Maximizing the Benefits of Residential Pre-Cooling

EEBA Excellence in Building – St. Louis, MO

September 23rd, 2014

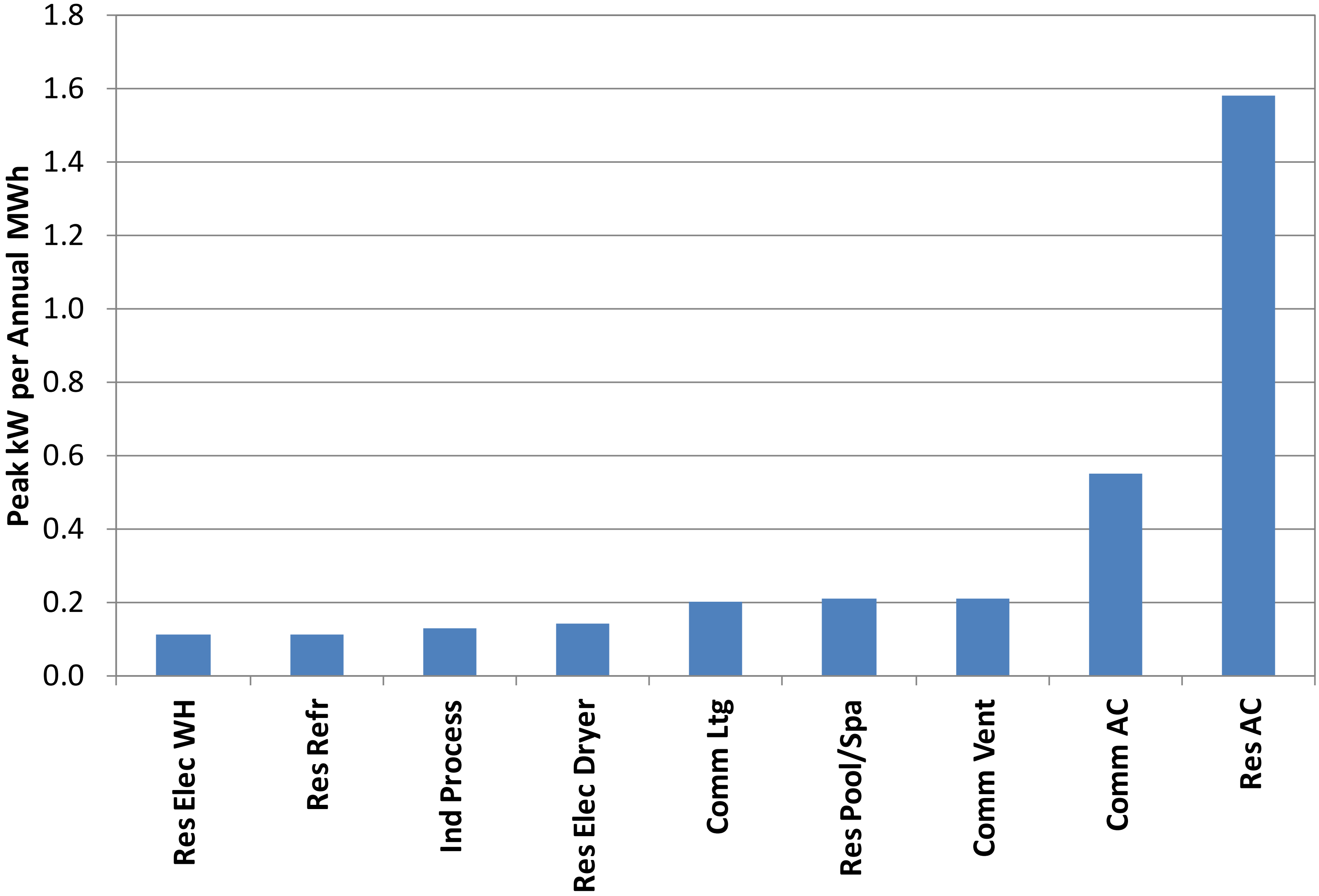
Overview

- Why Pre-Cooling?
- Project Background
- Field Monitoring
- Modeling Evaluation
- Alternative Pre-Cooling Strategies
- Conclusions

Learning Objectives

1. What are the optimal pre-cooling strategies in high-performance homes (higher levels of insulation, good glazing, thermal mass, tightly sealed)?
2. Are there viable pre-cooling strategies in lower performance homes?
3. What are the efficiency advantages of operating air conditioners during cooler off-peak periods?
4. What are the impacts of these strategies in terms of energy, peak demand, and occupant comfort?

Why Pre-Cooling?



Brown and Koomey. 2002. *Electricity Use in California: Past Trends and Present Usage Patterns*. LBNL. Pub#: LBL-47992.

Take Advantage of House Mass

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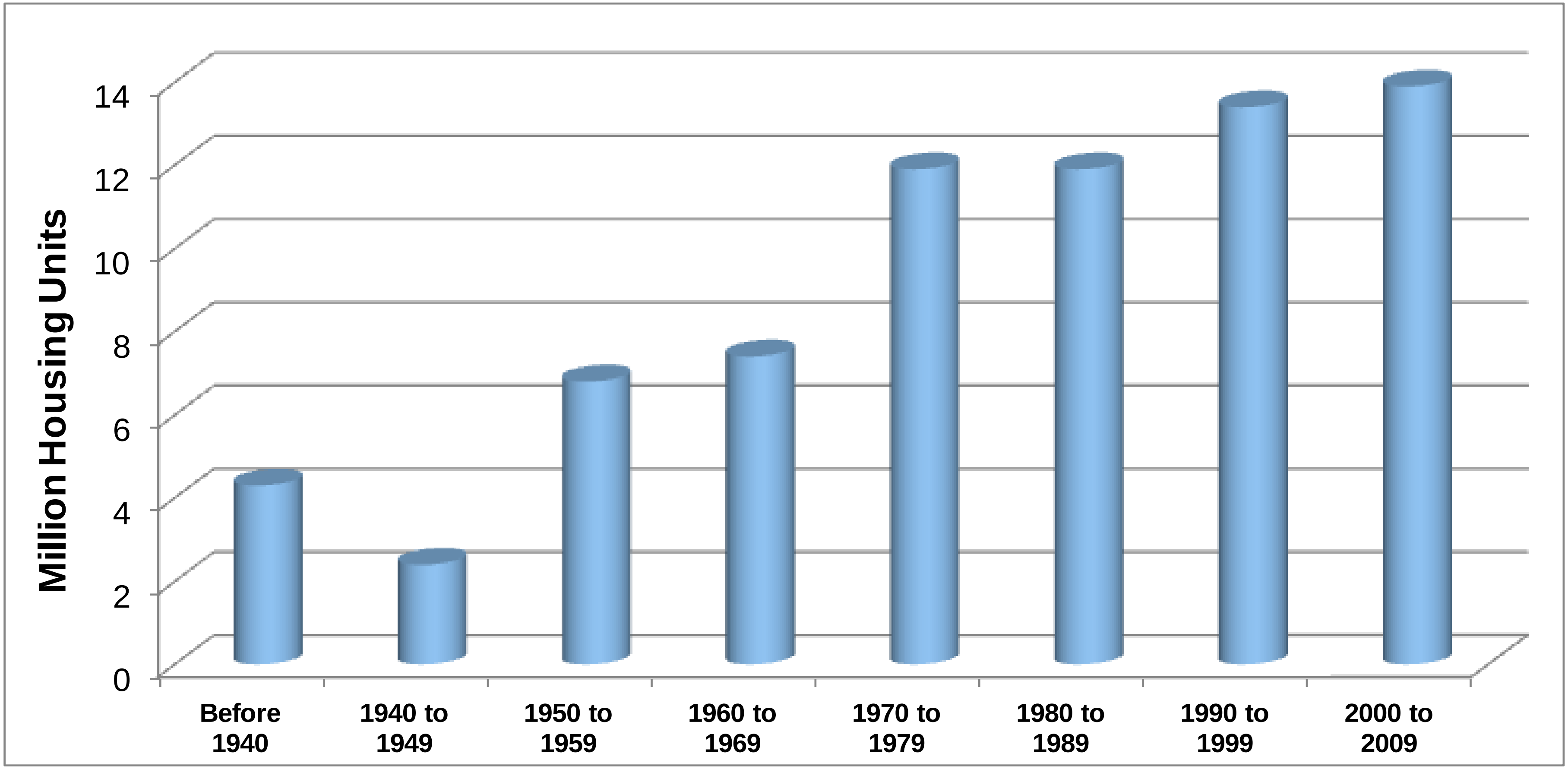
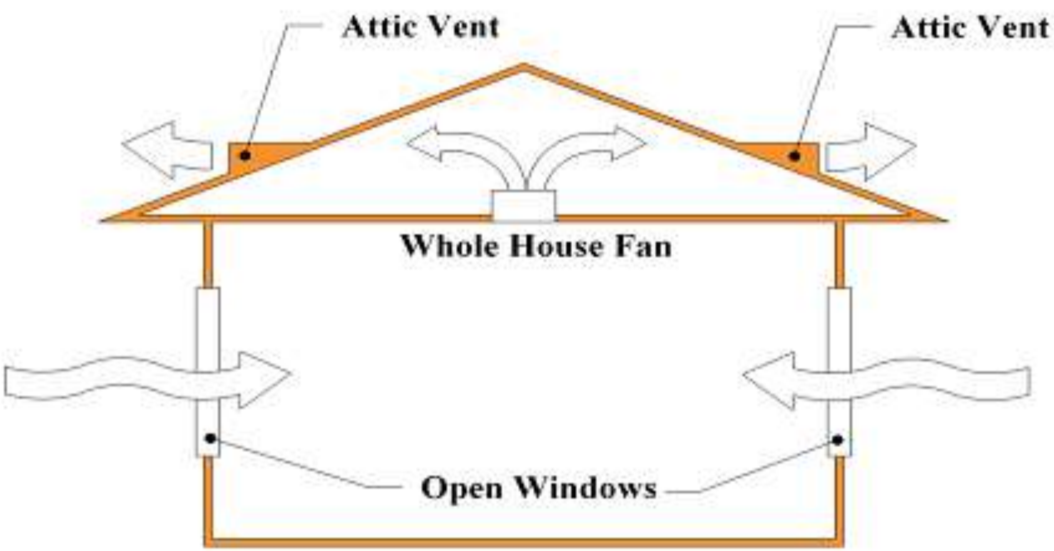
Age of U.S. Housing Stock



Data source: 2009 Residential Energy Consumption Survey

Pre-Cooling Strategies

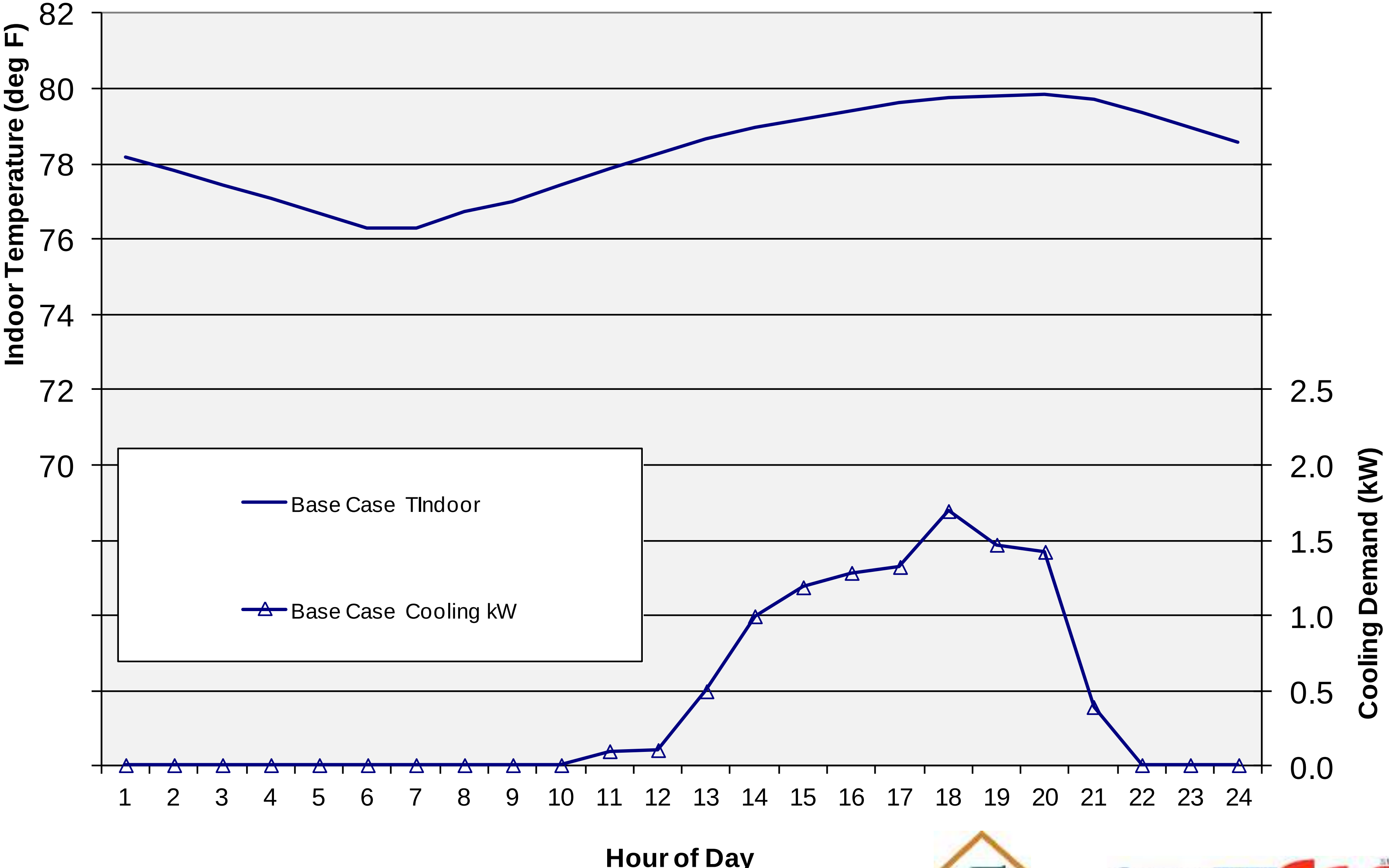
- Strategy for shifting peak demand
  - AC (favorable operating environment)
  - Night ventilation cooling
  - Floor mass (radiant cooling)



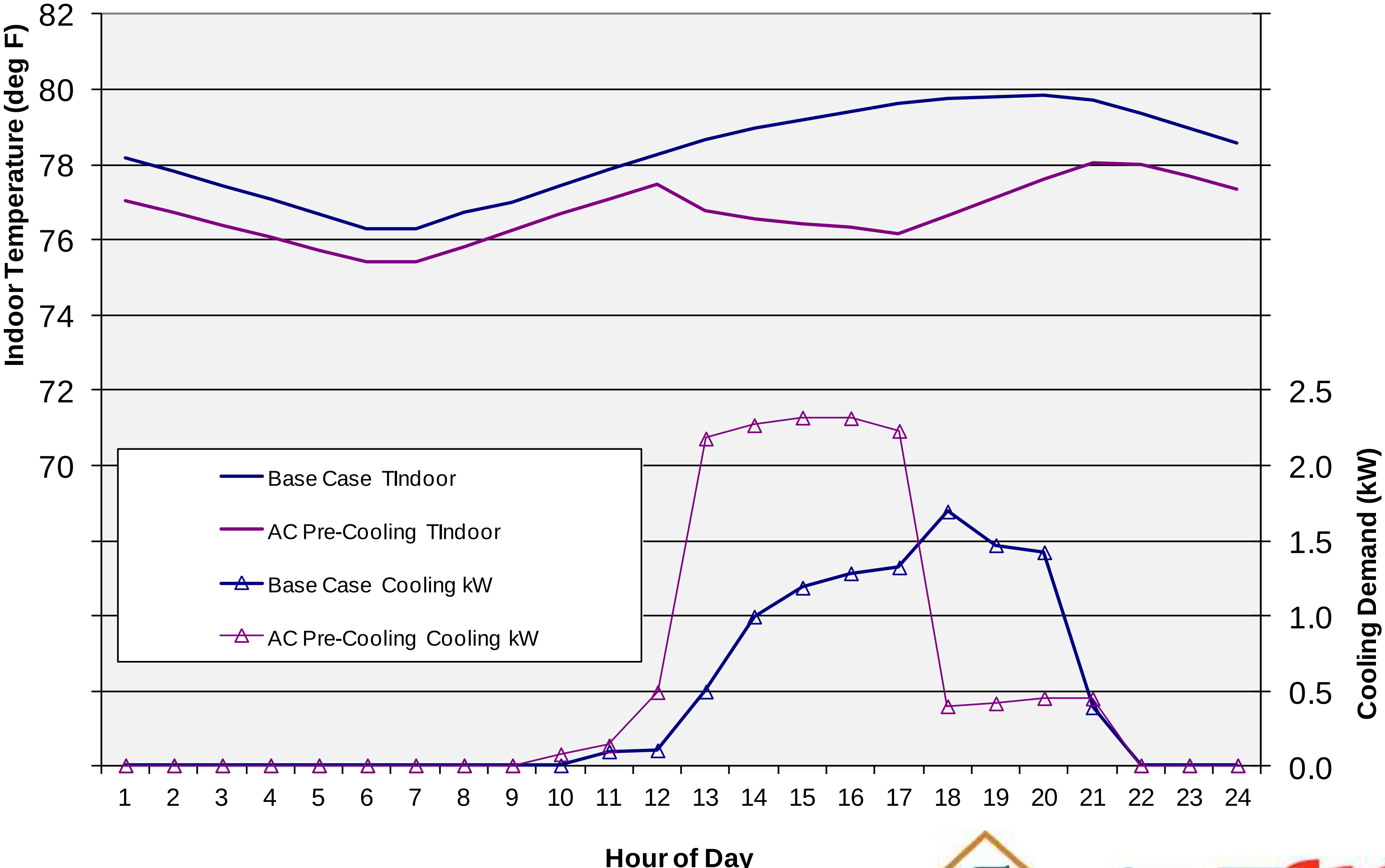
Ventilation Pre-Cooling

Mechanical Pre-Cooling

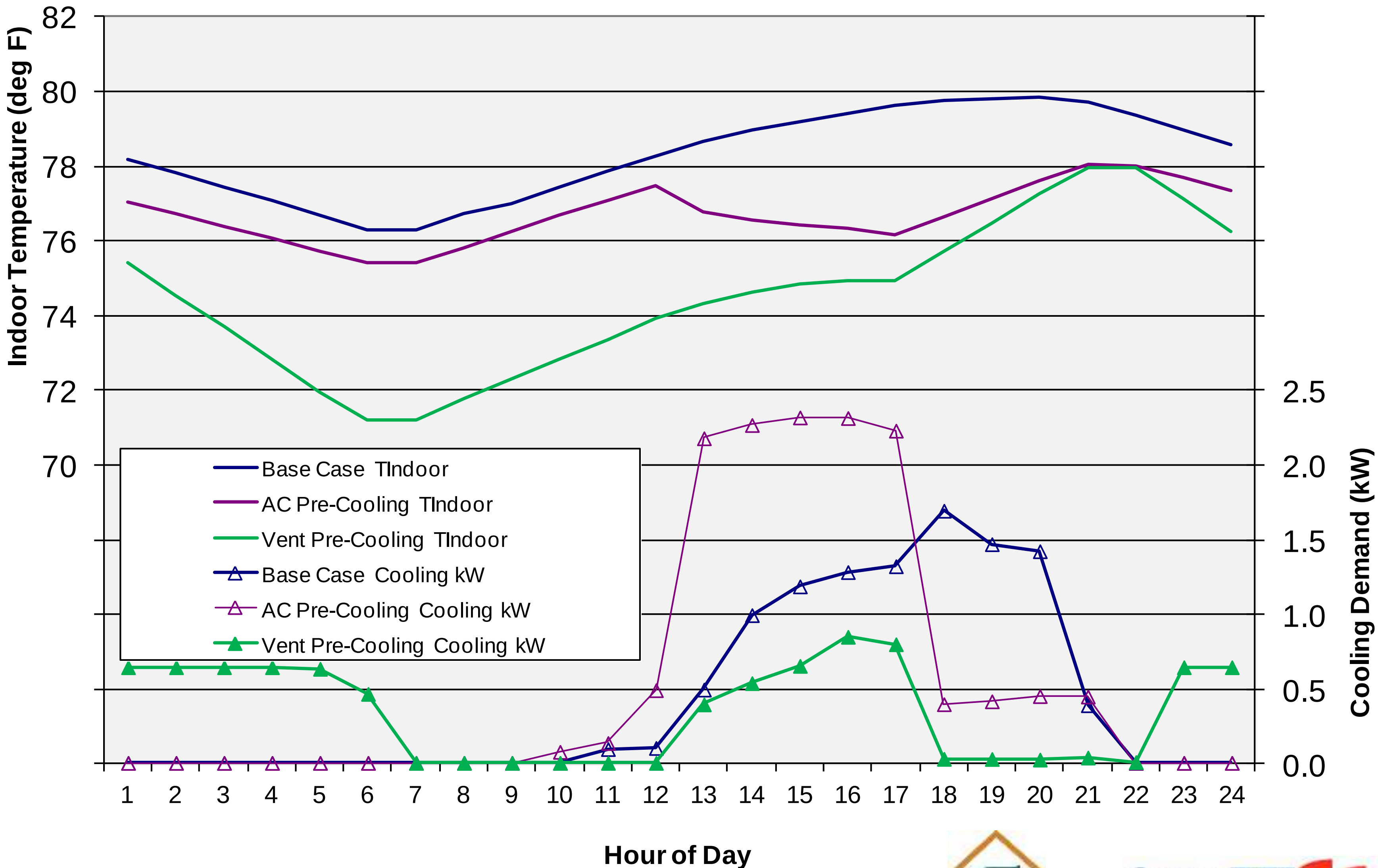
Pre-Cooling Impacts in Hot/Dry Climate: Base Case



Pre-Cooling Impacts in Hot/Dry Climate: AC only



Pre-Cooling Impacts in Hot/Dry Climate: Vent Clg



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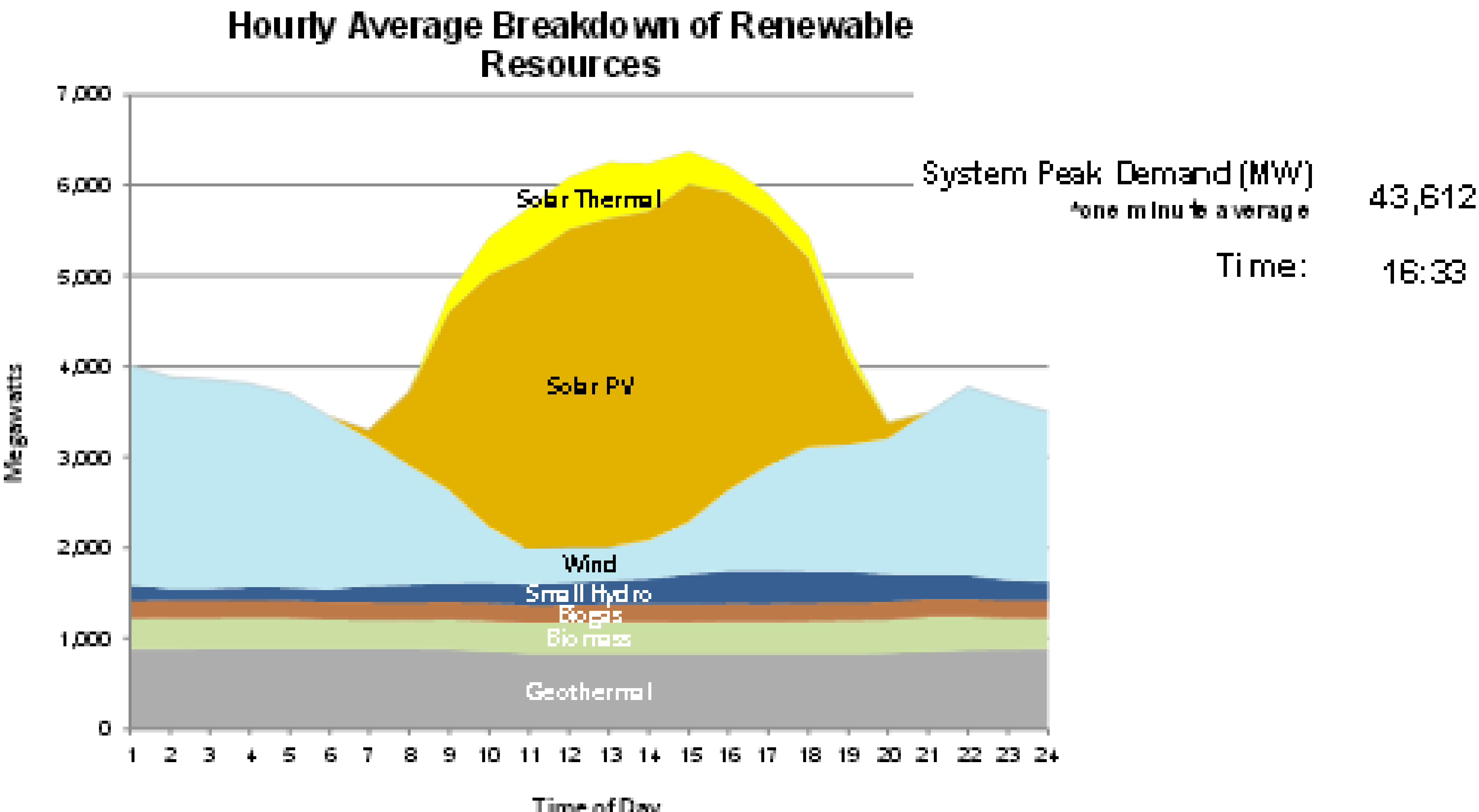
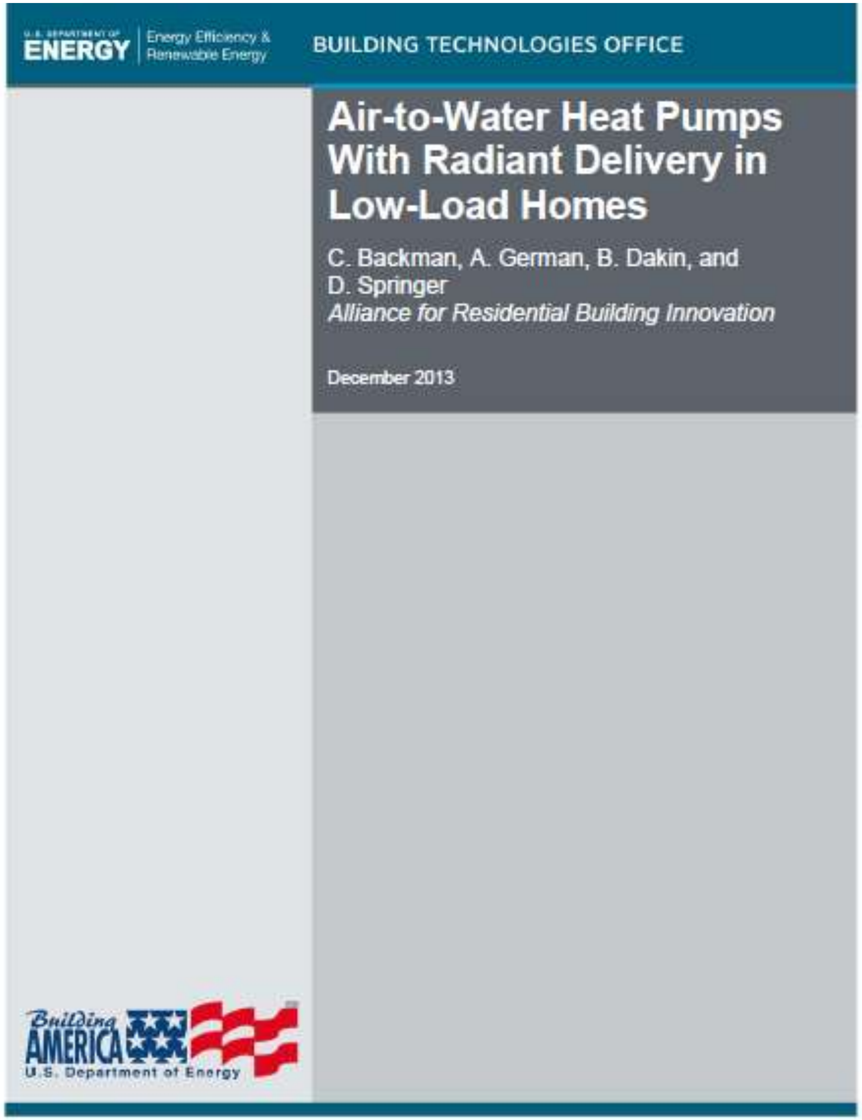
Aligning Pre-Cooling with Renewables- CAISO



This graph shows the production of various types of renewable generation across the day.

Prior Building America Reports



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

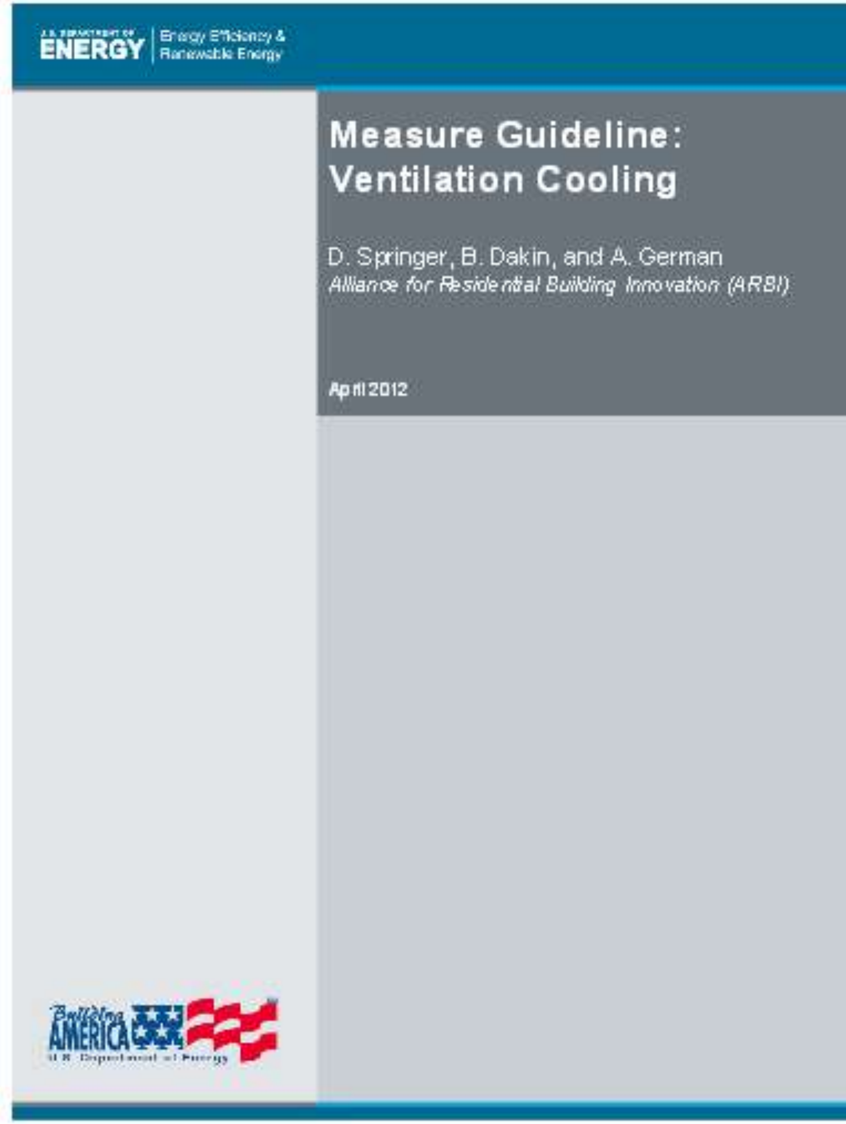
BUILDING TECHNOLOGIES OFFICE

Air-to-Water Heat Pumps With Radiant Delivery in Low-Load Homes

C. Backman, A. German, B. Dakin, and D. Springer
Alliance for Residential Building Innovation

December 2013

Building America U.S. Department of Energy



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Measure Guideline: Ventilation Cooling

D. Springer, B. Dakin, and A. German
Alliance for Residential Building Innovation (ARBI)

April 2012

Building America U.S. Department of Energy

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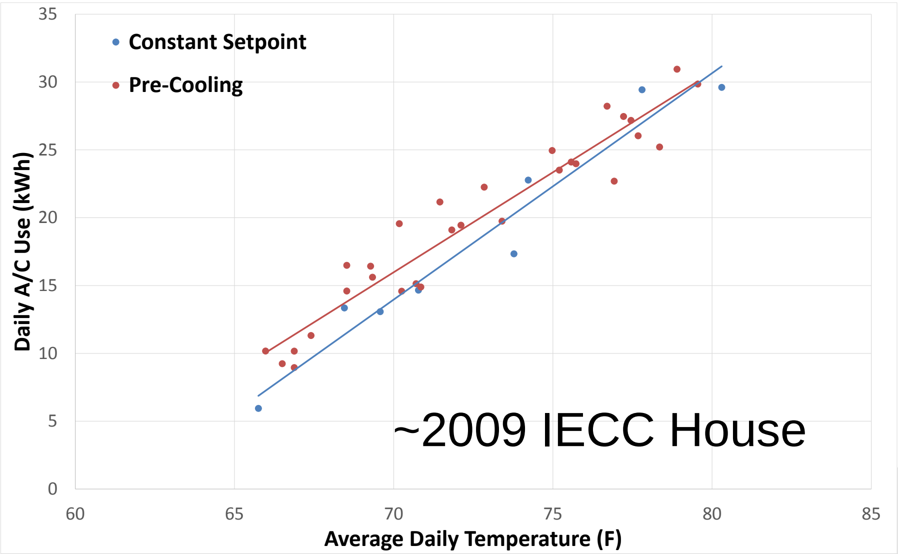
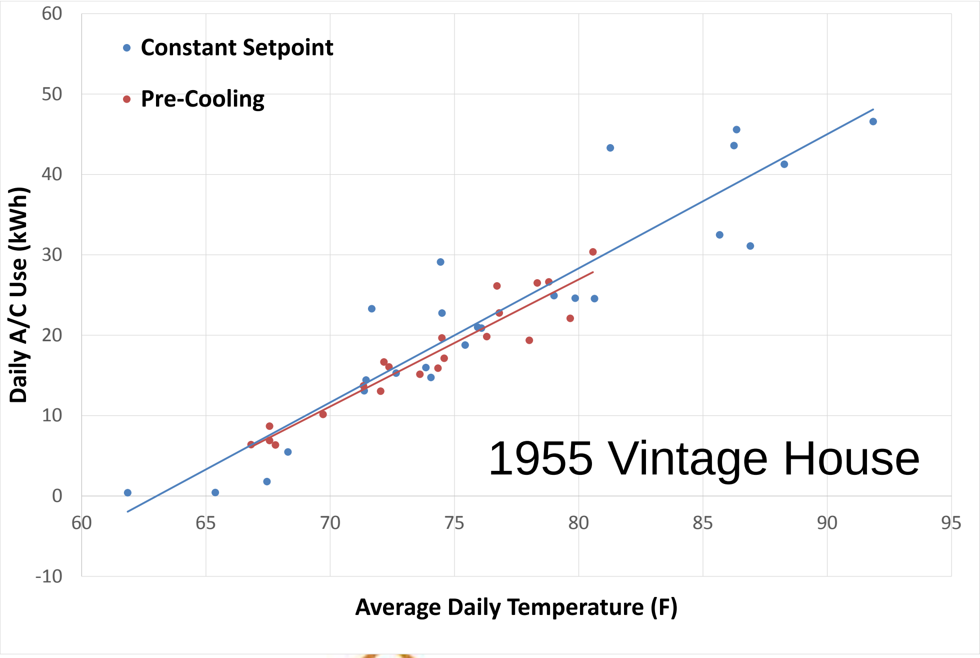
Field Monitoring

- Four houses within 30 miles of Sacramento
- Varying house vintages/ efficiency levels
- Ran different setpoint scenarios
  - Fixed 76F
  - 6am-10am, 72F
  - 10am-1pm, 72F
  - 3am-7am, 68F
- Findings
  - Climate variability in Sacramento area is challenging
  - Precise documenting of house parameters difficult
- Value of monitoring

Field Monitoring



- Difficult to draw clear conclusions
- Reduced operation on-peak with pre-cooling but energy savings unclear



EnergyPlus Modeling

- 2,150 ft^2 two-story home
- 15% window-to-wall ratio
- Building America HSP
- Climates
  - Phoenix (CZ2B), Las Vegas (CZ3B), Denver (CZ5B), Houston (CZ2A), Miami (CZ1A), Boston (CZ5A), Kansas City (CZ4A)
- Two performance models
  - Benchmark home (2009 IECC)
  - High Performance (25% - 30% lower energy use than Benchmark)

Key Assumptions

- 76ºF base case cooling setpoint
- AC sized to achieve 70ºF setpoint on all but the hottest summer days
  - Typically 0.5-1.5 ton oversizing
- 4-8 PM summer on-peak window
- 3:1 TOU rate ($.10 - $.30/kWh)
- 1-4 hour pre-cooling windows
  - Center around coolest AM period, or 12-4 PM
- 2-6ºF setpoint reduction during PC

EnergyPlus Modeling

Maximize Energy Savings

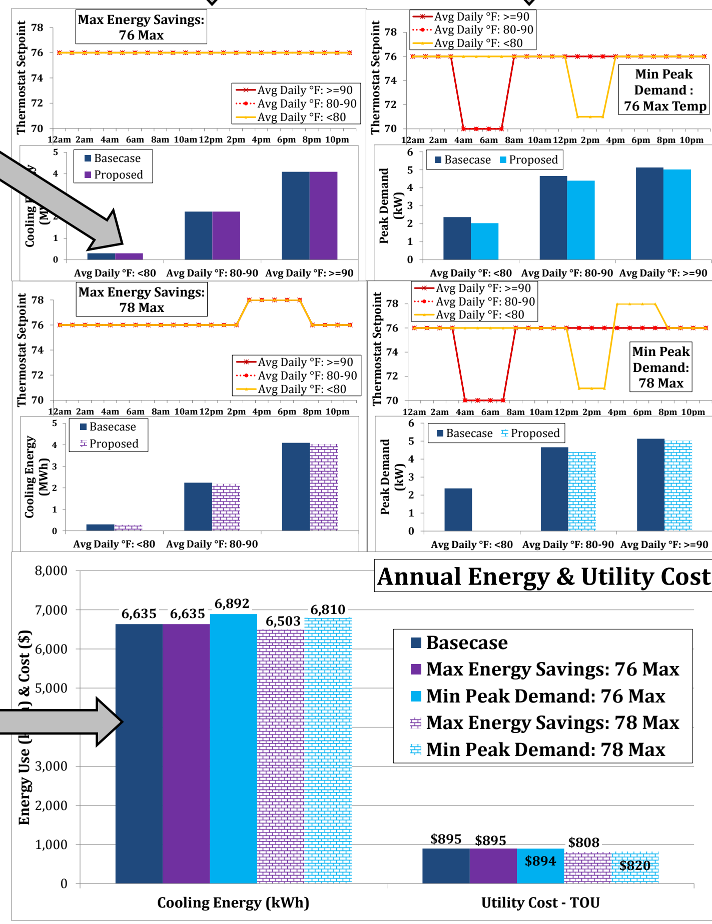
Minimize Peak Demand

Different Results for 2-3 Tiers of Average Outdoor Air Temperature

Maximum Acceptable Temp = 76F

Maximum Acceptable Temp = 78F

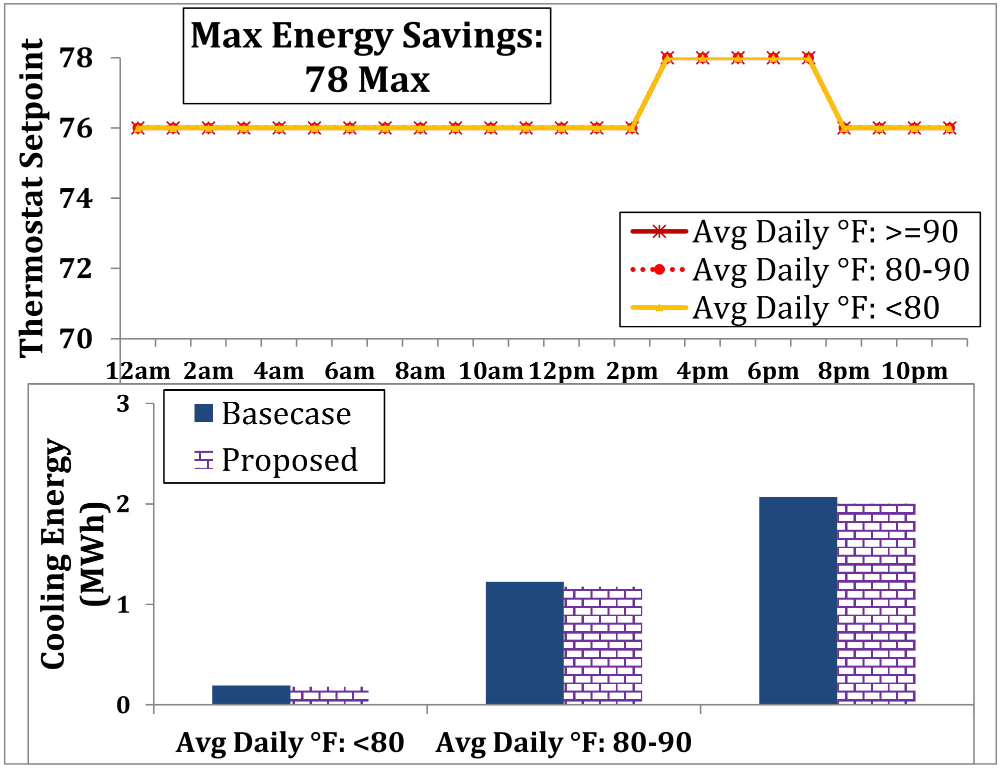
Annual Results for the 4 Best-Case Scenarios Presented Above



Modeling Results – Energy Savings

- Energy savings difficult to achieve with pre-cooling alone– need to float

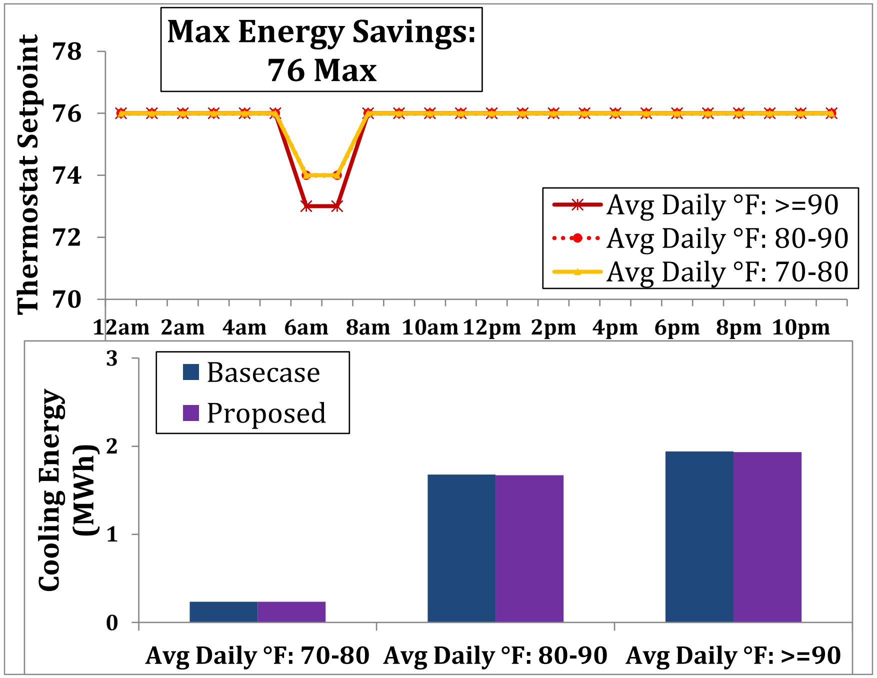
High Performance – CZ2B



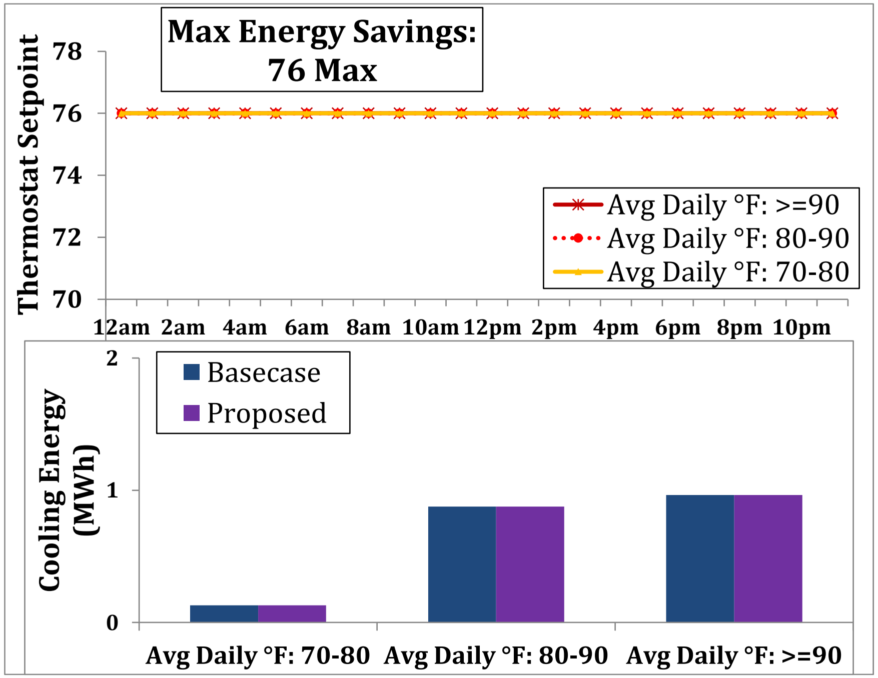
Modeling Results – Energy Savings

- Pre-cooling justified in Benchmark but not high performance home

Benchmark – CZ3B



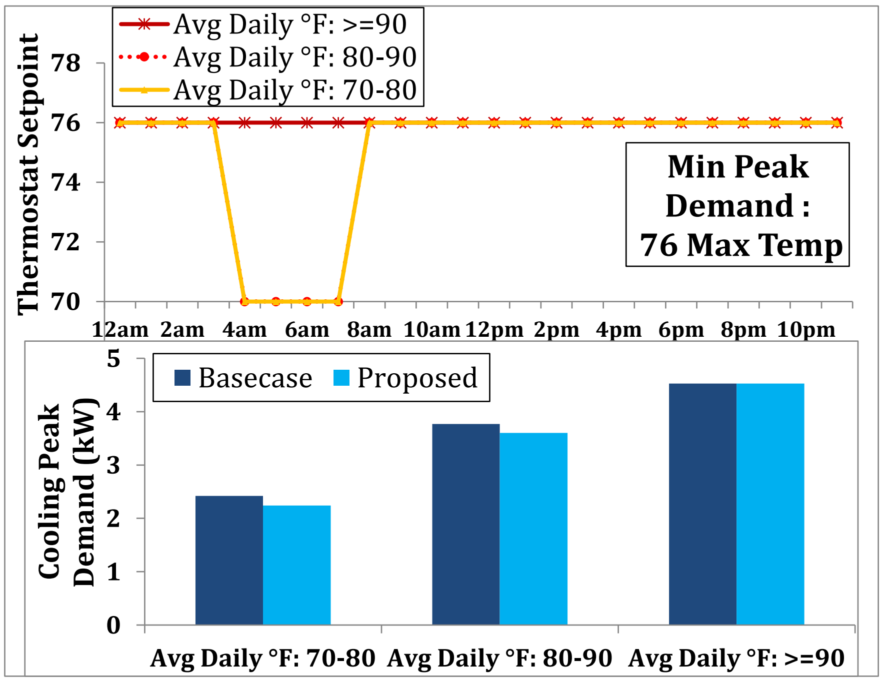
High Performance – CZ3B



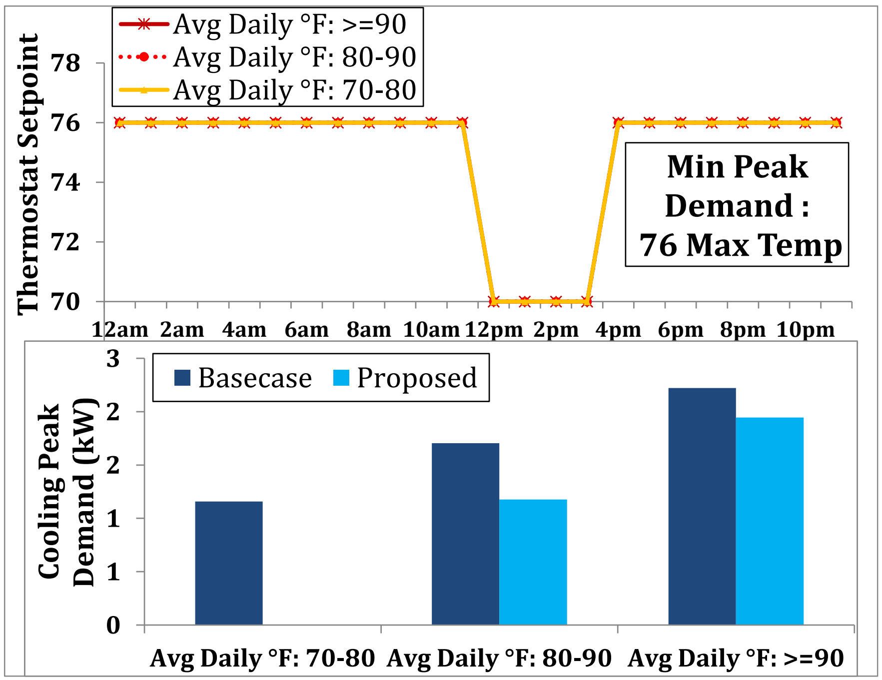
Modeling Results – Peak Demand

- Coincident peak demand reductions greater in high performance home

Benchmark – CZ3B



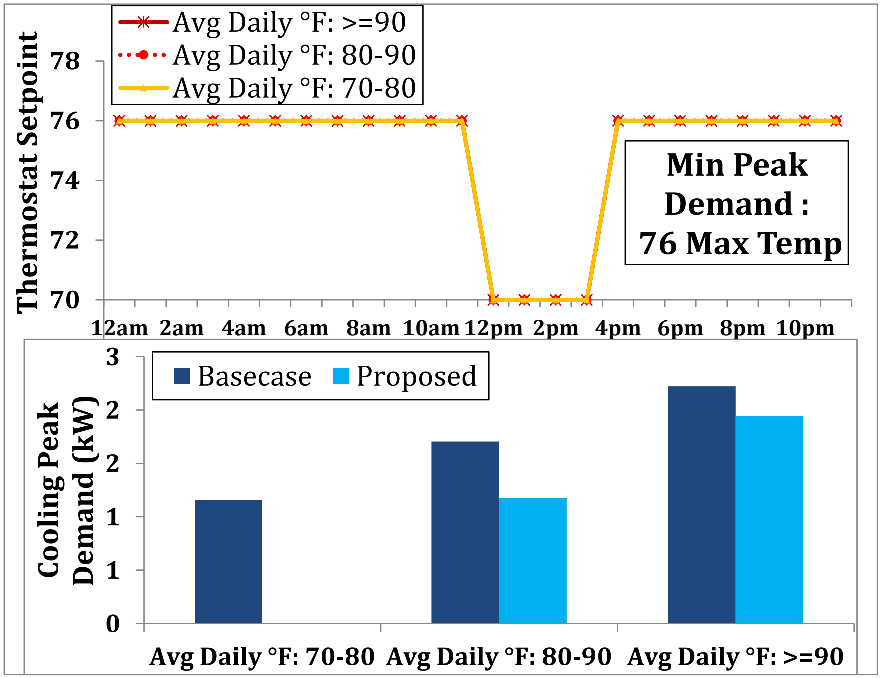
High Performance – CZ3B



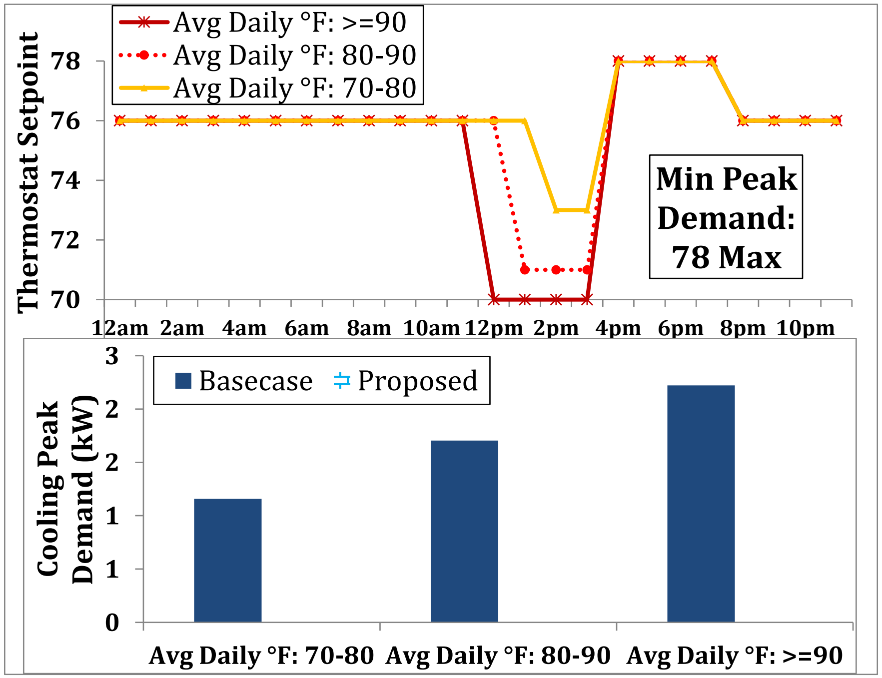
Modeling Results – Peak Demand

- Coincident peak demand eliminated with higher peak period setpoint

High Performance – CZ3B



High Performance – CZ3B

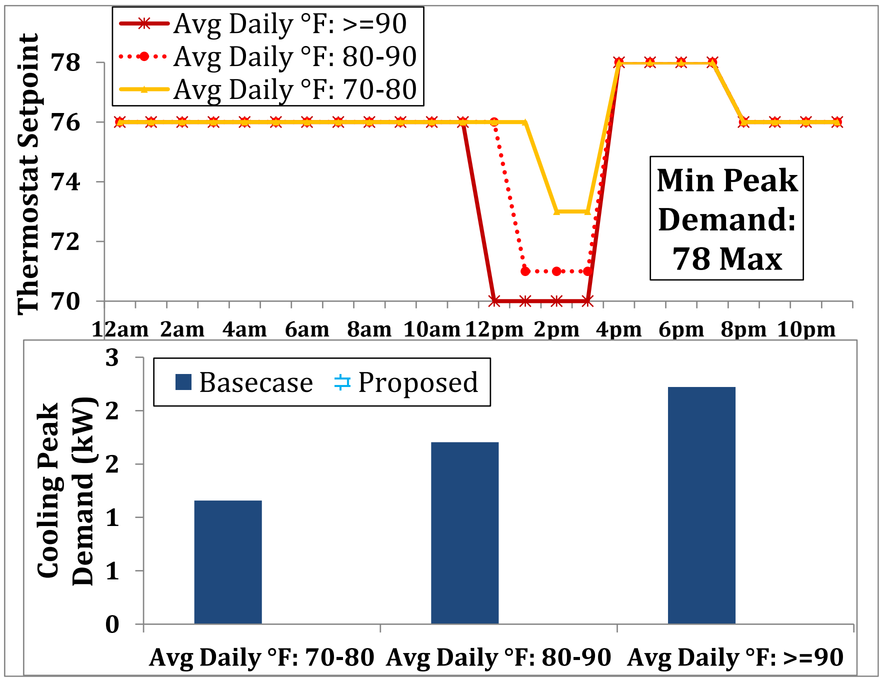


Modeling Results – Peak Demand

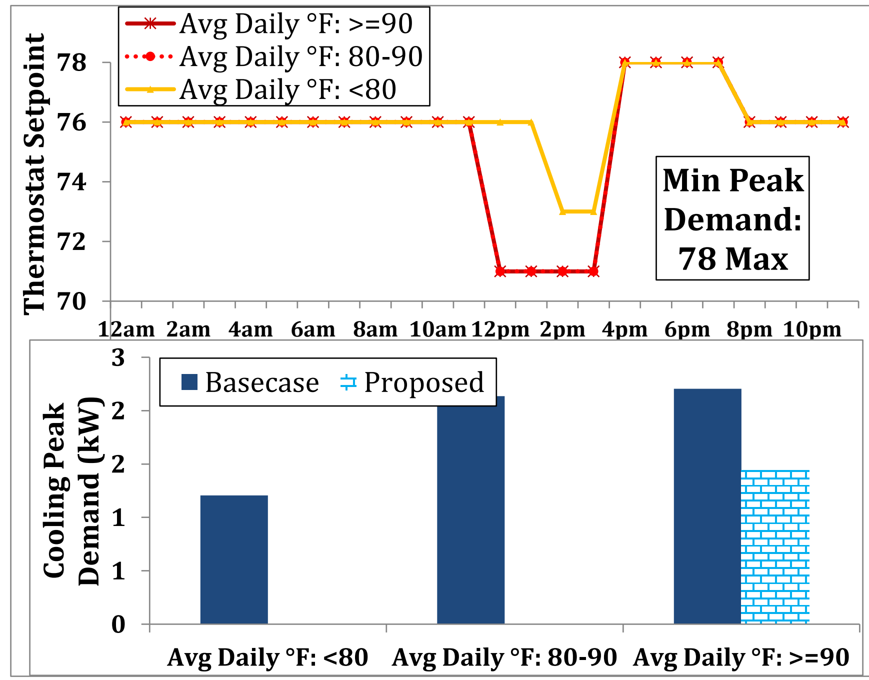
- Less savings in hotter climates

Hotter

High Performance – CZ3B



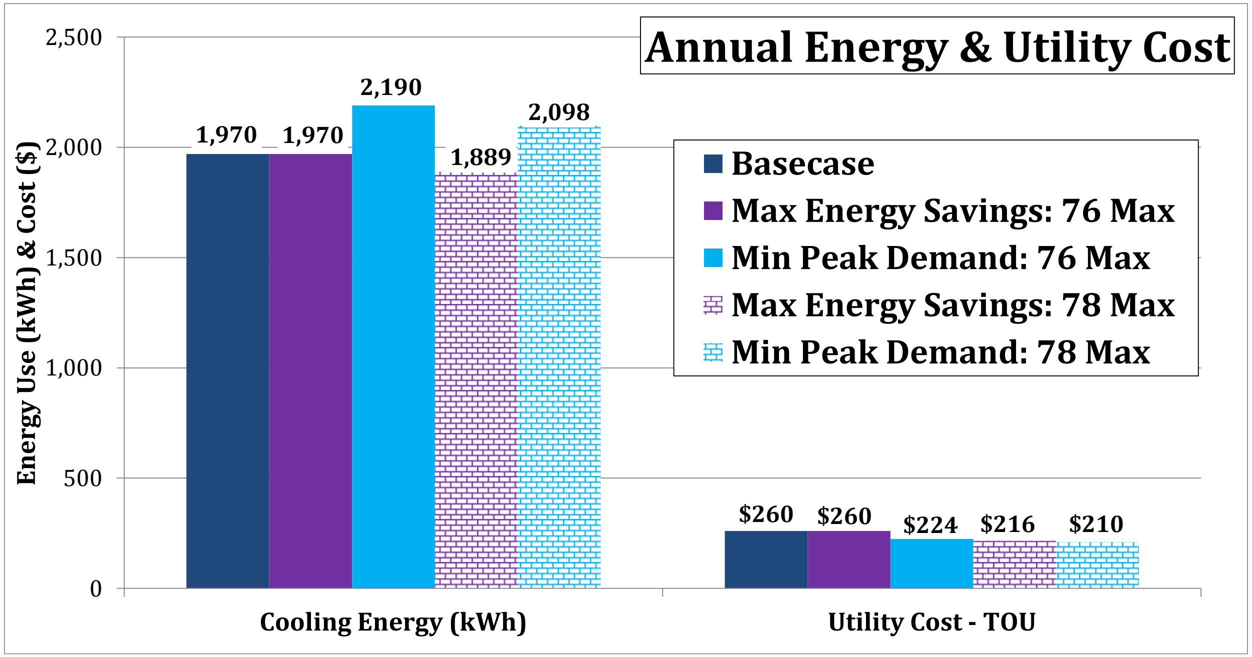
High Performance – CZ2B



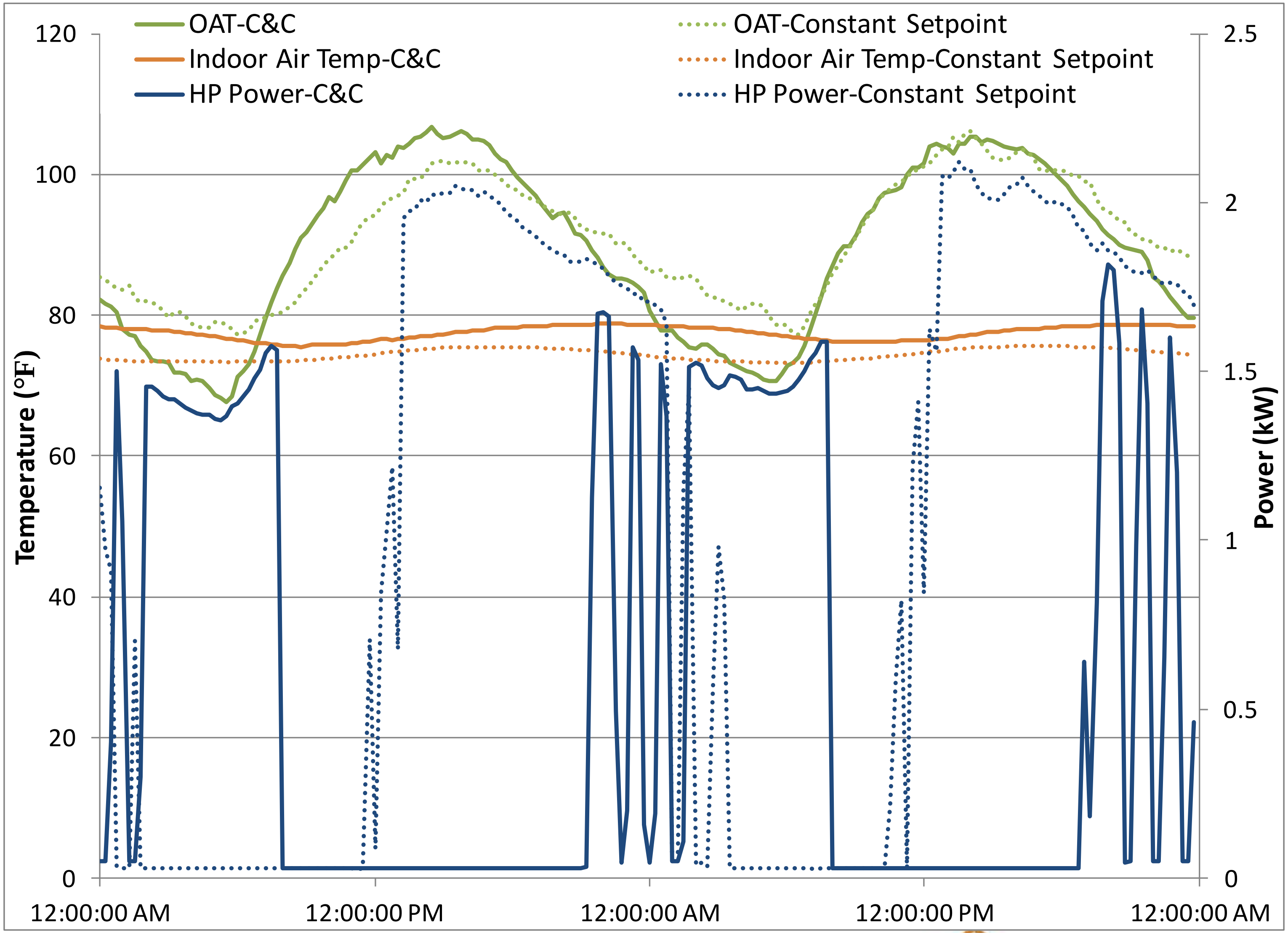
Modeling Results

- Impact on energy use by minimizing peak demand non-trivial
- Cost savings very dependent on rates

High Performance – CZ3B



Field Monitoring - Results



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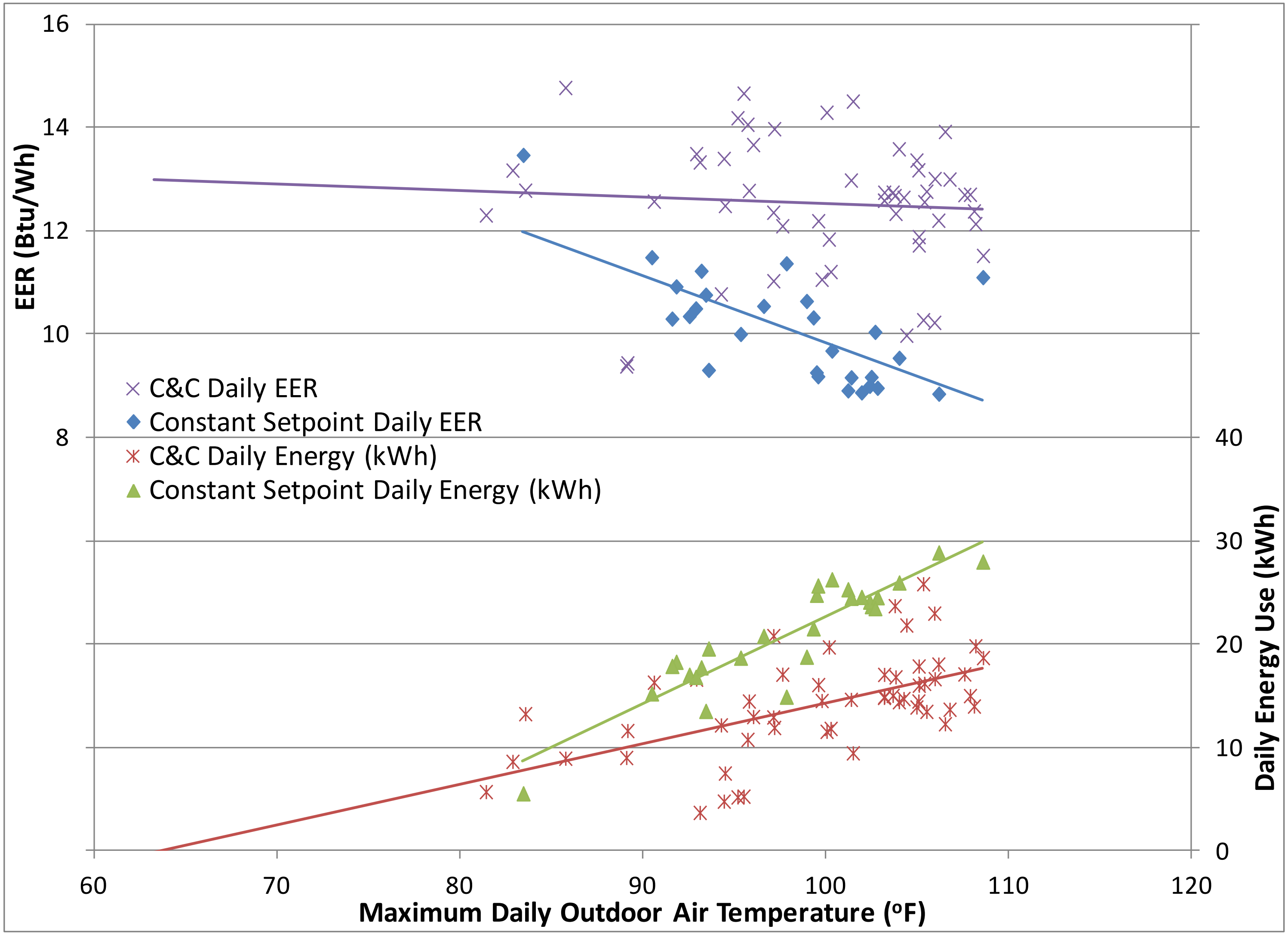
Field Monitoring - Results



Conclusions

- AC pre-cooling effective at reducing or eliminating coincident on-peak demand
- kWh savings difficult to achieve solely with AC pre-cooling…..
- However, real time pricing rate structures can significantly impact economics
- Individual houses will respond very differently to pre-cooling. Efficient envelopes and good glazing are essential prerequisites.

Conclusions

- Alternate strategies that directly charge house mass or utilize outdoor air have demonstrated significant energy & demand savings.
- Customized approaches tailored to a specific house, the day’s predicted weather, occupant patterns, and the utilities predicted demands.
- Current efforts by EcoFactor (Nevada Energy) and NEST (City of Austin)
  - Learning the house appears to be highly valuable

How Does This Support ZER Homes?

- Although residential market is diffuse, huge potential to improve AC load factor
- Improved interconnection between ZER homes and the grid will facilitate optimization of both ZER home efficiency and load profile
- ZER homes better adapted for pre-cooling strategies