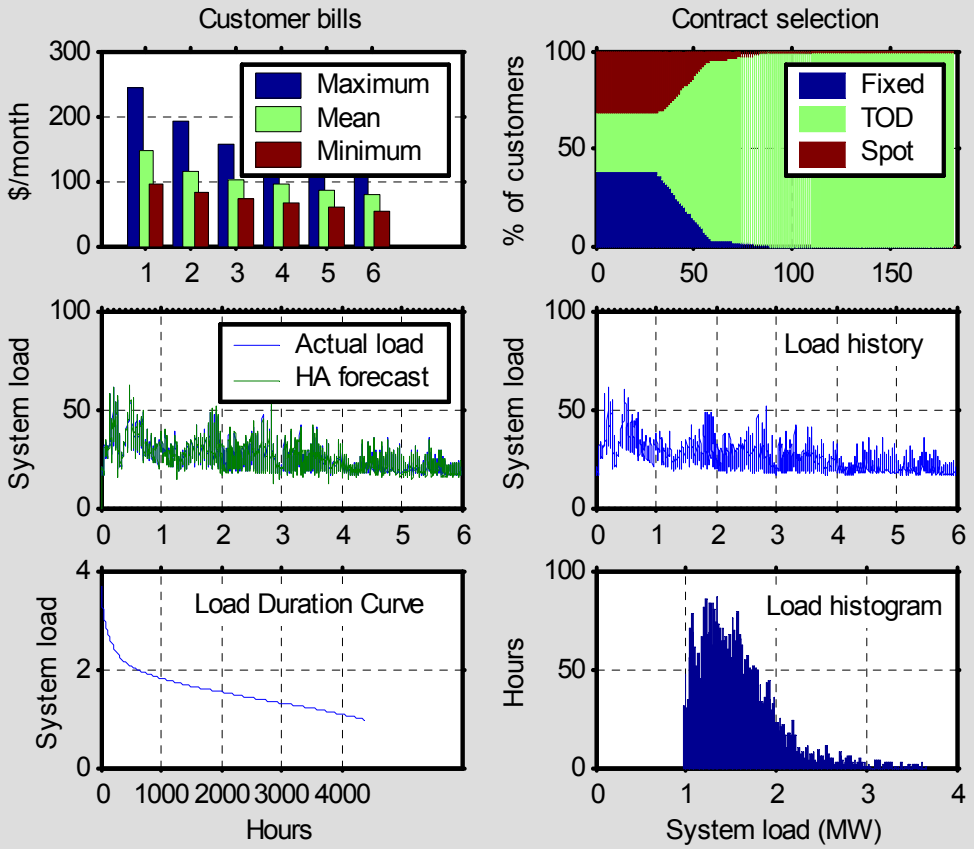


Customer/Utility Interaction – Agent-based Computational Economics



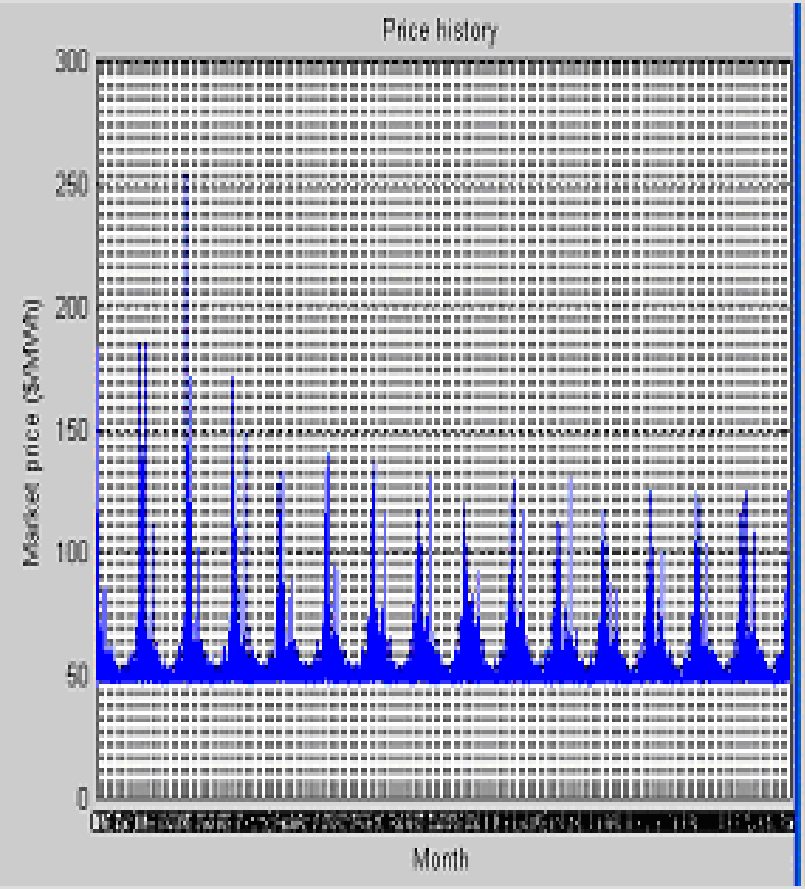
Inputs

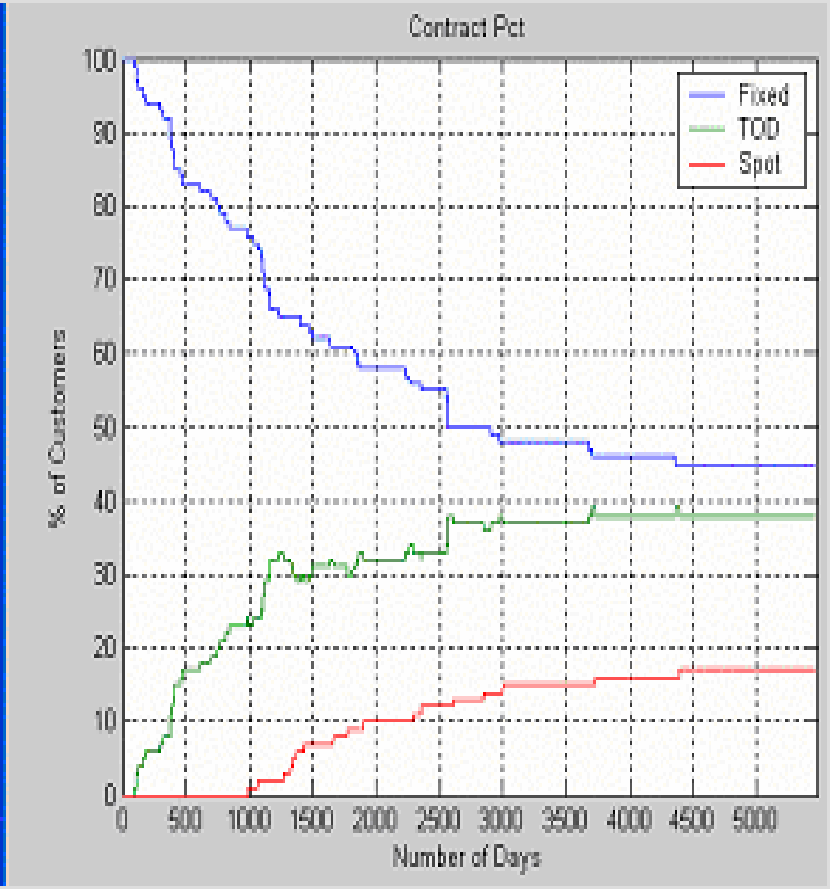




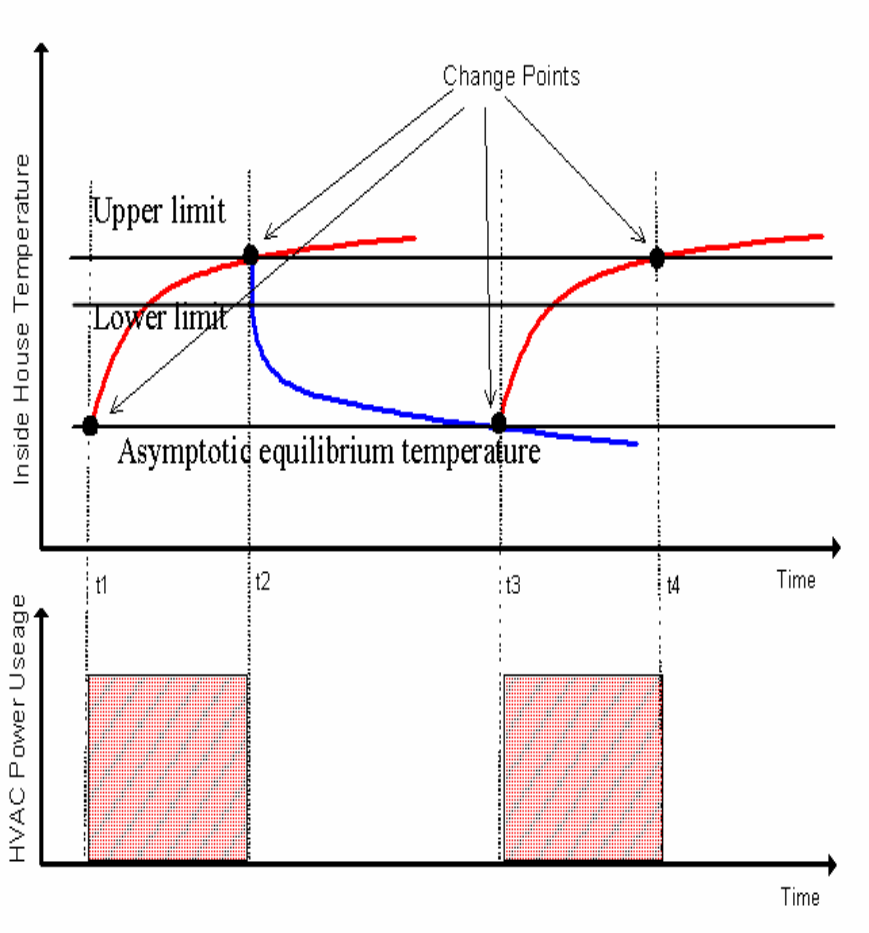
Outputs

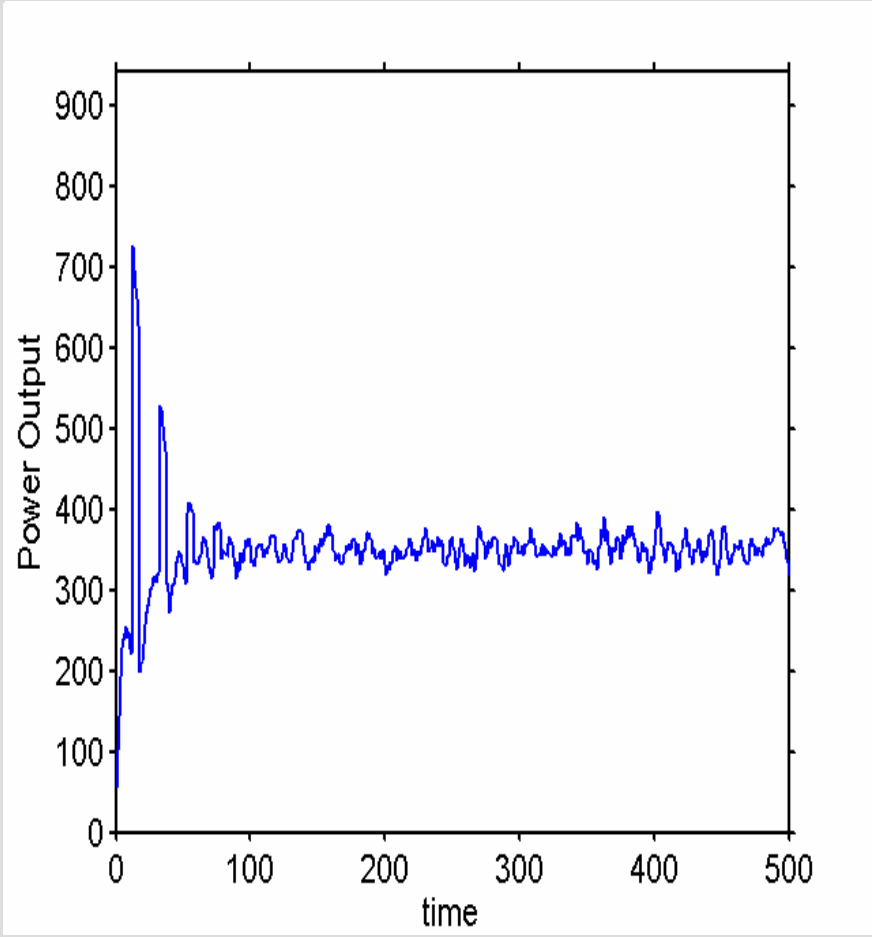
Preliminary Analyses - Lowering Bulk Electricity Price



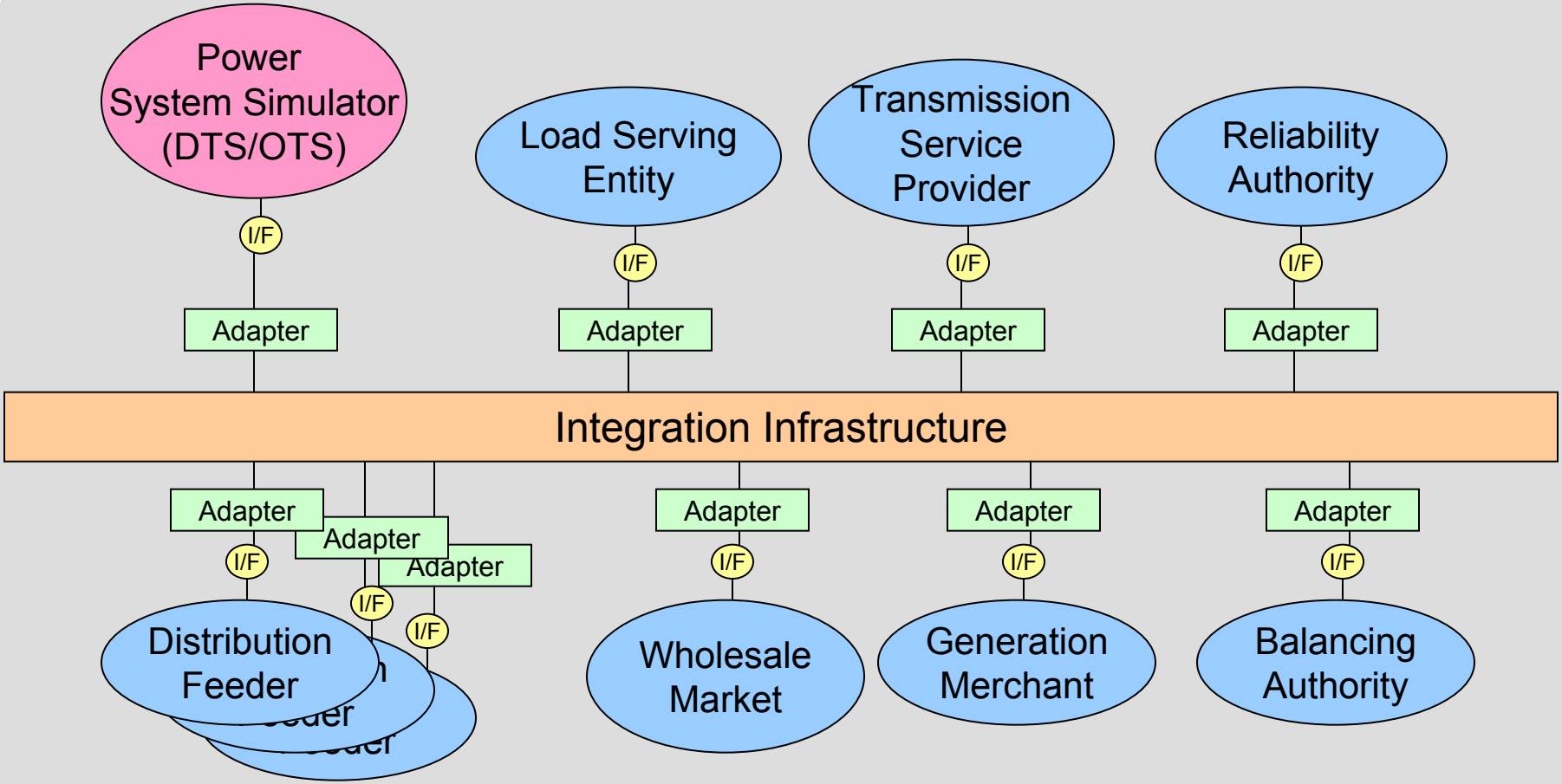


Price Responsive Feeder HVAC Demand Equivalent



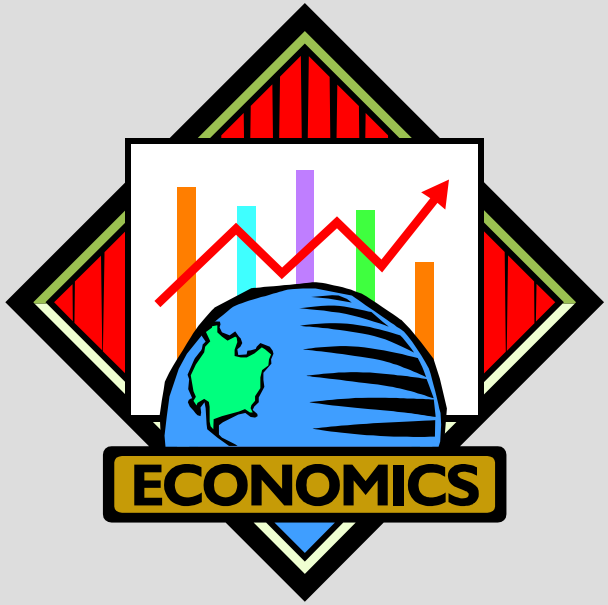


Vision for Open-Source, Component/Agent Based Simulation Infrastructure for Collaborative, Development



Impacts and Benefits

- Allows study of technology & economic decision-making, e.g:
  - Is it cheaper to build infrastructure or to reduce peak loading by economic incentives for DG & DSM?
  - What would be a typical consumer response to various rate structures (e.g. TOU, Fixed, Spot)?
  - Under what conditions will consumers be motivated to change contract types?
  - What would high penetration of DG do to the system?
  - How much load shifting could be accomplished by modifying end-use appliances and controls?



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