Tang Prize Sustainable Development Project at Berkeley Lab: Cool Building Solutions to Adapt to Extreme-Heat Events in a Warming World

Final report to the Tang Prize Foundation

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Preface

The Berkeley Lab Heat Island Group would like to deeply thank the Tang Prize Foundation for supporting our work to address the challenges of extreme heat. Resources provided by the Foundation have let us form global collaborations and initiate major projects helping Berkeley Lab bring resilient cooling solutions to California, the United States, and the world.

We also thank the late Art Rosenfeld for sharing this research grant opportunity with us.

Overview

Extreme heat events were responsible for nearly 8,000 excess deaths in the U.S. from 1999 to 2009 and are expected to grow 5 to 10 times more frequent by the end of the 21st century as the climate warms. With support from the Tang Prize Foundation, the Berkeley Lab Heat Island Group collaborated with the broader urban heat island countermeasures community, building scientists, public health scientists, and policymakers to advance passive and low-energy building energy efficiency strategies that help individuals and cities adapt to extreme heat events. Our accomplishments from 2017 to 2022 include

- establishing an international collaborative of research and practitioners;
- launching three major projects sponsored by California or the United States; and
- planning a *Resilient Cooling for All* Research, Development, Demonstration, and Deployment (RD^3) Center at Berkeley Lab.

(1) Creating the *Cool Building Solutions for a Warming World* collaborative

To advance the adoption of passive and low-energy cooling measures, the Heat Island Group at Lawrence Berkeley National Laboratory (Berkeley Lab) convened the *Cool Building Solutions for a Warming World* (CBS) Collaborative.

Mission and goals

The group's mission is to identify, assess, develop, and share passive and low-energy building energy efficiency measures that help individuals and cities adapt to extreme heat.

Our collective goals are to

- Lower air and radiant temperatures in unconditioned or incompletely conditioned buildings, improving human health and comfort
- Decrease peak power demand from fully conditioned buildings, reducing grid strain and the likelihood of power failures on extremely hot days
- Locally improve outdoor comfort—e.g., by shading or otherwise cooling pedestrians

Therefore, we are focused on

- Human-scale effects (health, comfort, productivity)
- Passive building cooling measures, including vegetative and water-based solutions
- Low-energy building cooling measures
- Building-scale solutions that link indoor and outdoor spaces

Berkeley Lab founded the multi-disciplinary group in autumn 2018. The Collaborative currently has more than 110 research and practitioner members from 15 countries (Figure 1). Its diversity in disciplines, professions, regions, and sectors is key to advance its ambitious goals.

In-person workshop

Berkeley Lab hosted the Collaborative's first in-person workshop in Berkeley, California on 22 - 23 July 2019. It featured more than 35 international, national, and local participants from academia, government, industry, and non-profits (Figure 2). Members shared their research and implementation activities; finalized the Collaborative's mission, goals, and scope; identified its activities and structure; and discussed barriers and opportunities for promoting its goals.

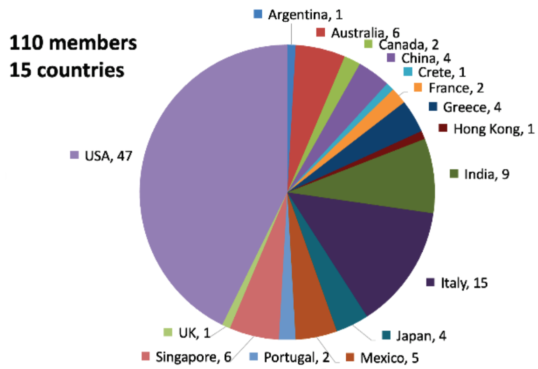


Figure 1. The Cool Building Solutions Collaborative (now larger) included 110 members from 15 counties when founded in 2018.

Figure 2. Over 35 participants attended the first in-person workshop of the Cool Building Solutions Collaborative (Berkeley, CA; 22-23 July 2019).

Workgroups

In 2020 we created workgroups to focus on (1) Solutions & Metrics/Methods; (2) Policy Development; and (3) Guidelines & Outreach.

Drs. Anna Laura Pisello, Claudia Fabiani, and Ilaria Pigliautile co-lead the Solutions & Metrics/Methods workgroup. Workgroup members collectively identified several key deliverables to collaboratively pursue. They are developing a 10-Question style review paper on cooling solutions and where they have been adopted; a textbook on cooling solutions, metrics, and methods; and an annual newsletter sharing new journal articles, relevant news, upcoming events, and research updates. The first newsletter was published in December 2021.

Drs. Komali Yenneti and Massimo Palme co-lead the Policy Development workgroup. The group developed a cool solutions policy tracker and established a “Tag & Talk” speaker series. The first Tag & Talk featured Umamaheshwaran Rajasekar (C-Cube and National Institute of Urban Affairs, India) and Tobias Massier (Energy and Power Systems Department, TUMCREATE Ltd., Singapore).

Dr. Gloria Pignatta and Naga Venkata Sai Kumar Manapragada co-lead the Guidelines & Outreach workgroup. Workgroup members prioritized several key activities to advance the group’s mission, including developing a database of guidelines, creating a map of Collaborative member capabilities and expertise, and establishing different pathways (e.g., webinars, websites) for CBS information dissemination.

Plenary meetings

In addition to the workgroup meetings, we organized several CBS Plenary meetings. These meetings, held one to three times per year, feature updates on the direction of the CBS; workgroup progress reports; surveys to gauge interests of CBS members; and lightning talks by CBS members on new research, programs, and projects. Speakers to date have included:

- Kurt Shickman, Extreme Heat Initiatives at the Adrienne Arsht-Rockefeller Foundation Resilience Center, USA
- Dr. Max Wei, Energy Technologies Area, Lawrence Berkeley National Laboratory
- Rajashree Kotharkar, Department of Architecture and Planning, Visvesvaraya National Institute of Technology, India
- Dr. Massimo Palme, Universidad Católica Del Norte, Centro de Investigación Tecnológica del Agua en el Desierto, Chile
- Alex Morrison & Matt Wolff, City of San Francisco, USA
- Guneet Kohli & Adam Jaffe, ARUP, USA & England

(2) Launching extreme-heat adaptation projects sponsored by California or United States

Leveraging staff-effort support from the Tang Prize Foundation and connections formed through Cool Buildings Solutions for a Warming World, the Heat Island Group collaborated with colleagues inside and outside Berkeley Lab to propose and launch three major extreme-heat adaption projects funded by California or the United States. Total California and U.S. support for these projects to date exceeds 2,500,000 USD.

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

Sponsor: California Strategic Growth Council
Funding: 1,000,000 USD
Period of performance: 2019 – 2022
Key publications: Sun et al. 2021 [1]; Zeng et al. 2022 [2]

Heat is increasingly brutal in California's Central Valley, where low incomes, poor air quality, old homes, and high utility bills disadvantage many residents. The good news is that we can act now on preventative strategies to mitigate heat health impacts. The multi-disciplinary Cal-THRIVES project has developed a cooling toolkit for local and state stakeholders below with the following objectives:

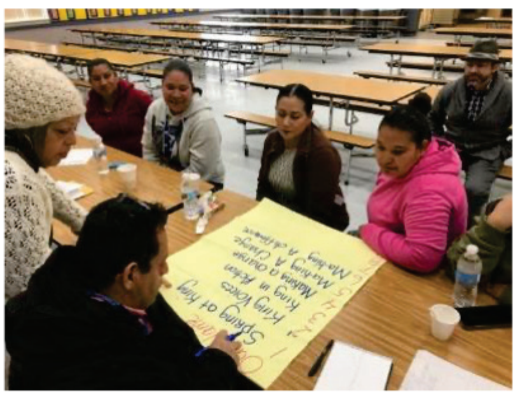
- Increase awareness of heat-related vulnerability
- Identify areas that are vulnerable to extreme heat events
- Remedy the built environment, such as building retrofits & increases to tree canopy
- Enhance community and home cooling programs
- Improve social capital and connectivity at the neighborhood level

Our research and heat-resilience recommendations incorporate both community inputs and science:

- Community engagement
- Cooling center characterization and improvements
- Neighborhood-scale building modeling
- Outdoor measure modeling

As illustrated in Figure 3, we have produced a Cooling Toolkit that includes

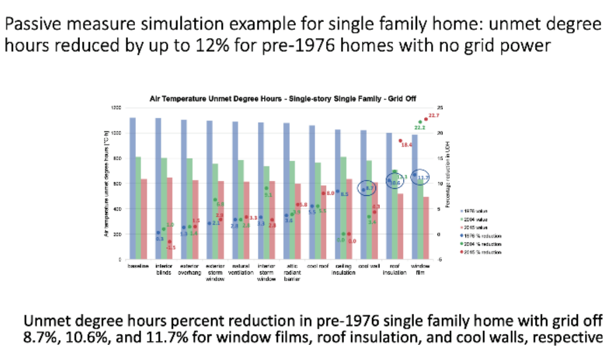
- Community cooling guides
- Fact sheets
- Modeling results
- Software tools
- Program and policy recommendations



(a)

(b)

(c)



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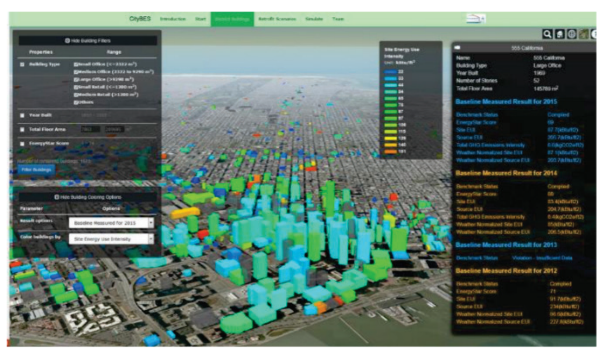

(e)

Figure 3. Cal-THRIVES activities and outputs include (a) community engagement in Fresno, California; (b) a cooling guide; (c) a cooling fact sheet; (d) modeling results; and (e) enhanced software tools.

International Energy Agency Annex 80: Resilient Cooling of Buildings

Sponsor: U.S. Department of Energy Building Technologies Office

Funding: 1,387,000 USD

Period of performance: 2019 – 2023

Key publications: Miller et al. 2021 [3]; Attia et al. 2021 [4]; Zhang et al. 2021 [5]; Levinson et al. 2023 [6]

The Berkeley Lab Heat Island Group leads the U.S. delegation to the International Energy Agency Energy in Buildings and Communities Program Annex 80: Resilient Cooling of Buildings. Quoting the Annex 80 website [7],

> The world is facing a rapid increase of air conditioning of buildings. This is driven by multiple factors, such as urbanisation and densification, climate change and elevated comfort expectations together with economic growth in hot and densely populated climate regions of the world. The trend towards cooling seems inexorable therefore it is mandatory to guide this development towards sustainable solutions.
>
> Against this background, it is the motivation of Annex 80 to develop, assess and communicate solutions of resilient cooling and overheating protection. Resilient Cooling is used to denote low energy and low carbon cooling solutions that strengthen the ability of individuals and our community as a whole to withstand, and also prevent, thermal and other impacts of changes in global and local climates. It encompasses the assessment and Research & Development of both active and passive cooling technologies of the following four groups:
>
> - Reduce externally induced heat gains to indoor environments;
> - Enhance personal comfort apart from cooling whole spaces;
> - Remove sensible heat from indoor environments;
> - Control latent heat (humidity) of indoor environments.
>
> The Annex 80's main objective is to support a rapid transition to an environment where resilient low energy and low carbon cooling systems are the mainstream and preferred solutions for cooling and overheating issues in buildings.

As illustrated in Figure 4, the U.S. team is collaborating with researchers from about 15 nations to

- define the concept of resilient cooling
- generate future weather files to simulate building performance over the next century, include that during future heat waves
- establish key performance indices for building energy use, thermal comfort, and thermal safety, with special attention to outcomes during heat waves and/or grid power failures
- qualitatively and quantitatively assess over a dozen passive or low-energy cooling strategies

- generate policy recommendations for resilient cooling
- create design guidelines and technology profiles for use by building practitioners

Within the U.S., it is also working with disadvantaged communities in Atlanta, Georgia (*existing* heat challenge) and Boston, Massachusetts (*emerging* heat challenge) to develop cooling toolkits modeled after those generated for Fresno, California in the Cal-THRIVES project.

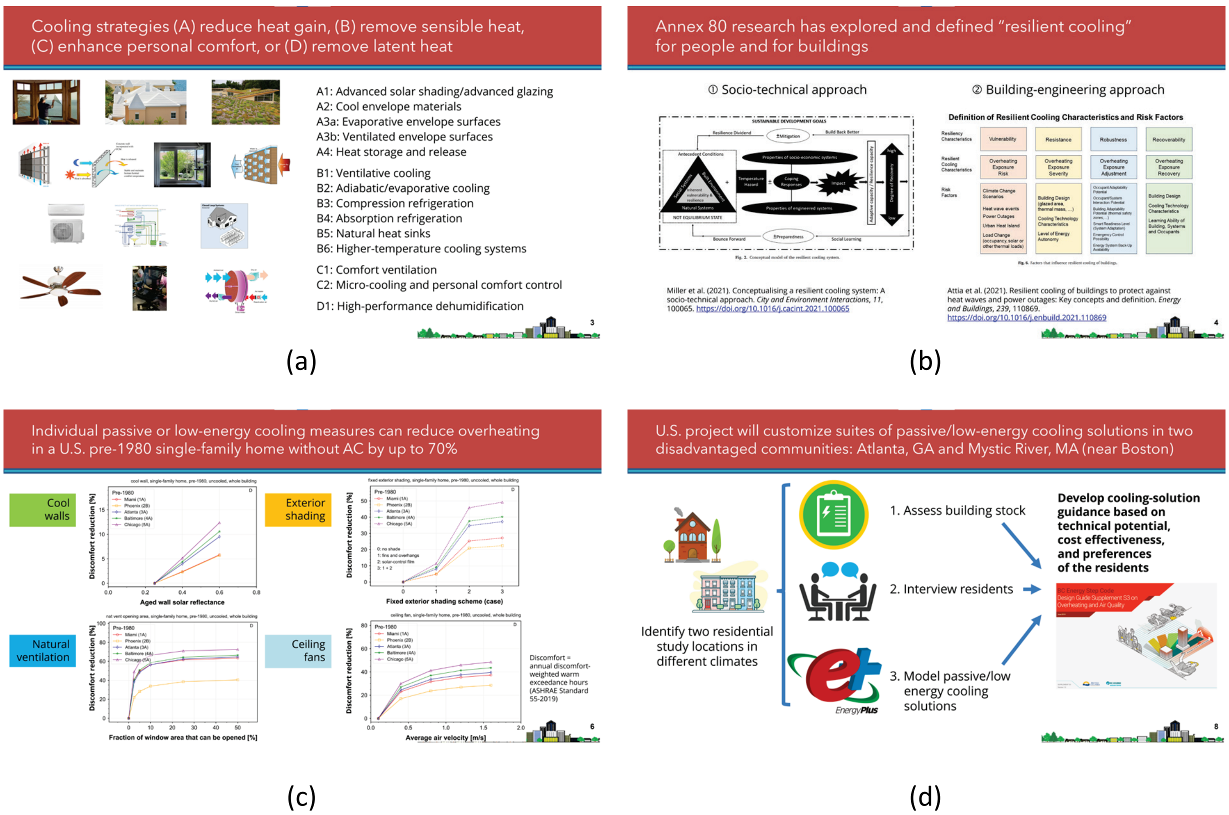

Figure 4. Annex 80 activities and outputs include (a) review of 14 passive or low-energy cooling strategies; (b) definition of the concept of resilient cooling; (c) detailed modeling of individual resilient cooling strategies across a wide range of climates; and (d) generating cooling guidance for disadvantaged communities in the United States.

Cool Surfaces Manhattan Project

Sponsor: U.S. Department of Energy Building Technologies Office
Funding: 250,000 USD (Phase 1)
Period of performance: 2022-2023
Key publications: Levinson et al. 2022 [8]

Solar-reflective building envelope surfaces, such as cool roofs and walls, can be especially helpful in disadvantaged communities that often have poorly insulated older homes, aging or absent air conditioning units, steep utility bills, polluted air, and high vulnerability and exposure to extreme heat. With support from the U.S. Department of Energy, our project seeks to dramatically increase the climate-appropriate deployment of cool surfaces across the United States with an emphasis on their application to disadvantaged communities.

Phase 1 of the project focused on development of the deployment plan. First, we sought to identify cool-surface deployment barriers, opportunities, and models by (a) reviewing the history of cool-surface deployment activities, (b) interviewing cool-surface stakeholders, (c) researching successful energy-efficiency/green building deployment models, and (d) interviewing the actors who have implemented these models. Second, we conducted a workshop to engage stakeholders in development of a deployment plan. Third, we asked several U.S. federal agencies (a) how cool surfaces and cool surface stakeholders could support their missions and (b) how agency activities could support cool-surface deployment. Fourth, we identified a set of transformative ideas that form the core of the deployment plan.

Transformative ideas include but are not limited to initiatives to (a) launch an educational campaign to make the general public and building professionals aware of how cool roofs and walls exclude unwanted solar heat; (b) create a "Cool Roof Prize" stimulating the development of affordable, high-performance cool asphalt roofing shingles; (c) conduct high-profile, large-scale demonstration programs that bring cool surfaces to disadvantaged hot-climate communities; and (d) support local, regional, and state climate action (heat mitigation) plans with cool surfaces. All 19 transformative ideas are listed in Figure 5.

If funded by U.S. DOE, Phase 2 of the project will implement the deployment plan.

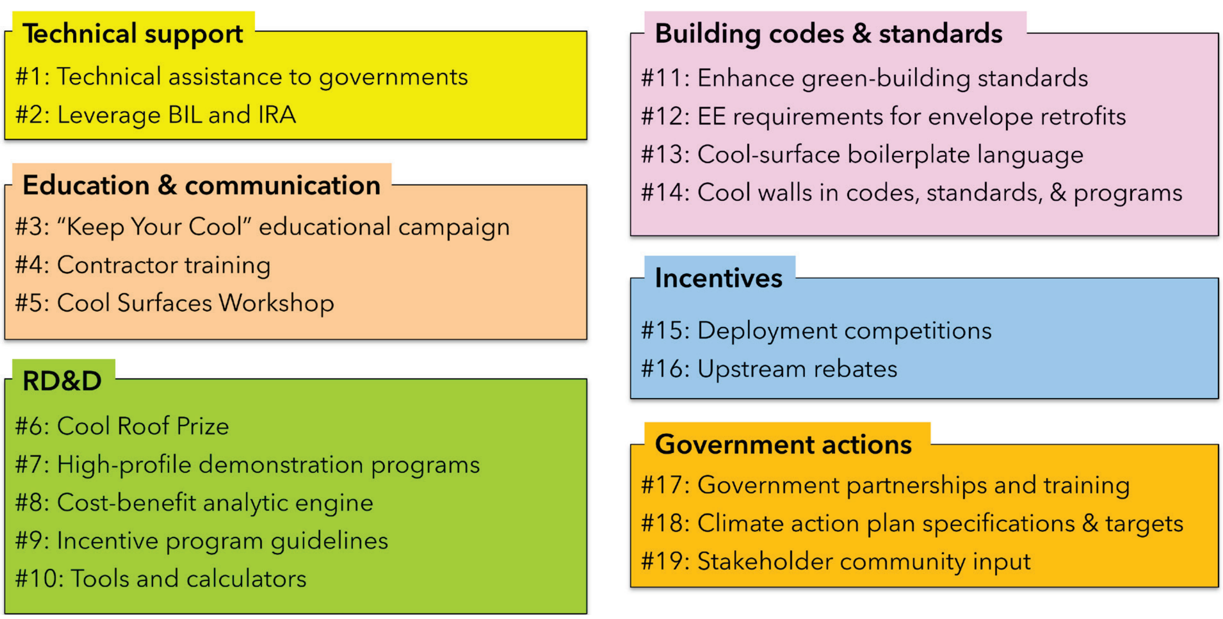

Figure 5. The plan created in the Cool Surfaces Manhattan Project proposes 19 transformative ideas to accelerate the climate-appropriate deployment of cool roofs and walls across the United States.

(3) Planning a *Resilient Cooling for All* Research, Development, Demonstration, and Deployment (RD³) Center

Over 30 leading U.S. experts in fields related to extreme heat and its mitigation gathered at Berkeley Lab's first Resilient Cooling Workshop (7 April 2022, Berkeley, CA) to unravel the societal and economical threats of climate-change driven overheating in the coming decades, and to map countermeasures. Their findings are summarized by Levinson et al. (2022) [9].

The resilient-cooling challenge requires multidisciplinary, multi-domain teams. However, existing research centers are narrow in scope and focus on specific areas such as policy or building technologies. We are in the process of planning a *Resilient Cooling for All* Research, Development, Demonstration, and Deployment (RD³) Center at Berkeley Lab. It will fill this gap by convening scientists, engineers, policy analysts, community-based organizations, and health professionals to collaborate on developing and implementing resilient cooling solutions, and serve as a global think tank to inform cooling policy development and implementation.

Tang Fund resources help support staff time dedicated to workshop execution and Center planning.

Figure 6. Website of the Berkeley Lab's first Resilient Cooling Workshop (7 April 2022).

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