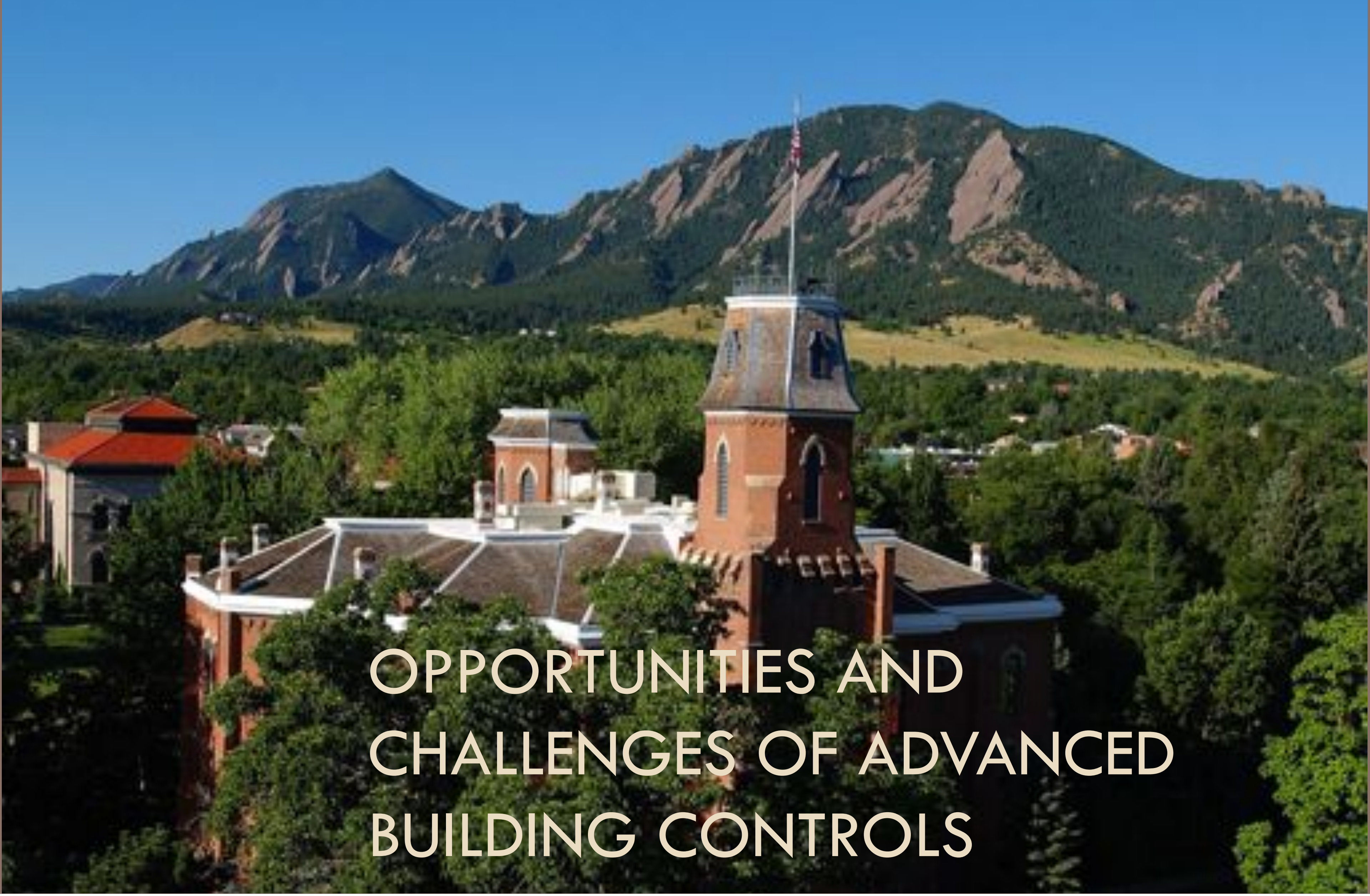


OPPORTUNITIES AND CHALLENGES OF ADVANCED BUILDING CONTROLS

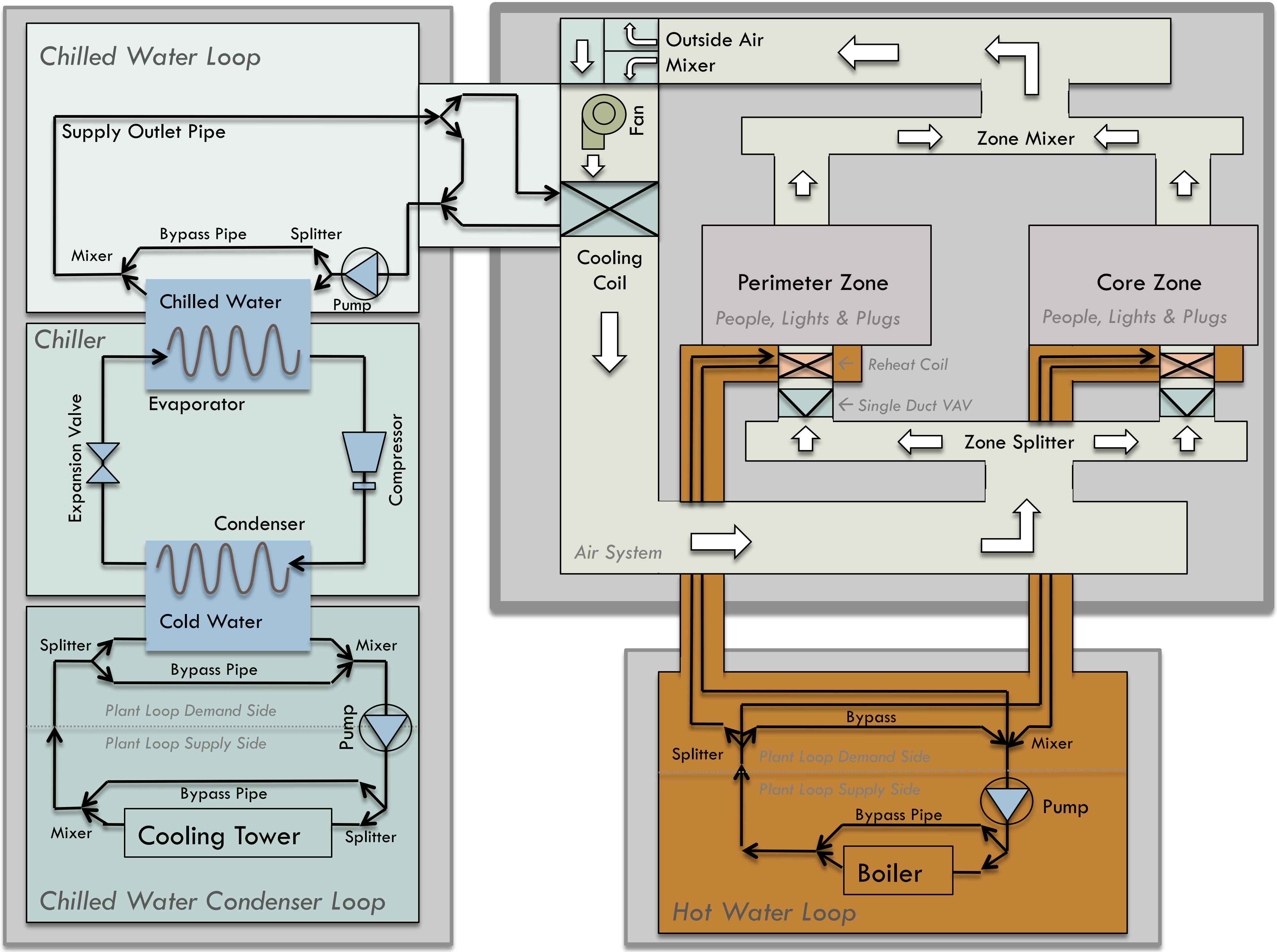
University of Colorado Boulder

Gregor P. Henze – November 2, 2011

CLEAN URBAN ENERGY

Floor Space and Energy Use

Floor area (ft^2)	Number of Buildings (%)	Floor space (%)	Energy use (%)
Less than 10,000	73	20	20
10,000 – 100,000	25	45	38
Greater than 100,000	2	35	42

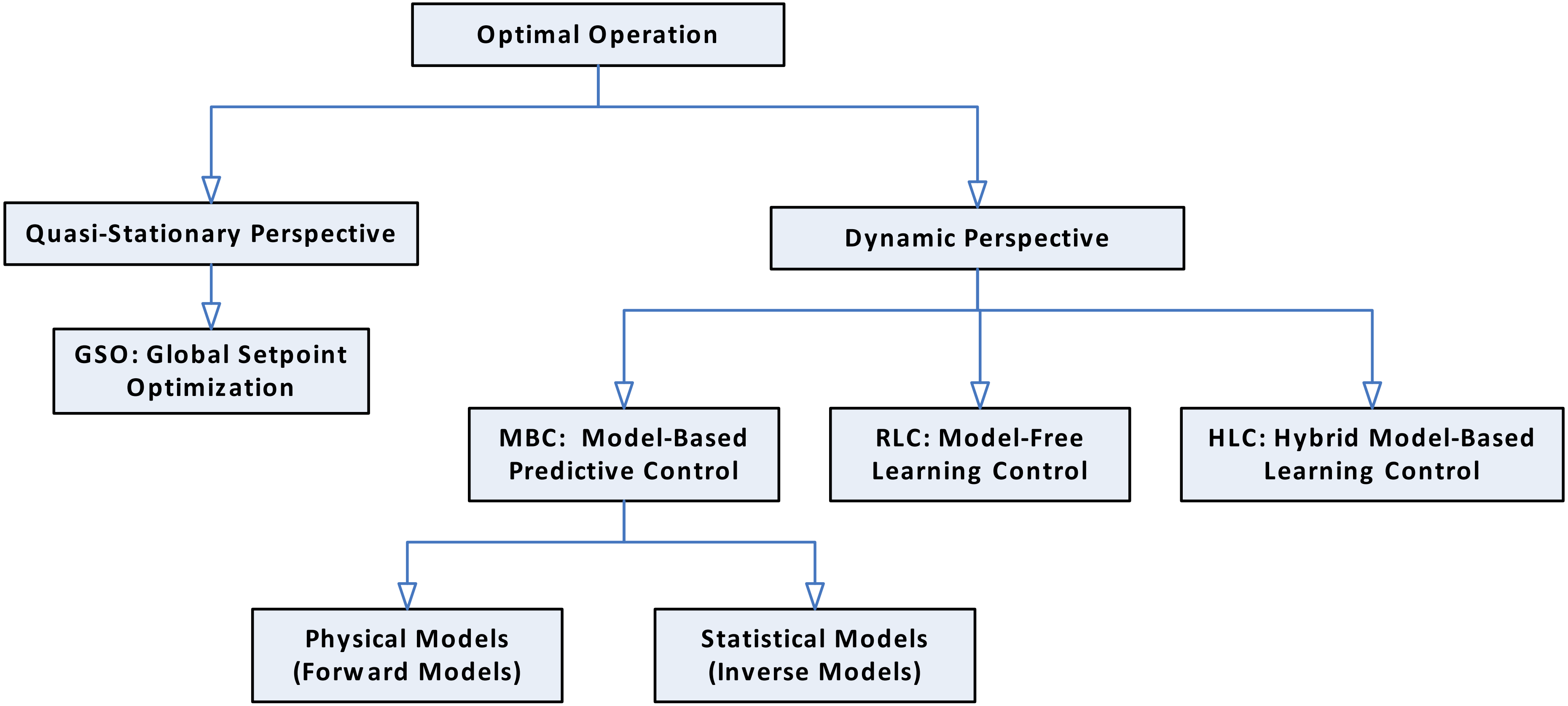


Chilled Water Loop
Supply Outlet Pipe
Bypass Pipe
Splitter
Mixer
Pump
Chilled Water
Chiller
Evaporator
Expansion Valve
Compressor
Condenser
Cold Water
Splitter
Mixer
Bypass Pipe
Plant Loop Demand Side
Plant Loop Supply Side
Pump
Bypass Pipe
Mixer
Cooling Tower
Splitter
Chilled Water Condenser Loop
Outside Air
Mixer
Fan
Cooling
Coil
Zone Mixer
Perimeter Zone
People, Lights & Plugs
Core Zone
People, Lights & Plugs
Reheat Coil
Single Duct VAV
Zone Splitter
Air System
Bypass
Splitter
Mixer
Plant Loop Demand Side
Plant Loop Supply Side
Pump
Bypass Pipe
Boiler
Hot Water Loop

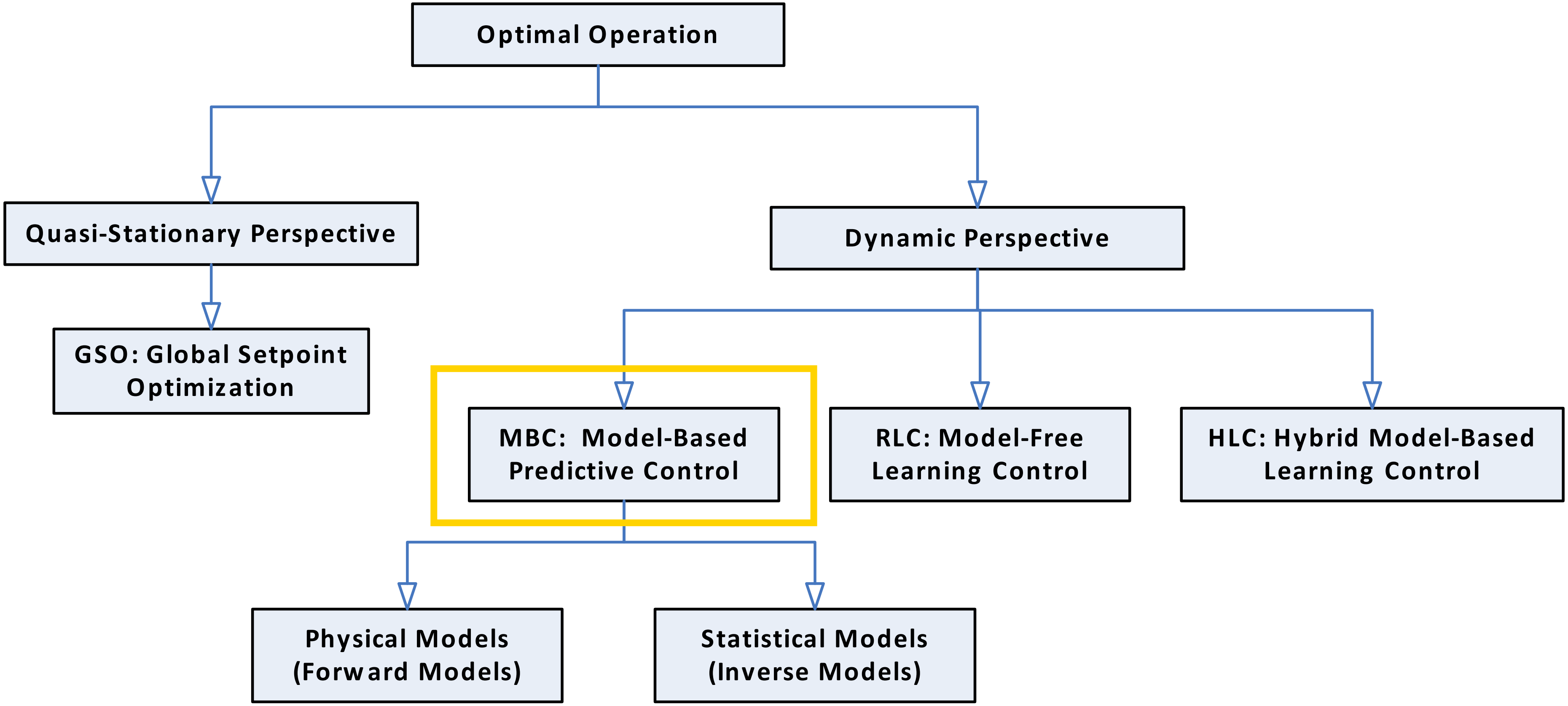
Why Advanced Control?

- Significant improvements already achieved
  - Envelope – reduced heat gains and losses
  - High-efficiency motors for pumps and fans
  - Chillers and boilers drastically improved in last 20a
- Yet, remaining needs in
  - Thermal energy distribution, storage, control
  - System integration
  - Energy efficiency and peak reduction potential

Opportunities for Optimization



Model Predictive Control



Why Model Predictive Control?

- Several HVAC system components – longer-term optimal control solution often not trivial.
- Temporal variations in comfort requirements and/or energy costs introduce additional complexity.
- Predictive control opens up the possibilities
  - to exploit the building's thermal mass
  - to use information on future disturbances (weather, internal gains) for better planning.
  - to integrate DG and distributed storage systems

Commercial Building Status Quo

- No use of weather, prices, or carbon forecasts
- No accounting for building dynamics and thermal inertia of commercial buildings
- No aggregation of similar buildings to provide concerted demand response or load leveling effect
- No use of short-term curtailment opportunities, very inelastic demand side response.

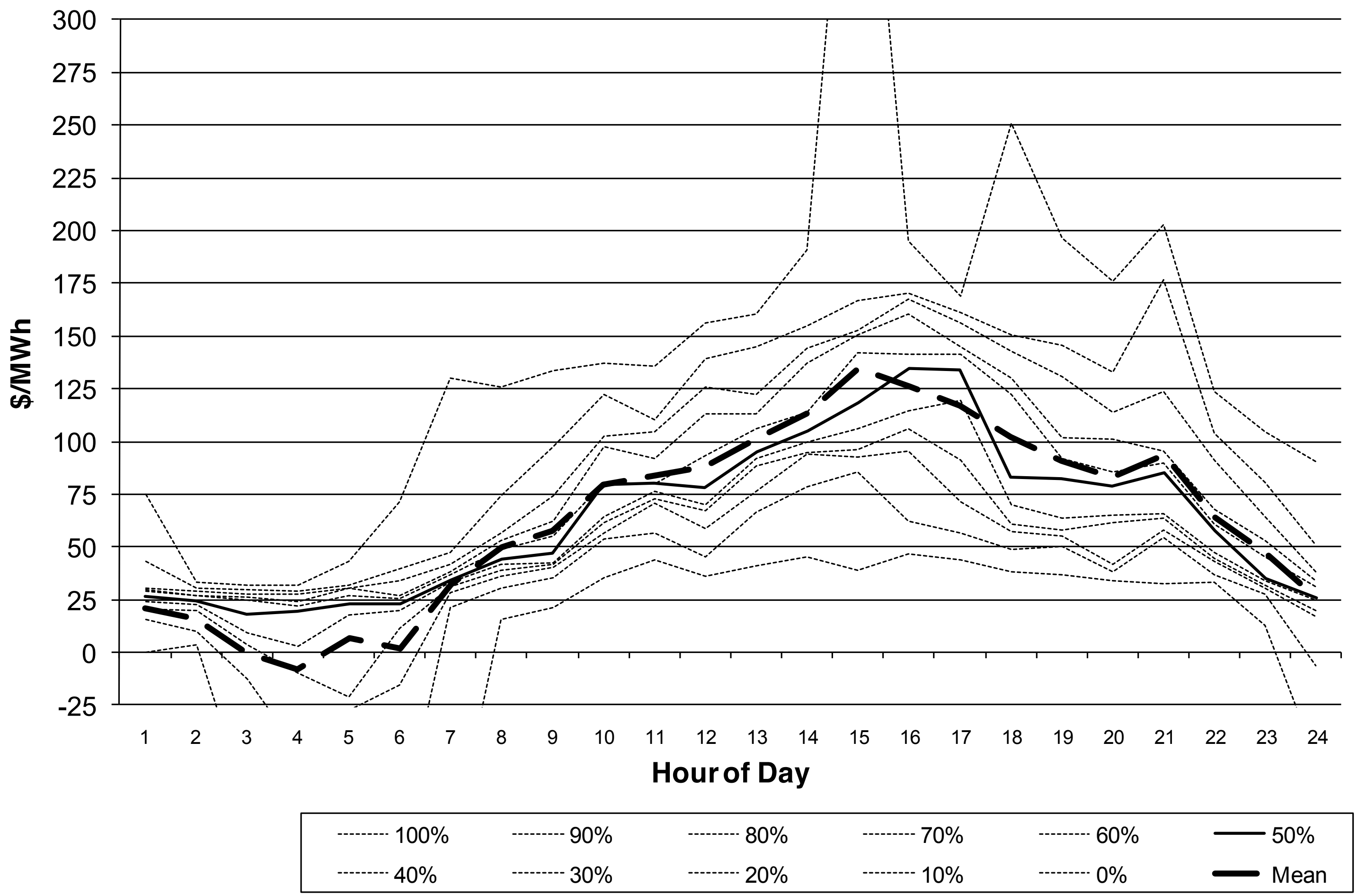
“Elastic” Commercial Buildings

Opportunity!

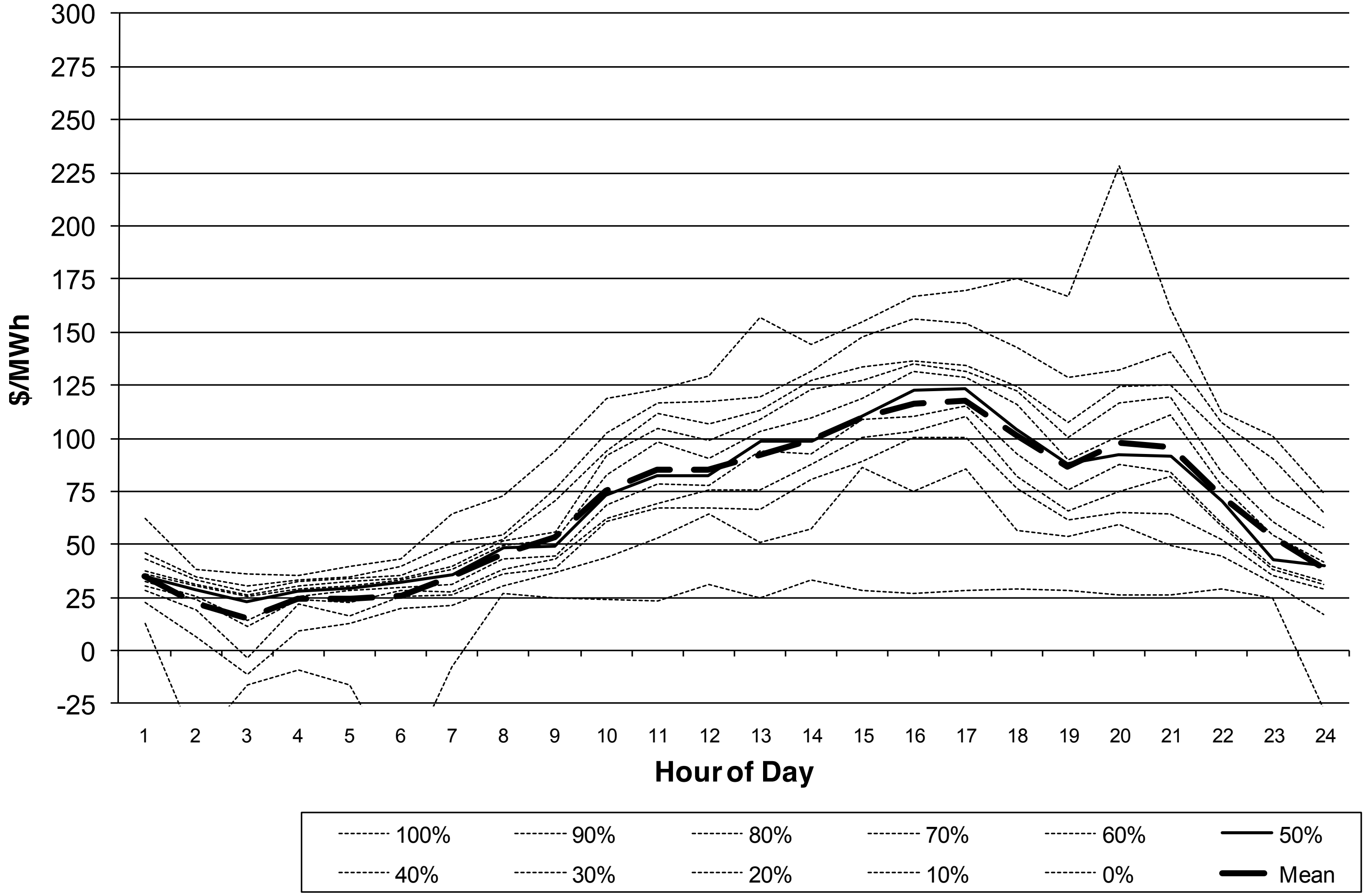
- Building/grid integration: Integrate commercial building operations with electric system markets
- Price responsive thermal mass control
- Enable short-term (<1h) response to dynamic electric market prices for ancillary services.
- Aggregate and optimize portfolios of large buildings into large responsive loads
- Alternative utility scale storage for renewables

CHICAGO DOWNTOWN

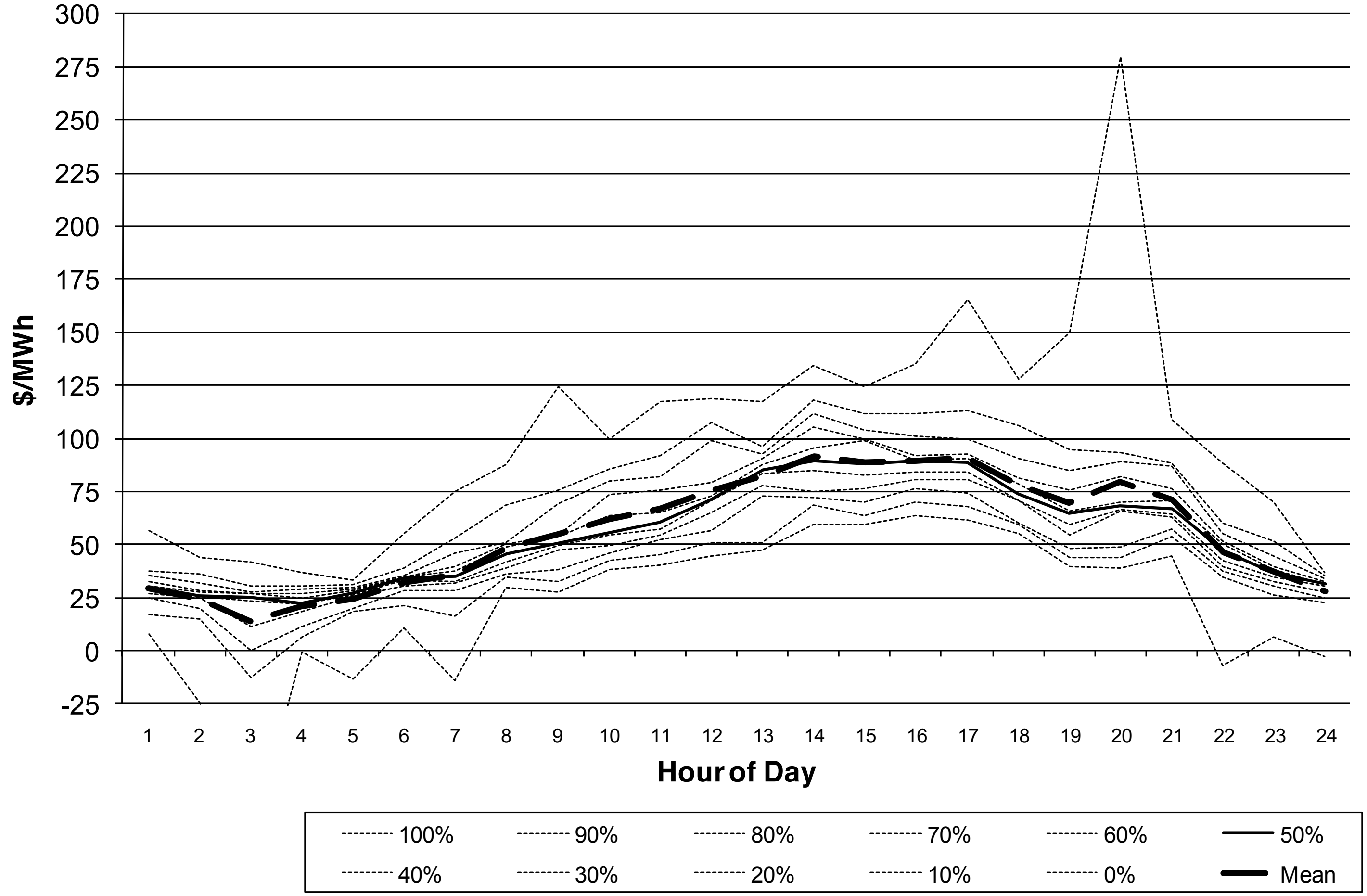
PJM Chicago June 2008



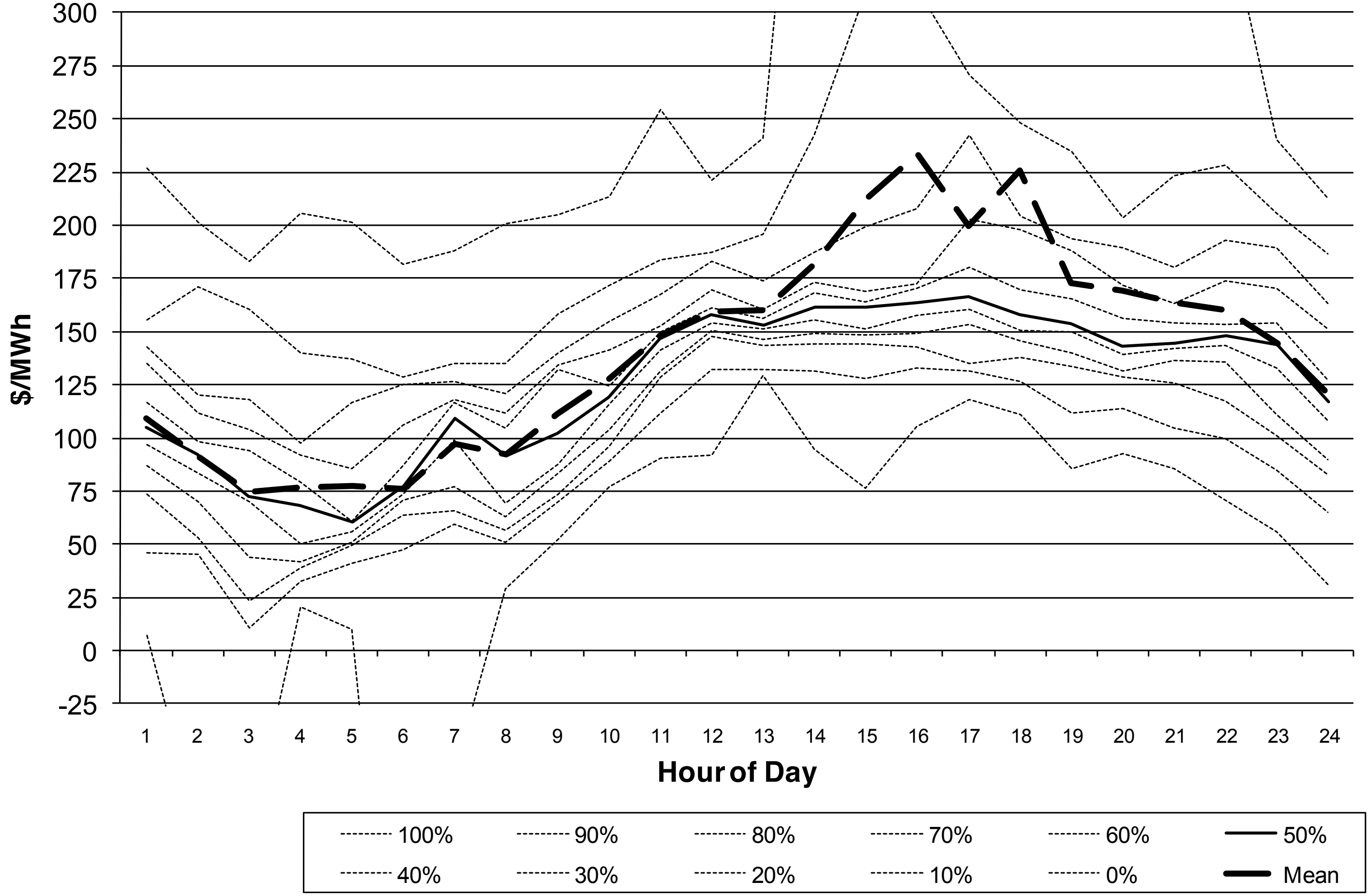
PJM Chicago July 2008



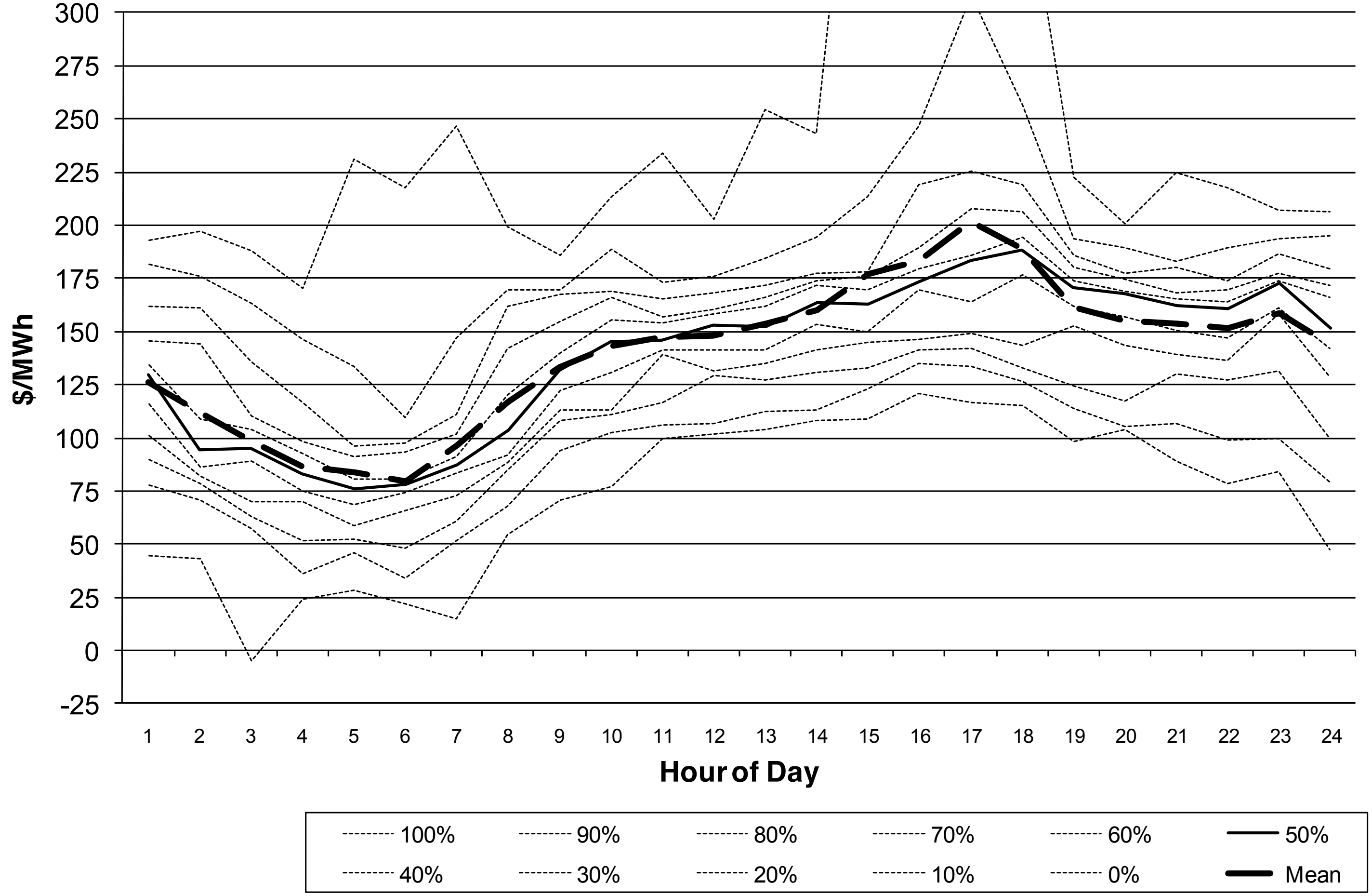
PJM Chicago August 2008



PJM NYC June 2008



PJM NYC July 2008



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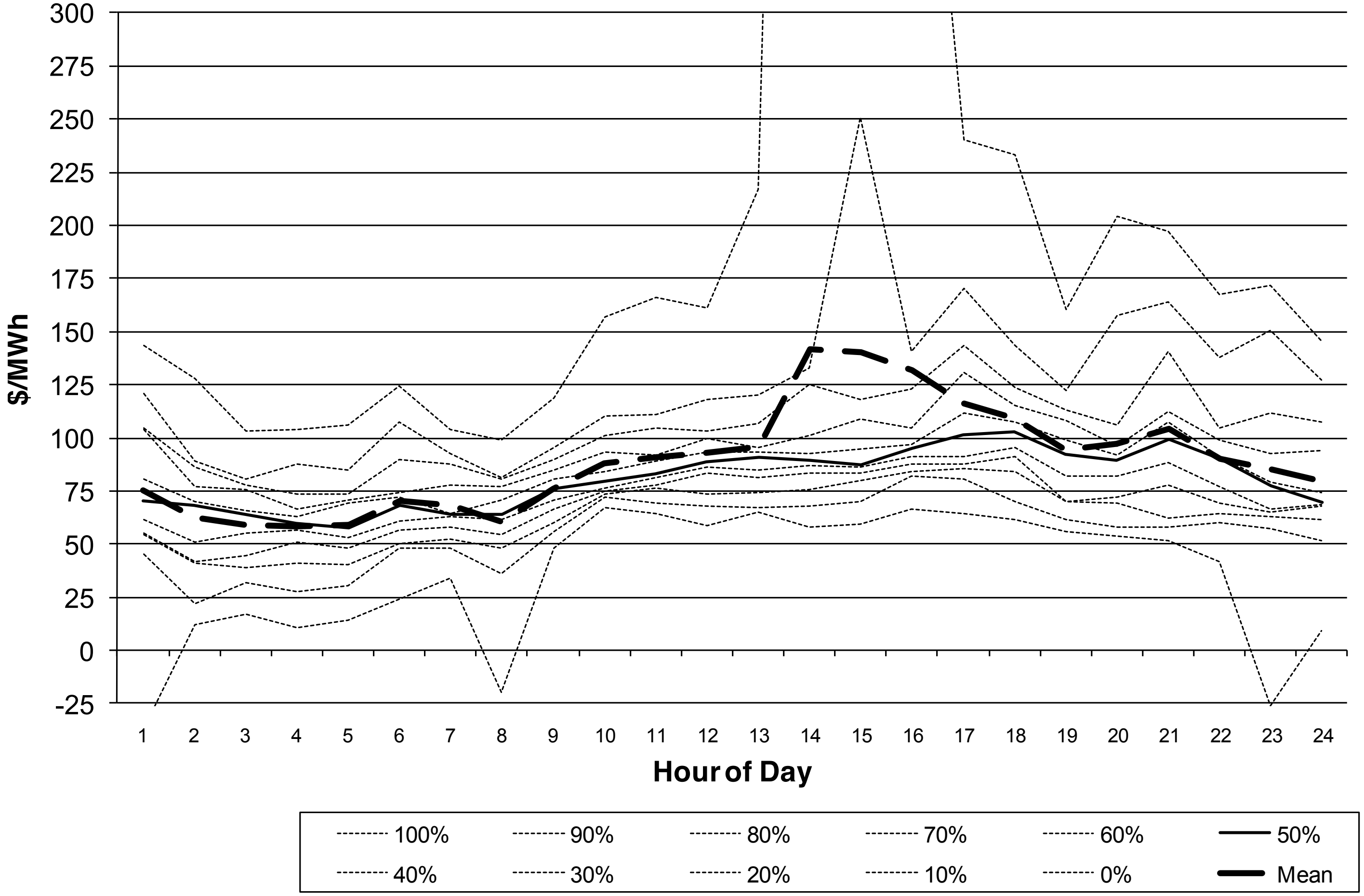
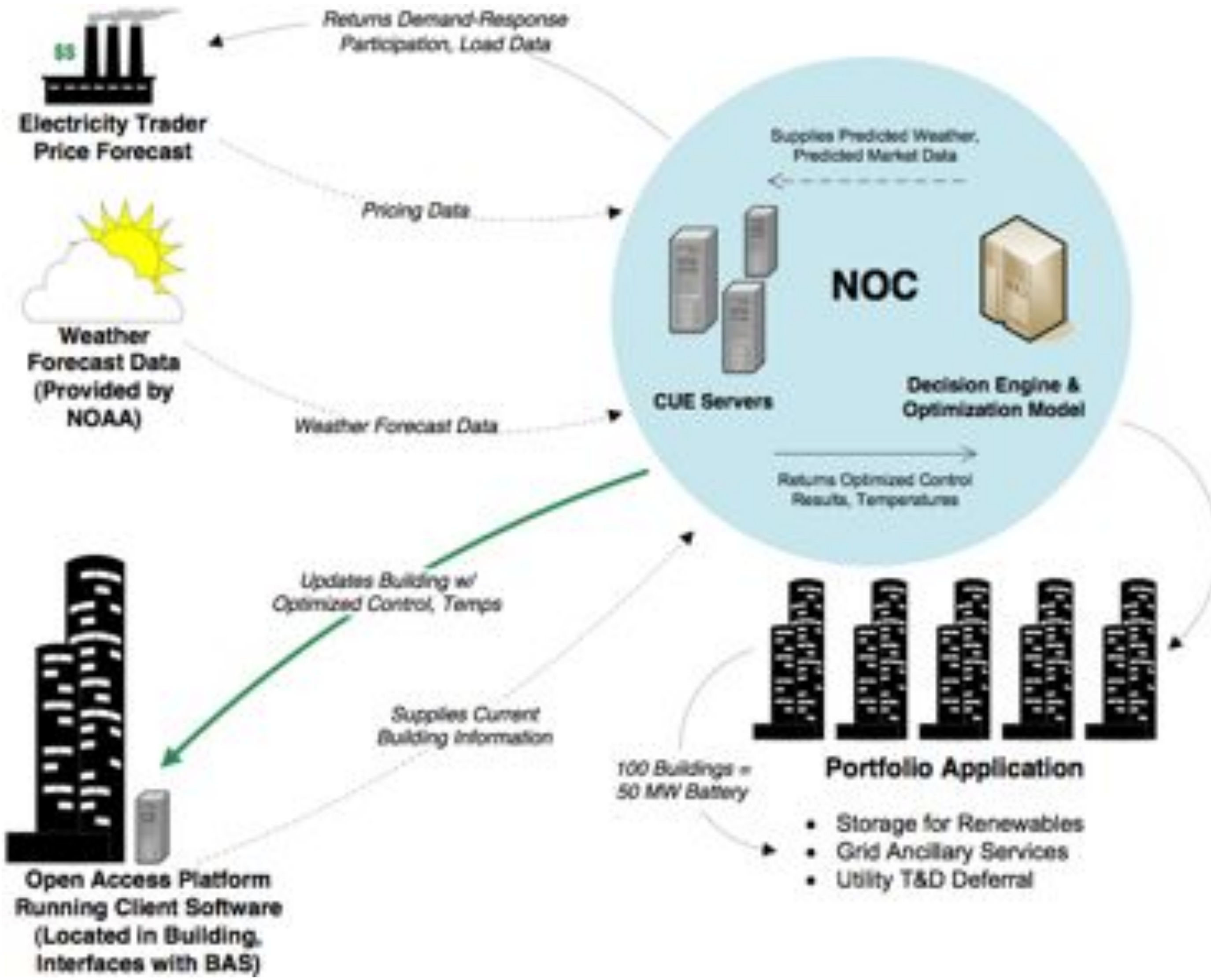
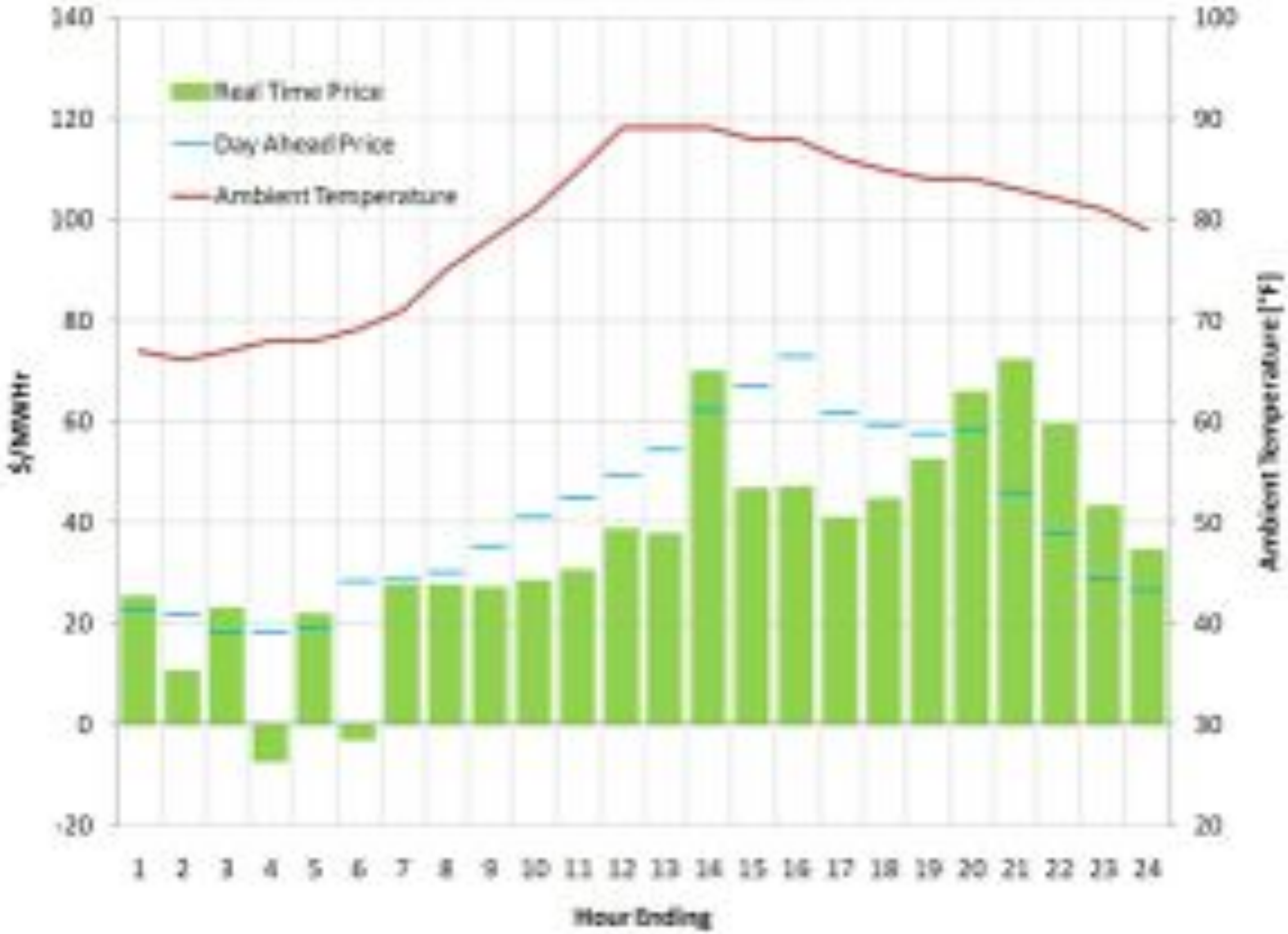


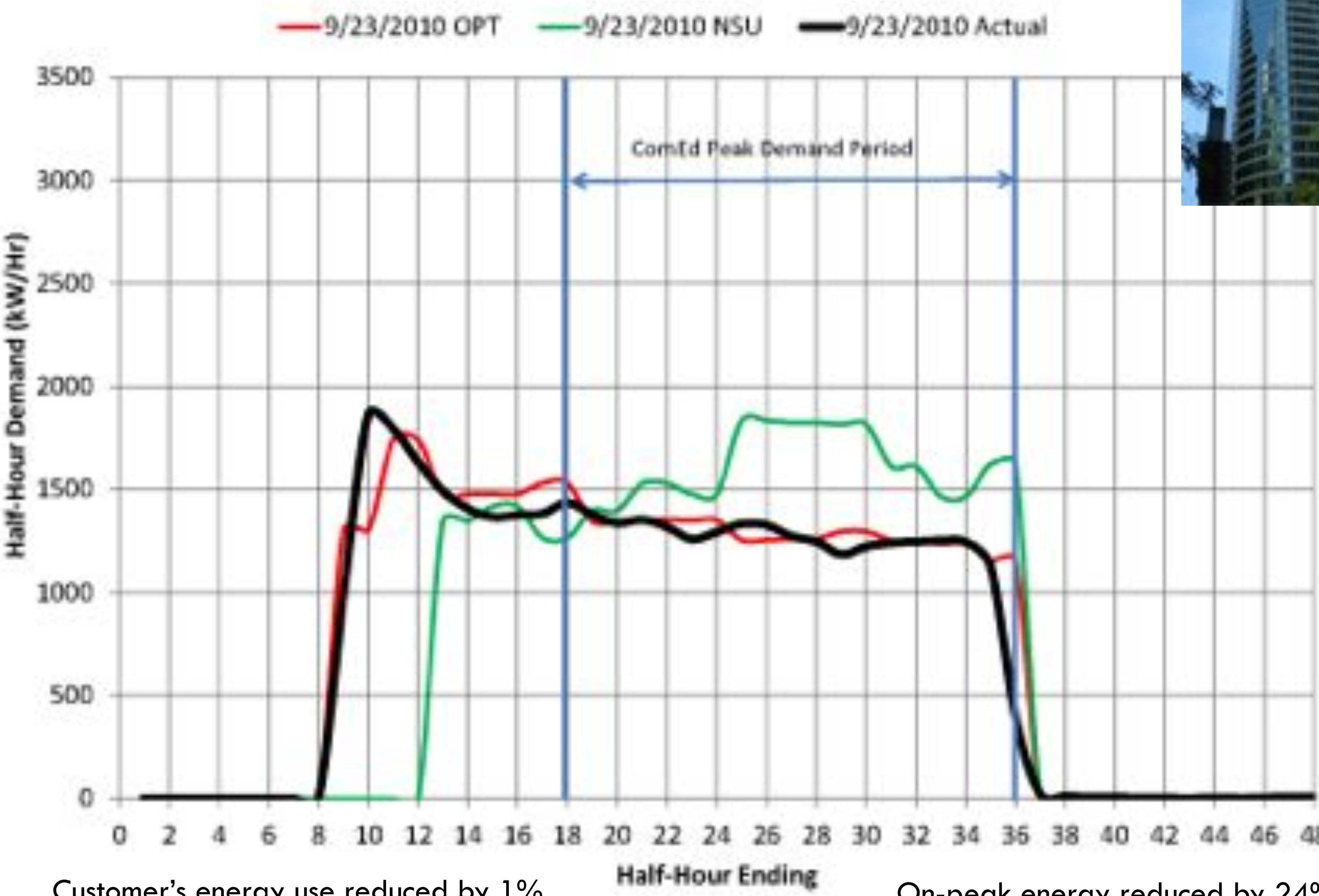
MPC as Cloud-Based SaaS



Chicago Example



Case Study in Chicago



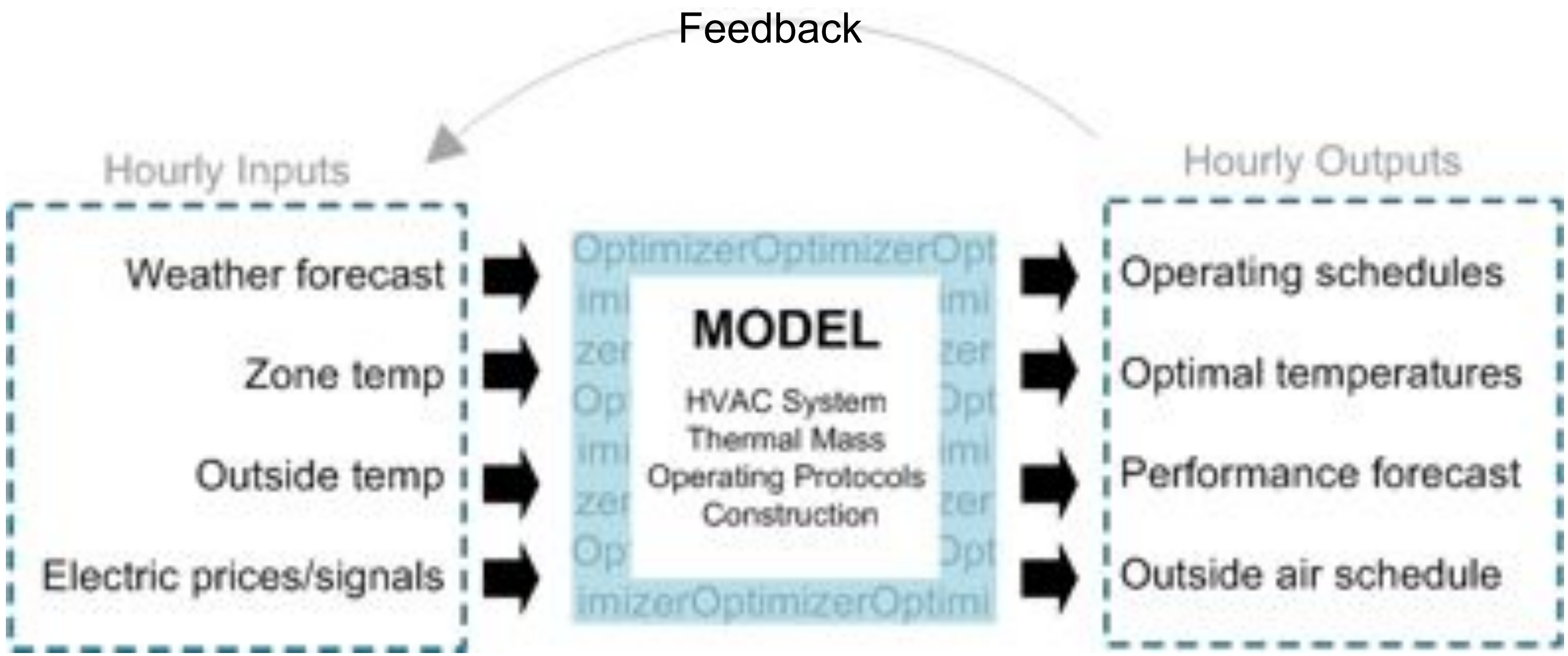
Customer's energy use reduced by 1%
Supplier's energy cost reduced by 18%

On-peak energy reduced by 24%
Peak demand reduced by 25%

Mapping building to grid dynamics

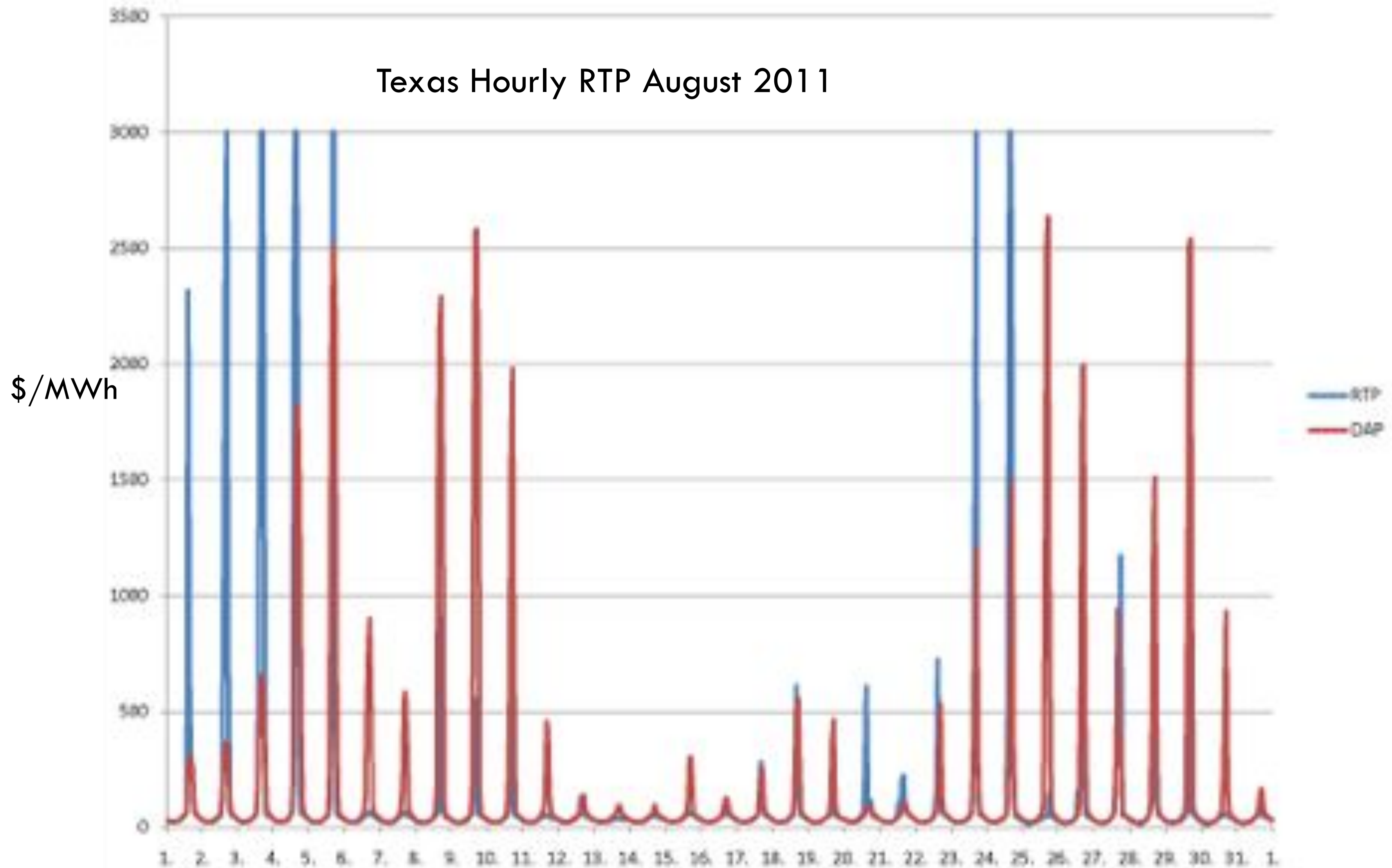
Optimal Strategy = F (Objective, $Price_{HR}$, $Weather_{HR}$, Chiller Curves, DCV, …)

Objective: ☑ Expense ○ Efficiency ○ Peak Demand ○ Chiller Starts ○ All

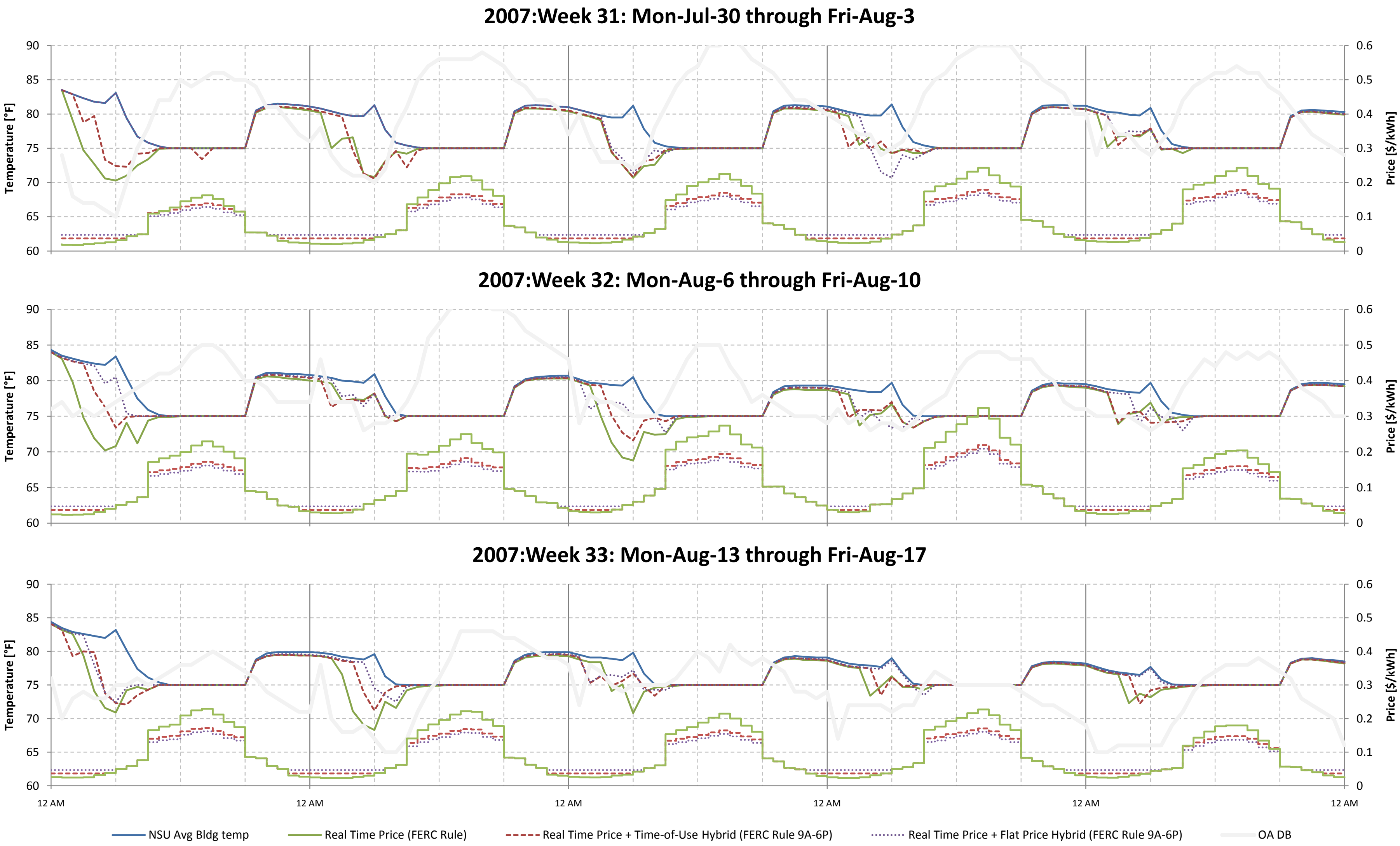


DR becomes large contributor to overall building expense reduction, especially in large grid-congested cities.

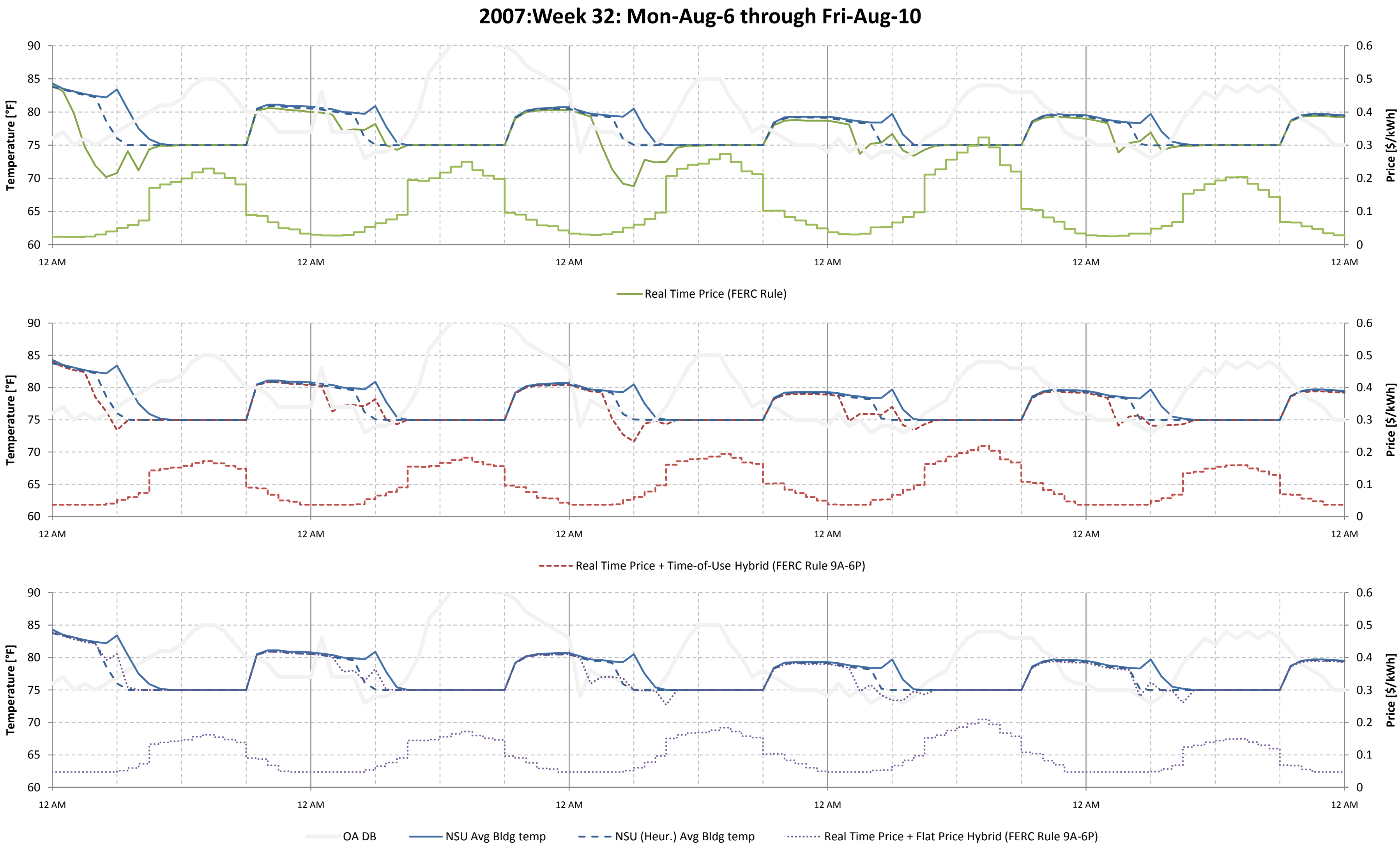
Texas August 2011



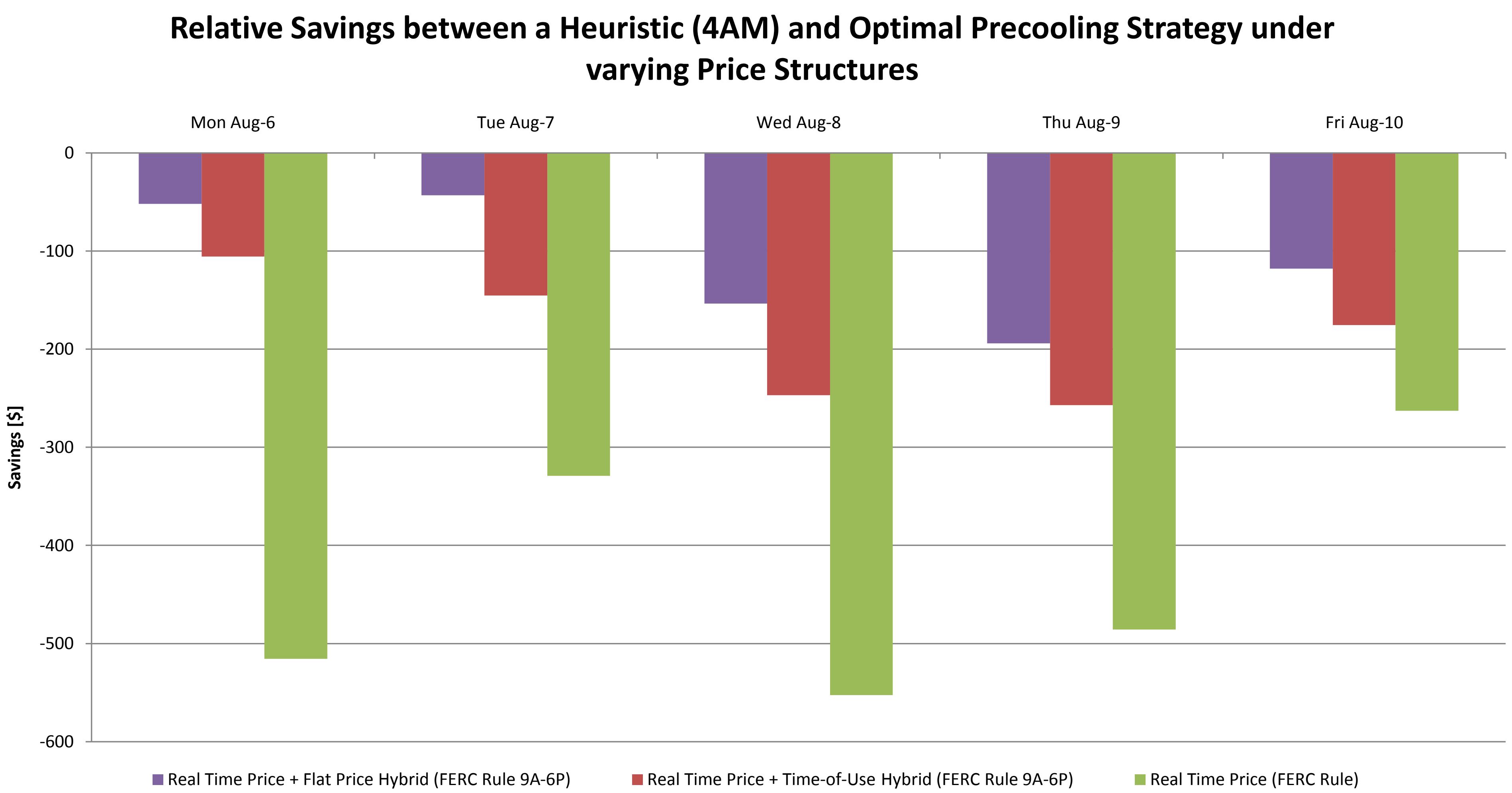
Variance in Strategies as f(t,price)



Variance in Strategies as f(price)



Comparison with Heuristic



MPC Challenges

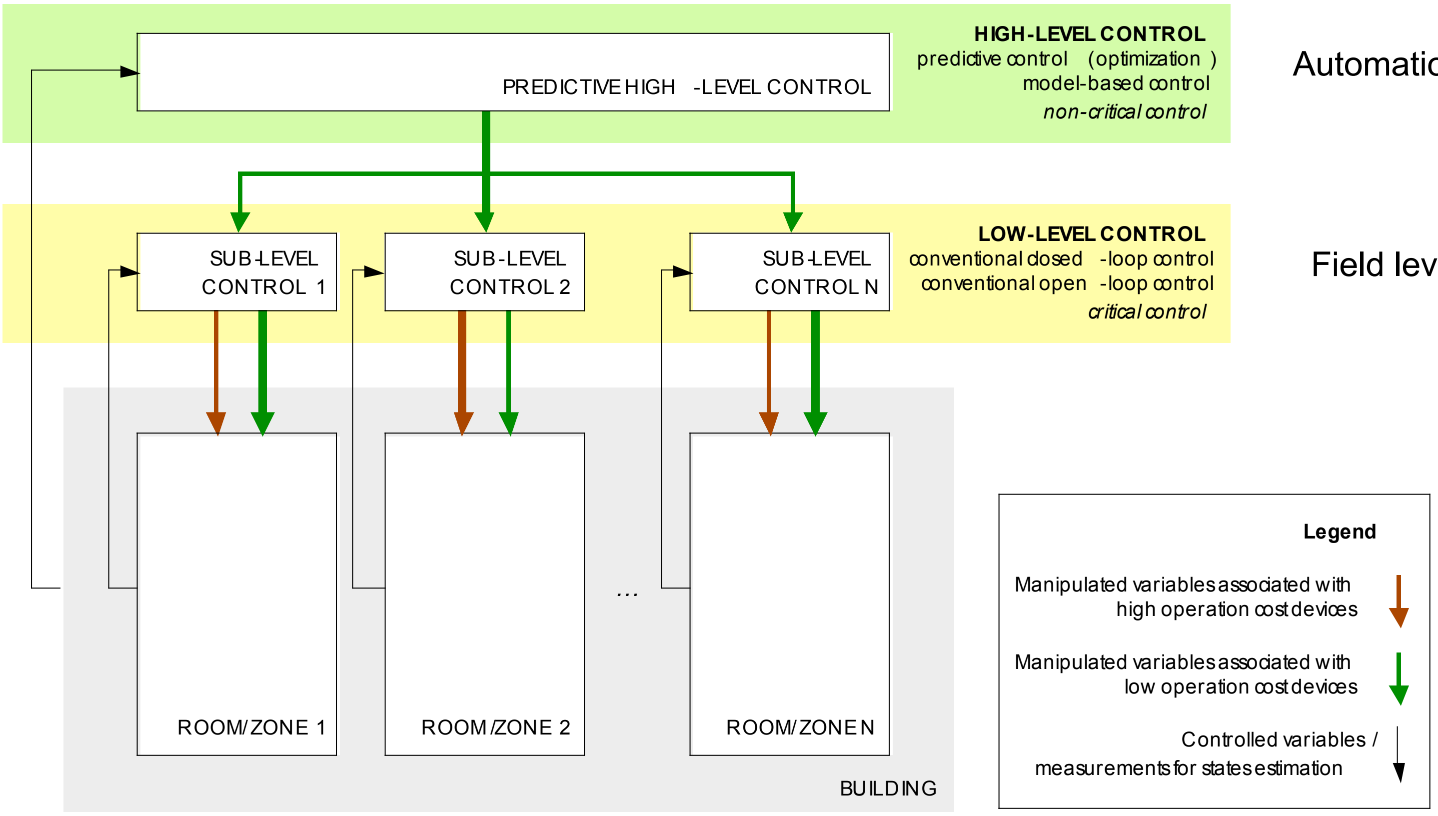
Challenge!

- Model Creation & Calibration
  - EEFG/OpenStudio
  - Fractional Factorial Analysis
  - Auto-Calibration
  - Bayesian Parameter Estimation and Model Competition
- Thermal History
  - Establishing State: Pre-Conditioning Horizon
  - EnergyPlus Modifications
- Simulation Speed: Reduced Order Modeling
- Model Mismatch: Feedback & History Management

Implementation

Challenge!

- Embed in existing automation systems



Market Opportunity

Opportunity!

- Saving potential:
  - 10-25% of HVAC costs, i.e., 0.15-0.40 $\$/ft^2/yr$
  - Example: 1 MSF building – 150-400 k$ per year
- Not capital intensive, but engineering skill needed
- Short payback periods (<1 year)
- Improves economics of classical energy retrofits

Time? Yes No

Benefits to Customer

- Lower peak charges – energy cost reductions
- Increase demand response revenue
- Maintain thermal comfort, meeting ASHRAE thermal comfort standards
- Improve energy efficiency
- Improve central plant operations

Site Requirements

- DDC to control local zone air temperature setpoints … on at least 20% of the floors.
- Unoccupied hours, with temperature flexibility.
- Central chiller system – for both individual building and campus applications.
- Variable Air Volume (VAV) system

THANK YOU FOR YOUR ATTENTION!

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