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Analytics for a Smarter Planet - A Point of View

Advanced Energy Conference, Nov 18, 2009

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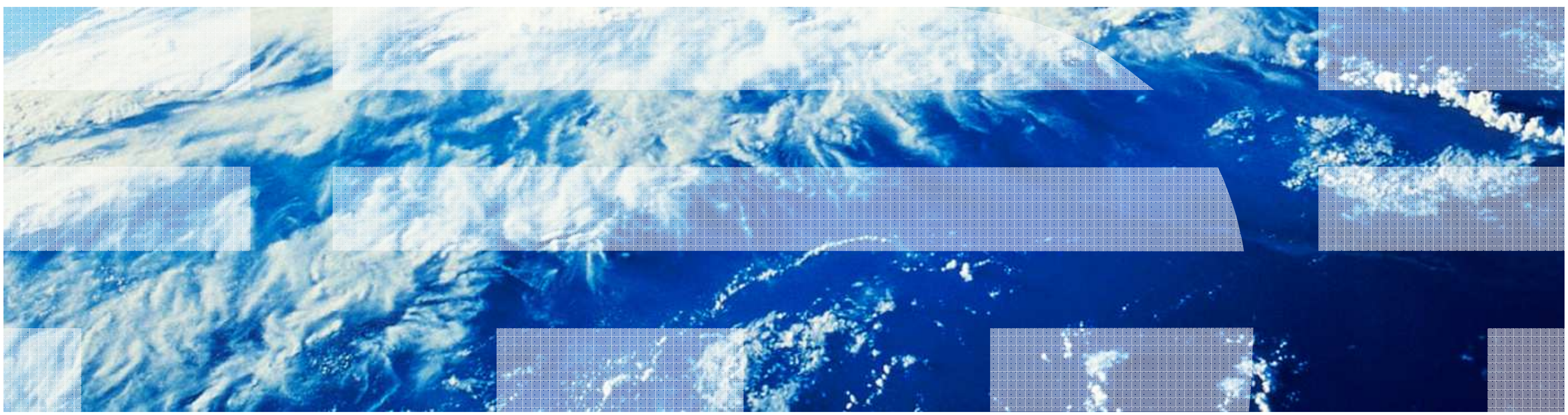

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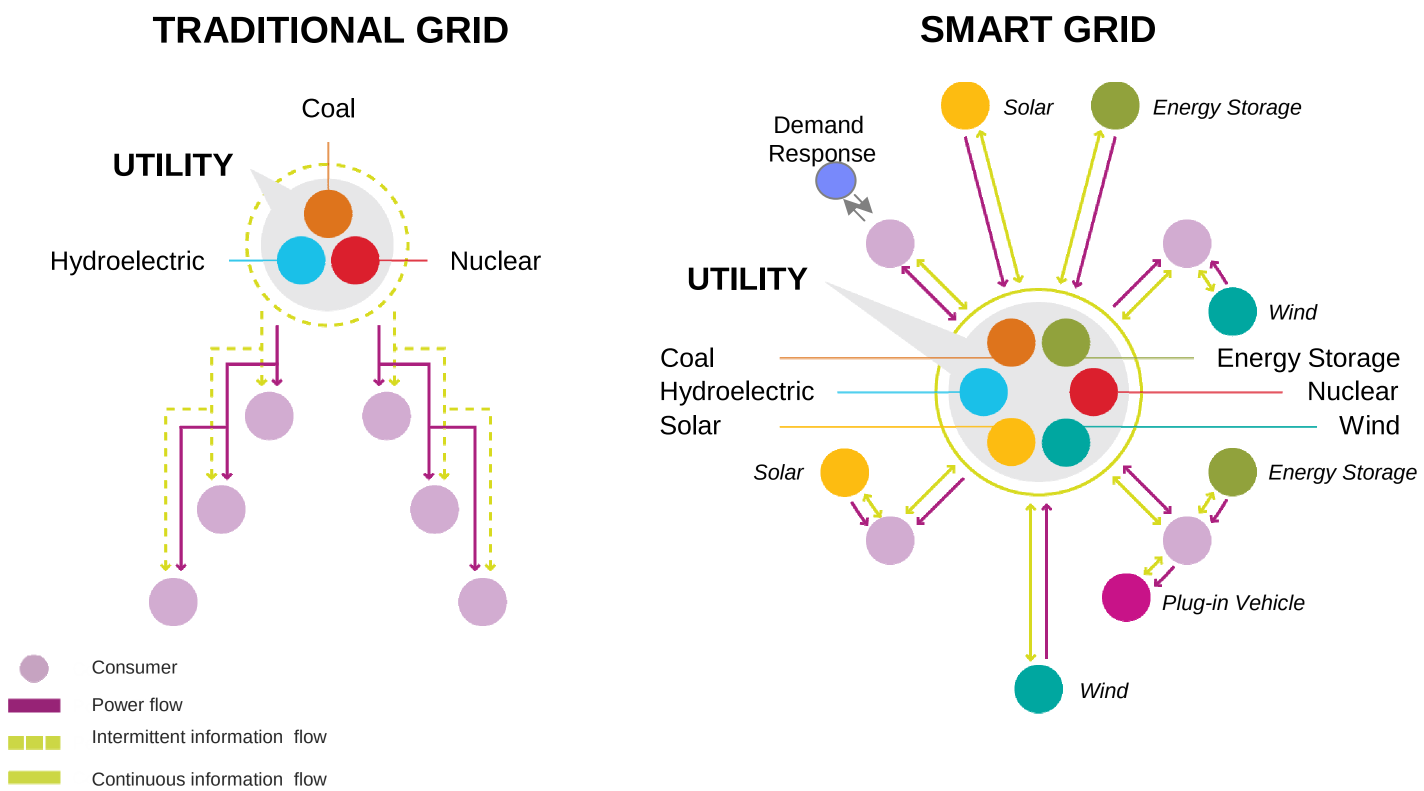
A Smartgrid will transform the generation and distribution of energy



Informed

Automated

Integrated

Connected

Intelligent

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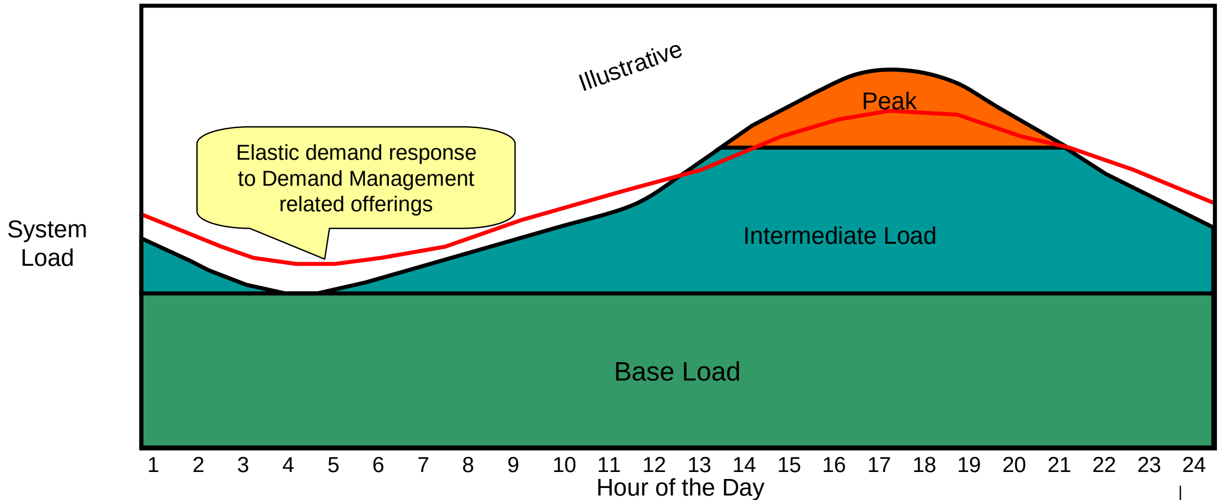
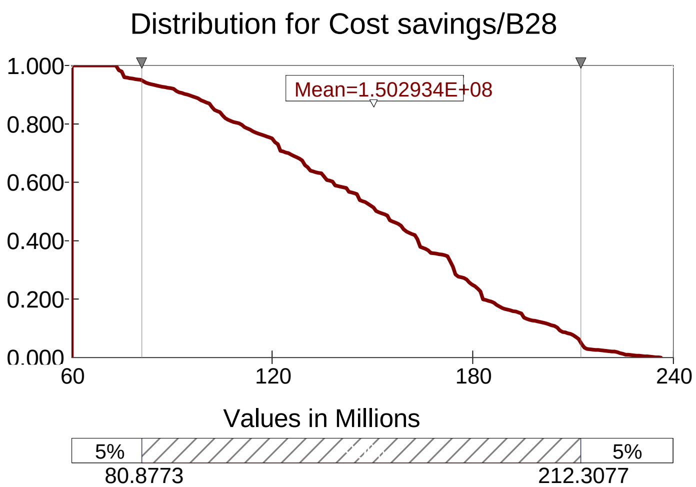
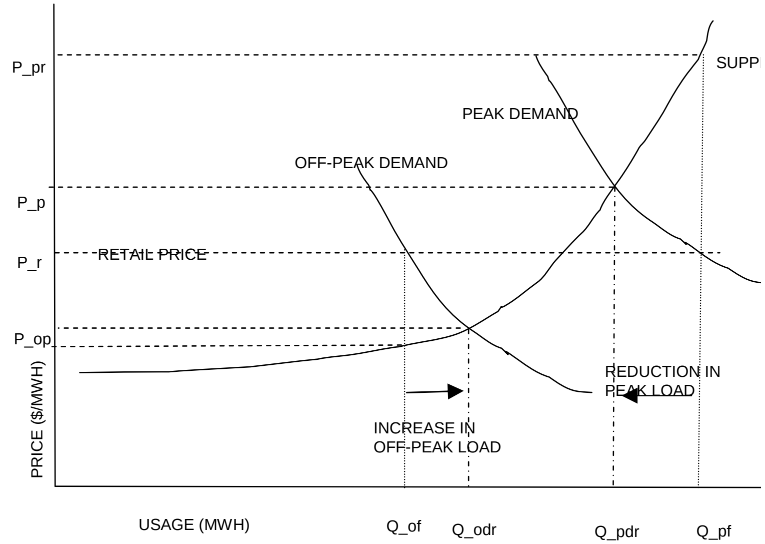
Demand Shaping and Shaving (Demand Response)







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Evolution of energy demand management

Planned (day-ahead) DR	Emergency (day-of) DR	Spinning Reserve	Dynamic Pricing

- Manual trigger → Automated trigger
- Manual action → Automated action
- Pre-defined window → Uncertain window
- Pre-defined response → Uncertain response

Implications

- **Buildings**: need automated decision support and management
- **Utilities**: need prediction of demand response as function of signal

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Energy demand management from building perspective

- **Capital decisions**
  - – Energy efficiency upgrades and renovations
  - – Demand shifting options: battery, fuel cell, stored cooling
  - – Co-generation
- **Energy procurement decisions**
  - – Energy block futures
  - – DR programs: future capacity market, next-day demand market
- **Operational decisions**
  - – Load forecasting and monitoring
  - – Load scheduling (stored cooling, pre-cooling, water pump, PEV charging)
  - – Load shifting (spinning reserve enablement, RTU coordination)
  - – Load shedding (preference-based thermostat and dimmer control)

These inter-related decisions would benefit from a common demand model

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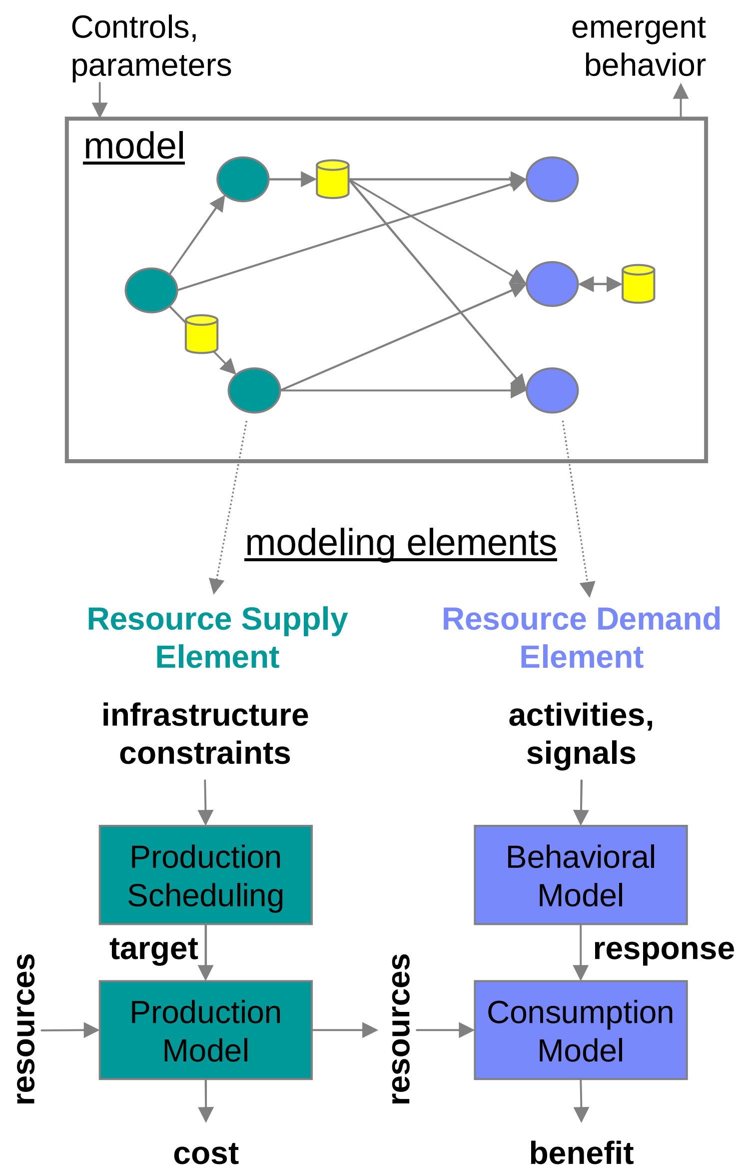
Urban System Modeler

- Modeling framework and simulation engine for modeling emergent demand and resource usage

- Targeted for an urban setting:
  - Heterogeneous individuals drive resource demand
    - Behavioral models including price sensitivity, social norms, and utility
    - Integration point for multi-resource interactions
  - Resource infrastructure in an urban setting constrains production and delivery
    - Capacity planned for efficiency
    - Physical models

- Supports analysis at various levels:
  - Building level demand management:
    - Capacity planning/procurement
    - Operational scheduling
    - Demand response
  - City or region level resource management:
    - Long-term supply planning
    - Impact of pricing policies
    - Interaction between multiple resources
    - Short-term resource provisioning decisions



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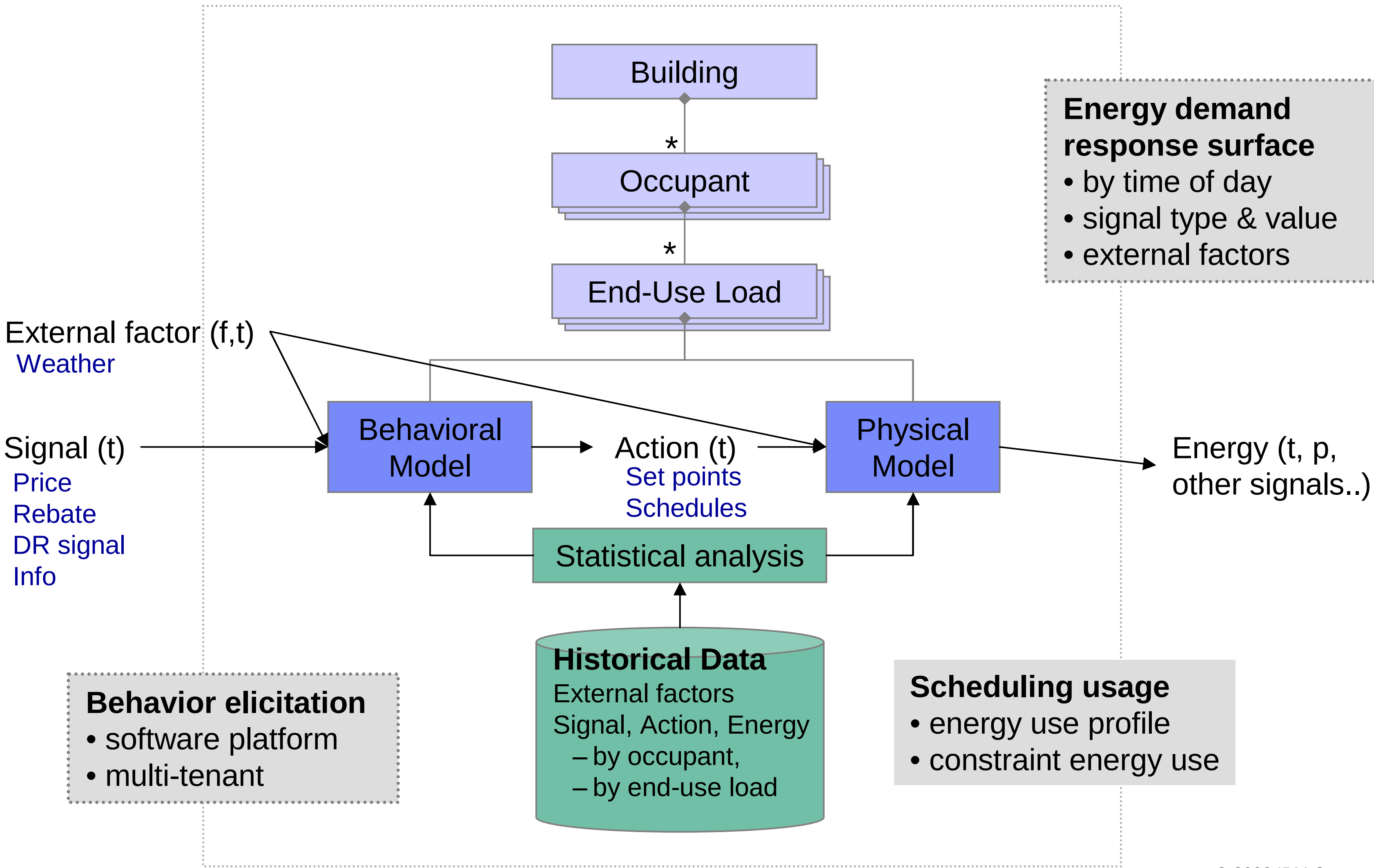
Building energy demand prediction



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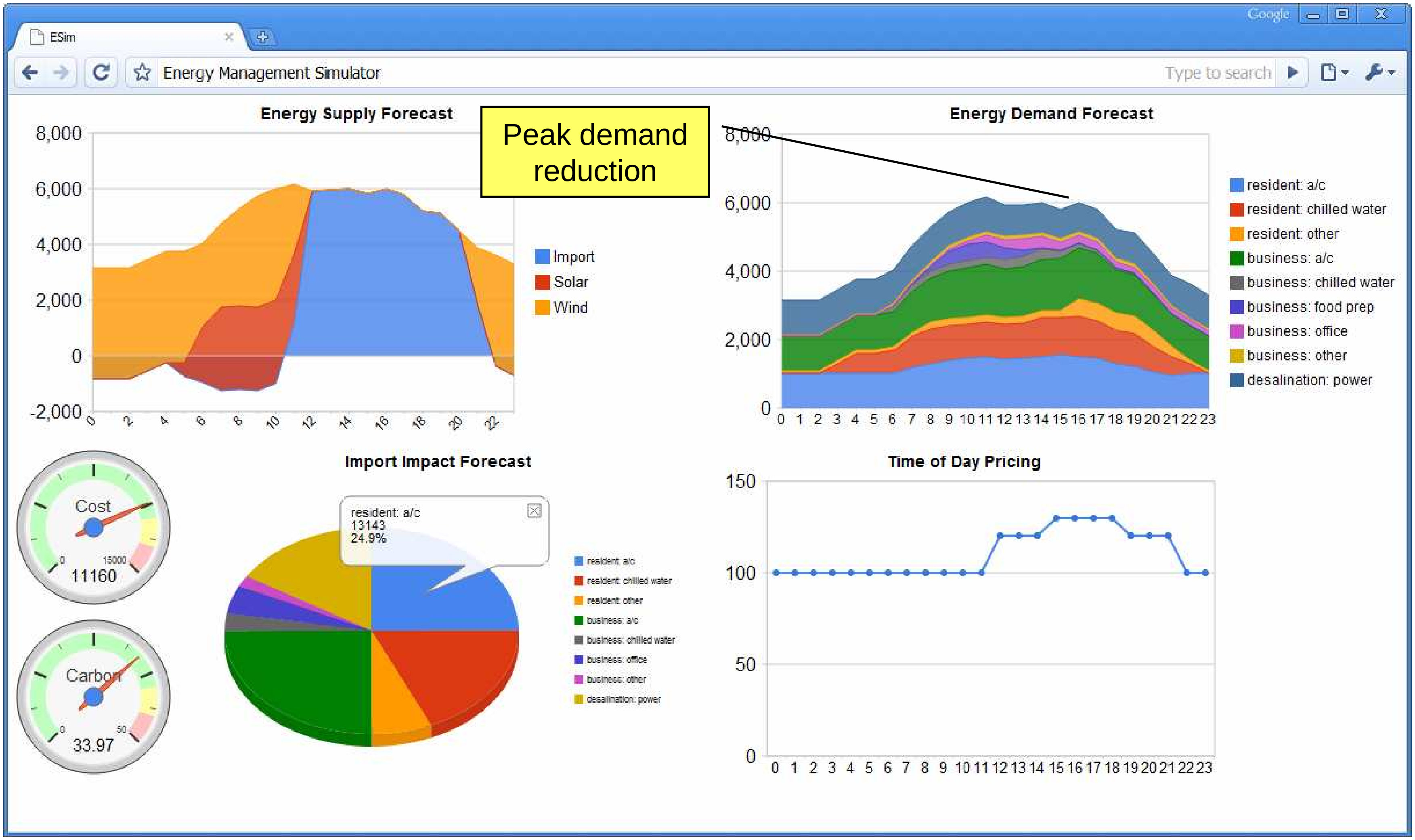
Example of Decision Support Scenario for Energy Management:

Decision maker imposes price premiums based on predicted impact on peak demand



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Decision support using building energy response surface

Energy Procurement Planning

- Select optimal supply of energy blocks (size, duration, time-of-use)
- Based on stochastic optimization over energy demand forecast and energy market prices (futures and spot)

Green Portfolio Planning

- Plan investments in green assets over a time-line
- Based on analysis of trends in demand, energy price, and technology maturity under uncertainty

Dynamic Demand Management

- Schedule discrete loads (water pumping, PHEV charging, energy storage charge/discharge)
- Generate control signals (info, price, caps) for optimal demand shaping

Behavior elicitation
• software platform
• multi-tenant

Energy demand response surface
• by time of day
• signal type & value
• external factors

Demand forecasting and monitoring:
- Analysis of load models to identify areas of improvement
- Buildings that are most/least efficient
- Discovery of load increase/decrease events

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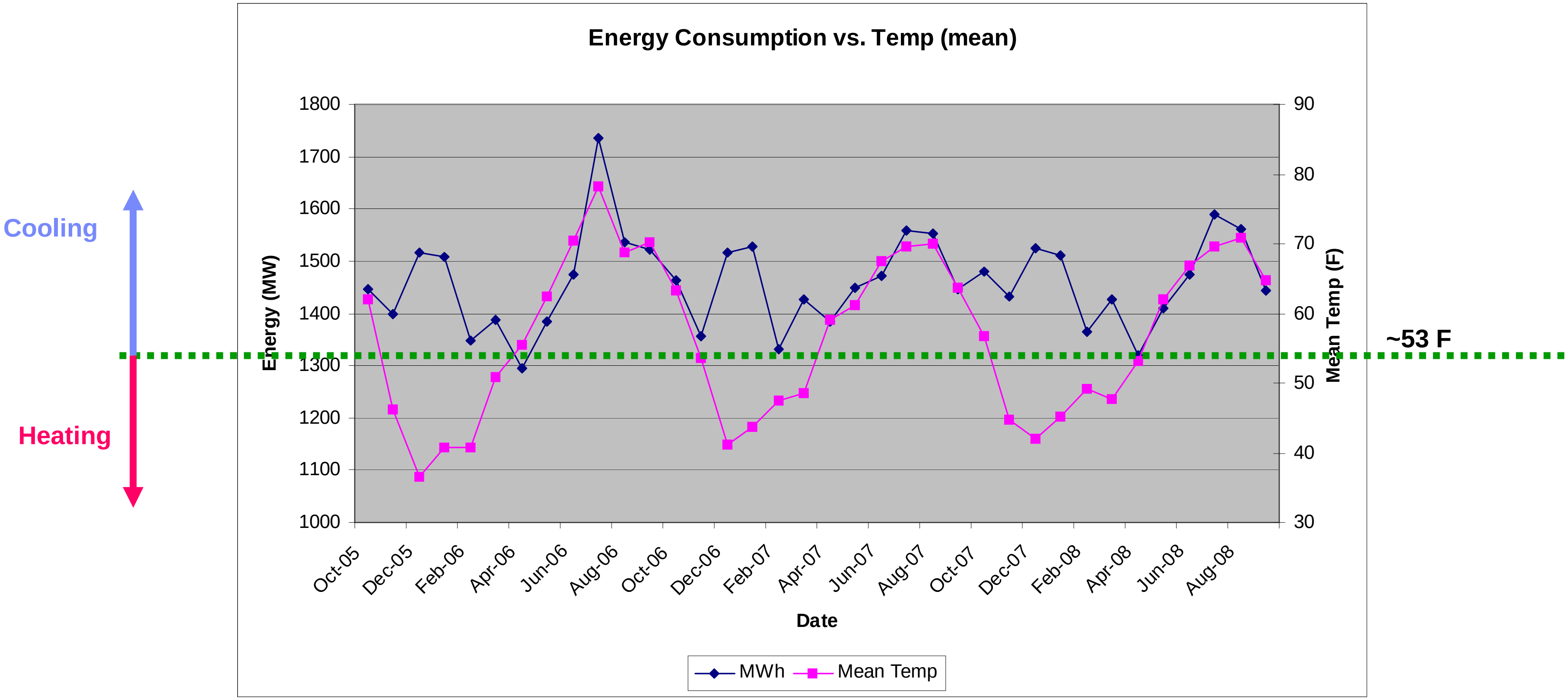
Impact of temperature on energy consumption - with mean temperature (outside)



- **It appears that cooling related energy consumption correlated strongly with temperature**
- **Is there a correlation with heating? yes**

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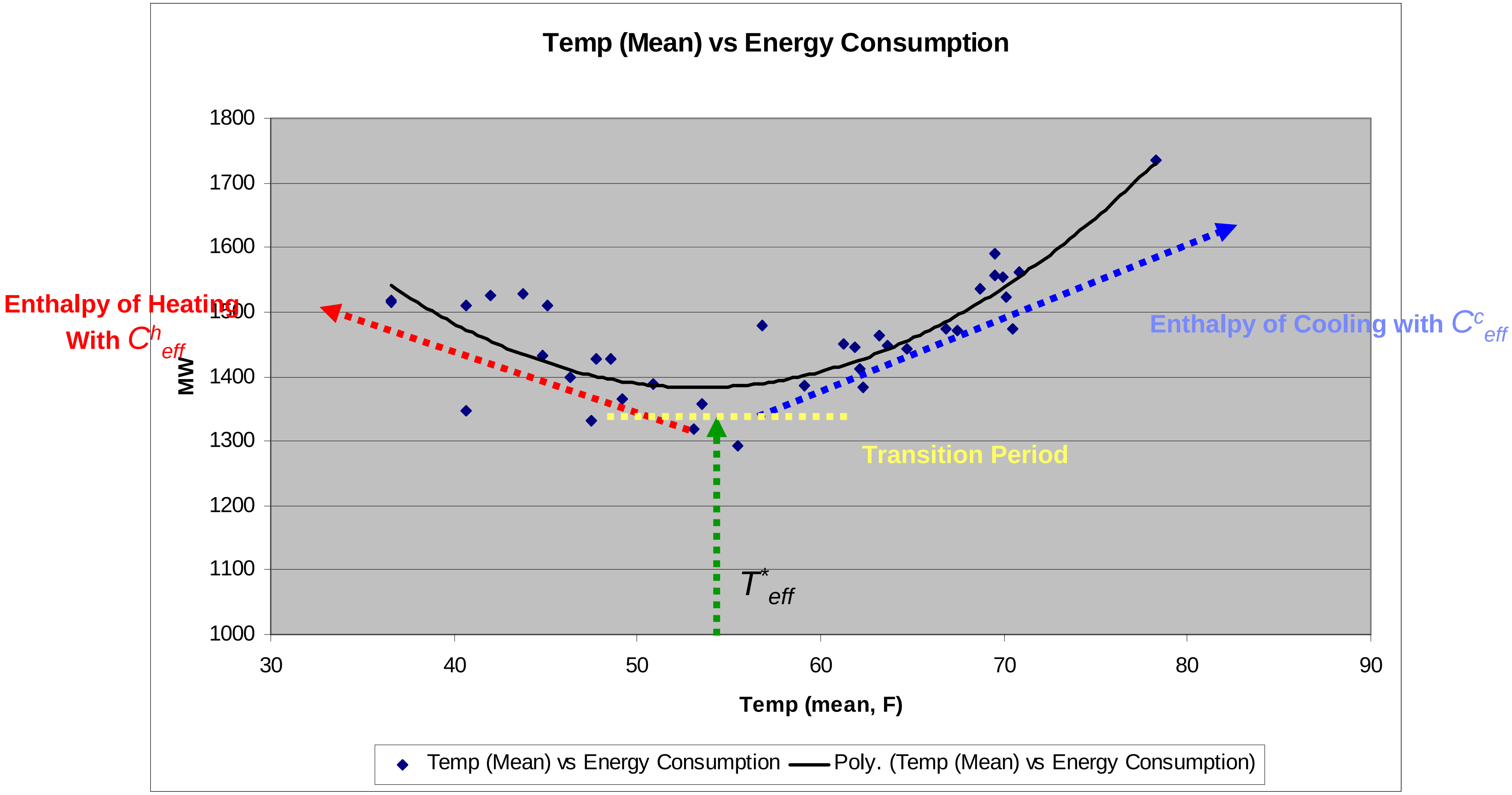
Computing effective heat capacity for cooling and heating



- Minimum temp (with heating season data) may be more suitable for modeling heat capacity for heating
- Maximum temp (with cooling season data) may be more suitable for modeling heat capacity for cooling

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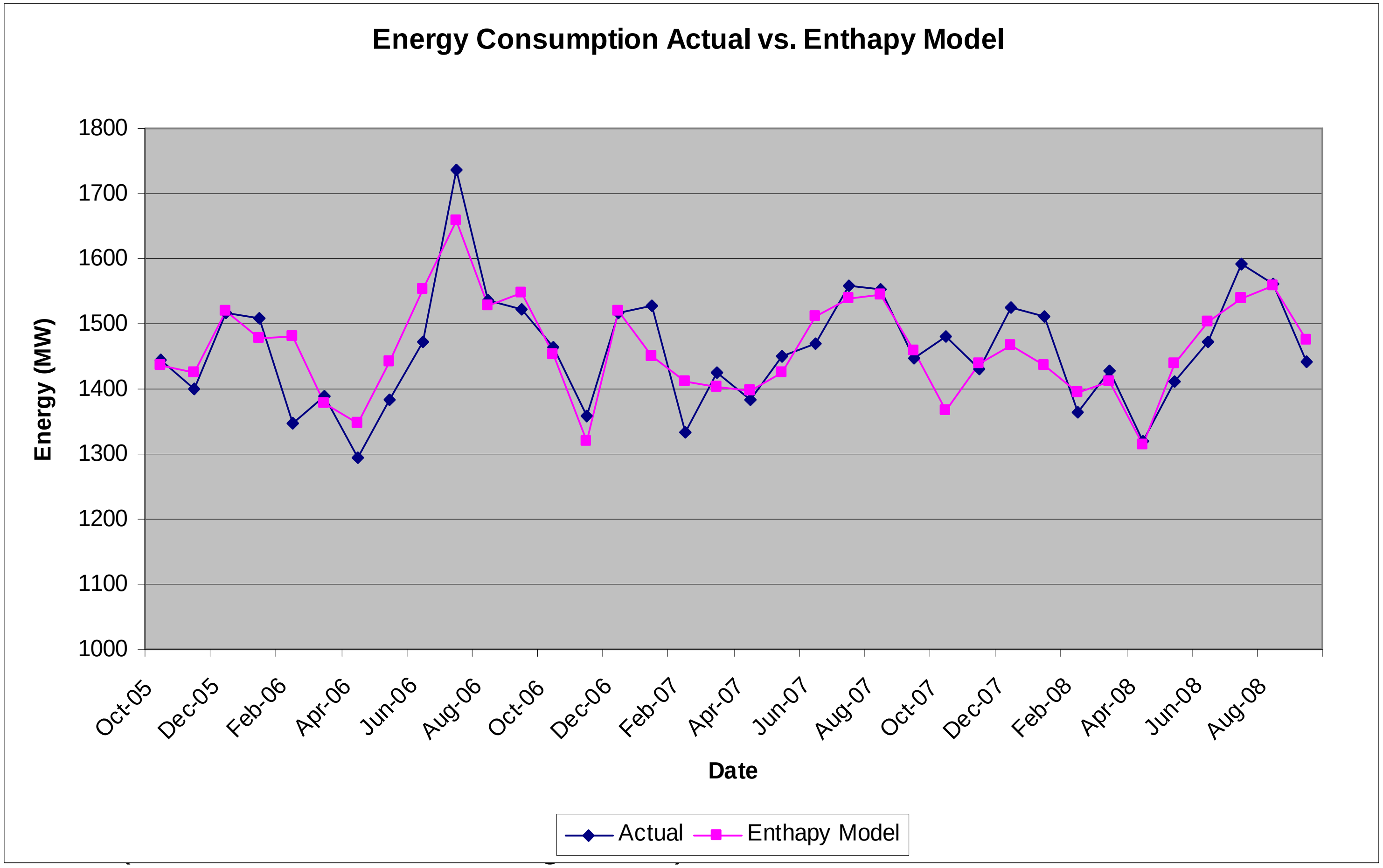
Enthalpy Model

Forecast with effective heat capacity of cooling and effective heat capacity of heating



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Energy management in multi-tenant buildings

- **Buildings with central energy infrastructure**
  – Energy demand separately controlled by each tenant
  – Energy payments based on combined consumption of all tenants
- **Operator-Tenant Interactions**
  – How to assign energy costs and DR rebates to condition tenant behavior

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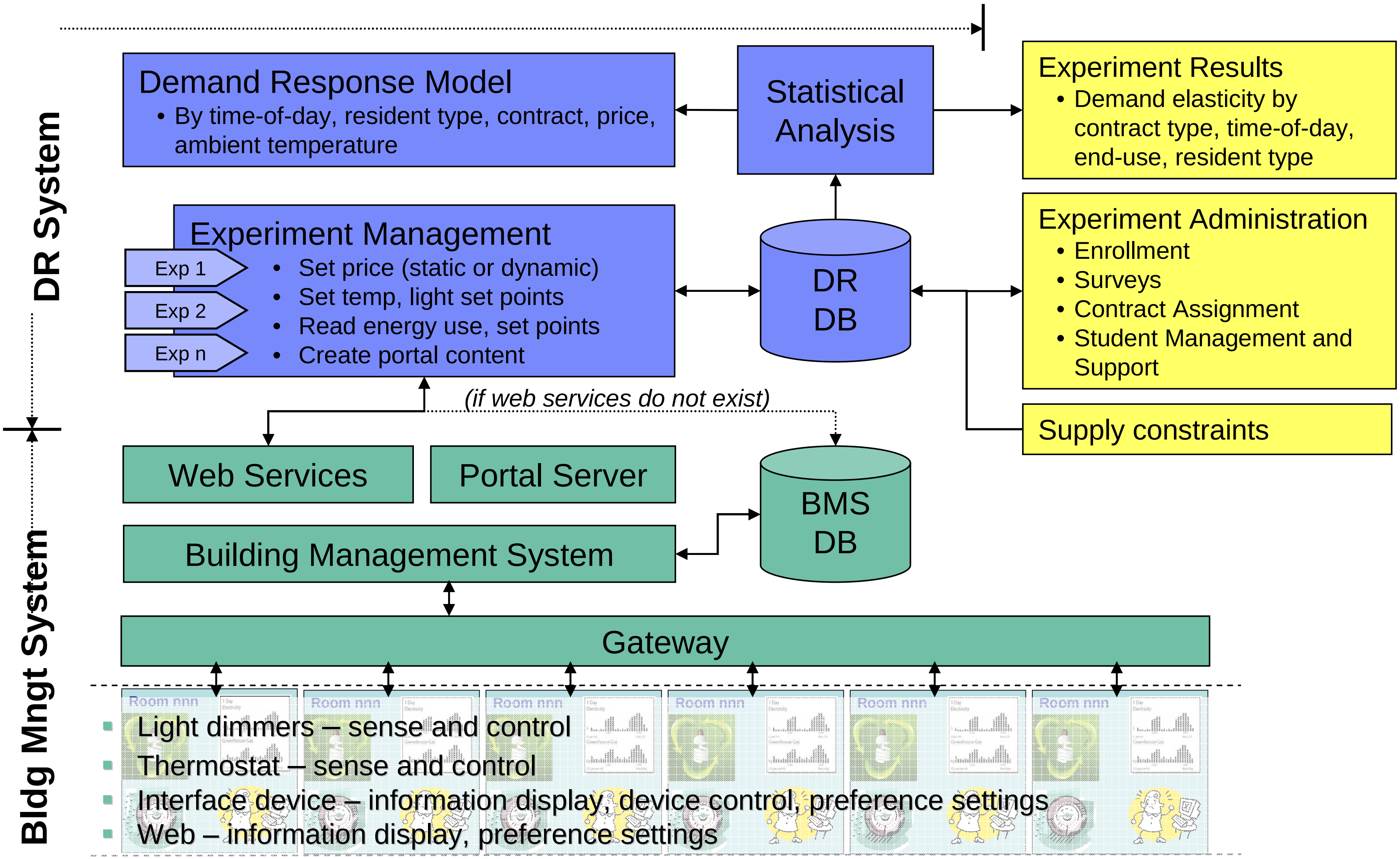
Demand Response Elicitation



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Demand Conditioning based on Dynamic Price Controls

- **The GridWise Olympic Peninsula Project**
  - 112 households
  - Thermostats programmed to response to price signals
  - Customer can choose between ‘more comfort’ and ‘more economy’
  - 3 options for pricing contract:
    - Fixed price
    - Time-of-use (with manually initiated critical peak price periods)
    - Real-Time pricing (double auction)

Results

- Real-Time Pricing group:
  - Peak decreased 15-17% (pre-heating/cooling)
  - Overall consumption 4% higher than fixed-price group
- Time-of-Use group:
  - -0.17 price elasticity
  - Overall consumption 20% lower than fixed-price group

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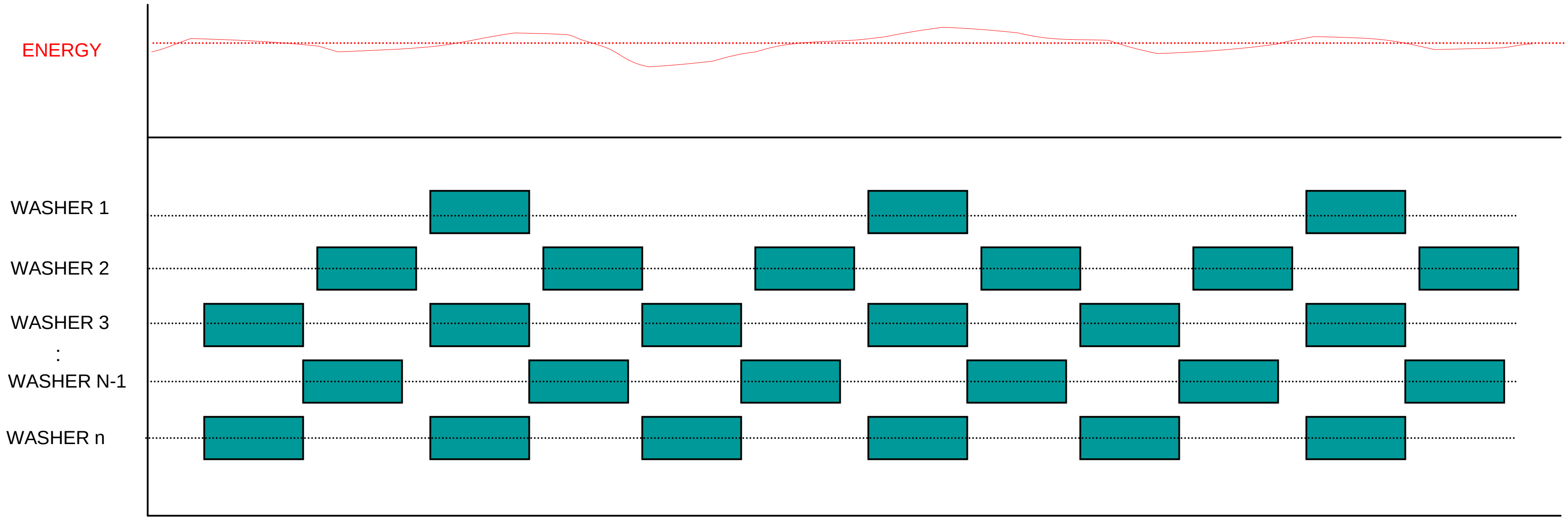
Energy Reservation System (Scheduling usage)



- Finally at an operational level (daily/weekly) how do we stay within the contracted load? (i.e. min spot purchases and control operational budgets)
  - smart devices such as washing machines
  - given the desired time window (based on price signal) schedule washing machines to level the load
    - This requires a higher level of individual commitment
    - Incentive alignment through pricing

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Energy demand management from utility/ISO perspective

- **Supply capacity decisions**
  - – Peaker units capacity vs. DR
  - – Spinning reserve generators vs. DR
- Tariff decisions?
- **Operational decisions**
  - – Voltage control?
  - – Spinning reserve deployment
  - – DR (or DP) initiation
    - Rebate/price level (by consumer or end-use type)
  - – Selective load shedding (by consumer or end-use type)

These decisions require a predictive model of demand flexibility for a region

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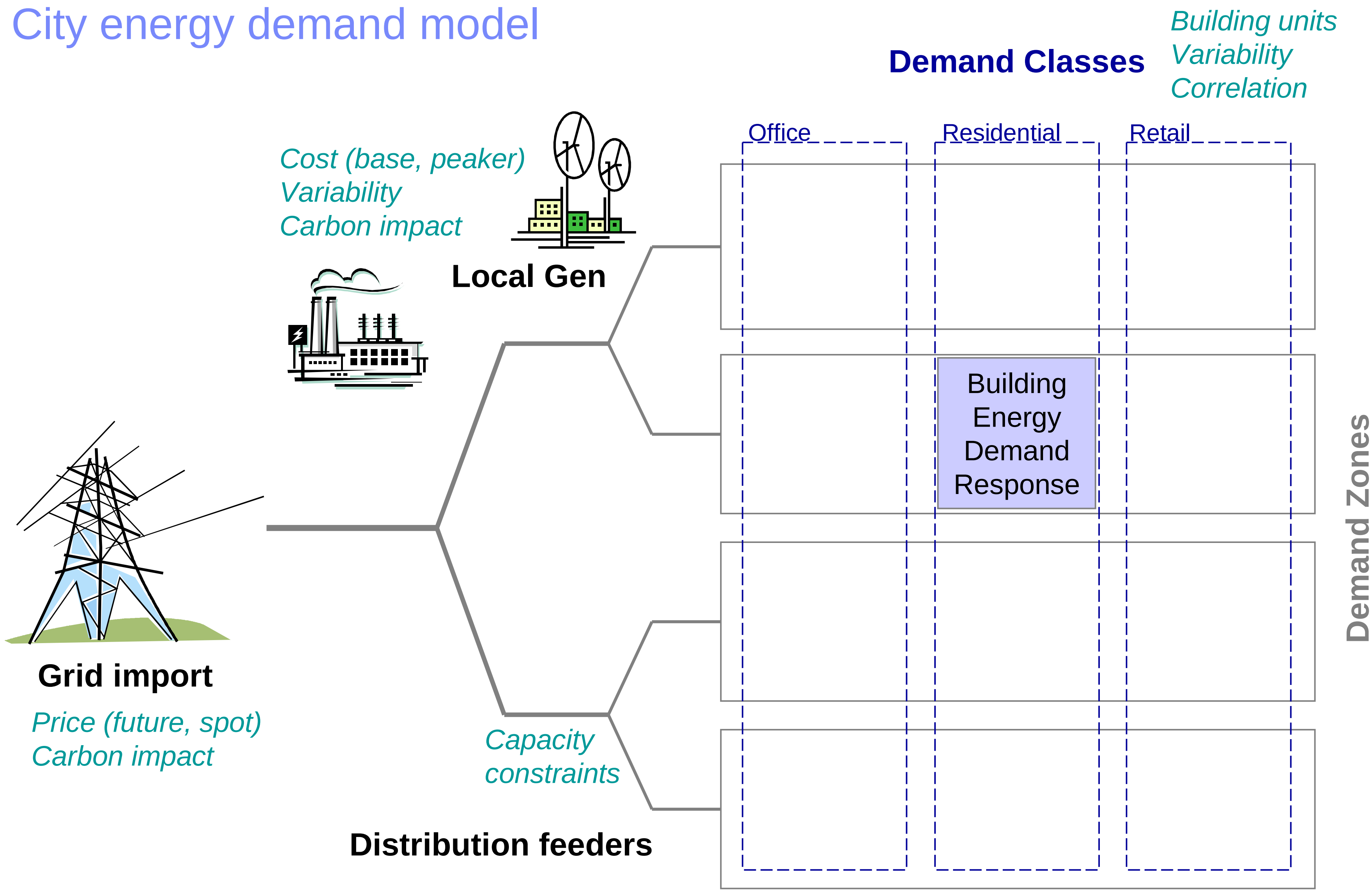
City energy demand model



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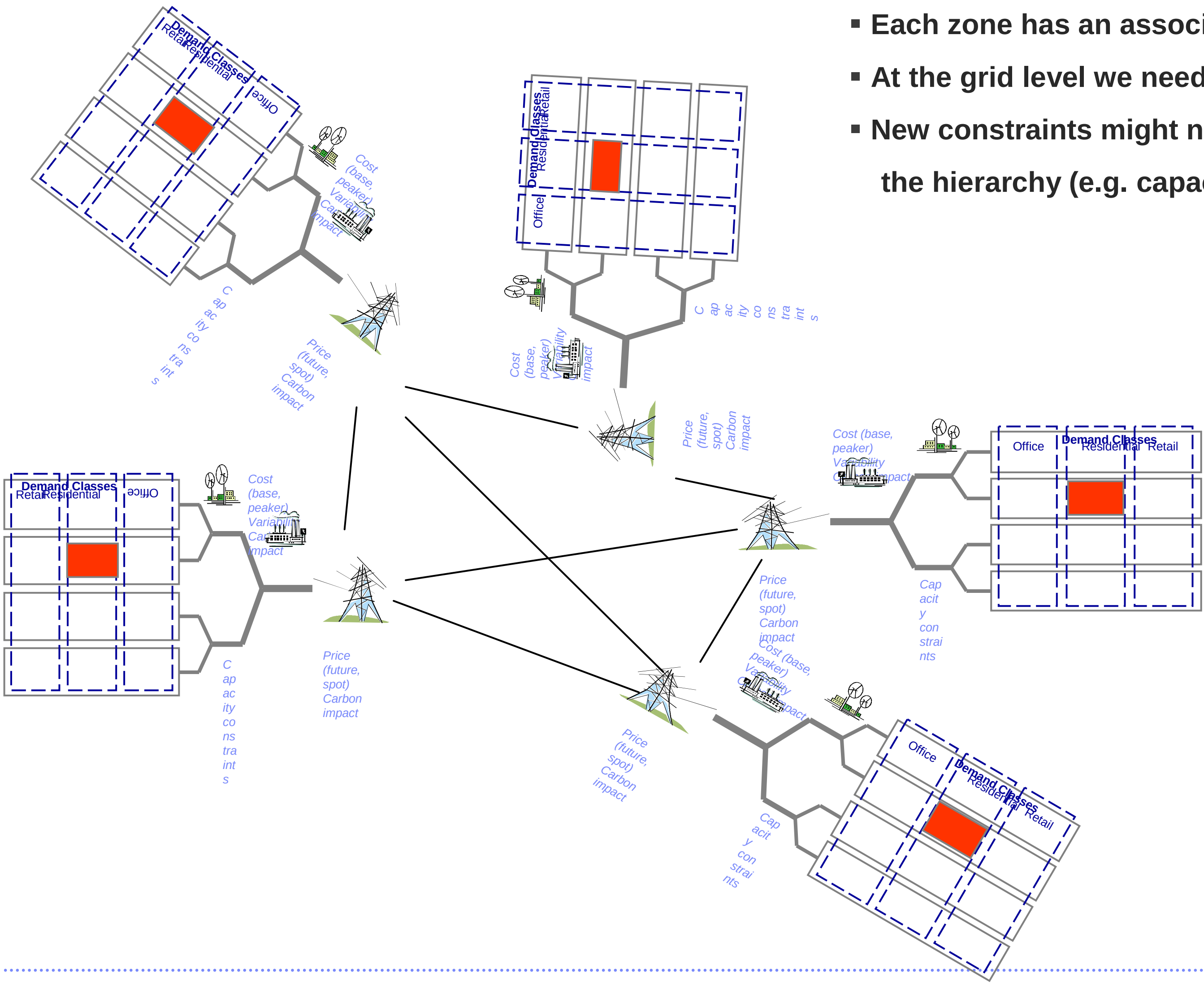
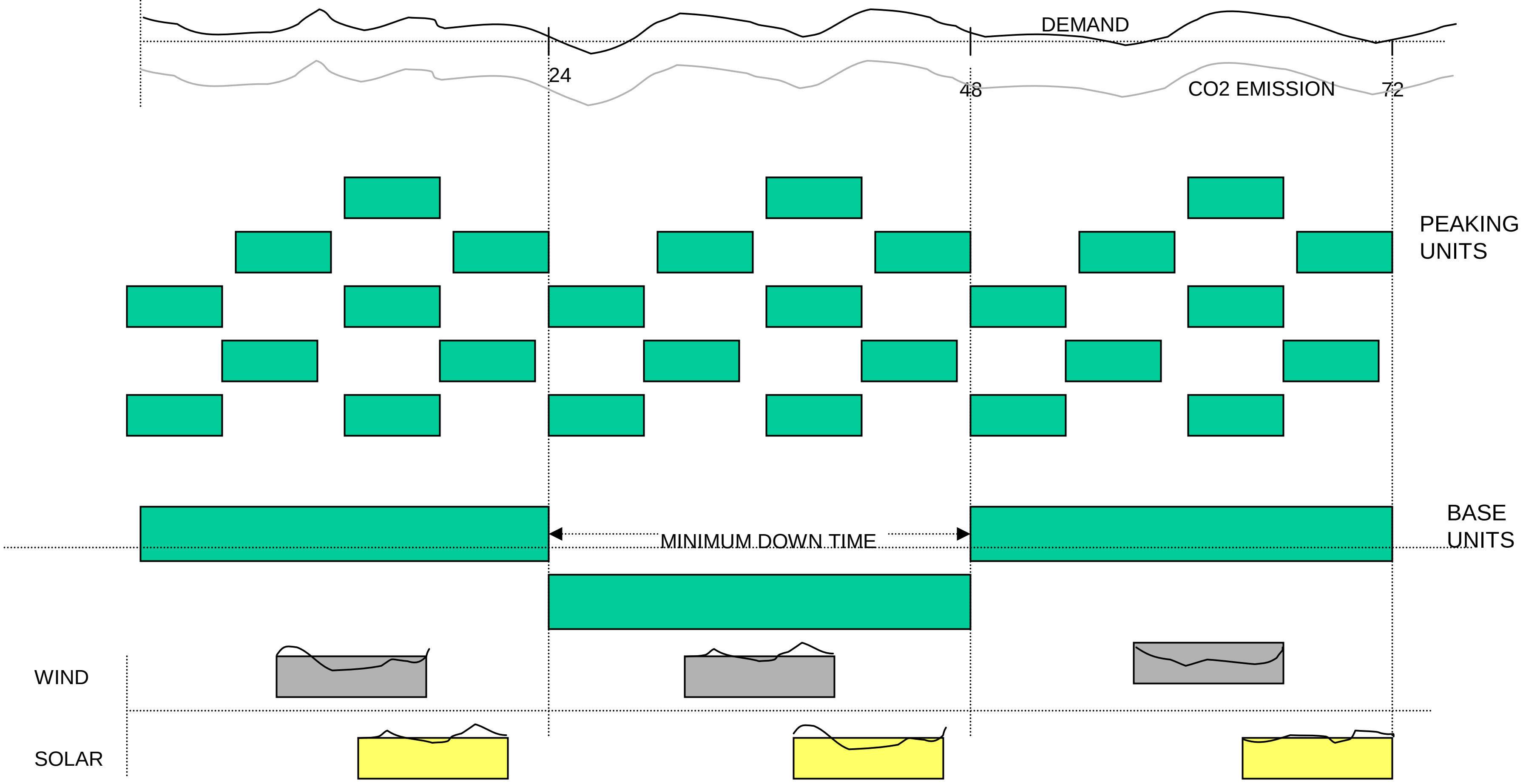
Energy Demand Modeling for the Entire Grid

- **At the grid level we have a node for each zone**
- **Each zone has an associated demand (supply)**
- **At the grid level we need to solve for a collection of models**
- **New constraints might need to be handled at each level of the hierarchy (e.g. capacity constraints on arcs)**



Unit Commitment Problem (Distributed Generation)



Integer programming problem with uncertain demand & supply
-> Stochastic optimization
The heat rate of a unit is a (nonlinear) function of load -> nonlinear optimization
- maintenance improves heat rate and hence CO2 emissions

Solver Engines for Unit Commitment

- The unit commitment problem solves a planning problem for a utility to provide a schedule for generators to minimize cost while
  - Satisfying demand
  - Satisfying production constraints
- The advanced solvers that we built in our engine has
  - Ability to scale to large number of units and 5-7 day horizon
  - Handle uncertainty in demand
  - Handle uncertainty in generation
    - Alternate generation such as wind and solar have uncertain yield and the solver needs to handle this
    - Incorporate new demand sources such as plug-in vehicles
    - Model storage as a new source of generation (aka demand response dispatch)
  - Handles nonlinear cost of production
  - Advanced Stochastic optimization techniques

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