Pre-cooling and DR Tool Development

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BERKELEY LAB

Overview

- Large commercial buildings (LBNL)
  - Field tests
  - Quick assessment tool
- Small commercial buildings (Purdue)
  - Field tests
  - Quick assessment tool
- Conclusions/future work

Executive Summary

- Precooling and demand shed strategies worked well in many commercial buildings and were able to reduce peak cooling loads significantly (15~80%).
- Properly controlled exponential temperature setup in the shed period can discharge thermal mass smoothly and with no rebound.
- No noticeable changes on occupant comfort level if zone temperatures are controlled within desired ranges.
- Night precooling and night ventilation can reduce both HAVC peak demand and energy consumption in heavy mass buildings, but not in light buildings.

Demand Shifting With Thermal Mass

- Precool at night during off-peak hours
- Adjust daytime setpoints to control discharge
- Cooled structure reduces daytime, on-peak cooling loads
- Savings due to
  - Reduced on-peak energy and demand usage
  - High COP at night and early morning
  - Night ventilation

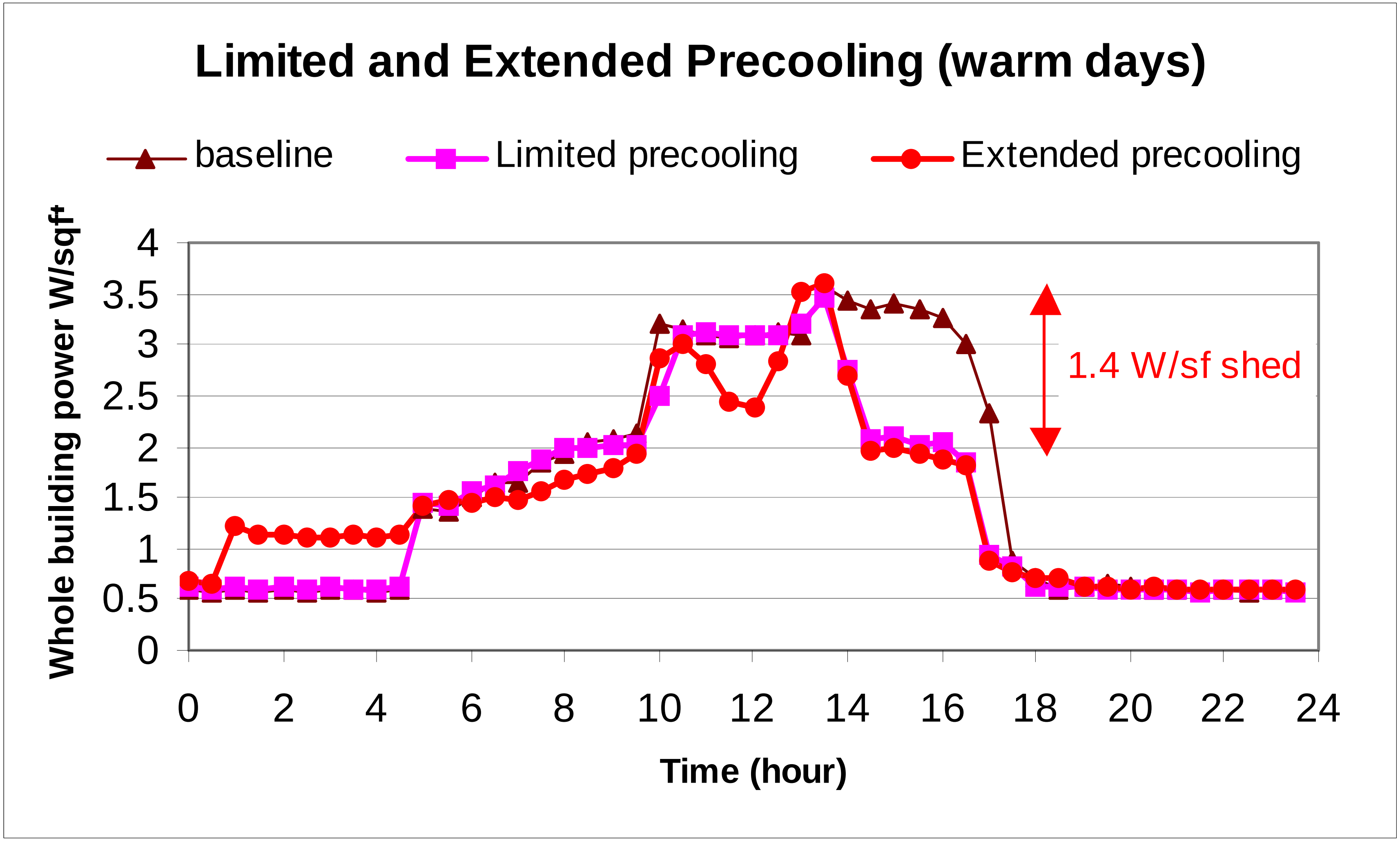
Case Study - 2003

- Started in August 2003
- Purpose - preliminary study to assess potential and need for further work
  - Potential demand reduction/load shifting in moderate-weight buildings
  - Effectiveness of precooling and zone temperature reset
  - Comfort and complaints

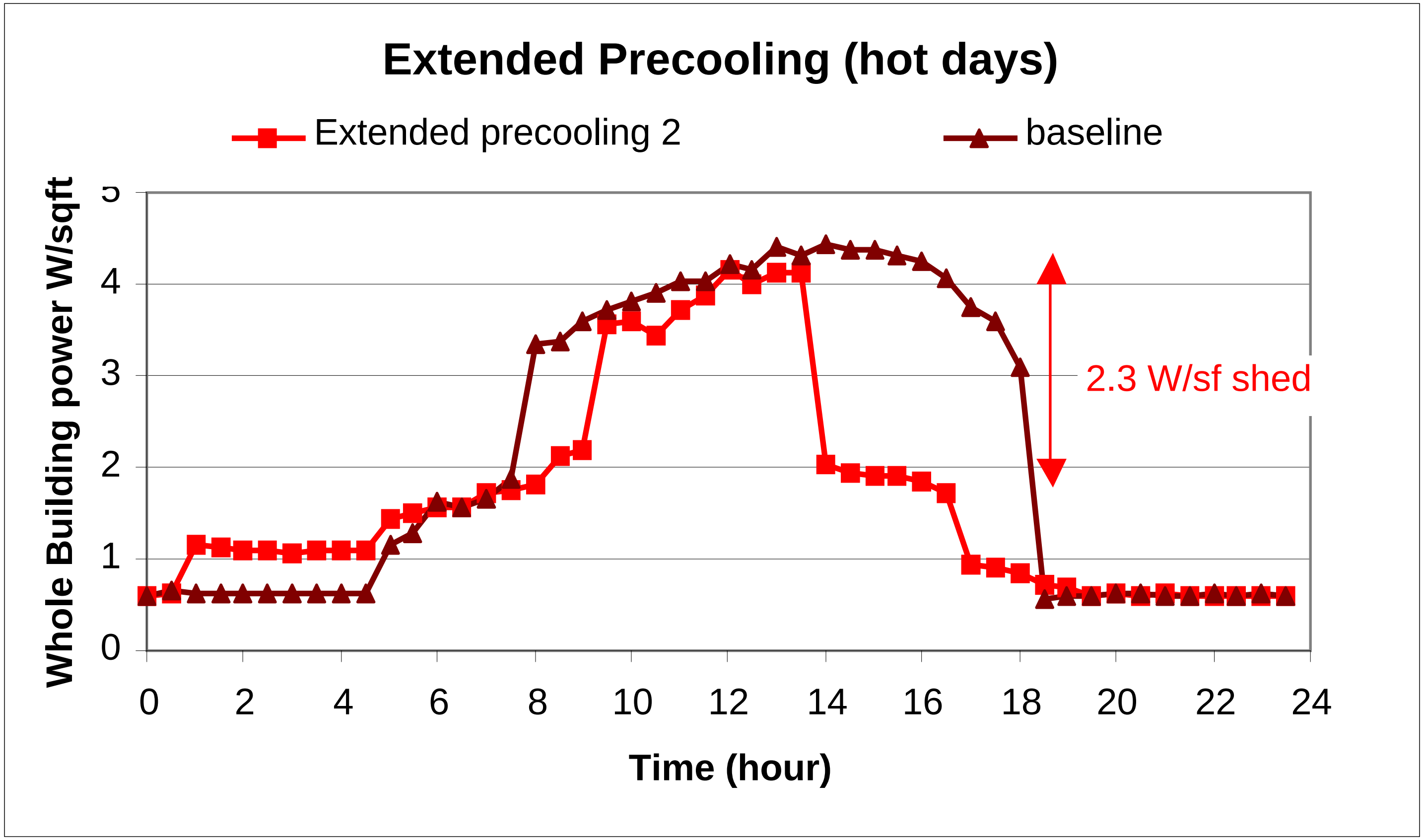
Test Site Description

- Medium-sized government office building
  - Santa Rosa, CA
  - 80,000 ft^2 (40,000 ft^2 office + 40,000 ft^2 courthouse)
  - 3 stories
- Typical building structure
  - 4 in. concrete floor, 4 in. concrete wall, medium furniture density, standard commercial carpet
- High window-to-wall ratio
  - Floor to ceiling glazing on south and north façade
- Typical internal loads
- Number of occupants
  - ~100 (office branch)

Case study results – 2003



Case study results – 2003



The building was pre-cooled at 68 °F from midnight to 5am, and at 70 °F from 5 am to 12 pm. After 1 pm, the temperature was raised to 78 °F.

Case study - 2004

- Key questions to answer:
  - Although there were no complaints, what was the actual comfort reaction?
  - What is the effect of extended (nighttime) precooling?
  - What will happen in hotter climate zones?

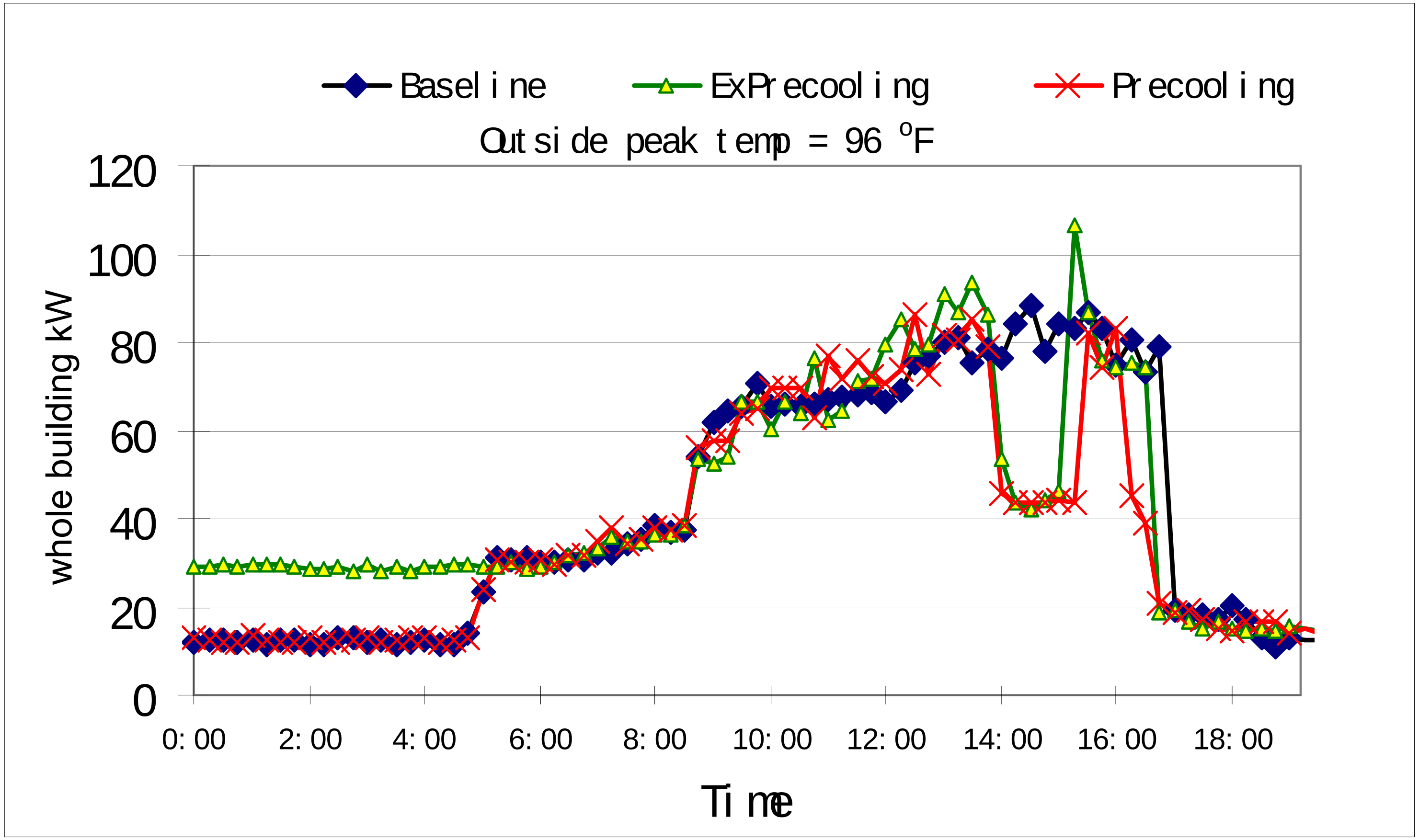
Test sites

- McCuen Property, Sacramento County building
- Santa Rosa Federal building

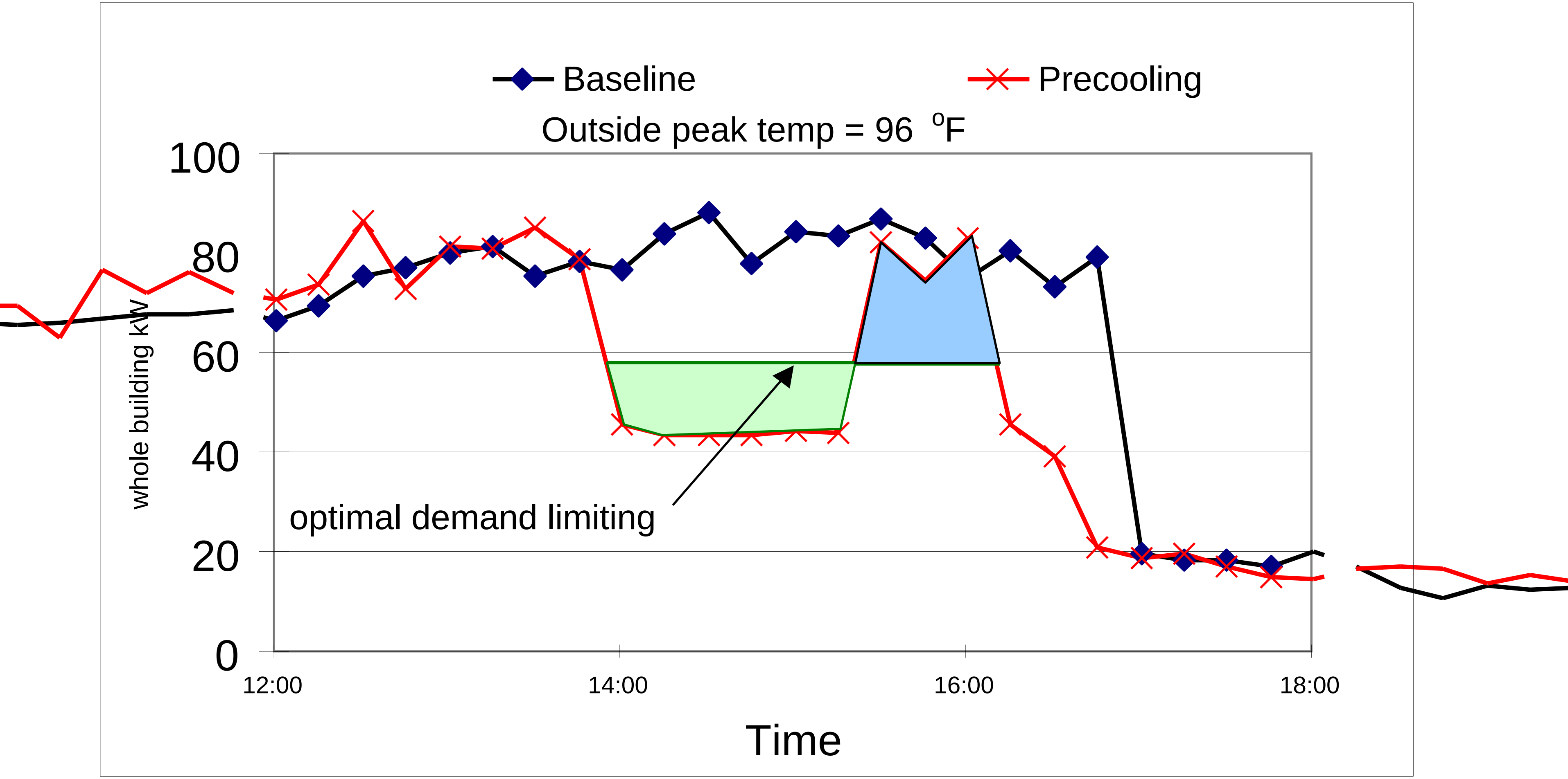
Test site in Sacramento

- Owner: McCuen Property
- Tenant: Sacramento County office
- Area: 80, 000 ft^2
- Year: Built in 2001
- Control: Automated Logic Control
- HVAC: Rooftop Package Units

Case study results – 2004



Optimal demand limiting



Web based comfort survey

- Sent survey request emails twice a day
- Two self-assessed questions

Please answer the following questions based on your experience right now:

How would you rate the current temperature in your workspace?

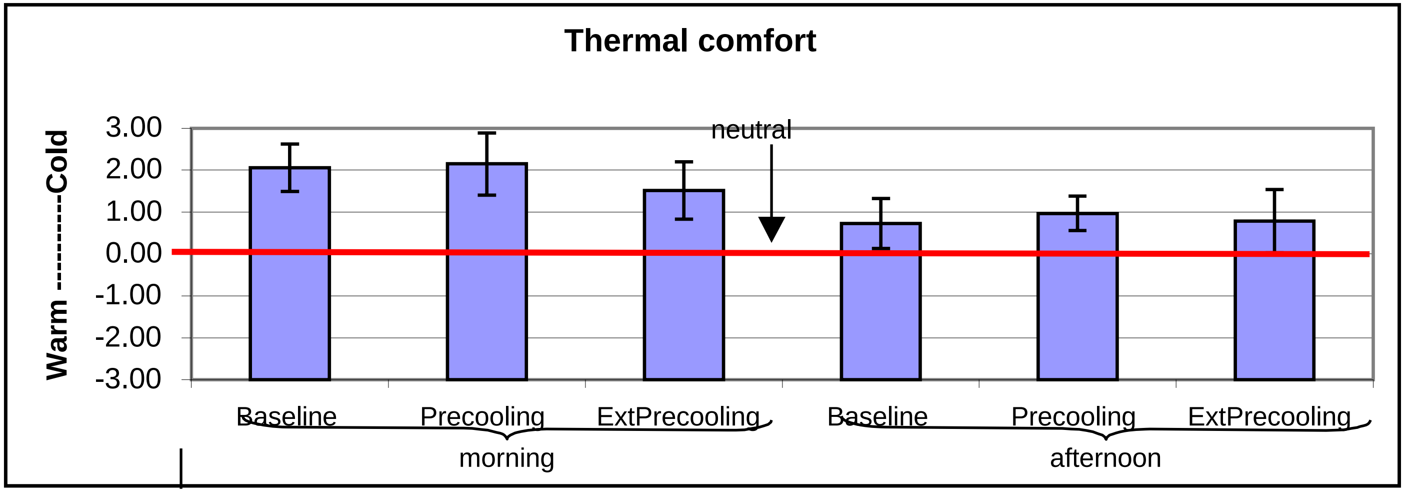
- ○ Much too warm
- ○ Too warm
- ○ Comfortably warm
- ○ Comfortable (and neither cool nor warm)
- ○ Comfortably cool
- ○ Too cool
- ○ Much too cool

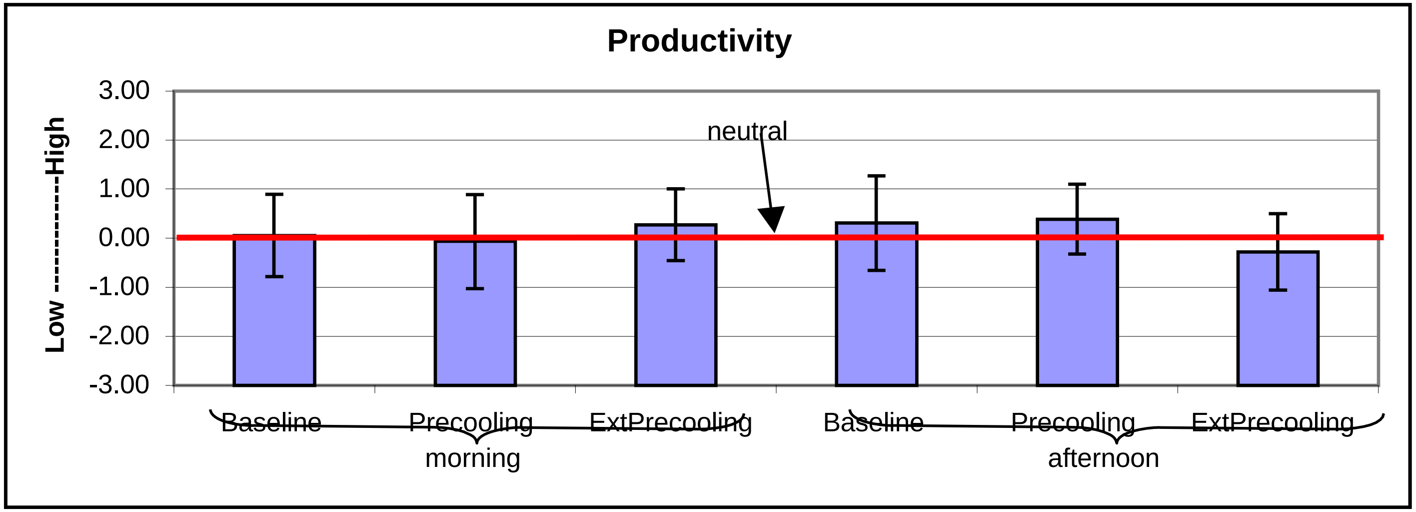
Does the current temperature in your workspace enhance or interfere with your ability to get your job done?

Enhances ○ ○ ○ ○ ○ ○ ○ Interferes

Any additional comments or recommendations about the current temperature?

Comfort Survey





Case study - 2005

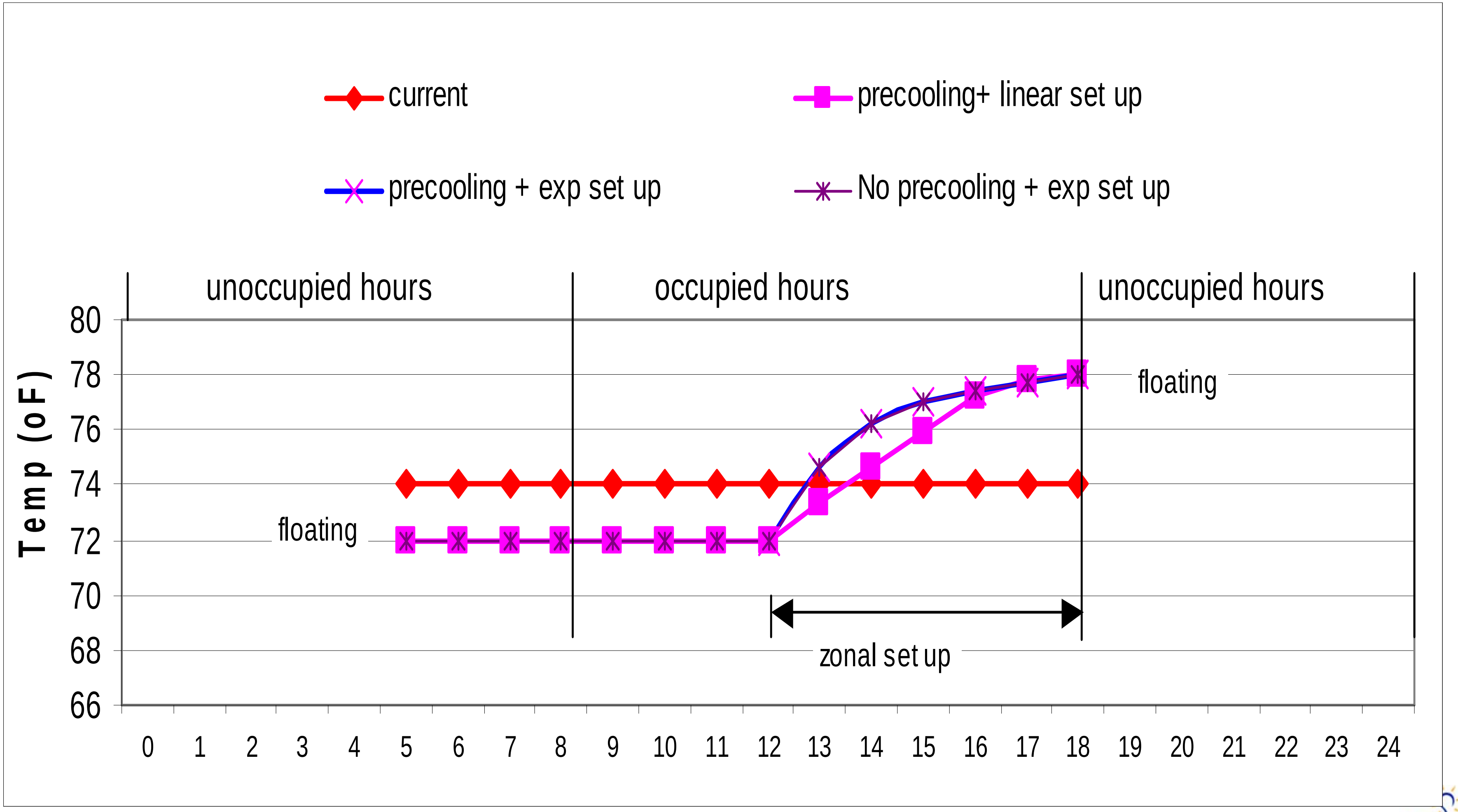
Questions to answer

- How can thermal mass be discharged more efficiently and more smoothly with no rebound?
- What will the comfort reaction be if temperature is controlled properly?
- What are the metrics of the building thermal mass and how are they determined?

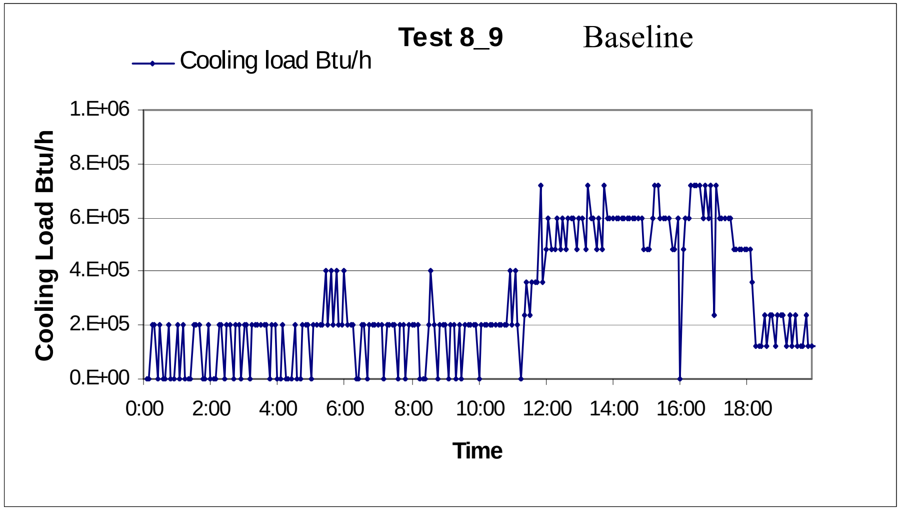
Field test I - 2005

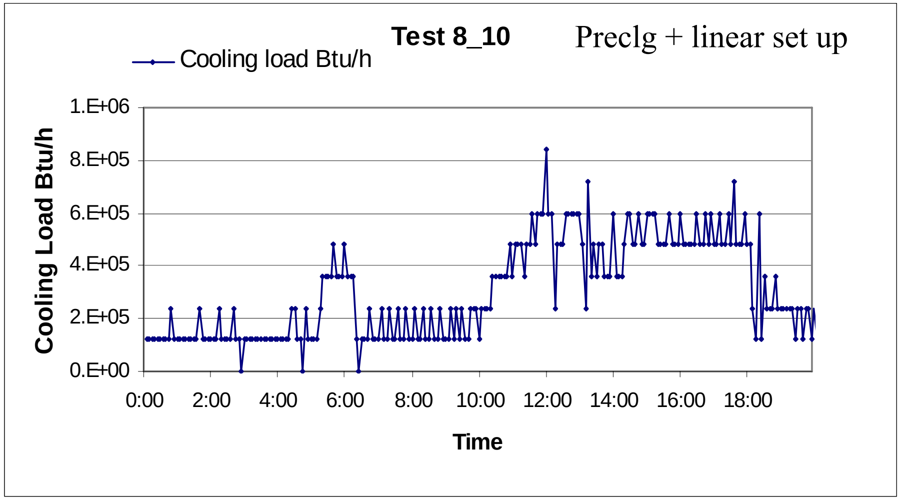
- Oakland Science Center
- Glass building – low mass
- 4 story building
- Single duct VAV systems

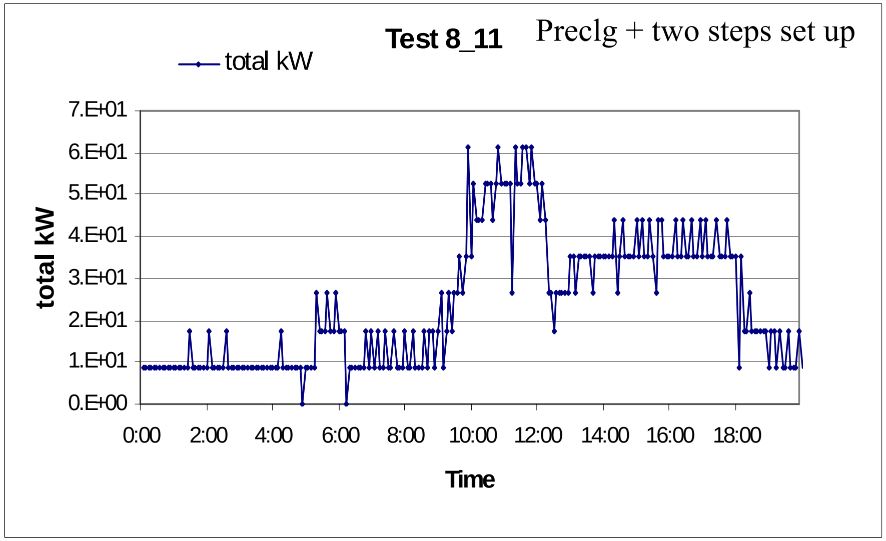
Demand Shed Strategies

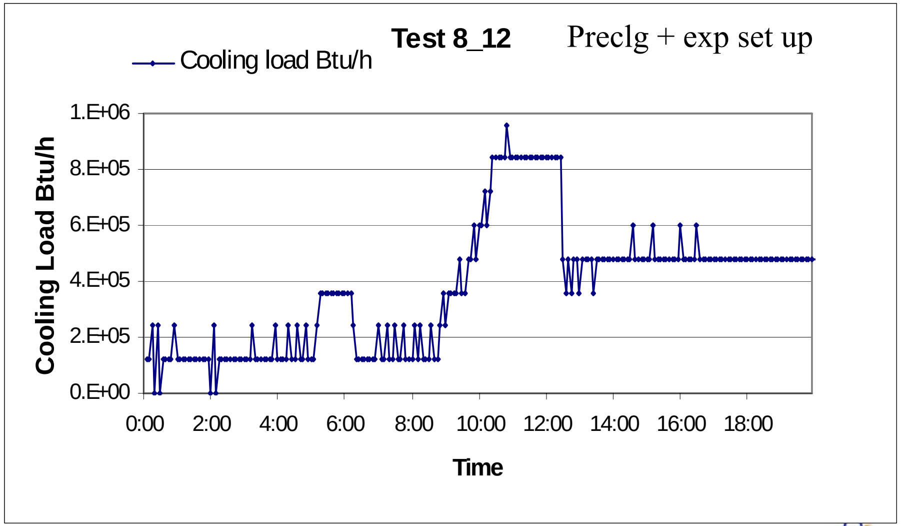


OSC results (shed strategies)





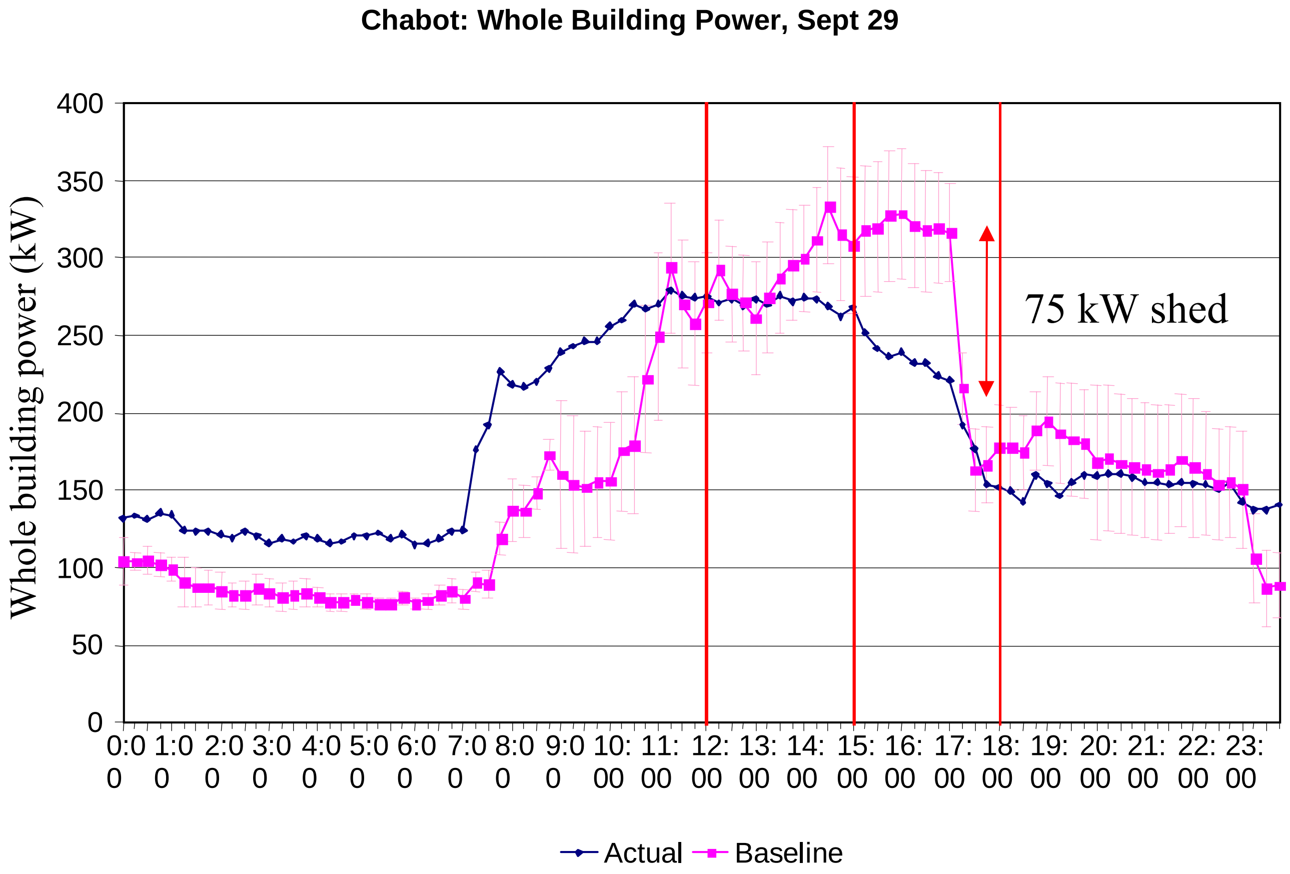




Field test II

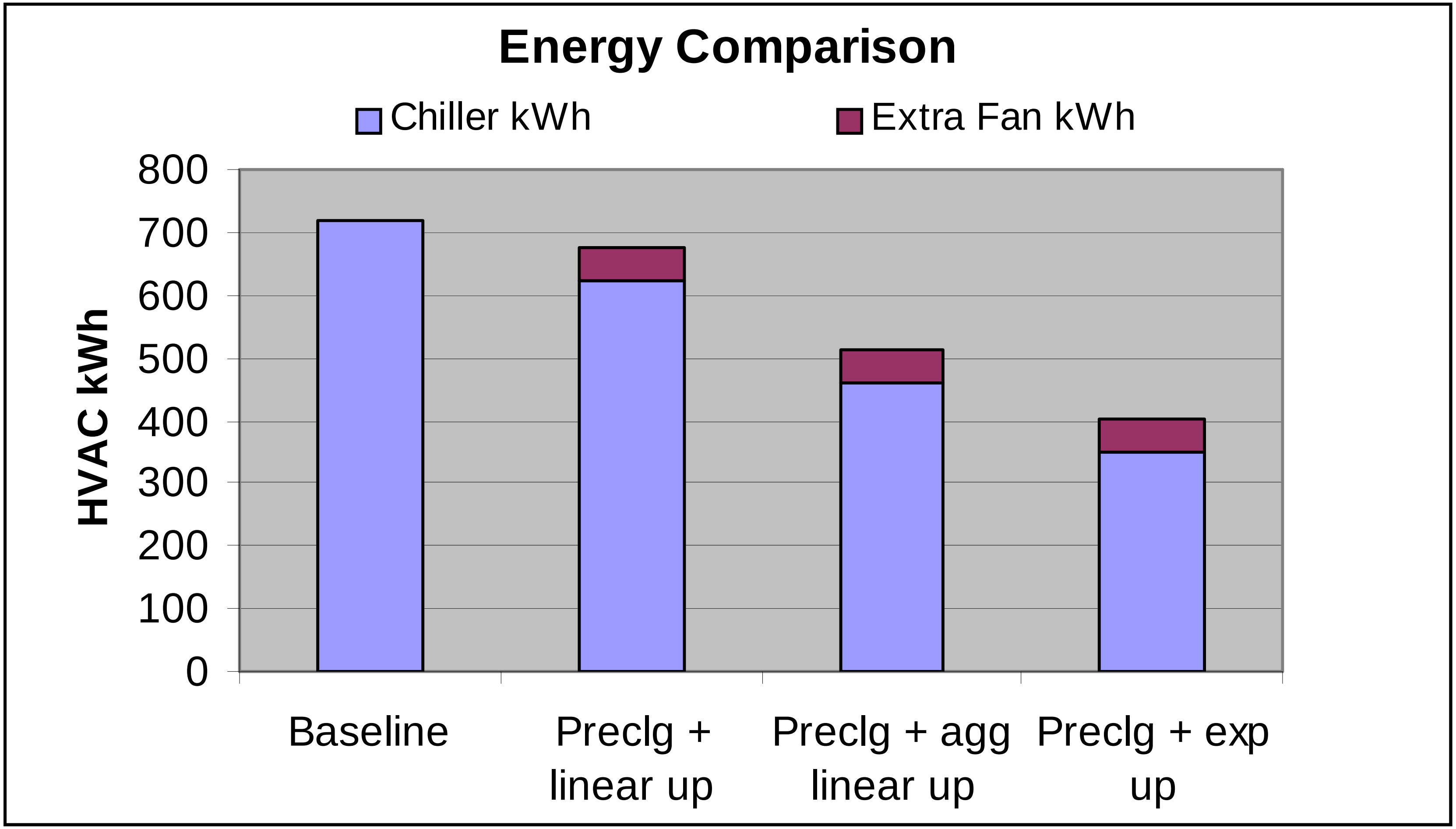
- Chabot Space and Science Museum
- Heavy mass building

Case study results – 2005



The building was pre-cooled at 68ºF from midnight to 5am, and at 70ºF from 5 am to 12 pm. After 12 pm, the temperature was gradually raised to 76ºF. The maximum shed period was from 3pm to 6pm (high price CPP period).

Energy consumption (Chiller)



Case study - 2006

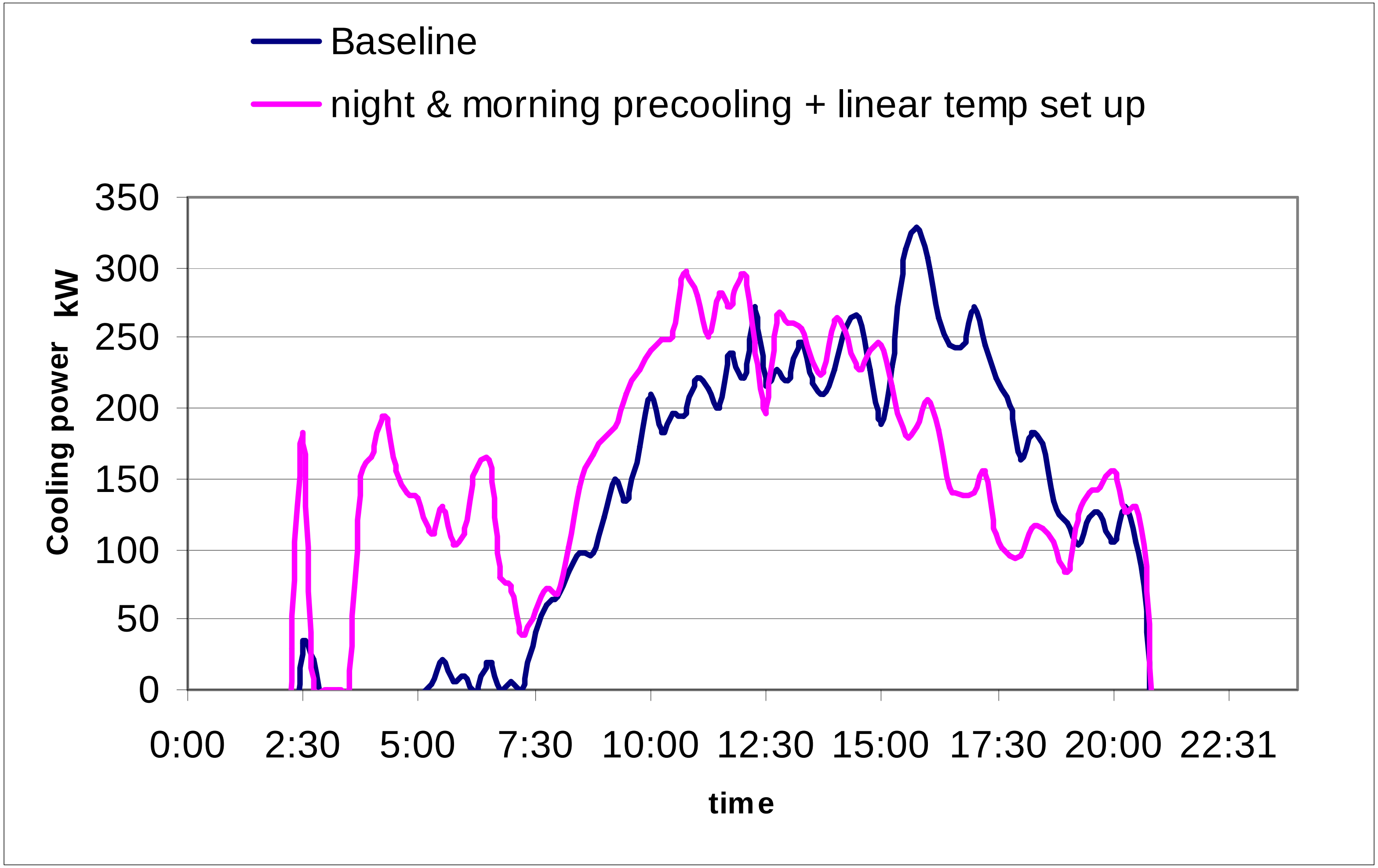
Questions to answer

- Will the strategies work equally well in extreme weather conditions?
  - Critical peak pricing would typically be invoked on extreme hot days
  - Will the comfort reaction be different?
  - Will load shed be large enough?
  - Will sheds last long enough?

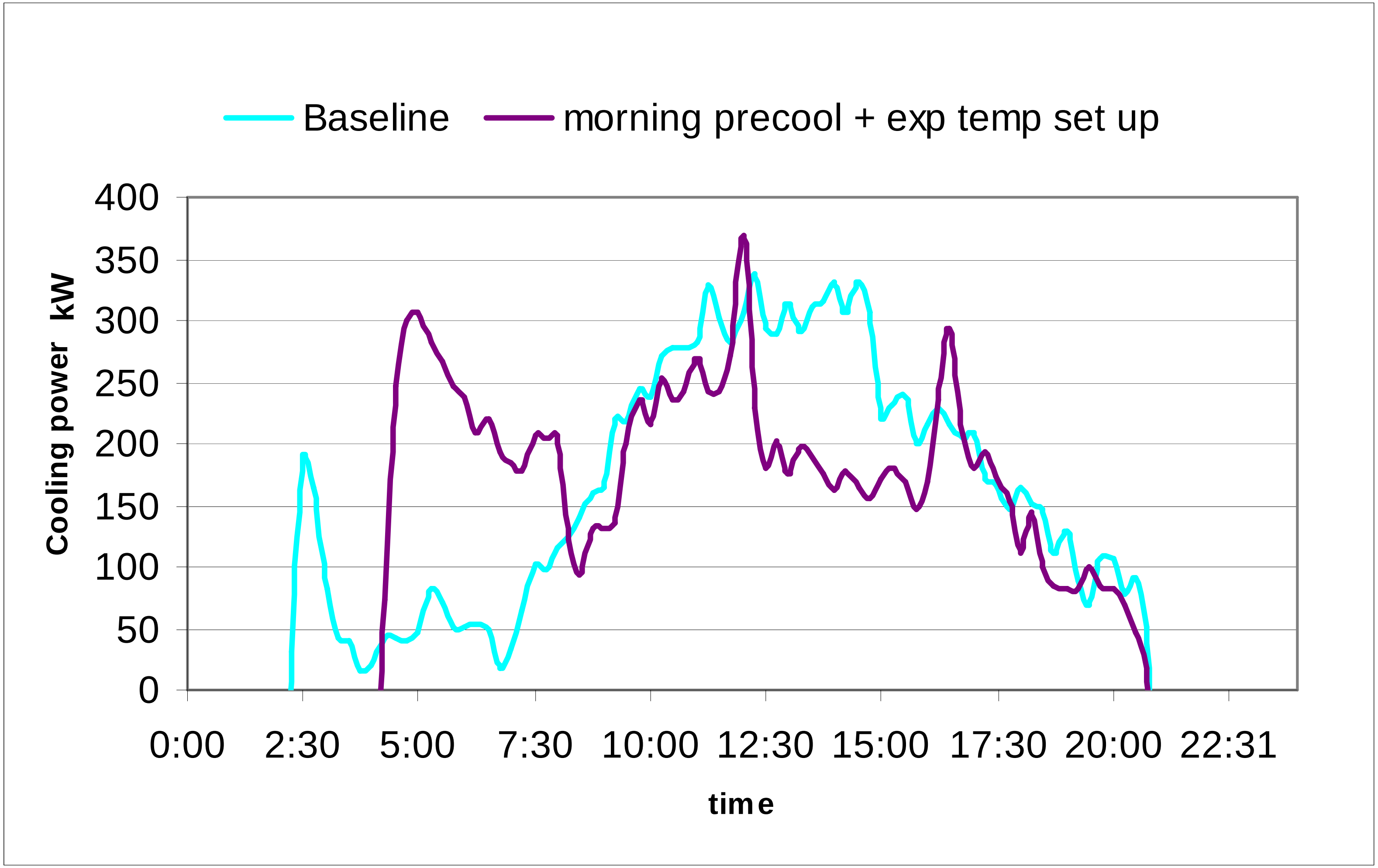
Cigna Building in Visalia

- Met all basic criteria
  - Required some minor programming changes to their existing EMS system
  - 130,000 Sq. Ft.
  - Single Occupant
  - Very motivated and cooperative property manager

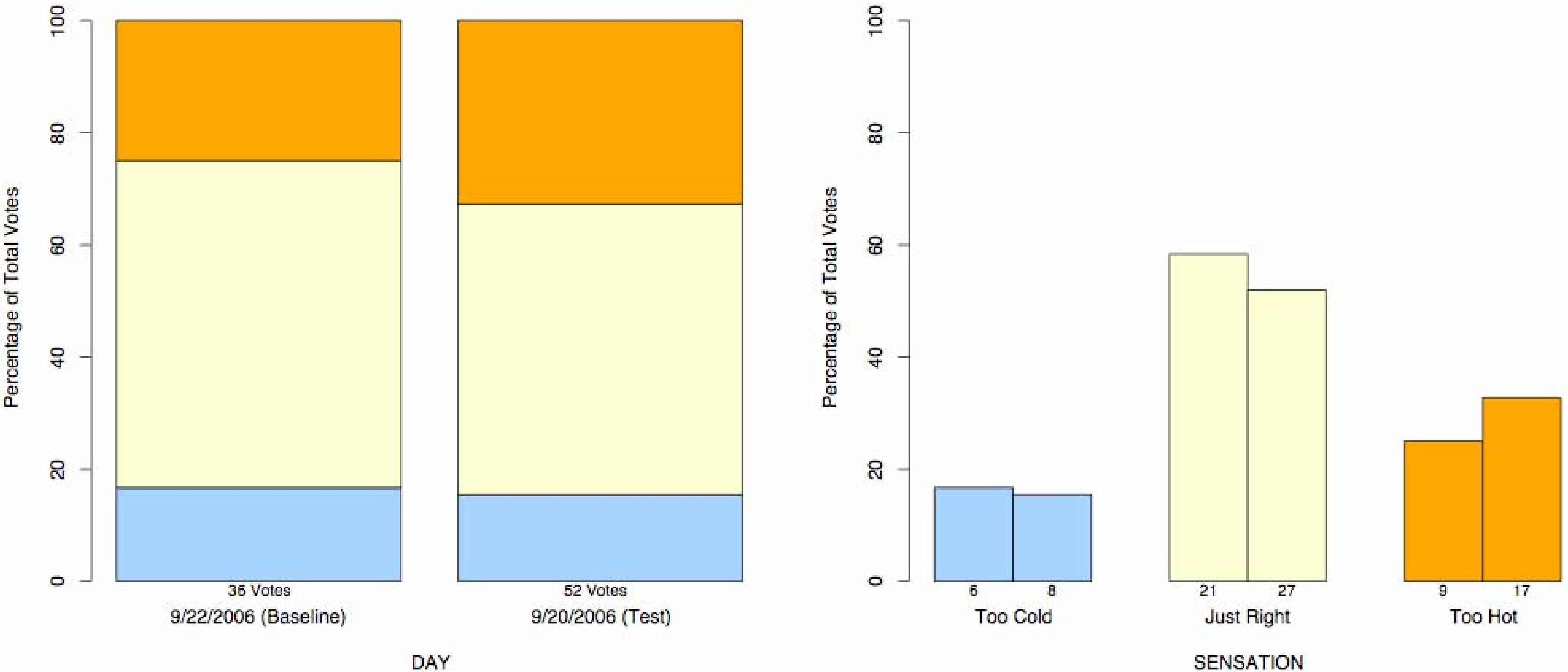
Precooling + linear temp reset



Precooling + exp temp reset



9.20.2006 Test: Sensation



Field Test Summary

	# of Sites	Peak reduction	% (whole building)	Strategies	Comfort	Peak outside temp
2003	1 (Santa Rosa)	2.3 W/ft^2	~60%	Preclg + temp set up (one step)	No complaints	90-95 ^oF
2004	2 (Santa Rosa, Sacramento	0.5~2.0 W/ft^2	10~66%	Preclg (w/o) + temp set up (one step)	Comfort survey	85-90 ^oF
2005	2 (Oakland	0.5~1.0 W/ft^2	10~25%	Preclg (w/o) + various shed and recovery strategies	Comfort survey + indoor monitors	80-85 ^oF
2006	1 (Visalia)	0.5~1.0 W/ft^2	10~15%	Preclg (w/o) + various shed and recovery strategies	Comfort survey + indoor monitors	95-100 ^oF

Market Outreach

- Audit 10 large commercial buildings for ease of DR implementation
- Interview building owners and utility account representatives.
- Building audits indicated
  - Good peak shifting potentials in large office buildings
  - Little technical barriers of implementing DR strategies
  - Lack of knowledge, resources, and incentives are the main barriers

Successful Story

Philadelphia Custom House

- ❑Precool to ~70 °F in morning
- ❑2006-2006, saved almost $70,000 during 2005-2006
- ❑2006-2007,expects savings of nearly $100,000 (about 15 percent of the facility's annual electricity bill)
- ❑Slight–perhaps 5 percent–energy (kWh) penalty from the pre-cooling

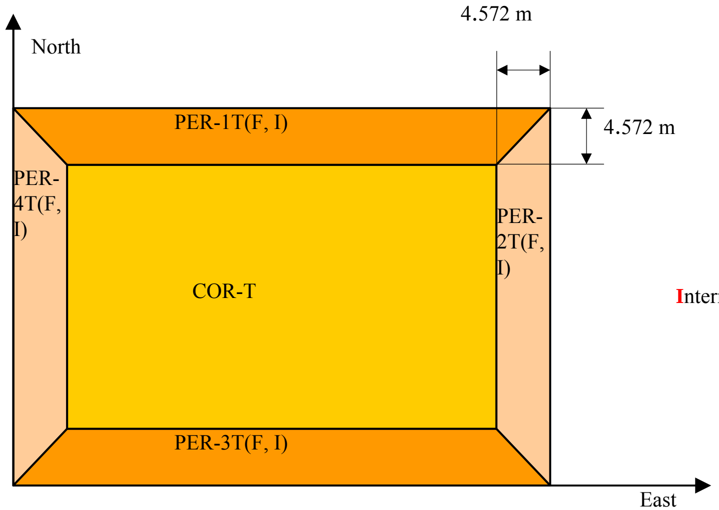
"Quick" Assessment Tool

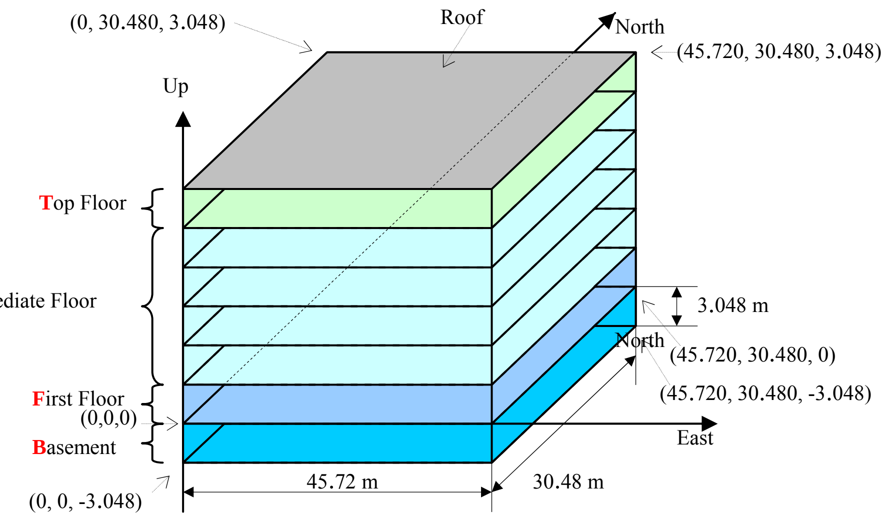
- Evaluate demand reduction and cost savings for large commercial buildings
  - Predict peak load reduction
  - Compare demand shed strategies
  - Predict comfort
  - Analyze energy cost

Method

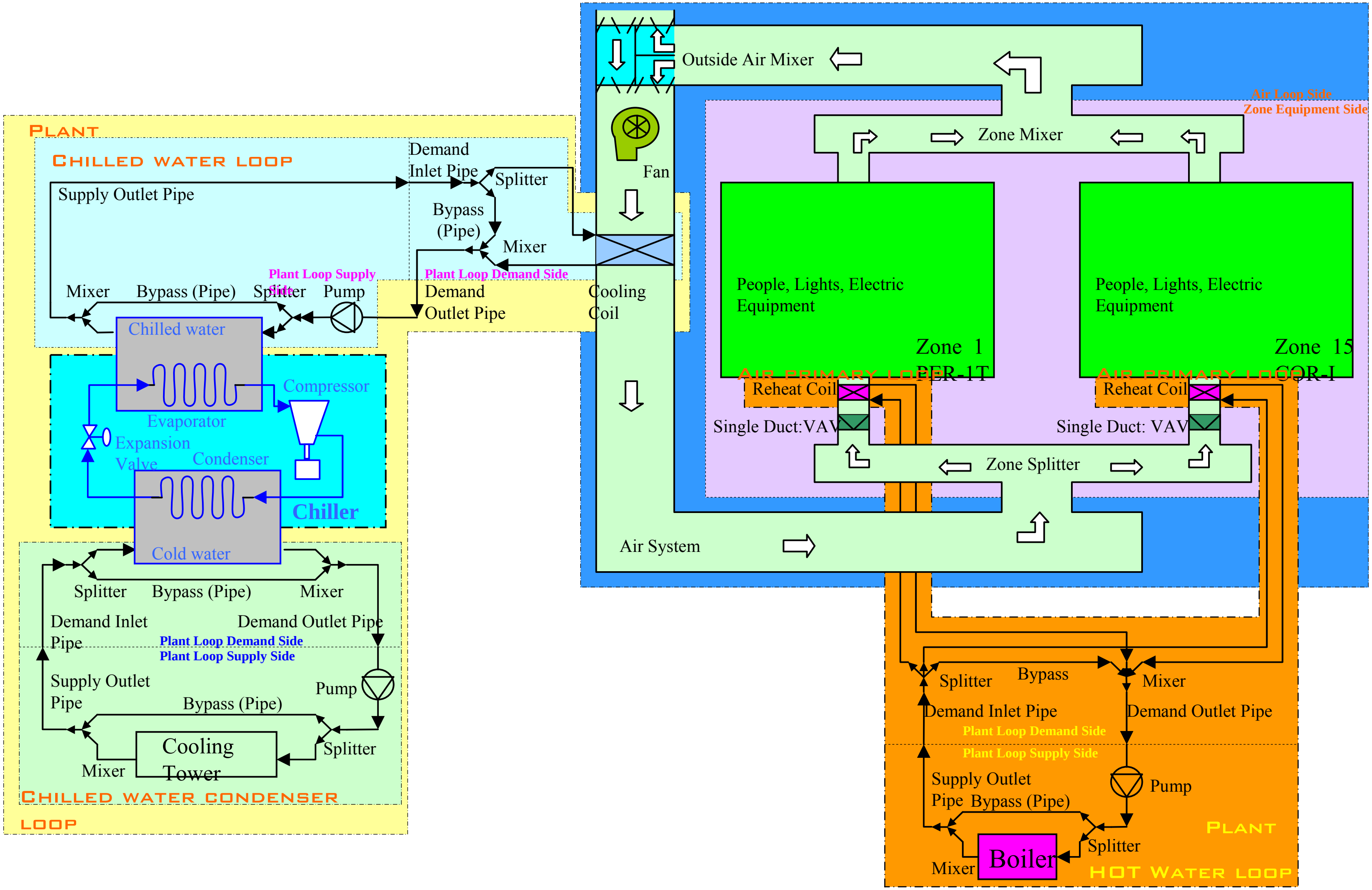
EnergyPlus prototypical office building model (Joe Huang's model)

ZONE
(TOP FLOOR)

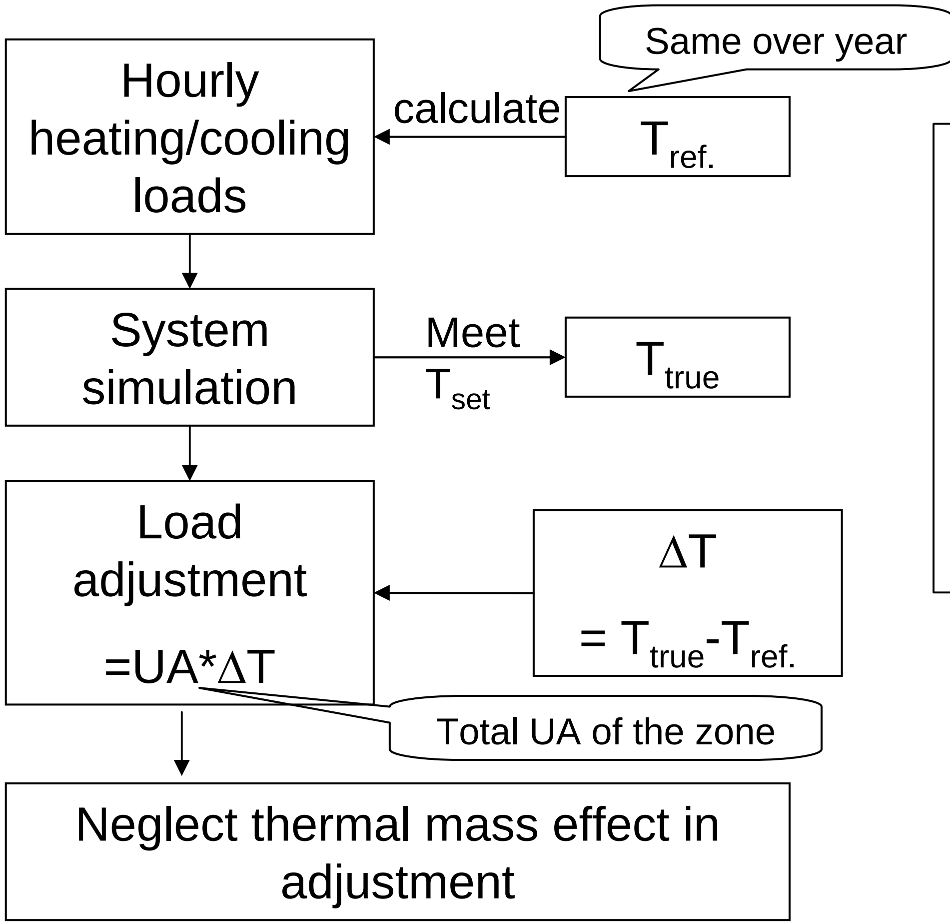


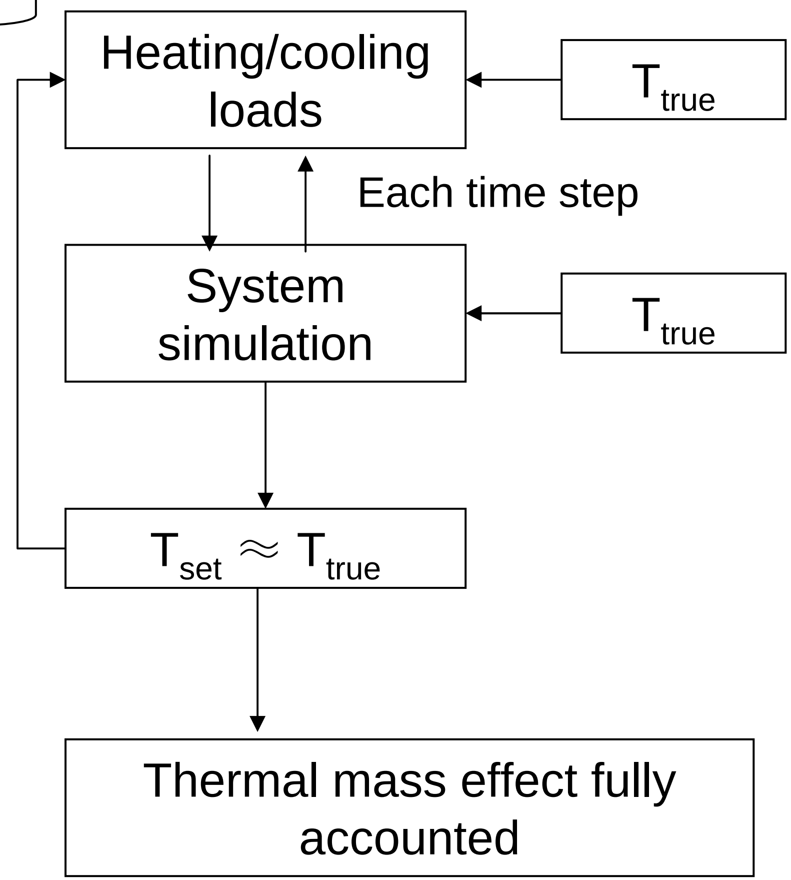


HVAC systems



Doe-2 | Energy+





Strengths: fast

Weaknesses: Buildings in simulation trend to be lighter than real ones

Strengths: accurate

Weaknesses: running slowly, hard to configure

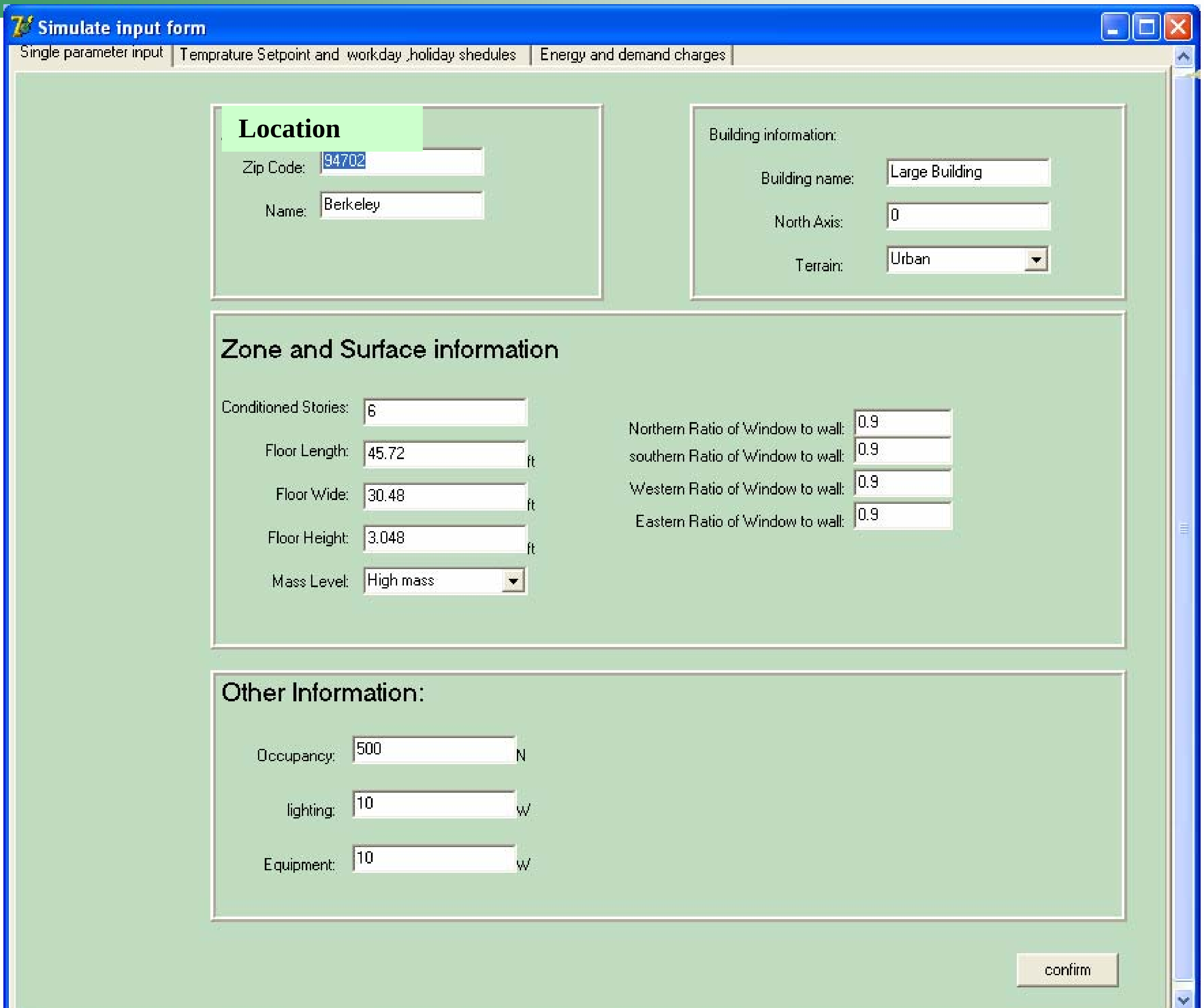
Regular User Inputs – Basic Info

- Zip code: automatically retrieve weather files
- Building orientation: North axis
- Conditioned stories
- Building dimensions: length/width/height
- Utility rate
  - Energy charge
  - Demand charge
  - CPP

Regular User Inputs –Load

- Internal loads
  - Occupants, lighting load, equipment load
- Construction materials
  - Automatically configured
  - Title 24 compatible
  - User adjustable
- Ratio of window to wall
  - Each orientation

User Inputs



Simulate input form
Single parameter input
Temprature Setpoint and workday ,holiday shedules
Energy and demand charges
Location
Zip Code: 94702
Name: Berkeley
Building information:
Building name: Large Building
North Axis: 0
Terrain: Urban
Zone and Surface information
Conditioned Stories: 6
Floor Length: 45.72 ft
Floor Wide: 30.48 ft
Floor Height: 3.048 ft
Mass Level: High mass
Northern Ratio of Window to wall: 0.9
southern Ratio of Window to wall: 0.9
Western Ratio of Window to wall: 0.9
Eastern Ratio of Window to wall: 0.9
Other Information:
Occupancy: 500 N
lighting: 10 W
Equipment: 10 W
confirm

Regular User Inputs –DR Strategies

Temperature set points schedules

- Zone temperature set points
- Chilled water temperature set point
- Supply air temperature set point
- HVAC running schedule
- CPP schedule
  - Implement DR only in CPP days

Advanced User Inputs

- Time step
- Zone depth
- Weather file
- Customer defined IDE file
- Internal mass properties
  - Material type
  - Weights
  - Surface area
  - Heat exchange co-efficient

Advanced User Inputs

Running period

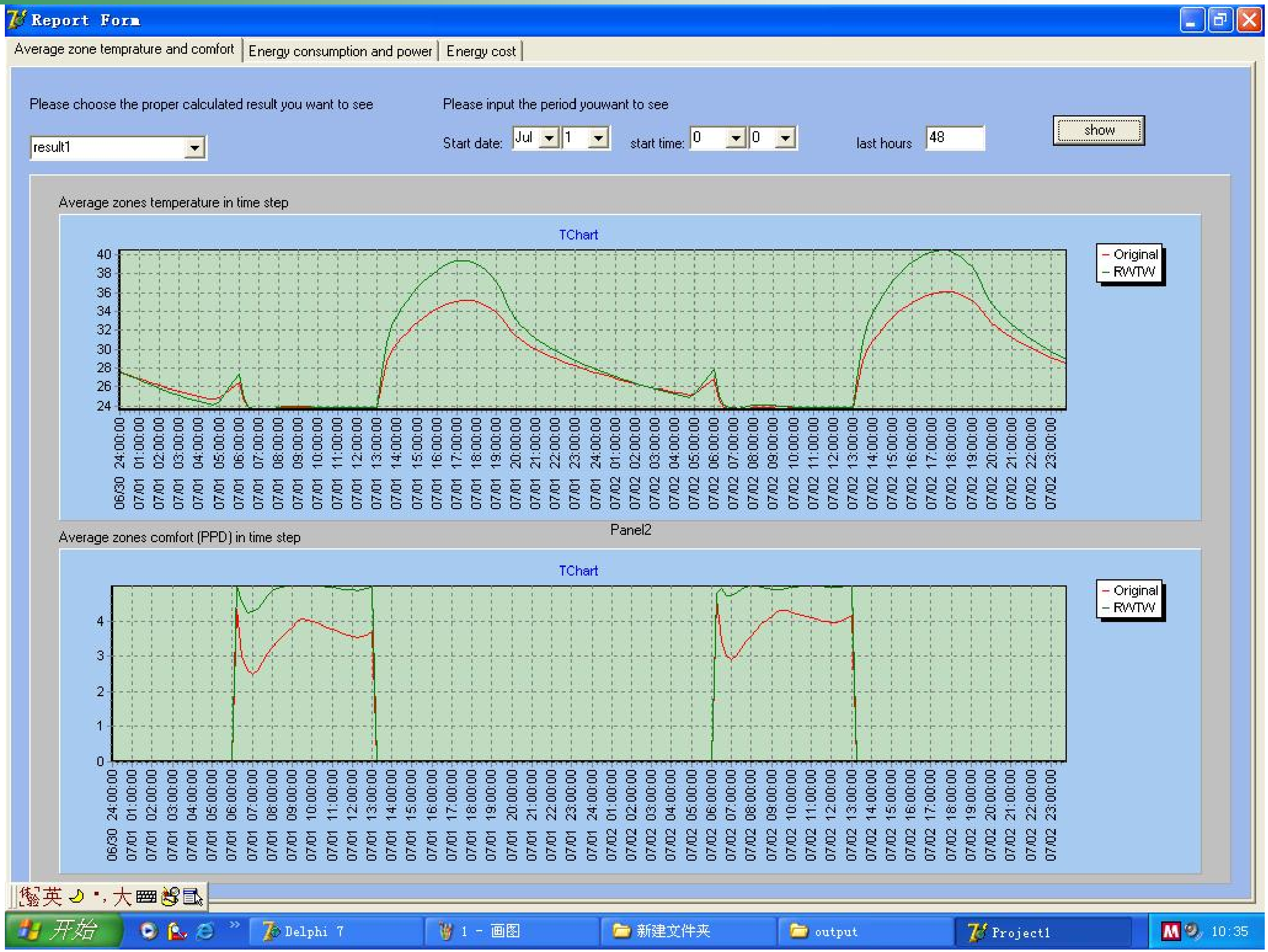
- Begin month of simulation
- Begin day of month of simulation
- End month of simulation
- End day of month of simulation
- Day of week for start day

EnergyPlus running speed control

- Minimum system time step
- Maximum HVAC iterations
- Loads convergence tolerance value
- Temperature convergence tolerance value
- Maximum number of warm up days

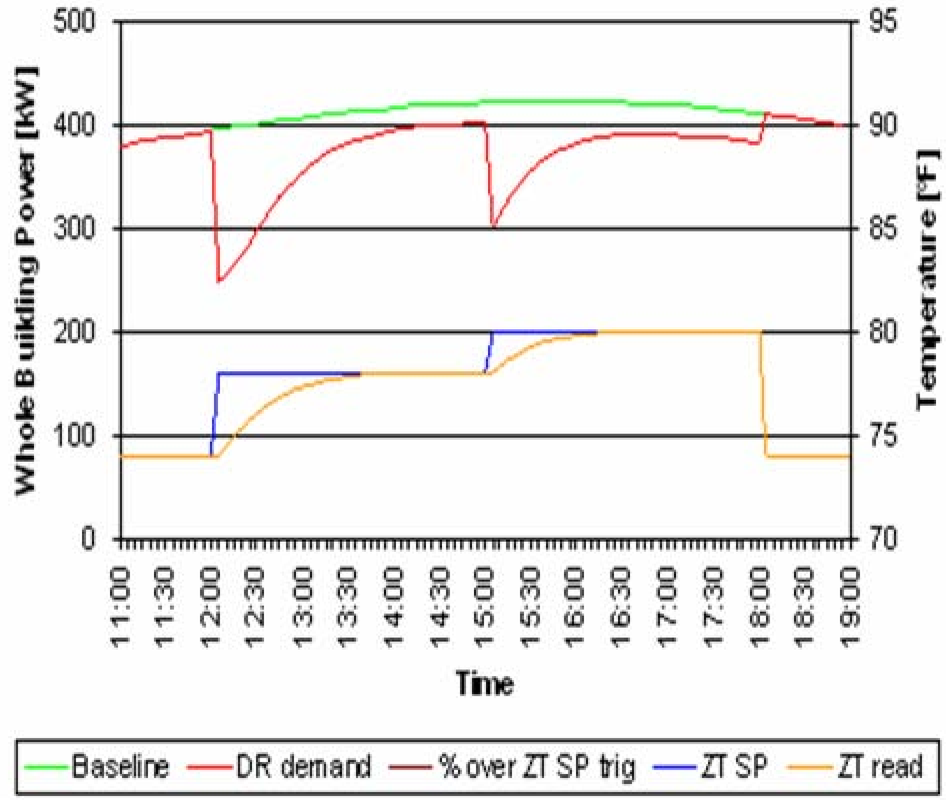
Analysis tool output

Analysis tool output



Simple Method DR Tool

- Simple regression method
  - Extrapolate from one test condition to another
  - Tool developed for retail stores with no windows
    - IKEA, Target



Conclusions – So Far

- Precooling and demand shed strategies worked well under both mild and extreme hot weather conditions and were able to reduce cooling loads significantly (20~30% on hot days).
- No noticeable change in thermal comfort if the temperatures are under control.
- Properly controlled exponential temperature setup in the shed period can maximize load reduction.
- The night precooling results are mixed. It worked well in heavy mass buildings but had no noticeable effects on typical and light office buildings.

DR Tool Next Step

- DR tool development
  - Beta release: 6/2007
  - Next phase: 6/2007 to 6/2008
  - TAG
    - Volunteers for the TAG
    - Inputs from audience
      - Who are the potential users?
      - Who will test it?
      - Define DR tool functional requirements.