Keep Our Cool:
How to Prevent Overheated Buildings
In a Climate Crisis

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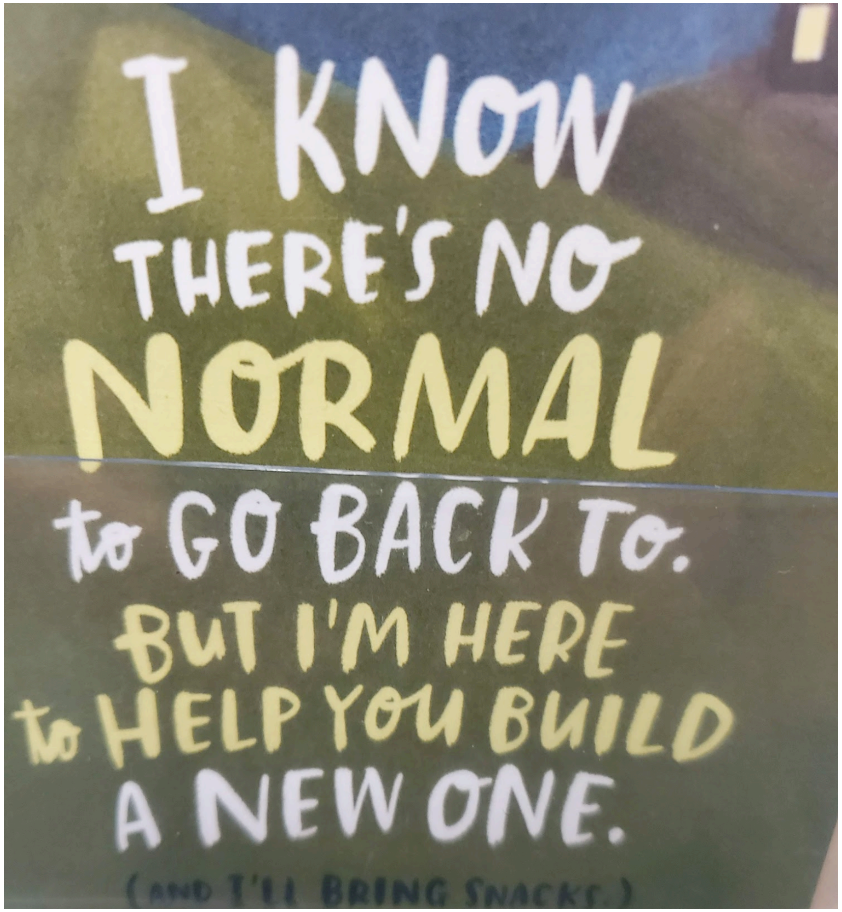
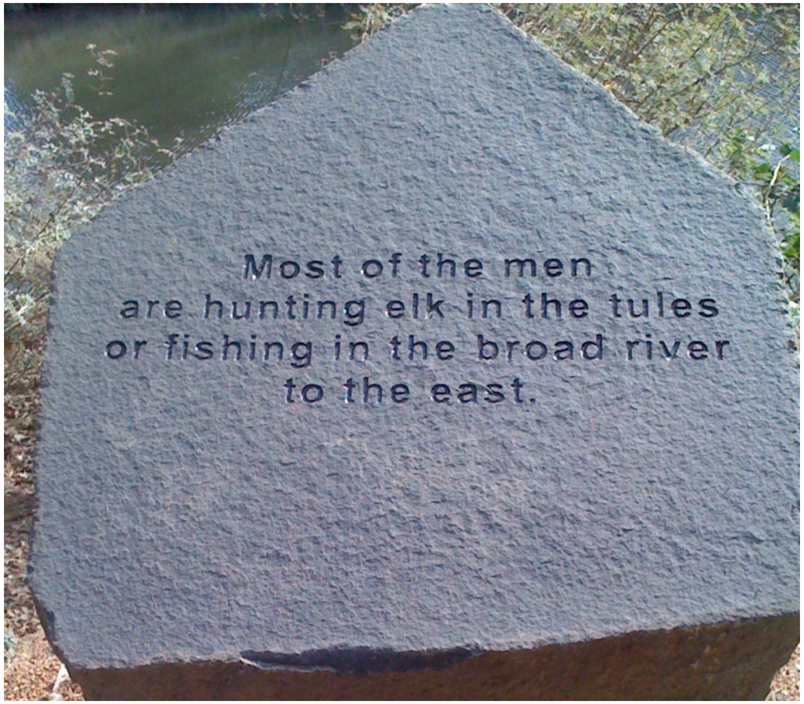
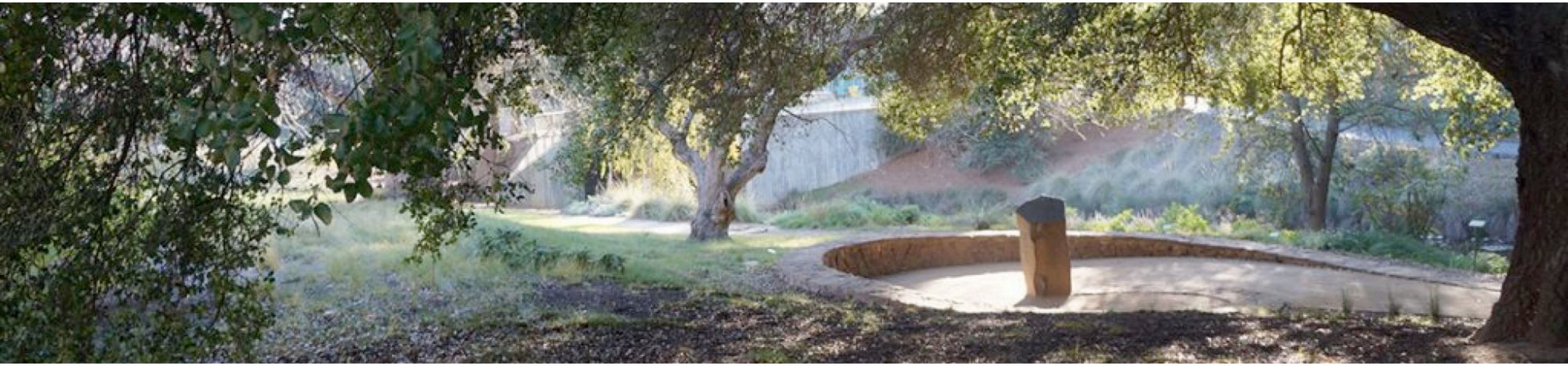
https://ncceh.ca/healthy-built-environment-forum



Sympathy Card for the Planet's
New ABNORMALS

Traditional Lands Acknowledgment:
The Patwin People



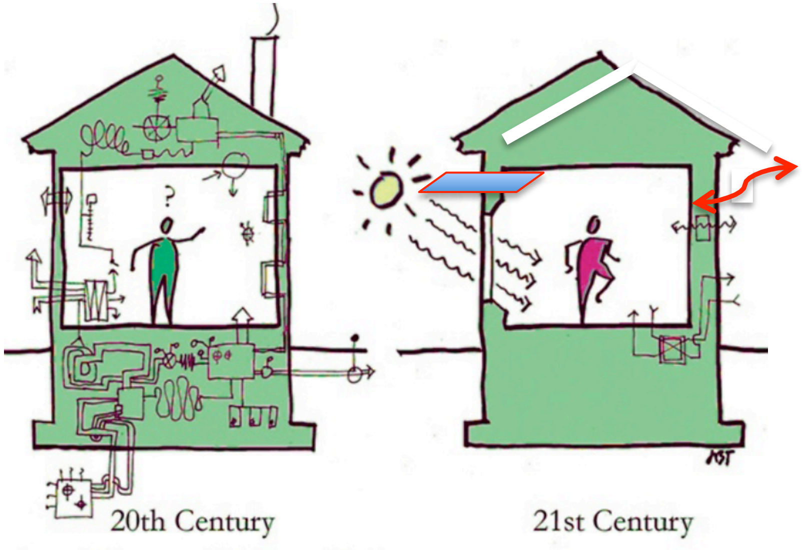


TOPICS

- **Introduction**
- **Overheating and Passive Survivability Standards and Guidelines**
- **Climate Resilient, Adapted and Mitigated (*CRAM*) Buildings: Examples**
- **Conclusions and Recommendations**
- **Q & A**

How must we adapt to extreme heat?

Passive, Low Carbon Cooling



OR

Air Conditioning Death Spiral

Top Image: Adapted from Albert, Righter & Tittman Architects

Canada Was a Pioneer in Climate Resilient Buildings

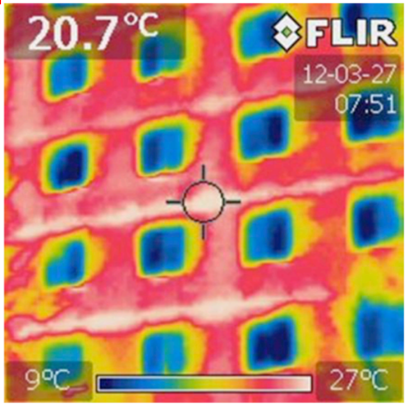
Saskatchewan: The birthplace of Passive House and passive solar home design

- **One of the earliest passive solar homes: Harold Orr et al., Saskatchewan Conservation House, 1977**

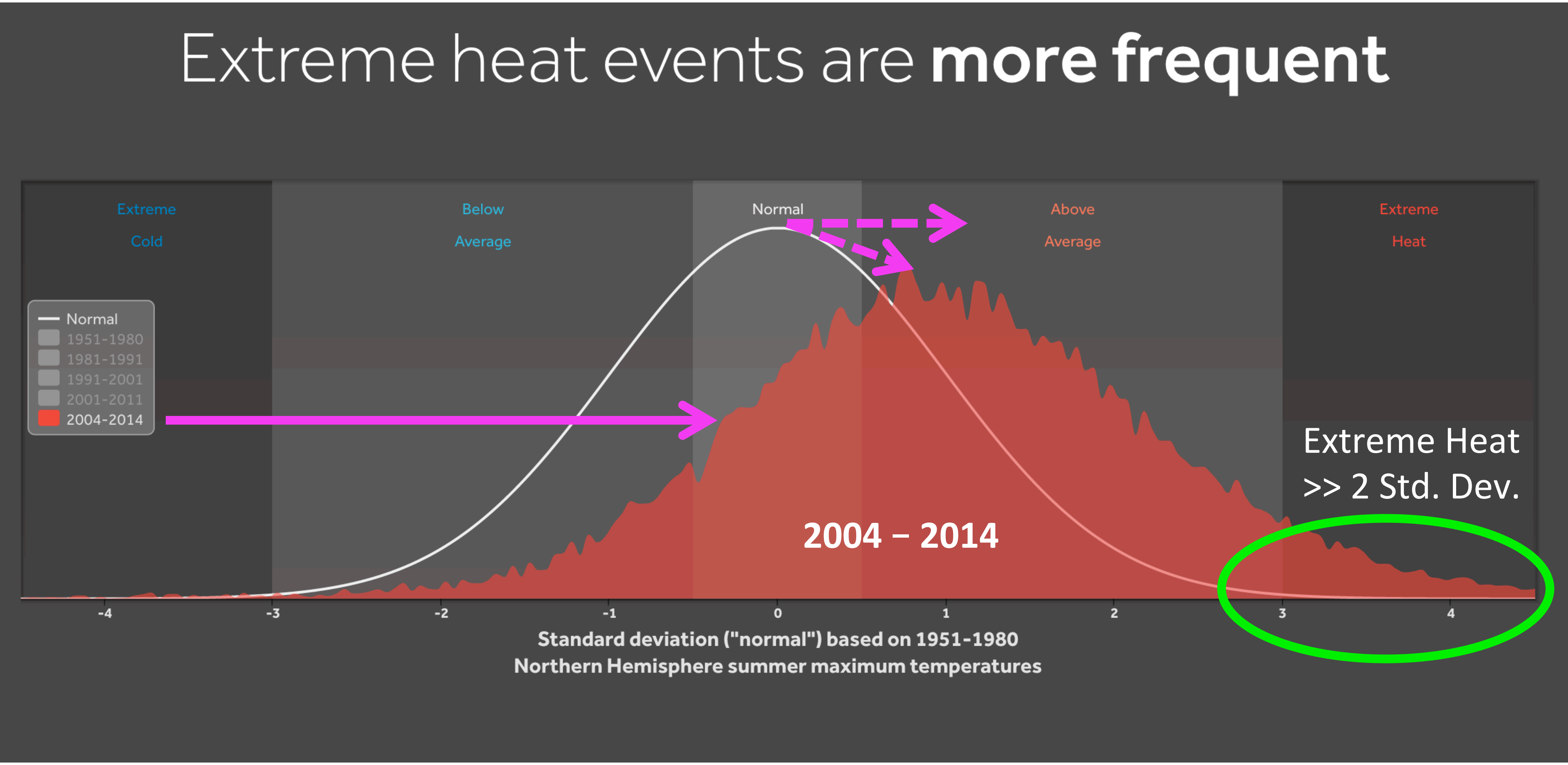
- **Building and infrastructure standards for future climate needed now: Heather Auld et al., 2008 +, Environment Canada**

• Inaction will have a significant cost
• Next Building Code (Canada) can include adaptation
• Adaptation Options available – different varieties

- **Toronto Tower Retrofit, 285 Shuter St.: One of the first in N. America to address overheating and climate change, 2012**
  - ✓ **PIEVC risk screening method**
  - ✓ **2050s climate model ensemble**
  - ✓ **The Atmospheric Fund support**



The New ABNORMALS:
Major Shift to Extreme Temperatures Already Occurring in N. Hemisphere by 2000's

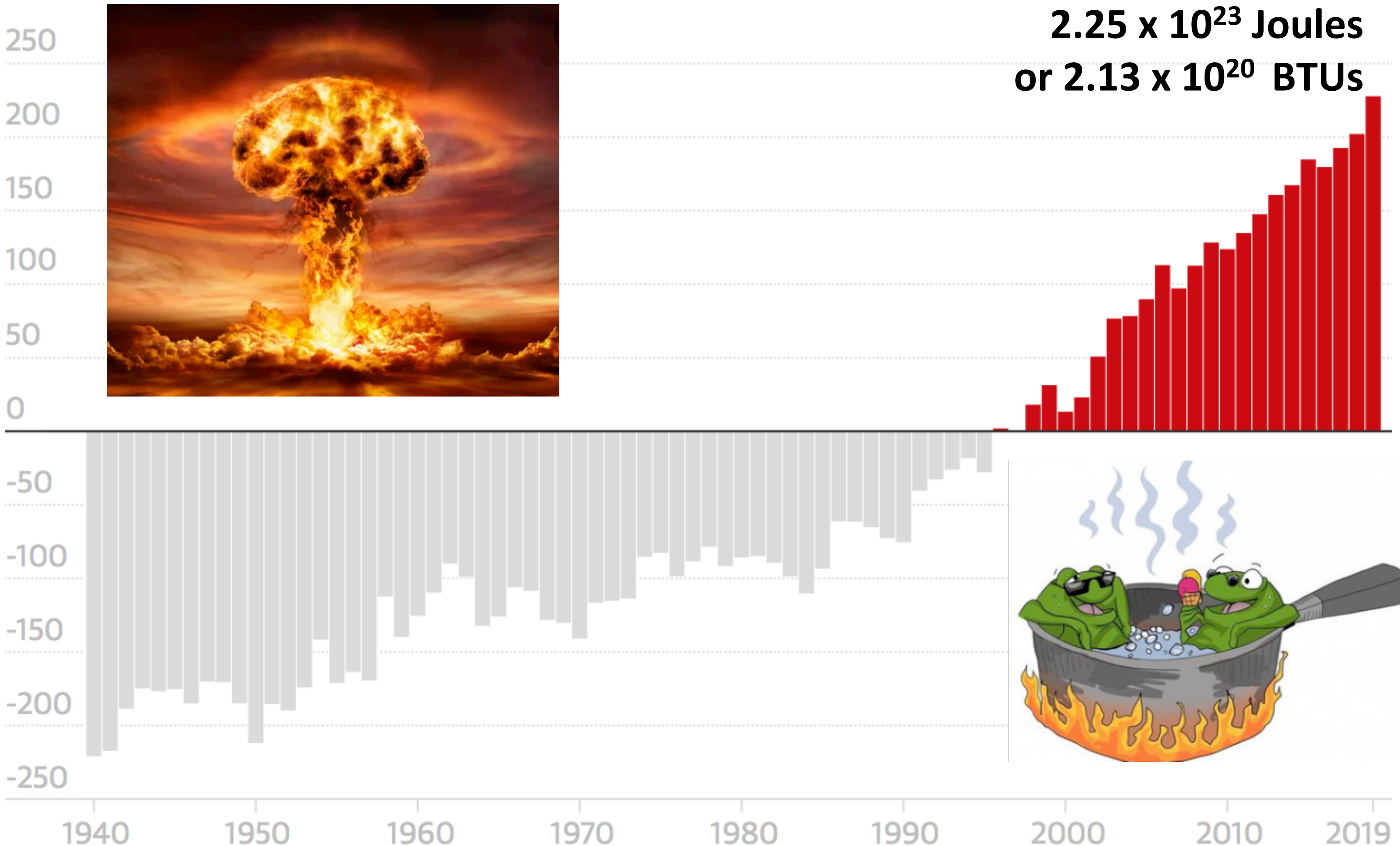


Adapted from Wx Shift, Jan. 2020. Extreme Heat. See Also: local time series chart of temperature anomalies. https://wxshift.com/climate-change/climate-indicators/extreme-heat.

Oceans Heating Rapidly Due Climate Change:
~ 5 Hiroshima bombs EVERY SECOND

Change in heat content relative to 1981-2010 average in zettajoules*

2019 increase:
2.25 x 10^{23} Joules
or 2.13 x 10^{20} BTUs



Guardian graphic. Source: Cheng et al, Advances In Atmospheric Sciences, 2020. *One zettajoule = 1,000,000,000,000,000,000,000 joules [The Guardian, Jan. 13, 2020.]

Climate Crisis / Emergency

- **The Future is Here Now**
  - **Extreme heat and storms**
  - **Megadrought in Southwest in progress**
  - **Mega Wildfires**
  - **Marine heat waves**
  - **Global systems tipping points are approaching quickly**
- **The Future is coming early,
and it is not distributed evenly**
- **Effective, large scale actions are needed immediately**

WHY
Is Extreme (Abnormal) Heat So Important ?

- **Hotter, Longer, and More Extreme Heat:**
  Extreme heat drives health, ecosystem, and infrastructure impacts

- **Health impacts of increasing heat are non-linear.**
  Moderate heat kills more people than extreme heat.

- **Cascading climate impacts and feedback loops**

- **Extreme heat is increasing rapidly now in many regions**

Extreme Heat in Canada:
Rising Faster, Will Get Worse

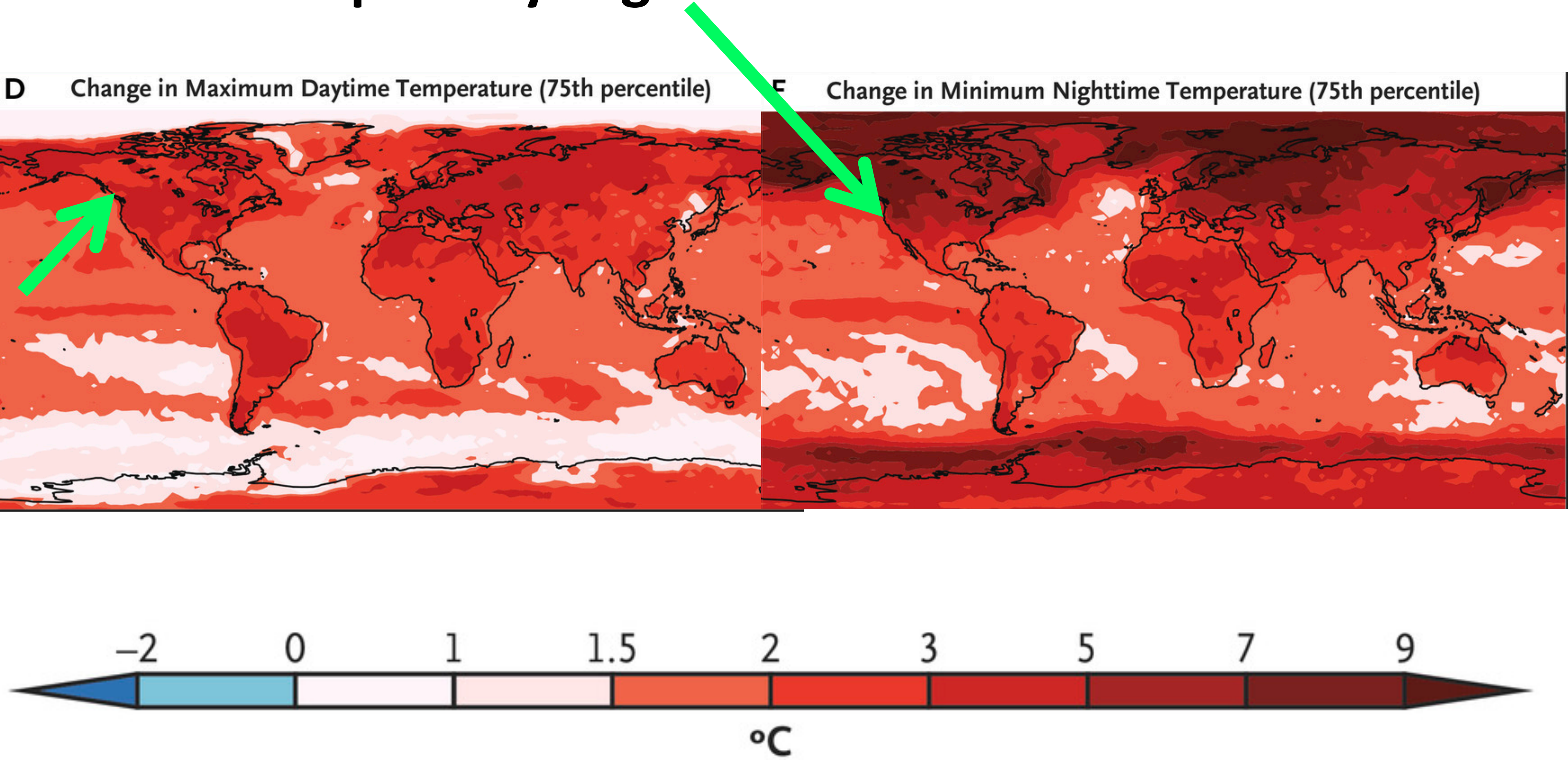
- **Temperature**
- **Heat Index, Humidex**
- **Cooling Degree Days (cooling demand)**
- **Buildings and Infrastructure are not prepared**

How Extreme Will the Heat Be?

- Hellaciously Hot (US)
  Blinking Hot (CAN)
- The Future is Here Now.
  It keeps coming sooner than you think.
  It will be worse than you think.[1]
- It is not evenly distributed.
  Nor is climate equity.
- Compound and cascading events are more likely (worst case scenarios).

1. Witze, 2022. Extreme heatwaves: surprising lessons from the record warmth. https://www.nature.com/articles/d41586-022-02114-y.

Historical Temperatures Increasing, Especially Nighttime: More in Canada



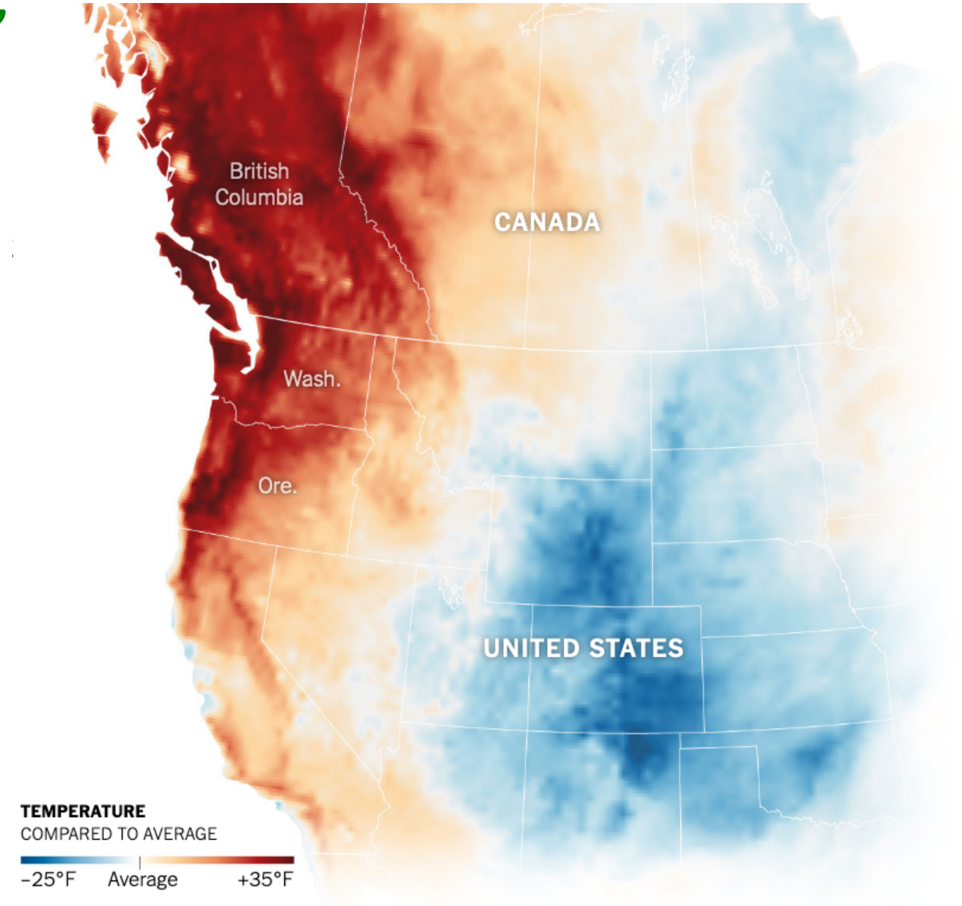
June 2021 Pacific NW Heat Dome: *"Mass Casualty"*

- **Premature deaths**
  - ✓ **~ 500 excess deaths in BC** [1]
  - ✓ **600 + deaths in Oregon & Washington**
  - ✓ **Thousands hospitalized**

- **Highest risks were indoors:**
  - ✓ **Older persons**
  - ✓ **Lack of AC, or AC not used**

- **Climate change impact** [3,4]
  - ✓ **Heat dome much more likely**
  - ✓ **Drought, Marine heat wave** [5]
  - ✓ **Heat from Gulf of Alaska anticyclone** [6]
  - ✓ **> 100 wildfires followed**

Large areas with average temperature 30 – 35 F over "normal"



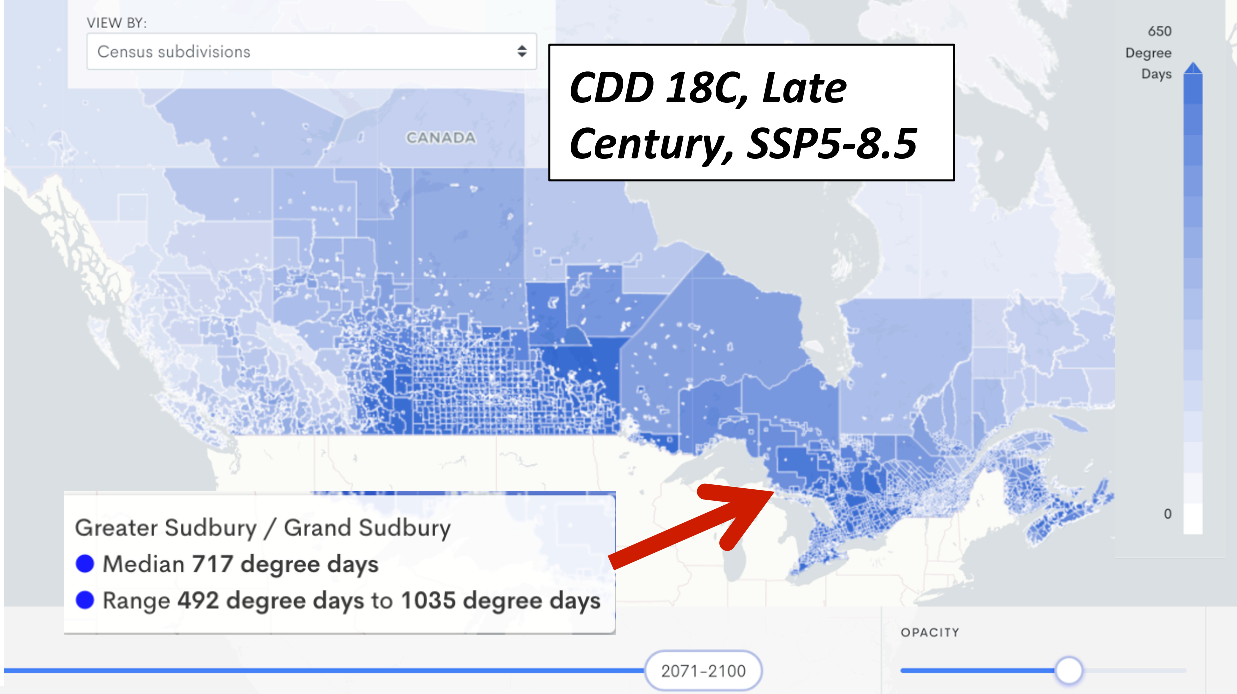
Source: Goddard Earth Observing System model, NASA • The map reflects air temperature at 2 meters (about 6.5 feet) above ground level on June 27, 2020, compared to the average temperature for the same day between 2014 and 2020.

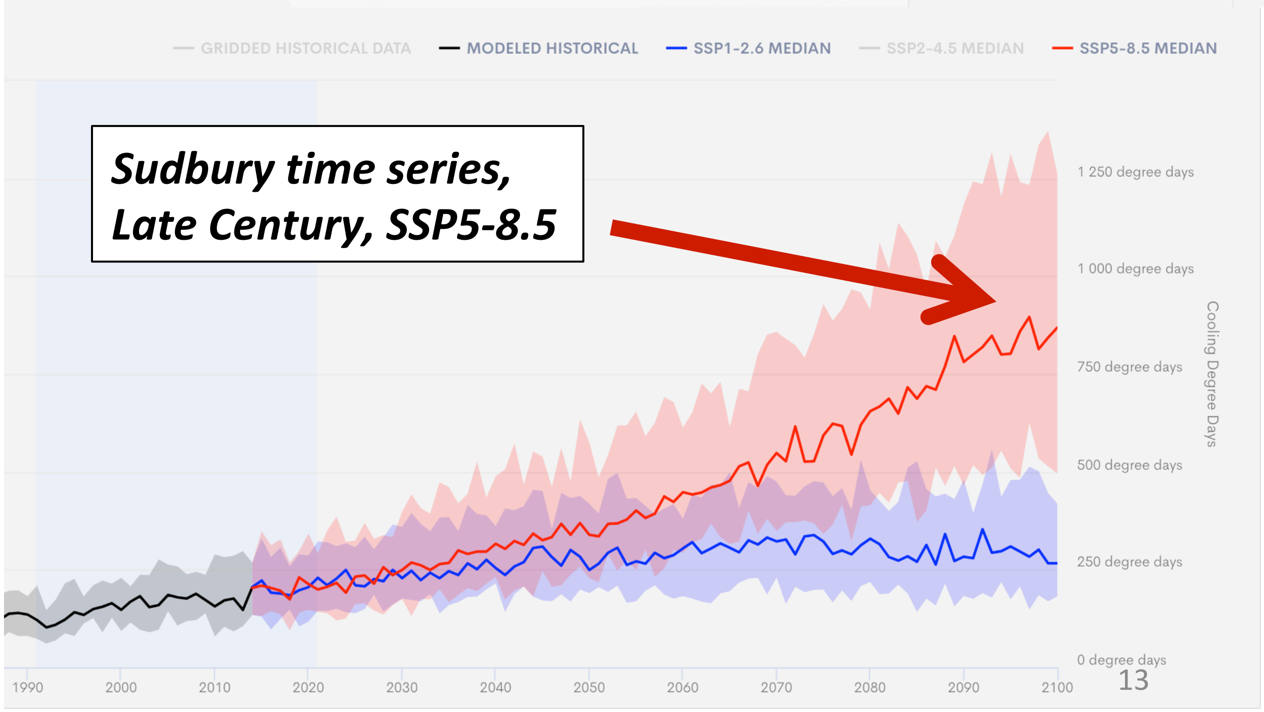
1. KUOW, July 12, 2021. Nearly 800 people believed to have died in Northwest heat wave.
2. NY Times, Aug. 11, 2021. Hidden Toll of the Northwest Heat Wave: Hundreds of Extra Deaths.
3. Wilson, Aug. 5, 2021. The Cascading Impacts of Drought and the Role Resilience Must Play. Resilient Design Institute.
4. White et al. 2023. The unprecedented Pacific Northwest heatwave of June 2021.
5. Cheng et al., 2022. Another Record: Ocean Warming Continues through 2021 despite La Niña Conditions.
6. Neal et al. 2022. https://doi.org/10.1029/2021GL097699.

ClimateData.CA: Interactive Map

- CDD, HDD, etc. 1951-2100
- Tropical Nights > 18, 20, 22 C
- Several hot spots, up to 1,000 CDD by late century
  - ✓ Sudbury example: over 700 CDD avg.
  - ✓ Over 300 by mid century

https://climatedata.ca/
CDD 65F = CDD 18C x 9/5

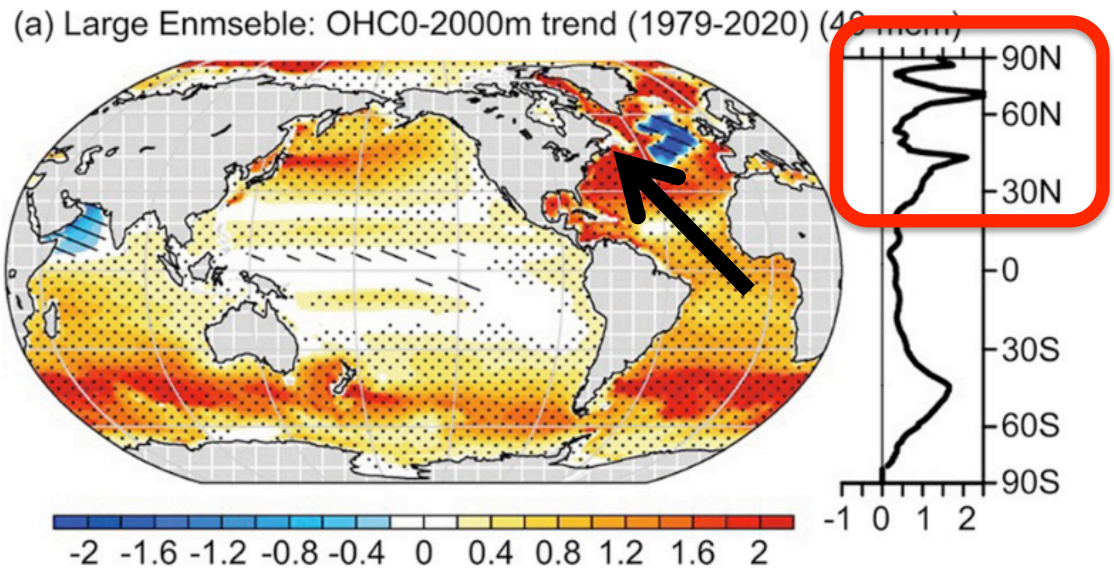


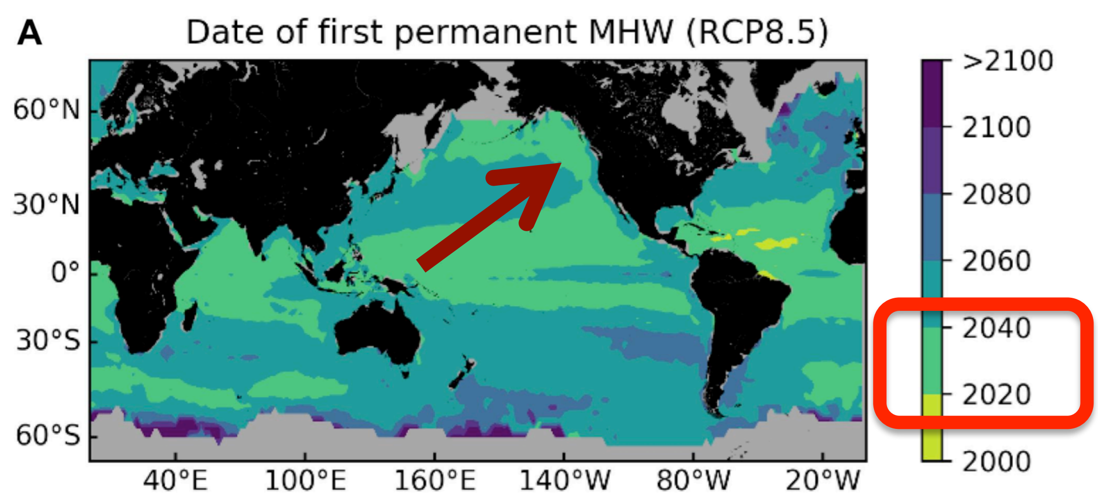


Fastest Warming Oceans in North America: Atlantic Coast [1,2]

- **NW Atlantic is fastest warming ocean in world**
  - ✓ **NE Coast of N. America is a hot spot**

- **Near-permanent heat waves in many regions after 2060 [3]**
  - ✓ **In NE Pacific, Gulf of Alaska, and other regions, by 2030s**



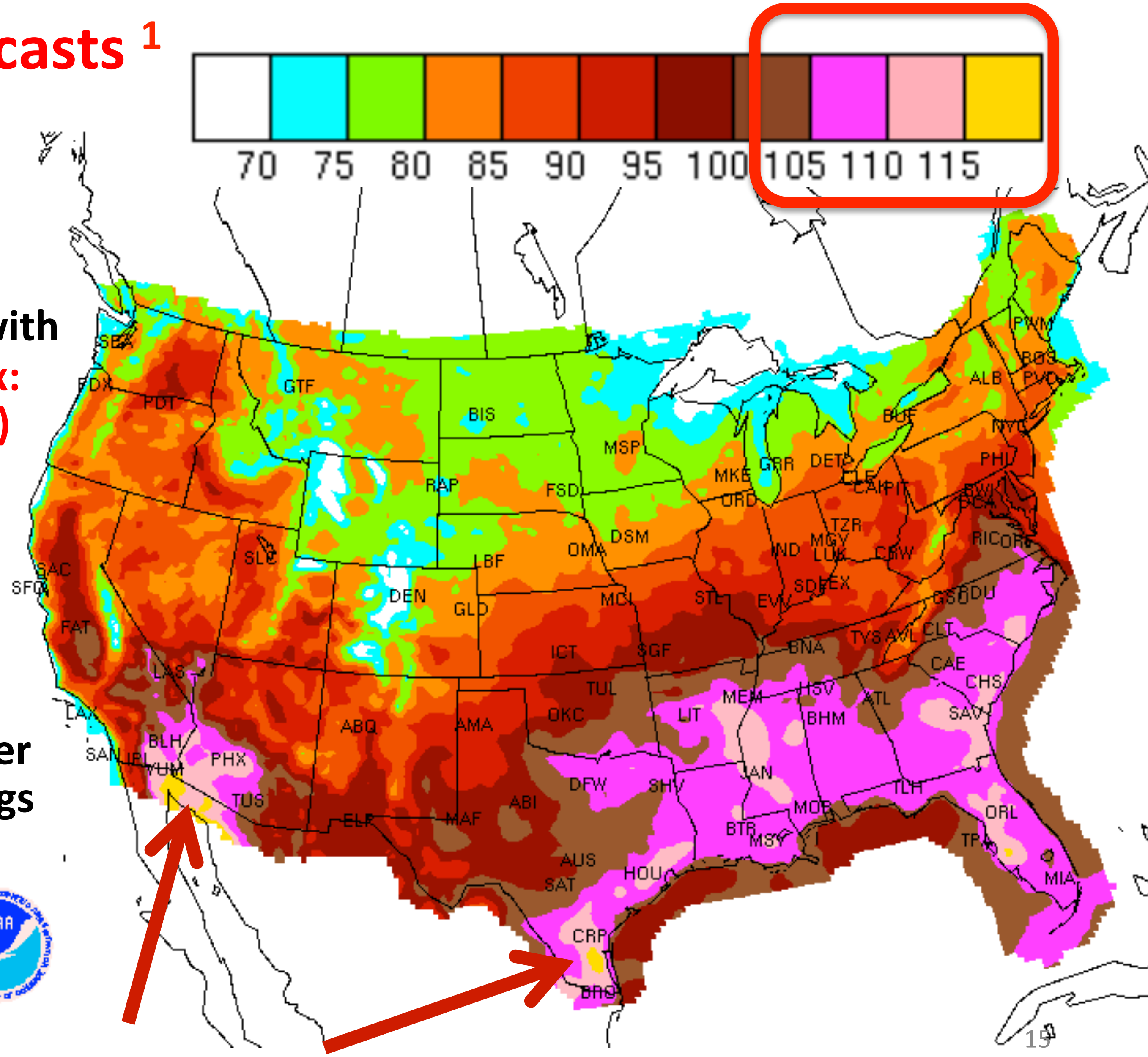


1. Karmalkar & Horton, 2021. Phys.org, 2021. The Coastal Northeastern US is a global warming hotspot.
2. Cheng et al. 2022. Another Record: Ocean Warming Continues through 2021 despite La Niña Conditions. Phys.org, 2022.
3. Oliver et al., 2019. Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact.

Now: NWS WPC

Heat Index Forecasts [1]

July 17: Max Heat Index Forecast for July 20, 2023

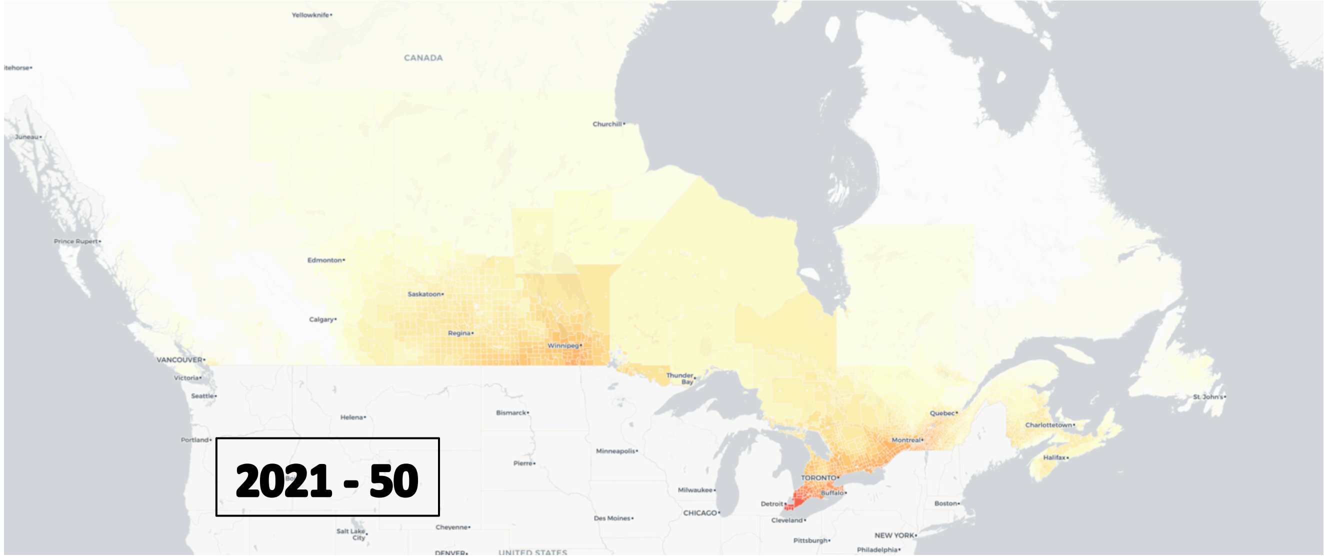


- **HI Maps & text:**
  Max, Mean, Min
- **Several areas lately with hazardous Heat Index: 105 - 115 F (41 – 46 C)**
- **> Max Temperature thresholds: 95, 100, 105, …**
- **> 100 M persons under extreme heat warnings etc. in last 30 days [2]**

1. https://www.wpc.ncep.noaa.gov/heat_index_MAX.shtml. 7/20/23.
2. NIHHIS. Current Conditions, 7/17/23..

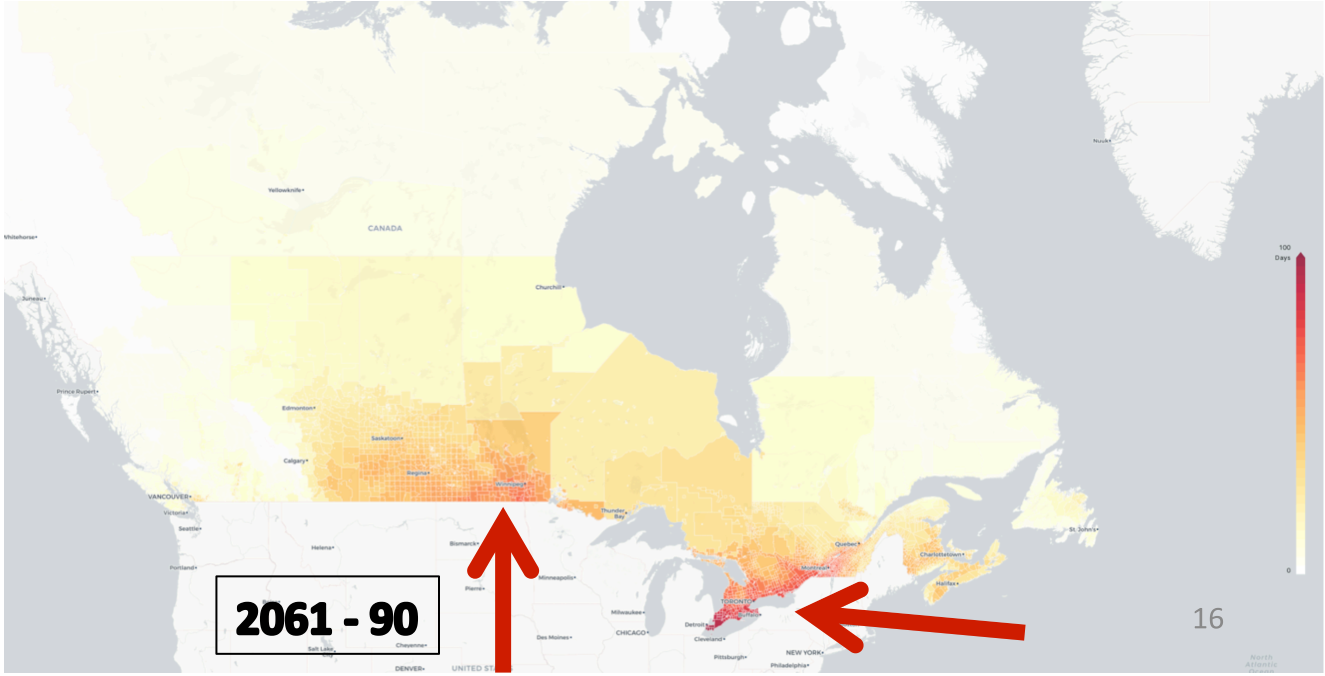
Humidex Projections in Canada: # Days >35 C

- **Next 3 decades: up to 50 days**



- **Late Century: More hot spots, ~ up to 100**

- **Other Humidex level options**

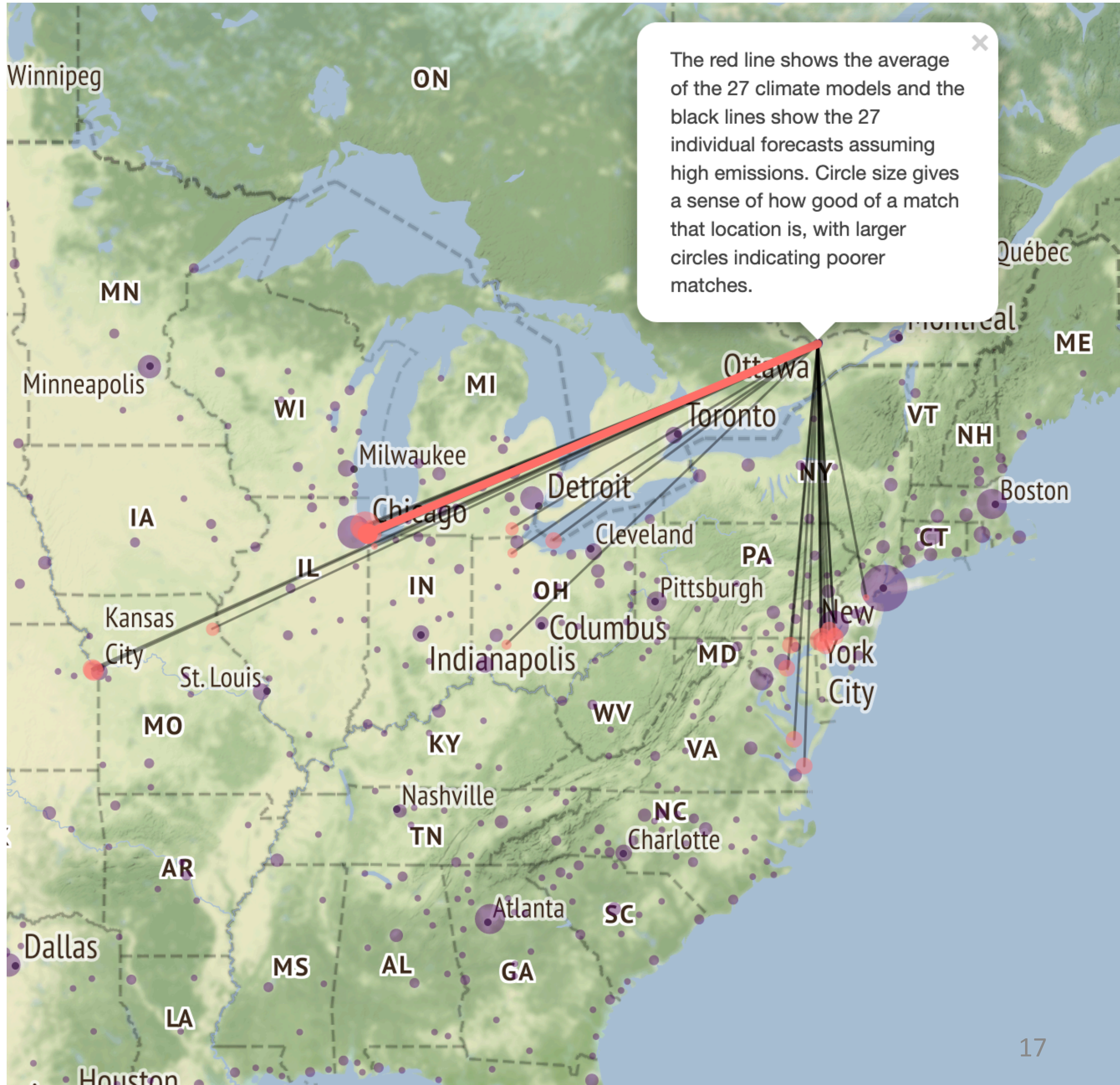


Canada's Climate is Moving South: Ottawa Example

- **27 climate models, by 2080**
- **12 weather variables**

- **Models average: By 2080, Ottawa will be most like Chicago, climate-wise**

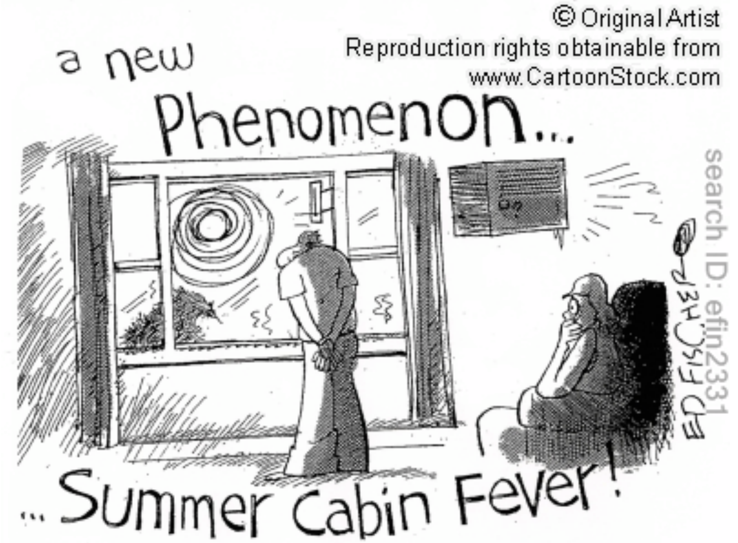
  ✓ **The typical summer in South Shore, Illinois is 6°F (3.3°C) warmer and 18.6% wetter than summer in Ottawa.**



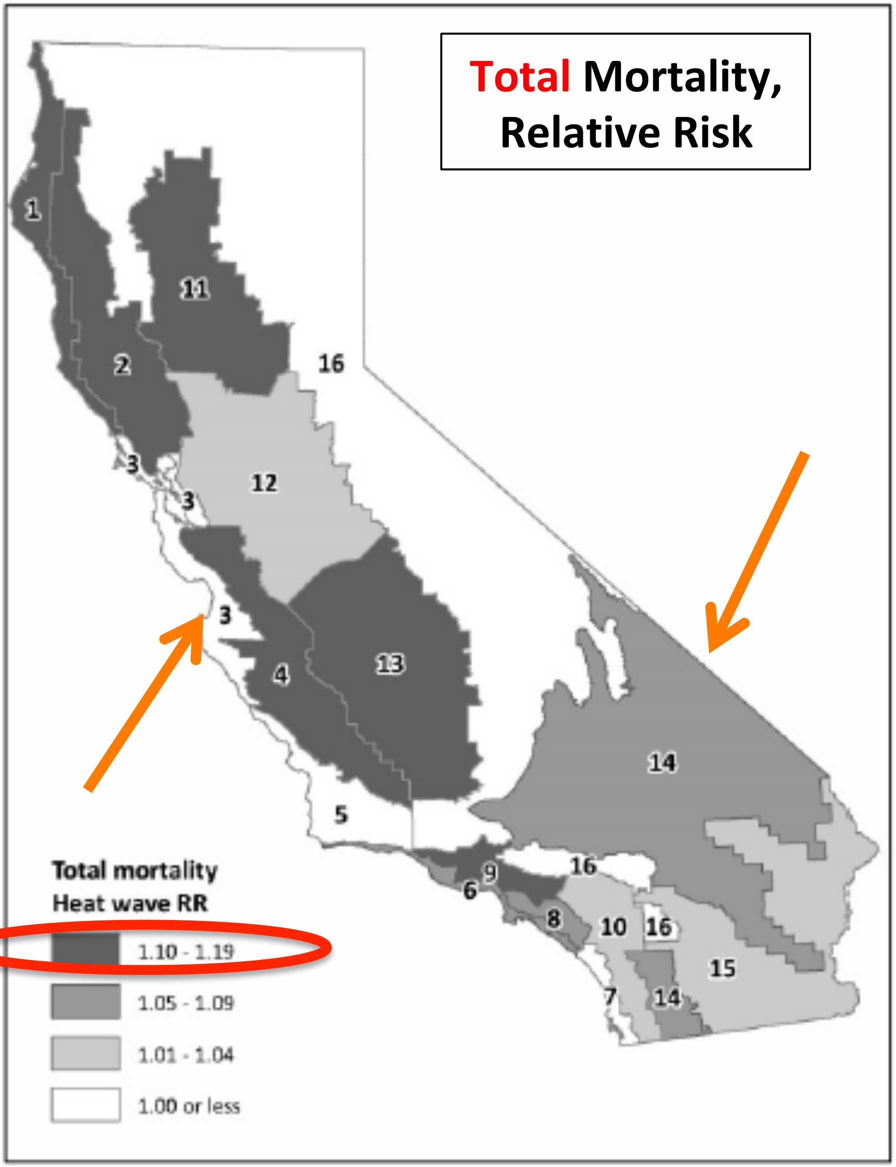
University of Maryland, 2019. Future Urban Climates. https://www.umces.edu/futureurbanclimates.

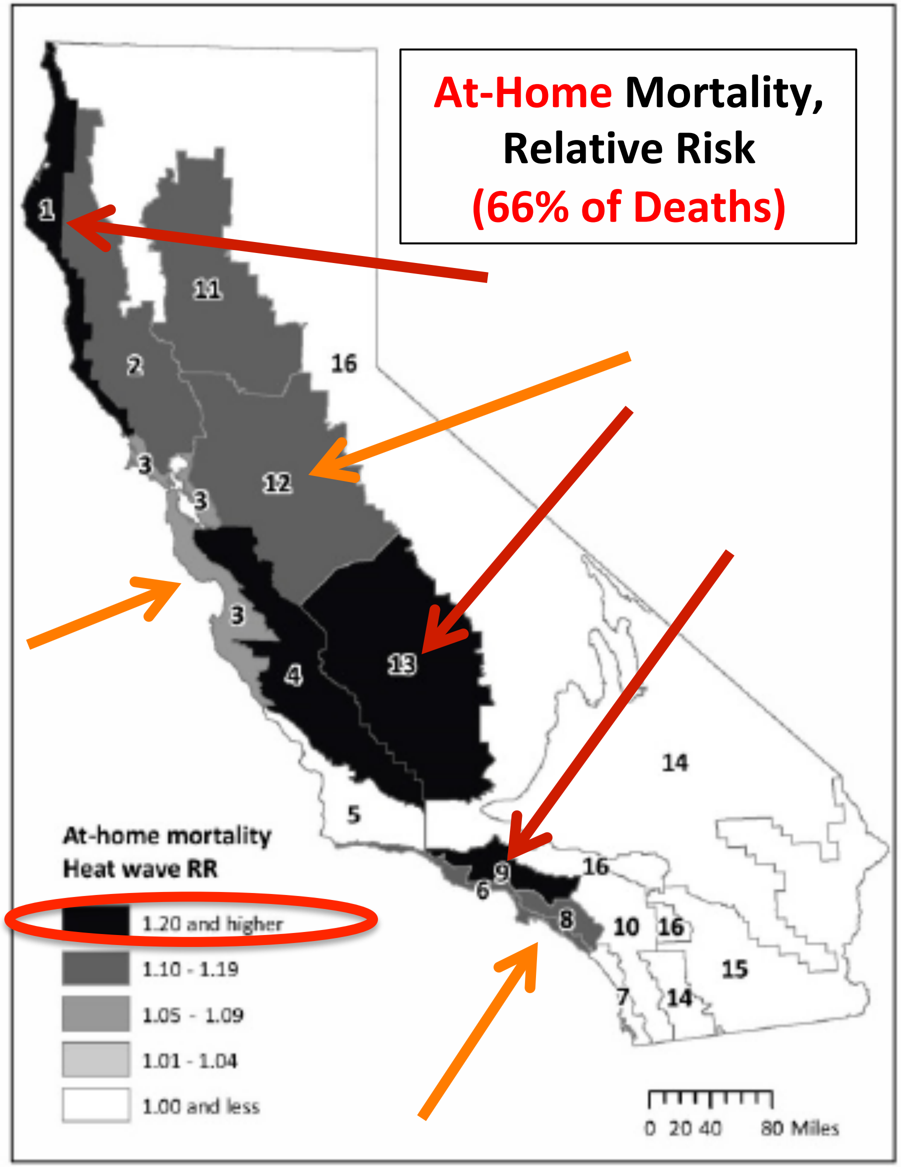
WHY
Is Indoor Heat Exposure So Important ?

- About 90% of our time is spent indoors on average, and even more for some vulnerable populations.
- Heat waves, pandemics, wildfires, and allergens have forced us indoors more.
  Power outages have increased dramatically.
- Most heat related deaths occur indoors.
  Indoor environments can become very hot, leading to deaths and hospitalization.
- Thermal stress has significant effects on other non-energy impacts such as sleep, student performance, and worker productivity.
- Energy and Climate Inequity occurs in many regions, and has been exacerbated by increased utility, housing, and healthcare costs.
- Our homes, schools, and other buildings must shelter us, and allow us to recover, from environmental stresses and hazards.



2006 California Heat Wave Mortality: Climate Zones





Adapted from: Joe et al. 2016. Mortality During a large-scale heat wave by place, demographic group, internal and external causes of death, and building standards climate zone. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4808962/.

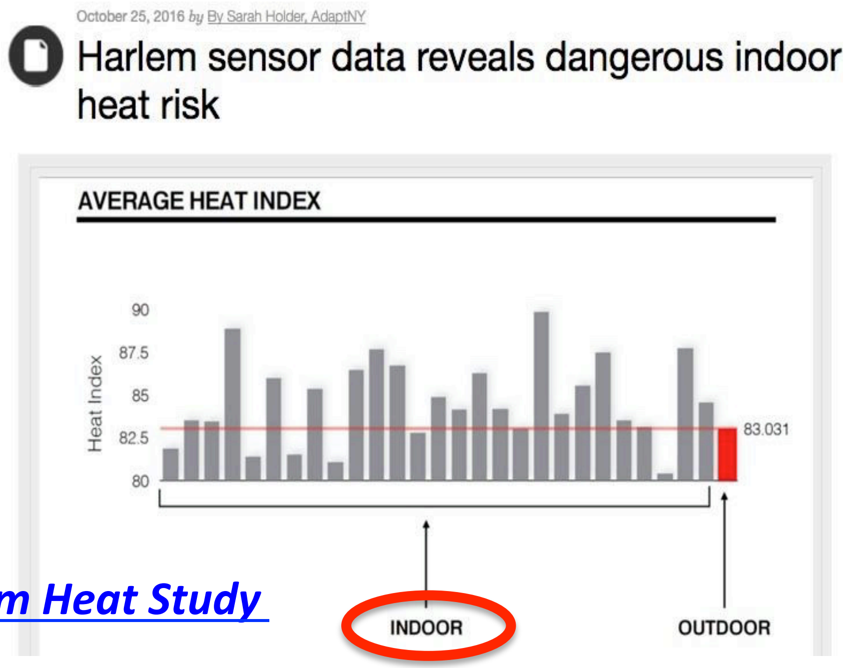
New and Existing Buildings: Already Overheating

- New CA Single Family homes:
  19% "too hot"
  (Offermann, 2005 CARB Report)

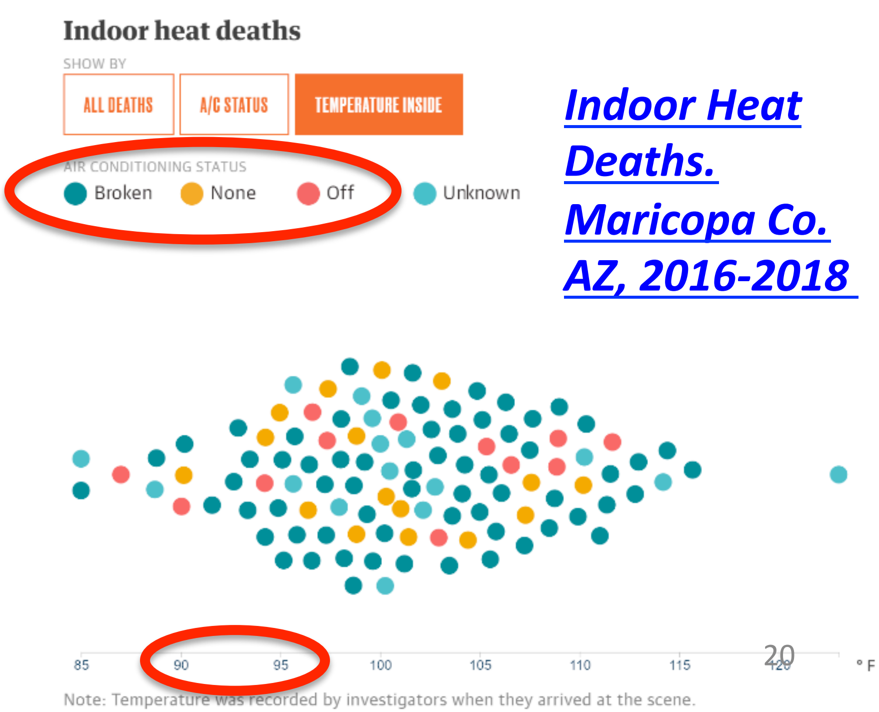
- NY City low income apartments:
  Indoor Heat Waves 24/7
  Heat Index: indoor > outdoor,,
  up to 90 indoors

- Many U.S. schools closing during heat waves

- Arizona heat waves,
  100 indoor deaths:
  - ✓ 100 – 125 F in half of homes
  - ✓ AC Broken or Off in most cases

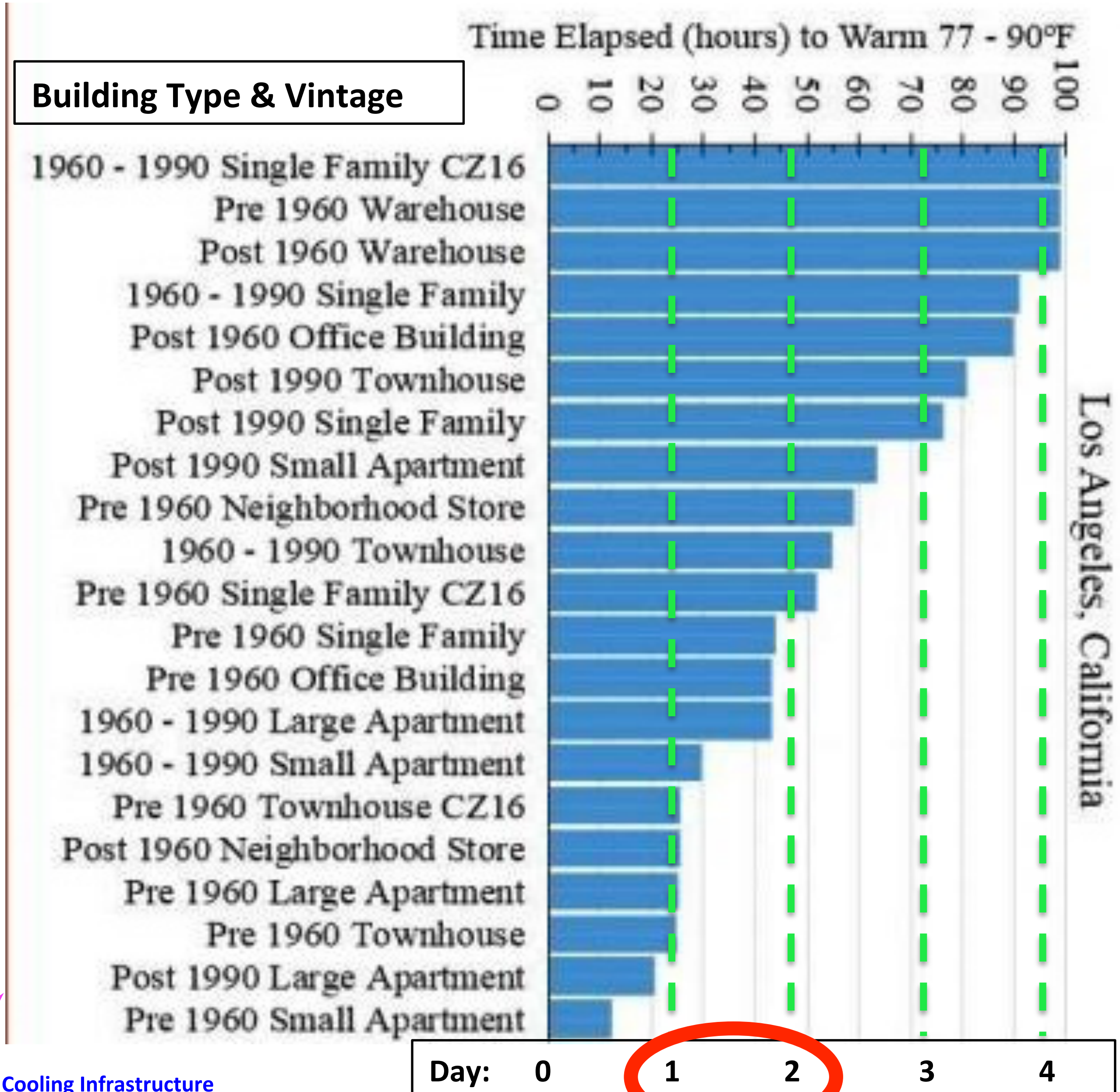


Harlem Heat Study



Indoor Heat Deaths. Maricopa Co. AZ, 2016-2018

Time to Reach 90 °F (modeled hours): Los Angeles



Mostly MFam, Townhouse
pre 90s,
pre 60s

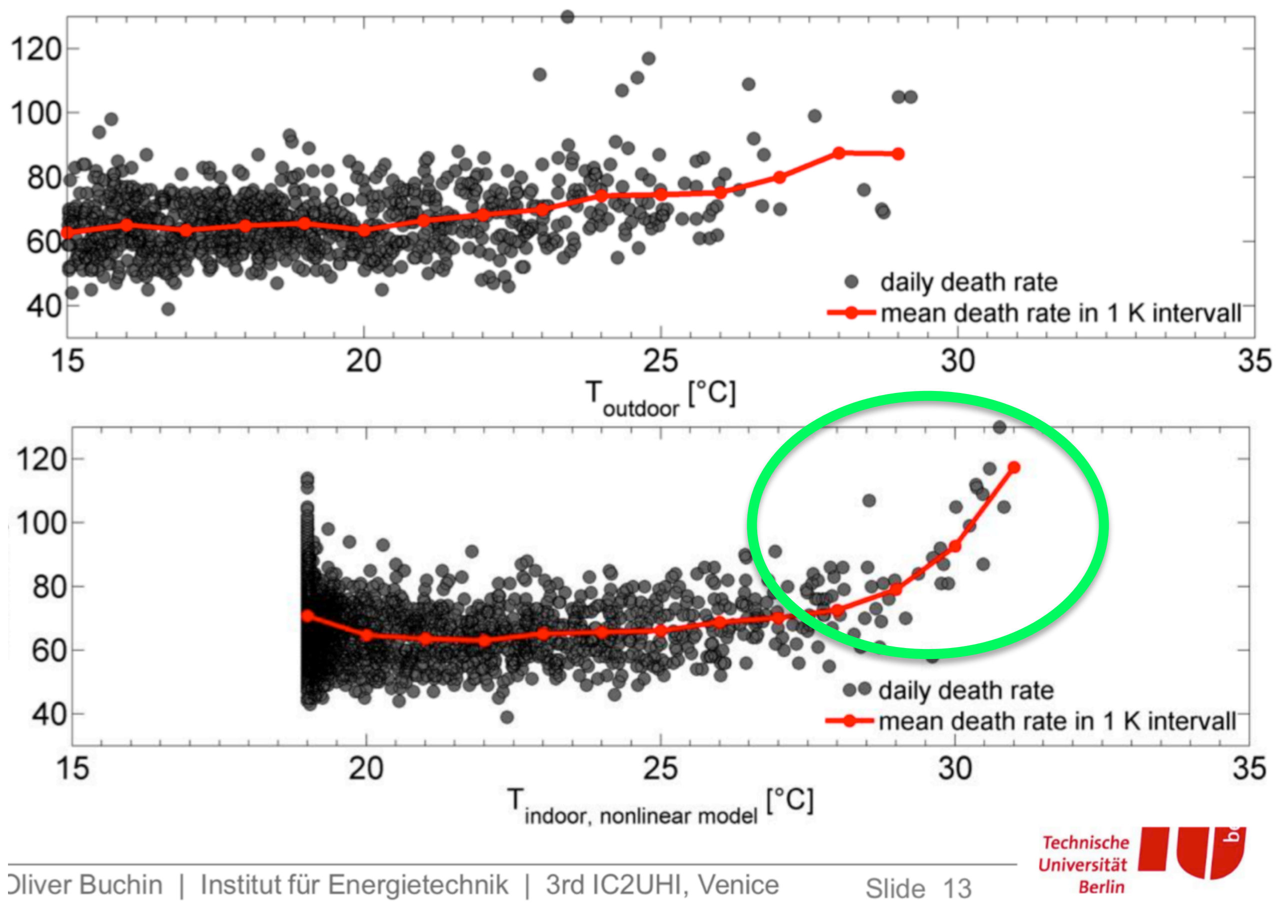
Mobile homes not included

* Chester et al., Sept. 9, 2015. Prioritizing Cooling Infrastructure Investments for Vulnerable Southwest Populations.
See also: Reyna & Chester, 2017 re: projected electricity demand in L.A. County.

Modeling Outdoor & Indoor Heat vs. Mortality Risk

- **Berlin apartment modeled**
- **Indoor Nonlinear model**
  - ✓ **More accurate assessment**
  - ✓ **Higher risk estimates**

Deaths per Year vs. OUTDOOR Temperature

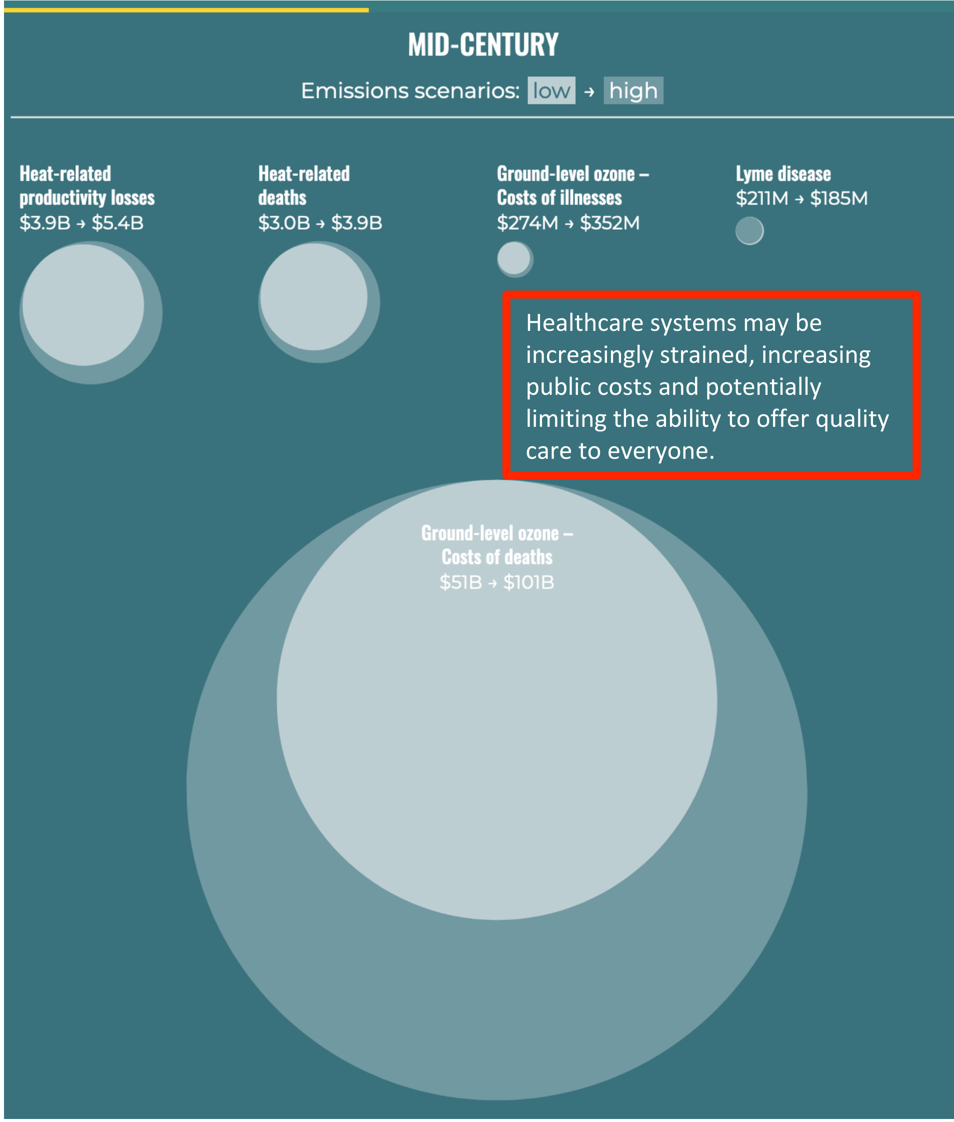


Deaths per Year vs. INDOOR Temperature

Buchin et al., 2014.
See also: Buchin et al. 2016. doi:10.5194/nhess-16-963-2016.

Canada: Cost of Heat Health Impacts from Climate Change

- Climate Change Impacts on Health [1]
  - ✓ Heat costs > $9 B/yr, mid-century
  - ✓ Ozone mortality $101 B
  - ✓ Wildfire smoke and other costs TBD
- Co-Benefits of Energy Retrofits [2]
  - ✓ Reduced mortality and energy use estimated for shading and green roofs
  - ✓ Tip of the Climate Iceberg: Climate change will exacerbate mental health and other environmental health problems



1. Canadian Inst. for Climate Choices, 2021. The Health Costs of Climate Change. Full Report: Boyd et al., Dec. 2020. Costing Climate Change Impacts on Human Health Across Canada.
2. Porter and Scawthorn, 2020. Estimating the benefits of Climate Resilient Buildings and Core Public Infrastructure (CRBCPI). Prepared for the National Research Council Canada and the Institute for Catastrophic Loss Reduction.

LIABILITY
Lawsuits and Criminal Charges

- **High rise condos overheating in San Francisco**
  - ✓ **1st case: expensive settlement, some cooling added**
  - ✓ **2nd case: ~$10 M award [1]**
- **Nursing home deaths**
  - ✓ **14 dead in Florida nursing home after Hurricane Irma: civil suits**
  - ✓ **After Hurricane Irma: 25% increase in nursing home deaths a week later, and a 10% increase in mortality rates after 30 days [2]**
  - ✓ **2 dead in Detroit nursing home: involuntary manslaughter charges [3]**
- **AIA and BC Engineers have produced professional guidance on climate liability, standards of conduct, and how to work with clients.**

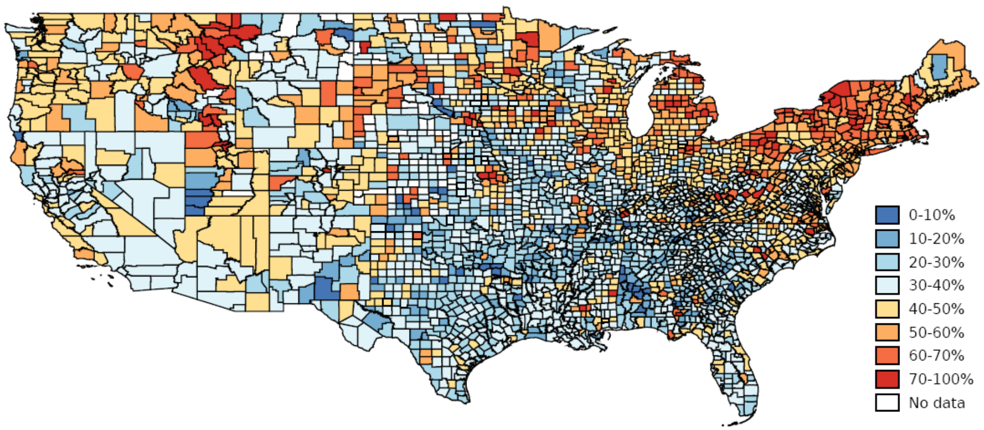
1. Landes, July 28, 2021. Nearly $10M settlement for "cooked" SF condo owners. Developers agree to take responsibility for making units too hot. E & W sides overheated. Inadequate ventilation per code.
2. WUSF, 2021. Power outages that followed Hurricane Irma affected 28,000 residents of Florida's nursing homes. Skarha et al., 2021 JAMA
3. Pintas and Mullins, 2021. Extreme Summer Temperatures Leads to Possible Heat-Related Nursing Home Death, 2008.

Where
Will Indoor Heat Impacts Occur?

- All regions
- Homes and Facilities for Vulnerable Populations
- Schools
- Maladapted buildings
- Urban and rural
- Maladapted power grid
- Lack of access to energy efficiency, emergency cooling, health care, etc.
- NO WHERE TO RUN
(cue Martha & the Vandellas song)
https://youtu.be/RQRIOKvR2WM?t=6

U.S. Schools: % Days Too Hot

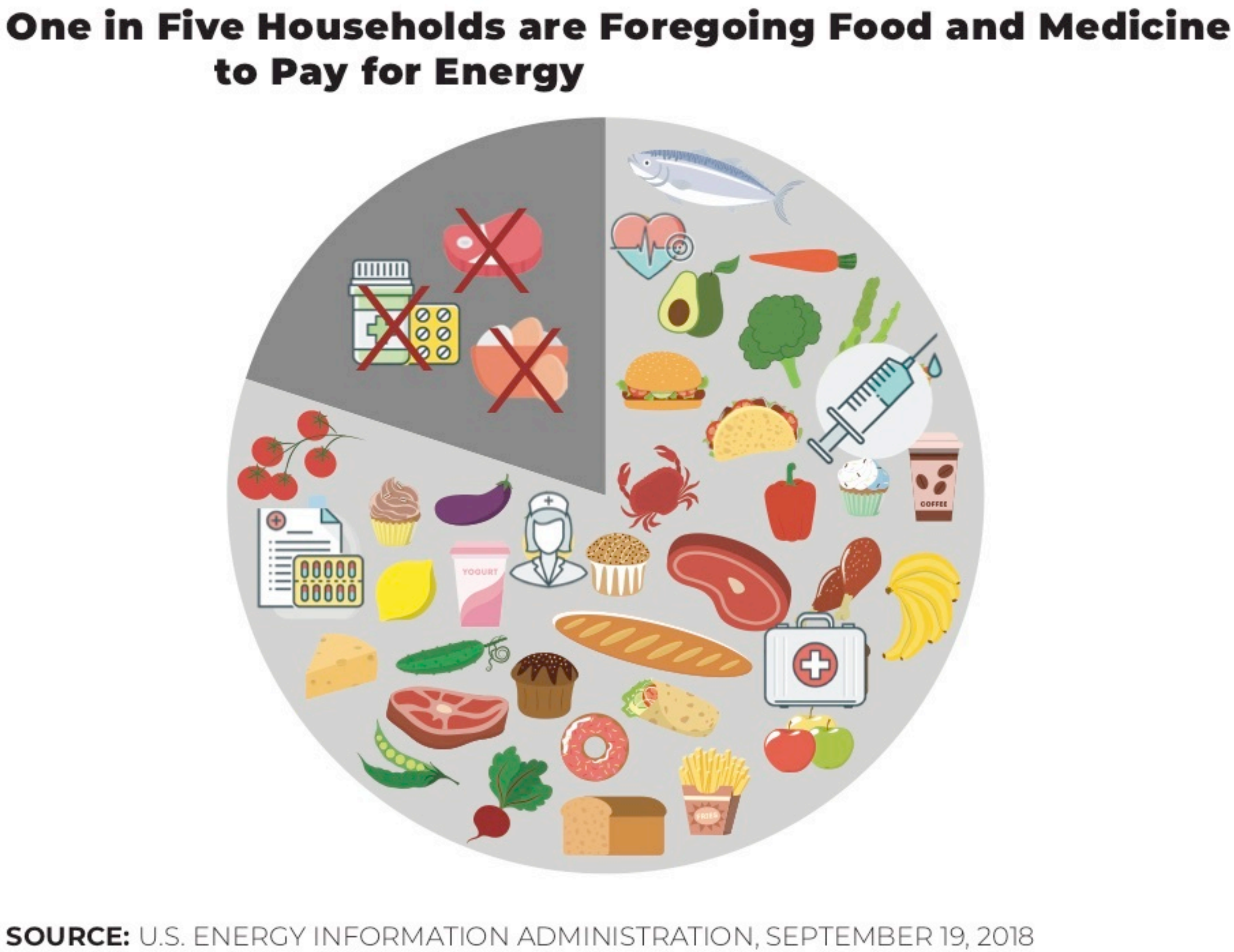
(A) Fraction of hot days when classrooms get too hot (students)



Climate-proof Duluth? Why the city is attracting 'climate migrants'. MPR News, Oct. 4, 2021.

Out-of-Towners Head to 'Climate-Proof Duluth'. NY Times, March10, 2023.

WHO
Will Be Most Affected ?



Heat Vulnerable Populations:
> 40% of U.S. Adults and Growing Rapidly

Selected High Risk Groups	Current and Projected Prevalence in U.S adults
Older, 65 y +, *in toto*	17% in 2020, 20% in 2050; Many alone in home
Obesity [6]	42% in 2018; 58% by 2035.
Severe Obesity	9%
Diabetes [5]	4-18% in 2019; up to 28% by 2050
Hypertension [1]	33%; 71% in elderly
Chronic Kidney Disease	14% in 2020, 34% in elderly.[3] 17% in 2030.[4] Greatly undiagnosed
Pregnant women [2]	3.75 million (2019); 6 - 8% are high risk
Social isolation [1]	17% in women, 21% in men
Low income [1]	15%
Little/no home insulation [1]	21%

1. Holmes, Phillips, and Wilson, 2016. Overheating and passive habitability: indoor health and heat indices. Updates needed.
2. Statista, 2021; UC San Francisco, 2021.
3. NIDKK, 2021; CDC, 2021. Up to 90% undiagnosed
4. Hoerger et al. 2015.
5. CDC, 2022; Ward et al., 2019. Large increase in diabetes projected in under 20s.
6. CDC, 2020; Large increase in obesity in children projected World Obesity Foundation, 2023.

Vulnerable Populations: Canada v. U.S.

- **More older persons in CAN v. USA**
  - ✓ 65 y +: 19 % (2022) v. 17% (2020)
  - ✓ 85 y +: 2% (2021) v. 2% (2020)

  - ✓ Age Projections: CAN v. USA
  - ✓ 65 y +: 22% to 30% (2068) v. 23% (2060)
  - ✓ 85 y +: 5 to 7% (2068) v. ~ 5% (2060)

- **Less obesity, diabetes, heart disease, kidney disease, etc. in Canada**

- **Asthma higher in Canada ?**
  - ✓ Triggered by indoor and outdoor extreme heat (Meta analysis, Relative Risk 1.07, Han et al. 2023)
  - ✓ 8.7 % (2020 12 yr +) vs. 7.7 % (2020, All ages)

Vulnerable Populations (contd.)

- Many people have co-morbidities (multiple health conditions) and other risk factors
- Dementia and Alzheimers population is growing rapidly

- Perfect (Heat) Storm:
  - Demographics (Silver Tsunami)
  - Chronic Health Risks increasing
  - Housing Crisis
    (costs, overcrowding, homelessness)
  - Health Care and Energy costs increasing
  - Power outages increasing
  - Climate Change ("Threat Multiplier")

Overheating and Resilient Cooling Jargon: It's Confusing and Complex !

- **Short Term**
  - ✓ Passive Survivability
  - ✓ Thermal Safety
  - ✓ Hours of Safety
  - ✓ Resilient Design

- **Long Term**
  - ✓ Future Proof
  - ✓ Fit For Purpose
  - ✓ Climate Adapted
  - ✓ Climate Ready, Forward Looking
  - ✓ Climate Resilient (Bounce back and bounce forward)
  - ✓ Life Cycle Optimized (30 - 100 years)
  - ✓ Resilient Cooling

- **No Standard Definition.**
  Significant overlap in the two approaches

Resilient Cooling Definitions & Components

Climate Vulnerability Assessment Required

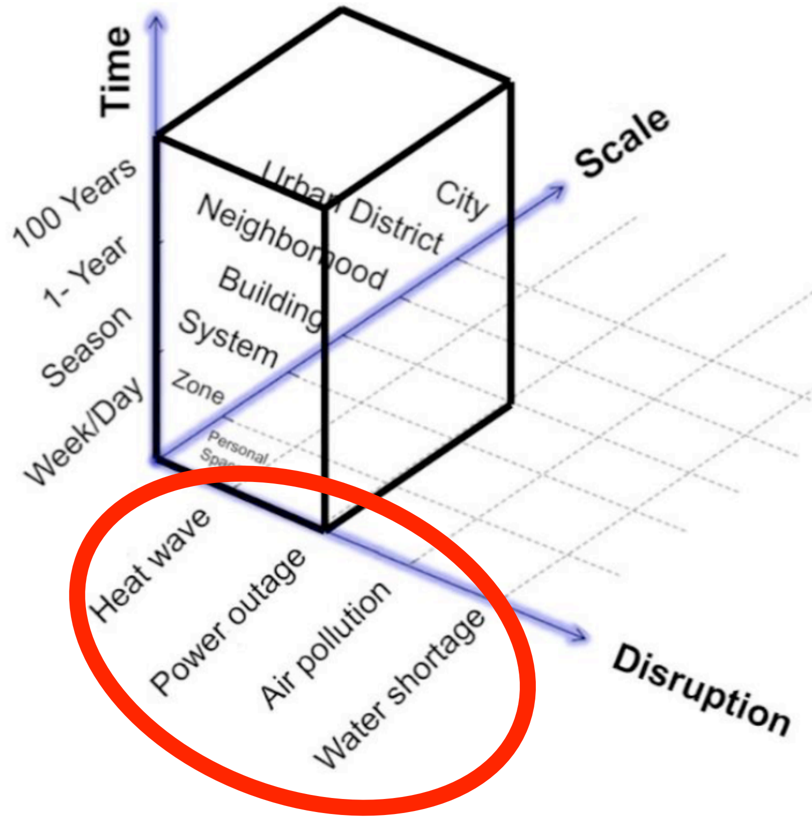


Fig. 1 - the components of a resilience definition within a specific field or domain

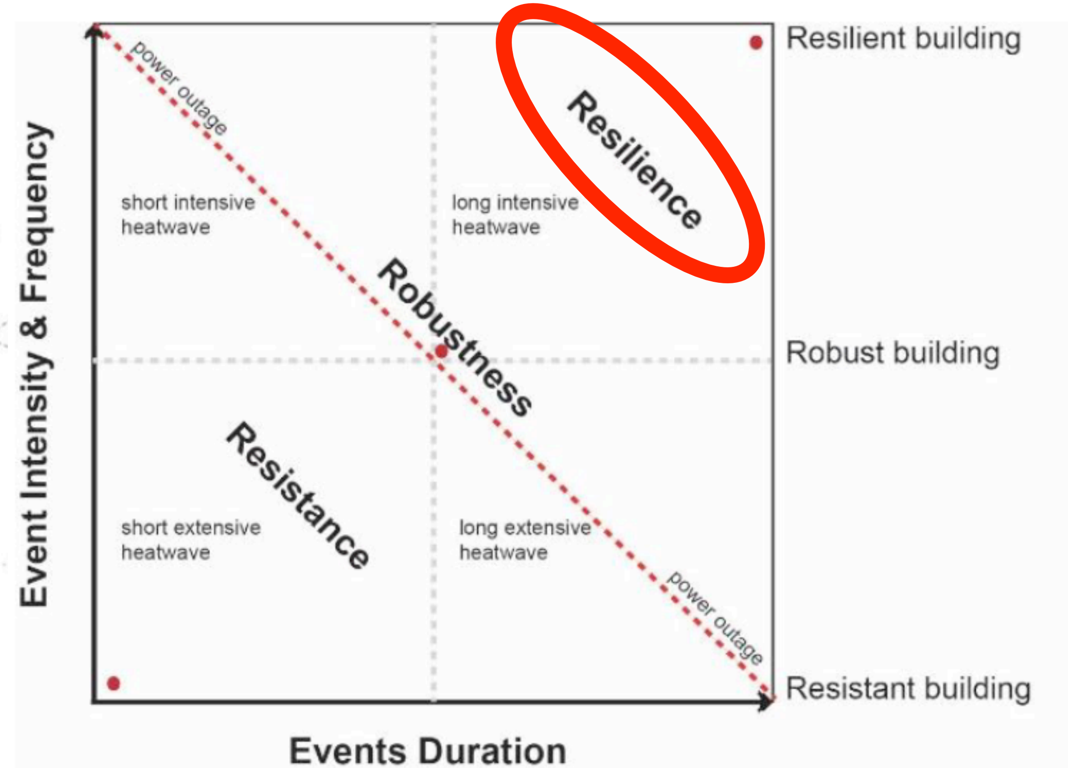
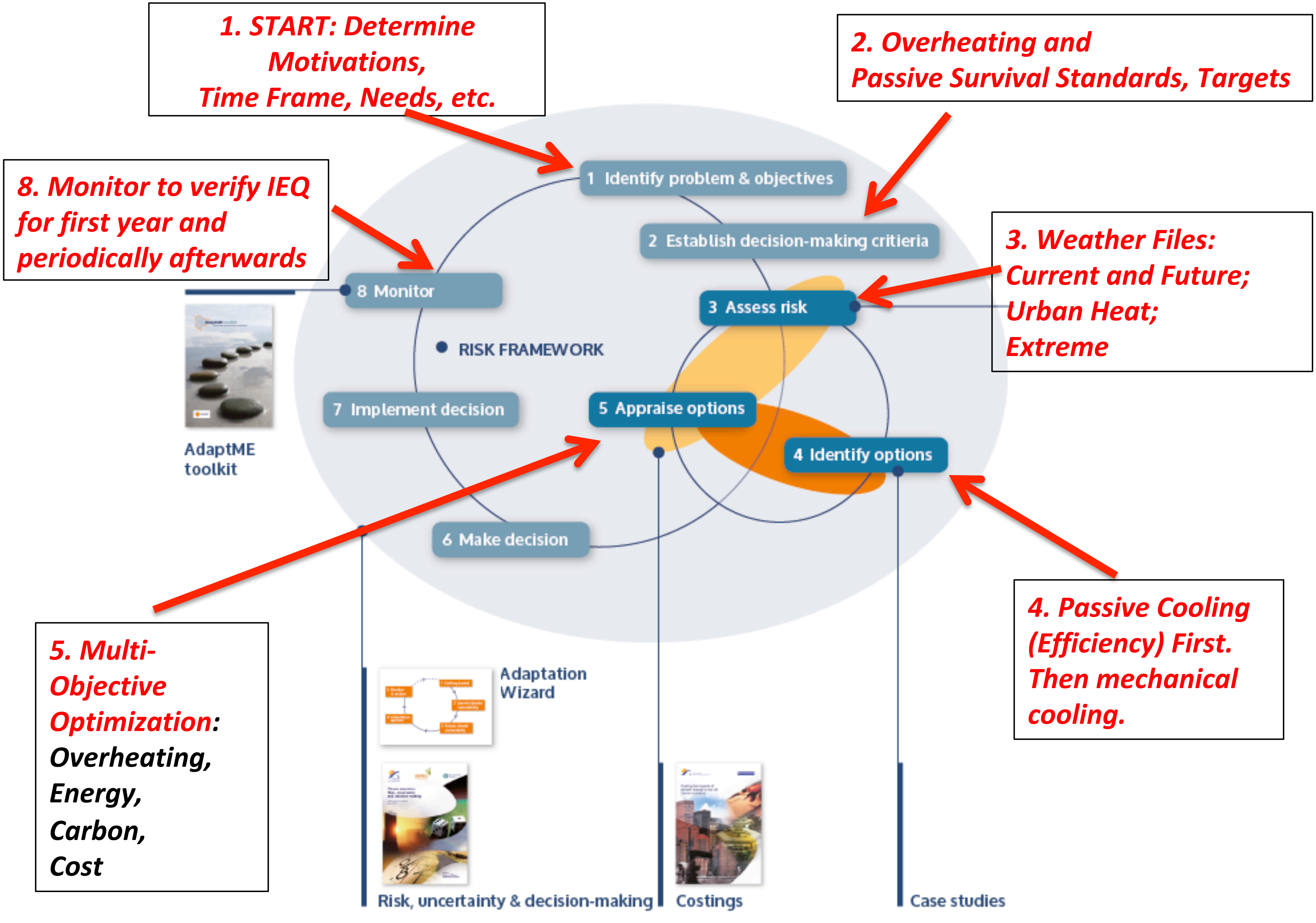


Fig. 2 - the components of a resilience definition within a specific field or domain

Attia et al., 2022. Resilient cooling definitions review. IEA Annex 80. https://proceedings.open.tudelft.nl/clima2022/article/view/195.



Adapted from UKCIP, 2013. [Adaptation Wizard](). See also: Case studies.

Deep Energy Retrofits Needed in BC

- **Deep retrofits should be priority in B.C.'s extreme heat event strategy. Pembina Inst., June 9, 2022.[1]**
  - ✓ **Preparations for unprecedented rises in temperature must include funding for infrastructure upgrades and focus on the most vulnerable.**
  - ✓ **Free AC and fans, and efficiency rebates proposed by the Coroner's report are not enough.**
  - ✓ **To protect occupant health and assets, a building retrofit must take into account both climate adaptation and mitigation measures, as well as how they interact.[2]**

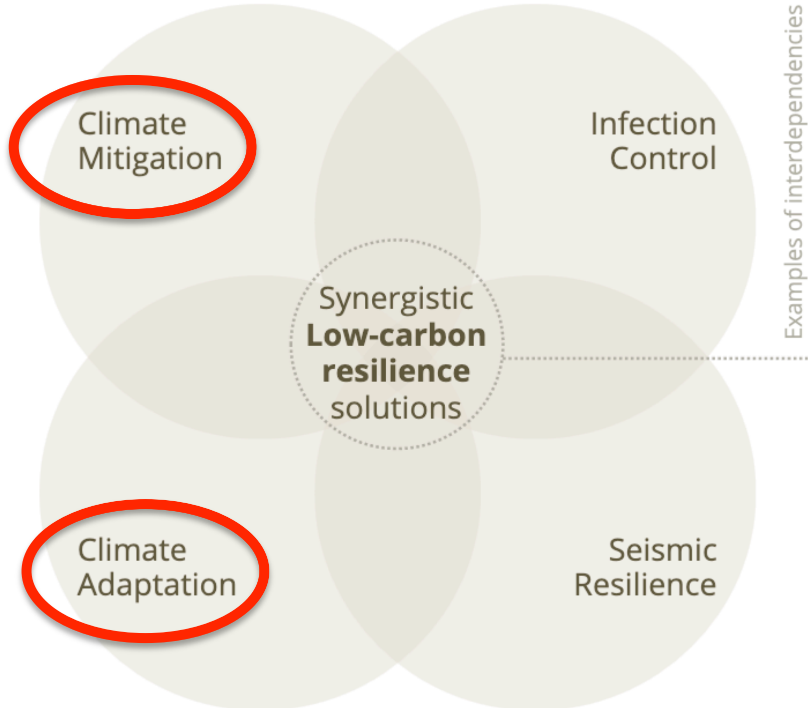


Figure 2. Integrating resiliency measures into low-carbon solutions

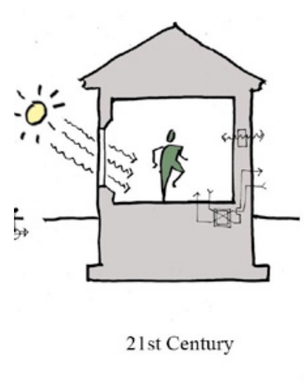
1. **Pembina Institute. Comment on BC Coroner's report, June 9, 2022. https://www.pembina.org/media-release/deep-retrofits-should-be-priority-bcs-extreme-heat-event-strategy.**
2. **Pembina Institute, 2020. Climate resilience and deep retrofits. A Reframed Tech Series primer.**
3. **See also: Indoor Heat Study of Portland housing, April 2023.**

Overheating Standards and Guidelines

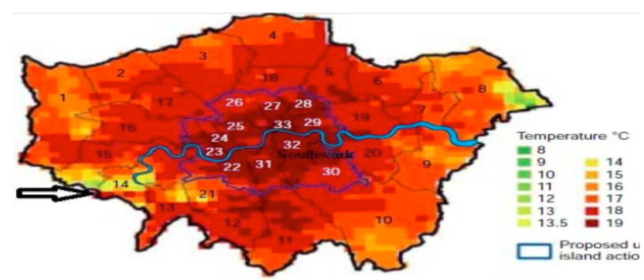
- International
- Canada
- U.S.
- California
- Australia

Overheating Standards and Guidelines: *International*

- **World Health Organization (1987 and 2018):**
  ≤ 24 C and ≥ 18 C (vulnerable populations). [1]
- **Passive House Program:**
  ≤ 10% (h/y) > 25 C, and moisture limit. [2]
- **CIBSE TM 59 Overheating Design Guide (UK):**
  - **Mechanical ventilation:** Operative Temperature ≤ 26 C for < 3% of occupied hours
  - **Natural Ventilation**: temperature (summer occupied hours) and annual delta T limits for bedrooms
  - **Future climate scenarios recommended:** high emissions scenarios recommended, mid & late century. [3,4]
- **CIBSE TM 49 Urban Heat Island Design Guide (UK and London Plan):** [5]
  - **Overheating risk assessment** for urban heat zones
  - **Design Summer Year** weather file
  - **Hierarchy of efficiency measures**, before mechanical cooling is allowed



Albert, Righter and Tittmann Architects



Average outdoor air temperature in London during August 2013

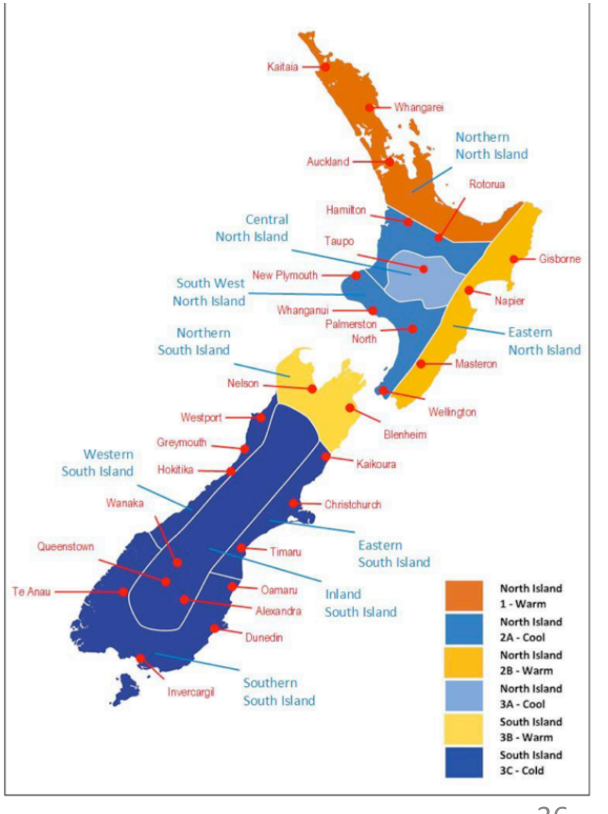
1. WHO, 2018. Housing and Health Guidelines.
2. Passive House Institute, 2016. Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard.
3. CIBSE, 2017. TM 59, Design methodology for the assessment of overheating in homes.
4. Diamond, S., May 22, 2017. CIBSE Overheating webinar. Inking Associates.
5. CIBSE, 2014. TM49 Design Summer Years for London. See also: ARCC Network, 2017. Designing for Future Climate.

Overheating Standards and Guidelines: *International (Part 2)*

RIBA Journal;

- UK Future Homes Standard and Building Regulations [1]
  - ✓ Overheating, low carbon, and ventilation requirements, based on CIBSE TM 59 and future climate
  - ✓ Over 1 million homes could still suffer from overheating (reviewer comments)
  - ✓ Health benefits estimated

- New Zealand School Design Guidelines: Overheating
  - ✓ Varies by region
  - ✓ > 26 C: 20 – 250 hours,
    > 28 C: 10 – 60 hours, 32 C max

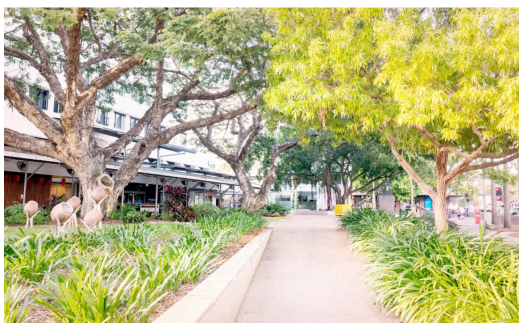


- European Overheating Standards: 2023 Review
  - ✓ Many national standards do not address climate change or heat events
  - ✓ Need for Harmonization for Energy Standards
  - ✓ Recommended framework, key performance indicators, time integrated metrics

1. Update; UK Future Homes Standards, 2021. Standards and consultations. News: https://www.architecture.com/knowledge-and-resources/knowledge-landing-page/the-future-homes-standard-explained.
2. B. Cruise., March 2018. AIVC Workshop. Guideline: NZ Ministry of Education, 2017. Designing Quality Learning Spaces – Indoor Air Quality and Thermal Comfort.
3. Attia et al., 2023. IEA Annex 80.

Overheating Standards and Guidelines: *Australia*

- **Darwin Living Lab (CSIRO, 2022 +)** [1]
  - ✓ **Darwin House Comfort Rating tool for living rooms and bedrooms: Degree Hours of Discomfort.** [2,3]
  - ✓ **Heat Mitigation & Adaptation Strategy** [4]
  - ✓ **Energy efficiency and renewable energy**
  - ✓ **Resources, symposia**



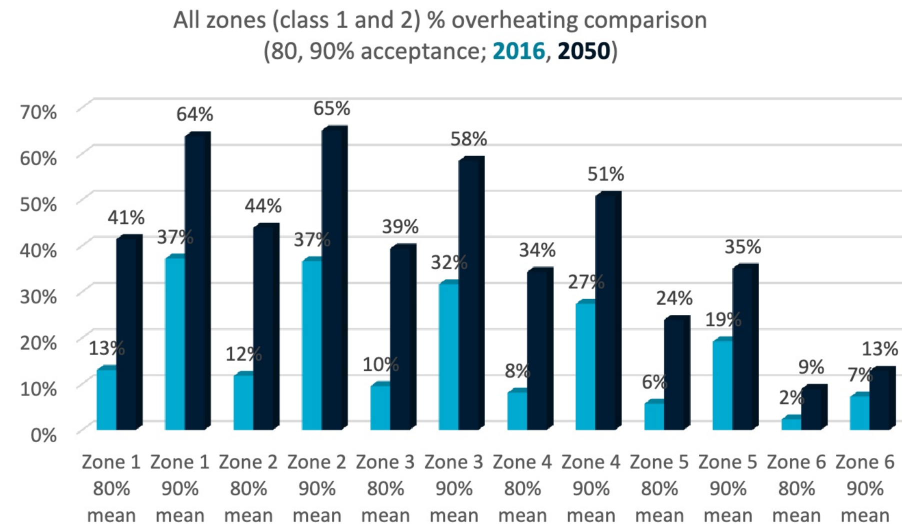


Figure 17 Comparison of 80 and 90% acceptability in current and future climate

Miller et al. 2023. ***Data Analysis Report and Comfort RatingRecommendations. Darwin House Comfort Project.***

1. **CSIRO, 2022. Darwin Living Lab.**
2. **CSIRO, 2023a. Darwin Home Comfort Rating.**
3. **Williamson et al., 2022. "Developing a Methodology to Assess Potential Overheating of Houses in Darwin". In Architectural Science and User Experience: How Can Design Enhance the Quality of Life:**
4. **CSIRO, 2021. Darwin Heat Mitigation and Adaptation Strategy.**

Overheating Guidelines and Standards: U.S.

- **No maximum temperature limits in residential building standards or schools, at the national or state level**
  - ✓ Some locales require AC and maximum temperature limits [1]
  - ✓ Some state Medicaid programs allow cooling or AC measures [1]
  - ✓ Many proposals have failed
- **Nursing homes, if certified after Oct. 1, 1990: ~ 71-81 F in residences, under *federal* law [2]**
  - ✓ *Michigan* law only applies if construction cost is $1 M or more
- **Hospitals and care facilities**
  - ✓ State and federal standards
  - ✓ Limited enforcement in care facilities

1. GHHI, 2020. Air Conditioning, Heat Vulnerability, and Racial Equity.
2. Michigan, 2004. Federal regulation, 42 CFR Part 483. 483.15(h)(6). Leeway allowed if heating or cooling needs are rare. Somestatres require AC and heating, such as Illinois.
3. Wilson, A., 2018. The LEED credits are back up. Resilient Design Institute.

Overheating and Adaptation Guidelines and Standards: Canada

- **British Columbia Housing (2019): Energy Step Code, Overheating and External Air Quality Supplement [1]**

- **Langley, BC (2021): Draft GHG, thermal resiliency (overheating), and energy equity policy) [2]**
  - ✓ Based on BC Guidelines
  - ✓ Modeling and Draft report, and public review planned.

- **National Research Council Canada, Construction Innovation (2021): [3]**
  - ✓ Overheating Risk Management Guideline and modeling results
  - ✓ Risk evaluation methodology
  - ✓ Summer reference weather files
  - ✓ Heat and cold stress metric and models

1. BC Housing, 2019. Design Guide Supplement on Overheating and Air Quality. PCIC future weather files used.
2. More info: Langley Builder Forum Series: Passive Cooling and Step Code (June 1, 2021).
3. NRC Canada. Various reports by Laouadi et al.

Overheating and Adaptation Guidelines and Standards: U.S., Voluntary

- **Build It Green (2019, 2021): GreenPoint Rated for CA Homes** [1]
- **Collaborative for High Performance Schools, U.S. (CHPS, 2020) Climate Adaptation and Resilience, 1-5 points** [2]
  - ✓ **Climate Vulnerability Assessment using climate change projections**
  - ✓ **Design, Maintenance, and Emergency Plans for 1 or 2 top risks**
  - ✓ **Energy Resilience: Primary power system (< 50% of load), secondary system that can be switched off**
  - ✓ **Passive Survivability/Habitability: 4+ days without power on primary system; energy efficiency and renewable backup power**

CHPS

- **LEED Pilot Credits (2018 and 2022 update): Resilient Design for new construction. Public input requested.** [3,4]

USGBC

1. Build It Green, 2020. Green Point Rated, Version 8.0. N8.2, Strategies to Address Assessment Findings
2. CHPS, 2020. US-CHPS Criteria v2.0. Sec. II C7.1 Design For Adaptation & Resilience. Net Zero Energy and daylighting are required. Low/Zero GHG is optional. 60-100 life cycle of building.
3. Wilson, 2018. The LEED credits are back up. Resilient Design Institute.
4. Melton, Dec. 2021. USGBC to Drop Its Resilience Rating System, RELi. Building Green News. Plans to integrate resilience.

Overheating Standards and Guidelines: *California*

- **Occupational Indoor Heat Standard, Cal OSHA, 2023 Draft.**
  - ✓ 82 F trigger temperature for work in hot environs or heavy clothing, etc.
  - ✓ 87 F triggers more protective measures
  - ✓ Final in August: pressure to reduce below 82 F trigger

- **Recommended Maximum Residential Temperature, AB 209.**
  - ✓ University contractor hired to review assist in the review and recommendation development
  - ✓ Recommendations due January 2025.Research projects and proposals to address indoor heat resilience valuation, climate change impacts, metrics, climate equity, etc.

- **Extreme Heat Action Plans: 2013 and 2022**
  - ✓ Addresses building standards and low income weatherization
  - ✓ Not fully funded

Step 2: Future Weather Files: *Dynamic Downscaled Projections*

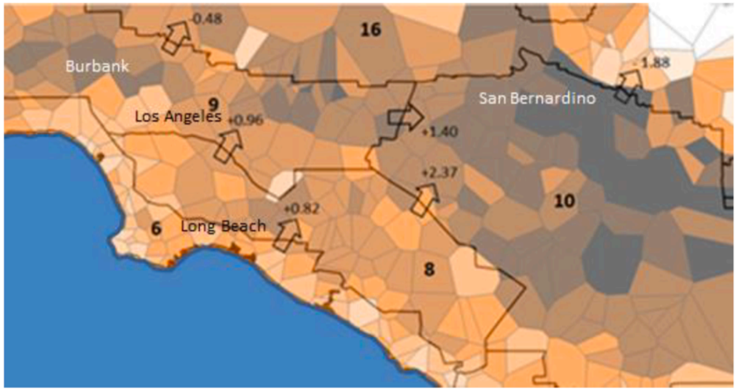
- **UK Climate Projections. Probabilistic, 2.2 km resolution [1]**

- **NARRCAP, Slipstream. 3 hour data for the U.S. Interpolate for major cities [2]**

- **Altostratus 2019.
  California climate changes
  and urban heat island changes.[3]**

- **Cal-Adapt Analytics Engine, 2022.
  Hourly + data for California climate change at 3 km +.
  Cloud based system.
  Extreme temperature event distribution (upcoming).[4]**

Figure 3: Southern California microclimate zones (color coded) created by Altostratus Inc. compared to existing, coarse climate zones (numbered 6,8,9,10,16) used in current energy modeling.

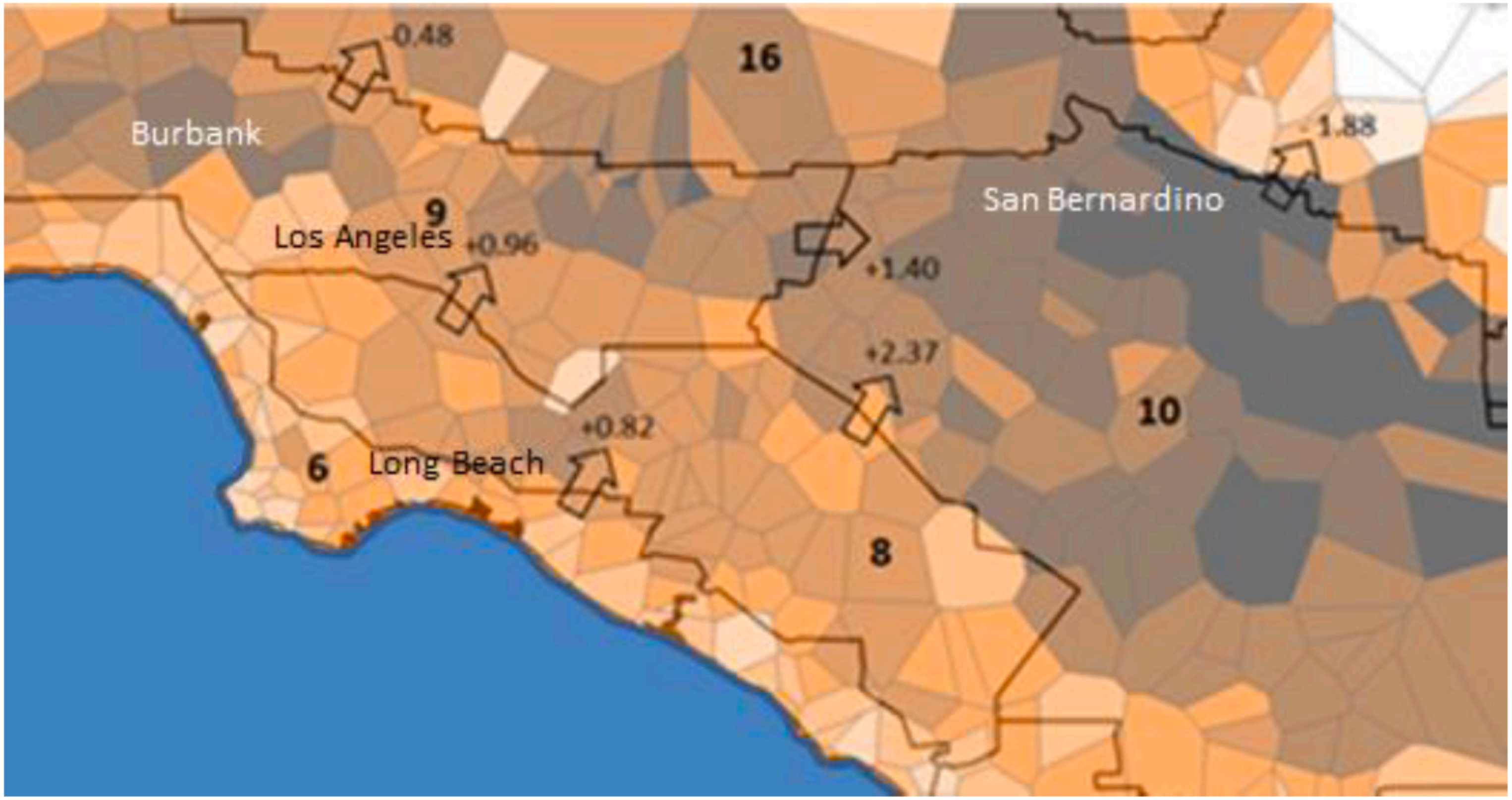


**Taha, 2019.
Publication No. CEC-500-2021-003.**

1. Met Office, 2021. UK Climate Projections.
2. Slipstrean, 2023. Climate Data Toolkit. Schuetter et al., 2014. Future Climate Impacts On Building Design.
3. Altostratus 2021
4. Eagle Rock Analytics, 2022. https://analytics.cal-adapt.org/

Future Weather Files:
*Dynamic Downscaled Projections, **

Figure 3: Southern California microclimate zones (color coded) created by Altostratus Inc. compared to existing, coarse climate zones (numbered 6,8,9,10,16) used in current energy modeling.



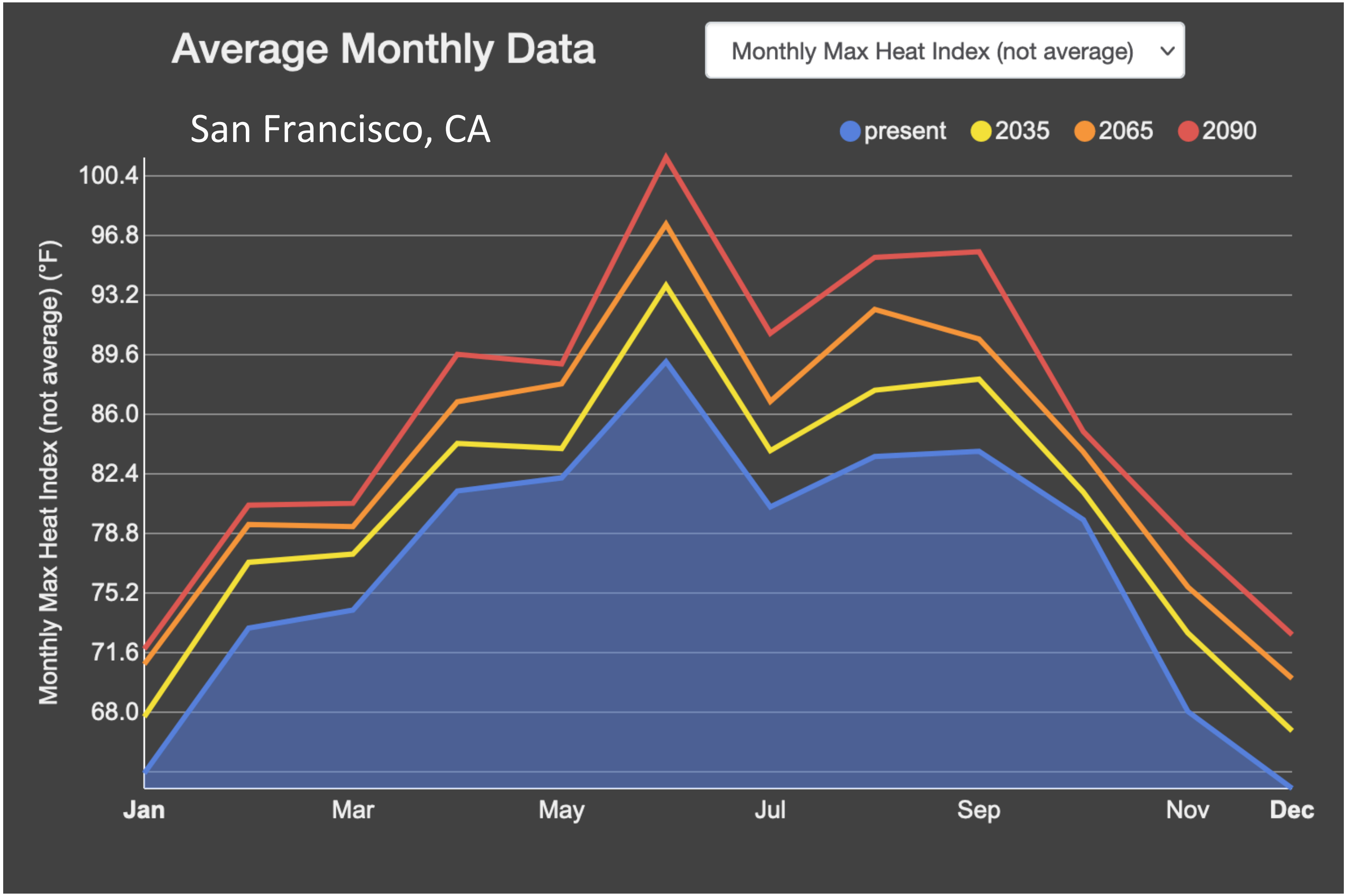
* Taha, 2019. Intraurban Enhancements to Probabilistic Climate Forecasting for the Electric System. Altostratus.California Energy Commission. Publication No. CEC-500-2021-003.

Future Weather Files:
Morphed, Statistical Downscaled Projections

- Climate Change World Weather File Generator. [1]
- WeatherShift. Based on maximum temperature. Fee. [2]
- MeteoNorm. Several weather variables. Monthly averages only. Urban effects for European cities. Fee. [3]
- Pacific Climate Impacts Consortium. All weather variables; all of Canada. [4]
- CSIRO, 2021. 83 locations in Australia, for building design and energy rating. [5]
- Epwshiftr R package, 2021. Uses CMIP6 climate model data.[6]

1. University of Southhampton, 2013. CCWorldWeatherGen.
2. Arup, 2021. Weathershift: Heat.
3. MeteoNorm, 2021. Version 8.
4. Pacific Climate Impacts Consortium (PCIC), 2020. Future weather files.
5. CSIRO, 2021. Predictive weather files for building energy modelling
6. Jian & Chong, 2021. epwshiftr: Create future EnergyPlus Weather files using CMIP6 data

Future Weather Files:
*Morphed, Statistical Downscaled Projections **



* **Weathershift. Heat projections. San Francisco.**

Extreme Weather Files:
Historical "Stress Test"

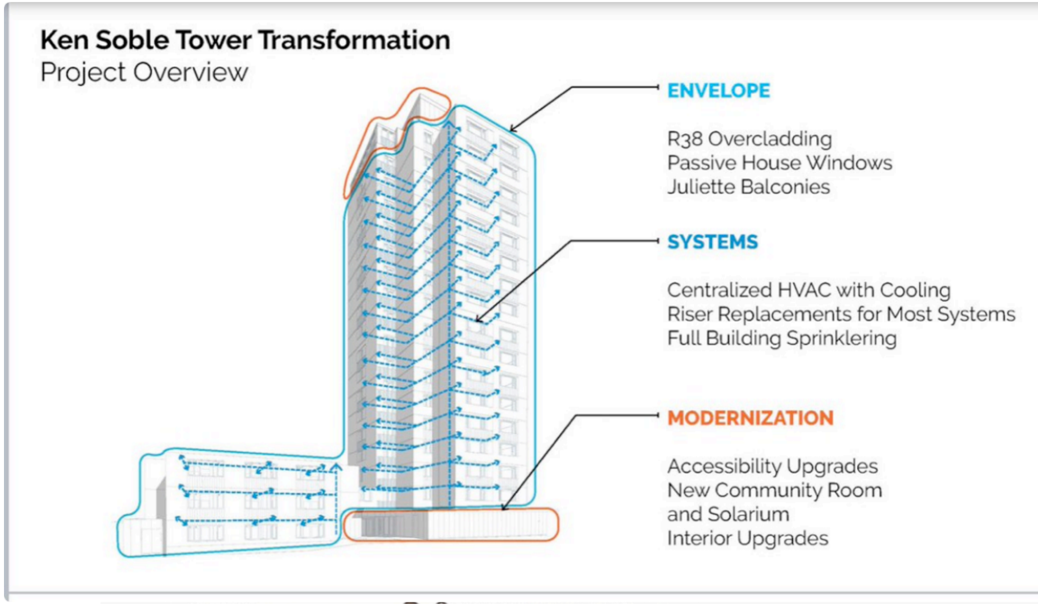
- Historical Heat Waves
- Design Summer Year (DSY)
  and Summer Reference Year (SRY)
- Extreme Meteorological Year (XMY)
- Review of weather file types for future simulation at Herrera et al., 2017
- New research focused on modeling extreme weather events and extreme future climates

Steps 3 – 4: Overheating Assessments and Climate Adaptation

Selected Examples

Multifamily Passive House Retrofit: Ken Soble Tower, Hamilton, Ontario [1,2,3]

- **Designed for a changing climate, all seasons: Used 2050 temperature projections**
- **Ultra-low energy use: 94% reduction of GHG emissions compared to existing building**
- **Passive resilience in case active systems fail:**
  - ✓ Stays warm in winter for up to two days (vs. 2 hours in a typical building)
  - ✓ Safe heat levels in summer for up to four days (vs. half a day in a typical building).



1. Toronto Tower Renewal Partnership et al., 2020. A Case Study In Deep Retrofit And Housing Renewal. Ken Soble Tower Transformation. Sec. 10, chart, etc.
2. See also: ERA Architects, June 10, 2020. Passive House Accelerator Happy Hour webinar.
3. Toronto Tower Renewal Partnership et al., 2023. Thermal Comfort, Deep Energy Retrofits, Housing Quality, GHG Reductions.

Designing Climate Resilient Multifamily Buildings: *British Columbia* [1]

- **Low and High Rise Multifamily: New and Existing archetypes modeled**
- **Thermal comfort assessed and mitigated**
  - ✓ **ASHRAE 55 Thermal Comfort metrics,**
    ≤ 200-hours above the 80% acceptability limit
    ≤ 20 hours for vulnerable populations
  - ✓ **RCP 8.5 climate change scenarios for 2020s, 2050s, and 2080s**
  - ✓ **Heating, cooling, and GHG metrics**
- **Power outages modeled**
- **Incremental costs calculated: single measures & bundles**
- **Design strategies recommended for each building type**

1. RDH, 2020. Report to University of British Columbia. BC Housing support.

Incremental Cost and Overheating Hours: Existing Low Rise, 2050s RCP 8.5

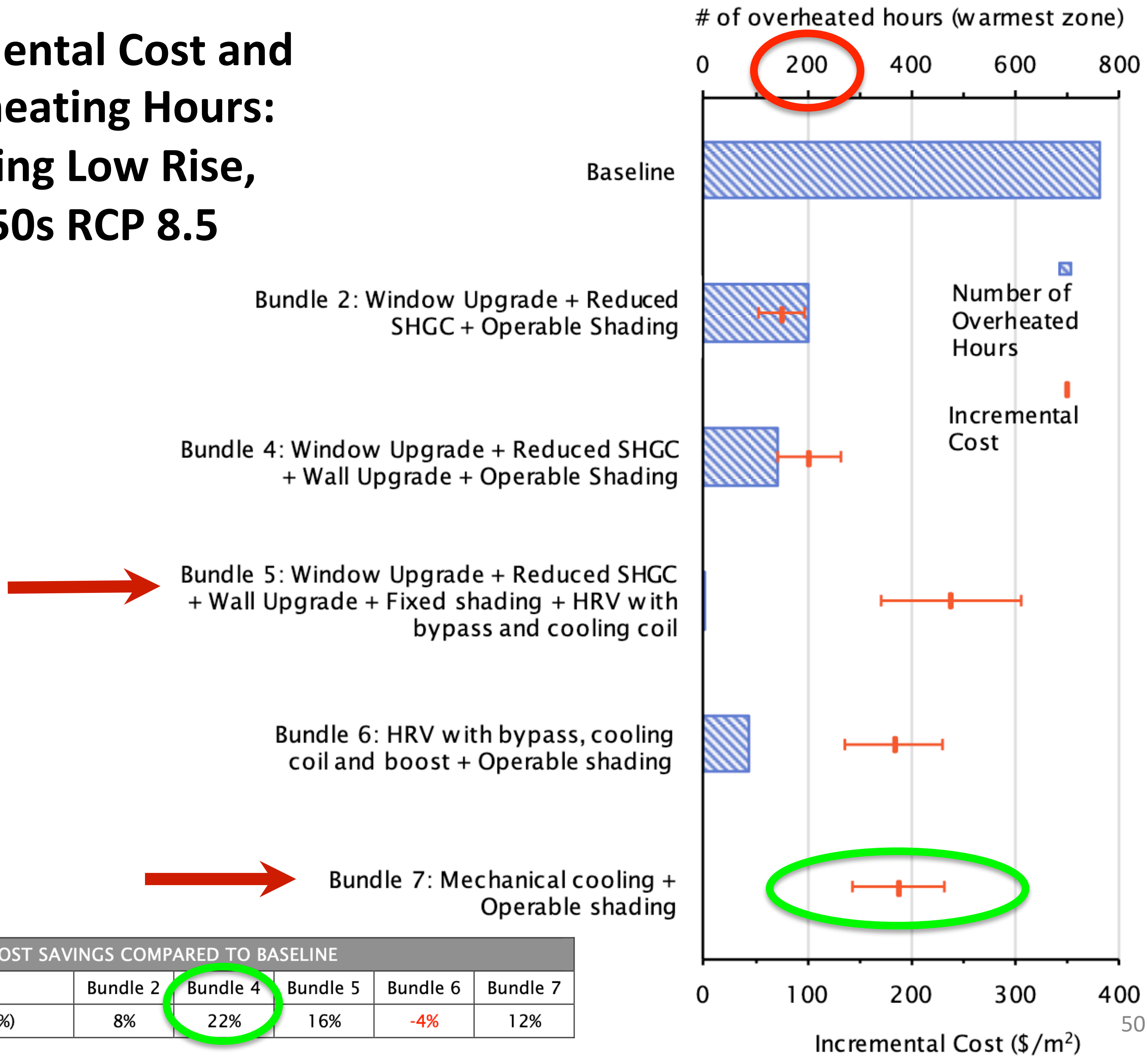


TABLE 0.5 ENERGY COST SAVINGS COMPARED TO BASELINE					
	Bundle 2	Bundle 4	Bundle 5	Bundle 6	Bundle 7
Energy Cost Savings (%)	8%	22%	16%	-4%	12%

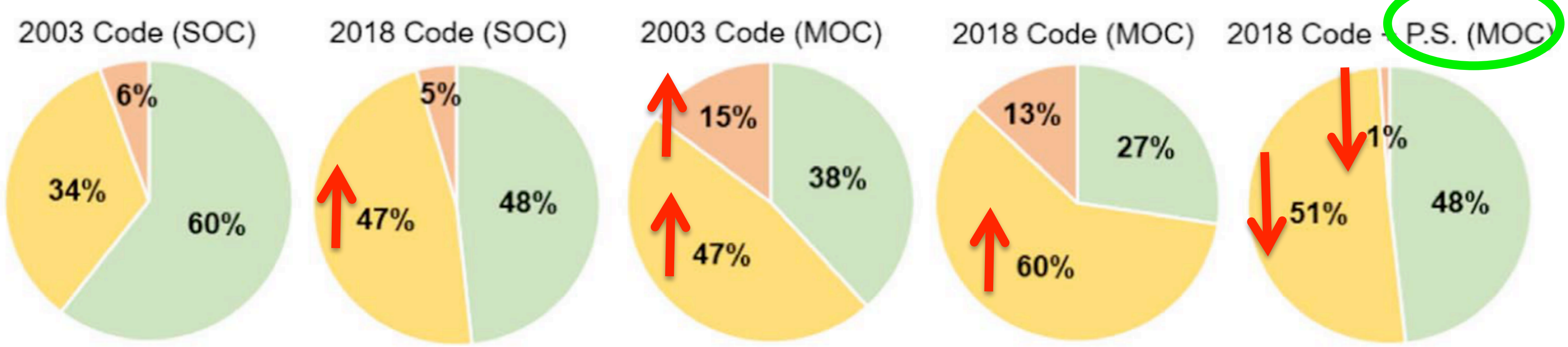
Passive Survivability (PS) Without AC:
Energy Efficiency and Climate Change Can Increase Overheating, Passive Cooling Can Reduce It

,

< 77 F	(Comfortable)
77 – 82.4 F	(Moderate Discomfort)
> 82.4 F	(Severe Discomfort)

CHICAGO: ASHRAE Climate Zone 6 (light blue)

Start of Century **Middle of Century (2050s)**



% Time at Indoor Temperature, Without AC in Cold Climate (Chicago)

Adapted from Baniassadi et al., 2019. [Passive survivability of buildings under changing urban climates across eight U.S. cities.](#)

Overheating Adaptation Packages for 2030s, 2050s @ Neighborhood Scale: SNACC

Bristol: St. Werburghs (Inner historic suburb)

Fabric + Systems:
100 % ➔ 1 % Overheating

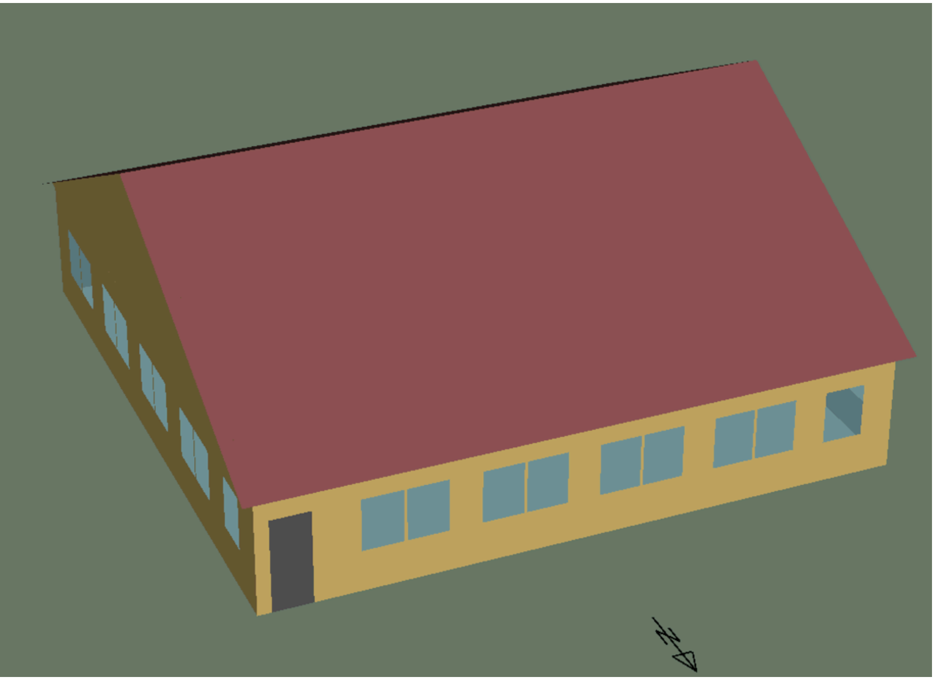
Gupta et al. 2011+.
SNACC: Suburban Neighbourhood Adaptation for a Changing Climate - identifying effective, practical and acceptable means of suburban re-design. Oxford Brooks University.

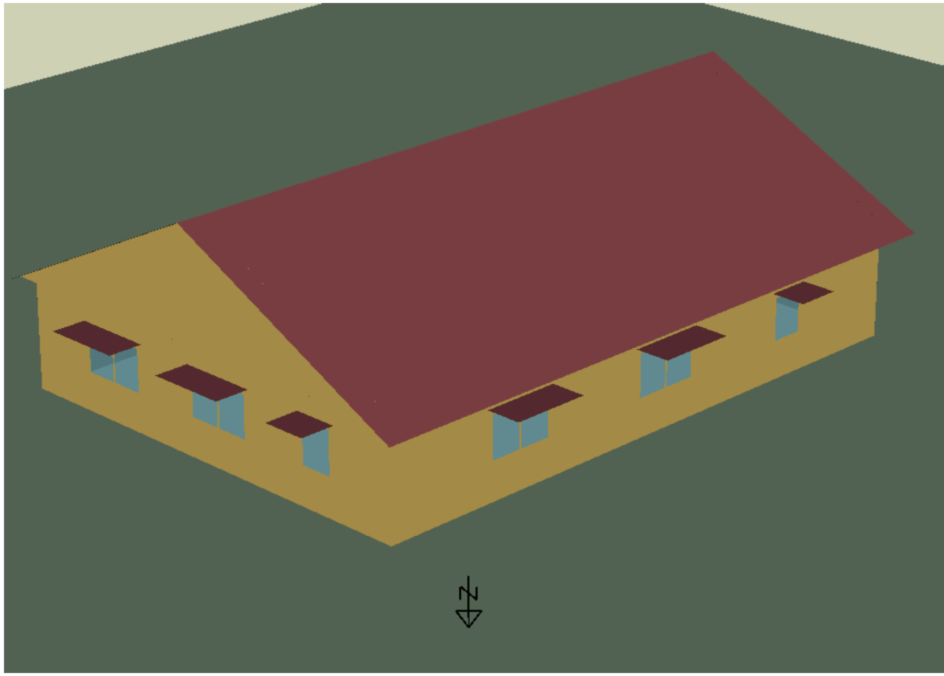
Bakersfield Future Climate Design:

Title 24 Standard vs. BeOpt Low TDV (BeOpt)

2019 Title 24 Reference Point:
Windows 105 SF/side, 20% CFA, HPWH, etc.

Cooling Optimization upgrades:
Windows 50 SF/side,
Eaves, overhangs, cool roof,
Insulation, low air leakage, HRV,
high SEER Heat Pump, etc.



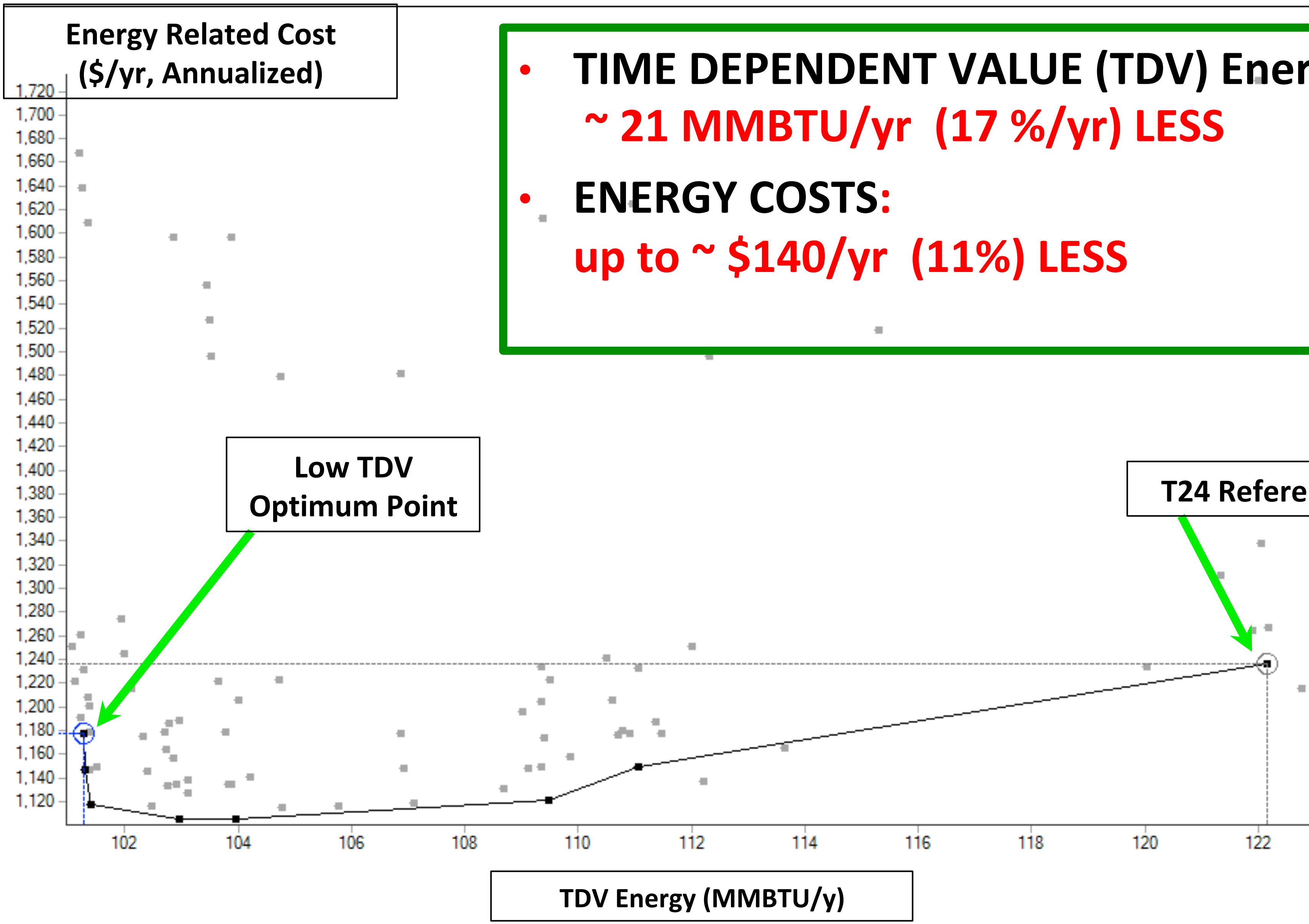


Phillips and Higbee, 2018 CHEE; 2020 Zero Carbon Retreat

BeOpt Results: Low TDV, Low Cost Case

Example: Title 24, HPWH, No PV; Roof, Thermal Mass, and HVAC Options

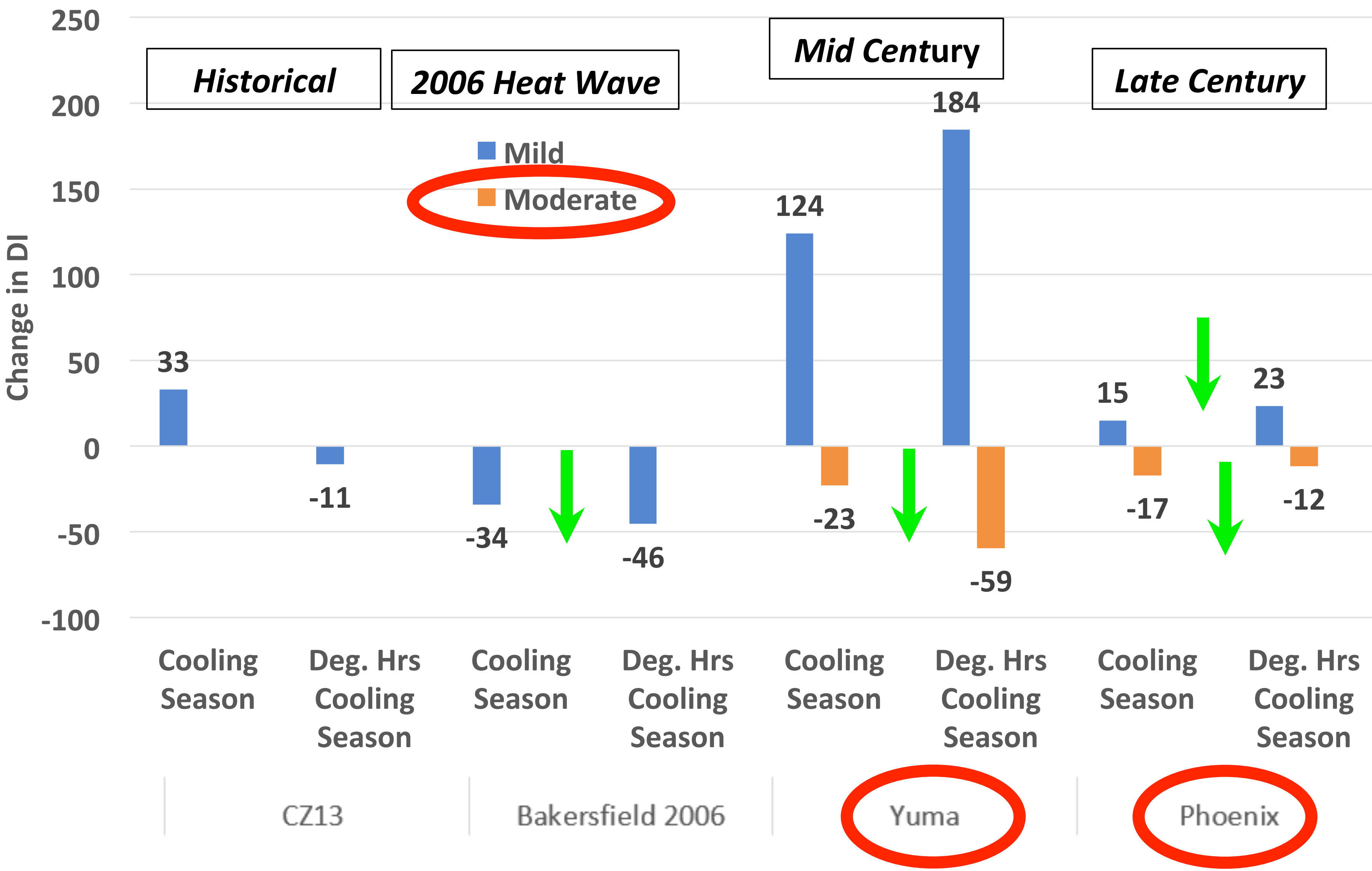
- **TIME DEPENDENT VALUE (TDV) Energy:**
  ~ 21 MMBTU/yr (17 %/yr) LESS
- **ENERGY COSTS:**
  up to ~ $140/yr (11%) LESS



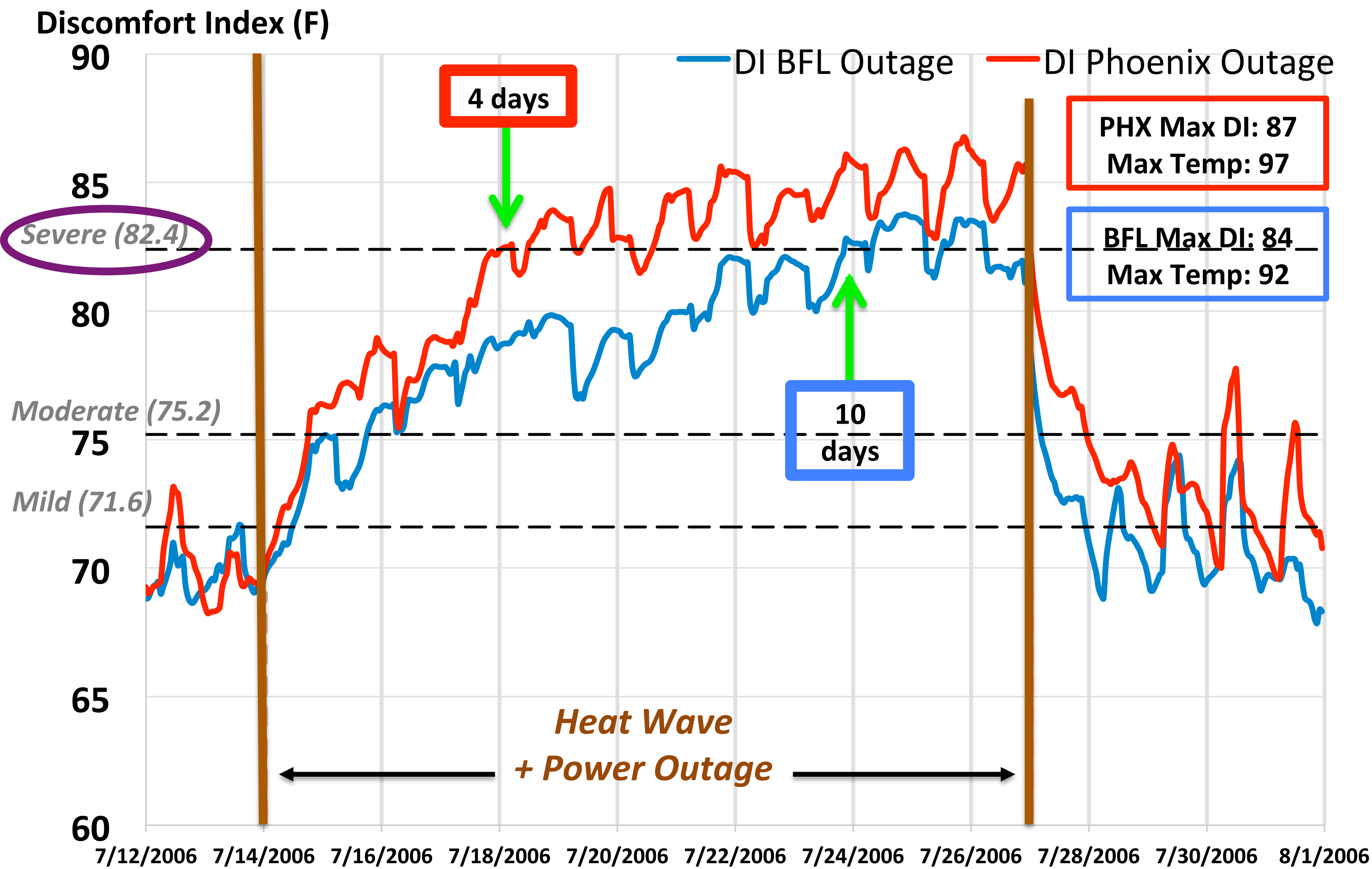
TDV Optimized Design minus Title 24 Baseline:

Discomfort Index: Hours and Degree Hours Reduced

Cooling Season (May-Sep)



BFL and Phoenix DI: *Heat Wave + Outage*



Climate Adaptation and Overheating in Canada: *FAST FORWARD TO 2020s: Canada is a Leader Again*

- **Climate Crisis / Emergency**
- **Toronto Tower Renewal Project**
- **Reframed Retrofit and Passive House Accelerator**
- **NRC Canada metrics, guidelines, weather files, etc.**
- **University of BC climate resilient dorms**
- **BC Housing demonstrations, policies, resources, training, etc.**

- **Paradigm Shift and Ramp Up:** **more needed now**

Growing R&D Areas: Stay Tuned

- **Indoor, Outdoor, and Personal Heat Modeling and Monitoring**
- **Valuation of Resilient Cooling, Overheating Prevention**
- **Multi Objective Optimization (MOO): Overheating, Cost, Carbon, etc**
- **Neighborhood Scale Modeling**

Indoor and Outdoor Heat Interventions

Heat Resilient City Project, *Leibniz Institute*

Impact of regional climate, future climate & urban heat islands

Comparison„Gründerzeit" and prefabricated building

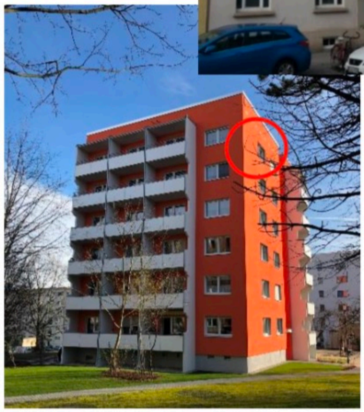
Normative representation of the DIN 4108-2 threshold of 1200 Kh/a

green	yellow	red
50 %	100 %	> 200 %

	Dresden	Hamburg	Köln	Potsdam	Stuttgart
First floor	110%	100%	160%	100%	110%
attic	240%	230%	330%	210%	290%

	Dresden	Hamburg	Köln	Potsdam	Stuttgart
First floor	60%	60%	60%	90%	50%
Attic	100%	90%	130%	130%	90%

→ Overheating intensity higher in top floor and higher for prefab. building

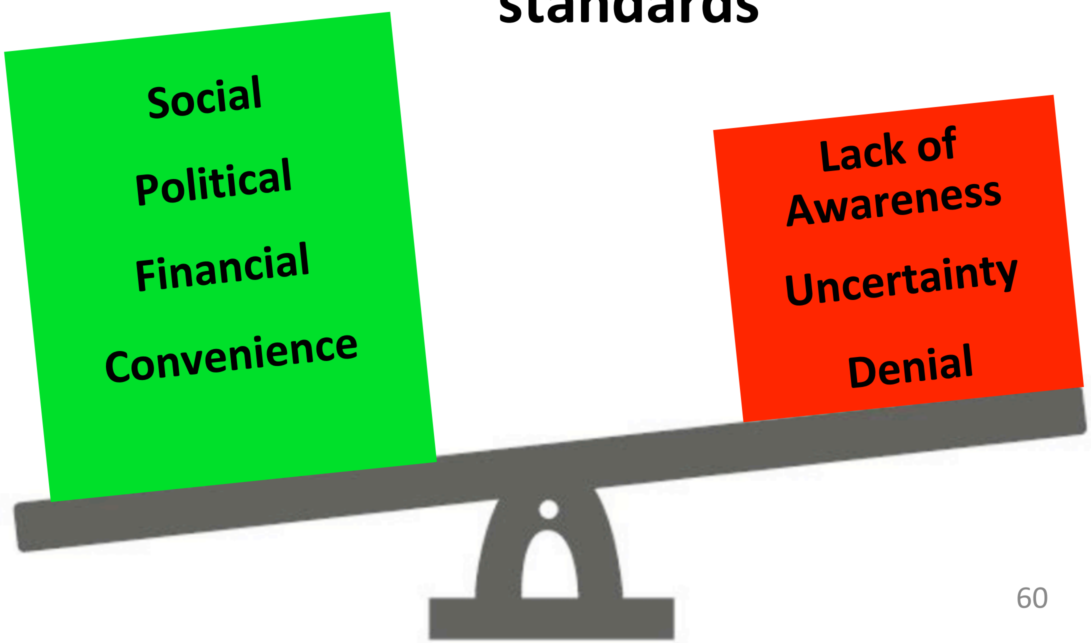


Schunemann et al., April 2023 Project Overview (English).
https://www.dropbox.com/s/dkamorar4b45fq3/
HRC%20German%20residential%20overheating%20webinar%2C%20Schuenemann%20US_2023-04-04.pdf?dl=0

ADAPTATION LEVERAGE POINTS

- **Positive Pressure**
  - ✓ Big climate change impacts
  - ✓ Media attention
  - ✓ Legislative mandates
  - ✓ Financial incentives
  - ✓ Liability and market forces
  - ✓ Public and private sector support
  - ✓ Affordable sensors

- **Negative Pressure**
  - ✓ Cost, Affordability
  - ✓ Uncertainty
  - ✓ Lack of good data, tools
  - ✓ Lack of consensus standards



CONCLUSIONS

- **Modeling and measurement tools are available to assess and mitigate overheating and energy impacts of climate change and urban heat, in order to keep buildings healthy, resilient, and future climate adapted.**

- **Overheating prevention is very active in the UK, and is spreading in Canada, Europe, and Australia. China is very active in overheating research.**

- **Federal, state, local, and private funding for climate action should be pursued**

.

- **We must integrate climate adaptation to extreme heat into all building programs & policies – NOW !!**

IR camera finds thermal leaks

ARCC, 2017. [Bicester NW EcoDevelopment](). Fact sheet and Master plan Final Report (2013).

RECOMMENDATIONS

Provide and promote future proof, healthy, and resilient buildings that adapt to and mitigate climate change, especially for extreme heat – at local, state & national levels

- ✔ **Assess climate vulnerability to extreme heat using future weather files, and design for full life cycle optimization and phasing. Use extreme, hot summer, or heat wave weather files if necessary.**

- ✔ **Upgrade passive cooling measures in retrofit and new construction programs, targeting heat vulnerable populations**
- ✔ **Future proof public buildings and schools; demonstration projects**
- ✔ **Update building standards and design guidelines now; tech assistance**

- ✔ **Educate, integrate, and train building, planning, & health professionals (Health in All Policies)**
- ✔ **Accelerate market demand through sustained financing, incentives, demonstrations, and marketing for future proof, resilient buildings**

THANK YOU FOR YOUR ATTENTION !

Thought For the Day:

BE PREPARED

for Extreme Heat

Contact Information

Tom Phillips, Healthy Building Research
tjp835@gmail.com

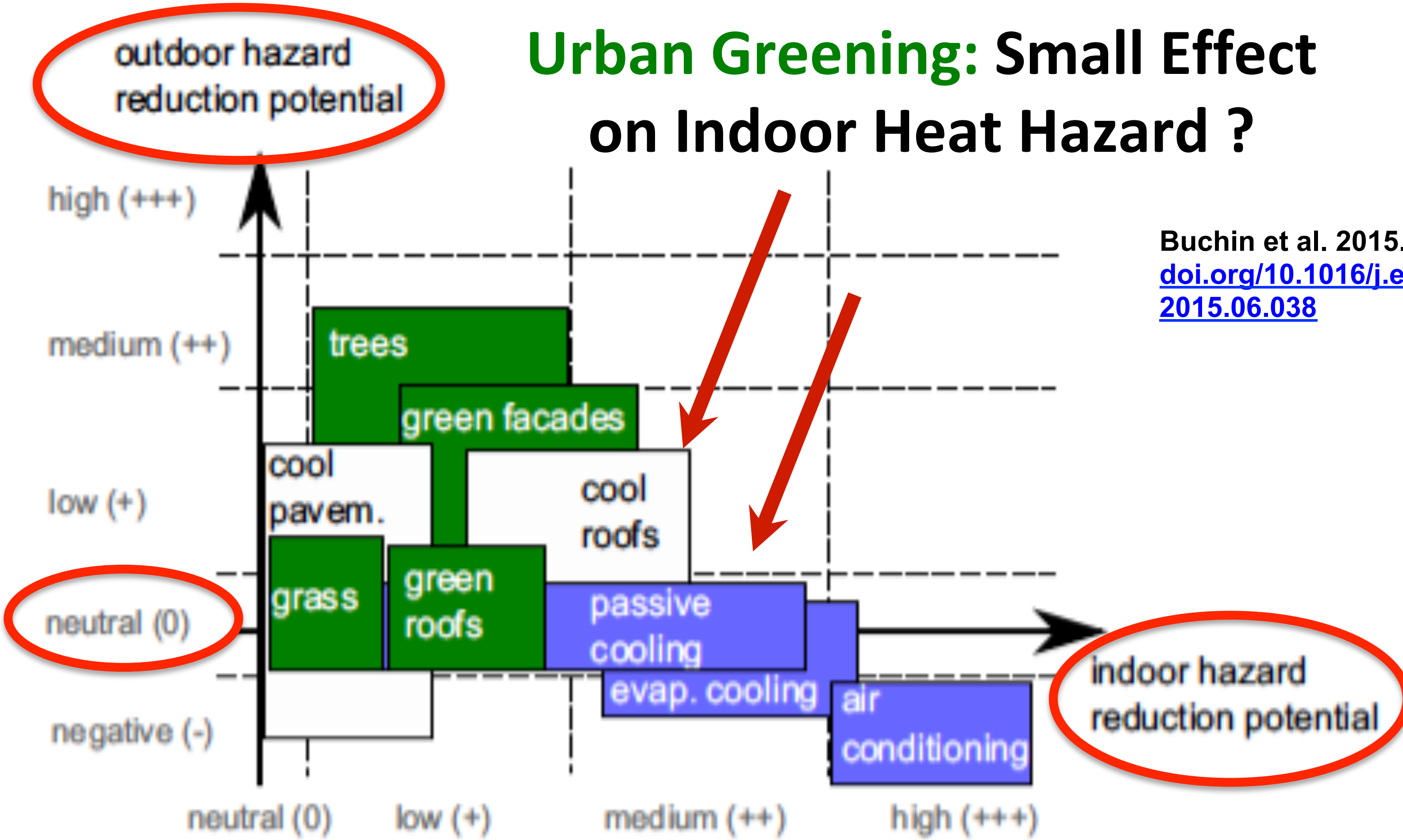
Music For the Day:

Mother Earth (Neil Young)

https://www.youtube.com/watch?v=t7hTATM4i_8
from the Honor the Treaties Tour: Don't trade away our children's days…

BONUS SLIDES

Urban Greening: Small Effect on Indoor Heat Hazard ?



Buchin et al. 2015. doi.org/10.1016/j.enbuild.2015.06.038

- Few studies have looked at the effectiveness of both indoor and outdoor heat mitigation.
- Berlin apartment study: urban greening is not necessarily effective in reducing indoor heat hazard
  - External shades were the most effective passive measure
  - Several building and neighborhood measures were needed to prevent overheating (including mechanical cooling)
  - Passive cooling measures did not have negative effects on outdoor heat and ozone hazard
- New U.S. indoor heat exposure studies: Stone, Mallen et al.., GA Tech.; Baniassadi et al., Harvard
- Maintenance and cost problems with urban forests (see NYSERDA Climate Equity study).

Denial + Delayed Effect → Emergency Response

=

Emergency Response AND Long-Term Solutions

- Cooling Centers, Misting Tents
- Fans, AC units
- Heat Wave Warnings
- Improved ambulance service
- Neighborhood Watch, Buddy Systems
- [Heat Health Checks](#) [1]
- Monitoring indoor heat [2]

1

Health checks during extreme heat events

A guide for doing in-person or remote health checks

Extreme heat events can lead to dangerous indoor temperatures in homes without functioning air conditioning. Health checks are used to assess how people at high risk of heat-related illness are doing during extreme events. In-person health-checks are best, but a remote health check is better than no health check.

This guide has five pages with important information for doing health checks during extreme heat events.

PAGE 1 Rapid risk assessment checklist

PAGE 2 Recognizing and responding to heat-related illness

PAGE 3 In-person health checks

PAGE 4 Remote health checks

PAGE 5 Measuring body and room temperature

Rapid risk assessment checklist

To assess whether someone is at risk, check all the personal factors that apply on the following list. The more boxes checked, the higher the potential risk.

☐	Older adult (60 years+)	The body's ability to cool itself is impaired as people age.
☐	Mental illness or cognitive impairment	Conditions such as schizophrenia, depression, anxiety, and dementia can reduce awareness of heat-related risks.
☐	Chronic disease	Chronic diseases such as diabetes, heart disease, respiratory disease, and cancer can limit the body's ability to cool.
☐	Living alone or socially isolated	People who live alone or do not have strong social connections are at higher risk because they have fewer people looking out for them.
☐	Substance dependency or use	The ability to sense and respond to heat can be affected by use of drugs or alcohol, especially for those who are dependent.
☐	Impaired or decreased mobility	People with impaired or reduced mobility might be less able to take protective measures during extreme heat events.
☐	Medication use	Some prescription medications for common conditions can cause dehydration and affect the body's ability to cool itself.
☐	Poor physical fitness	People who are not engaged in regular physical activity are less able to keep cool in the heat.

www.ncceh.ca

- Future-proof, climate-ready buildings and communities
- Passive survival, thermal resilience
- Cooling and carbon optimized buildings and communities
- Reliable, integrated, and resilient power systems
- Monitoring indoor heat
- Community support networks

[Passive Cooling, Mechanical Coolng, Low Carbon Materials. Clean Grid (Passive House Accelerator)](#)

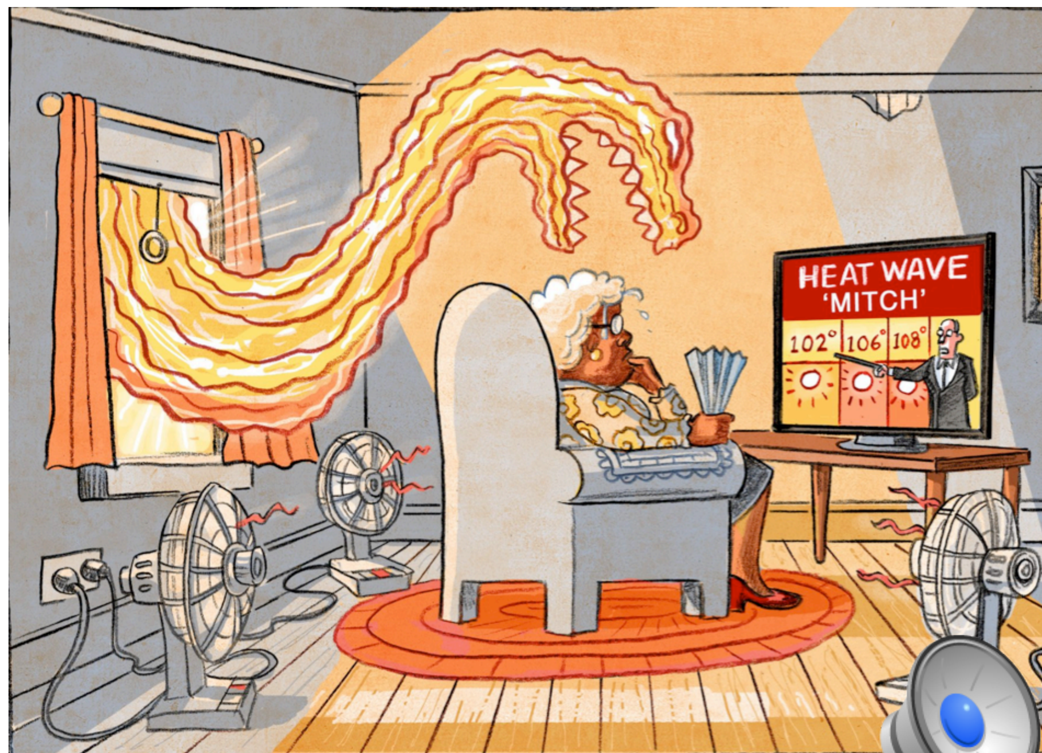
1. BC CDC, 2022.
2. S. Henderson, BC CDC. Aug. 2022.

How Should We Name a Heat Wave ?

- **Many cities and regions will do this (Seville the first)**
- **Many factors to consider**
- **Effectiveness is limited**

Name them after Big GHG Emitters and Greenwashers (France):
Total Energy
Exxon
Gazprom
CEOs of those companies
Banks financing fossil fuels

Total1, Exxon2, Gazprom3
: how should we rename heatwaves?
[Bon Pote, ,July 13, 2022.](#)



Peter Kuper / CartoonCollections.com

Efficiency-Resilience Nexus Project

U.S. Dept. of Energy, Bldg. & Technologies Office

- Developed and tested method to assess benefits of current and beyond-code design (Passive House)
- Joint probability of power outage with heat or cold wave
- New and existing homes in 6 climate zones & 1 assisted living facility
- Valuation of mortality, energy, property damage, and carbon emission benefits
- Reduced overheating hours, and increased Hours of Safety
- Benefit Cost Ratios, New Single Family, Beyond Code: 1.1 – 3.0 across 6 cities

Assisted Living Facility, Houston, TX 2021 Winter Storm

Resilience Metric	Published Data Pro-rated for Houston	Resilience-Efficiency Study for Houston
Excess deaths	249[1,2,3]	202
Excess deaths after implementation of beyond code measures		128
Population damages event[4]	$2.5 billion	$2.0 billion
Property damages (annualized)	$2.9 billion[5,6]	$0 (FEMA NRI)

Benefits of Beyond Code: $3.4 B

Franconi E. (PNNL), T. Hong (LBNL), and E. Wilson (NREL). 2022. "Enhancing Energy Resilience in Buildings: Development of a Standardized Methodology to Quantify Efficiency Benefits." PNNL-SA-177117. Online presentation to the U.S. DOE Building Technology Office. August 11, 2022.

zHome Village, Issaquah, WA (2011): Design Synergy

- PV solar array
- solar thermal heat
- 29,000 gallon cistern
- Sunshades
- HRV; Stack ventilation
- Low air leakage (0.2 ach)
- R35+ walls/R55+ roof – rockwool; R10 under slab
- condensing boiler central
- EV charging
- 100 year materials

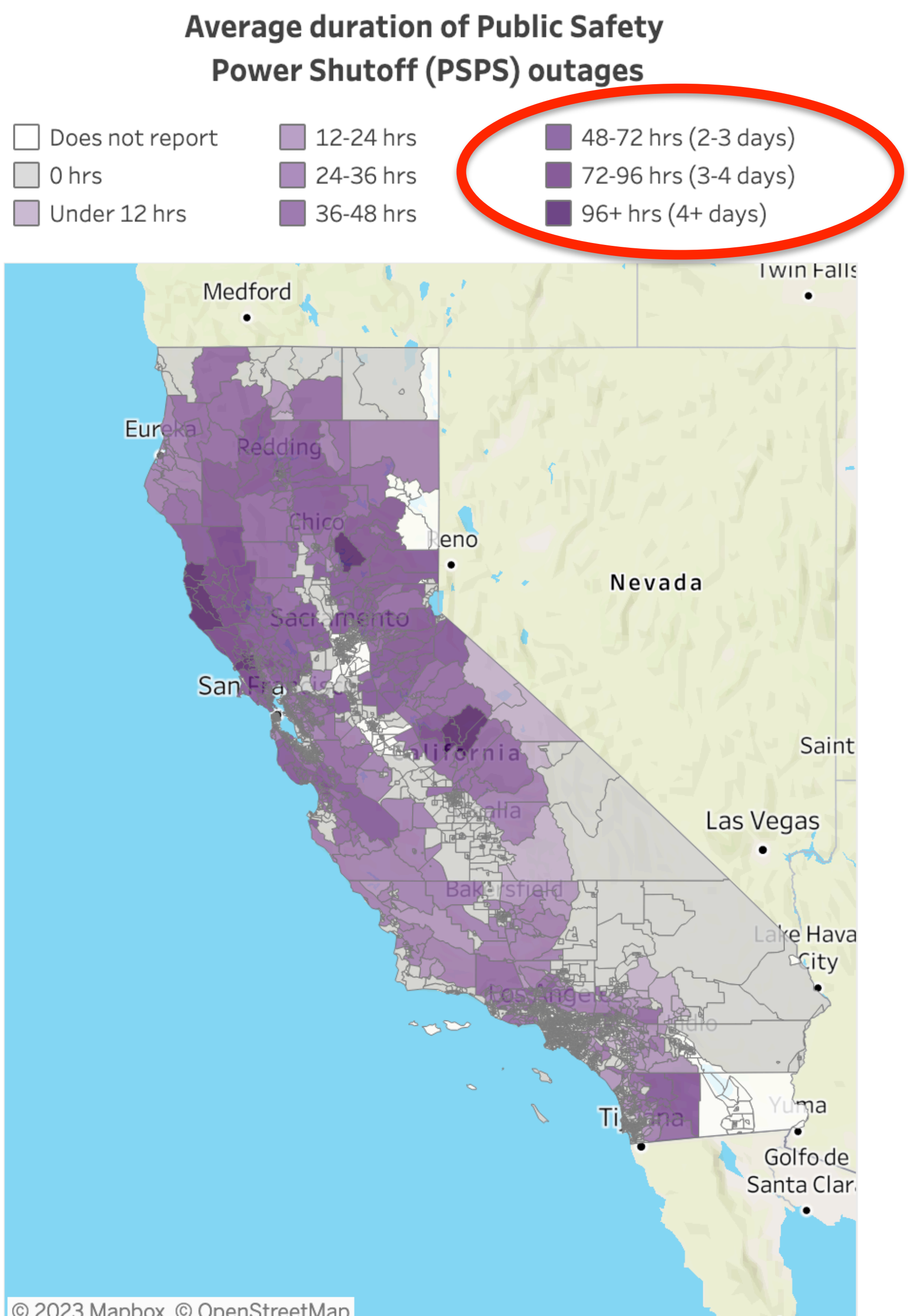
Net zero energy, zero carbon multifamily production homes

First in the U.S.

Affordable, healthy, comfortable

Source: zHome, Living Futures 2011 presentation. Case study. Phase 2, 2022.

CA Public Safety Power Shutoff: Interactive Map



Duration

Frequency

# of Households

Extreme Heat Days

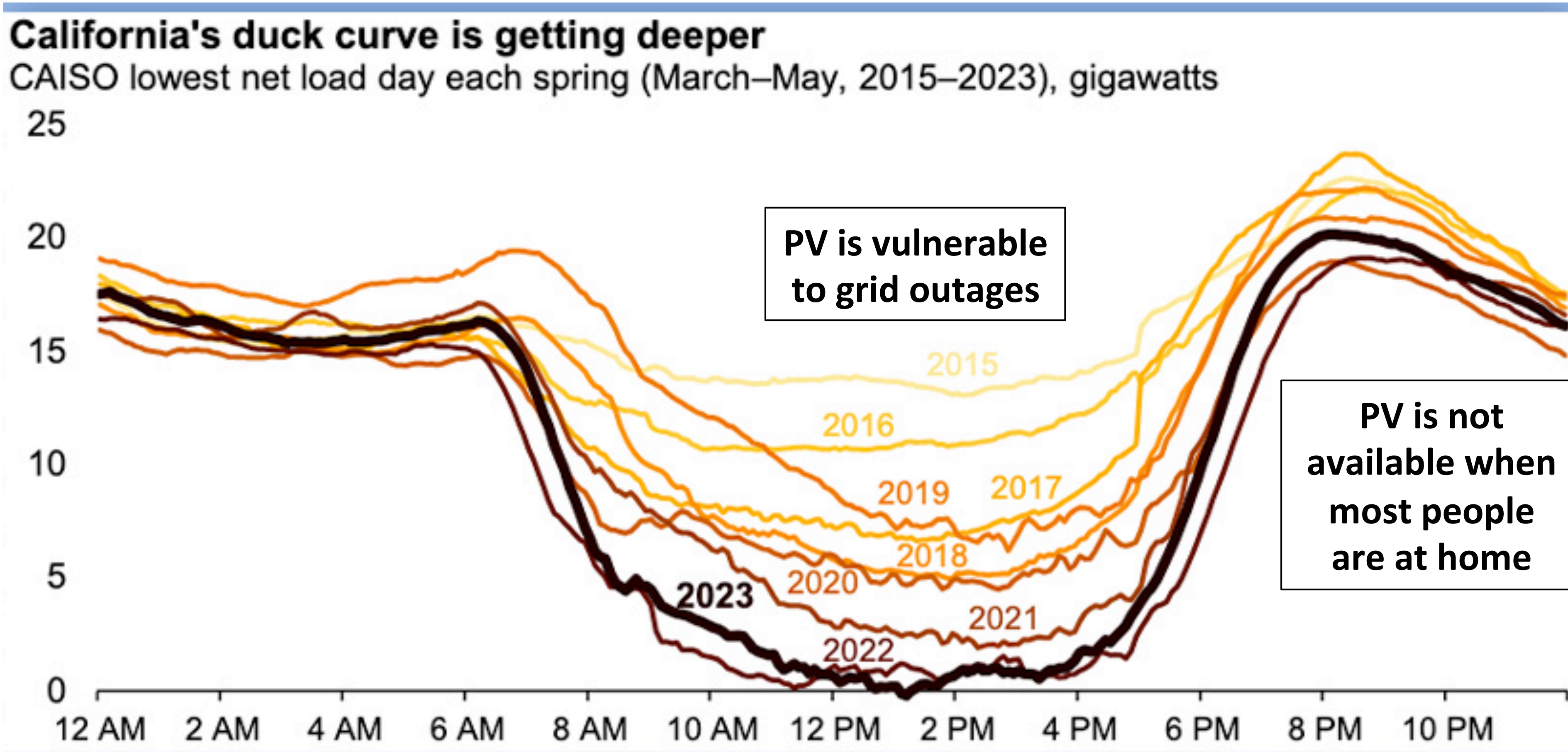
Poverty

Enviroscreen

Fire Threat

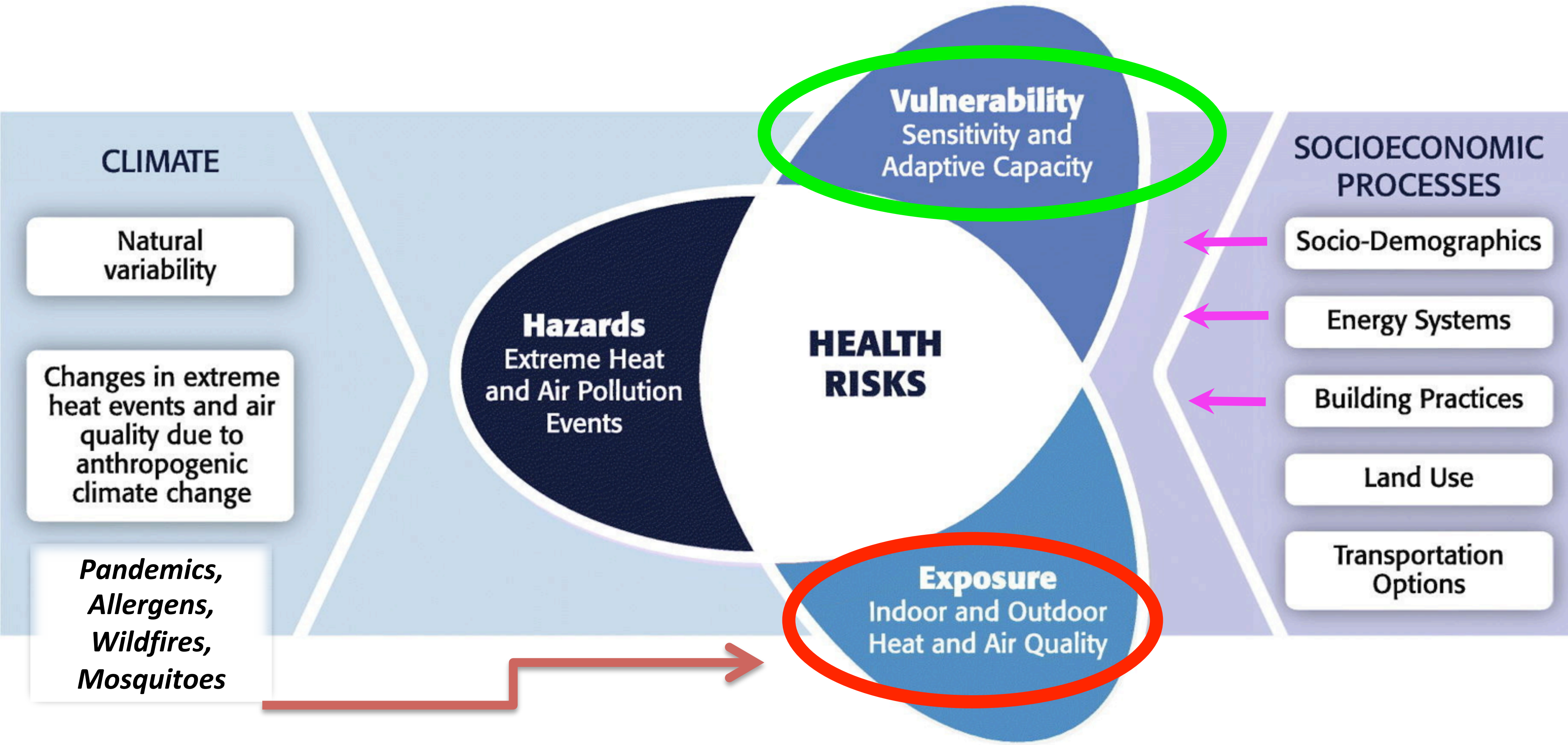
Accessed June 2023. Interactive Map, by census tract
https://www.psehealthyenergy.org/our-work/interactive-tools/california-public-safety-power-shutoff-interactive-map/#frequency

California Grid Load and Renewable Energy: Midday Load is Dropping; Night is Still High



NetZero Insider, 6/28/23, https://www.rtoinsider.com/48798-california-duck-curve-deepens/, from EIA data.

Conceptual framework for assessing population health risks to extreme heat and air pollution



Adapted from O'Lenick, et al. 2019. Urban heat and air pollution: A framework for integrating population vulnerability and indoor exposure in health risk analyses. https://doi.org/10.1016/j.scitotenv.2019.01.002.