Better Buildings
U.S. DEPARTMENT OF ENERGY

Better Buildings Residential Network
Peer Exchange Call Series

The Cost of Cooling: Air Conditioning, Climate, and Health

August 12, 2021

U.S. DEPARTMENT OF ENERGY

Agenda and Ground Rules

- Agenda Review and Ground Rules
- Opening Poll
- Residential Network Overview and Upcoming Call Schedule
- Featured Speakers
  - **Ronnen Levinson,** Lawrence Berkeley National Laboratory
  - **Brett Bishop,** Franklin Energy
  - **Vince Romanin,** Gradient
- Open Discussion
- Closing Poll and Announcements

Ground Rules:

1. **Sales of services and commercial messages are not appropriate** during Peer Exchange Calls.
2. Calls are a safe place for discussion; **please do not attribute information to individuals** on the call.

The views expressed by speakers are their own, and do not reflect those of the Dept. of Energy.

Better Buildings Residential Network

Join the Network

Member Benefits:

- Recognition in media and publications
- Speaking opportunities
- Updates on latest trends
- Voluntary member initiatives
- One-on-One brainstorming conversations

Commitment:

- Members only need to provide *one number*: their organization's number of residential energy upgrades per year, or equivalent.

Upcoming Calls (2nd & 4th Thursdays):

- *9/9: Behavior Change, Efficiency and Climate: What Really Happens vs. Models & Assumptions*
- *9/23: Emergency Replacement: The Biggest Real-World Obstacle to Efficiency*

Peer Exchange Call summaries are posted on the Better Buildings website a few weeks after the call

For more information or to join, for no cost, email bbresidentialnetwork@ee.doe.gov, or go to energy.gov/eere/bbrn & click Join

Call Attendee Locations

Opening Poll

- What is your organization's experience or familiarity with the relationship between air conditioning, climate, and health?
  - Very experienced/familiar
  - Some experience/familiarity
  - Limited experience/familiarity
  - No experience/familiarity
  - Not applicable

Ronnen Levinson
Lawrence Berkeley National Laboratory

U.S. DEPARTMENT OF
ENERGY

Passive & low-energy cooling solutions to adapt to extreme heat: highlights from Berkeley Lab

Ronnen Levinson, Ph.D.

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Lawrence Berkeley National Laboratory
Berkeley, California, USA
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Better Buildings Residential Network Peer Exchange Call
The Cost of Cooling: Air Conditioning, Climate, and Health
12 August 2021

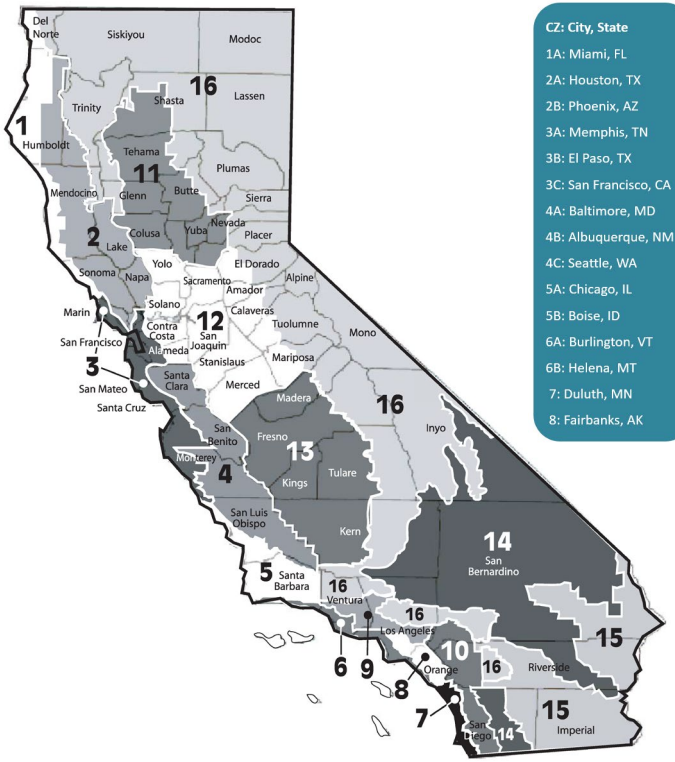
❶ Cool Walls

A **cool exterior wall** reflects sunlight to reduce need for air conditioning—saving energy, money, and carbon

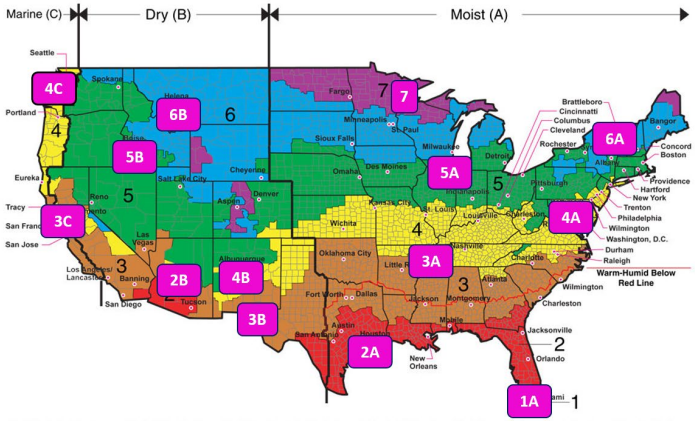
Wall solar reflectance

- Conventional ≈ 25%
- Cool color ≈ 40%
- Off or dull white ≈ 60%
- Bright white ≈ 80%

We evaluated **annual energy, cost, and emission savings** in each California and U.S. climate zone (> 100K simulations!)



CZ: City, State
1A: Miami, FL
2A: Houston, TX
2B: Phoenix, AZ
3A: Memphis, TN
3B: El Paso, TX
3C: San Francisco, CA
4A: Baltimore, MD
4B: Albuquerque, NM
4C: Seattle, WA
5A: Chicago, IL
5B: Boise, ID
6A: Burlington, VT
6B: Helena, MT
7: Duluth, MN
8: Fairbanks, AK



Cool walls save energy, carbon dioxide in homes, offices, and stores in all California climates and U.S. climate zones 1 – 4.

Rosado et al. (2019).
https://doi.org/10.1016/j.enbuild.2019.02.028

FUNDING PROVIDED BY THE CALIFORNIA ENERGY COMMISSION

Better Buildings

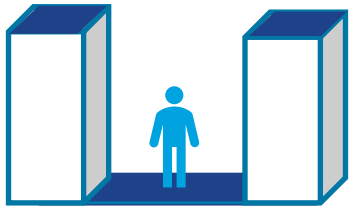
U.S. DEPARTMENT OF ENERGY

In July, reflective walls in Los Angeles **cool outside air** nearly as much as reflective roofs

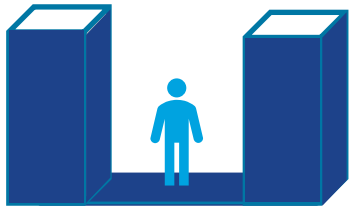
Cool walls vs. cool roofs: 44% less cooling at 2 pm

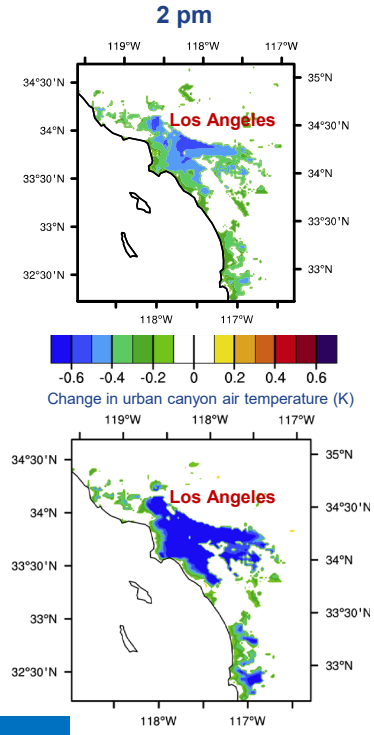
6% more cooling at 8 pm

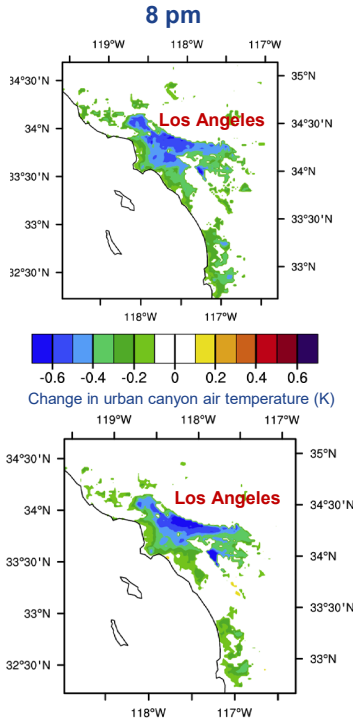
Cool Walls



Cool Roofs

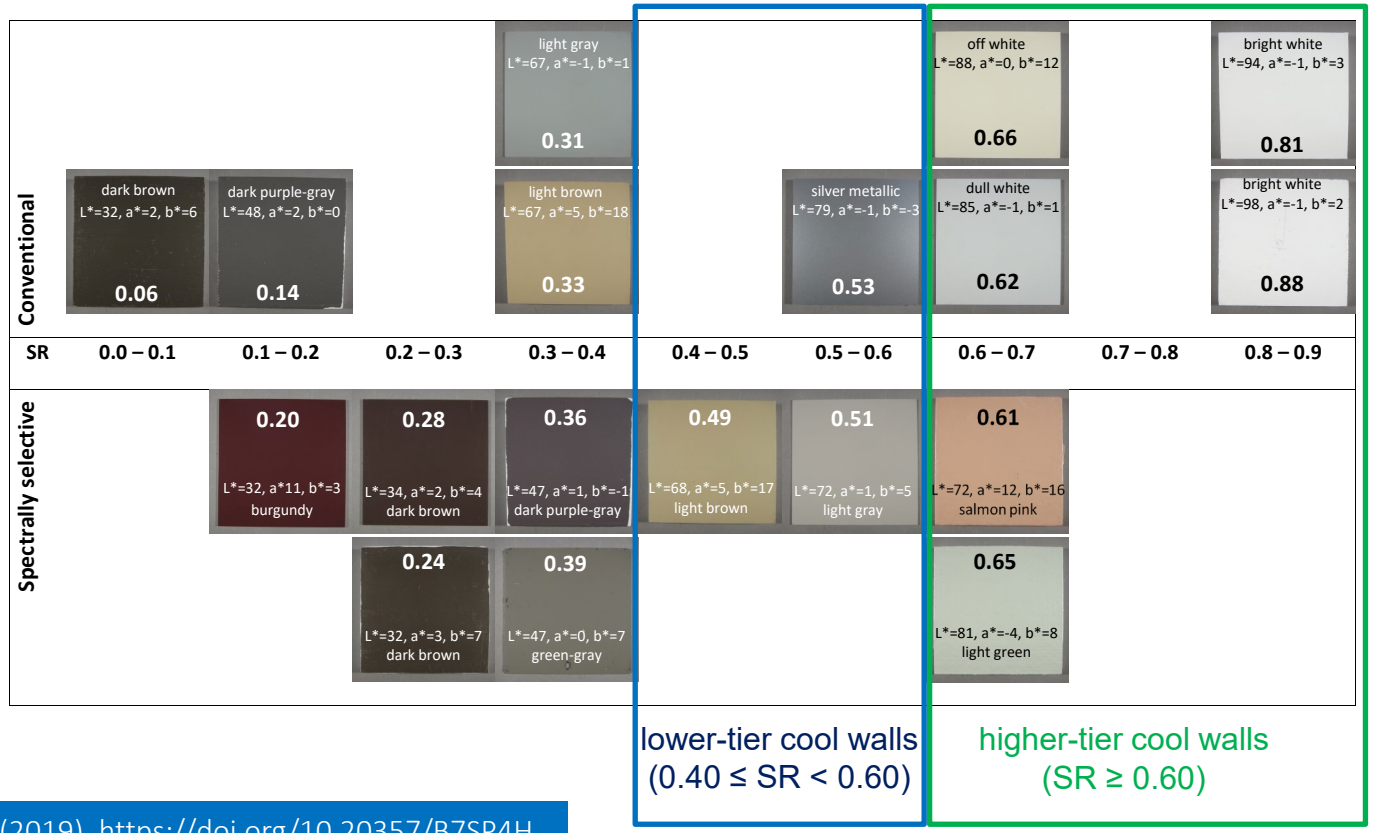






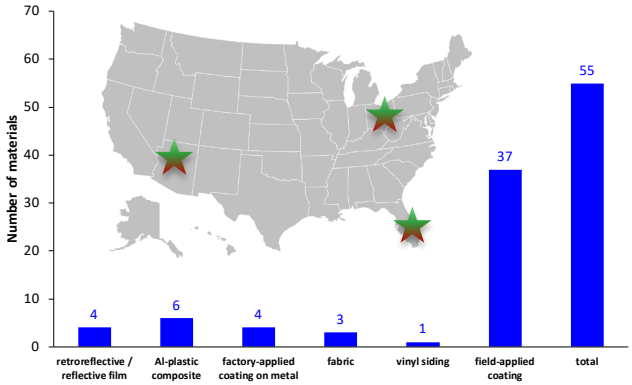
Zhang et al. (2018). https://doi.org/10.1021/acs.est.8b00732

Cool-wall products with high solar reflectance (SR) **are sold today**

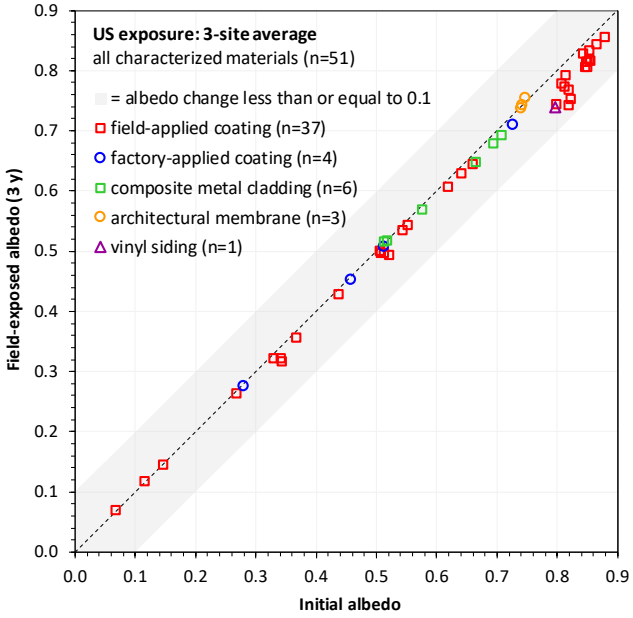


Levinson et al. (2019). https://doi.org/10.20357/B7SP4H

Cool-wall materials **stay clean and reflective** after 3 years of outdoor exposure



Average solar reflectance loss = 0.02



Chen et al. (2020). https://bit.ly/3gkfLjV

Learn more about **cool-wall product rating** and the **new cool-wall LEED pilot credit** from our news releases

NEWS CENTER

Can't Take the Heat? 'Cool Walls' Can Reduce Energy Costs, Pollution

Nationwide study by Berkeley Lab details benefits of lighter-colored, solar-reflective walls

News Release Glenn Roberts Jr. (510) 486-5582 • **July 9, 2019**

164 164 SHARES

Coating exterior walls with solar-reflective paints can lead to substantial energy savings in hot climates while curbing pollution, a Berkeley Lab study concludes. (Credit: iStock/YayaErnst)

IF THESE WALLS COULD TALK, they might tell you that cutting energy costs and pollution may be as easy as giving them a fresh coat of lighter, more reflective paint.

https://newscenter.lbl.gov/2019/07/09/cool-walls-can-reduce-energy-costs-pollution

NEWS CENTER

'Cool Walls' Get a Boost from U.S. Green Building Council

Berkeley Lab research helps city-cooling measure get test integration with LEED rating system

Feature Story Julie Chao (510)486-6491 • **May 18, 2021**

20 20 SHARES

White buildings stand along an alley in Los Angeles, California. Light-colored paints can help reflect sunlight, helping to cool cities and fight the urban heat island effect. (Credit: iStock)

Sunlight-reflecting "cool walls" have been shown to reduce energy costs by lowering heat gain in buildings. But they do more – reflective walls can also cool cities, fighting the urban heat island effect. The concept has new support from the U.S. Green Building Council (USGBC), which has issued a pilot credit for the installation of cool exterior walls in new homes, schools, and commercial buildings to mitigate urban heat islands.

https://newscenter.lbl.gov/2021/05/18/cool-walls-get-a-boost-from-u-s-green-building-council

❷ Extreme Heat

“**Heat now causes more deaths** than hurricanes, tornadoes or floods in most years” — *The Guardian*, 16 June 2020

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US news

Deadly heat is killing Americans: A decade of inaction on climate puts lives at risk

Dean Russell, Elisabeth Gawthrop, Veronica Penney, Ali Raj and Bridget Hickey, Columbia Journalism Investigations

Tue 16 Jun 2020 02.00 EDT

1615

▲ A man sells cold bottled drinks to motorist at a busy intersection in Phoenix, Arizona. Photograph: Ralph Freso/Getty Images

Heat now causes more deaths than hurricanes, tornadoes or floods in most years, creating a new public health threat. An investigation reveals why the CDC's prevention efforts have faltered

This story is co-published with Columbia Journalism Investigations, the Center for Public Integrity and Covering Climate Now. Read the full investigation here.

A pedestrian looks at a sign posted on the door of a hardware store during a citywide power outage in San Francisco, Calif. | Justin Sullivan/Getty Images

CALIFORNIA

California has first rolling blackouts in 19 years — and everyone faces blame

While California braced for another round of rolling blackouts Monday night, the state's grid operator held off for a second straight night.

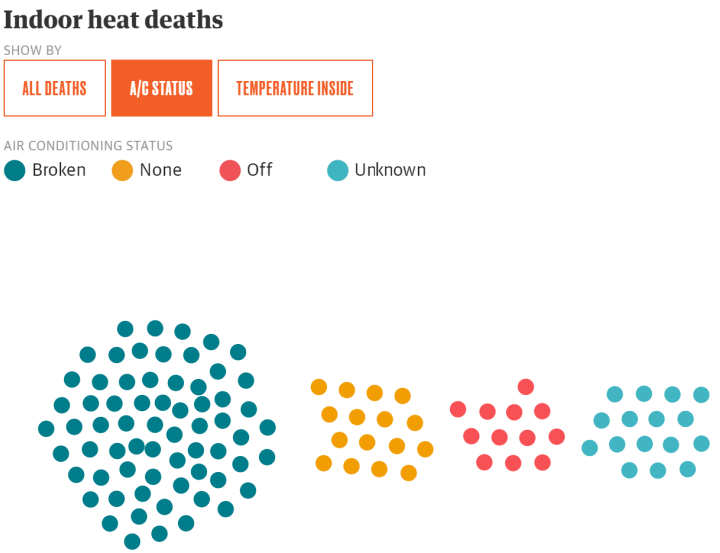
By DEBRA KAHN and COLBY BERMEL | 08/18/2020 12:19 AM EDT | Updated 08/18/2020 01:24 PM EDT

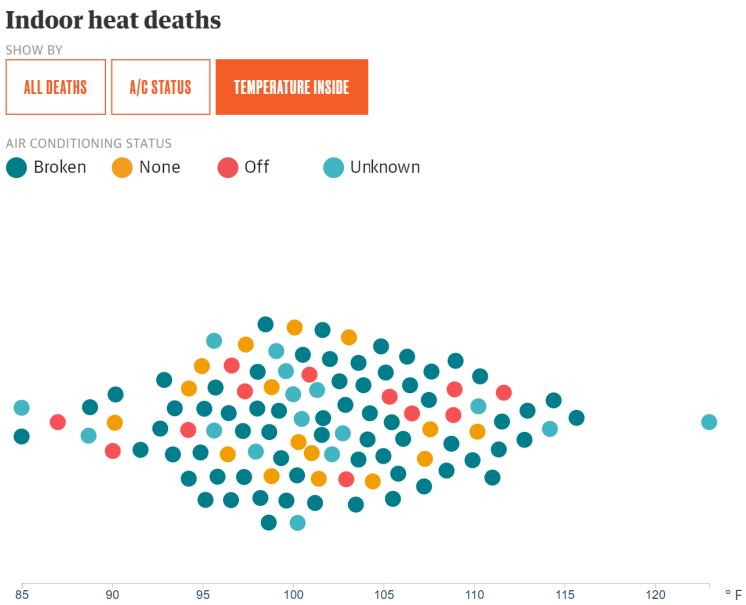
PUBLIC SAFETY POWER SHUTOFF

In order to keep communities safe, PG&E may need to turn off power when extreme weather or wildfire conditions are forecast.

This statewide initiative is called **Public Safety Power Shutoff.**

Without air conditioning, **homes can grow deadly hot** during extreme heat events





"Over the summers of 2016 through 2018, more than 100 people in Maricopa County, Arizona were killed by extreme indoor heat."

Note: Temperature was recorded by investigators when they arrived at the scene.

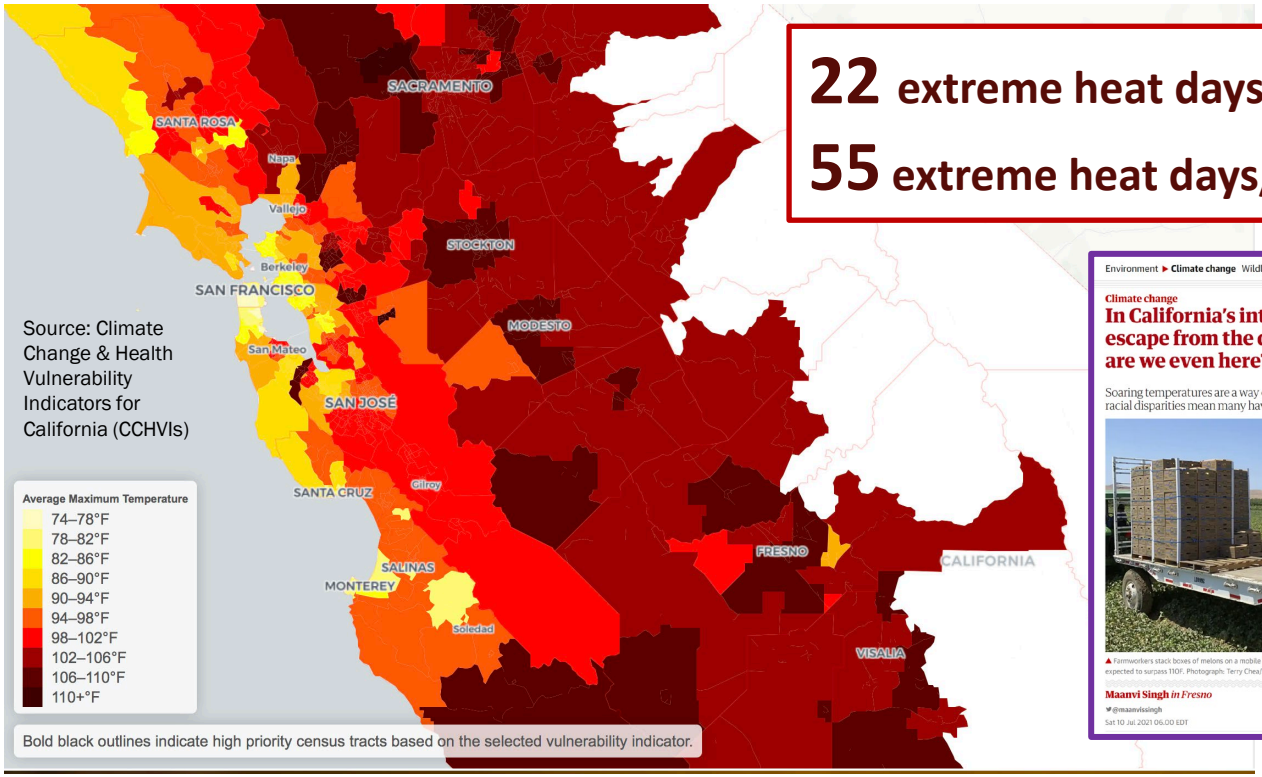
Source: Maricopa County Medical Examiner. Credit: Graphic by Veronica Penney and analysis by Elisabeth Gawthrop, Columbia Journalism Investigations / Center for Public Integrity

http://www.theguardian.com/us-news/2020/jun/16/climate-deaths-heat-cdc

❸ Cal-THRIVES: A California Toolkit for Heat Resiliency in Underserved Populations

Heat is increasingly brutal in California's Central Valley, where low incomes, poor air quality, old homes, and high utility bills disadvantage many residents

California and Fresno are hot …**and getting**



22 extreme heat days/year by 2040 - 2060

55 extreme heat days/year by 2080 - 2099


Environment ▸ Climate change Wildlife Energy Pollution Green light

Climate change

In California's interior, there's no escape from the desperate heat: 'Why are we even here?'

Soaring temperatures are a way of life in the Central Valley, but racial disparities mean many have no access to relief

▲ Farmworkers stack boxes of melons on a mobile platform in Firebaugh, California, where temperatures are expected to surpass 110F. Photograph: Terry Chea/AP

Maanvi Singh *in Fresno*

@maanvissingh

Sat 10 Jul 2021 06.00 EDT

https://www.theguardian.com/us-news/2021/jul/10/california-central-valley-extreme-heat-race

The California Strategic Growth Council is sponsoring research to **help Fresno residents adapt to extreme heat**

CAL-THRIVES: A California Toolkit for Heat Resiliency in Underserved Populations

Principal Investigator:
Max Wei, LBNL
MWei@LBL.gov

Max Wei(1), Ronnen Levinson (1), Tianzhen Hong(1), Kai-yu Sun(1), Zhao-yun Zeng(1), Wanni Zhang(1), Yu-jie Xu(1), Henry Willem(1), Susan Mazur-Stommen(2), Haley Gilbert(2), George Ban-Weiss(3), Alexandra Bruce(3), Yuxi Liu(3), Kayley Butler(3), Janice Mathurin(4), Yolanda Sue Randles(4)

(1) Lawrence Berkeley National Lab; (2) Indicia Consulting; (3) University of Southern California; (4) West Fresno Family Resource Center

BERKELEY LAB

INDICIA Consulting

West Fresno family resource center
Empowering the Community

USC

CALIFORNIA STRATEGIC GROWTH COUNCIL

CALIFORNIA CLIMATE INVESTMENTS
Cap and Trade Dollars at Work

Better Buildings
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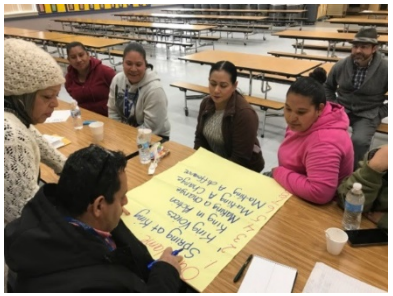
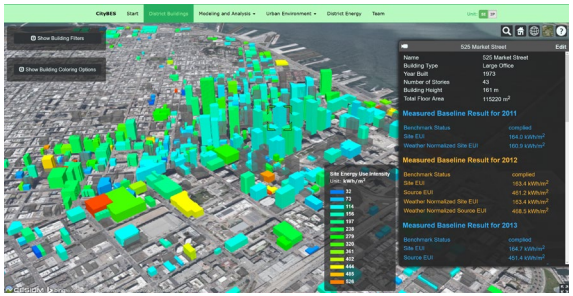
Our heat-resiliency recommendations will incorporate both **community input and science**

Community engagement

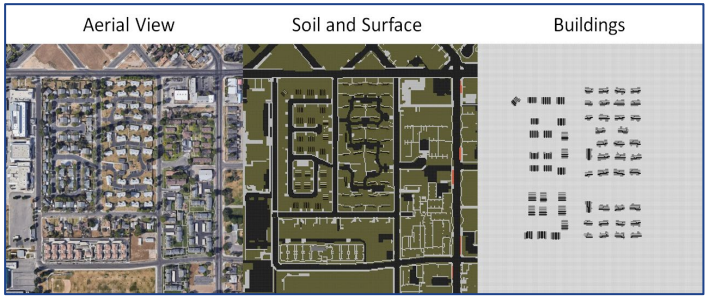


Neighborhood-scale building modeling



Cooling center optimization

Outdoor measure modeling



Heat Resilience Toolkit

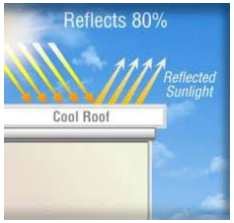
Fact sheets
Modeling outputs
Heat vulnerability index tool
Online tools (videos, webinars)
Policy/program recommendations

We're modeling **nine passive indoor cooling measures** in a worst-case heat wave, with and without grid power available

Window blinds

Window overhangs

Cool roof

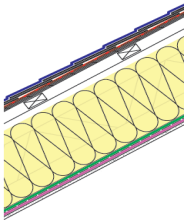


Cool walls

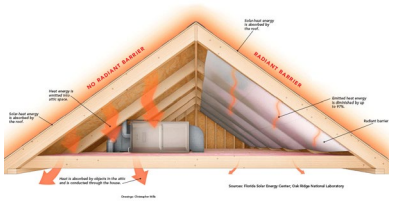
Storm windows

Solar-control window films

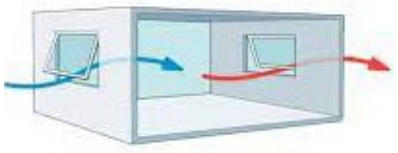
Roof insulation



Radiant barrier



Natural ventilation



We're also evaluating **eight active indoor cooling measures** and **four passive outdoor cooling measures**

ACTIVE INDOOR

Ceiling fans

Attic fan

Portable fans

Evaporative cooler

Central AC

Mini-split AC

Window AC

Portable AC

PASSIVE OUTDOOR

Cool pavements

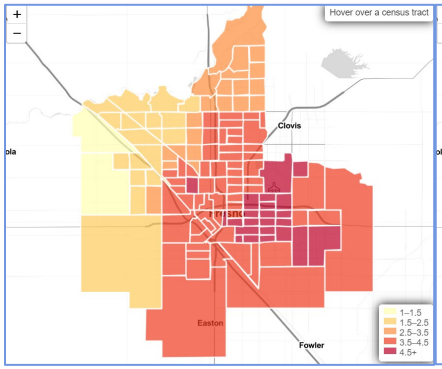
Cool walls

Trees

Canvas canopies

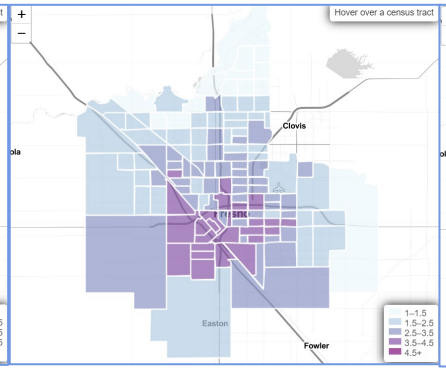
Our **Heat Vulnerability Index Tool** will map exposure, sensitivity, adaptation, and overall heat vulnerability

Exposure



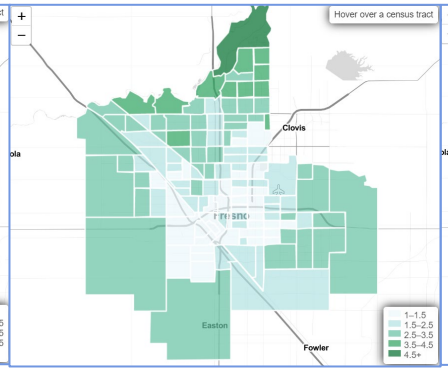
- Number of hours with high heat index
- Longest number of consecutive heat-wave days
- Number of heat-wave days
- PM2.5 concentration
- Ozone concentration
- Building heat resistance indicator

Sensitivity



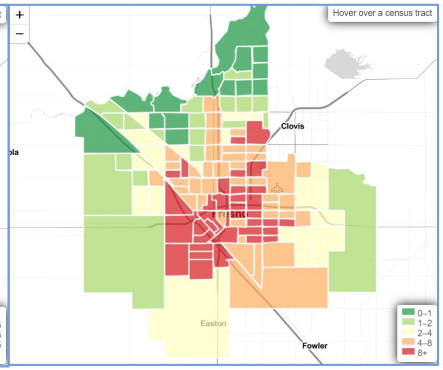
- Percent elderly and under 5
- Percent of pop. without high school degree
- Percent of pop. below poverty level
- Percent non-white pop.
- Percent of pop. with ambulatory disability
- Asthma hospitalization rate
- Heart attack rate
- Percent of pop. with a cognitive disability

Adaptation



- Median income
- Percent of area covered in parks

Heat Vulnerability Index



Highest vulnerability in south/central Fresno with high sensitivity and low adaptation

https://citybes.LBL.gov/?hvi=1

Cal-THRIVES modeling results and toolkit **will be available early next year**

- Estimated reductions in
  - Indoor air temperature
  - Unmet degree hours
  - Heat index danger hours
- Recommendations
  - Passive, active measures
  - Building code innovations

❹ IEA Annex 80: Resilient Cooling of Buildings

IEA Annex 80: **Resilient Cooling of Buildings** (2019 – 2023)

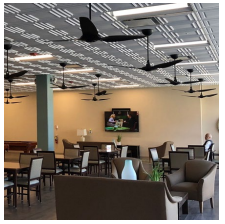
16 countries exploring passive/low-energy cooling solutions with three goals:

- Make building occupants more resilient to hot weather, boosting comfort, health, and productivity
- Make building cooling systems more resilient to hot weather, improving their ability to meet cooling load
- Make the electric grid more resilient to hot weather, reducing failures

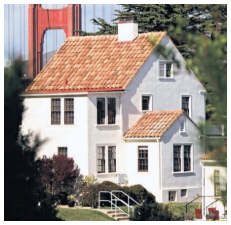
https://annex80.iea-ebc.org

Cool roofs

Solar-control windows

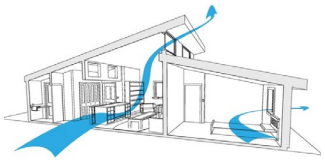


Ceiling fans



Cool walls

Window shading

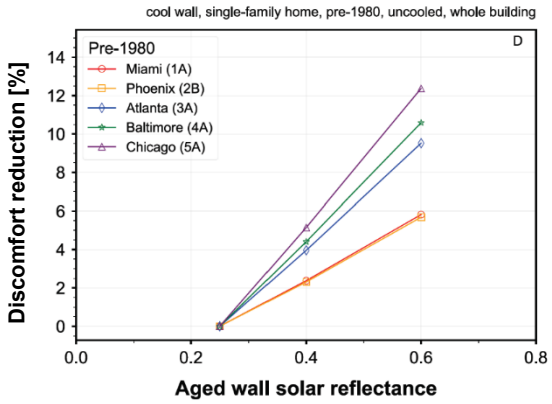


Natural ventilation

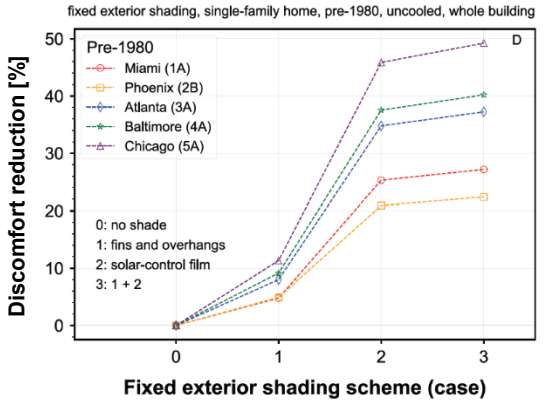
Focus of DOE-sponsored project at Berkeley Lab & UC Berkeley

Example: Individual passive or low-energy cooling measures can **reduce overheating** in a U.S. pre-1980 single-family home without AC **by up to 70%**

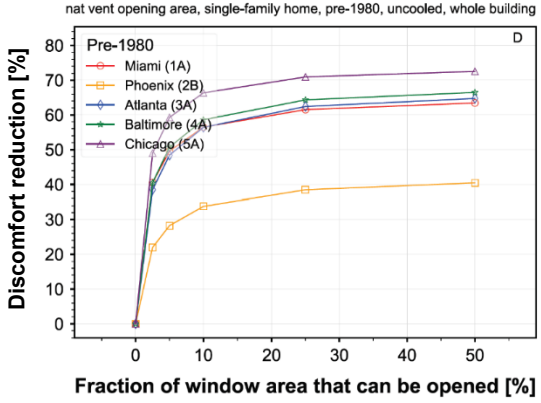
Cool walls



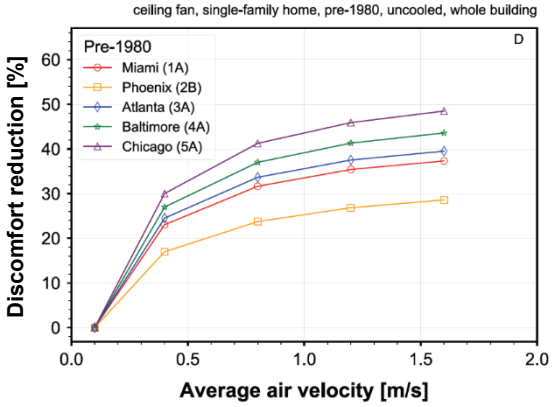
Exterior shading



Natural ventilation



Ceiling fans



Discomfort = annual discomfort-weighted warm exceedance hours (ASHRAE Standard 55-2019)

We will customize suites of passive/low-energy cooling solutions in another two disadvantaged communities: **Atlanta, GA** and **Mystic River, MA** (near Boston)

Identify two residential study locations in different climates

1. Assess building stock
2. Interview residents
3. Model passive/low energy cooling solutions

EnergyPlus

Develop cooling-solution guidance based on technical potential, cost effectiveness, and preferences of the residents

Thank you!

Brett Bishop

Franklin Energy

U.S. DEPARTMENT OF ENERGY

The cost of cooling: "Need to knows" the Implementation of heat pump HVAC in energy Programs

Brett Bishop
Director of Contract Services
August 12th, 2021

FRANKLIN ENERGY

Introduction & *Conclusion*

"Continuous improvement is better than delayed perfection."

Mark Twain

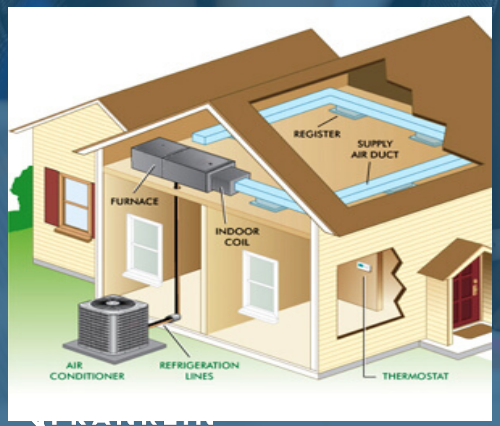
1. **Multiple benefits exist with Heat Pump HVAC**
   - **All non-energy benefits we know and love about energy efficiency will *NOT* be covered**
     - **Improved air quality, Comfort, quality of LIFE!**
     - **For this audience these are knowns**
   - **Population level load management**
   - **Increased load management opportunities**
2. **Solutions should be tailored at the site level**
   - **Barriers are varied by site and socioeconomics**
   - **Contractor training is critical**
   - **Shell measures optimize results**
   - **Heat Pump Technology is robust, proven, valuable, and synergistic with Grid Ops**
3. **Infrastructure improvements have impacts at the Portfolio Level and are inaccurately attributed**
4. **All stakeholders benefit if we get this right**
   - **The entire supply chain benefits and should be called upon for their unique specialties**
5. **We need to get this right the first time**
   - **Reliably drives the market!**

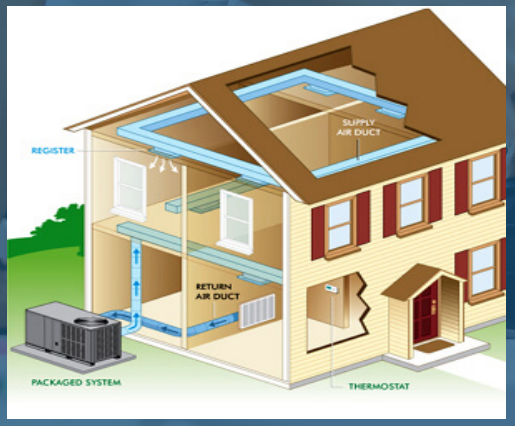
DUCTED AIR SOURCE HEAT PUMPS

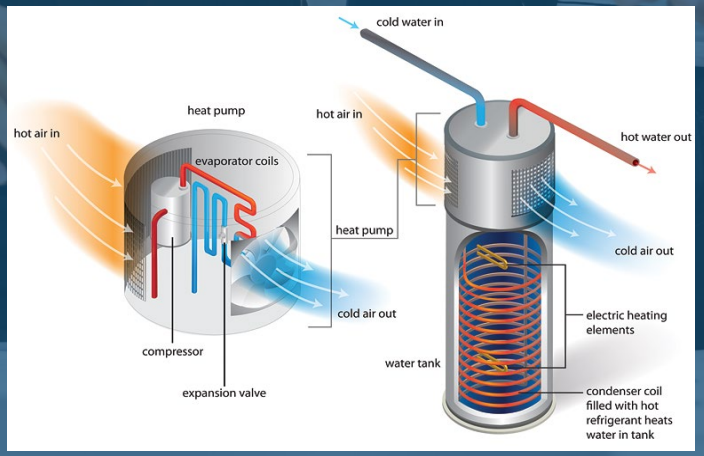
Split Systems
- Bi-Directional Refrigerant Flow
- Outdoor Condenser
- Indoor Air Handler
- **Refrigerant Line Field Installed**
- Two Circuits

Package Units
- Bi-Directional Refrigerant Flow
- Outdoor and Indoor Units in One
- Ducted through Roof or Subfloor
- **Refrigerant "Charged" at Factory**
- One Circuit

Water Heating is Very Different
- ***Single Direction Refrigerant Flow***
- ***Indoor Application Predominate***
- ***Refrigerant Charged at Factory***
- ***May Need Ducting due to Cold Air Discharge***
- ***One Circuit***

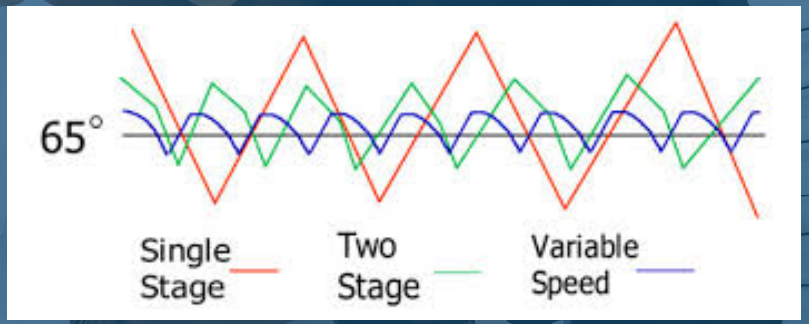






Approaches to HVAC System Demand

- Two Stage and Variable systems perform better from demand management and customer experience perspectives
- Two stage has been around a 20+ years and is often baseline for end user financed systems



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HVAC System Demand Dynamics

HP Only w/ 5 to 20 kW "Booster Heater"	Hybrid System	Variable Refrigerant Flow & "Oversizing"
1st Stage Heat is achieved by Heat Pump	1st Stage Heat is achieved by Heat Pump	Entirely HP Operation
2nd Stage is a LARGE DEMAND Electric Heater	2nd Stage is a Gas Burner	
Requires (2) 230 Volt Circuits	Reuse Existing Service for both Split & Package Systems	May or may not require electric service upgrades
Electric Resistance during Peal Grid Demand	Manages Demand during Peak Grid Demand	Manages Load 24/7/365
Lowest Cost	Mid-Range Cost	Highest Cost
Resistance heat is typically not captured by programs (invisible)	Will not appear to be fuel switching	Will falsely appear to be additional load

A 5 kW Solar Array will typically need 18 panels

Utility Service by Solution

HP Only w/ 5 to 20 kW "Booster Heater"

- Package Units will have a serviceable circuit existing
- Dual fuel Split Systems will have 230 Volts at the condenser and 115 Volts at the Air Handler
- Rewiring the Air Handler location to 230 Volts may be required for booster heat.
- 115 Volt Air Handlers exist and may work in some applications

Hybrid System

- Any dual fuel existing system will have the utilities needed where the equipment is located, this applies to both Split and Package systems

Variable Refrigerant Flow & "Oversizing"

- Split systems will require (2) 230 Volt circuits
- Package Systems will require (1) 230 Volt circuit
- Larger homes with poor shell measures may need booster heat *or* multiple systems, multiple systems is more costly yet manages loads better
- Shell measures are always most cost effective

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Secondary heating should only operate at or below freezing

Breaker Panel Concerns

100 AMPS OR LESS EXITING

- Potential to reuse circuits if there is enough capacity for existing and one or *maybe* two new circuits
- Potential to expend resources on new circuits and need a panel replacement later
- **Some level of service will be needed in any case**

200 AMP PANEL EXITING

- Typically, enough capacity to facilitate Renewables, Heat Pumps, and Evs
- Adding Heat Pumps or EV Charging Stations will require new or repurposed circuits
- **New circuit costs are easily attributed to measures**

NEWER & OLDER CONSTRUCTION

- ***NEWER*** construction typically has 200 Amp service existing with space and/or unused circuits
- ***OLDER*** construction typically needs panel improvements
- **Older homes in rural locations are likely to have 200 Amp service**
- **Every home is unique**

PANEL REPLACEMENT

- Costs vary by site conditions **Overlap with renewables and transportation**

- Detached garages cost more due to trenching
- Need and complexity in managing costs is greater
- **Where should costs be attributed?**
- **Income qualified customers need more support**

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An excellent example of Service Panel Rebates

What's done right here:

- Multiple Sectors Addressed
- Market Rate and Income Qualified get "Right Sized" Incentives
- Measure and Panel upgrade costs are captured distinctly

Implementation Concerns:

- Rich incentives in Income Qualified *may* lead to contractor price gauging
- More site data needed to verify need level
- Field QA/QC safeguards are more important, but can be redundant with code required inspections
- Data gathering to improve program operations is more robust than historical deemed savings programs

Central Coast Community Energy
CLEAN ENERGY. LOCAL CONTROL.

CHARGE YOUR RIDE
ELECTRIC VEHICLE CHARGER PROGRAM

TYPE OF PROJECT	BASE INCENTIVE: HOMEOWNER	BASE INCENTIVE MULTI-FAMILY, COMMERCIAL, INDUSTRIAL, & AG CUSTOMERS	INCOME QUALIFIED INCENTIVE & PUBLIC AGENCY INCENTIVE
LEVEL 2 CHARGER ONLY	$400	up to $1,000 ea. (3 chargers max)	up to 100% of project cost ($10K max)
ELECTRICAL WORK	up to $2,000	70% of project cost ($7K max)	
MAX INCENTIVE	$2,400	$10,000	$10,000

LEARN MORE AND APPLY AT: 3Cenergy.org
@3CEnergy

- Older buildings will need more significant improvements
- Disadvantaged communities will have older buildings
- Newer buildings will have circuits that can be repurposed

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Customers with Solar installed typically have corrected and/or upgraded service panels

- Building Departments and Code Officials view PV as added load on a system
- All in home end uses + PV system capacity dictates service capacity

Communities will have infrastructure costs to manage

- At the site level
  - The feeder wire coming to the meter may be too small
- At the neighborhood level
  - The transformer serving a neighborhood will ***eventually*** need upgrading with attrition or increases in demand
- At the grid level
  - Population growth and usage trends , including but limited to EVs and HPs, will incur infrastructure improvements

LOAD MANGEMENT

Load Managements Systems can be simple or complex.
A simple system may only share load from dryer to an EV in the garage.

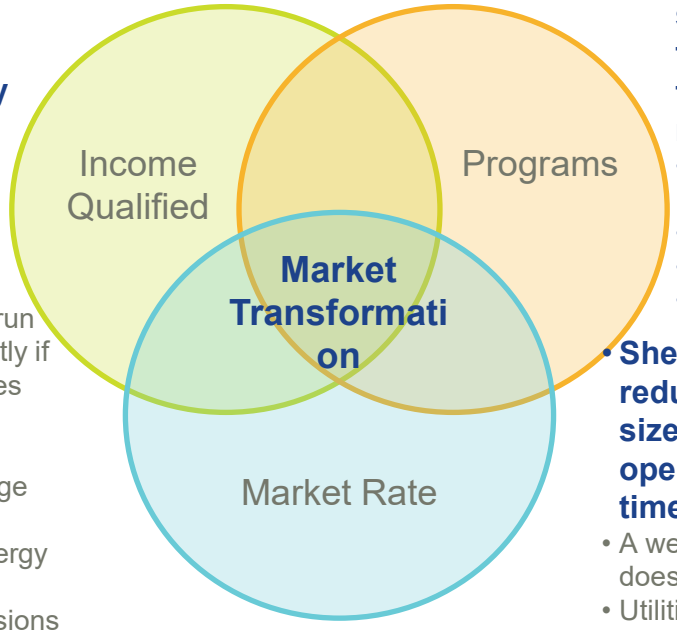
Smart breaker panels manage all loads, storage, EV, and PV, through phone apps with customized priorities and reports.

HEAT ONLY TO HP SYSTEMS, ADDITIONAL LOAD?

Moderate Climates with historically low cooling loads may have a significant percentage of heat only systems

- **All** HVAC HP Systems will provide both heating and cooling
- Adding AC where it did not exist before can be viewed as adding load
- As our climate continues to change market demand for cooling will increase
- Disadvantaged communities will be most effected by climate change
- **How will the market respond to new demand for cooling if they are not aided by an energy professional?**

- **Window AC is low cost, mobile, installed by lay people, introduce outside air, and are inefficient**
  - Systems will run more frequently if shell measures are poor or absent
  - Climate change will result in increased energy burden and harmful emissions



HVAC programs succeed when they engage the entire market

- **Manufacturing**
- **Distribution**
- **Trade Pros**
- **End users**

- **Shell measures will reduce system sizes, frequency of operation, and run times**
  - A well-trained workforce does better quality work
  - Utilities and local governments get greater visibility into the market

Newer systems can enable thermal storage, demand response, and Grid Harmonization.

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Effective implementation of HP-HVAC in energy efficiency programs

Lessons from the road

MARKET RATE & INCOME QUALIFIED

Comfortable Home Rebates PG&E

- Market Rate Program
- Meter Based Savings (NMEC)
- Contractor driven sales process
  - Education & training
    - Technical
    - Sales
    - Business Ops
    - Home as a system
- Rebate Level Considerations
  - Big enough to spur action
  - Small enough to manage the budget
  - **Only measures that produce at the meter**

Home Energy Savings MCE

- Equity Program
- Deemed Savings
- Neighborhood level customer outreach

- Customers can be cynical about any program due to prior experiences
- Customers often fear “new” technologies even if it’s free
- Customers routinely fear the permitting process

What Happens if we get this wrong?

The most important factors considered when choosing an HVAC system are:

1. ***The system will operate for a long time without needing to be serviced or replaced***
2. **The operating cost**
3. **Always produces the desired air temperature**
4. **Purchase price is also important among the buying segment**

Frank Landwehr
Emerson Climate Technologies
Residential Market Study 2015

Solar Thermal Lessons Learned,

"In the 1970s, solar thermal water heating rebates were generous, contractors installed them en masse, and most never reached their full potential. ***Solar thermal systems leaked, the tanks failed, and overall, it was not a successful effort****."*

Charley Cormany
Efficiency First California 2021

Lighting Lessons Learned,

*"****After imprudently producing low quality CFLs that spurred consumer dissatisfaction and created negative perceptions,*** *the large lighting manufacturers determined that they would not promote LED products until they were truly ready, despite the desire to be first to market."*

PNNL 2006

Multiple benefits to panel Upgrades

- **Improvements in electrical infrastructure impacts,**
  - **HVAC**
  - **Renewables**
  - **Water Heating**
  - **Transportation**

How can infrastructure costs be attributed to any one program or measure?

Food for thought,

Should the utility providers be allowed to include behind the meter improvements to capital improvement budgets (T&D) in Disadvantaged Communities?

Should HP driven technologies qualify Market Rate customers for lower rates? (i.e., “electric only”)

"Continuous improvement is better than delayed perfection."

Mark Twain

CONCLUSION

1. Multiple benefits exist with Heat Pump HVAC
    - Population level load reduction
    - Increased load management opportunities
    - All non-energy benefits we know and love about energy efficiency
        - Improved comfort, air quality, etc.
2. Solutions should be tailored at the site level
    - Barriers are varied by site and socioeconomics
    - Contractor training is critical
    - Shell measures optimize results
    - Heat Pump Technology is robust, proven, valuable, and synergistic with Grid Ops
3. Infrastructure improvements have impacts at the Portfolio Level and are inaccurately attributed
4. All stakeholders benefit if we get this right
    - The entire supply chain benefits and should be called upon for their unique specialties
5. We need to get this right the first time
    - Reliably drives the market!


THANK YOU
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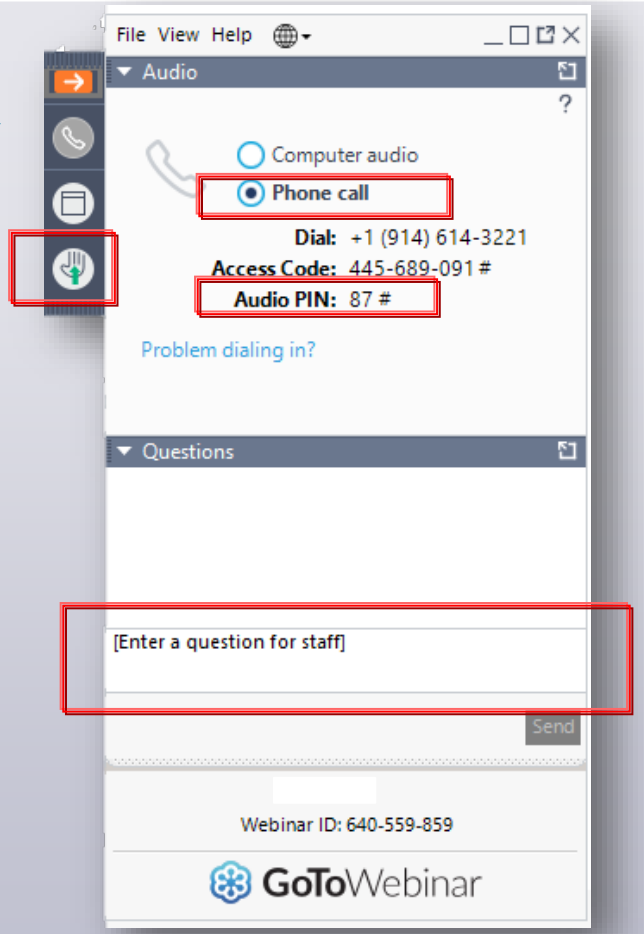
Discussion:
Share Your Questions

Open and close your **control panel**

Raise your hand to enter the discussion



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Vince Romanin
Gradient

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Gradient

How do we make people want heat pumps?

Vince Romanin, Aug 2021

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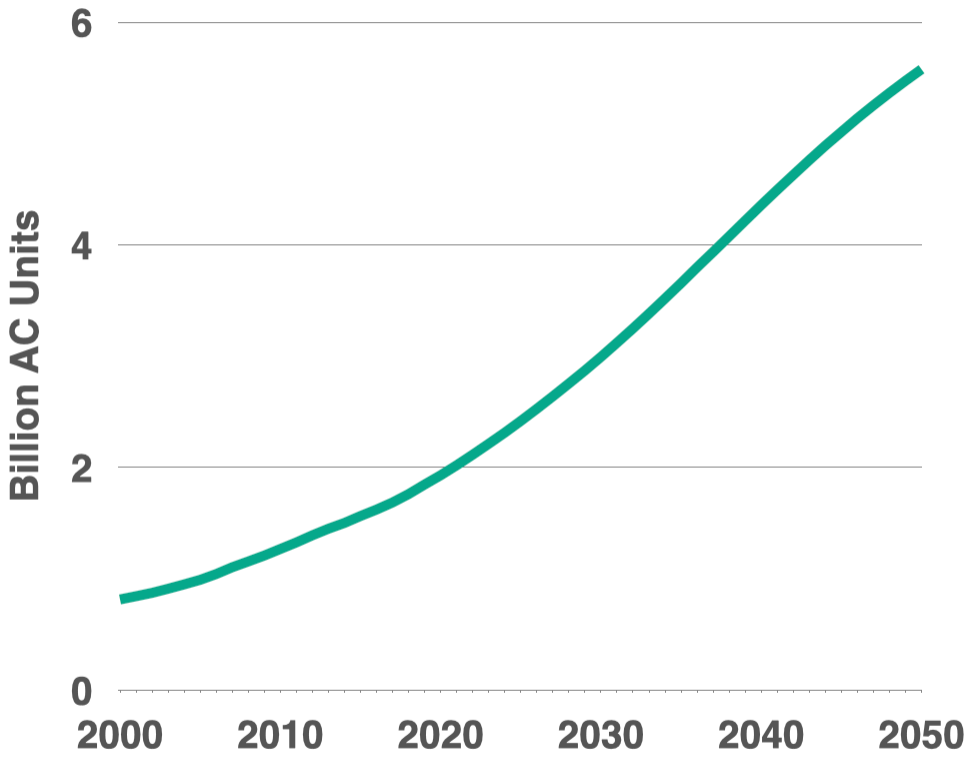
Our mission is to cool the world

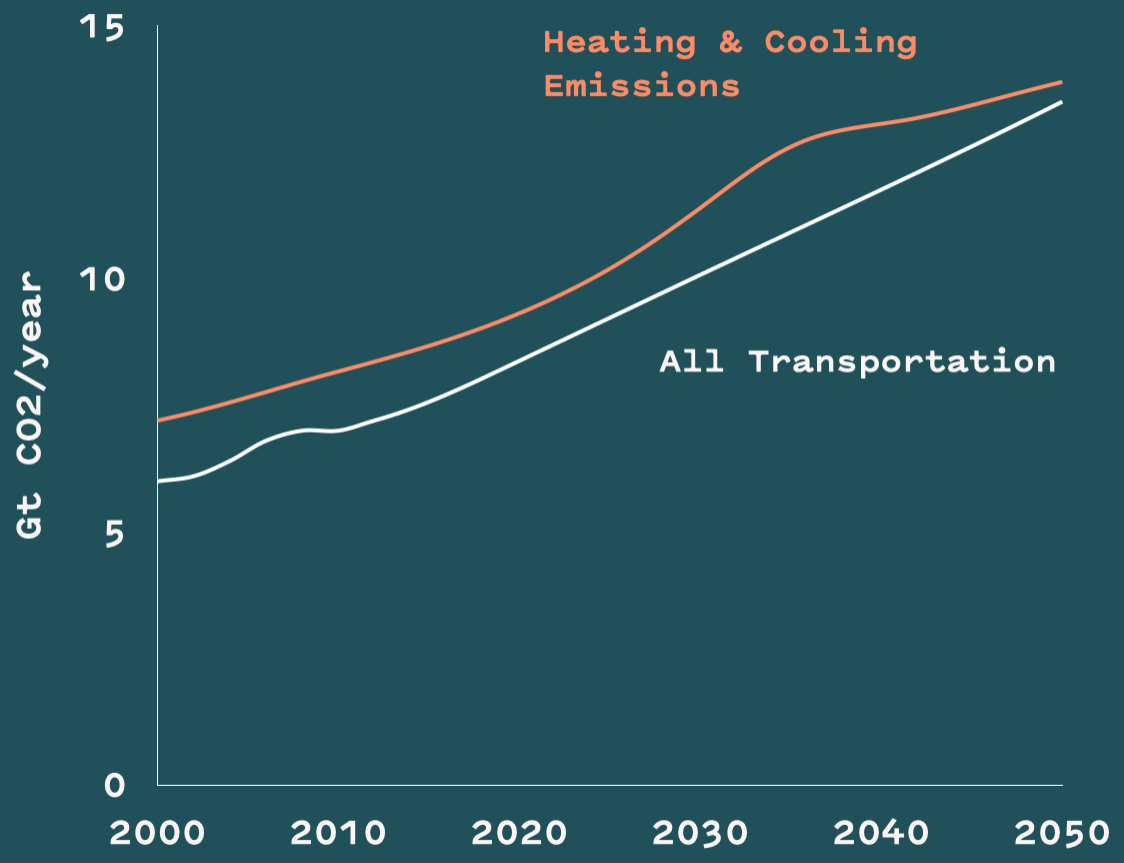
by transforming every home and building to be more comfortable and healthy for the people who inhabit it — without compromising the environment

Humans will add **4 billion more** air conditioners to the planet by 2050



www.iea.org/cooling

Our need for climate control is **killing the climate**



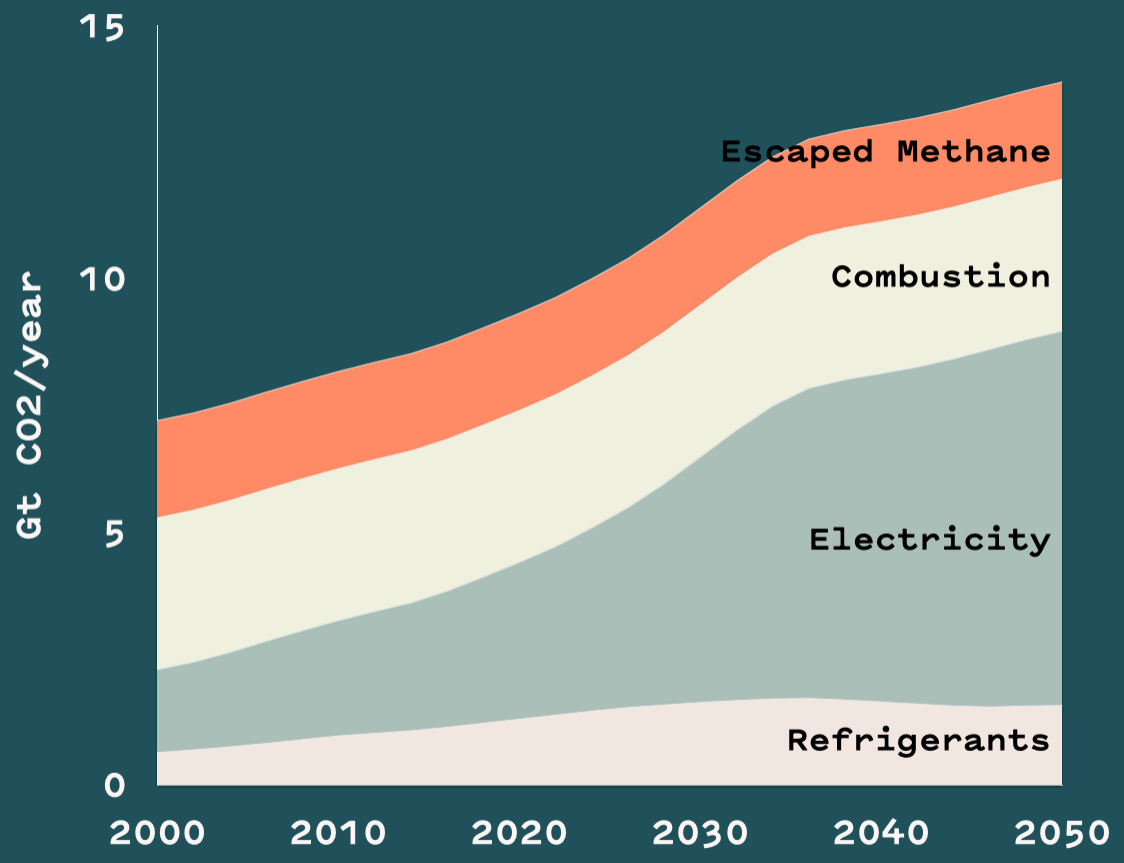
In the future:

everyone

has a **heat pump**

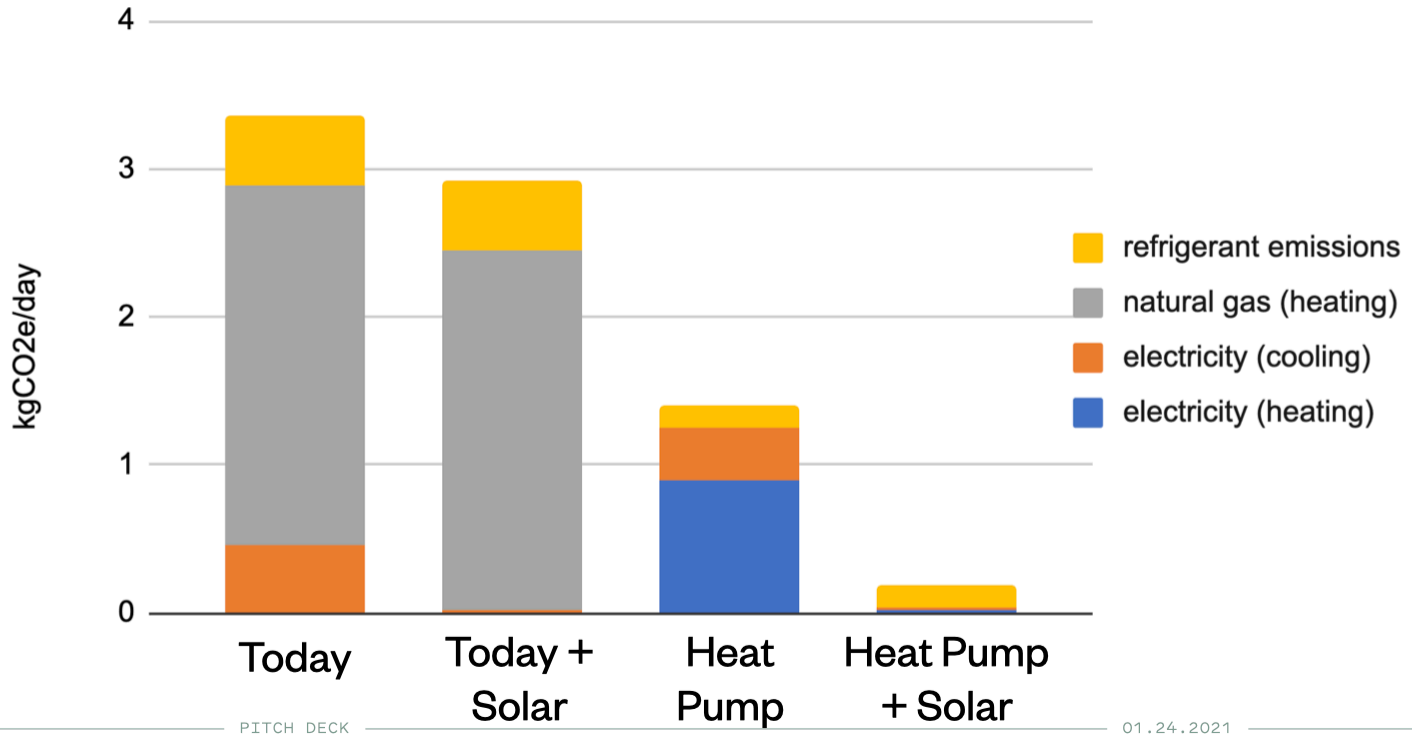
that is
smart & efficient,

and uses a
natural refrigerant



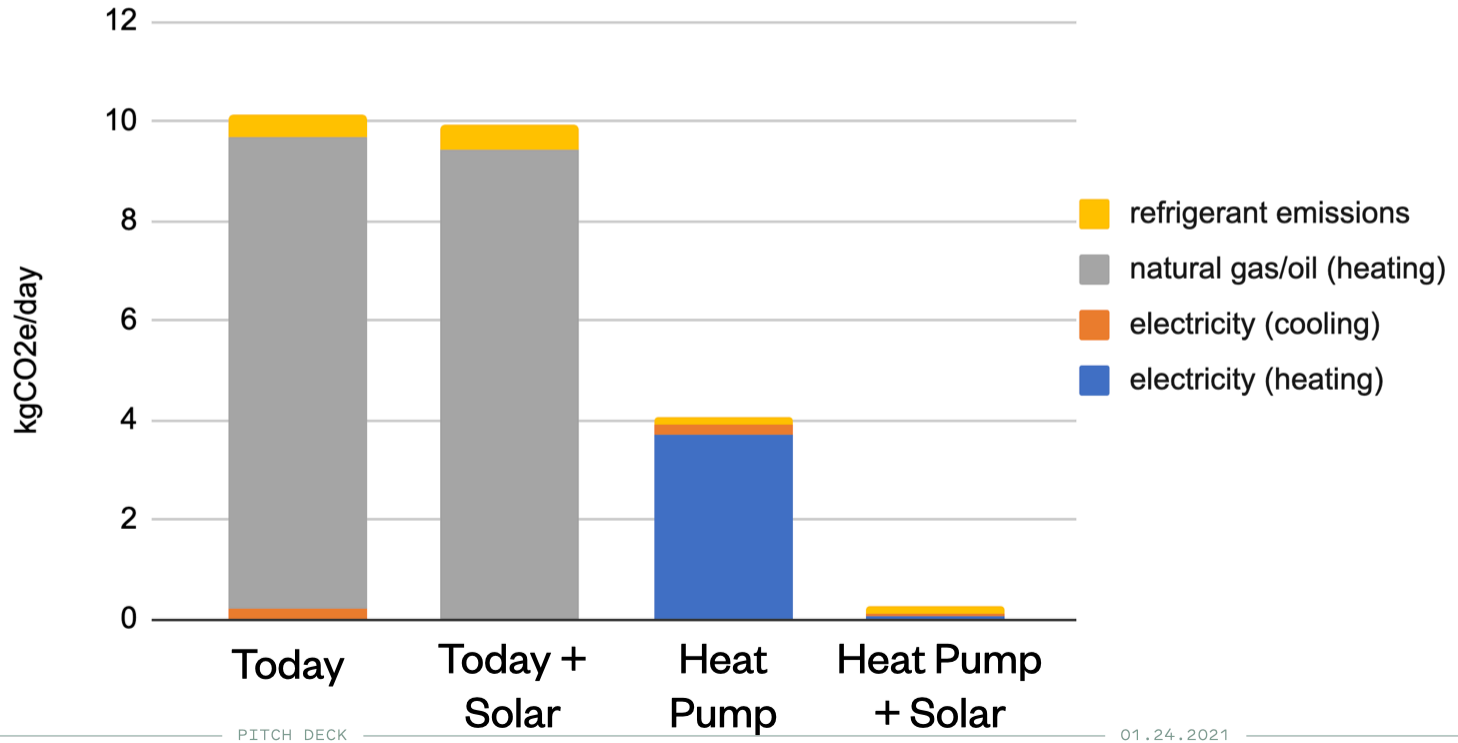
How much carbon could a heat pump save?

AVERAGE HOME IN CA

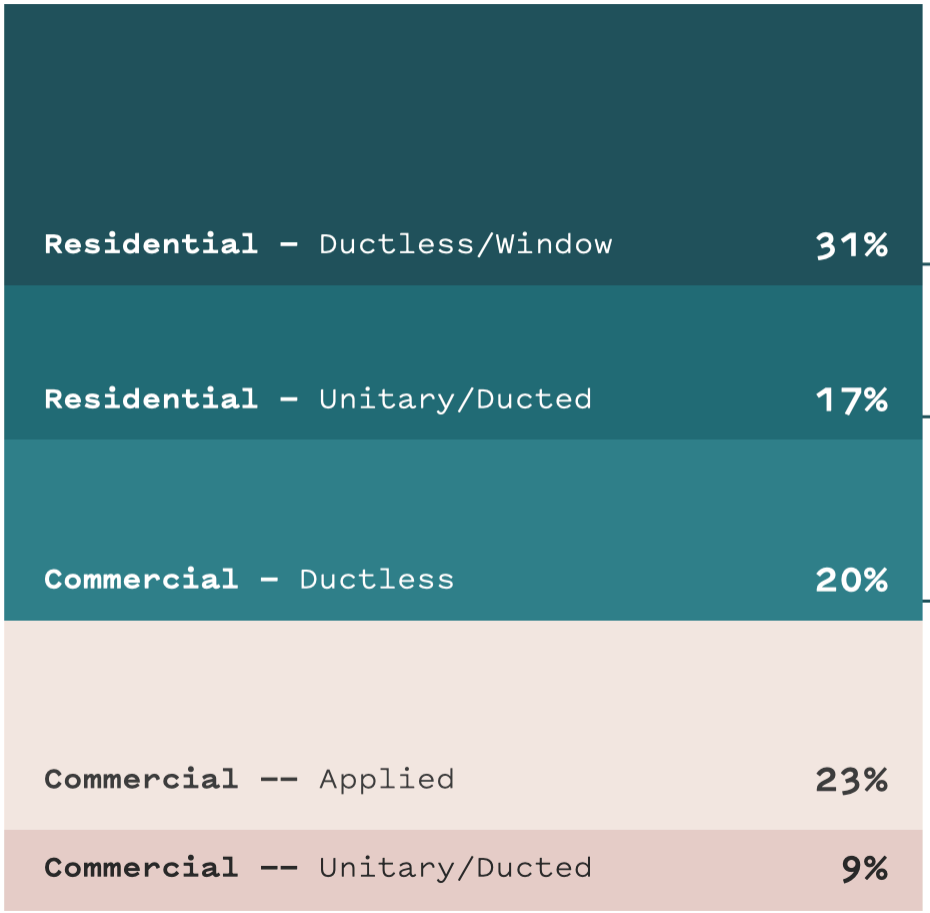


How much carbon could a heat pump save?

AVERAGE HOME IN NY



Global HVAC market



LAUNCH MARKET (2021)

MARKET 2 (~2022)

MARKET 3 (~2025)

Our first three phases cover **more than 2/3** (68%) of the total global HVAC market

Launch market: displace window ACs

LOUD

UGLY

DANGEROUS

INEFFICIENT

Split unit options

QUIET

10X COST

COMPLEX

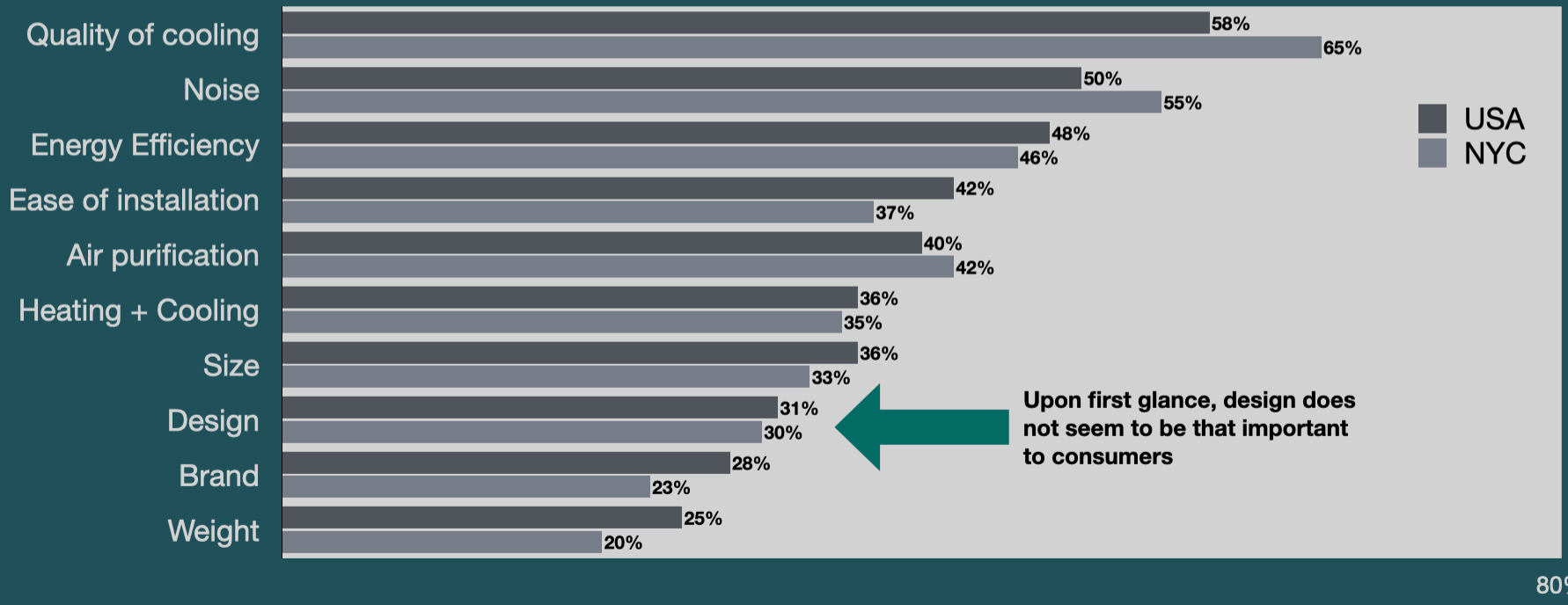
...STILL UGLY

2022: Direct-to-Consumer Launch

- Cooling + heating
- 9,000 BTU/hr
- No tools, DIY install in <15 mins
- Whisper quiet
- Climate-friendly refrigerant
- WiFi control via iOS and Android app

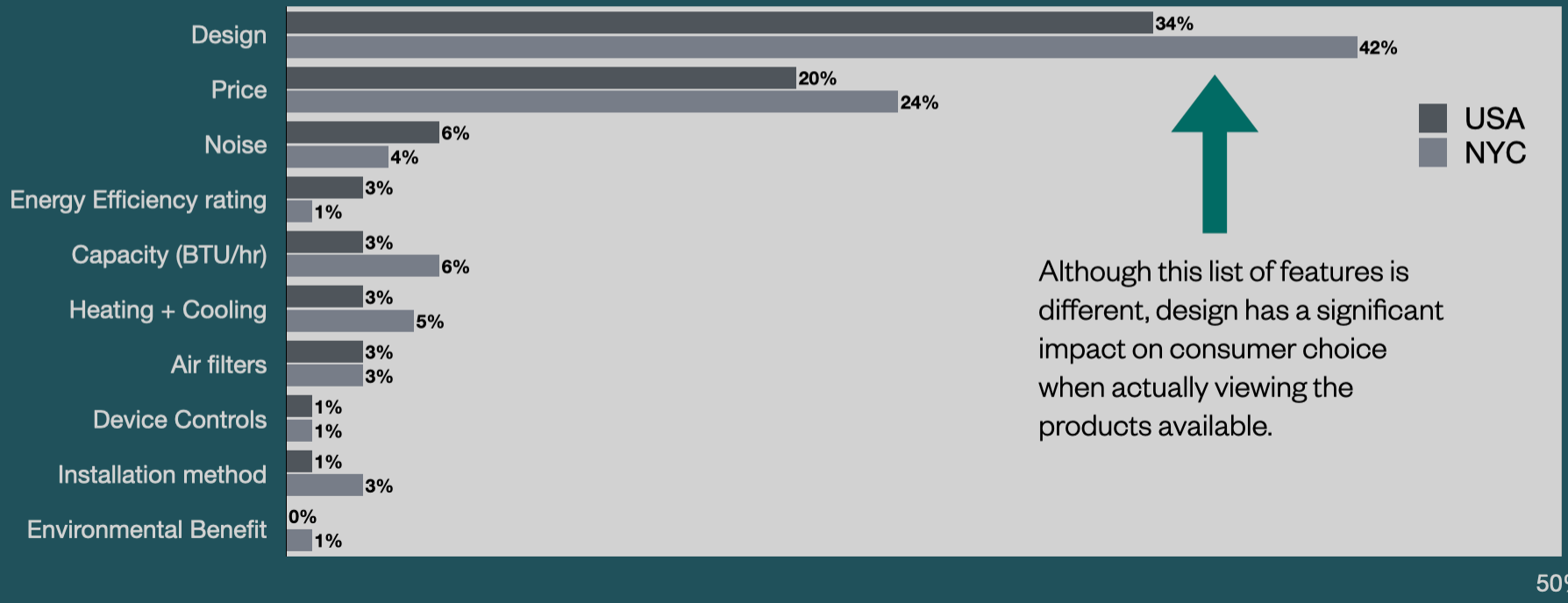
Customer research: Stated preferences

QUALITY AND NOISE ARE MOST IMPORTANT FEATURES BEFORE SEEING GRADIENT



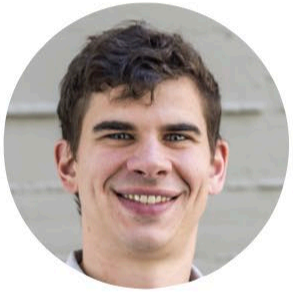
Revealed preferences

DESIGN RISES TO TOP WHEN FORCED TO CHOOSE BETWEEN GRADIENT & COMPETITORS



Gradient Leadership

DEEP TECH AND CONSUMER EXPERIENCE



Vince Romanin
CEO

Berkeley
UNIVERSITY OF CALIFORNIA

Kipp Bradford
CTO

MIT Massachusetts Institute of Technology

Amber Lucas
COO

TESLA

Kerry Cooper
Board

ROTHY'S

Dorian West
Board

TESLA

Want to help?

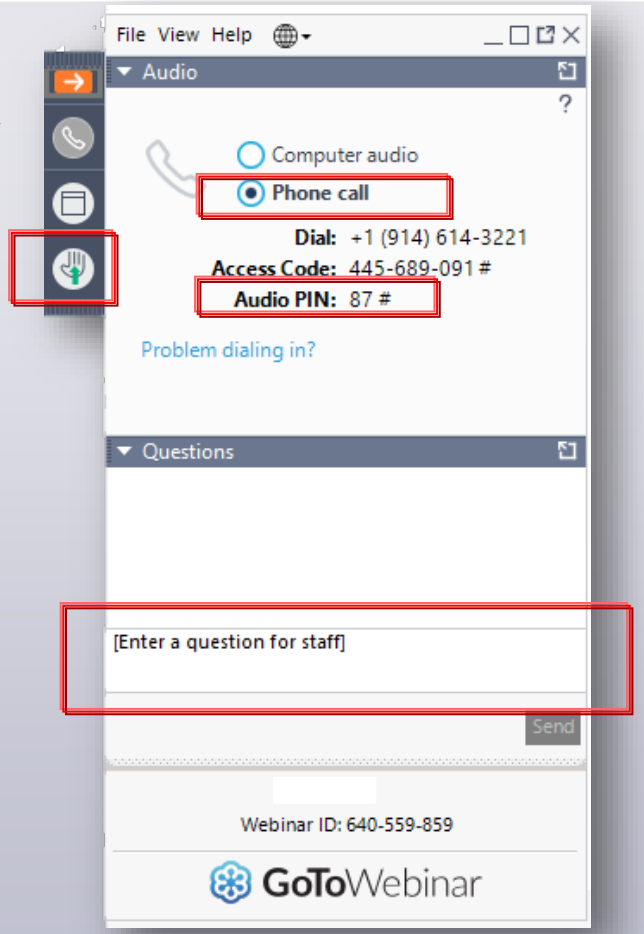
- Sign up to beta test:
  www.gradientcomfort.com
- Help us hire:
  www.gradientcomfort.com/pages/careers
- Help enable natural refrigerants in UL 60335-2-40 and ASHRAE 15
  vince@gradientcomfort.com

Thank you!

Discussion: Share Your Questions

Open and close your **control panel**

Raise your hand to enter the discussion



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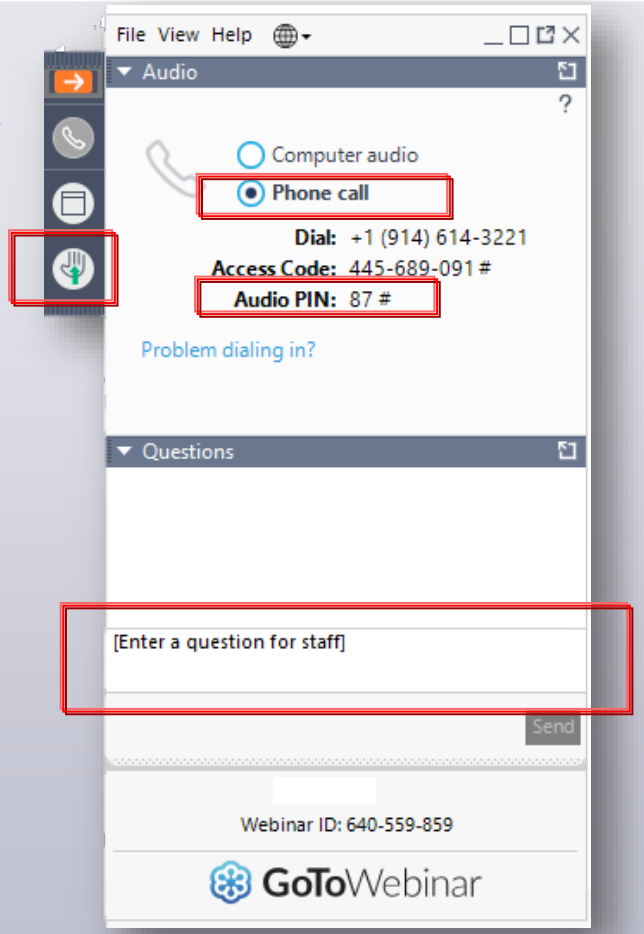
Open Discussion

Open and close your **control panel**

Raise your hand to enter the discussion



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If you have called in on a phone today, double check that you've selected telephone as your audio option.

Closing Poll

- **After today's call, what will you do?**
  - Consider implementing one or more of the ideas discussed
  - Seek out additional information on one or more of the ideas
  - Make no changes to your current approach
  - Other (please explain)


STEM
RISING
U.S. DEPARTMENT OF ENERGY
ENERGY.GOV/STEMRISING

Explore the Residential Program Solution Center

Resources to help improve your program and reach energy efficiency targets:

- Handbooks - explain *why* and *how* to implement specific stages of a program.
- Quick Answers - provide answers and resources for common questions.
- Proven Practices posts - include lessons learned, examples, and helpful tips from successful programs.
- Technology Solutions NEW! - present resources on advanced technologies, **HVAC** & **Heat Pump Water Heaters**, including installation guidance, marketing strategies, & potential savings.

https://rpsc.energy.gov

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bbresidentialnetwork@ee.doe.gov