Demand-Limiting Using Building Thermal Mass for Small Commercial Applications

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Jim Braun – Purdue University

Steve Fredrickson – Southern California Edison

Ed Arens – University of California - Berkeley

Outline

- Overall Objectives and Organization
- Simulation Results for California
- Iowa Energy Center Testing
- Field Testing in Southern California
- Conclusions
- What’s Next?

Research Objectives

- Determine potential for demand reduction and operating cost savings in small commercial buildings – simulation and field studies
- Evaluate comfort impacts and customer acceptance
- Develop general methods for determining zone temperature variations to limit peak demand for critical peak periods
- Develop “quick” demand-limiting assessment tools for end-users and utility program planners

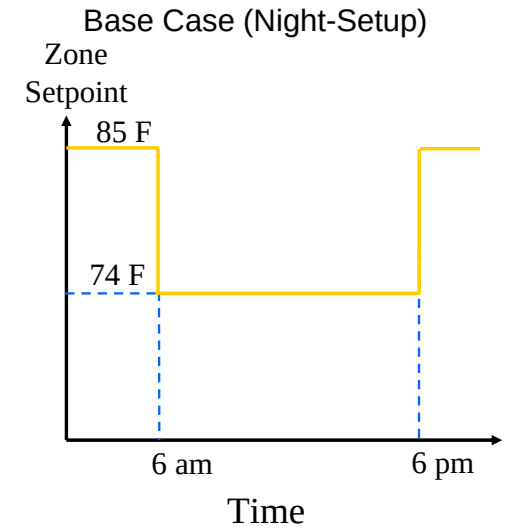
Organization

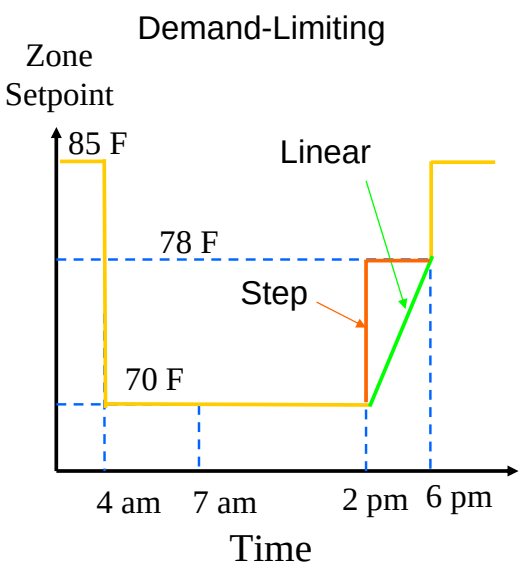
- Southern California Edison
  - Field site selection and implementation
  - Customer acceptance
- Purdue University
  - Control strategy development and evaluation
  - Simulation and field data analysis to evaluate demand limiting potential
  - Development of quick assessment tools
- University of California - Berkeley
  - Occupant thermal comfort and satisfaction evaluations

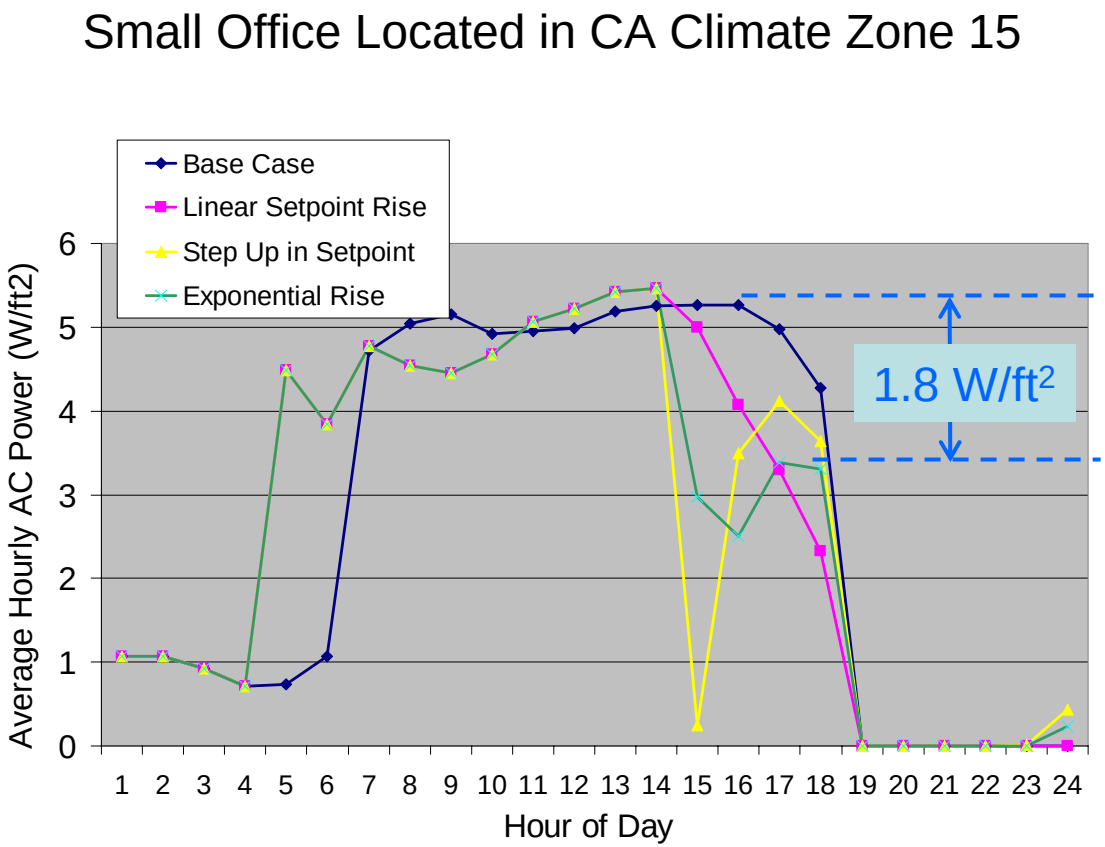
Simulation Case Studies

- Prototypical small commercial buildings in California climates
- Critical events on days having the 10 highest AC power demands
- Demand-limiting from 2 – 6 pm on critical event days
- 20% oversizing of AC equipment
- Conventional and CPP rates for SCE and PG&E

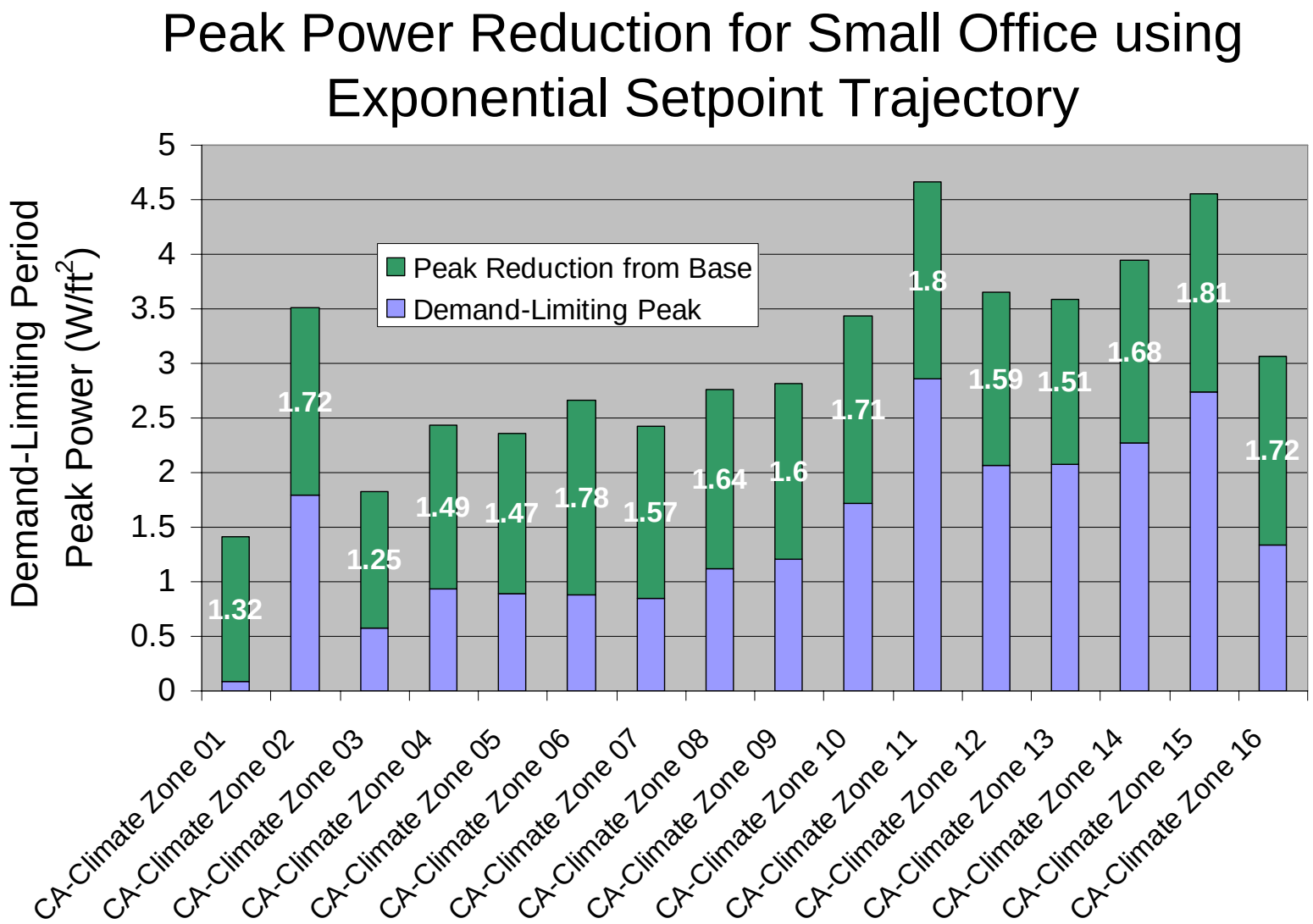
Importance of Setpoint Trajectory



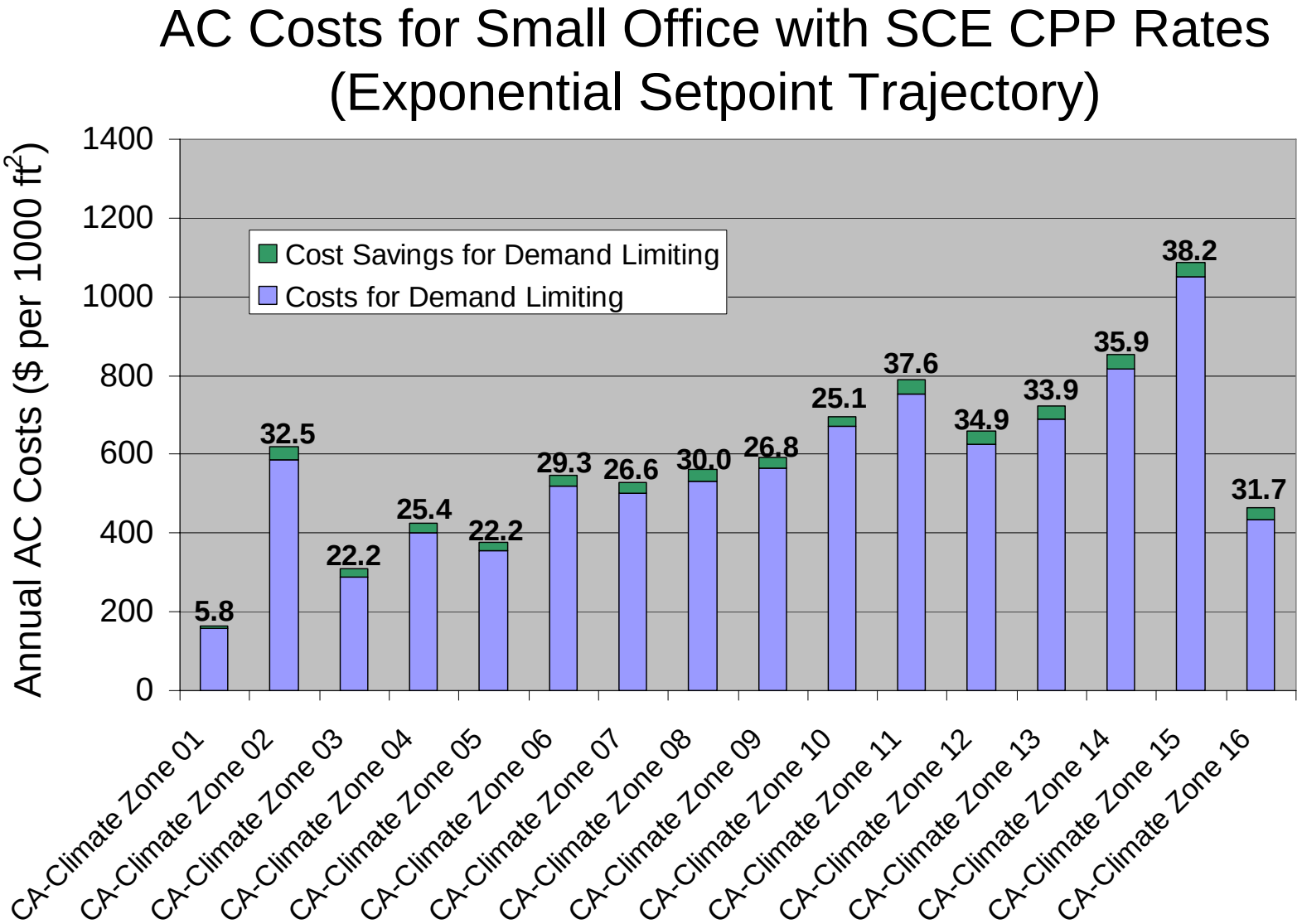




Demand-Limiting Savings Potential



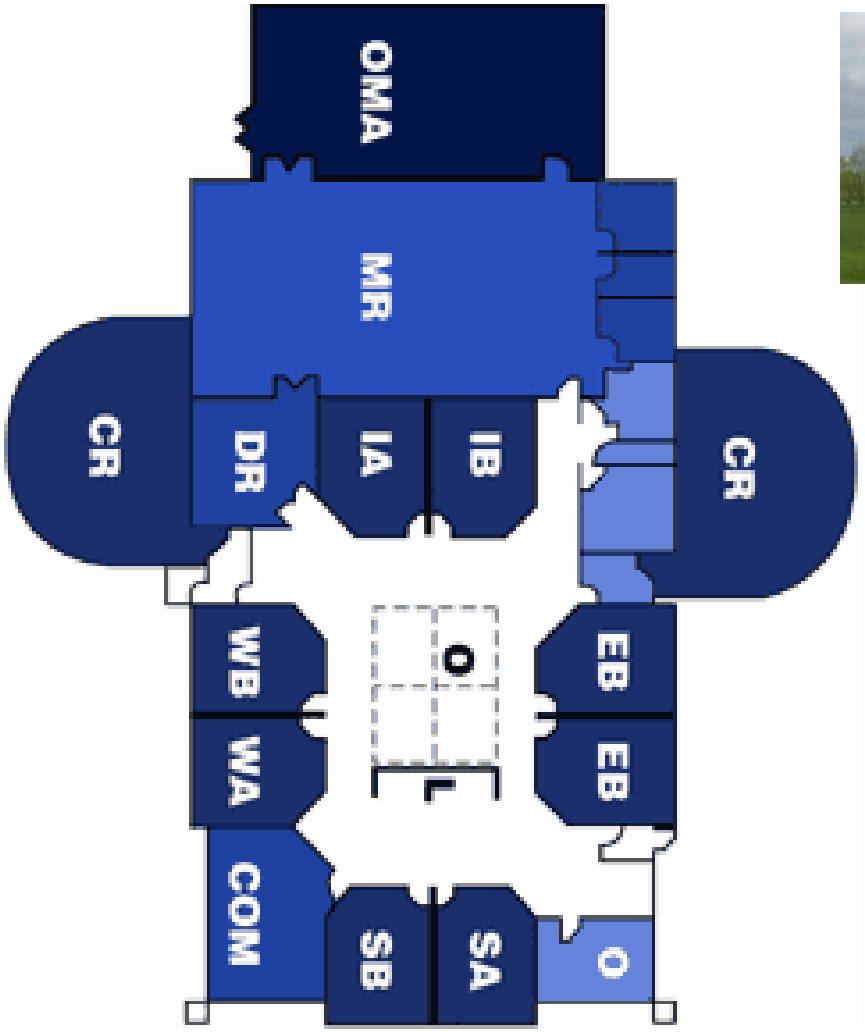
Impact on AC Costs



Conclusions

- Peak power reduction very sensitive to demand-limiting trajectory of zone temperatures
- Very significant peak power reduction potential
- Current CPP rate structures may not provide appropriate incentives for encouraging customers to minimize peak demand

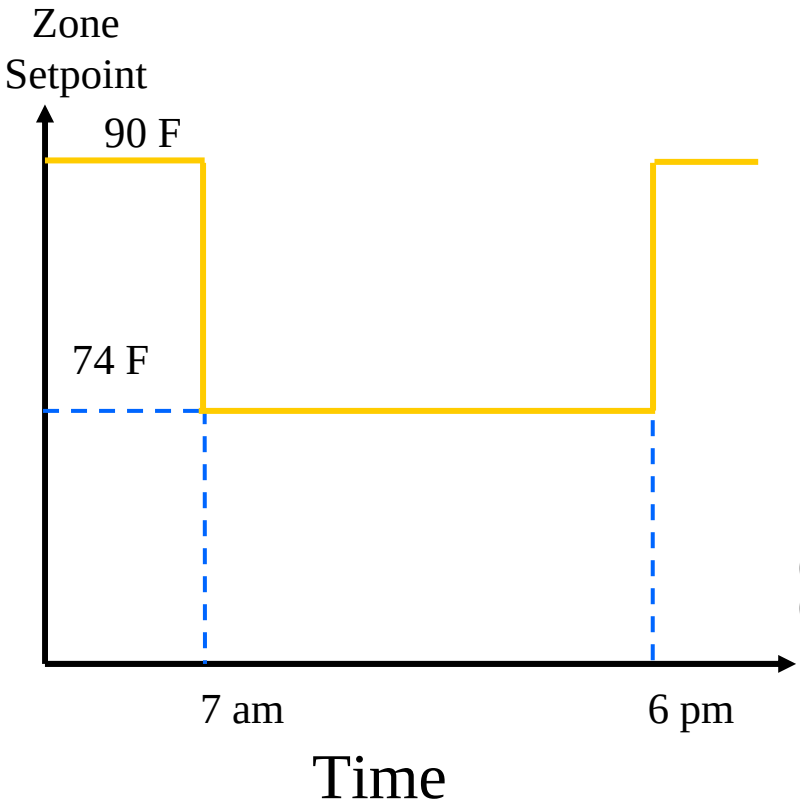
Iowa Energy Center



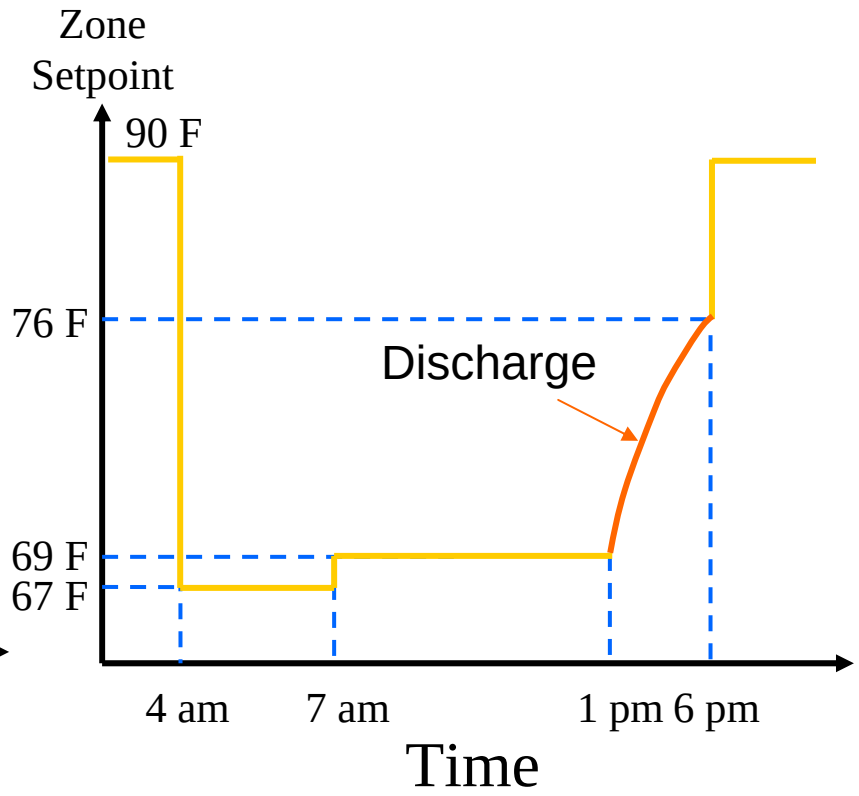
- Well-instrumented test rooms (east, south, west, & internal)
- Representative of a small commercial building
- No “internal” thermal mass (only floor, roof, and walls)

Peak Load Reduction Tests

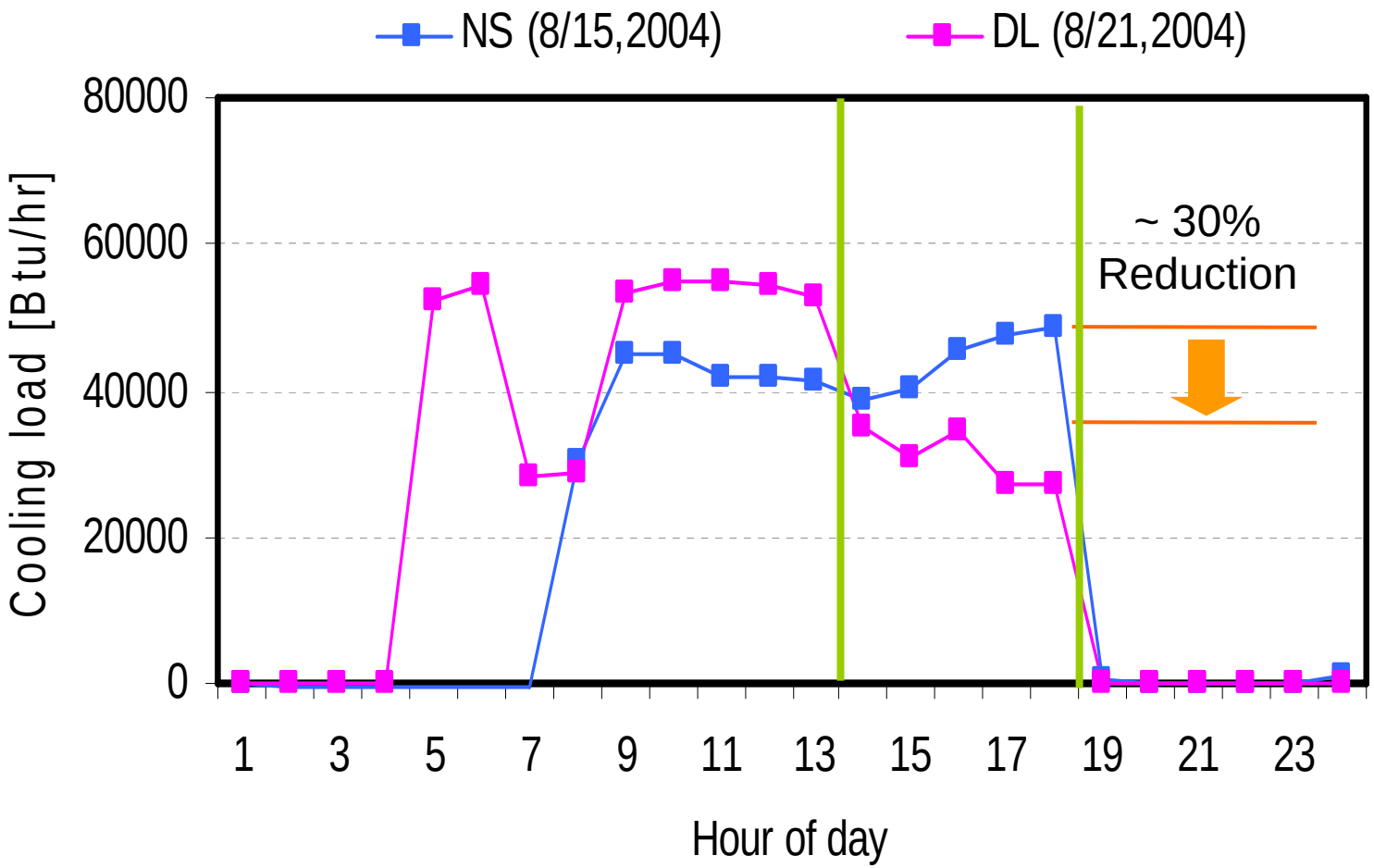
Base Case (Night-Setup, NS)



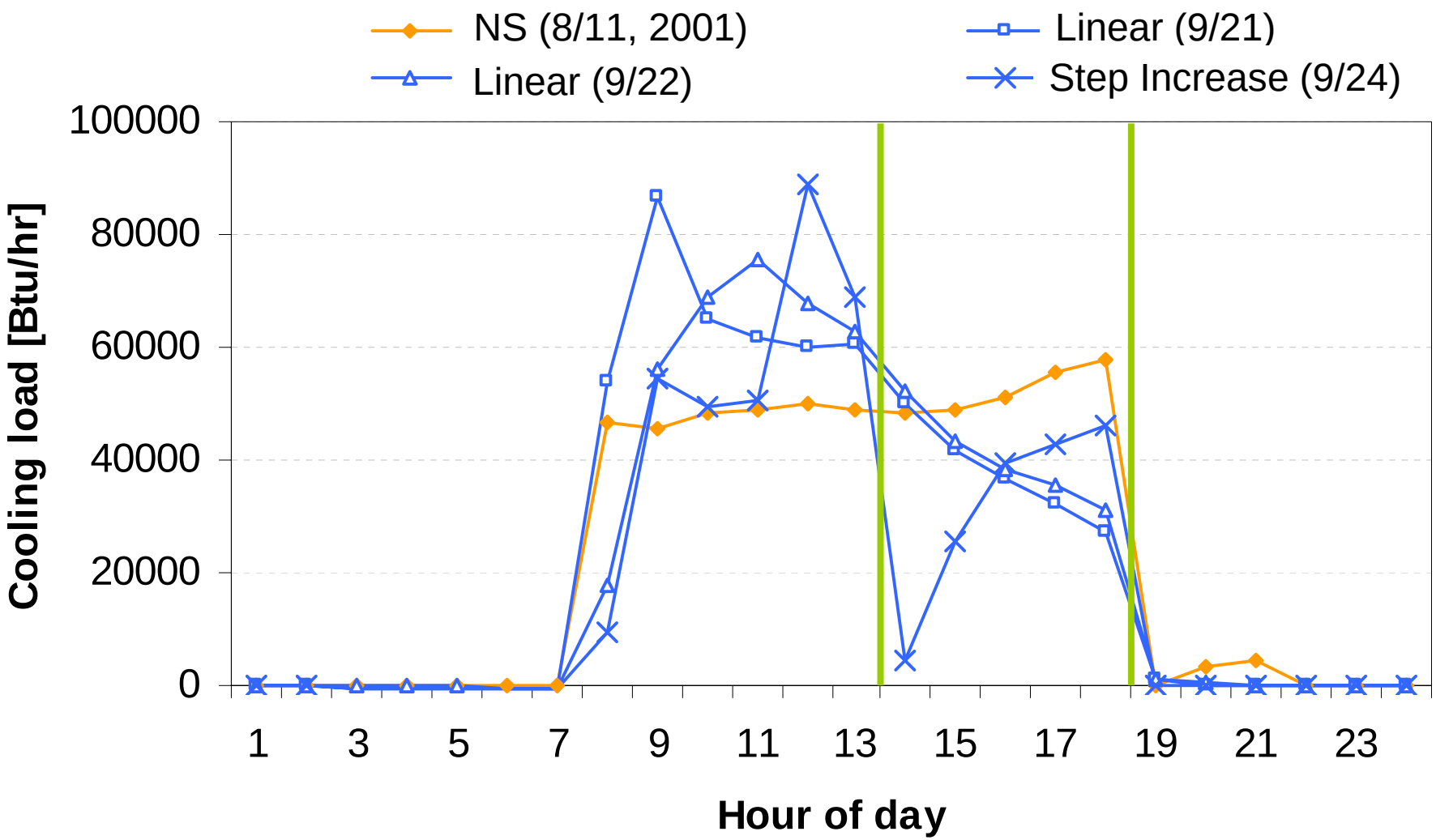
Demand-Limiting (DL)



Peak Load Reduction

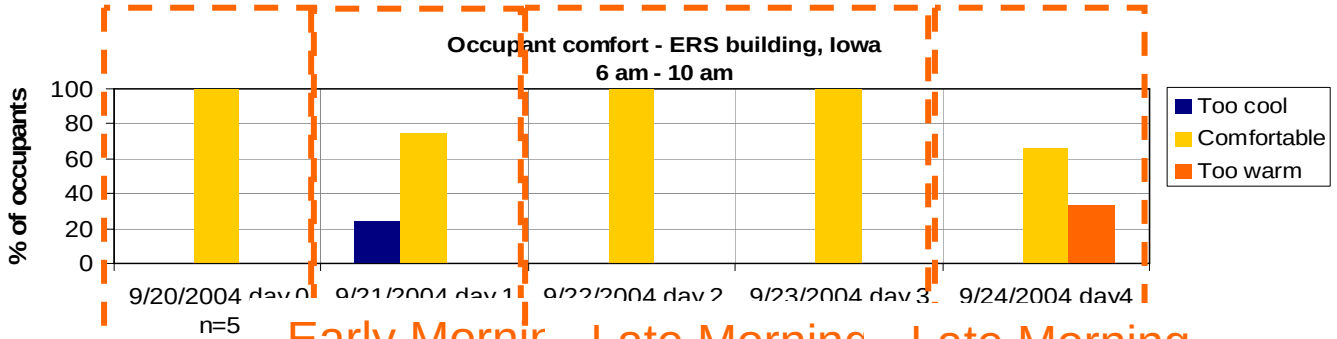


Impact of Setpoint Trajectory



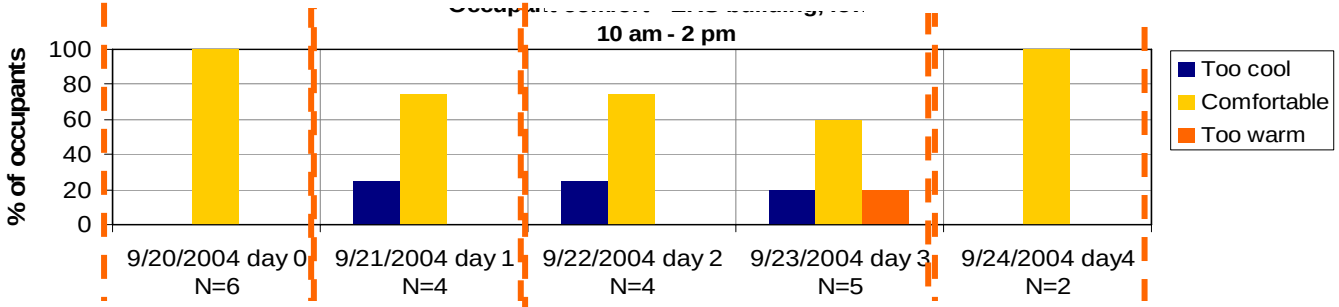
Comfort Survey

6 am – 10 am



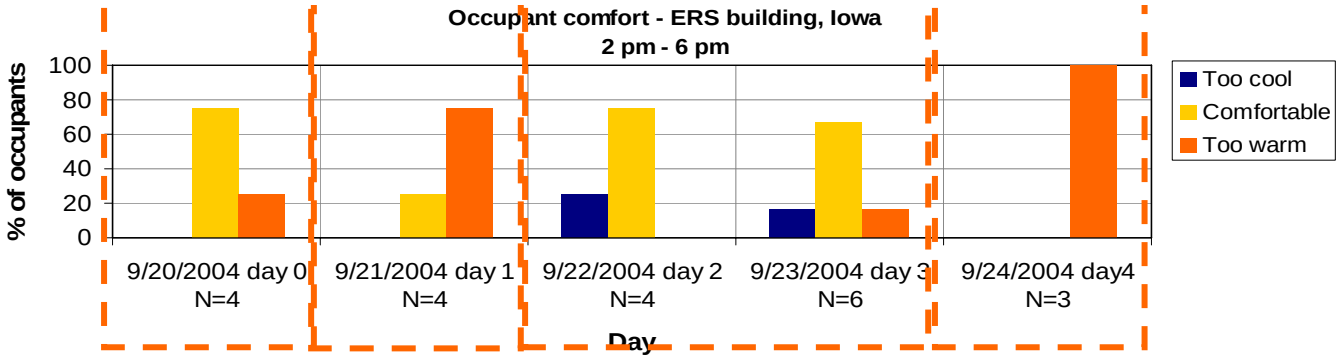
Early Mornir Precool | Late Morning Precool | Late Morning Precool

10 am – 2 pm

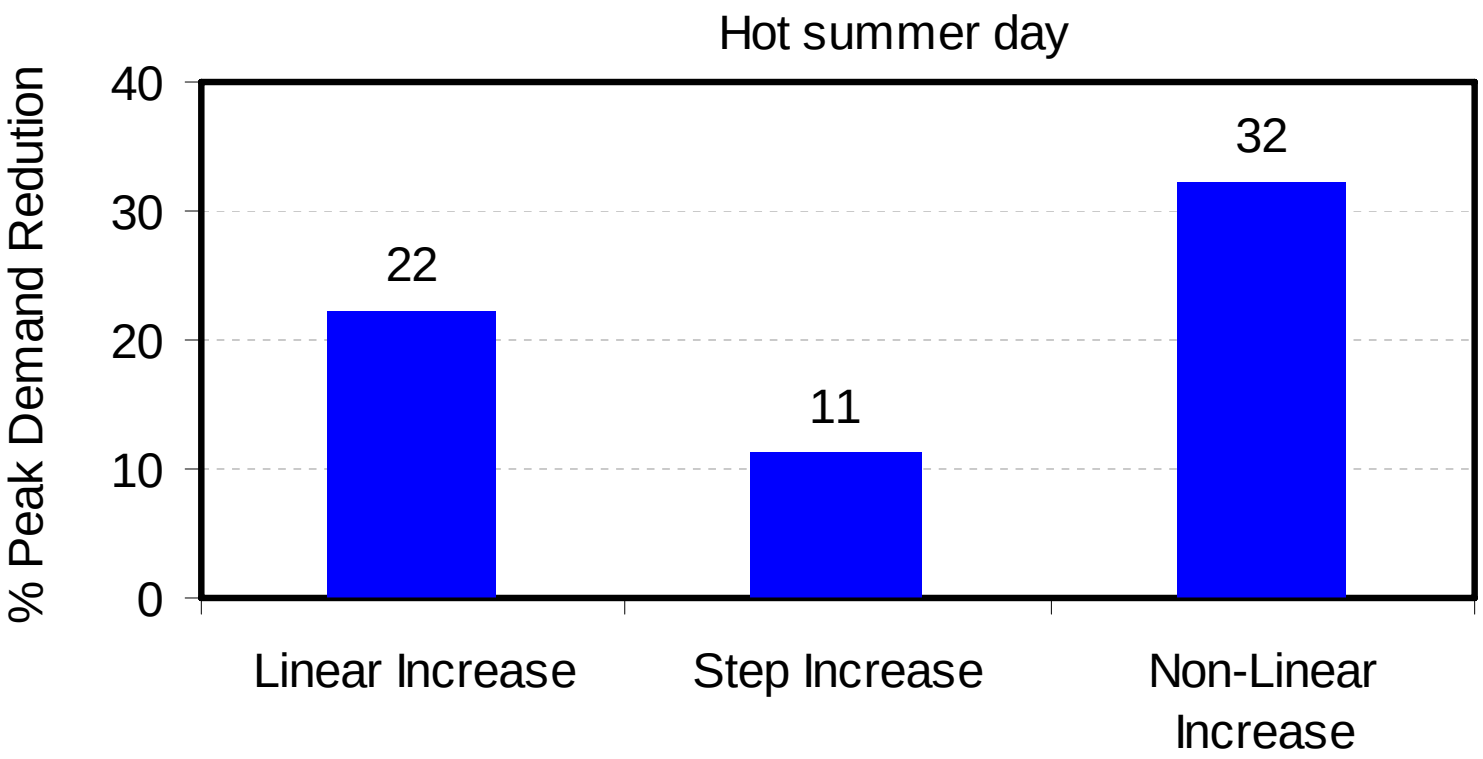


Night Set | Linear Rise | Linear Rise | Step Up

2 pm – 6 pm



Extrapolation of IEC Results

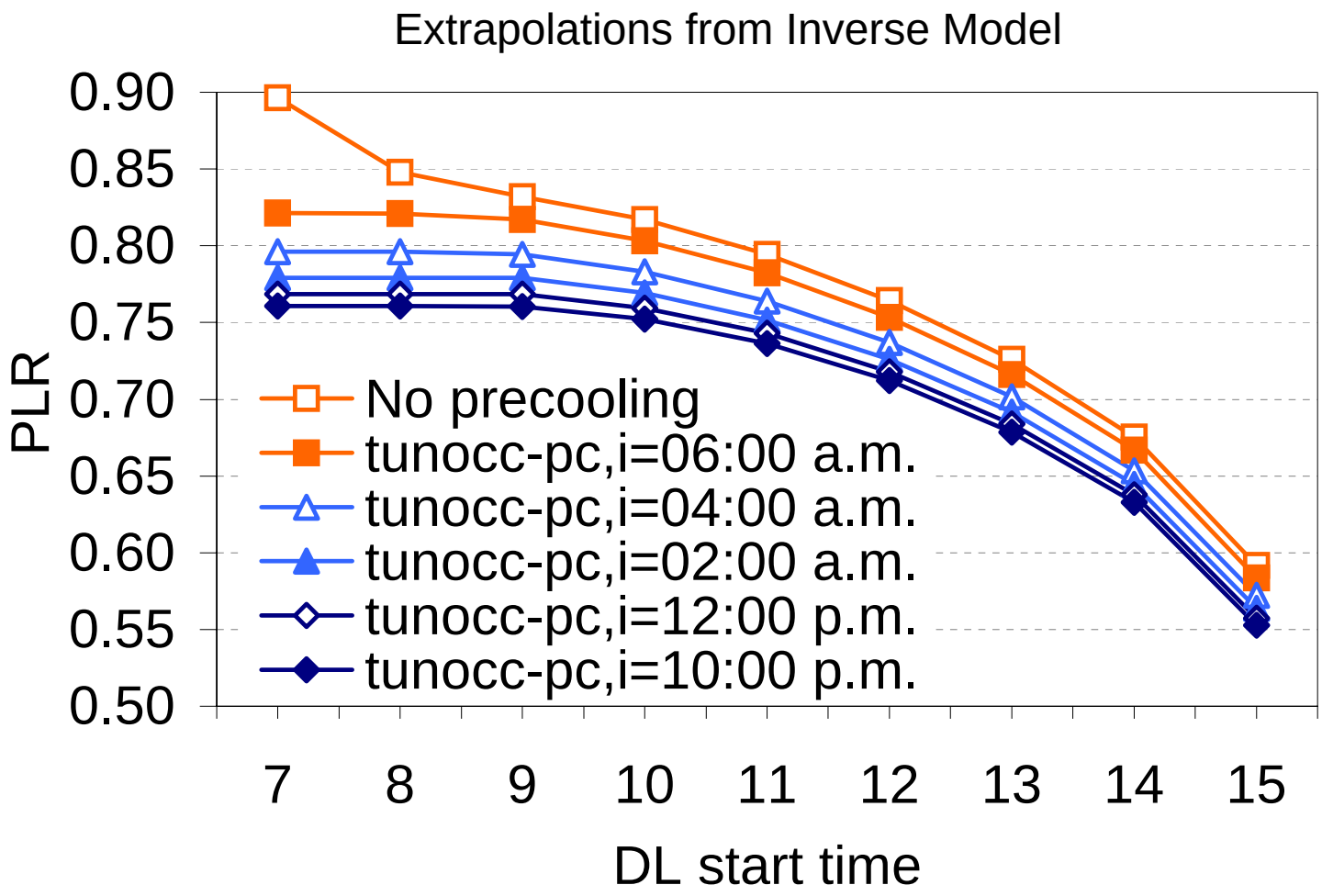


Control Strategies for Demand-Limiting Period

Precooling: 70 F from 9 am to 1 pm

Demand-Limiting: 1 - 6 pm,70 F to 78 F

Effect of Length for Precooling & DL



DL end time = 18

Conclusions

- Results consistent with simulation results for small commercial buildings
  - Peak load reduction very sensitive to demand-limiting trajectory of zone temperatures
  - 30% potential reduction in afternoon peak cooling load
- Tolerable impact on comfort in the range of 70 to 78 F (small number of occupants polled)
- Extrapolation of results to hot conditions using inverse model gave similar peak load reduction

Method Development

- Objective to determine site-specific setpoint trajectories for demand limiting with minimal requirements for data collection and training

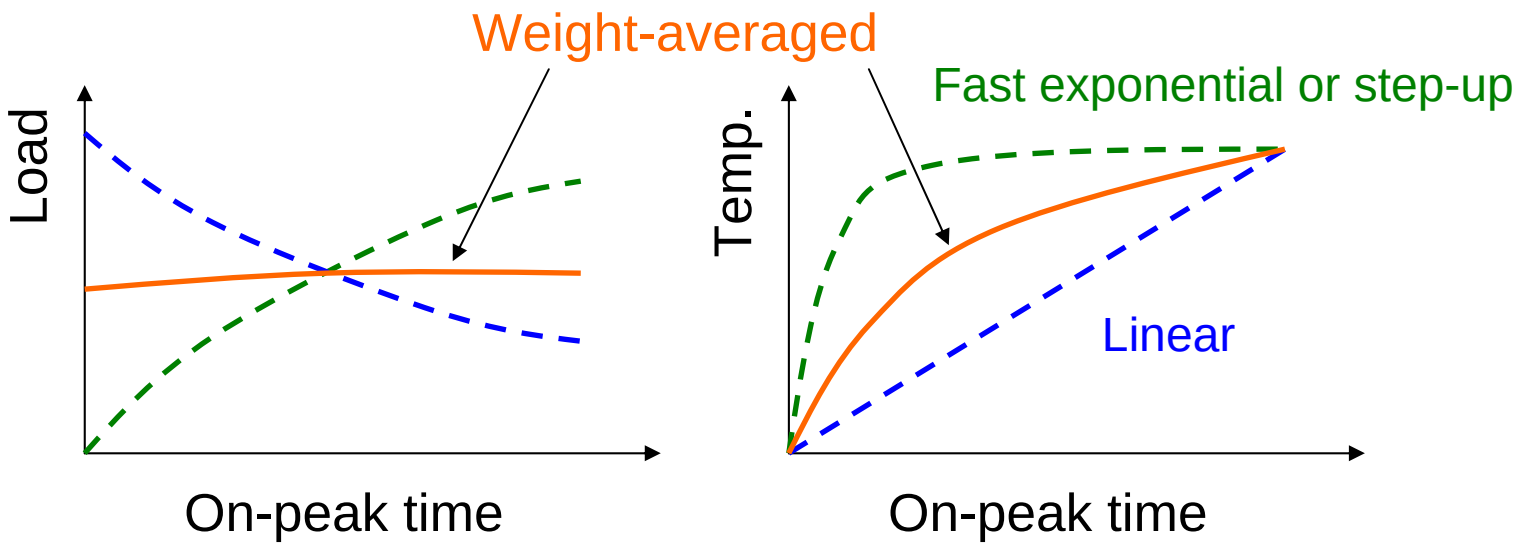
- Three methods were developed having different performance & data requirements

Demand-Limiting Methods

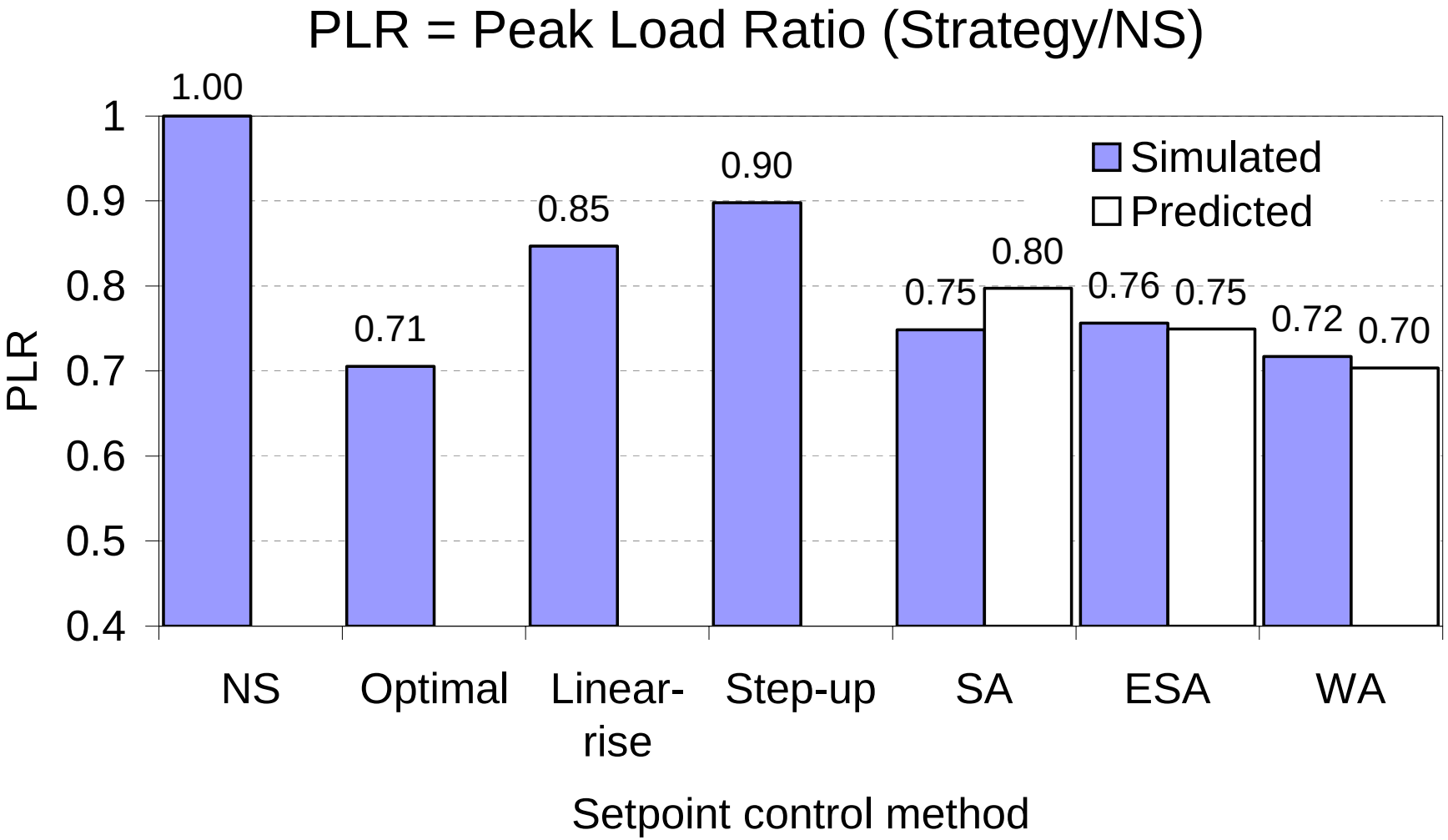
- **Semi-analytical methods (SA & ESA)**
  - Analytical setpoint trajectory equations derived from simplified models for dynamics and coupling of building thermal mass
  - Uses load measurements for one or two days under conventional control for parameter estimation
- **Load weighted-averaging method (WA)**
  - Assumes locally linear relation between zone temperature and building cooling demand
  - Uses load measurements for two or more days under different control strategies

Weighted Averaging (WA) Method

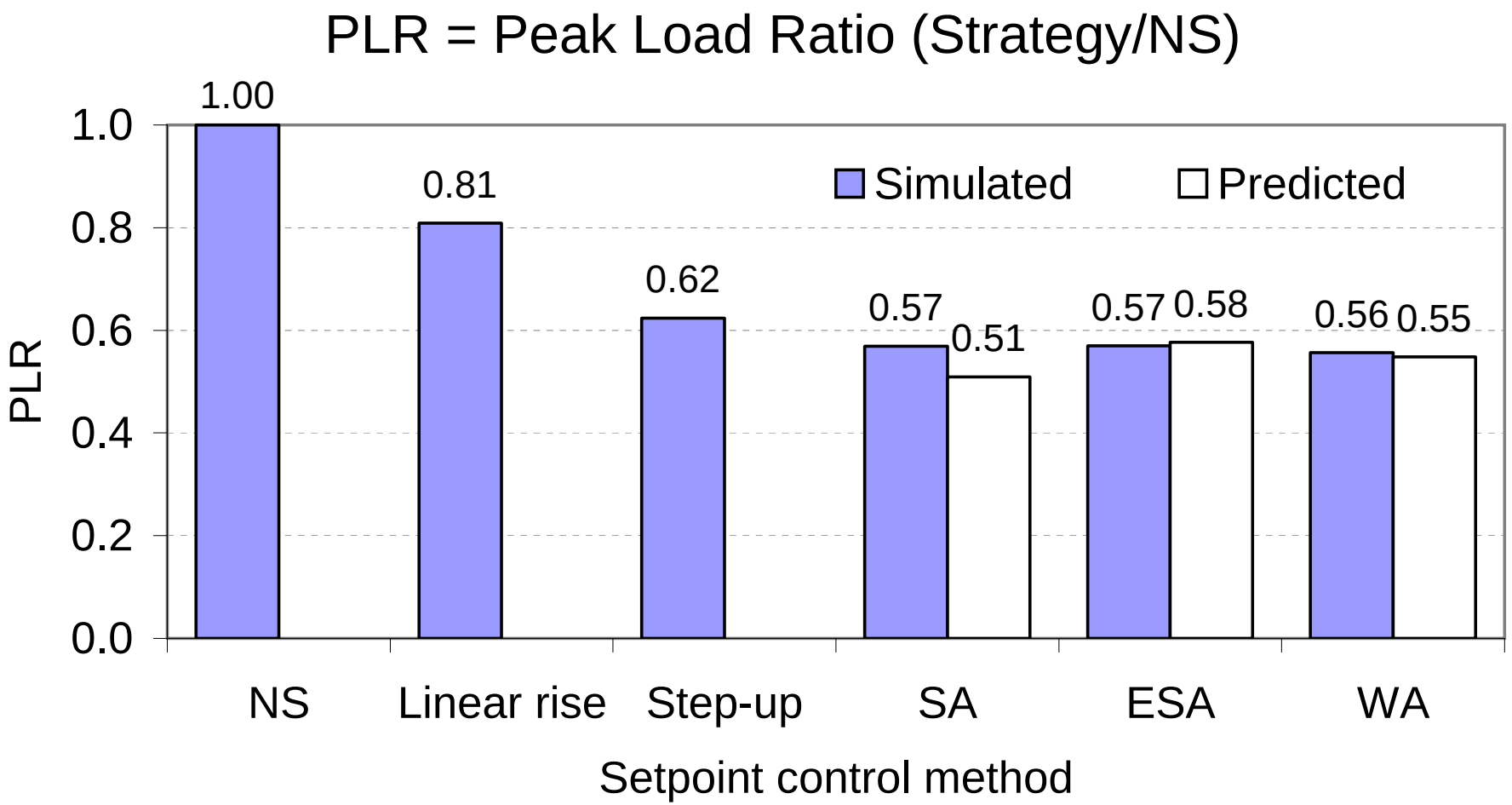
- Requires at least two test days
- Optimally weighted-averaging of two sets of load data
- Apply the weighted-averaging to the two setpoint trajectories
- Allows continuous updating of setpoint trajectory



Peak Load Reduction for IEC



Peak Load Reduction for Santa Rosa



Conclusion

- WA method is recommended
  - Provides greatest peak load reduction
  - Very robust with respect to building type and weather used for training
  - Works well for building aggregates

SCE Small Building Selection Criteria

- Less than 15,000 Sq. Ft.
- Hot Climate Zone
- Wire-for-Wire change out for new pageable thermostats
- Within SCE service territory
- Motivated Owner
- Typical construction materials for buildings of this size and type
- Rooftop Packaged Units
- Single or Two Story
- Single Occupant

Site Selection Process

- SCE customers contacted through assigned SCE Account Executives and Managers
- Several sites investigated in Palm Desert, Temecula, and Redlands
- Site review removed two sites due incompatible thermostats

Palm Desert Bank

- Met all basic criteria
  - Very motivated and cooperative property manager
  - Small single tenant bank
  - Occupancy: 8 am – 7 pm
  - On-peak period: 12 – 6 pm
  - 11 packaged rooftop units
- Monitoring of AC power consumption (15-minute averages), zone and ambient temperatures
- Polling stations for comfort monitoring

Test Schedule and Processing

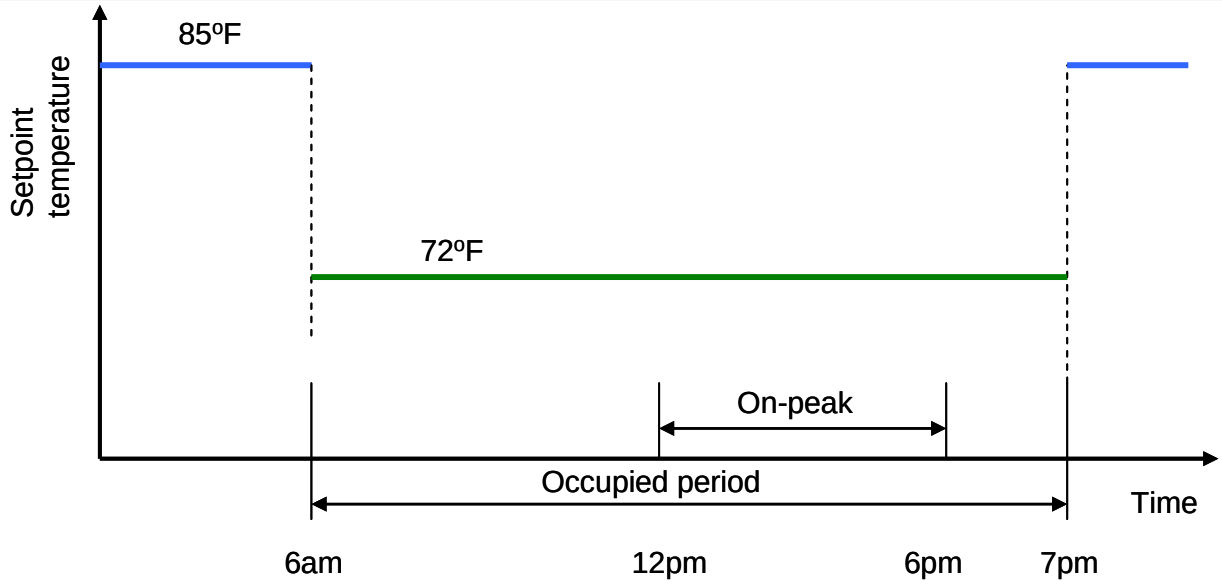
- 1st Week of Testing (2006)
  - Baseline NS (Night-setup): 10/9, 10/10, 10/13
  - LR (Linear-rise): 10/11
  - SU (Step-up): 10/12

- Use 2 days from 1st week of testing and apply WA method to estimate optimal demand-limiting trajectory

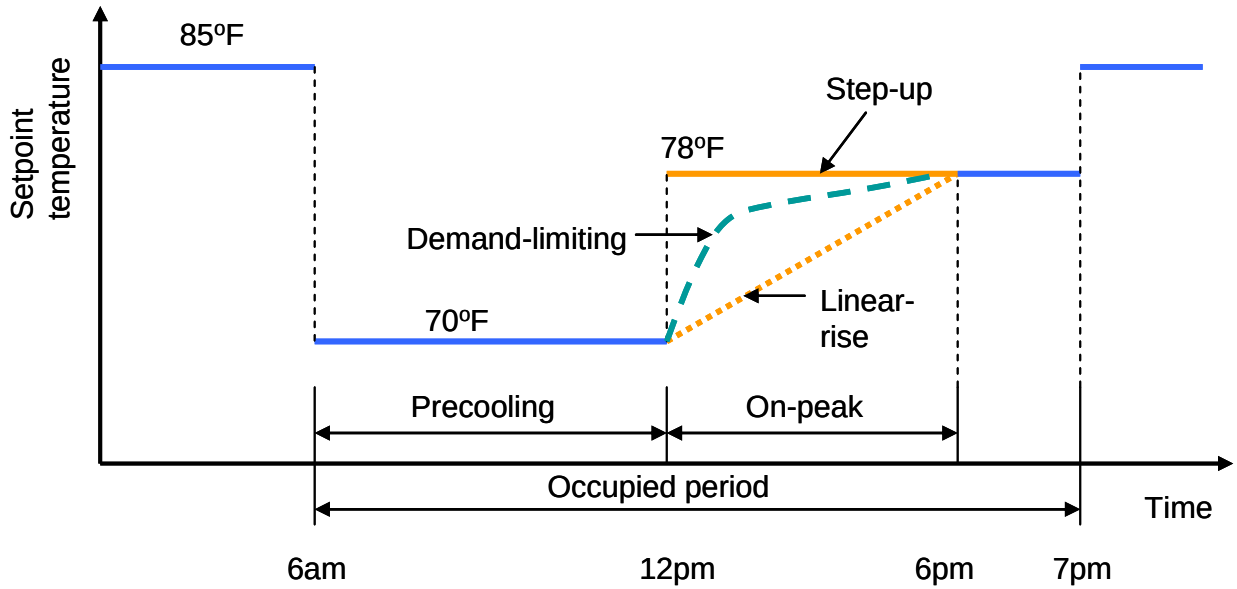
- 2nd Week of Testing
  - Baseline NS (Night-setup): 10/23
  - DL (Demand-limiting): 10/24-10/27

Temperature Setpoints

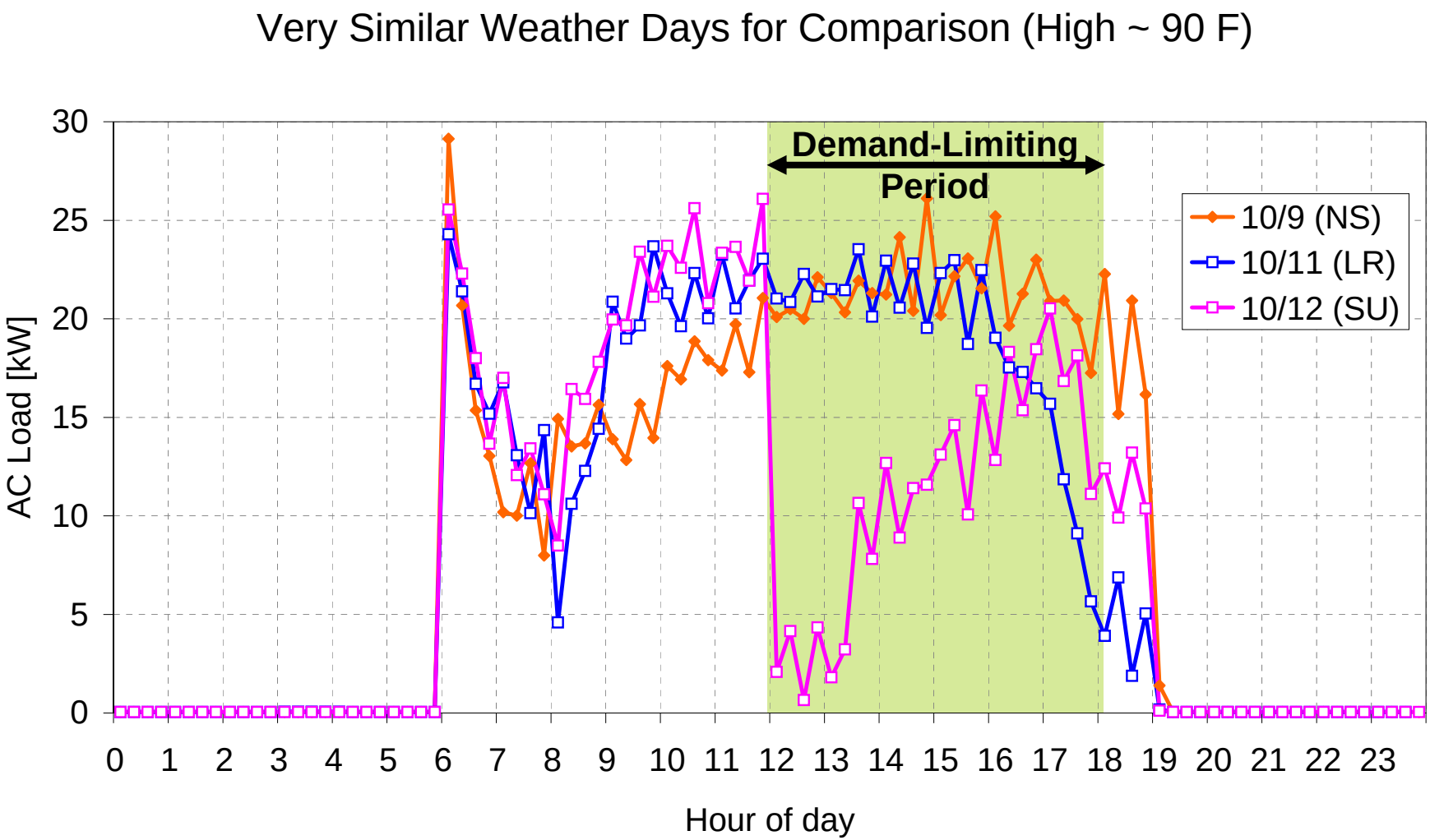
Baseline NS Strategy



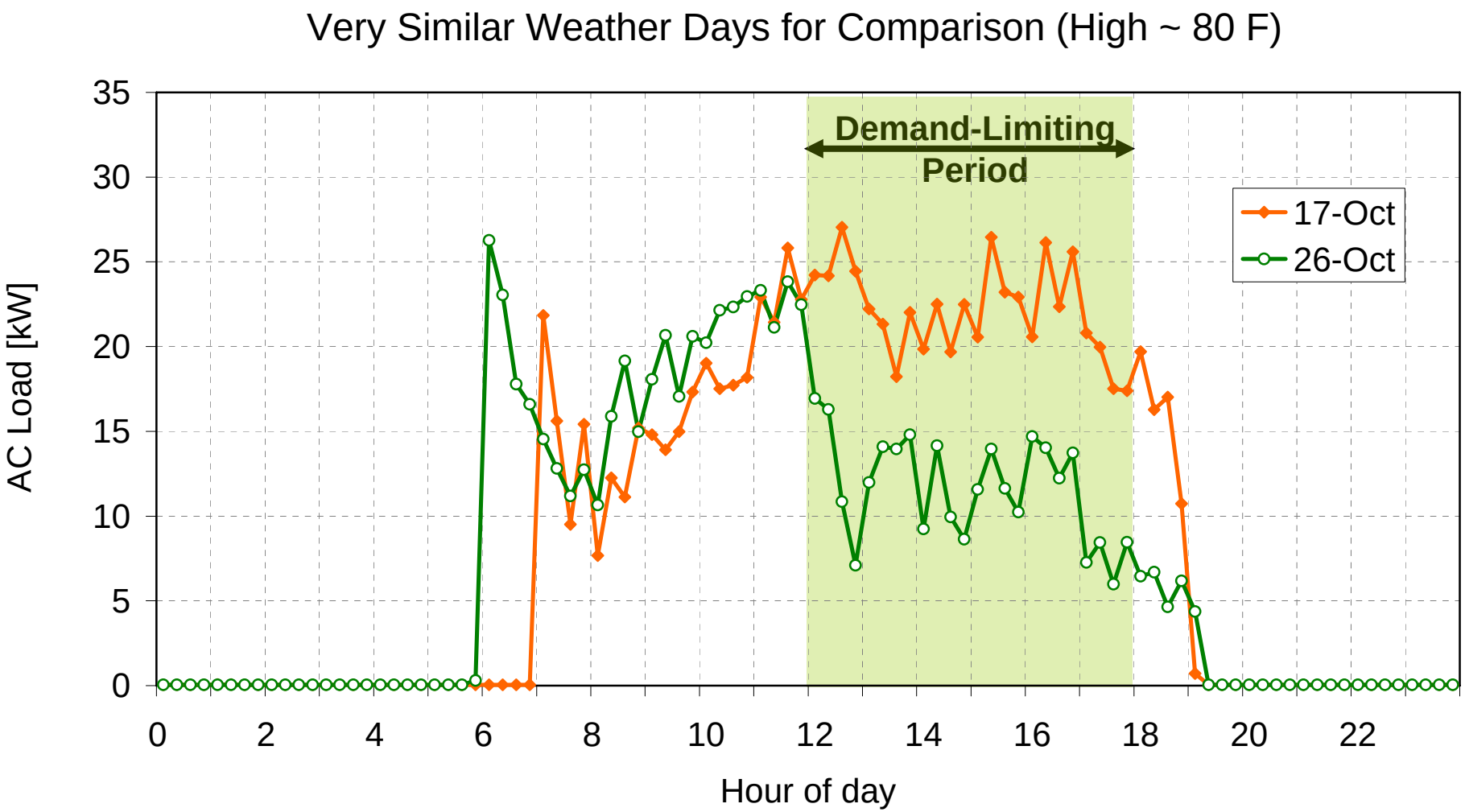
SU, LR, and DL Strategies



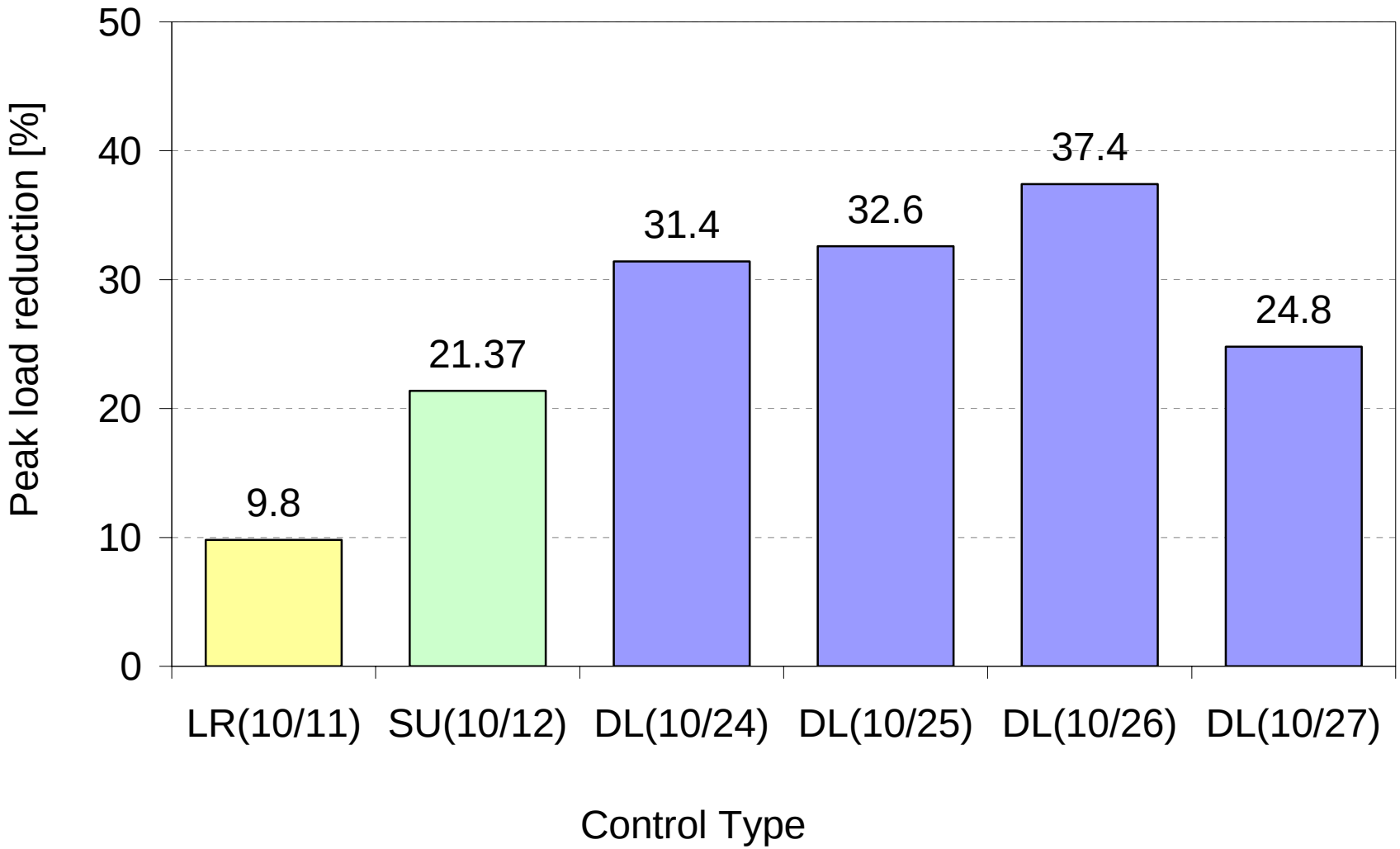
AC Power Comparisons – 1st Week



AC Power Comparisons – 2nd Week



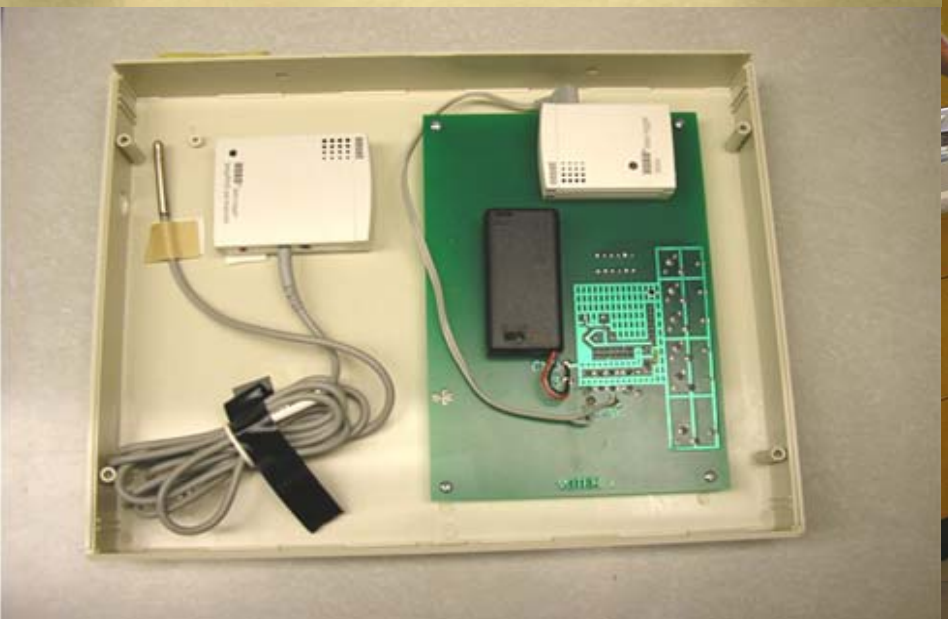
Percent Peak Power Reduction



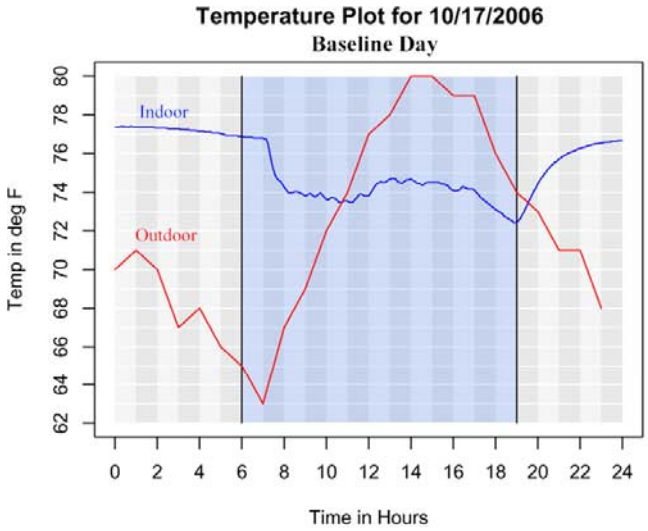
Demand-Limiting Conclusions

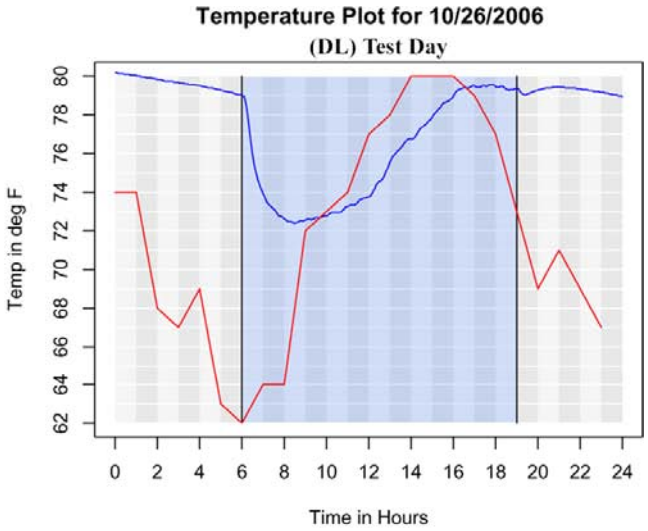
- Results consistent with simulation and Iowa Energy Center test results for small commercial buildings
  - ~30% AC power peak reduction
  - peak load reduction very sensitive to demand-limiting trajectory of zone temperatures
- WA method determines near-optimal setpoint trajectory for minimum demand

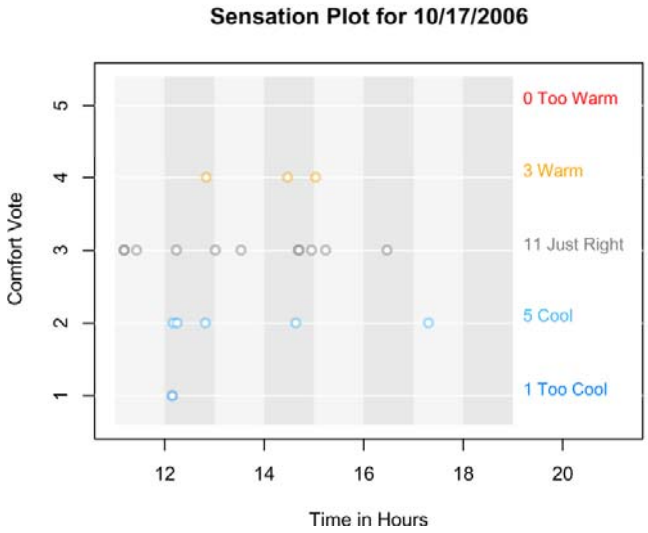
Occupant Comfort Polling

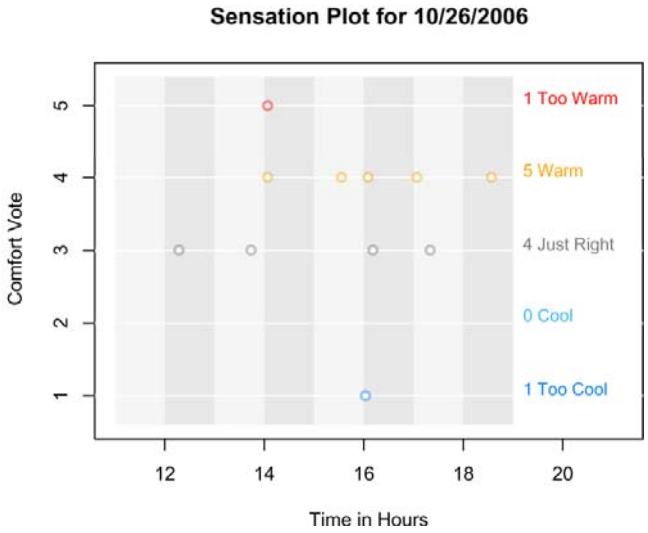


Example Comfort Comparisons

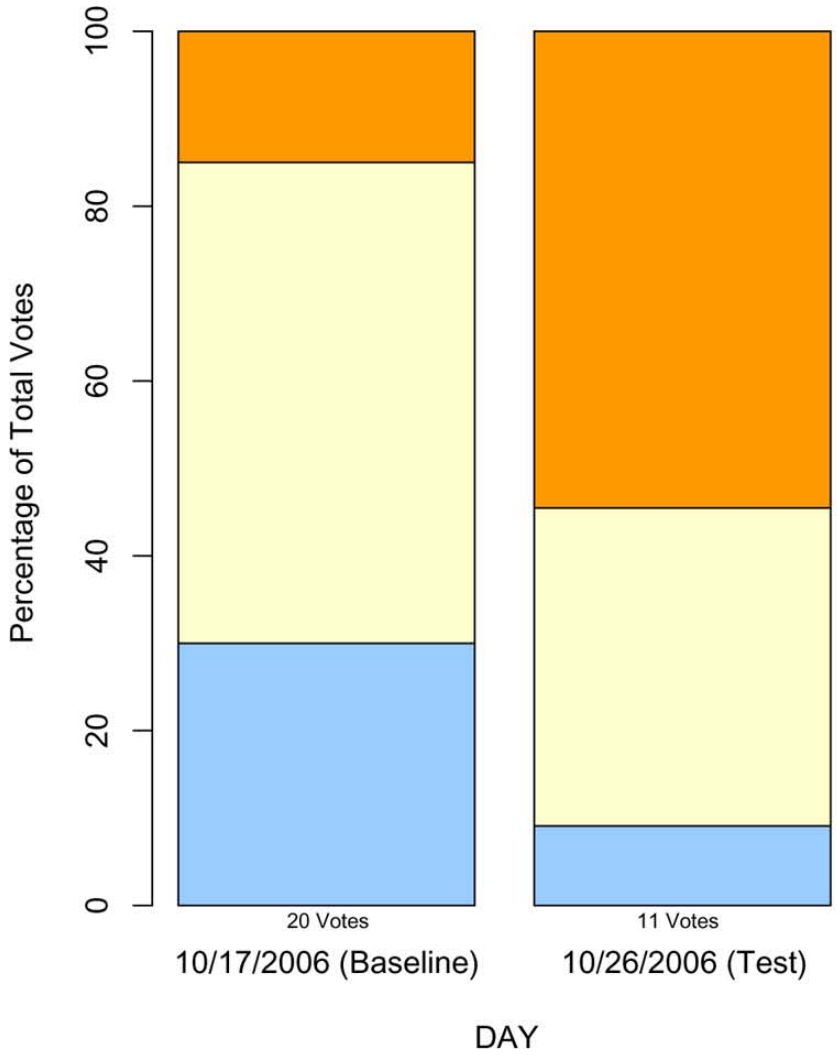


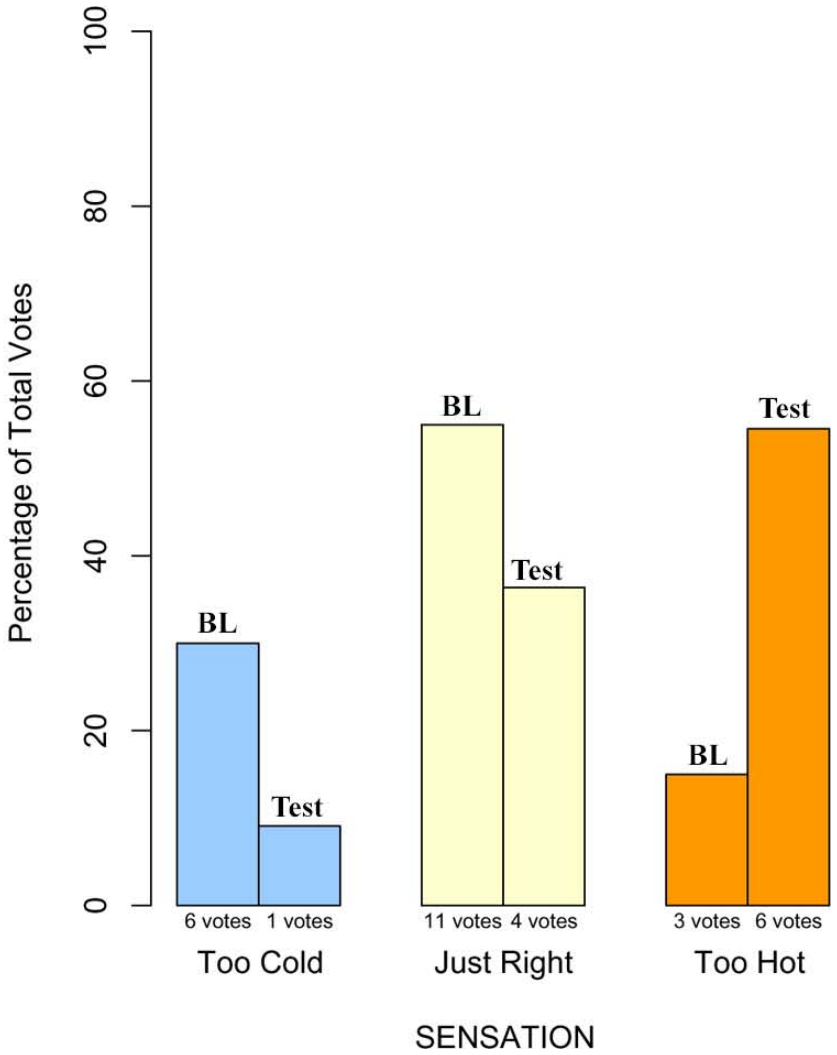






Example Comfort Comparisons





Comfort Conclusions

- Relatively small impact of demand-limiting strategy on comfort evaluations
- Would be better to separately poll bank customers and employees
  - Customers have very short exposure times
  - Employees are probably better indicators of comfort conditions

What's Next

- Additional testing in small commercial buildings
  - Demonstrate savings and comfort impacts with very hot conditions
  - Develop better understanding of range of acceptable zone temperatures for demand-limiting control