Cal-THRIVES: A California Toolkit for Heat Resilience in Underserved Environments

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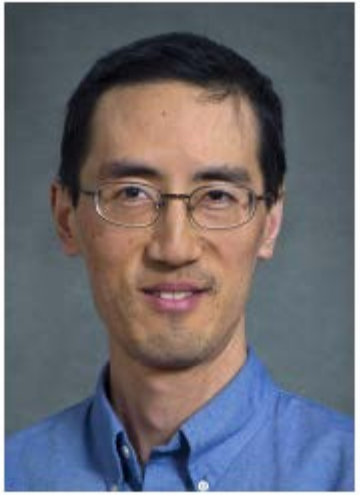


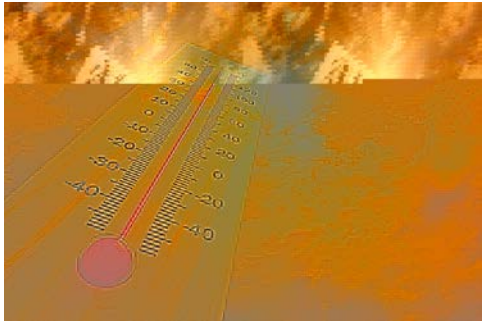
Feedback

- From Jose Roldan, DOE to Me (Direct Message) 05:30 PM
- Thank you Sir for presenting an interesting topic. As an employee of the lab (DOE) and resident of the central valley (Visalia, CA) and Daly City this was a truly informative subject to cover. Difficult topic to discuss in certain parts of the central valley due political differences, socio-economic as you stated, and educational access.
- From Jenn Tang | Berkeley Lab | to Everyone 05:43 PM
- To learn more, visit: calthrives.lbl.gov
- From Michael Brandt to Me (Direct Message) 05:43 PM
- Nicely done. Thanks, Max
- From Julia Hatton to Everyone 05:49 PM – standards do not take into acct resilience; my policy recs very relevant
- thank you, max!
- I think that distinction between discomfort/danger is important
- From Jenn Tang | Berkeley Lab | to Everyone 05:50 PM
- Really good point, Julia.
- From Dione Rossiter to Everyone 05:50 PM
- Great work!
- From Marcos Gandara to Everyone 05:51 PM
- Thank you Max...my head is spinning with too many questions...looking forward to doing a deep dive on your research
- From Jenn Tang | Berkeley Lab | to Everyone 05:53 PM
- Hi Marcos - we'll get Max's presentation (along with the others) up on the CAG website in the next day or so!
- From Me to Everyone 05:53 PM
- Thanks everyone for the feedback and great questions! Feel free to contact me if you have any follow up questions or thoughts (mwei@lbl.gov).
- From Julia Hatton to Everyone 05:55 PM
- @diz, we should connect re: building electrification! Diz Swift League Women Voters

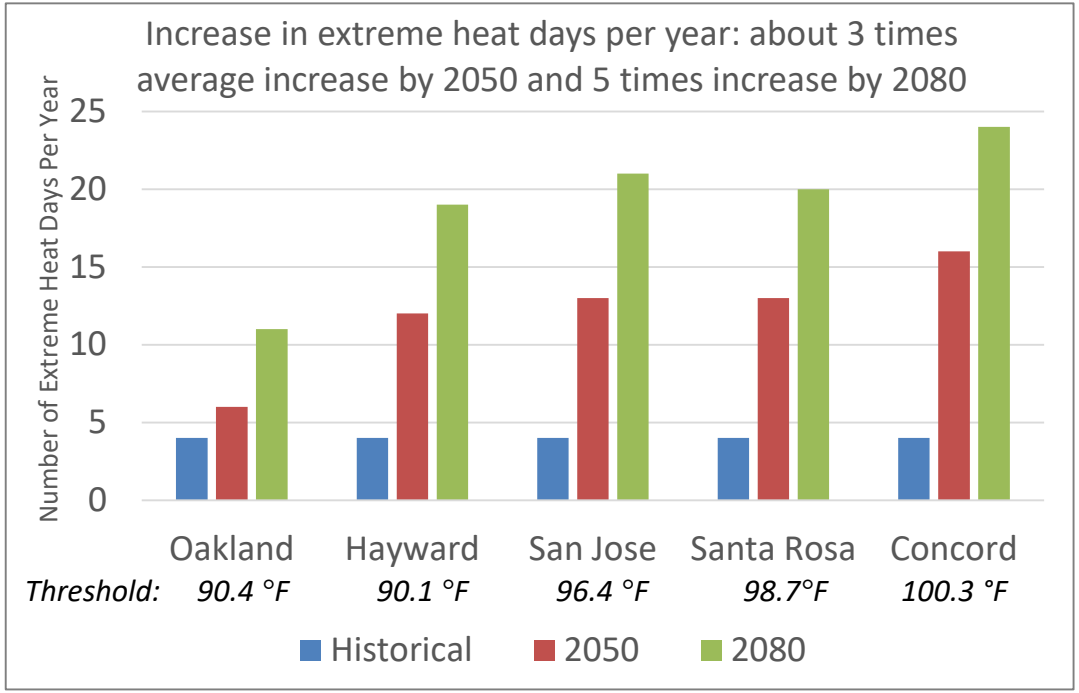
Extreme heat is highly coupled to equity, public health, natural resources, the energy system & GHGs

Extreme heat:

- has increased severity/frequency from climate change
- Impacts disadvantaged communities disproportionately
- Is a critical public health issue, leading cause of mortality from climate-change
- Degrades quality of life, increases discomfort/misery
- Worsens air quality
- Increases summer utility bills
- Increases wildfire risk & exacerbates drought
- Stresses the electricity grid from more air conditioning
- Increases GHG emissions from more air conditioning
- Stresses agriculture & ecological systems
- Strains other infrastructure



Bay Area will see several-fold increase in the frequency of extreme heat days

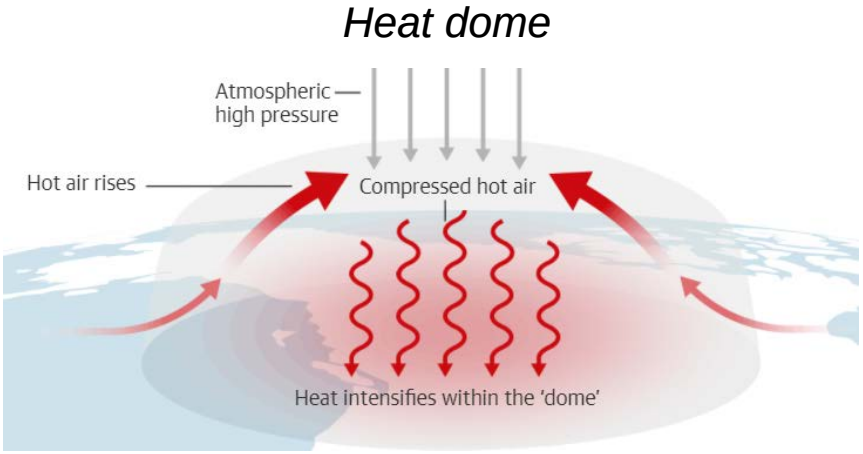


Ref: Cal-Adapt

What about worst-case conditions?

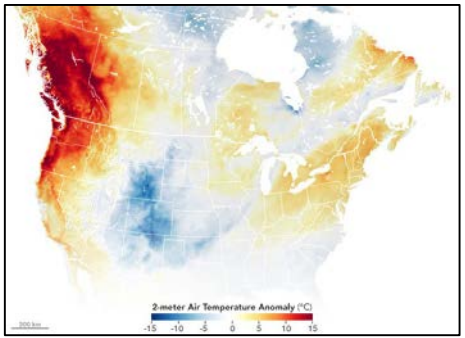
The preceding plot is for AVERAGE increases in the annual number of extreme heat days.

Worst case: “Heat domes”



Bay Area/Central CA escaped the 2021 Pacific Northwest heat dome

The 2021 Pacific NW heat wave has been deemed a “1 in 1000 year event”… but could become more frequent
e.g. Redding, CA had 15 days above 100 °F in June 2021 with **9 days at or above 105 °F, high at 112 °F**



KPIX CBS SF BayArea

Bay Area Escapes Heat Dome Searing Pacific Northwest, For Now

“The intense heat gripping the Pacific Northwest was originally intended for the Bay Area. As recently as June 18th, long range ***high resolution forecasts began depicting an intense heat dome centered over Northern California’s Central Valley*** *with daytime highs reaching up to 119 in Sacramento and 126 in Redding.” – CBS KPIX, June 28, 2021*

Cal-THRIVES Research Background and Objectives: focus on heat resilience in Fresno

EXTREME HEAT:

"**Heat now causes more deaths** than hurricanes, tornadoes or floods in most years"

The Guardian, June, 2020

"Most costly climate change impact in CA by 2050" *CA 4th Climate Change Assessment, 2018*

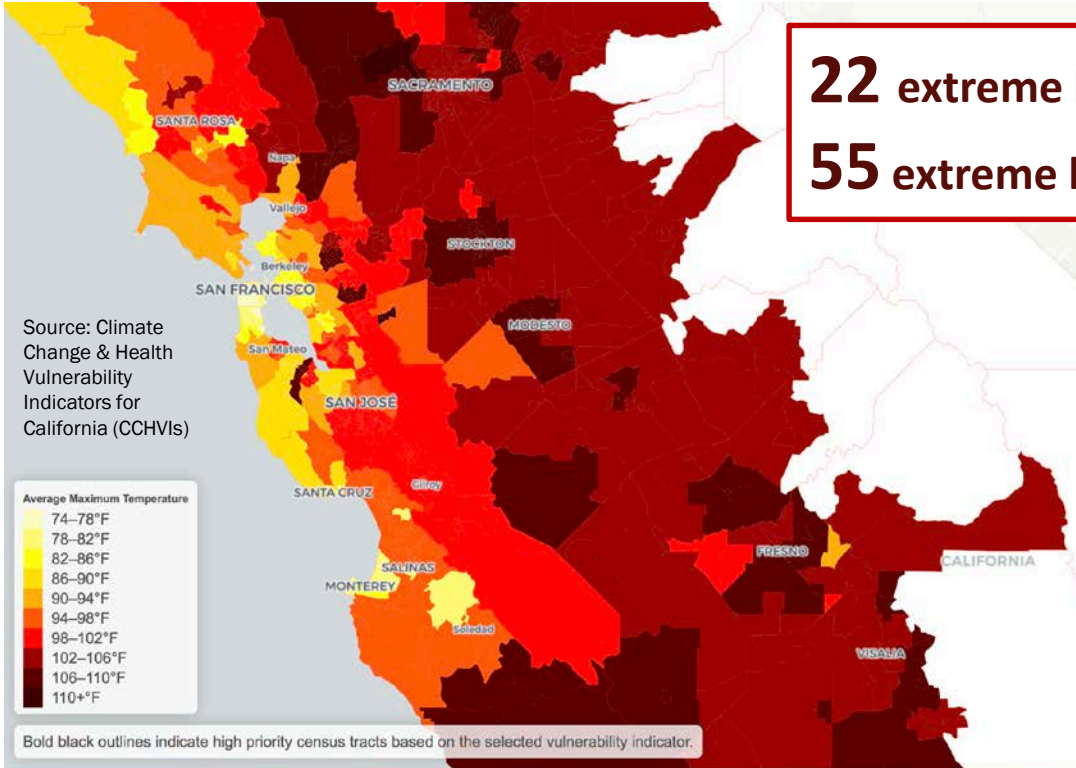
Research objectives:

- Develop methodology to model heat resilience at neighborhood scale
- Quantify resilience benefits of passive and active measures during extreme heat waves in a disadvantaged community
- Develop a set of toolkit items to help disadvantaged community (DAC) residents better cope with extreme heat

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 hotter



Source: Climate Change & Health Vulnerability Indicators for California (CCHVIs)

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

Maanvi Singh *in Fresno*

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

The good news is that we **can implement preventative strategies now** to mitigate heat health impacts

The Cal-THRIVES project has developed a toolkit for local and state stakeholders

SHORT TERM

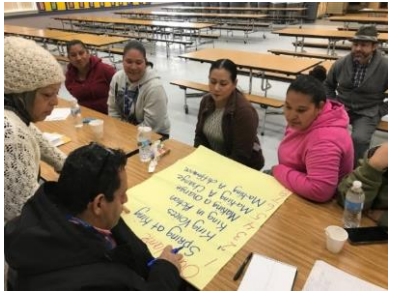
- Increase awareness of heat-related vulnerability
- Identify areas that are vulnerable to extreme heat events

NEAR TERM

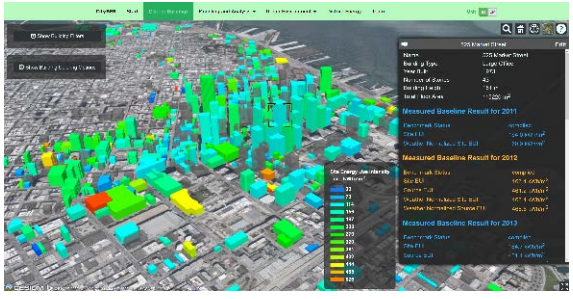
- Remedy the built environment, such as building retrofits & increases to tree canopy
- Enhance community and home cooling programs

Approach: Our heat-resilience toolkit incorporates both **community inputs and science**

Community engagement

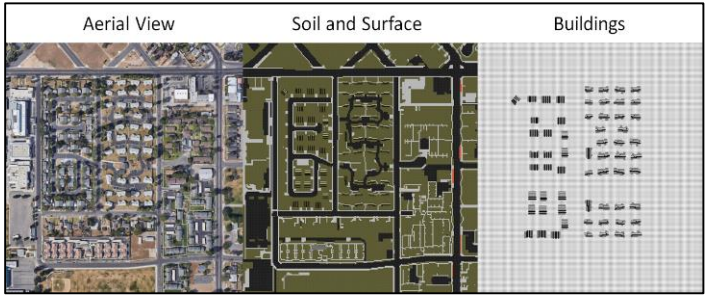


Neighborhood-scale building modeling



Cooling center optimization

Outdoor measure modeling



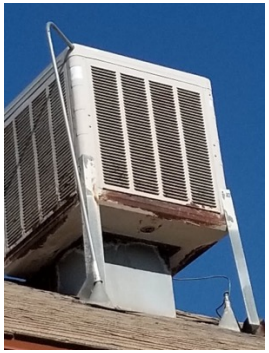
Heat Resilience Toolkit

Community cooling guide
Fact sheets
Modeling outputs
Heat vulnerability index tool
Online tutorials (videos, webinars)
Policy/program recommendations

We find **several key vulnerabilities** for residents in disadvantaged communities (DACs) in south Fresno

- Over 70% are uncomfortably hot at home very often during the summer
- Residents on the top floors and those residents in units that lack air conditioning (about 15%) are especially vulnerable

Old, inefficient window ACs

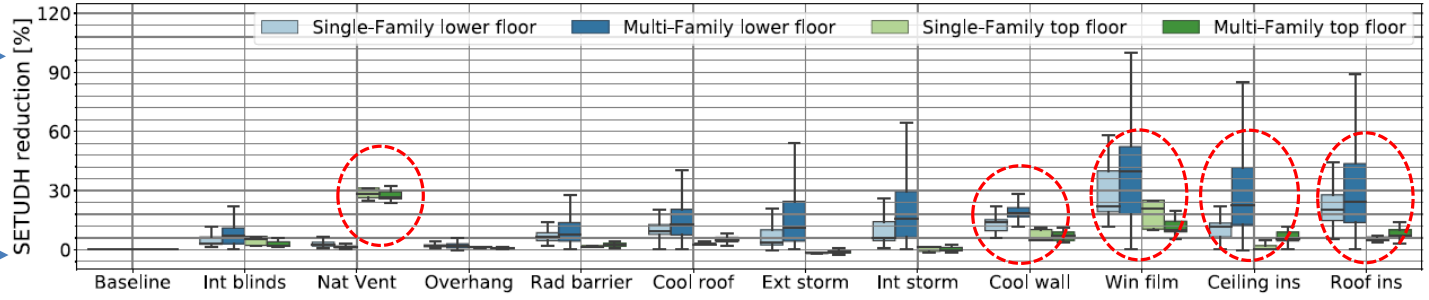


Swamp coolers

Window films, roof/ceiling insulation, and cool walls are the among the most effective passive measures overall; **natural ventilation** on top floors is very helpful

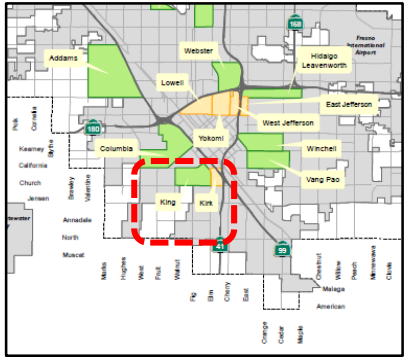
More protection from extreme heat (bigger value) →

Less protection from extreme heat (lower value) →



(c) King Passive 5-Day SETUDH Relative Reduction Grid Off

Modeled for worst case historical heat wave conditions across five days



King & Kirk neighborhoods in Fresno

Fact sheet example

Cal-THRIVES

Air Conditioning Systems

Purpose

This document provides summary information about air conditioning system options available in the market. The document also discusses air conditioning system selection and replacement considerations, installation practices, and tips/recommendations for its daily operation.

What Is an Air Conditioner?

An air conditioner (AC) cools your home by extracting indoor heat and expelling it outside. ACs improve indoor comfort and are usually required to keep you home at safe temperatures during extreme heat waves. There are many types of air conditioners and several important considerations when choosing a new or replacement unit. ACs are most commonly operated by using electricity.

Keeping You Cool And Comfortable

- Reduces temperature and humidity inside your home
- Eliminates life-threatening overheating and keeps you up to 18°F cooler during extreme heat waves compared to no air conditioning.
- Keeps you 5°F cooler and much more comfortable than evaporative coolers during extreme heat waves.

SOURCE: LBNL Cal-THRIVES

What Factors to Consider?

- Do you need an air conditioner?
- Equipment energy efficiency, reported as Energy Efficiency Ratio (EER) or Seasonal Energy Efficiency Ratio (SEER) — a higher EER or SEER means a more efficient unit and therefore lower electricity bill. EER is used to rate the efficiency of window and portable ACs as well as PTAC/PTHPs. SEER is used to rate the efficiency of central ACs, air source heat pumps, and mini-split ACs and heat pumps.
- Equipment cooling capacity/size to meet household comfort needs
- Noise level and other impacts to your home, such as limited access to window installed with a window AC type
- Quality and reliability
- Ease of installation and maintenance
- Equipment price
- Overall costs, including labor and other potential retrofit work

Types of Air Conditioning

Various types of AC exist in the market. In general, AC systems can be categorized in two groups: 1) Larger centralized systems, which have a cooling unit and air handler that distributes cooled air to different rooms through ducts or plenum space and 2) Smaller, "room-scale" systems, which supply cooled air directly to the room, such as window ACs, ductless mini-split ACs, packaged terminal units, and portable AC units.

The following is a list of AC types available in the market:

Central AC — A ducted system that cools many rooms in a home with a central evaporator and air handler indoors and a condenser outdoors.

Air source heat pump — Similar to central AC, it provides cooling in the summer but also heating in the winter, delivering cold or warm air to rooms through ducts.

Window AC — A non-ducted system that cools a room or an indoor space and is a self-contained unit, installed in a window opening, with a section exposed to the outdoor

Mini-split air conditioner/heat pump — These through-the-wall units join an indoor evaporator unit to an outdoor condenser unit with a pipe that carries refrigerant, and is typically used to cool or heat a single room. Some mini-splits provide only cooling, while others can also heat. It is more expensive to install than a window AC but can be much more energy efficient.

Packaged terminal air conditioner (PTAC)/ packaged terminal heat pump (PTHP) — These self-contained (single unit) "through the wall" units that can provide cooling only (PTAC) or both cooling and heating (PTHP). Commonly found in hotels and motels.

Portable AC — A self-contained unit (evaporator plus compressor) that sits on the floor and typically cools a single room, blowing hot air from its compressor out a window-mounted hose. "Dual-hose" models that use outside air, rather than room air, in a sealed loop to cool the compressor are more efficient and won't create a vacuum that can draw outside air through cracks below doors and around windows. Portable ACs are easy to install but are among the least energy efficient choices.

BERKELEY LAB


Window AC


Portable AC


Mini-split heat pump indoor unit


Outdoor unit

Other than the ACs, there are other types of mechanical cooling systems that may also provide some level of thermal comfort, as follows:

Evaporative cooler — Not a mechanical air conditioner, this device cools the air by evaporating water. Evaporative coolers use little energy, but do require water. They work best in dry climates.

Fans — Portable fans and ceiling fans improve indoor comfort by circulating air, and let you raise the temperature set point of your air conditioner without sacrificing comfort. This can save on energy and utility bills during the cooling season.

Installation

Air conditioners can be professionally installed or can be a do-it-yourself project for smaller self-contained units such as window ACs or portable ACs.

The cost to install an AC unit (equipment cost plus installation cost) varies widely for different AC options and depends on the existing AC in the home. For example, a new mini-split AC can be much more expensive to install than a portable AC, but cost less to operate because it's more energy efficient.

The labor cost to replace an existing unit, such as an old window AC, with a newer, more efficient version is much lower than the labor cost to install a new central cooling system. Consult an HVAC installer if you need a new system to cool multiple rooms.

When to Consider Getting a New AC?

In general, when an existing air conditioning system is no longer delivering sufficient cool air for comfort, and cannot not be repaired cost effectively, a new AC may be the solution. This is especially critical if the lack of thermal comfort is adversely affecting productivity, health, and risks during extreme heat events. The typical lifetime of ACs used to cool a single room is ten to 15 years. Central ACs and heat pumps, as well as mini-split ACs and heat pumps, have typical lifetimes of 15 to 20 years.

Adding AC to a home without it: If you are uncomfortably warm during the summer even when using a fan, and have explored other energy efficiency measures for your home such as increased insulation, a radiant barrier in your attic, solar control window films, or cool roof/cool walls.

When to Consider this Retrofit—Ownership

- ☑ Homeowner
- ☑ Apartment/Home Renter — Long Term
- ☐ Apartment/Home Renter — Short Term
- ☑ Live in a Condo/Townhouse
- ☑ Live in a Historical District

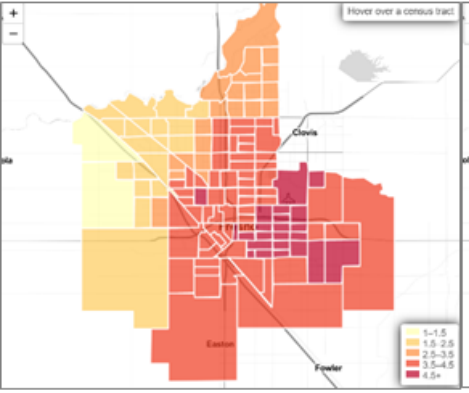
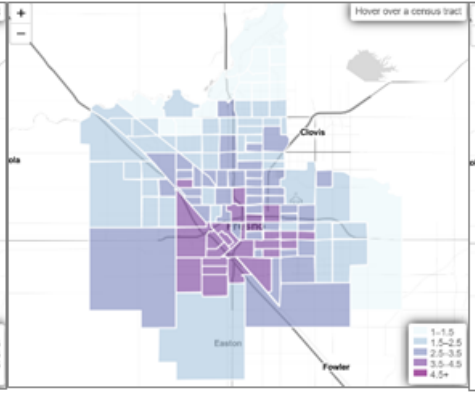
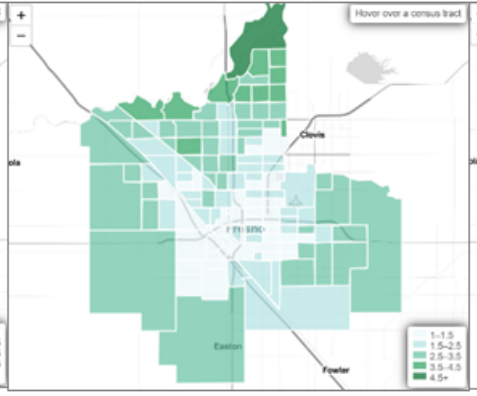
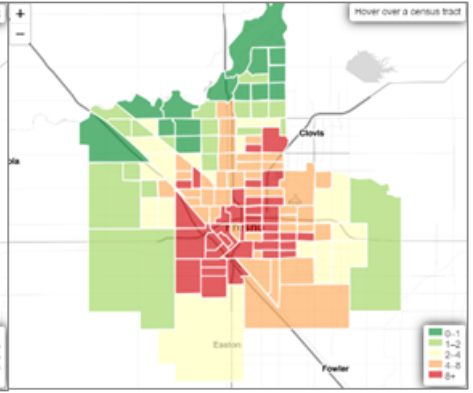
What to Look at When Your AC is Not Performing Well?

Here are potential problems with an existing AC:

1. Not working as designed — needs service to repair compressor or fan
2. Not working as designed — needs service to fix refrigerant leak, typically in either the refrigerant line or evaporator (i.e., indoor heat exchanger) of a central or mini-split AC or heat pump
3. Not working as designed — distribution system needs service to fix duct air leaks or replace/install duct insulation
4. Working as designed, but not suitable for today's climate (evaporative AC or undersized mechanical AC)
5. Working as designed, but costs too much to operate because it's inefficient.

For #1–2, the first step might be to service the AC equipment. For #1 as well, if the compressor fails in a window or portable AC, the cost of repair typically exceeds the cost of a new unit. For #3, the first step might be to fix the ducts. For #4–5, a new system might be best.

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

Exposure	Sensitivity	Adaptation	Heat Vulnerability Index
			
Number of hours with high heat index	Percent elderly and under 5	Median income	
Longest number of consecutive heat-wave days	Percent of pop. without high school degree	Percent of area covered in parks	
Number of heat-wave days	Percent of pop. below poverty level		
PM2.5 concentration	Percent non-white pop.		
Ozone concentration	Percent of pop. with ambulatory disability		
Building heat resistance indicator	Asthma hospitalization rate		
	Heart attack rate		
	Percent of pop. with a cognitive disability		

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

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

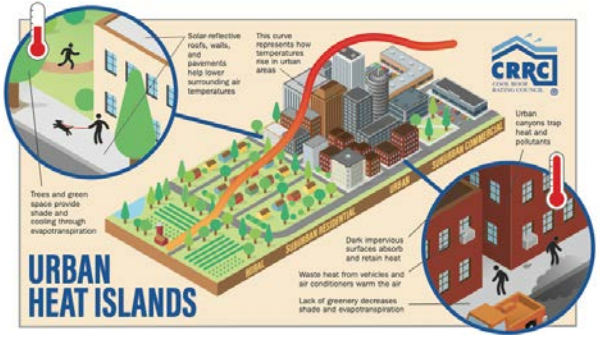
Some policy and program recommendations

❶ Heat-island countermeasures provide **failsafe cooling** and can be **5-10X more effective indoors** than outside

Cool roofs

Cool walls

Shade trees



We propose more stringent requirements for cool walls and cool roofs when roofs need replacement and when homes need repainting

R. Levinson - LBNL Heat Island Group Leader

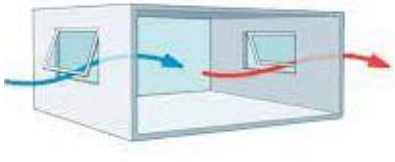
❷ We need to **pilot and demonstrate** these promising passive and active cooling measures to determine what works best for residents

Examples of high impact measures:

Solar-control window films

Cool walls

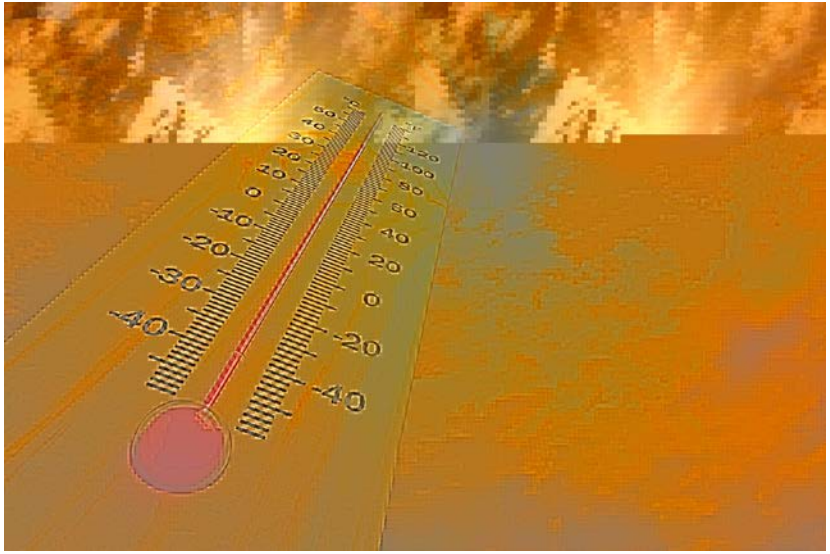
Natural ventilation



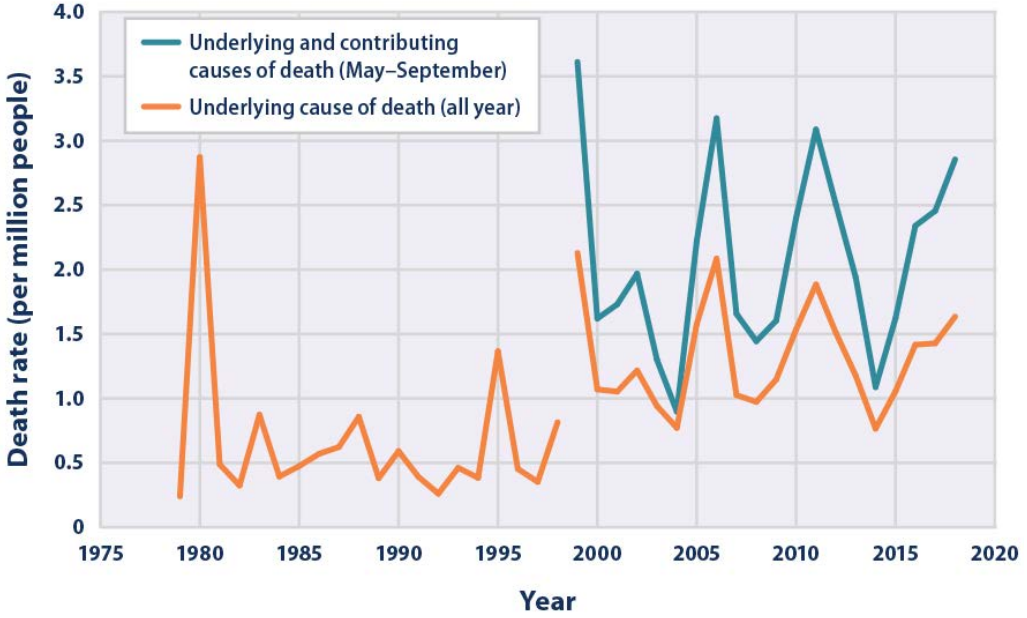
Ceiling fans

Mini-split AC/heat pumps

❸ To guide California's future investments, extreme-heat mitigation programs should dedicate resources to **monitoring outcomes**



U.S. heat deaths per million people, 1979-2018 (U.S. EPA)



Let's learn what works by measuring

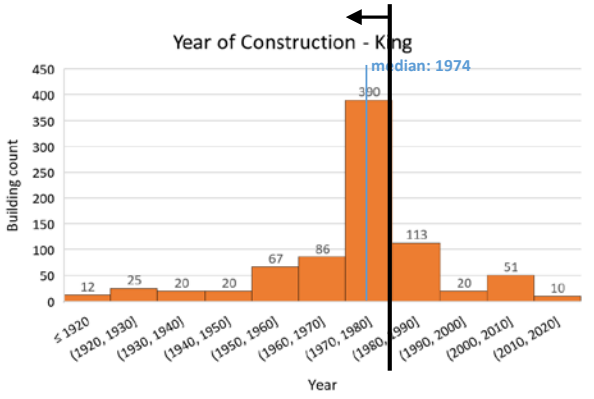
- <u>reductions</u> in temperature, heat stress, illness, hospitalizations, deaths
- <u>improvements</u> to health, comfort, productivity, learning

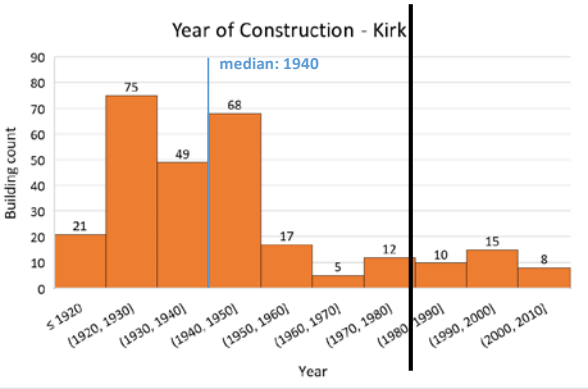
❹ **Expanding weatherization audits** for energy efficiency (EE) to include climate resilience is recommended for identifying homes most in need of heat resilience upgrades

- Climate resilience audits expand the scope of existing EE audits and auditors would need additional training and well-defined protocols for privacy and data collection
- Additional home audit checklist items might include
  - Testing AC system operation
  - Collecting demographic information about residents
  - Noting risk factors for overheating – top floors, south facing windows, inoperable windows, mobility of residents, transportation options of residents
- These should feed into a ‘heat vulnerability index’ score to identify those most in need for interventions such as home cooling upgrade

❺ We need mechanisms/ programs to ensure adequate cooling in **existing homes,** especially in **Low Income/DAC** areas with older buildings

Pre-1980 homes





- Most of the homes in southwest Fresno are **older single-family homes** (80% are pre-1980)
- We need to find mechanisms other than new building codes to cool these existing buildings, e.g.:
  - Expanding existing weatherization and low-income assistance programs
  - Requiring adequate cooling on home point-of-sale
  - Requiring cooling equipment inspection during other home inspections

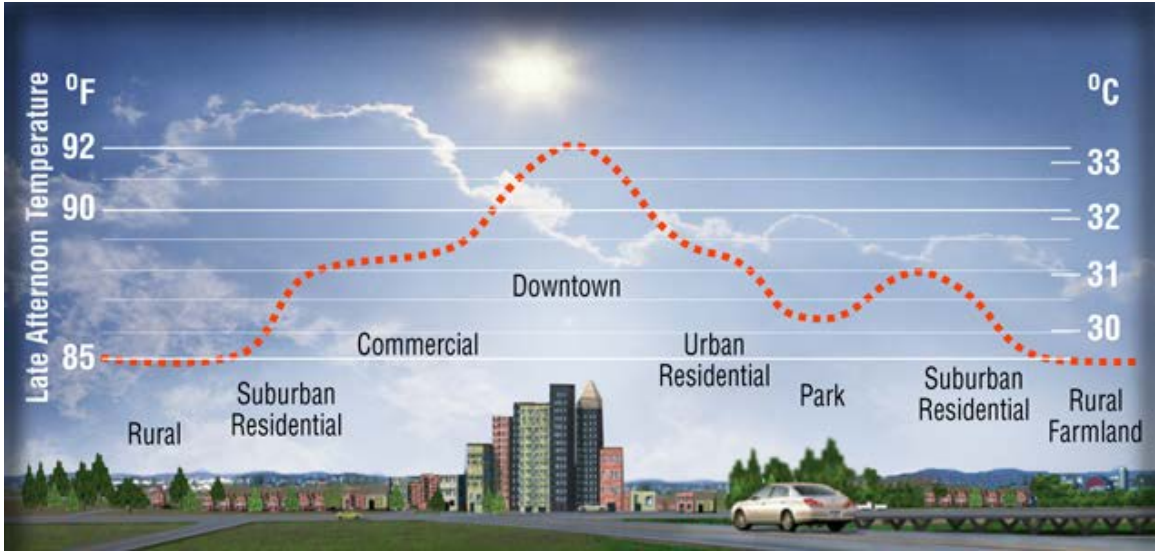
Thank you

Max Wei, MWei@LBL.gov

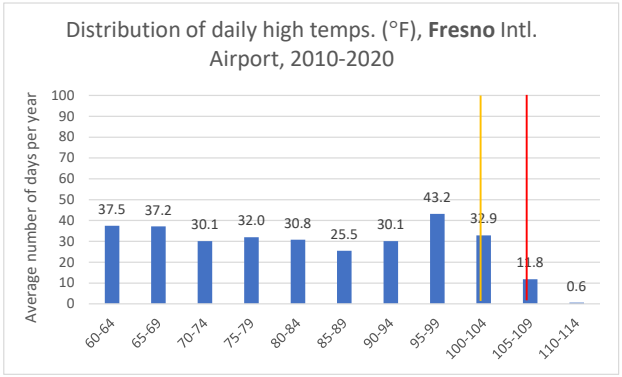
Cal-THRIVES.LBL.gov

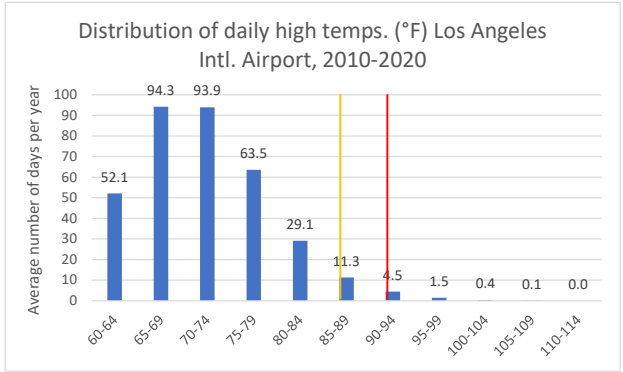
We also thank the **SGC Climate Change Research Program** for their support and our research partners below:

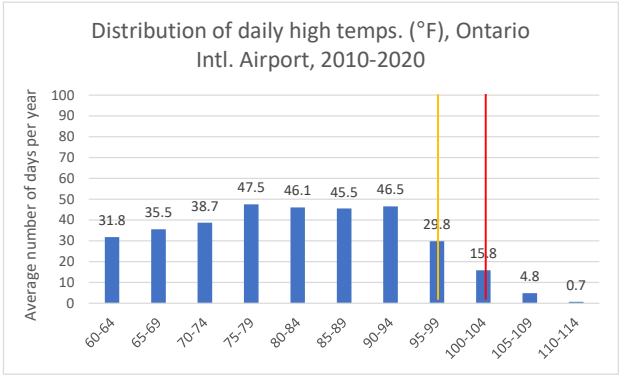
Urban Heat Island effect

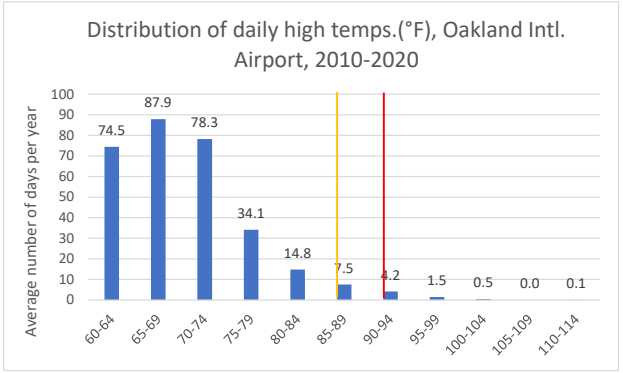


There are **large differences in annual distribution of heat** (chronic vs. acute heat): about twice as many “very hot to extremely hot days” in Fresno and Ontario (CA), for example, than in coastal areas, and 50-100 times more days above 100 °F









	“Extreme heat day” thresh-old (°F, red line); Days/yr.	“Very hot day” (within in 5 °F of extreme heat, orange line)	Annual Days above “very hot day” thresh-old	Annual Days above 100 °F
Fresno	**106.1; 10**	**101.1**	**39**	**45***
Ontario	103.6; 10	98.6	30	22
Los Angeles	90.5; 5	85.5	17	0.4
Oakland	90.4; 7	85.4	14	0.5

*__Chronically hot:__ Fresno days >100 °F have increased by 21% since 1960-90 to an average of 45 days per year.

Note this data is for the recent PAST few years.

The main deck has a slide for future projected heat.

Additional policy recommendations

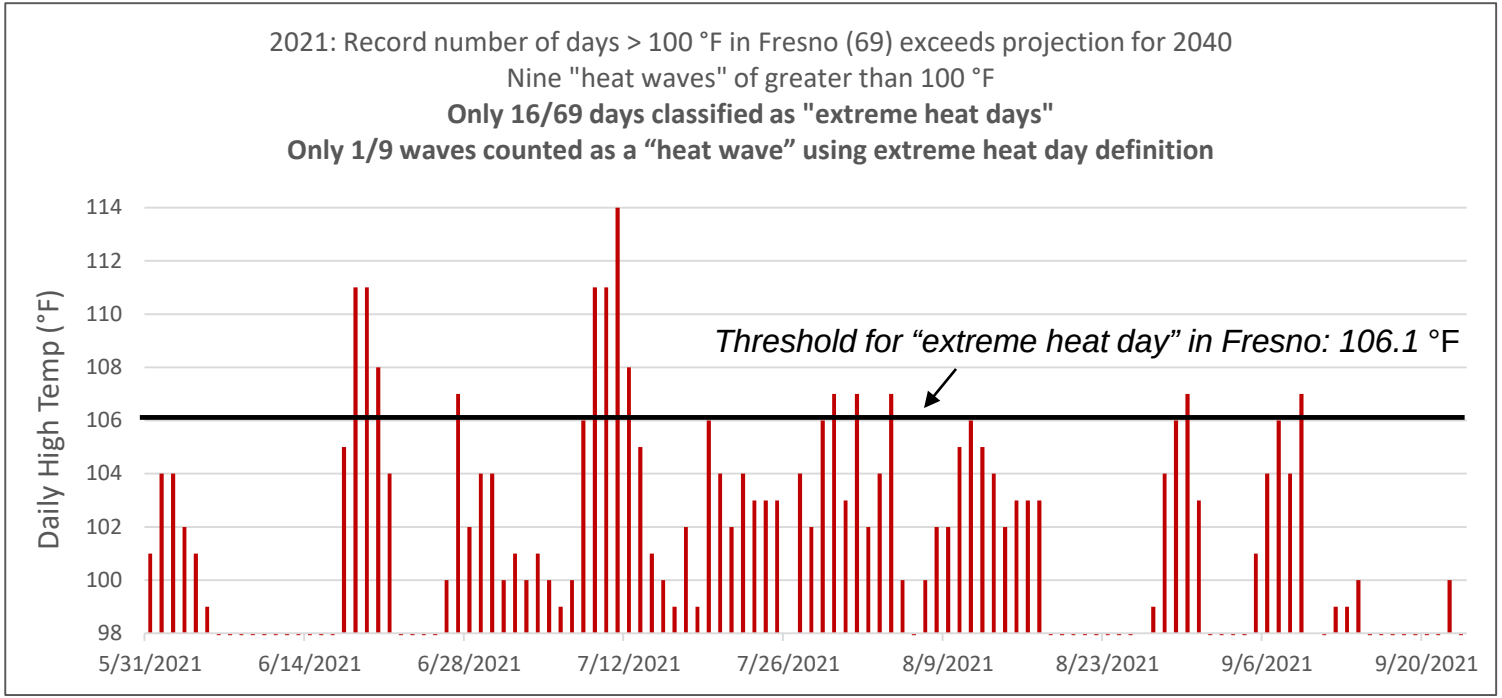
California's building standards should be upgraded to promote extreme-heat solutions based on **human outcomes** (⇩ death, illness, & misery)

CALGreen

California's Title 24 energy & green building standards currently focus on **energy**, **carbon**, and/or **cost savings**

Standards should reward improvements to thermal safety, comfort, & productivity

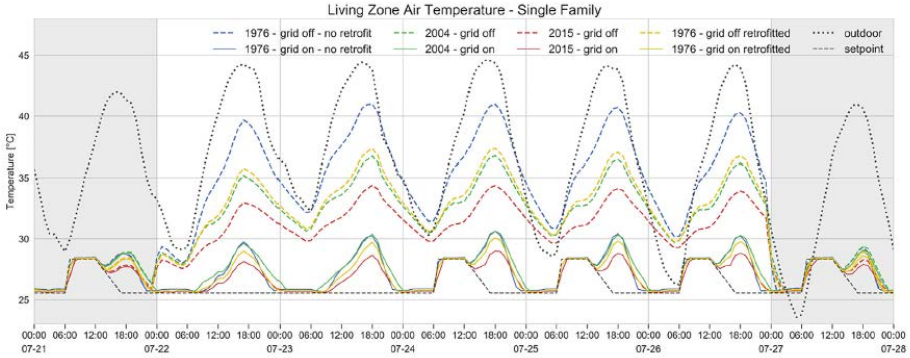
We need more **equitable definitions** of extreme heat and heat waves



Consider fixed-value definitions for extreme heat and/or extreme heat waves, such as “four or more days above 100 °F,” in addition to location-dependent thresholds for extreme heat days

All homes should have a **minimum cooling standard** or equivalently a max indoor temperature allowed

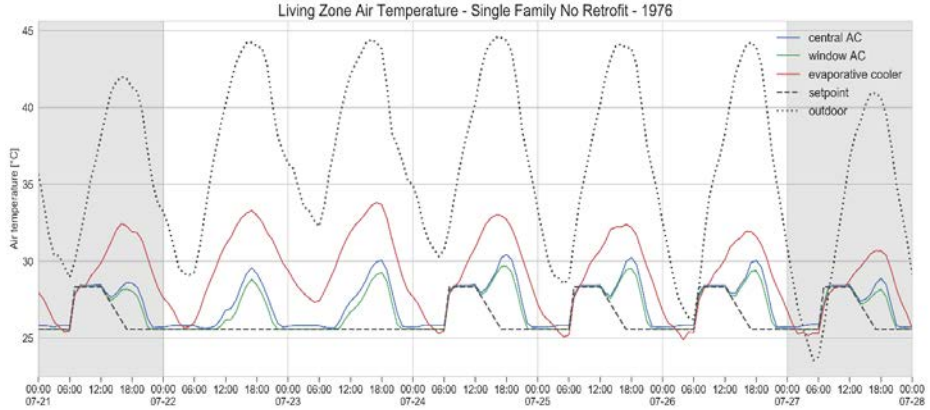
- Our research shows homes without AC get dangerously hot and increasingly so with climate change (95-106 °F, fig. below)
- Minimum cooling standards would avoid dangerous situations and prevent worst case heat exposure to residents
- Some policy options include:
  - New homes: include in Title 24 building code or CAL-GREEN
  - Existing homes: state habitability requirements
  - Existing owner-occupied: require inspection at point of sale, or require inspection during other permitting work
- Specific requirements would be set by a consensus process similar to Title 24 approach



Modeled for worst case historical heat wave conditions across five days

All homes without an AC unit in Fresno should get **at least one AC or heat pump (HP) unit** to safely withstand extreme heat waves

- Many homes in Fresno without an AC unit and only have swamp coolers, which are inadequate for extreme heat (fig. below)
- Homes without an AC in Fresno and other hot climate areas should be prioritized for upgrades to receive an AC or heat pump unit
- Increased use of cooling will increase electricity consumption and additional financial assistance may be needed to avoid residents facing higher utility bills



Modeled for worst case historical heat wave conditions across five days

More R&D is needed to support resilient, equitable decarbonization

- Non-energy metric development and quantification of impacts to support codes and standards development
- Monitoring of installed measures and their effectiveness
- Development of “comprehensive climate assessments” to consolidate separate audits/assessments
- Decision support tools for larger scale deployment
  - E.g., tool like Home Energy Saver for extreme heat and climate resilient buildings