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# Case Studies in Advanced Thermostat Control for Demand Response

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*With updates (2008)*



*Case Studies in Advanced Thermostat Control for Demand Response*  
J. Lopes; AEIC Load Research Conference – St. Louis, MO; July 2004/Updated 2008

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## Introduction

- **More Demand for Demand Response Programs!**
  - Utilities no longer control supply in many states due to deregulation
  - Need for more flexibility and “distributed” options like demand-side peak reduction
  - Regulators, consumers concerned about shortages and price spikes
  - Transmission constraints



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# Introduction

- **What are the best options for proven demand response?**
  - In Summer-peaking systems, air conditioning loads are the primary driver of peaks
  - Air conditioning is somewhat discretionary
  - New homes have a high degree of air conditioning
  - Nearly all businesses have air conditioning



# Air Conditioning Demand Response

- **Historically, implemented with one-way switches on central A/C systems**
- **New generation of electronic thermostats now available and used by many utilities:**
  - Two-way communications, which ensures verification of signal reception
  - Monitoring and control capability
  - Internet access
  - Interval data (runtime and temperature) available for virtually all sites
  - Customer overrides can be tracked/time-stamped



# Case Studies

- **AEG experience with six utilities:**
  - LIPA (NY), Southern California Edison, Consolidated Edison, Aquila, **Colorado Springs Utilities, FPL Energy**
  - Use the same technology electronic programmable thermostats with override
  - Thermostat with two-way communications and data access via public pager networks
  - Control of either duty cycle or temperature
  - Internet access
  - Hourly runtime and temperature data available for virtually all sites
  - **Actual programming (7-day, 4-period setpoints), mode (auto, cool, heat) and status (hold on/off: programming used/not) available**

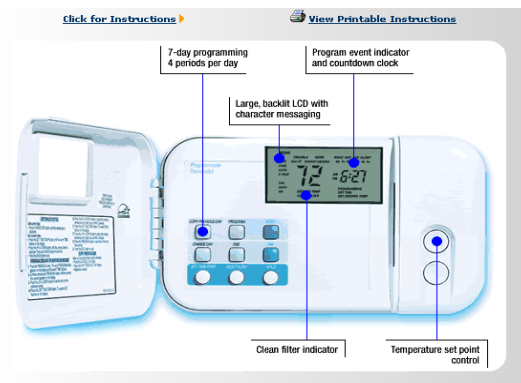


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# Controllable Thermostat

Programmable thermostat with 2-way pager access



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## Case Studies

- **Long Island Power Authority (LIPA)**
  - Since 2001, Central A/C units in over 20,000 residential, 3,000 small commercial
  - Free thermostat and \$25 (one-time)
  - Customers have thermostat access over Internet
  - LIPA can control up to 7 days from 2-6 pm
  - Customer can override without penalty



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## Case Studies

- **Consolidated Edison Company of NY**
  - Since 2002, now over 15,000 thermostats at residential sites
  - Free thermostat and \$25 (one-time)
  - Thermostat access over Internet
  - Controls when NY ISO requests (typically peak summer days 1-6 pm)
  - Customer can override without penalty
  - **Small Commercial Pilot Program (2004)**
    - Same terms except scalable one-time incentive (\$25 per 3 ton increment)
    - By 2008, over 6,000 thermostats



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## Case Studies

- **Southern California Edison (SCE)**
  - Since 2002; target of 5,000 small commercial sites (achieved in 2003); approved for 2004
  - Free thermostat plus \$300 annual incentive, with \$5 penalty for each override
  - Control varies from 1-6 pm; in 2003 up to 20 control days allowed
  - Logger data on sample confirmed runtime data accuracy (within 3%)



## Thermostat Control Options

- **Duty Cycle Control**
  - Limits runtime to a fixed percentage (e.g. 50% control limits to 15 minutes off per half-hour)
  - LIPA and Con Edison typically used 50% duty cycle control
- **Setpoint Temperature Control**
  - Increase current A/C thermostat setpoint by a specific value (e.g. 4 degrees)
  - SCE typically used 4 degree temperature control



## DLC Impact Evaluation

- **Hybrid Comparison Day Analysis**
  - Use best comparison day, based on closest day with similar weather
    - Temperature, humidity, heat build-up
    - Patterns change over course of summer
    - Not cost-effective to collect every day
  - Compare baseline and control day
    - 2-3 hours before control hour should match closely
  - Small Adjustment may be needed to match up

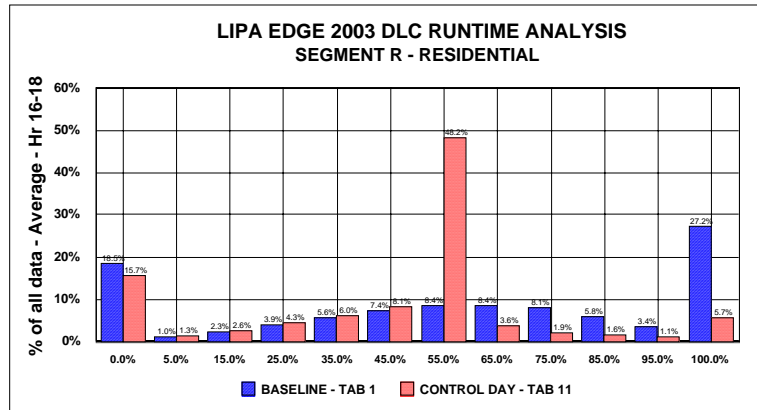


## Duty Cycle Control Case

- **LIPA (NY) and Con Edison**
  - Use 50% Duty Cycle Control
  - Both residential and commercial sites
  - Typically control during afternoon utility peak period (1-6 pm or 2-6 pm)
  - Allow overrides without penalty
  - Can confirm control and monitor overrides



# Duty Cycle Control Case



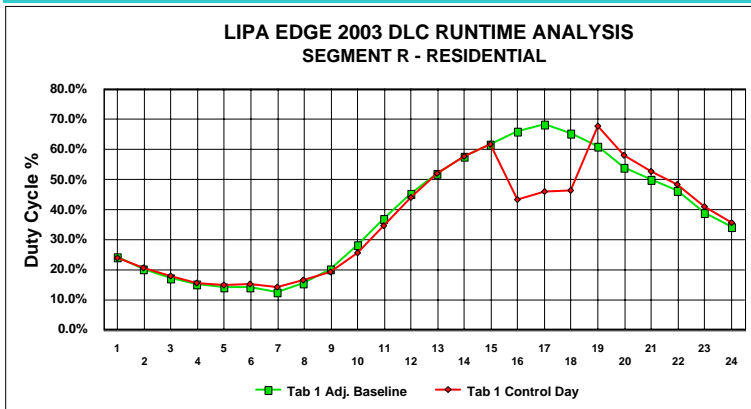
15-18% off; 25% of baseline @ 100%; only overrides over 55%



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# Duty Cycle Control Case



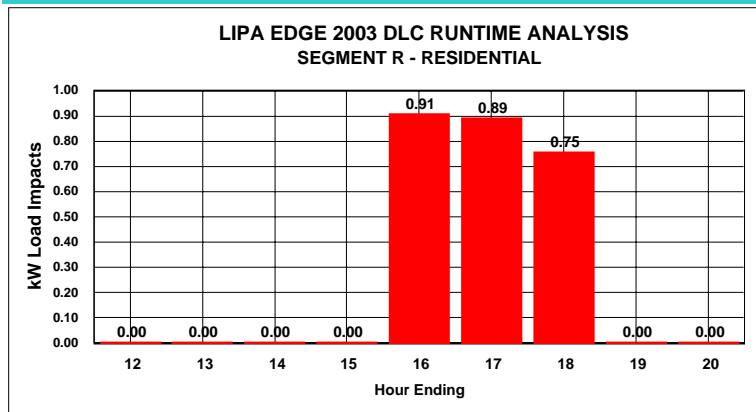
Control 3-6 pm; Some "payback" after control ends



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# Duty Cycle Control Case

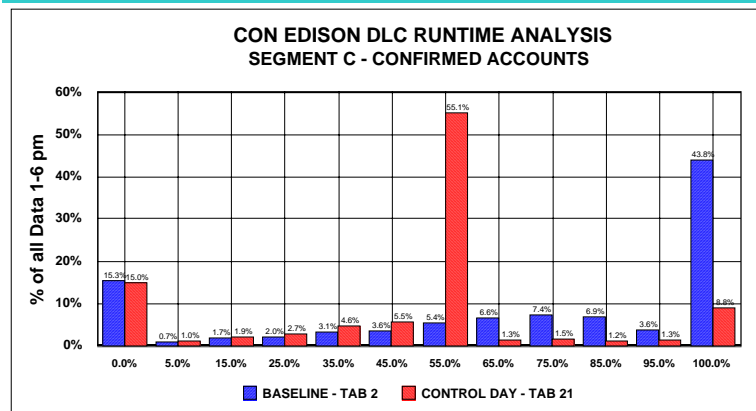


Impacts reduced over time mainly from increased overrides



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# Duty Cycle Control Case

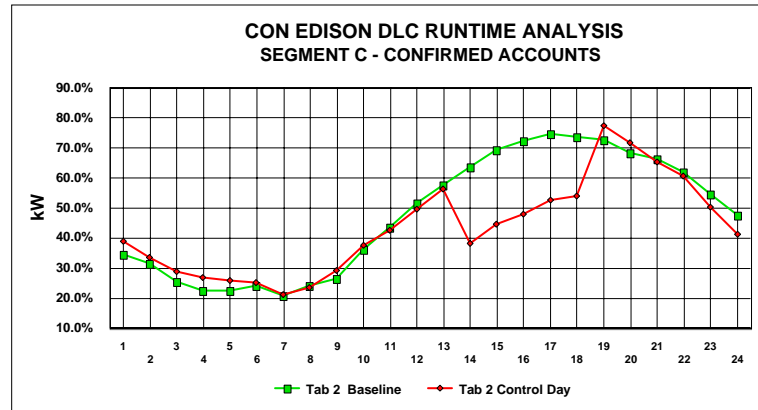


Residential: 15% off; 44% of baseline @100%



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# Duty Cycle Control Case



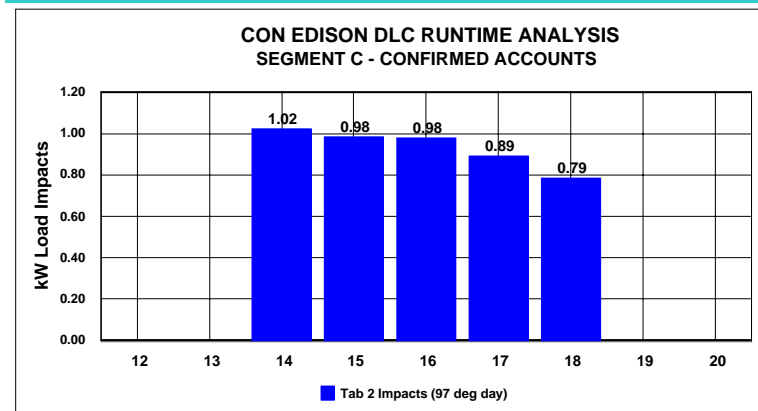
Residential 1-6 pm control - some "payback" after control ends



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# Duty Cycle Control Case



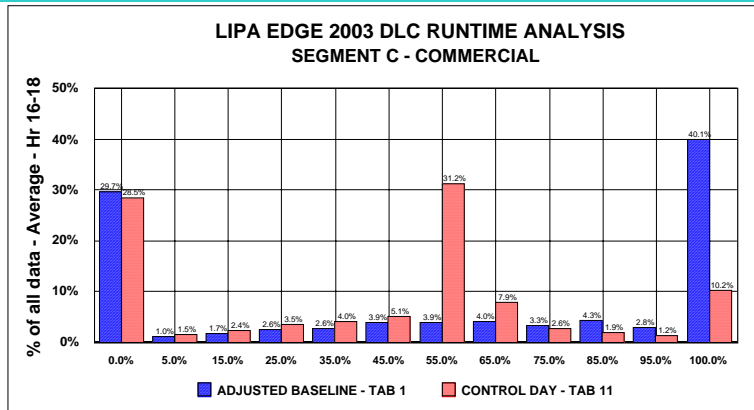
Impacts reduced over time mainly from increased overrides



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# Duty Cycle Control Case

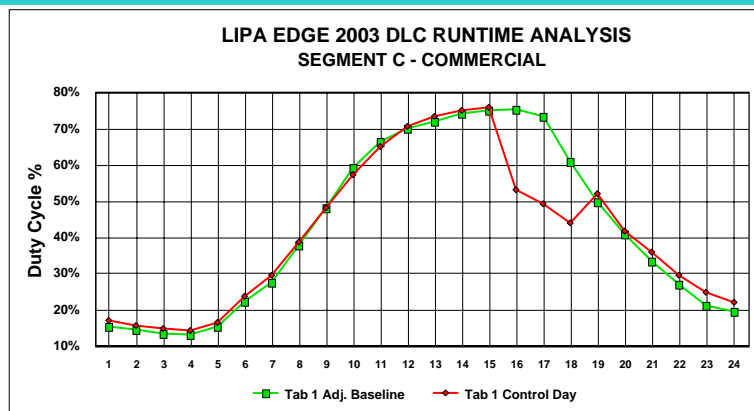


Commercial: About 40% @100%, nearly 30% of units were off



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# Duty Cycle Control Case

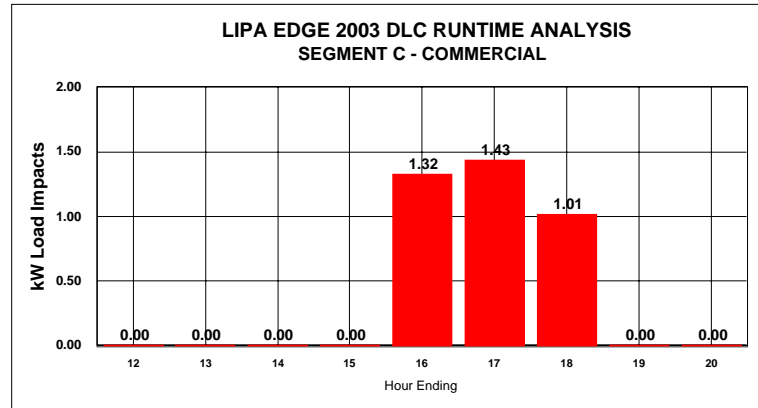


Control 3-6pm; No observed payback



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## Duty Cycle Control Case



Impacts reduced over time mainly from declining loads



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## Duty Cycle Control

- Only effective on customers whose base duty cycle (runtime) exceeds limit (e.g. 50%)
- Impacts are larger on more severe days as more customers exceed the duty cycle limit – more suited to emergency operation
- Impacts are more consistent and maintained for a longer period
- Potentially more severe on some customers than others, such as those with undersized systems
- Easy to identify overrides from runtime data



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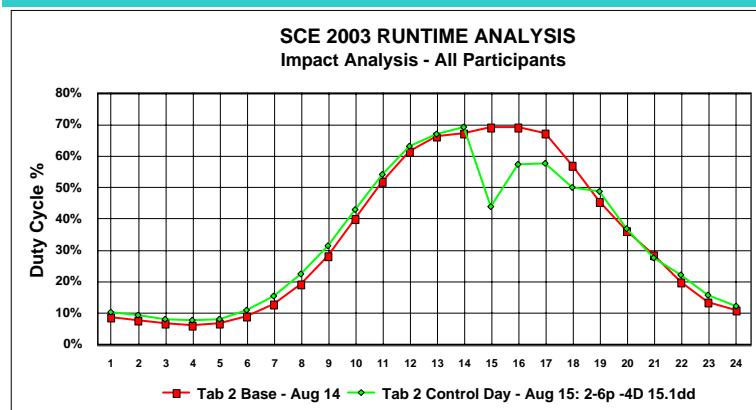
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## Setpoint Temperature Control Cases

- **Southern California Edison (2003)**
  - Thermostat setpoint increased
    - #1: Aug 12 (3-5, 2 deg.) – 96 degrees max
    - #2: Aug 15 (2-6, 4 deg.) – 98 degrees max
    - #3: Aug 18 (2-4, 4 deg.) – 88 degrees max
  - About 4,400 runtime data points each day (all commercial sites)



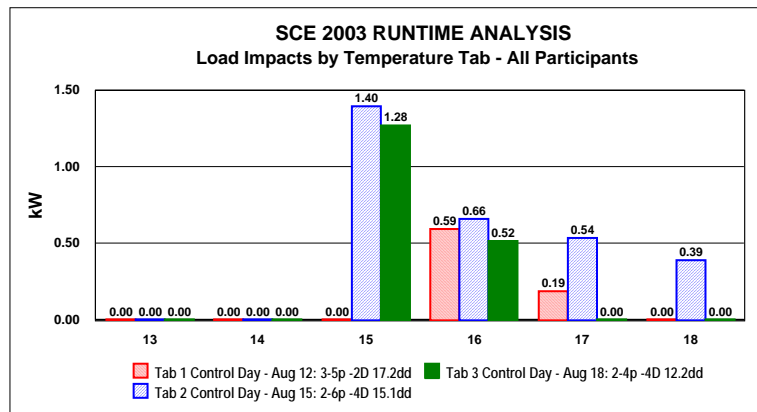
## Setpoint Temperature Control Cases



98° max day; 4° setpoint change 2-6pm, no payback



# Setpoint Temperature Control Cases



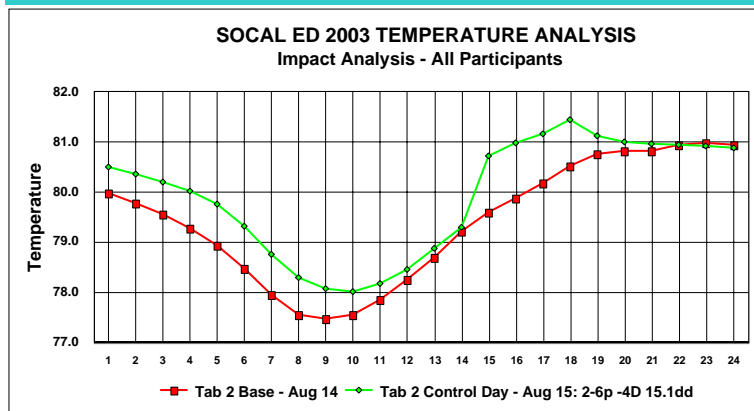
RED (96° max) 3-5pm, 2° control; BLUE (98°) 2-6pm, 4° control;  
GREEN (88° max) 2-4pm, 4° control



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# Setpoint Temperature Control Cases



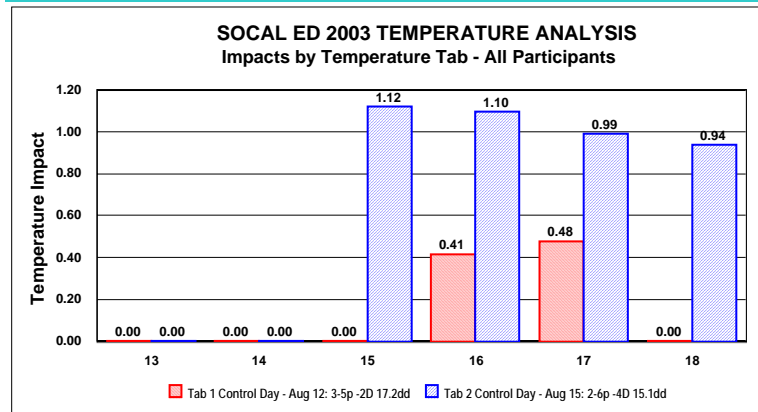
98° Day (2-6pm, 4° control) hourly indoor temperature impacts



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## Setpoint Temperature Control Cases



RED (96° max) 3-5pm, 2° control; BLUE (98°) 2-6pm, 4° control –  
Indoor Temperature Impacts



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## Setpoint Temperature Control

- Affects all customers equally in terms of relative comfort
- Impacts are consistent across a range of weather conditions – more suited to frequent use as a load reduction option
- Impacts are more pronounced in first hour and decline in subsequent hours
- Potential for customers to pre-cool and reduce impact achieved
- Could penalize customers already conserving
- Difficult to identify overrides from runtime data, but should see fewer overrides



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## Duty Cycle vs. Setpoint Control

- **Duty Cycle Control**
  - More effective for longer periods
  - More suited to residential
- **Temperature Setpoint Control**
  - More consistent across participants
  - Higher initial hour impacts
  - More suited to commercial (declining PM loads)



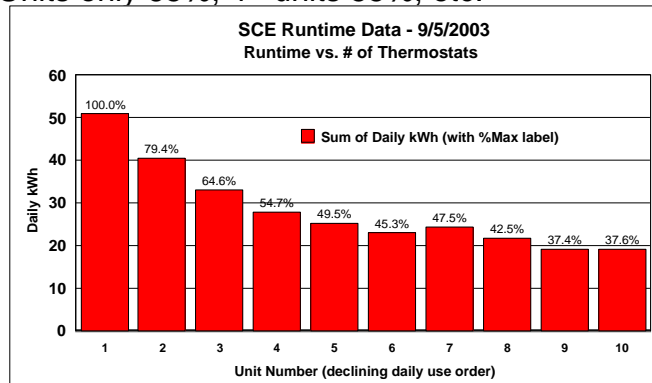
## Free Riders

- **Some Participants off during control period:**
  - App. 15-18% of residential units off on hot days
    - Mostly people not home, on vacation or prefer not using their A/C
    - Some multiple units (e.g. 2<sup>nd</sup> Floors) are 31% of LIPA; 81% of all units are single/1<sup>st</sup>
  - App. 22-30% of comm. units off on hot days
    - Multiple units are 60% of all units in SCE; 60% of units are single/1<sup>st</sup>; 21% are 2<sup>nd</sup> units



## Free Riders: Multiple Units

Commercial: 2<sup>nd</sup> Units use only 79% of Primary Units;  
3<sup>rd</sup> Units only 65%, 4<sup>th</sup> units 55%, etc.



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## Free Riders

- **Could only be reduced by pre-qualifying units at a site to increase average impacts**
  - Potential Discrimination Issue
  - Minimum summer use billing increment level
  - Residential sites could exclude 2<sup>nd</sup> floor if only bedrooms (lower use and less coincident)
  - Commercial sites would require evaluation of likelihood of little-used units
- **Free Riders are generally unavoidable, but must be factored into any assessment of potential impacts and costs**



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# SUMMARY

- **For Residential programs**
  - Duty cycle control works best, especially for only a few control days per season
  - Could reduce free riders by target marketing to higher summer use customers
  - Temperature setpoint control would work best for energy conservation improvements (by utility or customer)
  - Most customers (77%) use programmable features of thermostats themselves



# SUMMARY

- **For Commercial programs**
  - Temperature setpoint control works best if many control days or short-duration curtailments – should also reduce overrides
  - Duty Cycle control works best for more hours of sustained load reduction
  - Runtime data could provide good source of baseline A/C load profiles by business type
  - Targeting specific business types would be advisable

