

# WCEC Year-In-Review Celebrating 10 Years

Mark Modera  
Western Cooling Efficiency Center  
May 15<sup>th</sup>, 2017





# THANK YOU TO OUR AFFILIATES & PARTNERS



## WCEC Affiliates Forum: Celebrating 10 Years



# Today's Program

- » 9:00-10:15am: WCEC - Celebrating 10 Years  
Mark Modera, Director, Western Cooling Efficiency Center
- » 10:15-11:30am: What Is the Future of Upstream HVAC Programs?  
Paul Thomas, *Senior Energy Programs Advisor, San Diego Gas and Electric*  
Paul Kylo, *Director, CLEAResult*  
Richard Lord, *Senior Fellow, Carrier*
- » 11:30-1:00pm: Lunch: Flexible Tour and Poster Session
- » 1:00-2:30pm: Future of Refrigerants  
Chun-Cheng Piao, *VP of Technology Alliances, Daikin*  
Steve Kujak, *Director Next Generation Refrigerant Research, Trane*  
Glenn Gallagher, *Air Pollution Specialist, California Air Resources Board*
- » 2:30-3:00pm: Next Steps in Evaporative Cooling: Energy+ Modeling Tools  
Jonathan Woolley, *Associate Engineer, WCEC*
- » 3:00-3:15pm: Break
- » 3:15-4:15pm: Emerging Technologies Program Update  
Jerine Ahmed, *Senior Engineer, Southern California Edison*  
David Hungerford, *Demand Response and Behavior Research, California Energy Commission*
- » 5:30-8:00pm: Complimentary Dinner— Bicycle Hall of Fame, Davis, CA

# 10 Years of History at WCEC

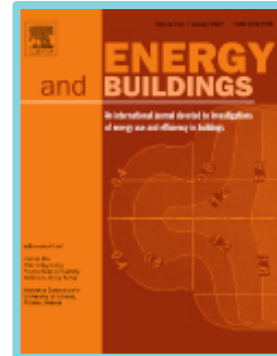


WCEC recruits Director Mark Modera  
First Affiliates Forum



Coolerado meets WCEC's Western Cooling Challenge

First journal pub: Swimming pools as heat sinks



WCEC graduates first MS student: Nelson Dichter

Honda Smart Home demonstration constructed



Associate Director Vinod Narayanan joins WCEC



WCEC graduates first PhD Student Zhijun Liu



WCEC begins development of aerosol building shell sealing technology and tracer gas flow measurement technology

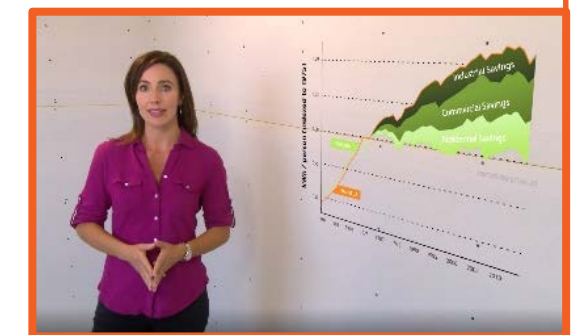
WCEC moves to West Village



Environmental chambers commissioned



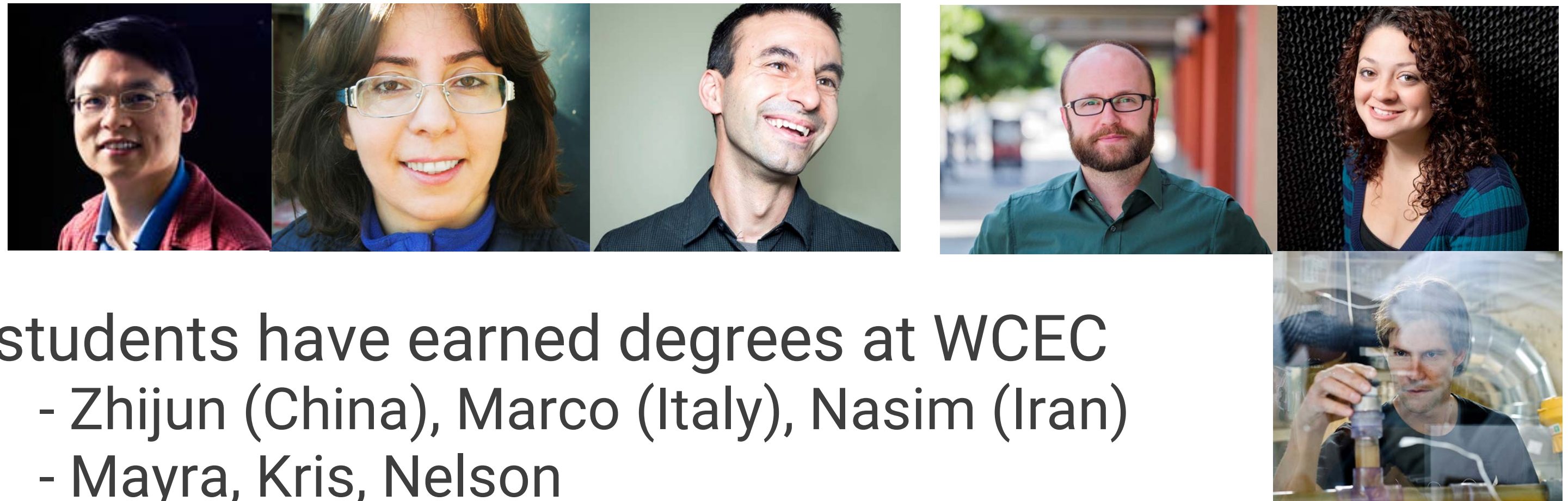
WCEC expands outreach mission to include video production





# First 10 Years: Student Development

- » Created two new courses at UC Davis
  - ECI 125: Building Energy Performance (Civil/Environmental Engineering)
  - EME 164: Introduction to HVAC (Mechanical Engineering)
- » Employed over 50 undergraduate students from around the world
  - UC Davis
  - France
  - Germany
  - India
  - Brazil
- » Six graduate students have earned degrees at WCEC
  - 3 Ph.D. - Zhijun (China), Marco (Italy), Nasim (Iran)
  - 3 Master's - Mayra, Kris, Nelson

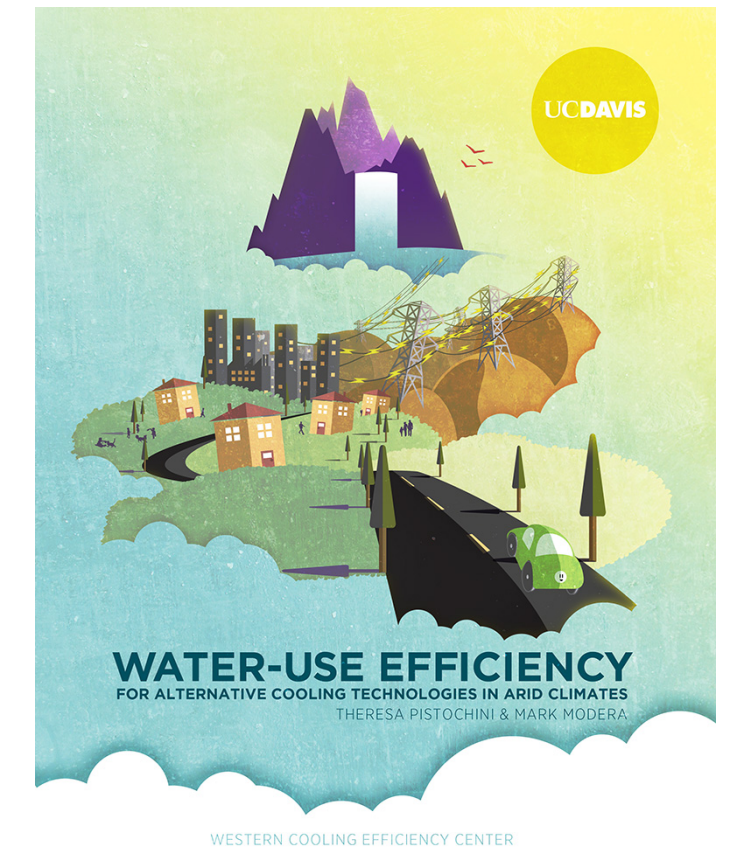
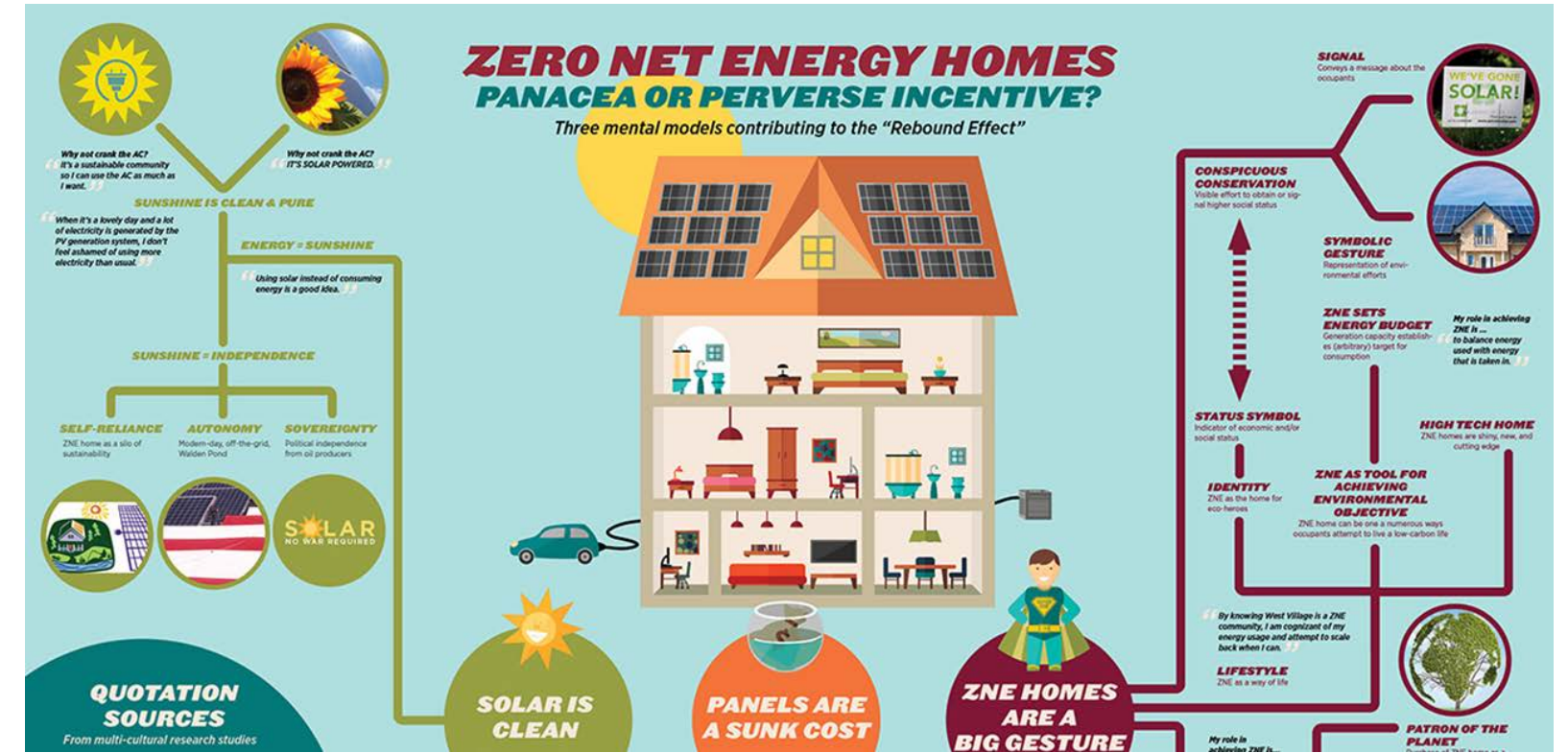




# First 10 Years: Publications

## » 17 Academic Publications

- Evaporative Cooling (2 papers)
- Swimming Pools as Heat Sinks (2 papers)
- Water-Energy Nexus (2 papers)
- Precooling Test Protocol (1 paper)
- Ground Source Heat Pumps (1 paper)
- Aerosols (1 paper)
- Thermostats/behavior (6 papers)
- Duct Leakage (2 papers)





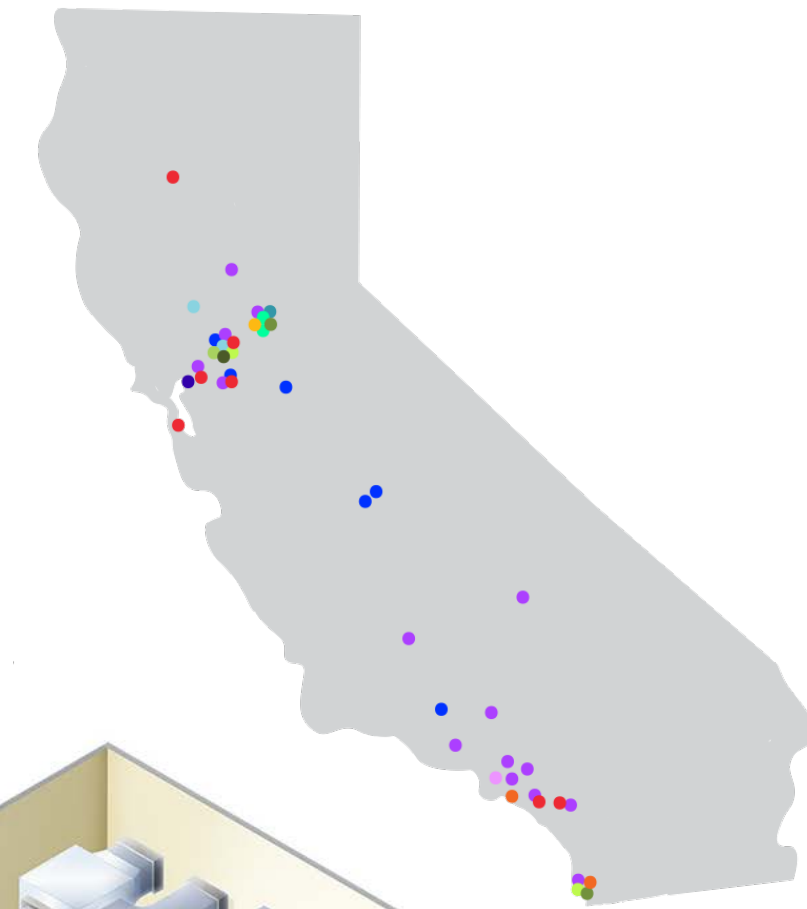
# First 10 Years: Patents

- » Roll-up Radiant Mat
- » Aerosol Sealing of Enclosures
- » Aerosol Sealing of Pipelines
- » Tracer Gas Measurement Tool
- » Dryer Controls
- » System Performance for Heat Pumps

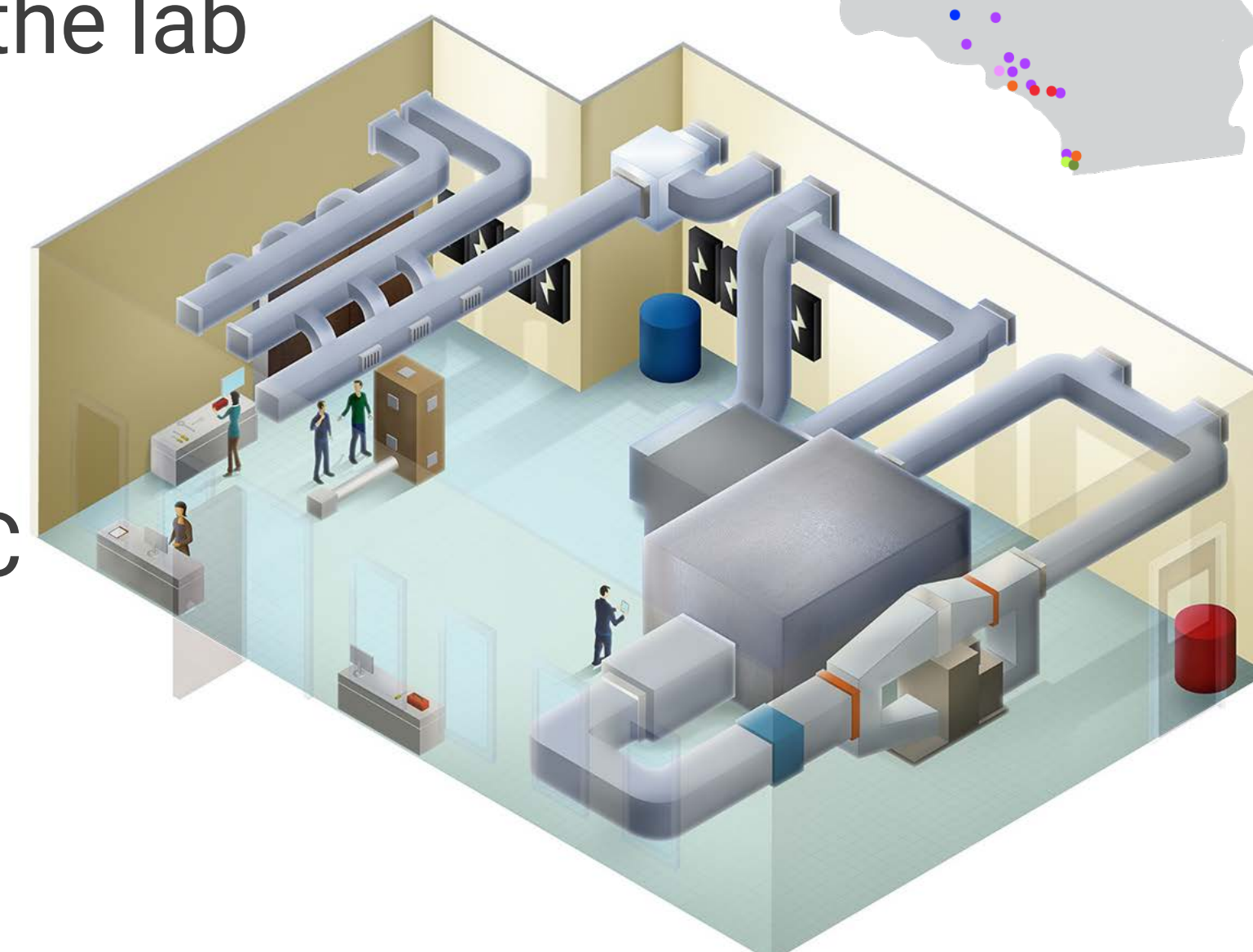




# First 10 Years: Notable Expertise



- » Climate appropriate cooling technologies
  - Evaporative cooling of all sorts
  - Water characterization and management
- » Laboratory testing
  - Unique ability to produce hot dry climates
  - Testing of overall system performance in the lab
- » Field testing
- » Aerosol sealing
  - Buildings and Natural Gas Infrastructure
- » Energy modeling
  - Energy Plus for Hybrid Cooling, NZE/MTLC Optimization
- » Behavioral research
- » Policymaking (ASHRAE, T-24)

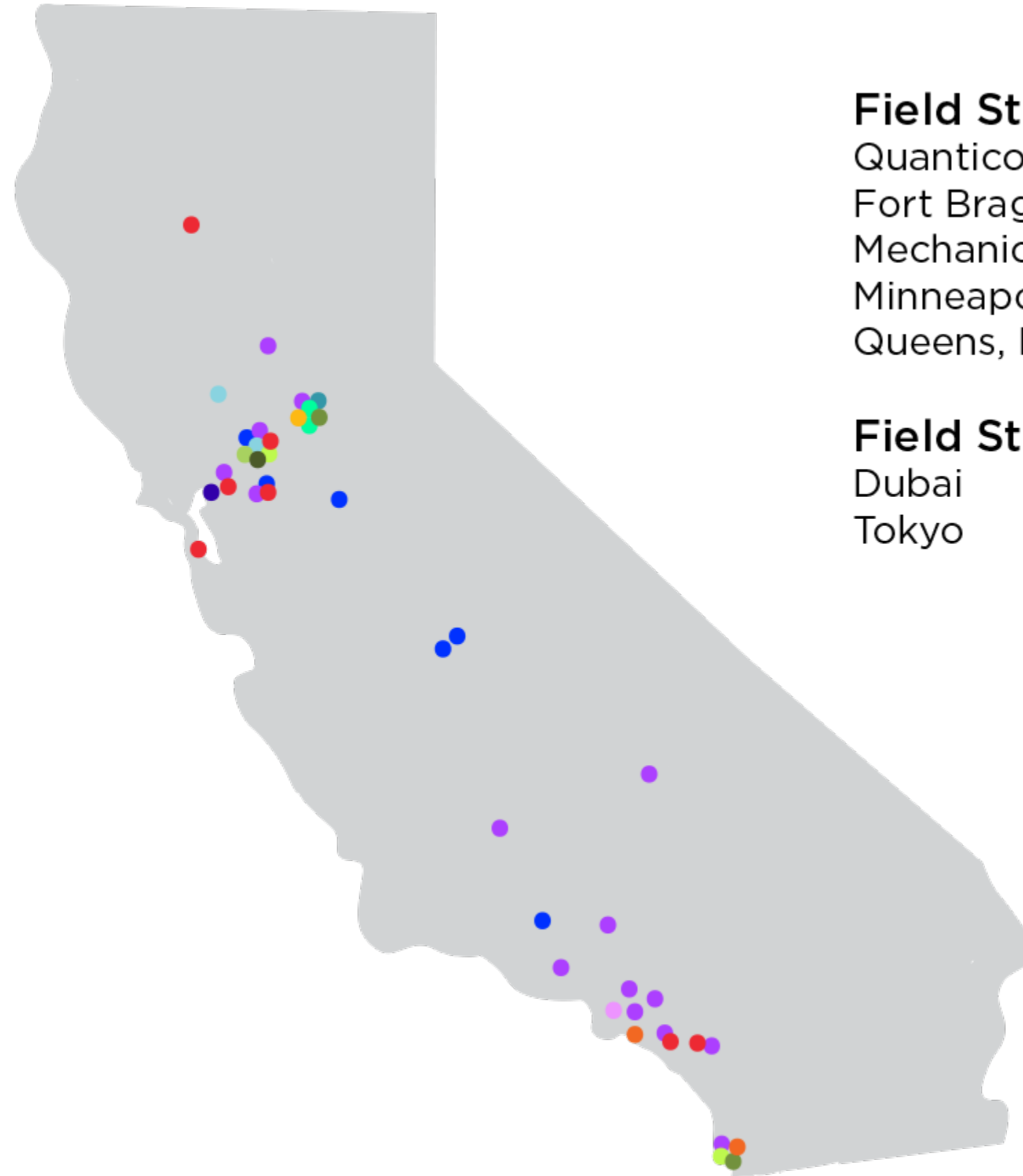




# First 10 Years: Field Test Sites

## Field Studies Across California

- Building shell sealing
- Duct Sealing and Air Balancing
- Evaporative Cooling Technologies
- Gas Engine Heat Pump
- Ground Source Heat Pump
- Polymer Bead Laundry
- Radiant Cooling
- Smart Thermostats
- Solar water heating
- Swimming Pools as Heat Sinks
- Variable Refrigerent Flow Systems
- Variable Speed RTU
- Ventilation/Economizer Retrofit
- Ventilation in Schools



## Field Studies Across the U.S.

- Quantico, VA
- Fort Bragg, NC
- Mechanicsburg, PA
- Minneapolis, MN
- Queens, NY

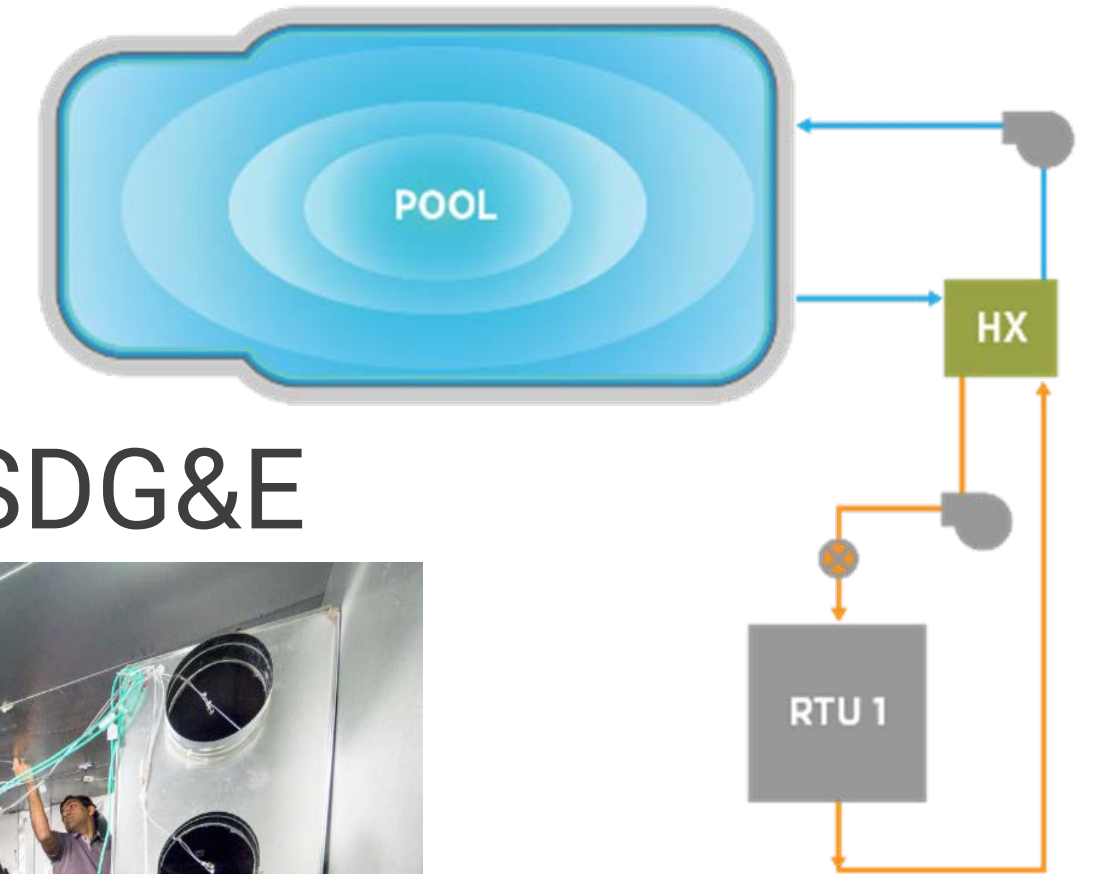
## Field Studies Around the World

- Dubai
- Tokyo



# CURRENT Project Highlights

- » Climate Appropriate Cooling
  - Evaporative Pre-Coolers - SCE
  - Cow Cooling – CEC (Animal Science Department)
- » A/C Heat Rejection Swimming Pools – CEC and SDG&E
  - Residential ⇔ Hotels
- » K-12 Schools (School of Public Health)
  - Energy-Efficient HVAC and IAQ
- » Indoor Farming – Xcel (Plant Science)
- » Aerosols
  - Production New Construction – DOE
  - Non-Residential Buildings – DOD
  - IoT Leakage Diagnostic - NIST
- » Outreach and Training
  - Title-24 Training Videos - CEC





# Evaporative Pre-Coolers for Vapor Compression Systems

## » What is an Evaporative Pre-Cooler?

- Cools Outdoor Air Entering Air Conditioner Condensers by Evaporative Cooling
- Air Conditioner power draw decreases, and cooling capacity increases

## » SCE-Supported Effort at WCEC (PG&E and SMUD supporting parallel efforts)

- Field Testing of Performance
- Development of ASHRAE Test Standard (for rating alternative products)
  - **Proposed Standard 212 went out for Public Review on April 28<sup>th</sup>**

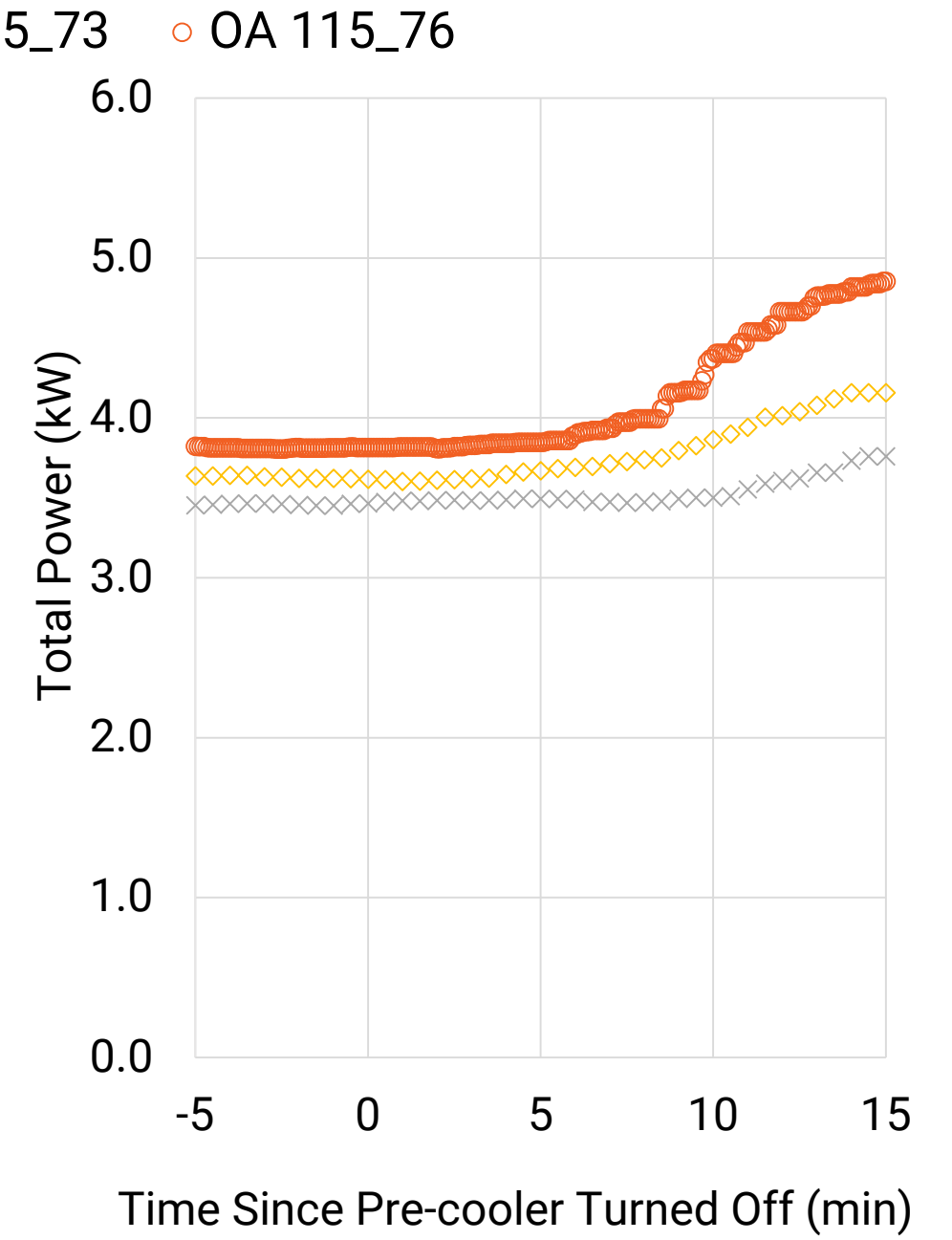
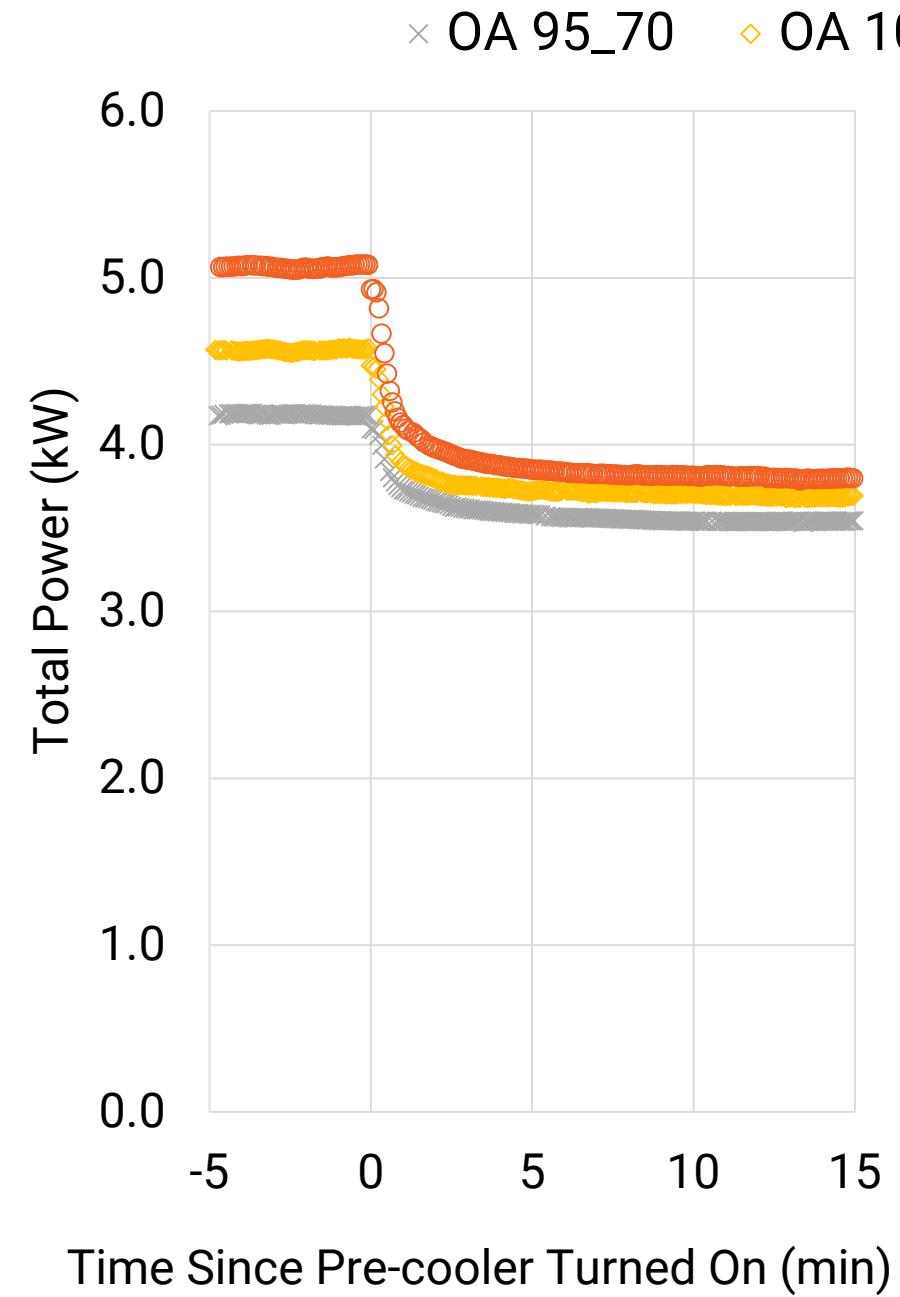
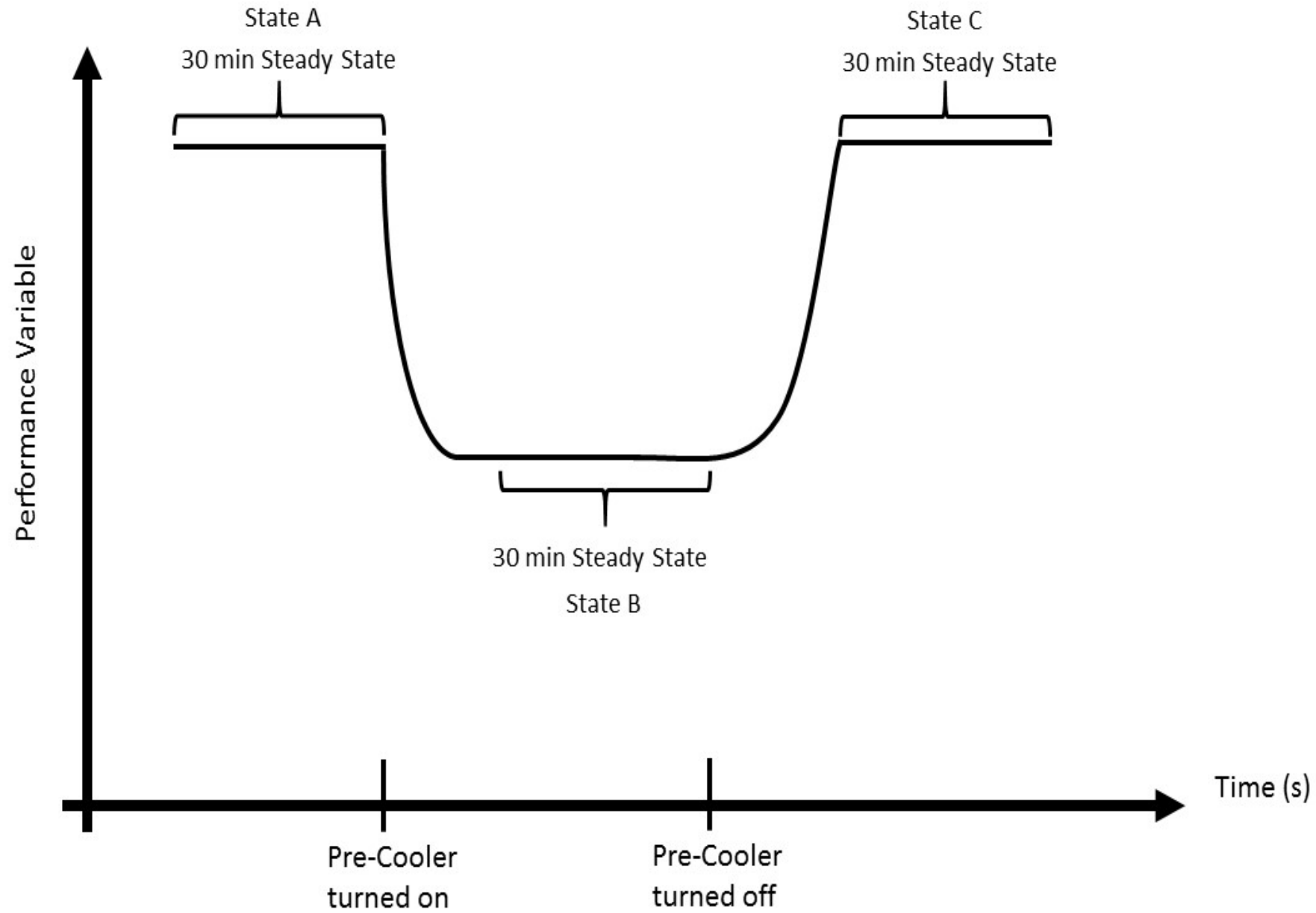
## » Potential for Dispatchable Pre-Coolers (WCEC for SCE)

- No disruption to customer experience
- Minimal water-use impact
- Lab testing completed
- Planning field test on Walmart stores this summer





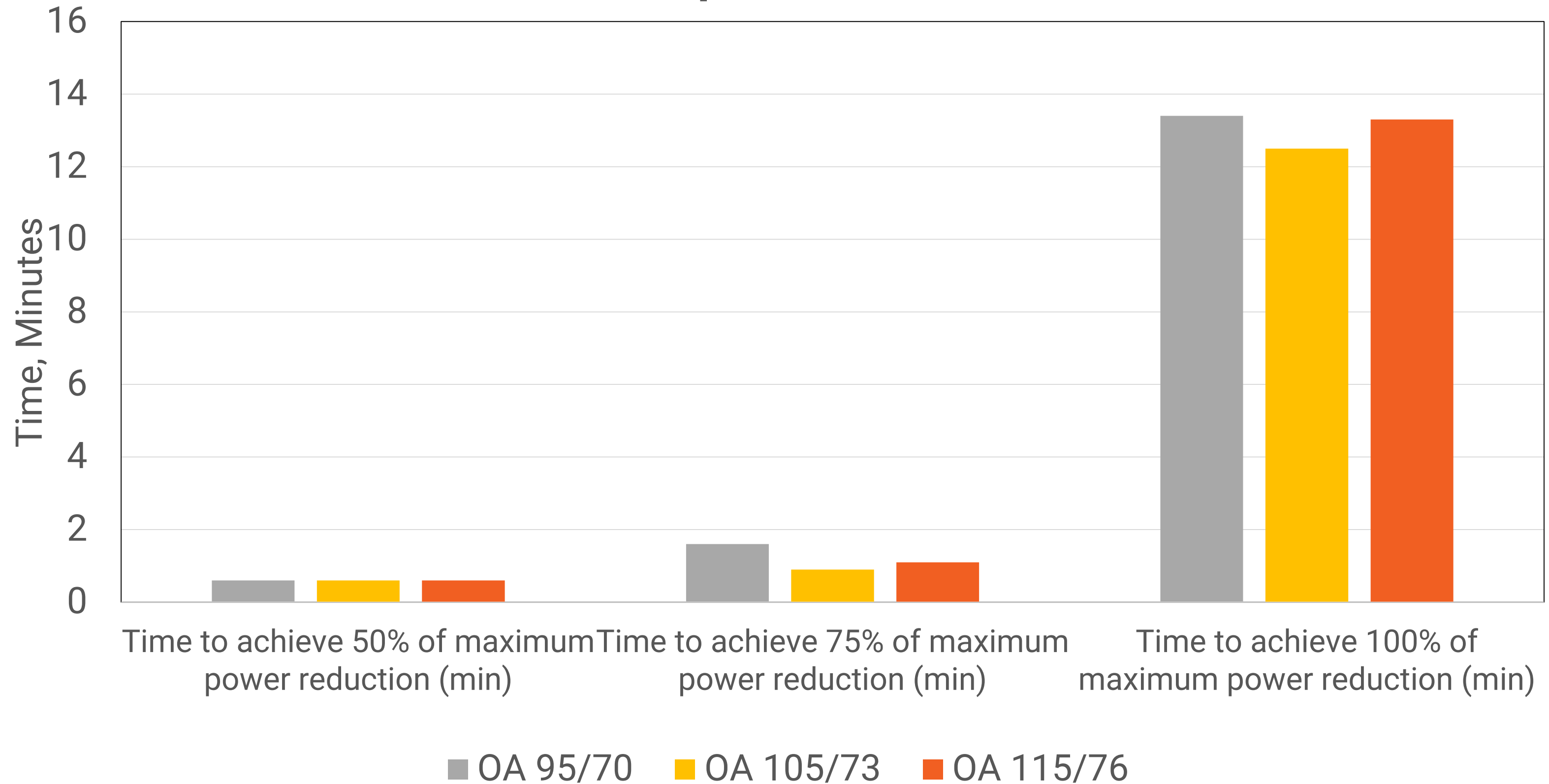
# Dispatchable Evaporative Pre-Coolers - Lab Testing





# Dispatchable Evaporative Pre-Coolers – Lab Testing

## Response Time

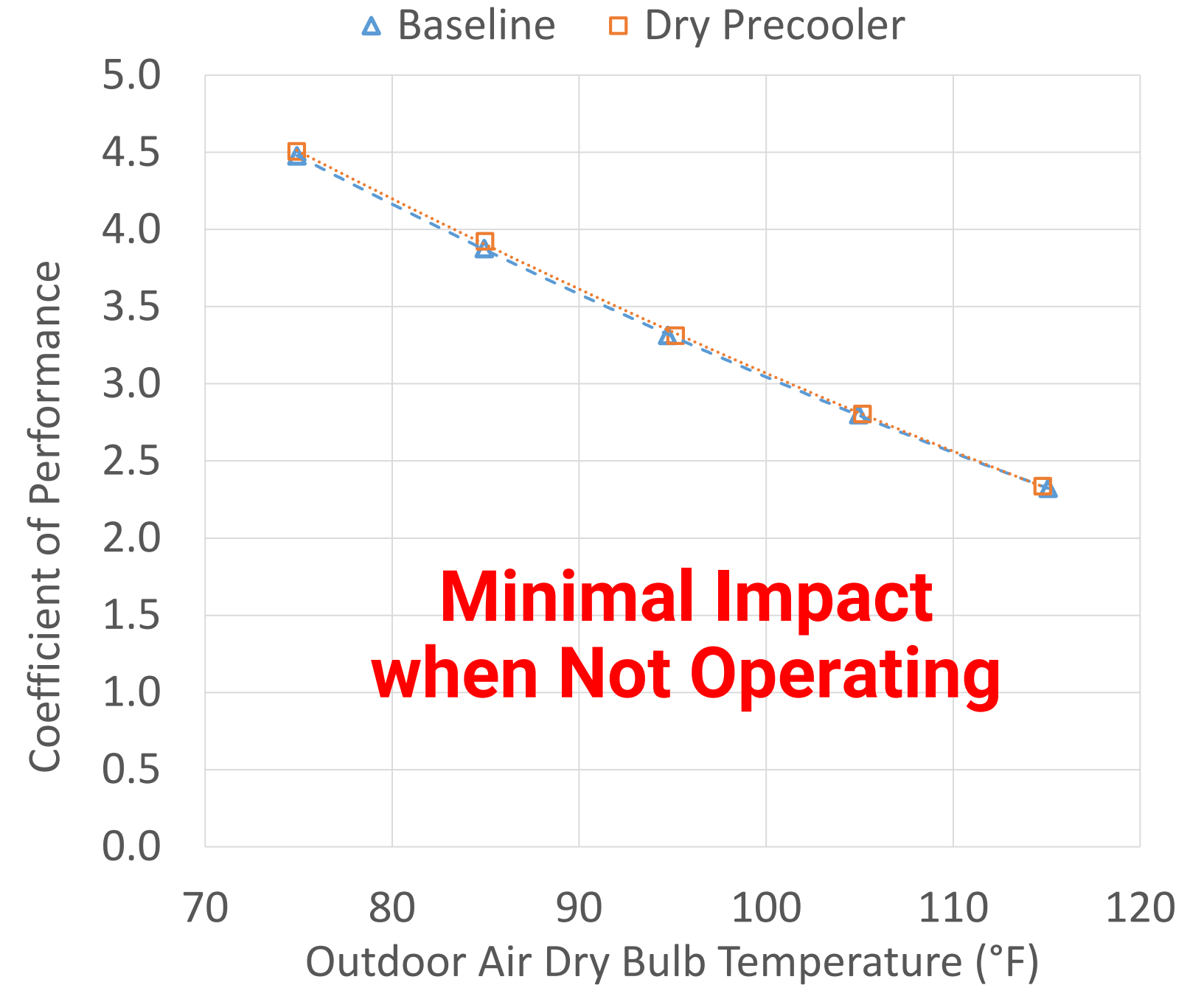
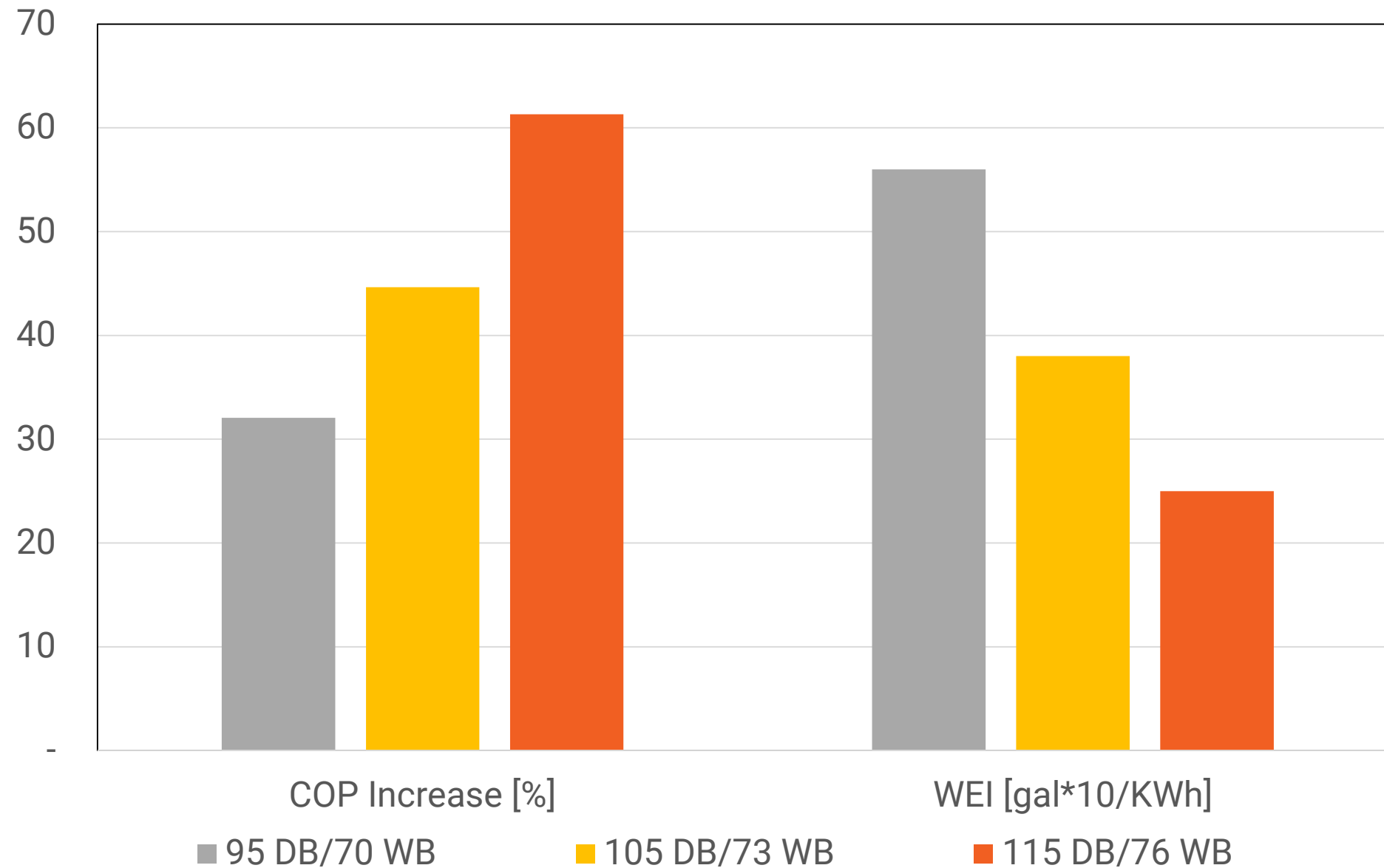




# Dispatchable Evaporative Pre-Coolers – Lab Testing

## Water Efficiency and Off-Time Impacts

Electricity and Water Performance



**Best Impact and Water Efficiency at Peak Conditions**



# Dispatchable Evaporative Pre-Coolers – Field Testing

## Field Test in Southern California

- » Existing Installation of Dual Evaporative Pre-Coolers (5 – 20 ton RTUs)
- » Additional Planned Installation of Condenser Air Pre-coolers on Six RTUs (total 50 tons)
- » Controls will dispatch entire rooftop of pre-coolers
- » WCEC will characterize transient demand impacts



# Cow Cooling with UC Davis Animal Science

- » Funded by California Energy Commission's EPIC Program
- » Develop optimal approach to cool dairy cows under California summer climate conditions
- » Objectives:
  - Use significantly less energy and water than current dairy cooling systems
  - Demonstrate, on a pilot scale, two innovative approaches to cooling dairy cattle
- » Project Team:
  - UC Davis Western Cooling Efficiency Center (led by PI Narayanan)
  - UC Davis Department of Animal Science (led by Cassandra Tucker)
  - Integrated Comfort (Equipment Manufacturer)
  - Jim Bruer (Dairy Consultant)





# Cow Cooling with UC Davis Animal Science



» California has:

- 1,450 Dairies
- 1.78 million dairy cows
- Mostly located in the central valley



- » Average CA cow produces over 8 gallons of milk each day
- » Production generates a lot of metabolic heat

# Cow Cooling with UC Davis Animal Science

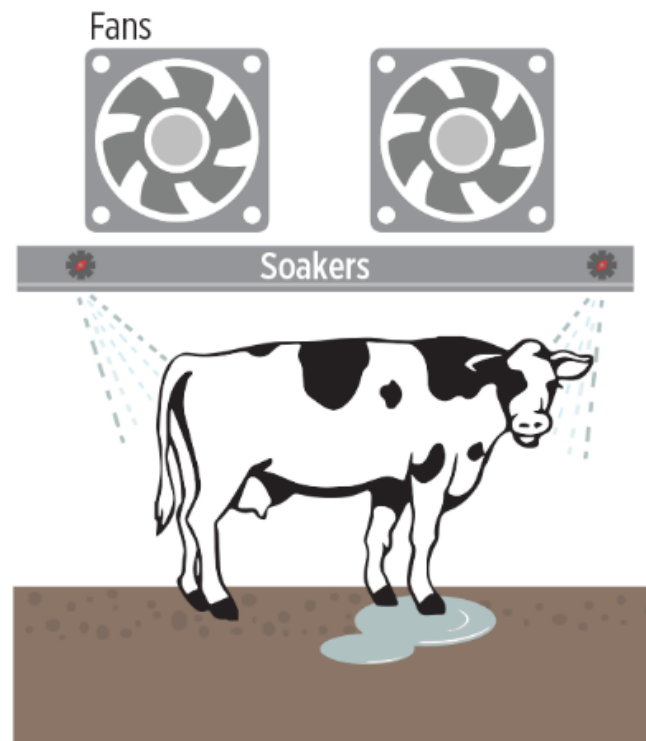
## What Happens If Heat Load is Not Managed



- ↑ Body temperature
- ↓ Milk production
- ↓ Reproduction/fertility
- ↑ Disease risk
- ↑ Mortality



# Cow Cooling with UC Davis Animal Science



BASELINE APPROACH

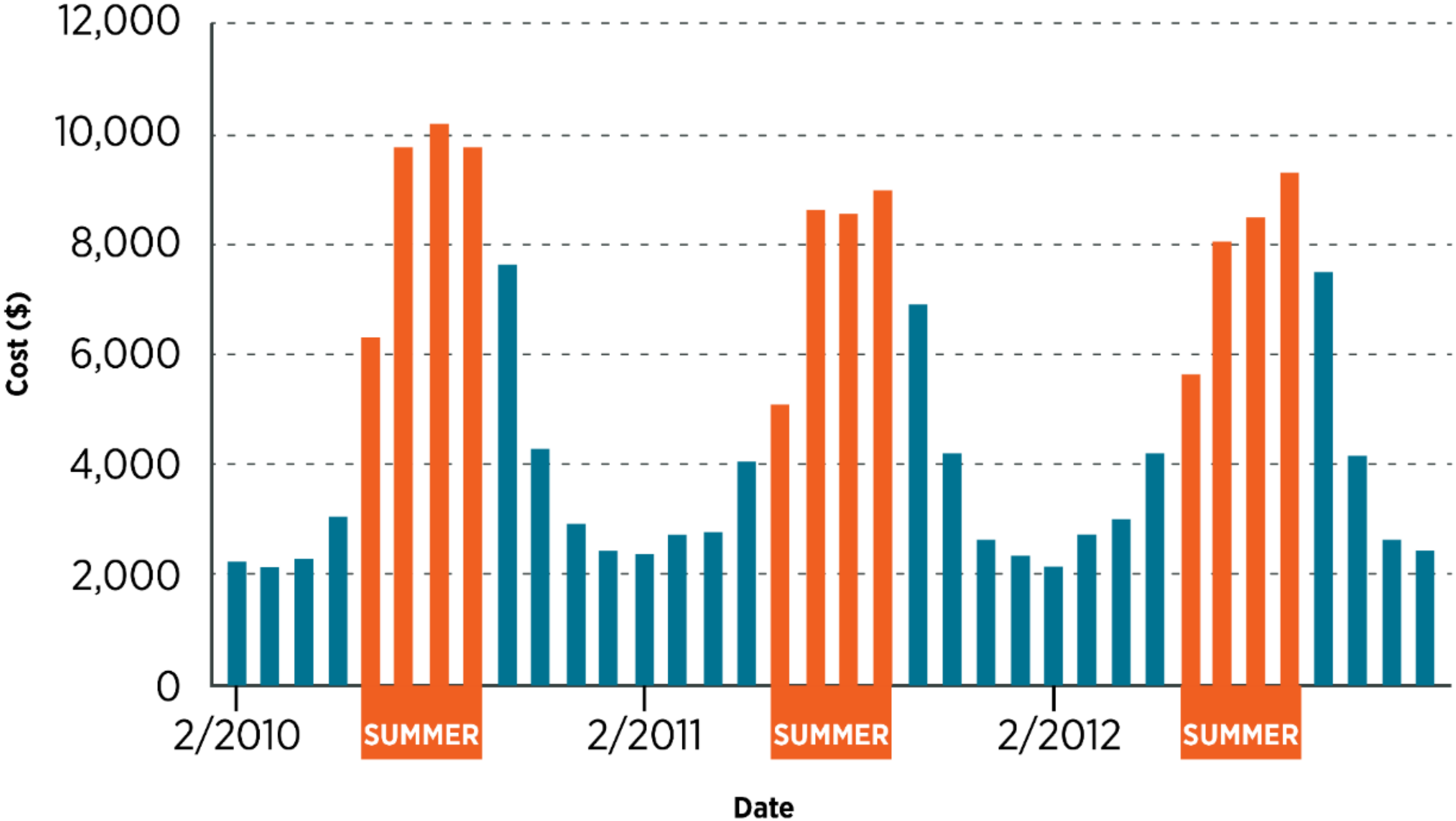


- » Sprinklers over feed bunk, milking parlor
- » Fans in bedding area, milking parlor
- » In top 3 water uses at a dairy



# Cow Cooling with UC Davis Animal Science

## Energy Costs for a California Dairy

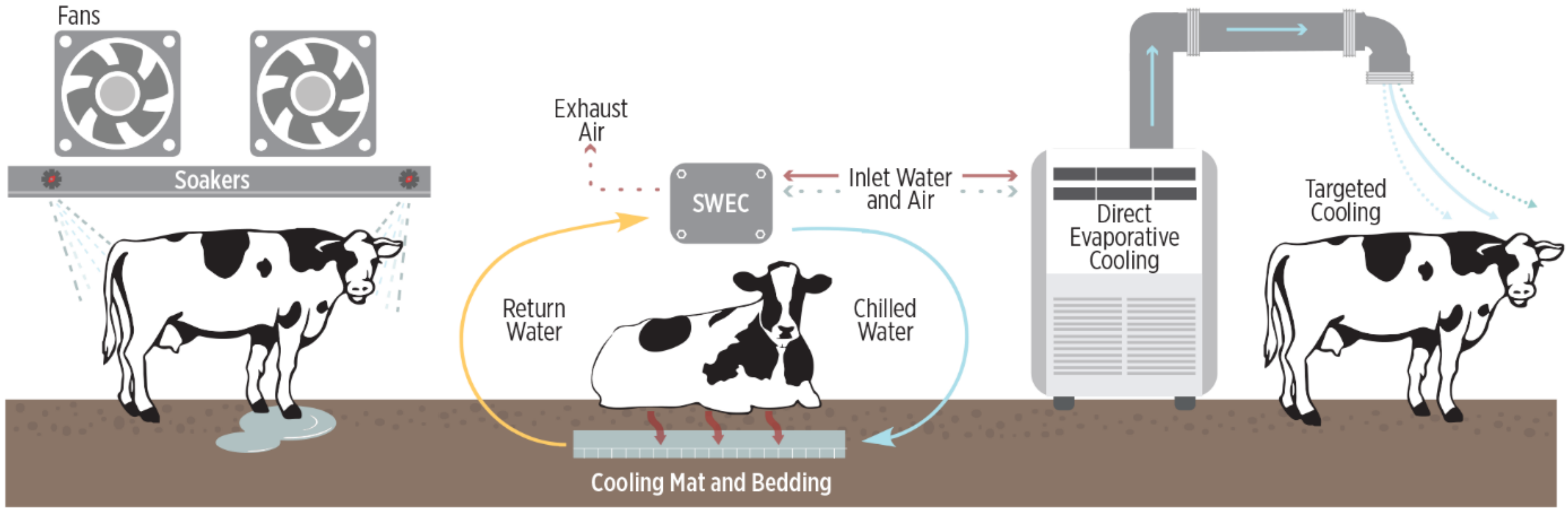


*Energy costs at California's dairies peak in summer*



# Cow Cooling with UC Davis Animal Science

## Proposed Solution



BASELINE APPROACH

(A) CONDUCTION COOLING

(B) TARGETED CONVECTION COOLING



# Cow Cooling with UC Davis Animal Science



## STATUS

- » Currently Commissioning Test on Cows at UC Davis Campus
- » Planning Field Test in Tulare
- » Goal is **30-40%** Energy and **70-80%** Water Savings



# Swimming Pools as Heat Sinks



Initial Model Validation (2009)



Residential Demonstration (2010)



Commercial Demonstration (2017)

- » Demonstration at Wyndham Hotel in San Diego (SDG&E)
  - Supplement pool heating with heat rejection from A/C
- » Measure reduction in natural gas use to maintain pool temperature
- » Measure A/C performance improvement over air-side heat rejection



# Effective Energy-Efficient School Ventilation

## Project Goal

Assess Current Ventilation/IAQ Performance and Potential Improvement for HVAC Retrofits in Schools

## Objectives:

- Characterize HVAC Retrofits Completed between 2013-2016 (including satisfaction surveys)
- Deploy and Test Energy Efficient HVAC Retrofits
- Use Simulations to Investigate Implications of Experimental Findings

## Project Team:

- UC Davis Western Cooling Efficiency Center (including behavioral research)
- UC Davis Department of Public Health Sciences
- UC Davis Energy Efficiency Center
- Lawrence Berkeley National Laboratory

## Technology partners

- Trane, Geary Pacific/Bard, IQ Air



# Effective Energy-Efficient School Ventilation



## Research Questions

- Ventilation Rates
  - Higher rates reduce CO<sub>2</sub> levels
  - Higher rates increase Heating and Cooling needs
  - Higher rates increase outdoor pollutant entry (particles and ozone)
  - OA filtration increases fan power
- Analysis of Trade-offs

## Preliminary Phase-I Results

- Five school districts tested to date
- Large range of results

# Effective Energy-Efficient School Ventilation

## Preliminary Phase-I Results

- Two Types of Equipment
  - RTUs and Wall-Mounted units
  - One per classroom

## Vertical Wall Mount Units

Roof Top Unit (RTU)

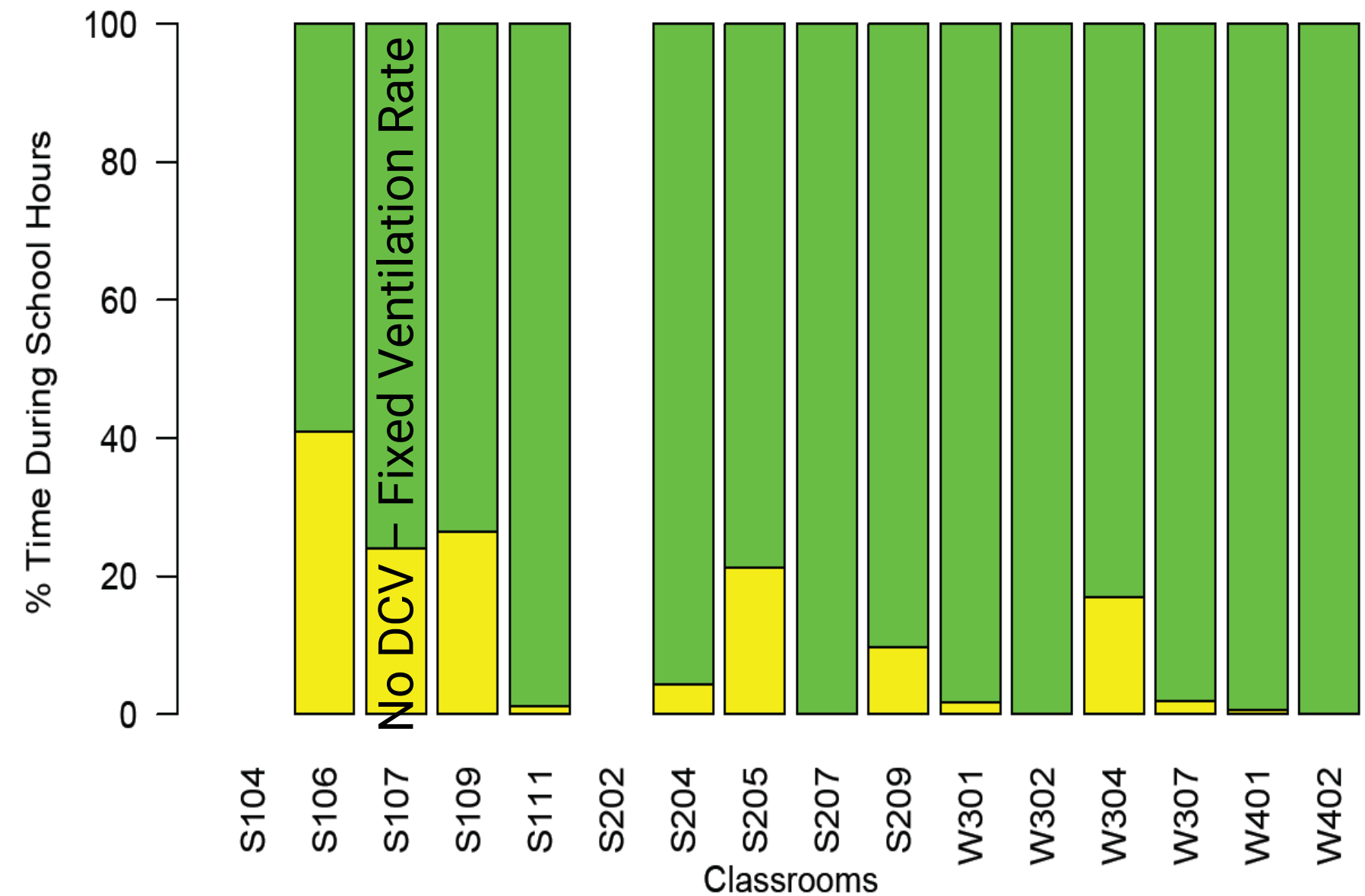
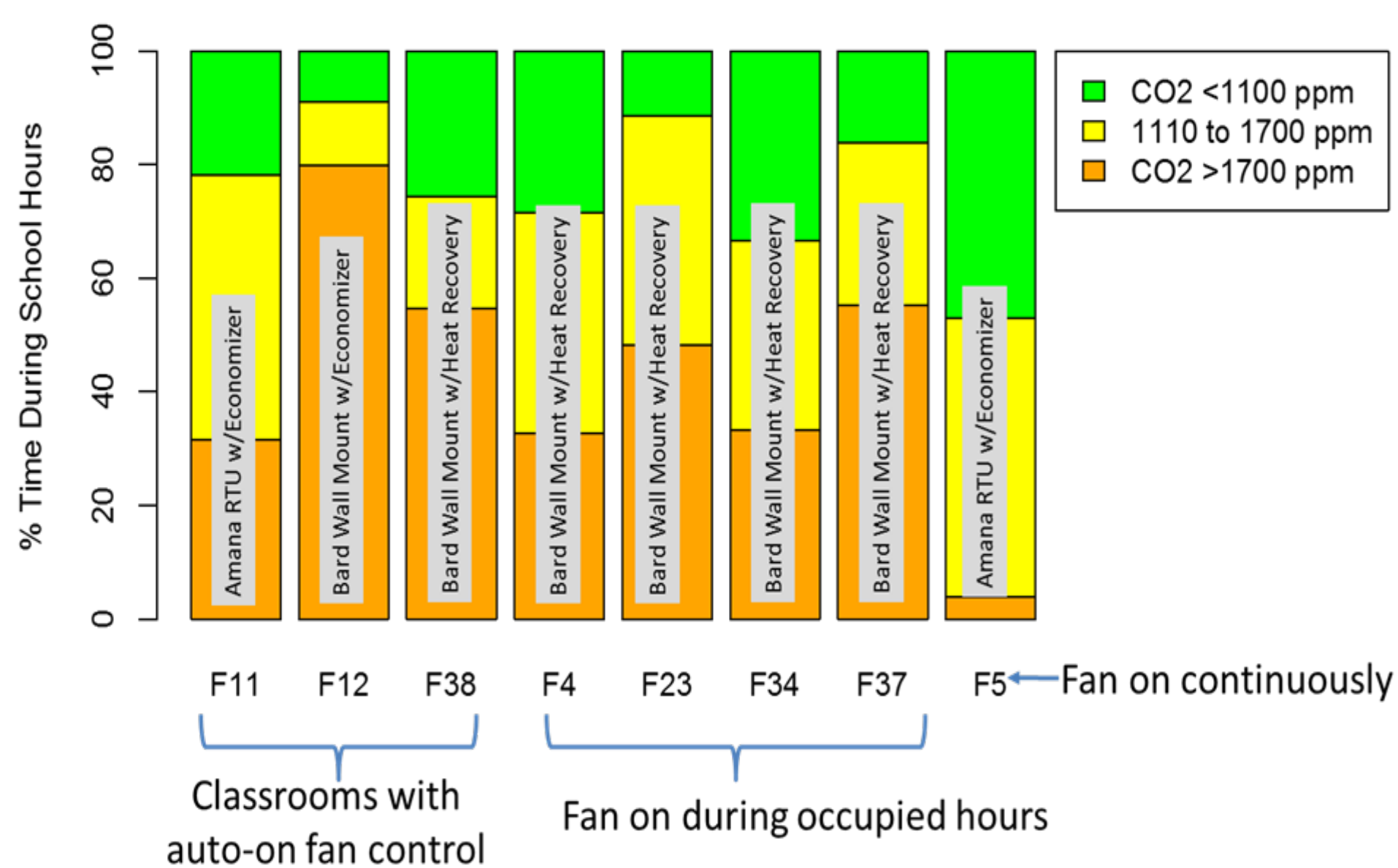




# Effective Energy-Efficient School Ventilation

## Preliminary Results

- CO<sub>2</sub> Tests on Classrooms with HVAC Retrofits Completed between 2013-2016
- Large Range of Results



CO<sub>2</sub> level results for classrooms over 4 weeks for scheduled occupied hours only

# Effective Energy-Efficient School Ventilation

## Ventilation Produced by Infiltration

- Blower door tests on individual classrooms
- Need to know if classrooms are receiving ventilation that is not passing through the HVAC system

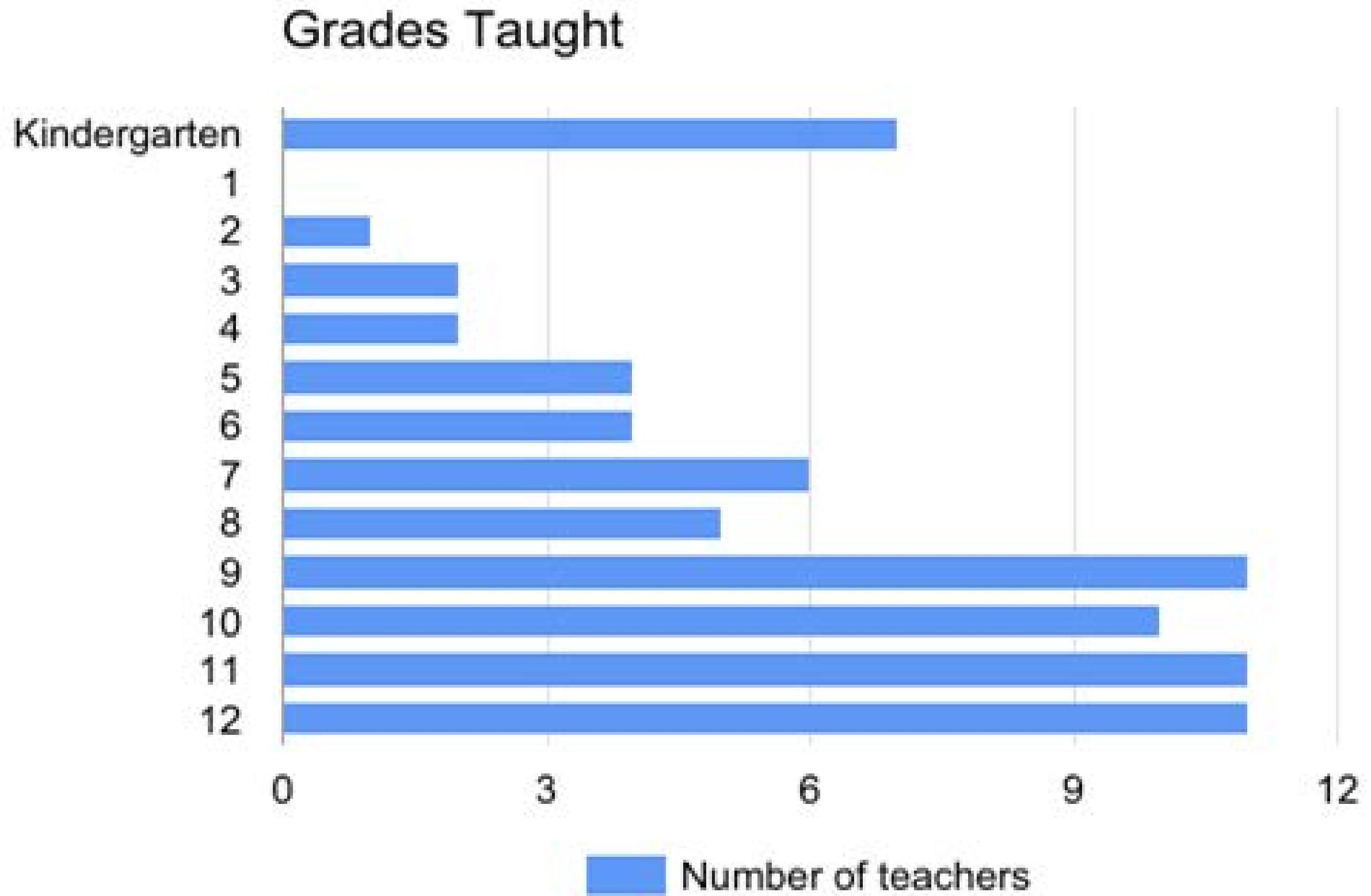


School	Room #	CFM@50 Pa
Temecula	5	1575
Temecula	37	1212
<b>Willows</b>	<b>202</b>	<b>4178</b>
Rio	F1	747
Rio	F2	747
Rio	F3	777
Rio	F4	1290
Rio	F5	894
Rio	F6	853
Rio	F7	789
Rio	F8	916
Rio	F9	684
Rio	F10	720



# Effective Energy-Efficient School Ventilation

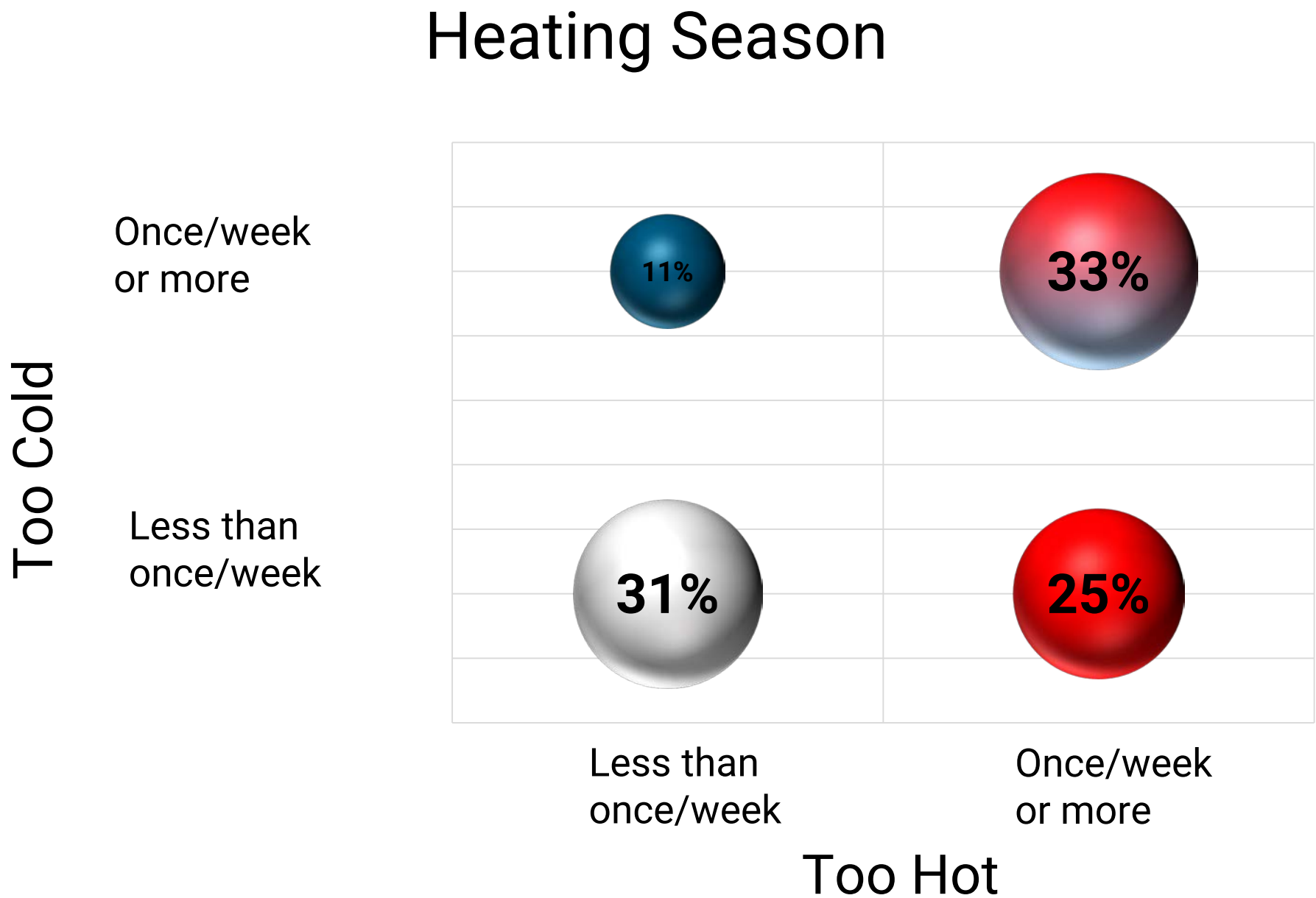
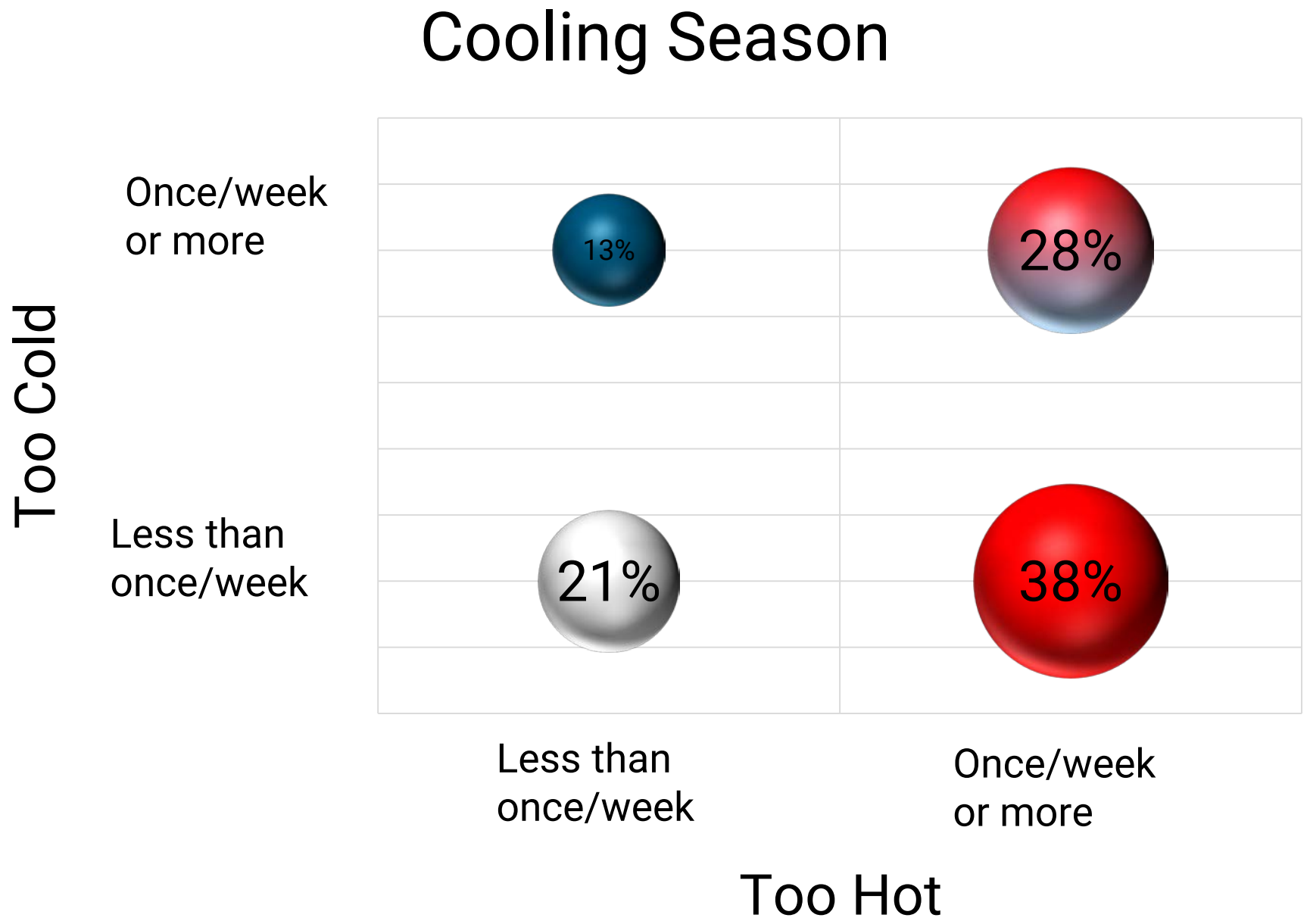
## Teacher Survey: Early Analyses



# Effective Energy-Efficient School Ventilation

## Teacher Survey: 87.5% of teachers reported having a thermostat

- 100% of classrooms had a thermostat (or controller of some kind)

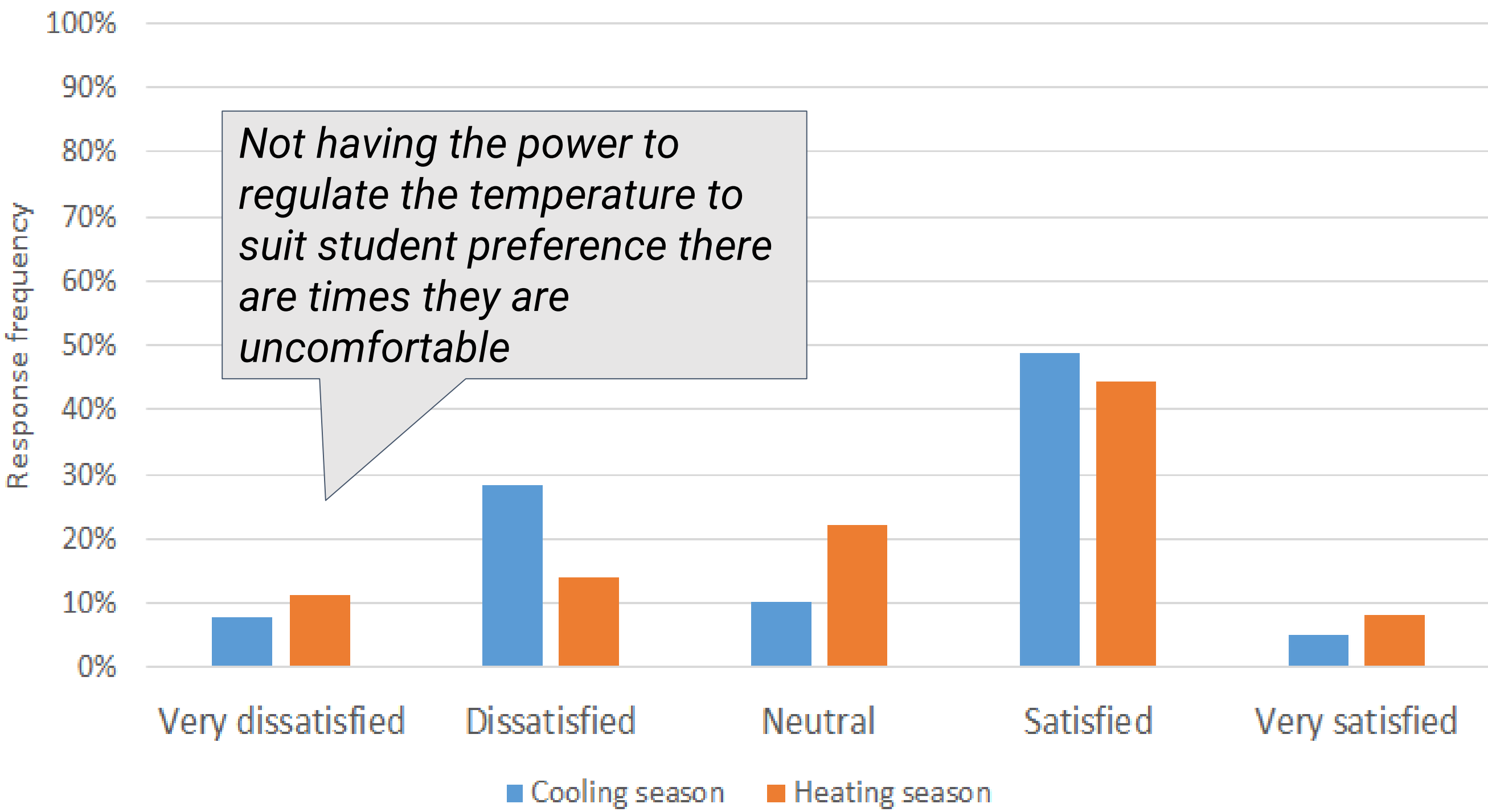




# Effective Energy-Efficient School Ventilation

## Teacher Survey: Satisfaction with classroom temperature

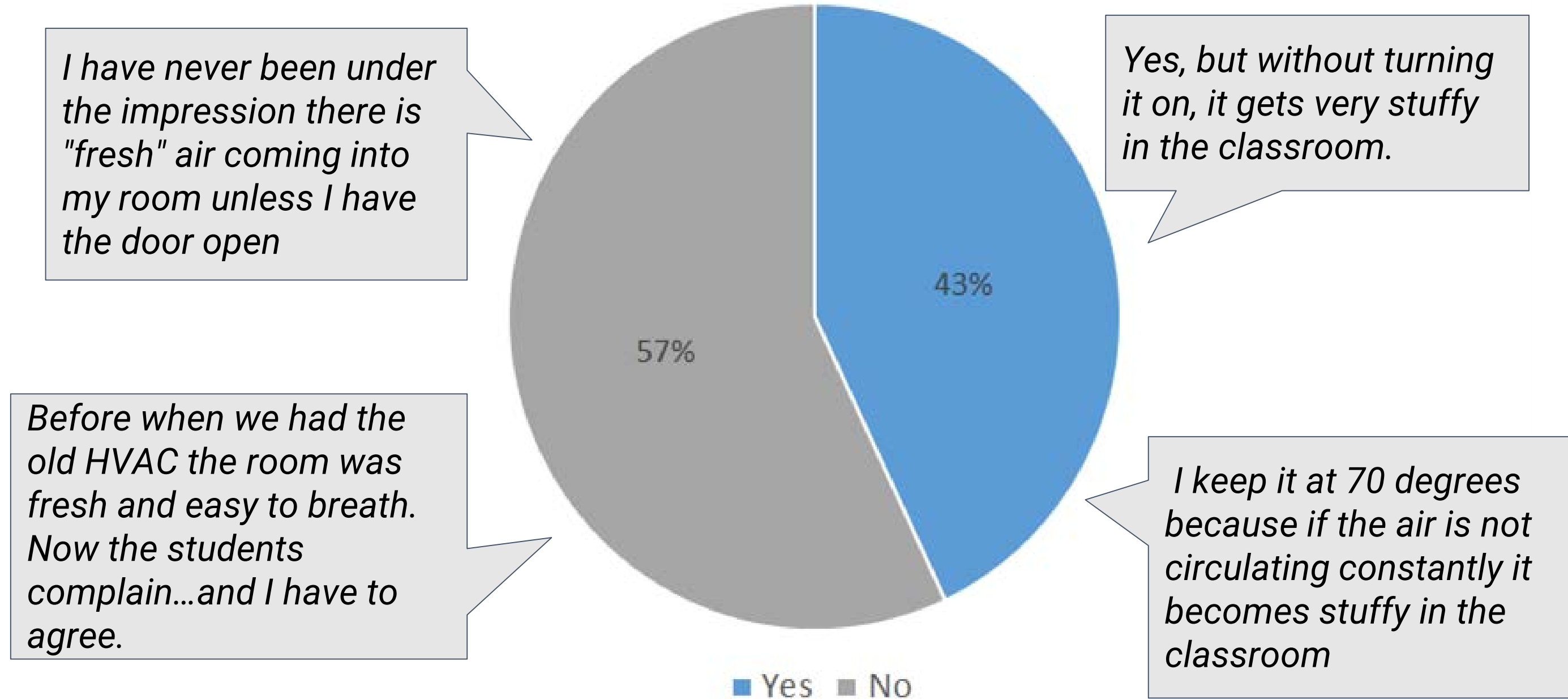
*How satisfied are you with the temperature in your classroom?*



# Effective Energy-Efficient School Ventilation

## Teacher Survey: Sufficient fresh air from HVAC alone?

*Does your classroom get enough fresh air from HVAC alone?*

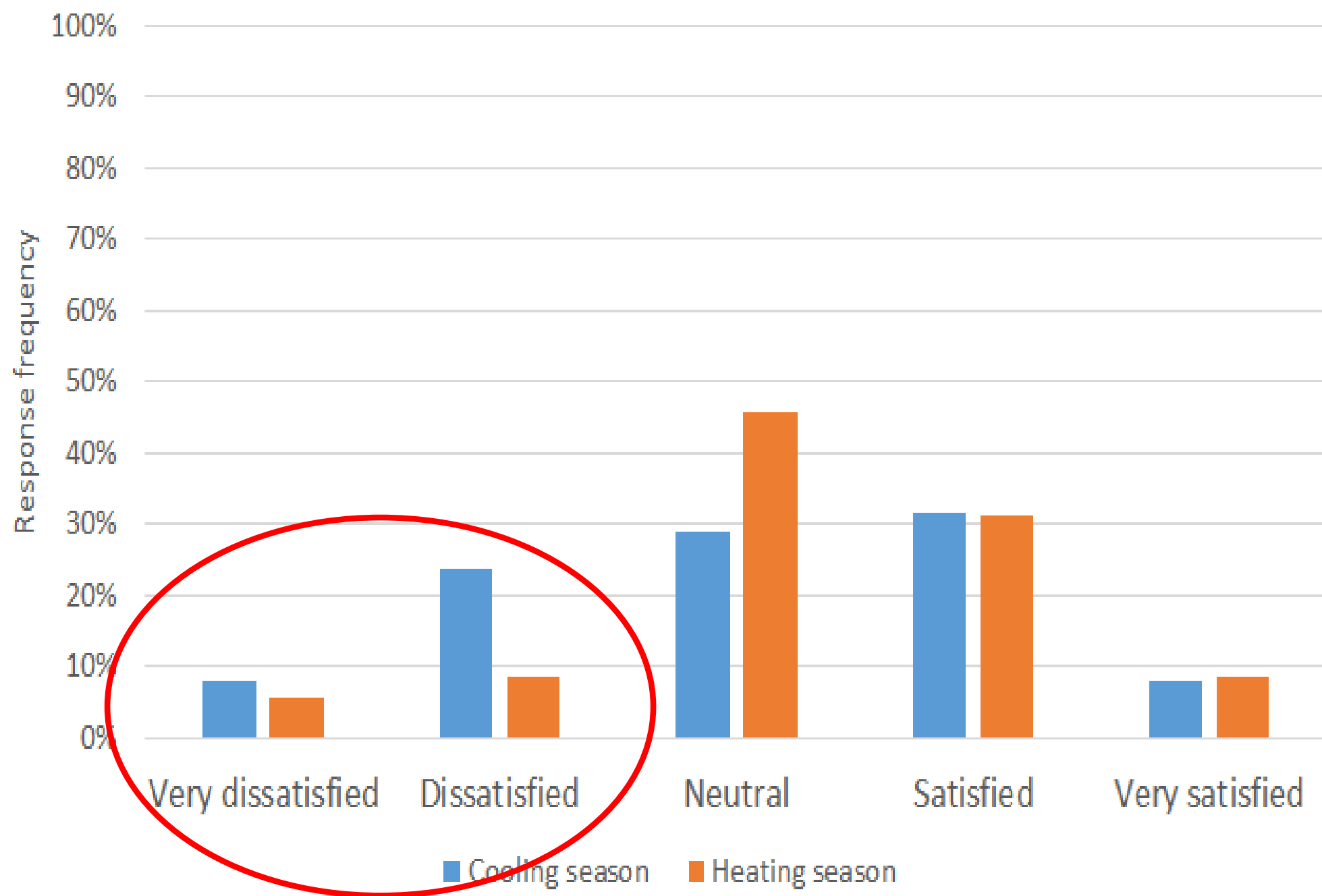




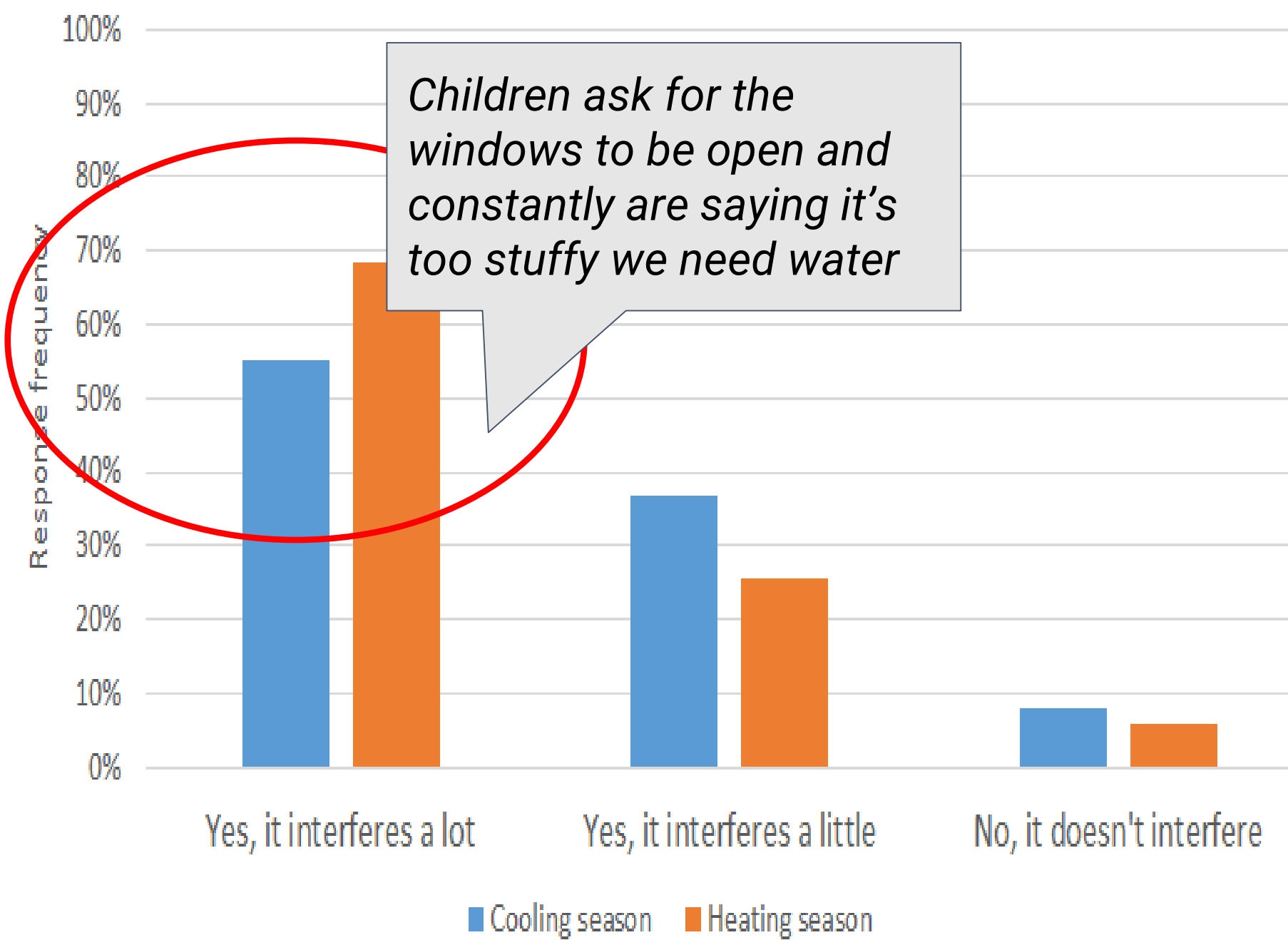
# Effective Energy-Efficient School Ventilation

## Teacher Survey: Satisfaction with classroom air

How satisfied are you with the air quality in your classroom?



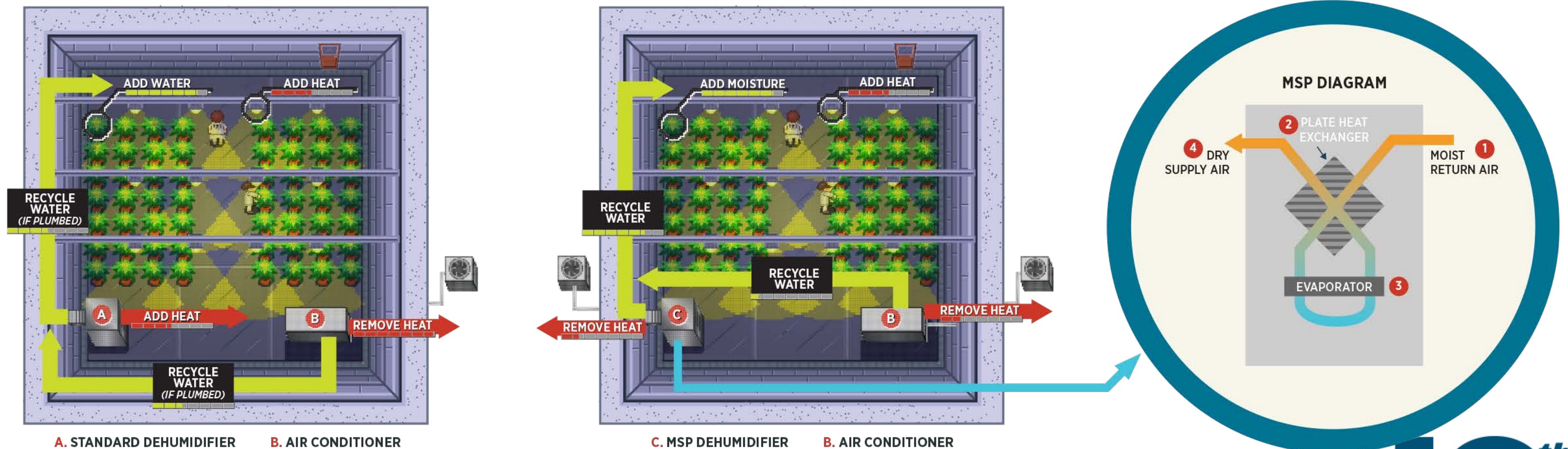
Does the air quality in your classroom interfere with the learning environment?



*Children ask for the windows to be open and constantly are saying it's too stuffy we need water*

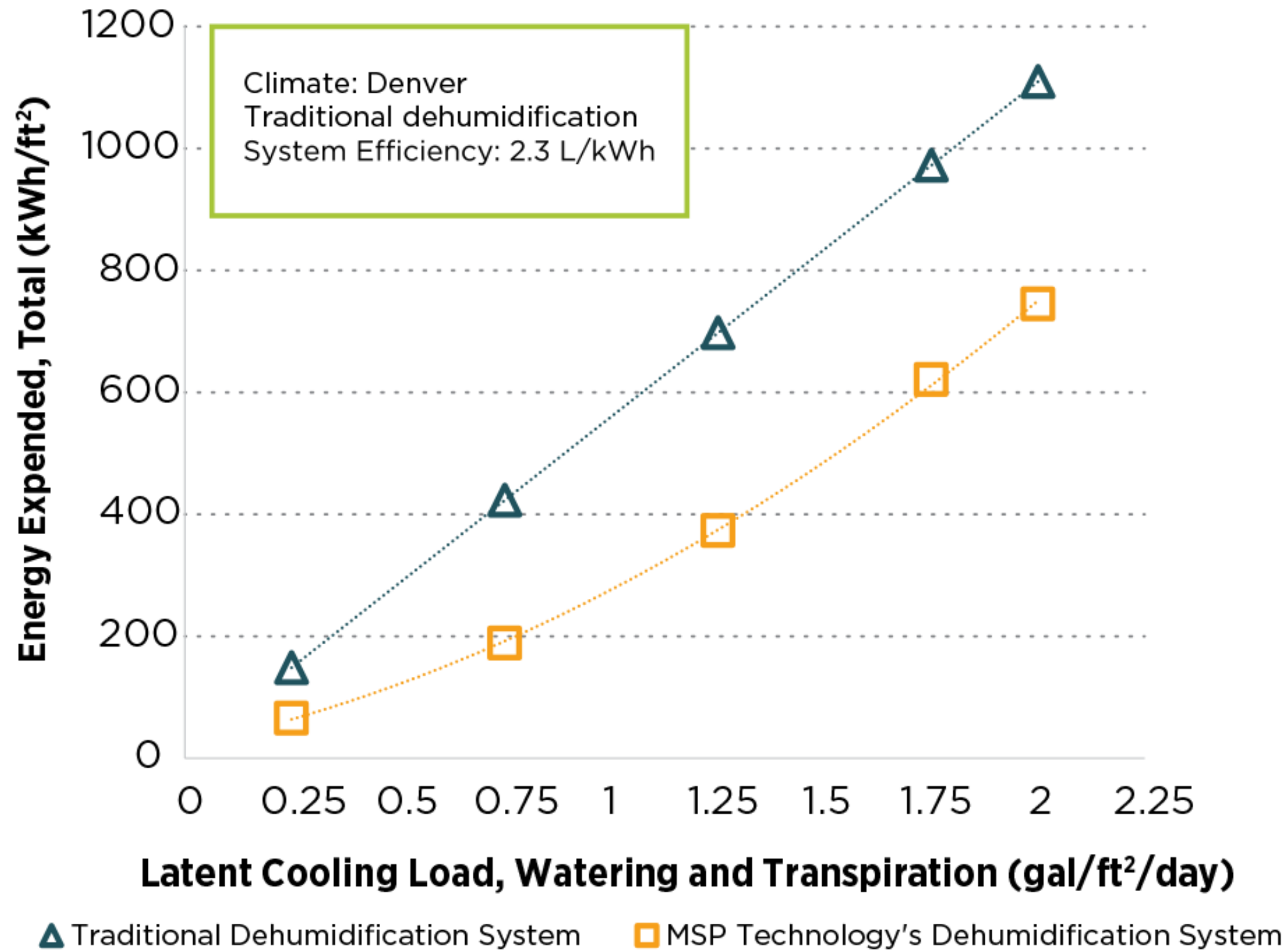
# Indoor Farming: Dehumidification

- » High dehumidification requirements due to plant transpiration
- » Lab study forecasted 30-65% energy savings relative to traditional dehumidification and cooling
- » 100% of the water removed from the air can be re-used to water the plants
- » Exploring additional work and collaboration





# Indoor Farming: Dehumidification



*Latent load from watering and transpiration versus annual energy expended for dehumidification and reconditioning of air*

# First 10 Years: Field Sites for Aerosol Sealing

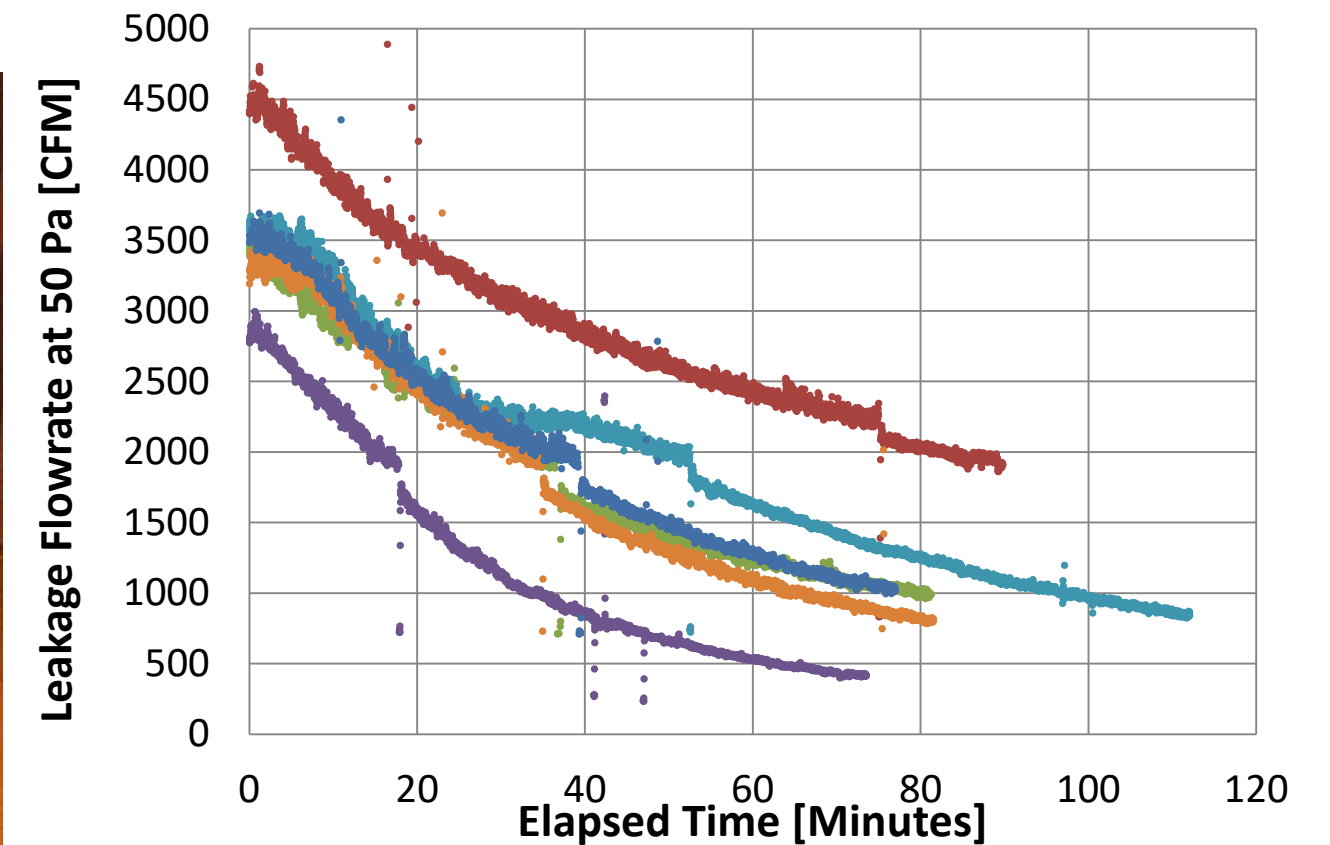
## » Aerosol Sealing Sites – Single Family

- Davis, CA (1 demo)
- Clovis, CA (6 demos)
- Stockton, CA (4 demos)
- Lancaster, CA (1 demo)



## » Aerosol Sealing Sites – Multifamily

- Davis, CA (3 demos)
- Minneapolis, MN (27 demos)
- Queens, NY (4 demos)
- Quantico, VA (4 demos)
- Fort Bragg, NC (3 demos)
- Mechanicsburg, PA (8 demos)





# Aerosol Envelope Sealing (DOE Building America) – New Residential

- » Integrate aerosol sealing into new home construction
- » Test multiple options (i.e. before insulation, after drywall)
- » Determine manual sealing efforts that can be eliminated
- » Assess sealing performance, cost, scheduling issues

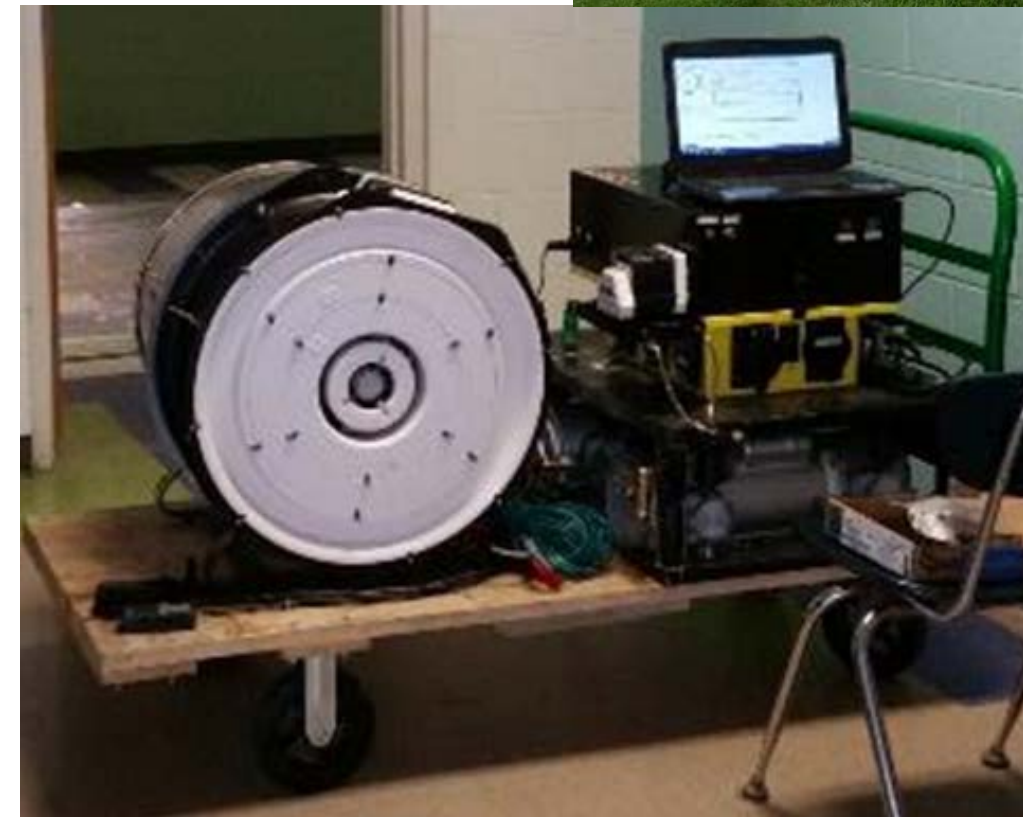


Manual sealing  
details



# Aerosol Envelope Sealing – Past Year

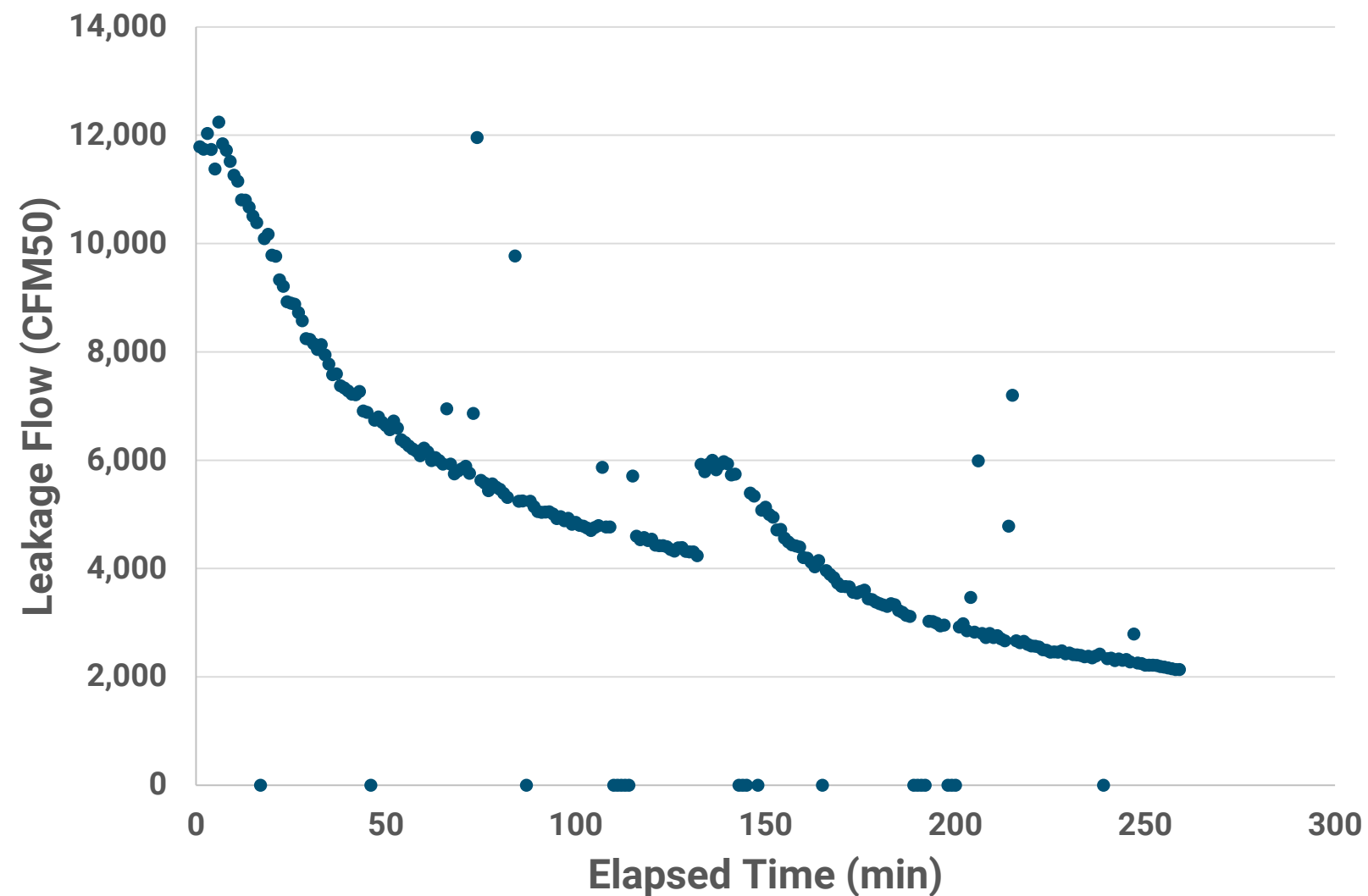
- » First non-res installations including:
  - 17 demonstrations on military bases
  - Quantico – 5,000 ft<sup>2</sup> grade school
  - Mechanicsburg – 8,400 ft<sup>2</sup> industrial building
  - Mechanicsburg – 22,000 ft<sup>2</sup> Officer's Club
- Some buildings required supplemental manual sealing
- » First applications by a subcontractor
- » First applications by licensee



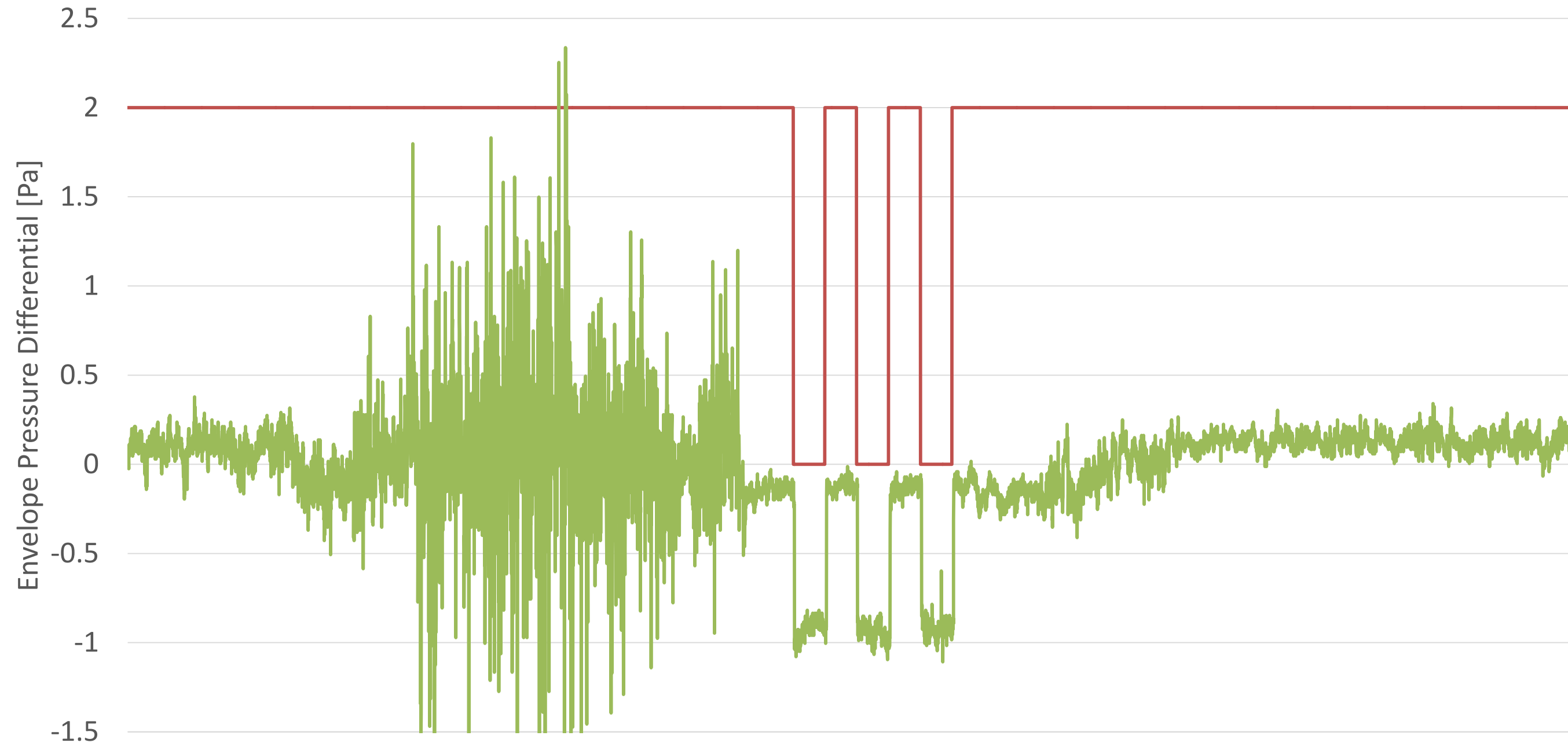


# Aerosol Envelope Sealing (DoD ESTCP)

- » Two Sealing events
- » Sealed >80% of sealable leakage
- » 65% leakage reduction after ~4 h of injection



# Building Leakage Diagnosis using IoT

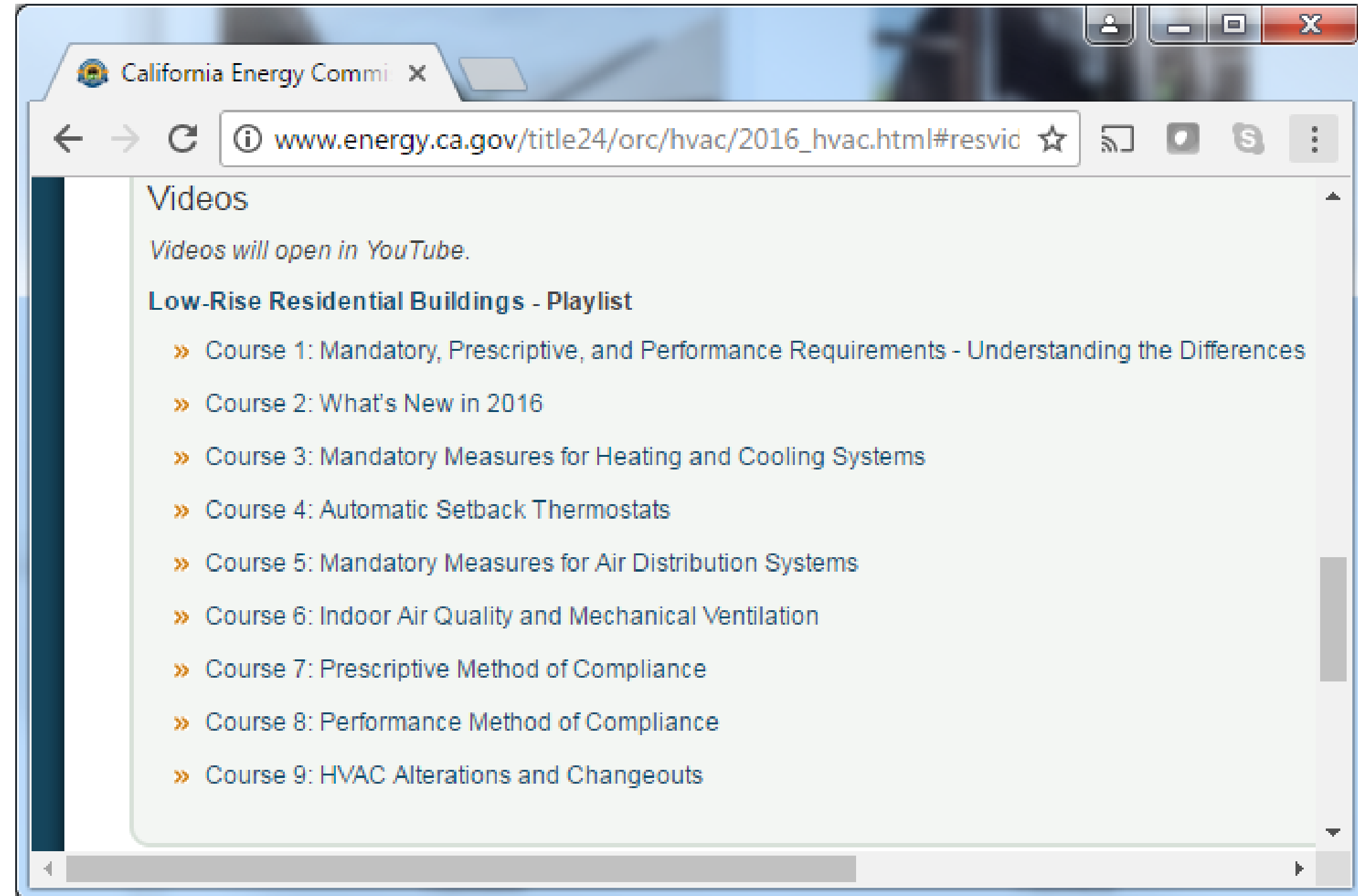


- Uses changes in building pressure to quantify duct and envelope leakage
- Clear change in  $\Delta P_{\text{envelope}}$  with fan operation
- Excellent day to day consistency: 0-5% standard deviation
- NIST project as consultant to XCSpec – UC Davis/XCSpec proposal submitted



# 2016 Residential Building Energy Efficiency Standards - HVAC

- » Funded by CEC
- » Nine Residential HVAC Standards Courses ⇨ two hours of content
- » Commercial HVAC Standards Videos Underway
- » Example: [Explanation of Intermittent Ventilation](#)



**Thank You for All Your Support**

**Any Questions?**

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