# Healthy Urban Environments (HUE) Initiative

# Heat and Health Maps for Decision Making in Tempe

Above: Sun rising over the Superstition Mountains and Tempe, AZ on June 17, 2021 when the air temperature at Sky Harbor Airport set a new record of 118℉.
Photographer: Paul Coseo

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## Acknowledgements

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## Preface

*Healthy Urban Environments* (HUE) funded a ***practice-led***, ***place-based***, ***research-informed*** project within an ongoing city-university partnership between the City of Tempe and Arizona State University to tackle the challenge of using heat, health and equity relevant  information to make decisions for implementing equitable urban cooling. For our team, ***equitable urban cooling*** means to create the most cooling in those areas of the City that are experiencing the worst impacts of heat exposure and vulnerability. The roots of this city-university partnership to address extreme heat go back to 2015 (see figures 1 and 2).


Figure 1: Overview of the  ASU City-University Partnership forming an evolving applied research program focused on heat research that is expanding to include a variety of audiences starting with City staff, but expanding to community (youth) and real estate developers (Urban Land Institute or ULI).

From May 2020 to June 2021, 16 City staff and nine ASU technical experts (i.e. five researchers, two PhD students and three student workers) collaborated on these objectives:

- review and organize existing processes and raw data from 2017-2020;
- co-create new heat data with NASA DEVELOP students; and
- document and address hurdles to decision-making and implementation of equitable urban cooling
- establish a practice of heat planning and heat management

These objectives help implement the Climate Action Plan, specifically its priority area "Building Resilience to Extreme Heat" with the overarching goal of achieving equitable urban cooling.

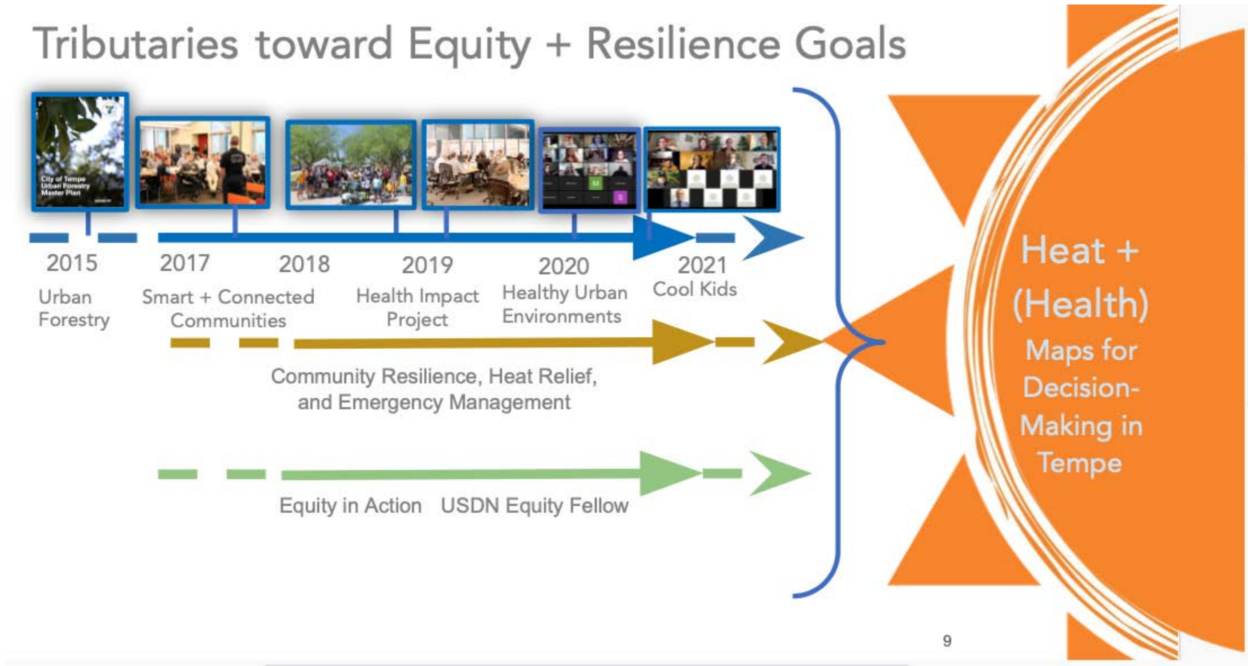



Figure 2: HUE work was combined with other streams of applied research focusing on city-wide approaches to (i) align equity values with city practices as well as (ii) emergency management with community engagement[1] in order to establish a city-wide practice of heat planning and heat management.

Below, we provide details on the number and types of interactions involved to achieve the project's goals. Offering these details allows for better planning and budgeting of future similar processes. City-university partnerships and associated processes often set forth ambitious goals of co-creation, yet fail to appropriately budget the time needed for building continuity, giving rise to familiarity and commitment.

From July-December 2020 (see Appendix A for a complete list), this City-University team met 28 times (all through Zoom due to COVID-19) composed of:

- 2 HUE 2019 and 2020 cohort convenings;
- 12 bi-weekly meetings to discuss decision-making using **city-wide macro data** for **placing** infrastructure;
- 8 bi-weekly meetings to discuss decision-making using **site-scale micro data** for **designing** infrastructure accounting for the site-specific urban and cultural context;

[1] Bhagavathula, S., Brundiers, K., Stauffacher, M., Kay, B. (2021). Fostering collaboration in city governments' sustainability, emergency management and resilience work through competency-based capacity building, *International Journal of Disaster Risk Reduction*;
Gilbertson, P., Brundiers, K., & B. Kay (2019). A Community Resilience Approach to Emergency Management. Report prepared for the City of Tempe, AZ, USA;
Vidaure, M., Brundiers, K., Eakin, H. (2021). Reviewing The Role of the Tempe Community Council (TCC) Within Participatory Budgeting; report prepared for and in collaboration with the City of Tempe; School of Sustainability, College of Global Futures, Arizona State University

- 1 HUE Resilience Workshop to review results generated so far and make plans for the second half of the project; and
- 5 internal meetings to prepare for the HUE resilience workshop.

From January to June 2021, we reconfigured our approach to work on educational and learning materials with a spring 2021 workshop. The spring workshop was split into two separate sessions to better accommodate City staff availability while offering the same content in both sessions (session IIa: March 26, 2021 and session IIb: April 21, 2021).

We present this information upfront to provide a better context for the amount of time and energy City staff and ASU participants contributed to the outcomes of this work including the continued growth of this work in 2021 and beyond. This type of co-production of applied research requires an adaptable team that is amble, creative, and invested in creating data for decision making that is scientifically credible, salient for city staff and legitimately produced (Cash et al. 2020). This combination of credibility, salience and legitimacy is both critical and urgent for the City staff that were part of this project. They want better data and information to plan for heat and air quality now, but also struggle inventing this new form of heat and air quality management practice.

This project implemented the findings of a previous co-production process developed in 2018 for a resilience to extreme heat and cold city-university partnerships to advance our knowledge of heat planning, management, and response in U.S. jurisdictions (Hamstead et al., 2020). A key aspect of the explicit process design are regular and focused meetings with City staff to exchange information, build trust, and find convergent narratives as the foundation of creating effective relationships and shared understandings of the challenges and opportunities. This work centers around listening sessions, where our team heard from diverse departmental perspectives in previous work with City staff. These listening sessions were to ensure that departmental priorities and values were integrated into content to make meetings: (1) relevant and meaningful to cross sector participants; (2) start with discussing overlaps in approaches; and (3) addressing key gaps in decision making. Applying the findings from Hamstead and colleagues (2020) in this HUE project proved valuable as this report demonstrates.

The aspiration of this project was to integrate heat data with health (air quality) and equity data. This aspiration was implemented whenever possible but not throughout the project. An example of good integration of all three data types is the NASA Develop Project, which will be presented below. An example where the project failed to integrate heat, health/air quality and equity data is in an expansive discussion of how air quality data should be integrated into decision making. Being cognizant of this limitation, we reflect on it in the section “Implications”.

# Introduction

**Why heat? Why from a health lens? and Why now?**

On March 2, 2018, at the start of the City of Tempe's work to better address resilience to extreme heat, the City Manager of Tempe challenged the city-university team by asking two questions: Why heat? Why now? Since that time, these questions have framed how our team approaches the work of creating a heat planning and management practice. In the HUE work, we expanded on these critical questions by asking: Why heat? Why looking at heat from a health lens? Why now?

**Why heat?** Heat is a silent killer. Severe heat illness kills more people in the US than the sum of natural hazards combined. The Center for Disease Control recorded 10,527 deaths resulting from exposure to heat (2004-2018). More than one third of these heat-related deaths occurred in only three states -- Arizona, California, and Texas. Together, these states only account for 23% of the US population. Heat-related deaths impact Black, Indigenous and People of Color the most. Non-Hispanic American Indian/Alaska Natives had the highest rate of heat-related deaths (0.6 per 100,000 population). Non-Hispanic blacks had the second highest rate (0.3 per 100,000 population) and second highest number of heat-related deaths (1,965). Non-Hispanic whites had the highest number of heat-related deaths (6,602). Additional highly vulnerable groups include the elderly and people experiencing homelessness. Overall two third (70%) of all heat-related deaths occurred in males (Vaidyanathan et al., 2020). Locally, figure 3 describes the continuing trends of black and indigenous communities being more vulnerable to heat mortality than other communities (MCDPH, 2021).

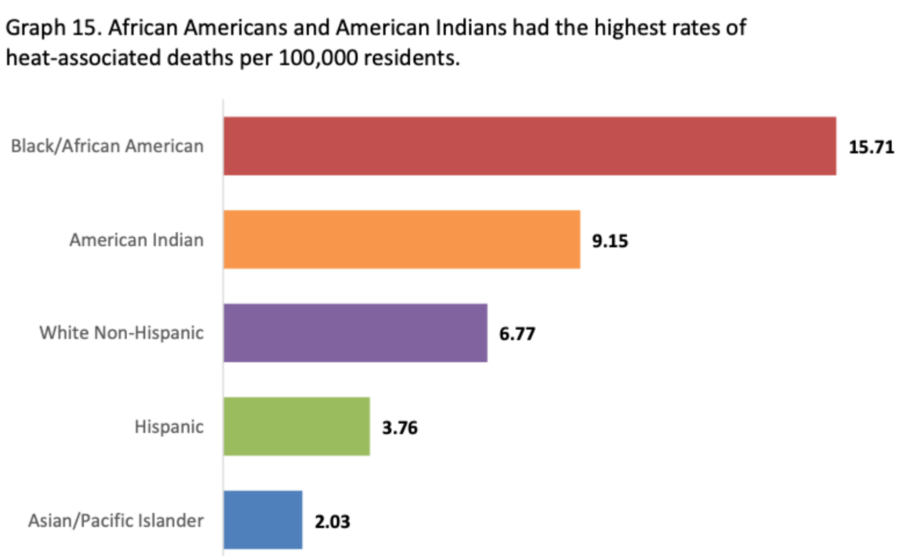



Figure 3: From the "Heat-Associated Deaths in Maricopa County, AZ Final Report for 2020", black and indigenous communities are impacted by heat more than other communities (MCDPH, 2021).

**Why from a health lens?** Exposure to excessive heat occurs indoors and outdoors and creates wide-ranging and cascading effects. Extreme heat impacts everyday life from raising from bed in a poorly air conditioned home/outside after a hot night, walking to an unshaded bus shelter along an unshaded sidewalk,  going to schools in an heat island or to an outdoor worksite, to coming home along the same route, finding a hot home and few shaded and cool recreation opportunities nearby. As extreme heat impacts everyday life its impacts reach from the individual level (cognitive abilities, mood, physical performance) to economic productivity and to community engagement and cohesion. Recent local research from Edison Eastlake by Guardaro and colleagues (2020), Dzyuban and colleagues (2019), and Crank and colleagues (2021) on vulnerability to heat and air pollution shows the importance of taking a whole person perspective to this work including both physiological and psychological dimensions of people using both objective and subjective measures.

The CDC numbers showed how death is inequitably distributed across race/ethinic groups; Similarly, daily heat experiences and exposures are inequitably distributed. These inequitable impacts are reflective of structural racism. The urban landscape with cooler and hotter neighborhoods are one of its clearest examples, showing the long-term effects of racist redlining planning practices implemented in US cities since the 1930s (Hoffman, Shandas, & Pendleton, 2020) and detailed for Arizona. Both exposure to extreme heat as well as heat vulnerability are human-made and are thus preventable, if the criticality of mitigation measures were recognized.

**Why now?** The report "Killer Heat" by the Union of Concerned Scientists makes clear that the "United States is facing a potentially staggering expansion of dangerous heat over the coming decades." The intensity of this expanding heat danger depends heavily on how quickly society acts now. The report presents a stark choice: We can continue the current path, where emission reductions fail targets and extreme heat soars. The alternative is to take bold action now, doubling down on emission reductions in order to prevent the worst from becoming reality (Dahl et al., 2019).

While locally, heat has not yet been recognized as a critical hazard by the disaster management community and impactful heat mitigation actions have been missing until recently in hazard mitigation plans (Gilbertson et al., 2019), the last summer provided experiences of what lays ahead: complex and compounded emergencies and their cascading impacts. The summer of 2020 was an urgent reminder of compounding emergencies involving extreme heat, the COVID-19 pandemic, anti-racism protests demanding social justice, and a train derailment. Every incident affects people differently, amplifying the existing racial and social inequities as well as disparities. Addressing these compound incidences demands promoting organizational cultures that encourage cross-disciplinary and multi-stakeholder planning, involving cross-organizational collaboration, and most importantly, working with communities who hold the lived experience (Kruczkiewicz et al. 2021).

Against this background, the **overall goal** of this project was to support equitable urban cooling in the city; equitable urban cooling means to create the most cooling in those areas of the City that are experiencing the worst impacts of heat exposure and vulnerability

**Approach to achieve this goal**

1. To establish a **city-wide practice** of heat planning and heat management
2. To provide **desktop ready data** on heat, health, and equity data to inform decisions on investing in infrastructure. Desktop ready means datasets that are easily accessible and provide understandable, reliable and usable information. The datasets and metadata account for the city's context and thus can be consistently used by any department. As such, the datasets reinforce confidence in city staff users, enabling them to explain and defend this data to other City officials, organizations, and community members.
3. To **translate** the desktop ready data into usable and learnable decision tools that align with City staff needs and the City's [strategic priorities] as well as equity goals and associated values including accountability, diversity, collaboration, accessibility, service, inclusion, empathy, liberation, and transparency.
4. To provide data on three levels relevant for infrastructure planning, explaining how data across these levels integrate with each other. The three levels are: **city-scale to inform placing** these infrastructures, on **touch-scale to inform designing** these infrastructures and on the **neighborhood-scale to connect** these infrastructures to each other using cool places and cool corridors
5. To provide **approaches for integrating data** on heat, health and equity and use this integrated data to make decisions for developing and implementing plans.

This approach was implemented through a **collaborative process** in order to reinforce and advance city-university action-oriented research-to-practice relationships and agendas that aim to more effectively create more relevant heat and air quality knowledge for the practice of equitable urban cooling.

In discussing the goals and objectives of this project with city staff, they identified three sets of hurdles for building City infrastructure for equitable urban cooling pertaining to process, literacy, and data:

- **Process**
    - **Hurdle 1a - Stakeholder coordination**: Need coordination across city

departments and with external stakeholders including residents and developers. City staff mentioned as one example the diverse public opinions around trees ranging from people wanting trees to residents not wanting trees.  This example demonstrates the need for tailored explanations to the specific questions that the public and decision makers are asking.

  - **Hurdle 1b - Regulatory constraints & budgetary constraints** that make it difficult to connect city-wide data with touch-and site-specific data; city staff mentioned the following constraints: utility locations, budgets and costs, accessibility/ADA, archaeology impacts; space constraints in the right-of-way, constraints to planting strips - while they are great locations for planting trees, busses and large trucks often impact the city's ability to plant trees in the planting strips.
- **Literacy**
  - **Hurdle 2 - deficits in practitioner and lay knowledge:** City staff shared how they encountered deficits in practitioner and lay knowledge about urban climate science, health, and equity components of the hazards. This lack of knowledge impacts how fluent practitioners are at applying the most current urban climate and public health knowledge to change the built environment. Practitioners may not understand the differences between objective  (e.g. surface, air, and MRT) and subjective (e.g. thermal comfort/discomfort, thermal sensation, heat stress) measures. Some measures are more appropriate than others for specific applications (e.g. City scale versus touch scale). Thus, the hurdle is a lack of learning and educational materials to build basic literacy around heat and air quality.
- **Data**
  - **Hurdle 3a - Comparable decision-making benchmarks**: How to measure the results from different infrastructure options in order to compare and prioritize them?
  - **Hurdle 3b - Data integration**: How to organize the newly created heat and health data so that city staff can layer this data with the existing GIS and socio-economic data that the city is already using in order to manage related performance measures (i.e. ADA, shade canopy, 20 minute city, Vision Zero bike/ped crash data). Overarchingly, the city staff aims to create overlapping maps of various hazard types and integrate multiple types of data and information into resource deployment and decision-making.

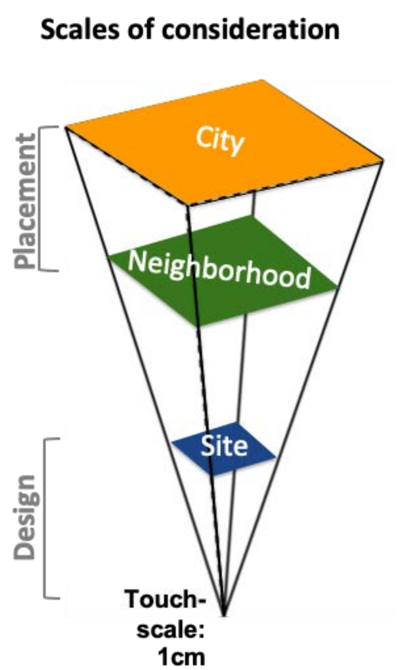
Exploring how to address these hurdles in further meetings, city staff and researchers identified an approach to each hurdle:

1. **Process hurdle: Establishing a practice** of heat planning and management for equitable urban cooling by and for practitioners including stakeholder coordination and better documenting existing regulatory and budgetary constraints. This practice employs heat and health data not as a single decision-point or as an element written in a city plan, but as a mindset, language, and culture of safety that accounts for heat, air quality, and health data in city staff's everyday practices.
   **HUE Project deliverable that helps address this process hurdle**: Documentation in this report of our co-creative city-university and city-community processes and relationship building.
2. **Literacy hurdle**: Shared understanding that an effective **implementation** of this emerging people-centered practice focused on building equitable urban cooling will require a larger shared understanding of heat as an experiential hazard. To facilitate city staff's interpretation, communication, and application of heat and health data, we co-created communication materials that ground this data in the lived experiences of residents in the City of Tempe.
   **HUE Project deliverable that helps address this literacy hurdle**: Educational videos that describe where in the city it is hot, for whom, and why and explain how placing and designing infrastructure contributes to equitable urban cooling. The videos in the final editing stages with and will be hosted on the EngageHUE.org website by August 2021.
3. **Data hurdle**: Establishing a learning exchange, making data **needs translated** from practitioner to researcher with reciprocal **data translation** from researcher to practitioner for more seamless desktop ready use of data to inform urban cooling.
   **HUE Project deliverable that helps address this data hurdle**: Practitioner informed videos and library of databases with datasets from touch-to-city-scale; the videos explain what data is entailed in each database, how to employ this data to improve equitable urban cooling, and who maintains/owns this data.

## Approaches to address hurdles

In 2020 alone, we had 28 meetings (see Appendix A for table) to work with City staff on a Tempe practice for heat planning and heat management. Workshops in fall 2020 (December 9, 2020) and spring 2021 (March 26 and April 21) were used to socialize hurdles, review available data and new datasets, and facilitate more targeted discussion on ways to address the hurdles through the available data resources.

*Our HUE organization for City-university partnership engagements:* To address the hurdles in the most effective ways, we organized our project teams by way of where and how people work when planning infrastructure developments in the city. Some city staff's daily planning practice is more focused on the city-wide scale as they plan where to place infrastructures, while others' daily practice is more focused on how to design infrastructures within the site-specific context. This scale-sensitivity was also reflected in the researchers' approaches - with some researchers studying heat on the city-wide scale and others on the touch-scale. We thus formed smaller city-researcher teams that met regularly to discuss questions pertinent to their focus/scale and organized large group meetings to exchange information across scales and explore how to integrate practices across departments and scales of infrastructure placements and designs that support equitable urban cooling (see figures 4 and 5).




| Placement Team | Design Team |
| --- | --- |
| *City Staff +* | *City Staff +* |
| *ASU Researcher* | *ASU Researchers* |
| City Engineer | Parks (playgrounds) |
| Emergency Management | Recreation Centers |
| Equity & Inclusion | Transportation |
| GIS | Urban Forestry |
| Parks & Recreation | Community Dev |
| Stormwater | |
| Strategic Mgmt | |
| Streets ROW | |
| Transportation Planning | |
| Urban Forest | |

Figure 4: Our HUE organization for City-university partnership engagements: Organizing project teams to reflect city staff and researchers's focus of daily practices

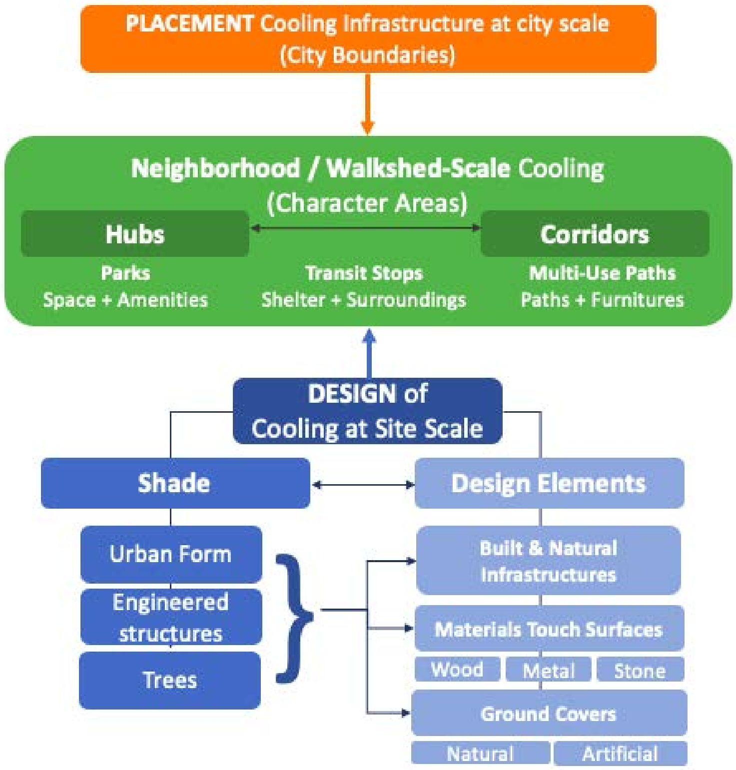



Figure 5: Joint meetings, where the placement-teams and design-teams worked together, helped to integrate heat and health data on the level of the neighborhood.

The immediate goal of integrating data was to create cool places (parks) that are linked with each other through cool corridors (multi-use paths, transit stops).

The overarching goal was to inform a shared understanding and vision of the thermal wellbeing as concept for Tempe.

## Approaches to address the Process hurdles

This HUE grant provided a replicable cross-departmental process that is integrated with researchers (that collected those data) to revisit and synthesize existing data (e.g., HUE projects, Health Impact Project, as well as data generated by other ASU heat researchers). This allowed us to address hurdle 1a (stakeholder coordination), where city staff identified the need to have coordination and tailored information to make better decisions and get buy-in. A key part of this work was establishing a process to understand and use people-centered data. Examples include data and information collected through participatory action research instruments including community engagements events and heatwalks (figure 5) that explored community climate action planning (figure 6). Presenting this data allowed a discussion on the following questions:

- how does this data fit together to support infrastructure decisions for equitable urban cooling?
- what data gaps remain? and
- where does City staff want to take this work into the future?

Key insights from these discussions included grounding the collaboration in current, real world examples such as planning for bus shelters or the upcoming improvements to parks and multi-use paths. Trying to ground the collaboration in how the data fit together to improve decisions, what gaps remained, and where City staff want this practice to go made it much more tangible to “see” where this practice might be going. A key limitation of the HUE work, related to process and hurdle 1b, was that we were unable to do more than identify the hurdle and acknowledge that longer term action-research needs to be conducted to better address practitioners needs related to regulation and budget constraints. Complementary GIS data for above and below ground utility locations, lighting, and other non-heat or health data may help understand these barriers to cooling opportunities and constraints earlier in the planning process. In addition, as part of this work, we had conversations about the importance of reframing infrastructure language (Appendix B) to include a variety of non-grey infrastructure for connecting with more federal funding related to 2021 infrastructure legislation to support more equitable urban cooling.

Figure 6: Urban Heat Walk at Kiwanis Park to explore and record how community members experience heat when walking around various locations in the city, including parks.
Data from the Heat Walk was integrated into HUE decision-making and educational materials. For instance we are in the process of developing a graphic to show the scales of urban climate from the touch-site scale of the heat walk and how that relates to decision making at larger scales (see figure 6).
Photograph credit: Mary Wright

Figure 7: Community engagement event to explore how community members approach and inform Climate Action Planning. Data gathered at the community engagement event around Climate Action Planning event was integrated into HUE decision-making, educational materials, and concurrently funded projects. For instance the HUE partnership helped synthesize this previous community engagement work as the  foundations of our Cool Kids project. These priorities that emerged from these meetings include:

- Climate urgency
- Collective ownership + identity
- Amplifying action
- Social cohesion + connectivity
- People-centered + frontline communities.

Photograph Credit: City of Tempe.

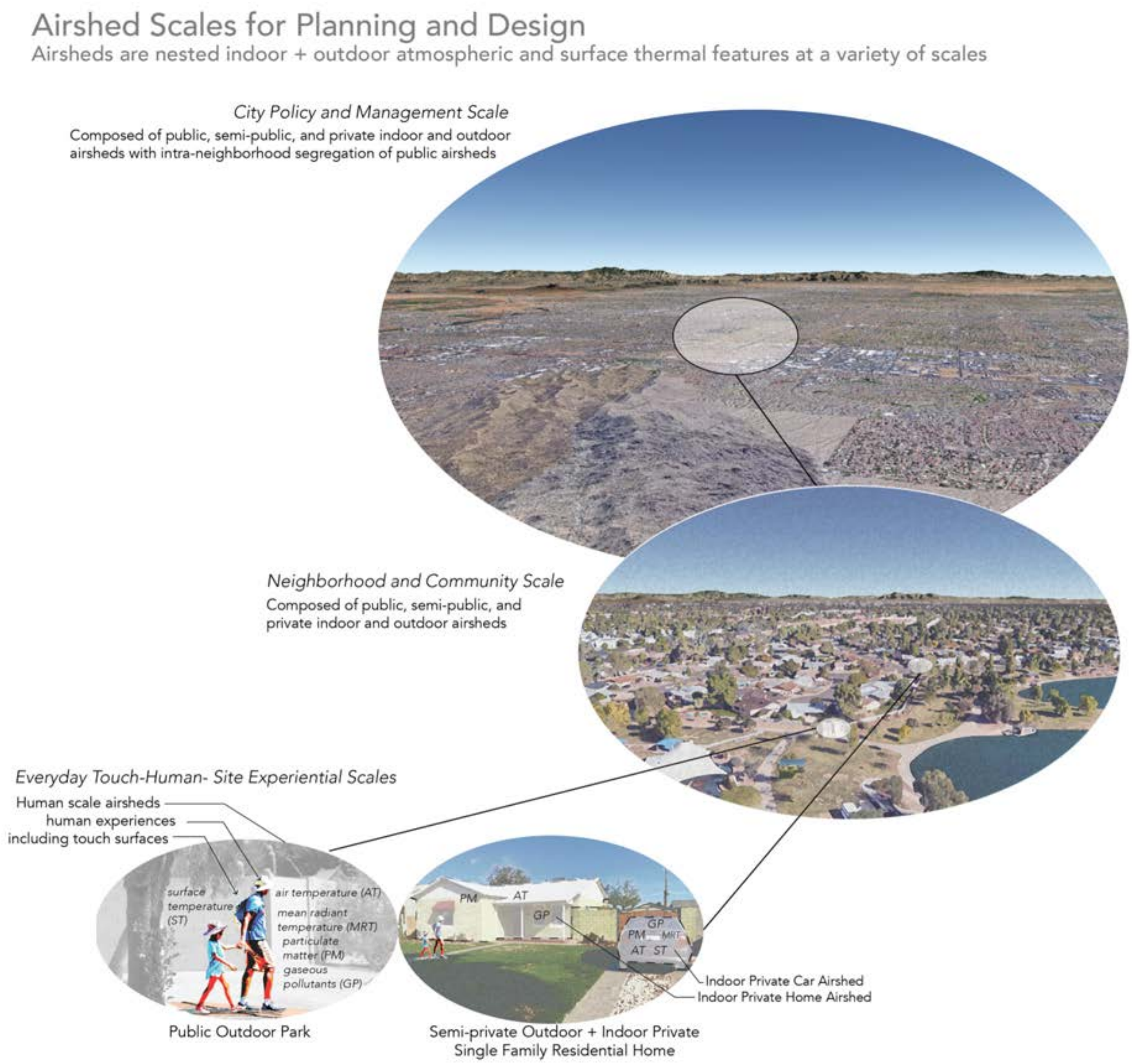



Figure 8: This illustration was made to describe what we call "airsheds" based photographs from the heat walk of September 19, 2019 of two heat walkers (photo by Mary Wright). In the future, we can add data to these illustrations to better explain the thermal and atmospheric environment. For now we envision airsheds akin to watersheds, but for our atmosphere instead of our hydrological systems. Airsheds are heavily influenced by the built environment for both heat and air quality. The images depict the three scales of airsheds in Tempe for planning, design, and engineering. Our experience with atmospheric conditions including surface temperatures, air temperatures, radiation, gaseous pollutants, and particulate matter is mediated by our ability to adapt our atmosphere directly around our human bodies or airshed. Through a combination of public and private shelters, technology (e.g. HVAC, cars, bus, trains), and greening we can moderate our airsheds through artificial or natural processes. Differences in affluence allow some people to use semi-private or private airsheds to protect them and their families from public airshed heat and air pollution hazards, while others are more reliant on public indoor (e.g. public housing, public transit, public cooling centers) or outdoor airsheds (e.g parks, streetscapes, schools, and other public spaces). As we move from the touch-human-site scale we become part of a

neighborhood community airshed with diverse experiences in public, semi-public, and private airsheds. At the city level, research shows that some neighborhood community airsheds are more degraded (hot with poor air quality) than other neighborhood airsheds (Harlan et al., 2006), which require City level policy and management to reduce inequitable atmospheric hazards.

A second approach to address process hurdles was to create a shared understanding among city staff and researchers of the sequence of decisions that are involved with *placing* infrastructure on the city-scale and *designing* it context-specifically on the site-scale. This awareness allowed us to jointly explore where in this sequence best to insert the new heat and health data in order to maximize the actual cooling effect for people experiencing heat (see figure 9). Both teams had their participating departments map out their decision making sequence for built projects, while the researchers focused on listening, as they were unfamiliar with this existing practice. Understanding the planning sequence helped researchers to contextualize and translate their data to make it usable for this decision process.

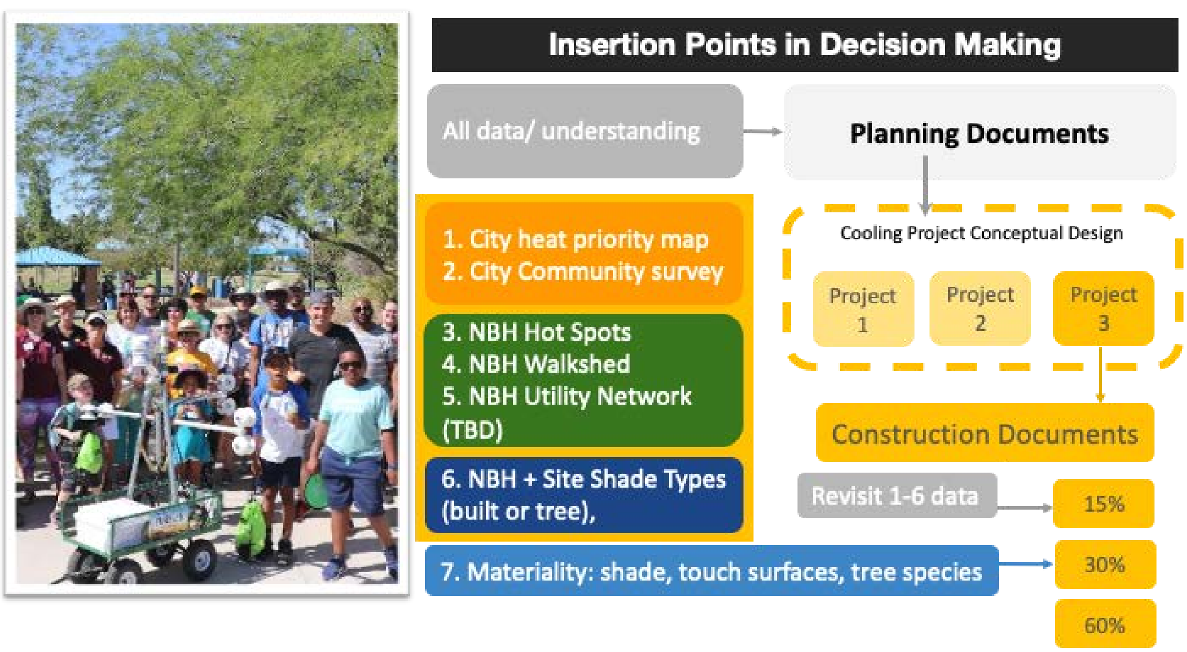



Figure 9 represents the phases of a pedestrian-oriented transportation planning design project including the key phases including:

1. foundational planning document requirements or guidance,
2. conceptual design, and
3. construction documents at 15%, 30%, and 60% complete for the bidding and implementation of infrastructure projects.

Photograph Credit: Mary Wright

The key take-away from this process is obvious: heat and health data need to be inserted as early as possible in the planning process and defended with reliable data through to when planning documents are approved by City Council. City staff told us they need the political backing of policy makers through approved documents to ensure cooling items are not “value engineered” out of the project. “Value engineering” is a design term for reducing costs through eliminating “unrequired”, “unnecessary”, or “undefendable” items in the design. We heard that this strategy of “value engineering” often reduces the cooling impact of projects as project cooling elements (e.g. trees, shade structures, and water fountains) are downscaled or removed with each phase to reduce costs and address perceived constraints to the bare minimum of what’s required. While this is not necessarily a breakthrough insight, the breakthrough insight was generated through the discussion of how to best negotiate with policy makers and better equip consultants, contractors and stakeholders with the knowledge, data, information, and resources they need in order to integrate for those elements that will facilitate equitable urban cooling. In particular, City staff suggested that planning, design, and engineering consultants need a **City requirement checklist or similar explicit protocols** for what the City expects for existing and proposed heat assessments including guidance on performance metrics (such as in figure 9) to use so they are better equipped to reinforce and maintain a high level of skill and effectiveness in taking equitable urban cooling from a planning concept to a built reality.

*Textbox 1: Other City, academic and practitioner engagements:*
In addition to the city-university engagements, over the past year, our team’s process was to participate with outside groups in several invited presentations and conferences to share the work and further discussions for avenues of improvement. We have indicated if there is a video recording of the presentation after each citation. These venues include:

- Kay, B. & Coseo, P. (July 28, 2020). Placing + Designing Cooler Pedestrian Infrastructure in Tempe. Presentation to the Association of Pedestrian and Bicycle Professionals (APBP) Arizona Chapter. Online through Zoom. Recording available.
- Kay, B., Brundiers, K., & Coseo, P. (December 14, 2020). Heat + Health Maps for Decision Making Maps in Tempe. Presentation to City Council of Tempe. Online through Microsoft Teams. Recording available.
- Kay, B., Brundiers, K., & Coseo, P. (January 21, 2021). Heat + Health Maps for Decision Making Maps in Tempe. Presentation to City Council of Tempe. Online through Microsoft Teams. Recording available.
- Coseo, P., Kay, B., Brundiers, K., Middel, A., Vanos, J., Hondula, D., & Logan, G. (March 19, 2021). Heat & Health Maps for Decision-Making: Climate Action for Resilience to Extreme Heat in Tempe, Arizona. Council for Educators in Landscape Architecture. Online Conference. Recording available.

## Approaches to address the Literacy Hurdle

We define heat literacy as increasing people's knowledge on heat and health to a level that people can apply that knowledge to plan, design, and advocate for equitable urban cooling in their neighborhoods, city, and region. We are detailing here two pathways where HUE products help advance heat literacy. As of June 30, 2021, these products are still in development with most having substantial drafts. We've indicated below products that are "complete" and ones that are "in-progress".

First, the HUE project work contributes data, information, and graphic content for another project, the Cool Kids project. The Cool Kids project develops a series of modules to raise participants' knowledge of systemic injustices as they relate to heat inequity (e.g. colonization, segregation, and trauma). One of the modules is on "Heat Equity and the Promise of a Collective Movement for Urban Cooling" (In-Progress, with an August 2021 expected completion). A core element are three short videos that present the persisting impacts of colonization, segregation, and infrastructure decisions that cause and reinforce urban heat inequities. The video and associated reflection questions and facilitated discussions, heightened awareness around how racism is embodied in our built infrastructure as well as in planning documents. It also provides specific information on how heat and health data can inform action to support equitable urban cooling. An example of this is a segment in the video presenting data showing the experience of heat from the touch scale to the site-scale and neighborhood-scale in two very thermally different neighborhoods. There is downtown Tempe with heavy investments of trees, shade and cooling infrastructure and Victory Acres with limited investments in cooling infrastructure.

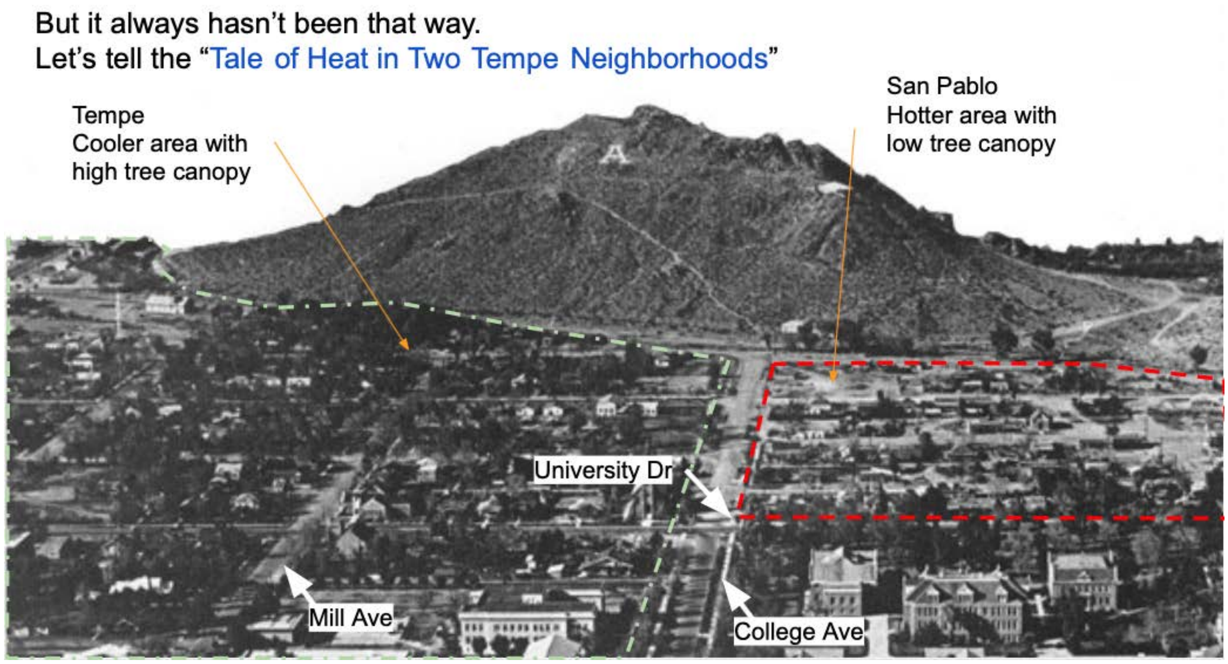



Figure 10: Historic image of Hayden's Butte looking north in the 1930s showing white Tempe, west of College Avenue, with San Pablo the Mexican-Amercian barrio, east of College Avenue. Notice the difference in tree canopy, which urban climatologists have shown would result in the low tree canopy barrio being hotter than the white areas with more shade trees near Hayden's Butte. This image helps set the framing for the module's learning objectives related to systemic roots of heat inequity.

Second, we created an EngageHUE.org webpage (beta version ready figure 11, expected launch date in August 2021) to advance heat literacy and connect stakeholders to current climate action planning efforts in Tempe. This online resource compiles the last several years of climate action on extreme heat in Tempe in one centralized location. This information can then be integrated into decision-making for the City, organizations, and residents to make Tempe a cooler place. The website helps to articulate a heat planning and management practice that uses *equity + heat + health* data not as a single decision written in a city plan, but as a mindset and culture of safety that accounts for *equity + heat + health* in city staff's everyday decision-making.

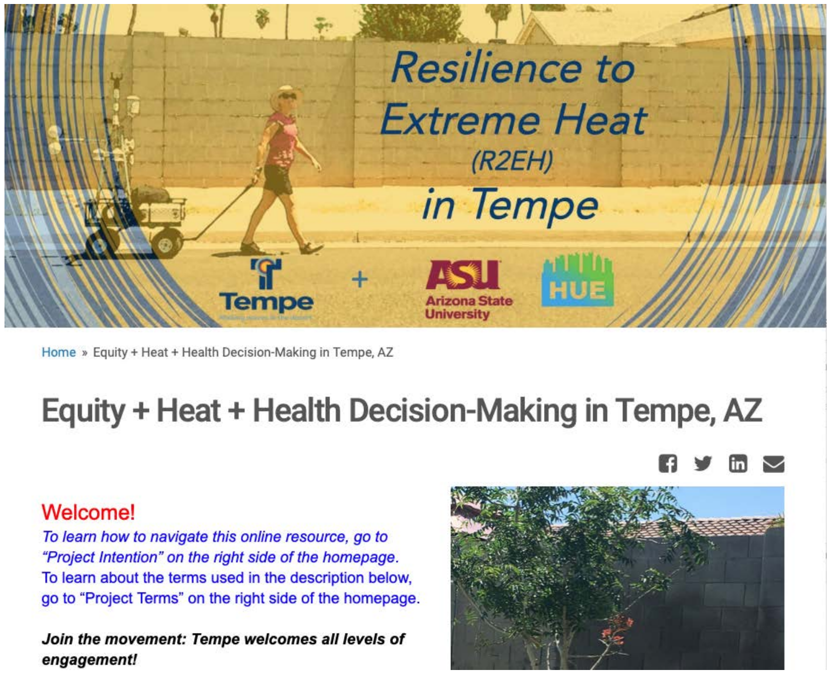



Figure 11: Screenshot of the Welcome-page of the EngageHUE.org website.

**This website is:**
A resource to learn about resilience to extreme heat and climate action planning in Tempe and the region.
A public resource to share our friends and families' discussions on resilience and diverse extreme heat stories.
A place to share the Tempe story with other municipalities.

**And will help:**
City decision-makers include heat equity in prioritizing infrastructure investments.
Community organizations and leaders advocate for place-specific cooling strategies.

**This resource has the following:**
Training Materials for Climate Literacy and Action

- "iHeat Map" and "Ideas" tools below. (In-Progress, with a Fall 2021 expected completion)
- Got-A-Minute videos explaining complex project terms, such as Mean Radiant Temperature (MRT) (voice over complete, In-Progress, with an August 2021 expected completion)
- List of key terms related to heat and air quality mitigation strategies, which--in combination with equity data--can help create equitable urban cooling (Appendix B). Although we were able to integrate these into some graphics and learning materials, more work is needed to better develop these key concepts for the Sonoran Desert region (In-Progress and ongoing)
- Learning module on "Heat Equity and the Promise of a Collective Movement for Urban Cooling" (In-Progress, with an August 2021 expected completion)

Desktop Ready Equity + Heat + Health Data for Decision-Making

- Learning tools beginning with "Resource Library" (Complete).


Figure 12: Green infrastructure - Bioswales are one example of green infrastructure that provide localized cooling solutions and harvest stormwater. Picture credit: City of Tempe

## Approaches to address the Data Hurdle

The NASA DEVELOP team has also created a story map for Tempe titled "[Establishing Heat Priority Scores for Tempe, Arizona]". The story map provides a great overview of the heat, health and equity data from the DEVELOP team and thus is a powerful tool for communication and building shared literacy. Additionally, the story map is also an example of what "desktop ready" data means as the NASA Develop team worked closely with the City's GIS Manager to ensure integration with the City's information infrastructure and existing datasets. As such, the NASA Develop approach partially influenced how we structured our "desktop ready" showcase for heat and health data and information.

Data that is desktop ready emerged as a need that informed this HUE proposal because of the following challenges:

- Scholarly research data is often *not salient* for cities because scholarly questions are often driven by national or international disciplinary discourse and are often not place and contextually specific enough for practitioner's needs. Hence, the data collected may be mismatched to the practitioner's needs for temporal dimensions, scale, and other specificities of practice.
- Scholarly research is often *not timely*. While it takes researchers years to discuss the research design, collect the data, present final results, and publish the results; practitioners need data more immediately. Additionally, the time needed to produce data results in city staff and researchers no longer being at their institutions, which creates a disconnect, loss of data, or makes data irrelevant.

- Scholarly research often lacks sensitivity to the specific context within which data is being applied. This context includes the processes and data used by city staff as well as the existing information and data management infrastructure. To design a research process that generates data that is generic and applicable to a specific context it requires coordination among multiple city departments (e.g., the user-department, the IT/GIS department, and potentially the risk management department) as well as researchers. A city-university partnership would need to be established to ensure such coordination across departments, interests, and time. City staff seeking out their own partnerships with no larger city-university coordination can pose a large coordination burden on the city staff and lead to conflicting data sources for the same type of data (e.g. land surface temperatures).

In light of these challenges, we define desktop ready as addressing the issues as follows: *Desktop ready means datasets that are co-produced with and for practitioners, grounded in their existing practice, information infrastructure, and decision making procedures.* This definition is based on our team's perspective that desktop ready databases should build on existing practitioner expertise and decision making scaffolding for more familiar, easily accessible, understandable, reliable and usable information anchored in practitioners existing understanding, but with feasible (e.g. time, education level, resources) pathways for expanding heat and health data and literacy knowledge. This also means that practitioners feel a sense of ownership for the database with motivations to critique the methods and data to improve it over time and defend the reliability of the data. The datasets and metadata account for the city's existing diversity of practice, local context, and thus can be consistently used by any department. As such, the datasets reinforce confidence in city staff users, enabling them to explain and defend this data to other City officials, organizations, and community members. Thus, desktop ready datasets may necessarily differ between regions and municipalities and more generalized web tools that are not connected to governmental unit information and political decision making may not be as effective for improving and defending decision making. However, the team feels this approach to co-develop desktop ready datasets can be replicated by other government agencies with enough supporting resources of time, money, and skill sets.

Over the year-long project, we co-created a "desktop ready" heat and health data resource, which includes:

- a data library (e.g. with GIS, MaRTy data),
- metadata (data about the data), and
- showcases explaining the data in the data library (each showcase includes PowerPoint slides and a video walking users through the data) .

The desktop ready data library is a series of Google Drive folders containing all the data. Subfolders contain the information on specific sets of data that is being made available. Box 2 describes the details on each subfolder or file in this “desktop ready” data library folder. The data included in these folders is customized. City staff can use this data to evaluate a planned infrastructure project and its impact on increasing heat or cooling in the city. This assessment can be done on various scales: from the city-wide scale, to the neighborhood scale, down to the touch-scale.

*Textbox 2: Tempe Heat and Health “desktop ready” data library*

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**Data Overview:** Data Showcase Powerpoint

- This powerpoint walks through the general information about each dataset and its general use, source, and compatibility.
- There are two datasets in the powerpoint that do not have their own folders (MesoWest and NAIP imagery). These two datasets are publicly accessible online. The links are found in the powerpoint.

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**Data Overview:** Data Showcase Video

- A conversation between Peter J. Crank and Braden Kay (City of Tempe Chief Sustainability Officer) about the data available to the City through the HUE data. Video was recorded on March 29, 2021 by Grace Logan

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**Data Overview: Data Showcase Extended Video**

- Some data was made available after the initial video was created. As such, the data have been added to the Powerpoint and are then discussed in this video.

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**Heat Vulnerability, Exposure, and Priority Scores** created by NASA DEVELOP

- the GIS data from the NASA DEVELOP Fall 2020 team was used to create Heat Vulnerability, Exposure, and Priority scores by census tract in the City of Tempe.
- The data are in a geodatabase (.gdb) and are easily viewed and analyzed using a GIS (ArcGIS or QGIS). These data have been shared with Dr. Stephanie Deitrick. Enterprise GIS Manager at City of Tempe, previously, but are made available here as well. Datasets include:
    - Heat Exposure
    - Heat Vulnerability
    - Heat Priority
    - LST and unshaded bus stops (LST = Land Surface Temperature)
    - LiDAR Shade analysis of Gilliland and Escalante neighborhoods.

- In this folder, there are two subfolders. One is data provided by the City of Tempe (this includes the city boundary shapefile and some demographic shapefiles). The second is the main data from NASA DEVELOP, it is titled "Fall2020_AZ_TempeUDII_Geodatabase".
- These data come with their own presentations, metadata, and videos compiled by the NASA DEVELOP team from Fall 2020. These additional sources of information should be referred to for more detail on this data.

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**Tempe Heat + Health Survey**

- These survey data from a mail and online survey conducted by Dr. David Hondula provide the City with information on heat-related illness in the City of Tempe and perceptions of risk and health by residents. This data is aggregated for the sake of anonymity. The data do include information at the zip code level on heat-related illness.
- Intended to be repeated every 5 years or so.

#### DATA STILL MISSING #### (Note: we are preparing the data to be published on the NSF-supported CONVERGE repository, and will send along the link when the full package is available).

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**Mean Radiant Temperature in Tempe parks** collected using MaRTy

- Data on mean radiant temperature at several parks as well as stretches of sidewalks in the City that have been used to study the impacts of shade interventions on thermal comfort in the City.
- Locations include:
    - Kiwanis Park
    - Cole and Rotary Parks
    - Palmer Park
    - Country Club Way
    - Tempe Beach Park (Rio Salado)
- These data were collected by Dr. Ariane Middel using the MaRTy cart that she developed. More details on the cart itself can be found by contacting her directly at ariane.middel@asu.edu. Ariane can provide access to a video and pdf content explaining how the cart is built and how the data are cleaned and prepared for analysis.

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**Bus Stop Shelters & Shade Curves**

- Information on how Bus Stop shelter shade varies throughout the day and can be used for general guidelines on how shade will vary between differing street orientations in the same neighborhood.
- This folder contains an executive summary of the 50 Grades of Shade paper (soon to be published) and the early access online version of the paper. Together, these two documents

are intended to provide sufficient information to aid the decision making process of designing bus stop shelter shade.

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**Air and Surface Temperature Data Across Tempe Parks**

- These data are collected in various parks across the City where air and surface temperature were collected at various points within the park to better understand the current thermal conditions of the park and its materials. This data is available in tabulated excel spreadsheets where observations were noted by time of day, park location, surface material, surface temperatures, and observational notes.
- The data were collected by Dr. Jenni Vanos (jenni.vanos@asu.edu).

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**Air, Mean Radiant Temperature, and Surface Temperature on Paideia Academy green spaces**

- The data are from a South Phoenix charter school on the impacts of green space changes being implemented in the school's recess spaces. The dataon the school site include:
  - air temperature,
  - mean radiant temperature (collected using MaRTy), and
  - surface temperature (collected using a thermal drone)
- The data were collected by Dr. Jenni Vanos (jenni.vanos@asu.edu)

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**Infrared data visualizing heat stored in walls along major roads in Tempe (Arterial Walls Data)**

- The data are IR camera data on the thermal environment of arterial road walls in Tempe from 2019.
- These data were collected by Dr. Ariane Middel

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**Impact of tree and shade structures on temperatures in Tempe Beach Park (Rio Salado)**

- The Rio Salado data are collection data from summer 2018, 2019, and 2020 to see how tree planting and shade implementation at Tempe Beach Park is impacting the thermal environment and the thermal comfort of park visitors. The data in this folder contains the processed data of 2018, 2019, and 2020 and a summary of each year's data collection. There is also a data log/route metadata excel sheet that documents the physical characteristics of each site in the park.

## Implications of this HUE Project

This HUE Project focused on compiling, integrating, synthesizing and applying data and information, specifically about heat, health, and equity, with the goal to apply this knowledge in planning projects across city departments; in essence: to build a city-wide practice of incorporating heat planning and management. Complementing this was an emphasis on building a foundation for practice- and community-oriented heat literacy.

The challenge was that this data was collected over a *couple of years*. Moreover, it was collected by *various researchers,* using various data collection methods and stored in various locations. Unfortunately, this may be an all too common research practice, making it difficult for municipal partners to receive the full benefit of their involvement in city-university partnerships. The translation part of the research is undervalued by universities for tenure and promotion processes, leaving municipal partners with only partial benefits of the relationship. Translation of data is a critical step that tests the applicability and usefulness of data. However, it is a step that is often omitted in research projects as the traditional research approach centers on formulating research questions, collecting data, analyzing data and publishing it. Thus, this HUE project was timely as it started the important process of completing the reciprocal intent of city-university partnerships by compiling and translating science for use in practice. *The implication for HUE is to request proposals that intersperse this traditional approach by adding a translation and testing data phase with and for practitioners, keeping in mind that heat literacy might necessarily be part of the deficies.*

Translating and teaching science for use in practice required a collaborative, co-production approach, involving the researchers and city staff partners to ensure the data is not only scientifically rigorous but also practically salient, usable, and defendable considering the city's data management infrastructures and practices. Thus, translating and teaching existing research findings/data requires mutual learning about a) how that finding/data was created and b) how it will be used in practice and c) to what extent existing infrastructures and processes support or hinder the incorporation of the new data. Through the careful design of our collaborative approach, we facilitated that mutual learning process.

*The implication for HUE is to request proposals that frame the proposed approach explaining how they will design the collaborative, co-production approach and documenting in the budget justification that they have set aside the needed resources for it. Transdisciplinary research requires funding for a Transacademic Interface Manager (Brundiers et al., 2013), who serves as a broker, facilitator, and mediator between researchers and practitioners (also called a city-university partnership manager). However, these roles are rarely formally and budgetarily accounted for, which means that either one of the researchers and/or one of the practice partners takes on these dual roles and added responsibilities. As the HUE initiative endeavors to* *support more transdisciplinary research, this position and its related tasks and competencies could be explained and included in the RFP (accounting for the city-university partnership). For projects that translate & apply data in practice, our experience inspires us to recommend a variation of the Transacademic Interface Manager with a focus on data management: a city-university partnership data manager (e.g. similar to Steven Earl at the Central Arizona Project Long-Term Ecological Research Project, but for translation of heat, air, and health research data to different cities information infrastructure and decision making procedures). The task-portfolio of this city-university partnership data manager builds on the core tasks of a data-manager and combines this with additional interface-management competencies, including the ability take the perspective of both researchers and city staff and speaking both 'languages', facilitate mutual learning processes, and navigate the institutional landscapes and regulatory environments shaping universities and city governments.*

This mutual learning process shed light on aspects that seemed removed from decision-making at first glance, and their further exploration revealed the full extent of the work to be done. Three examples illustrate these aspects:

- *Infrastructure of data management* entails where data is stored, who owns this data, when and how the data is updated, and how a city staff can gain access to this data and use it on their own computers for planning processes. These questions might seem irrelevant for heat and health decision making, but if the procedure to apply for access to data is cumbersome or takes too long, chances that the data will not be used in decision-making are high as timelines pressure city staff to move forward.
- *Is heat data a means or an end in itself?* The mutual learning process helped clarify to what extent heat data is a means or an end. From a research perspective, collecting the heat data often is the 'end'; the data instruments are the means to that end. From a practice perspective, however, the heat data is a means to achieve the end of equitable urban cooling. Heat data will inform when and why activities, like playing outdoors, move from daylight times to nighttimes in order to be healthy and safe. Experiences of health and safety depend on where people are positioned i.e., where they live and how their age, gender, and race intersect. Together, this informs the city in devising strategies targeted to different groups. For instance, lack of nighttime lighting may make some sidewalks, parks, and other amenities unusable at night when it's coolest for some groups. Some City staff thought better lighting of these infrastructures would improve the existing investments to maximize their usability at cooler times of day (e.g. night), as these pedestrian infrastructure would become cooler and hence more usable over more hours of the day. This may be just one example of practitioner and community expertise providing new insights into unexamined pathways to enhance cooling opportunities that may already exist, but are underutilized due to underrecognized factors.

- *Heat data points into the right direction; achieving that goal is riddled with hurdles*. Heat data informed where to place cooling infrastructures such as trees or other shading structures on a city- and site-scale. Further pursuing this plan revealed challenges that currently inhibit such tree plantings or installation of cool infrastructure; these challenges entail conflicts with the utilities or buried infrastructures such as water pipes (i.e. a legacy of canal laterals being buried in place) under sidewalks coupled with city and utility regulations that require tree setbacks from pipes. The assumption is that trees need to be kept away from pipes for fear of tree roots growing into leaking pipes. Either reassessing the scale of this risk of tree roots to water pipes and/or moving pipes to the center of roads during infrastructure upgrades were some of the suggestions from City staff. Another regulatory cooling hurdle that came up in discussions was that new building overhangs require developers to pay the City for use of air rights in the public rights-of-way, making it an additional cost or penalty to provide more shade over sidewalks. Addressing these challenges requires 'institutional work', a concept which refers to the deliberate assessment of which practices and protocols need to be changed, discarded, and maintained in order to allow for the new practice to take root.

These experiences remind us that decision making is not a purely cognitive process, but involves human biases and practicalities. Thus, the implication is that providing and translating heat data alone is not enough, as this process points to related aspects, which need to be addressed in order to be able to act on the information provided by the heat data. The use of insights from behavioral economics, institutional work theory, and targeted universalism can facilitate that.

These two activities (designing a collaborative, co-productive approach, translating science for practice and learning) with the goal to inform a city-wide practice of heat planning and management used up the time and bandwidth of the project's leadership. It explains why this project lacks an explicit research question and research-based approach. Additionally, the project failed to integrate air quality data and information in an expansive discussion. This may have been a result of the practitioner-centered approach where practitioners did not bring up air quality often in their concerns and/or our research team were at the limits of their bandwidth to integrate all the existing heat and health data that had been produced over several years. This type of city-university work is time consuming and thus it could benefit from additional resources including diverse PhD students or researchers that are integrated into the process but are fully dedicated to document the process.

In hindsight, various research opportunities seem obvious. For instance, we could have adopted a formative evaluation approach collecting data that would allow us to assess the quality and usefulness of the work as well as create a 'reflective practice' component into the heat planning management practice. Collecting data on these research questions would have been possible as our approach entailed likely more than 40 meetings with 28 meetings in 2020 alone, where insights, comments, and explanations could have been recorded and analyzed. The implication for translation & application projects is to fold evaluative research into the collaborative translation & application approach: formative evaluation that qualifies the process (i.e., does our process meet our own standards? how are researchers accountable to practitioners and vice versa?) as well as the outputs and outcomes of that process (i.e., Is what we develop evidence-supported and socially-effective at advancing sustainability and resilience to extreme heat and poor air quality? Can we find credible evidence related to the work we have done?). *HUE could include this expectation into the RFP and provide a hand-out informing about the basic designs of this sort of evaluation (we can help provide that).*

## Next Steps

This section outlines next steps for the core-team of this HUE project (Braden Kay, Paul Coseo, Katja Brundiers) and suggests steps, which the HUE Leadership team may consider taking on.

This HUE project is part of the broader and long-term city-university partnership between the City of Tempe and Arizona State University. Thus, the next steps resulting from this HUE project will be realized in alignment with the City of Tempe's Climate Action Plan, specifically with its priority area of Resilience to Extreme Heat, which includes four highlighted actions:

1. Green Infrastructure
2. Green Construction Code
3. Urban Forestry Master Plan
4. Emergency Management Program

In each of the four highlighted actions, the city combines three pathways of action including

- Policy, such as resilience density bonus
- Programs & Projects, such as the Cool Kids program
- Infrastructures, such as green infrastructures pilots (figure 12)

For each of the three pathways of action, we are presenting here one example:

**Policy**: this includes formal and informal policy. An example of an informal policy is the suggestion of city staff to create a City heat and health data package with checklist or similar explicit protocol expectations for planning, design and engineering consultants. This checklist/protocol would clearly explain what the City expects for existing and proposed heat assessments including guidance on performance metrics (such as in figure 8). This would equip city staff to reinforce and maintain a high level of skill and effectiveness in taking equitable urban cooling from a planning concept to a built reality. An example of a formal policy will be finalization of performance measures for heat as part of the City's Strategic Priorities, in particular expanding the definitions of safe and secure communities, quality of life, and sustainable growth and development to include heat-health outcomes in their definitions. Performance measures to track the efficacy of cooling interventions are still in discussion, but conversations have stressed the importance of including both objective and subjective measures to ensure communities' lived experiences are better understood and represented in measuring performance.

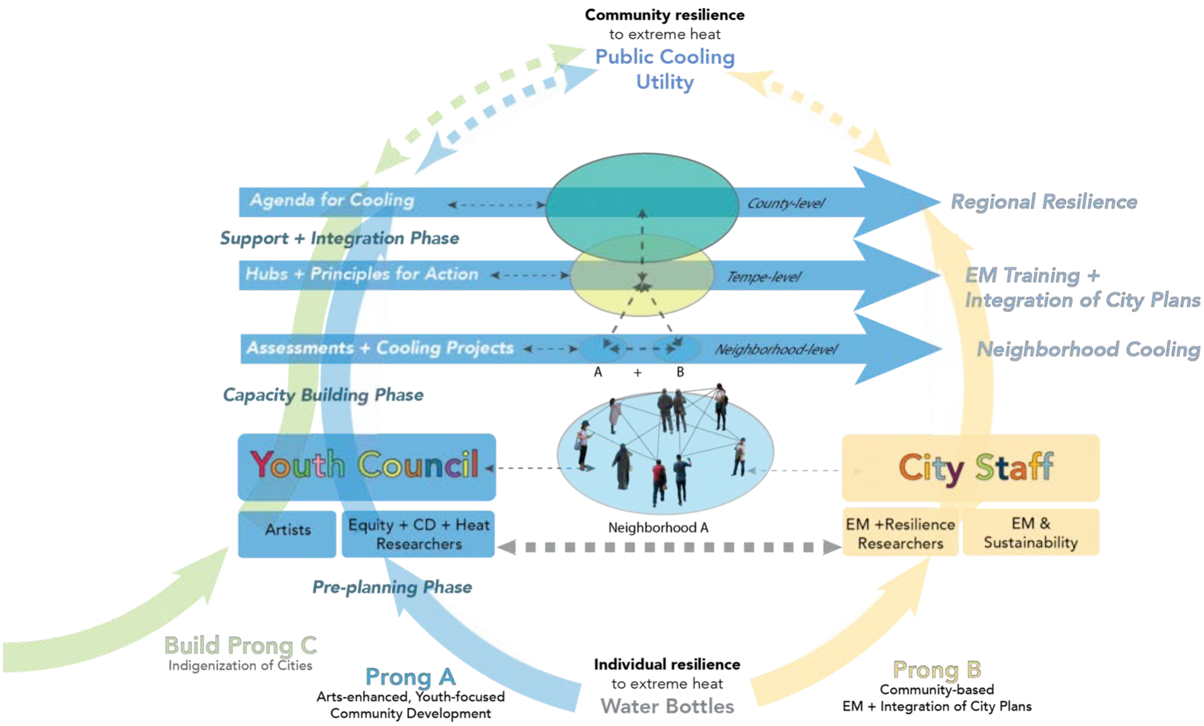


Figure 13: Cool Kids, Cool Places, Cool Futures framework with Prong A representing youth council participants, Prong B representing City staff participants, and Prong C representing a reframing, retooling, and repairing (Jackson, 2021) framework where diverse participants help to decolonize and bring racial justice to the center of the project.

**Programs & Projects**: The Cool Kids program serves to further deepen the city-wide awareness of heat as a health and quality of life threat to Tempe's sustainability and resilience. It will further the resilience to extreme heat activities including collecting stories about people's heat experiences as well as expanding community participatory action research to include this heat data and information into neighborhood, city, and regional planning processes. To advance the HUE initiated heat planning and management practices, Prong A and C (figure 13) of Cool Kids will organize youth around urban climate research and action through an arts-enhanced approach to community development for equitable urban cooling.  While Prong B (figure 13), Emergency Management & Community Resilience, will continue the HUE city-university work through two city-wide working groups:

- Infrastructure/Planning Group: led by Braden Kay; this group is largely composed of city staff who have been part of the HUE project
- Human Services /Community Outreach Group: led by Michelle Seitz; this group includes some city staff who have been part of the HUE project and also additional city staff who are joining the effort.

Both groups will continue the heat planning and management practice related to their work on mitigating extreme heat, including both reducing GHG and adapting to increased temperatures, as well as preparing for and responding to extreme heat events accounting for the possibility that they may compound with other co-occurring incidences. The overarching goal of the Cool Kids program is to develop a broadly supported proposal for a **regional cooling utility** (figure 13), which would include funds to support related cooling infrastructures (e.g., green infrastructures, resilience hubs), policies (e.g., building and zoning codes) and programs (e.g., continuation of a Cool Kids Youth Council program on the regional level).

Another example of a project is the HUE Project "Online Decision-Making Tool for Active Shade Management in the Southwest" led by Arianne Middel. This future work will parallel Prong B in Cool Kids with a minimum of three workshops (online or in-person) to support continued city staff – researcher co-creation and the co-creation of a practitioner facing products for regional active shade efforts. The City of Tempe staff have deepened their heat literacy through their participation in this HUE funding project and this 2021-22 collaboration will leverage their heat expertise to ground the tool in practitioner needs and expertise to embed the tool into an emerging model of heat management practice. The three meetings with the City (as part of the ongoing Cool Kids work) will: 1) define the parameters for the tool; 2) provide feedback on the user interface once it's up; and 3) have City staff test the tool and do a de-brief.

Integrating heat data with health (air quality) and equity data is essential as areas with high heat exposure overlap with areas of high air pollution and are often home to people who have heightened vulnerabilities due to structural inequities. This project strove to account for this integration whenever possible; however we mostly integrated heat and equity data. The mechanisms used for the integration can now be expanded to include health (air quality and other) data. The HUE core Tempe team is also happy to support HUE Leadership in their efforts to collaborate with developers and use this HUE project to inform future HUE activities. Next steps for the HUE Leadership could involve considering the implications offered for HUE in the above section and highlighted in italic.

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## Appendix A: Overview of sequence of project meetings

We are providing detailed information on our July-December 2020 meetings as this was a key piece at having City staff lead the HUE data organization and integration activities. City staff had representation at the majoring of bi-weekly working meetings.

| Date | Meeting | Purpose |
|---|---|---|
| June 17, 2020 | HUE Initiative June Convening | Convene the 2019 and the 2020 cohorts to support education, research, and discoveries that empower solutions to mitigate urban heat and air quality in Maricopa County |
| July 1, 2020 | Internal HUE meetings | Planning for HUE, Tempe kick-off |
| July 20, 2020 | Internal HUE meetings | Planning for HUE, Tempe kick-off |
| July 23, 2020 | | Hiring students and prepping for beginning of the school year<br>Work plan and adjustments to the schedule – booking City virtual workshops early<br>Develop meeting practices |
| July 29, 2020 | HUE Initiative July Convening | Convene the 2019 and the 2020 cohorts to support education, research, and discoveries |
| July 30, 2020 | ASU-Tempe Bi-Weekly Meeting for **Macro Data** | Kick-off of bi-weekly meetings for macro data discussion |
| August 6, 2020 | HUE, Tempe **Kick-off** meeting with City Staff | Orient City staff to the HUE project and gauge their needs and ideas regarding "desktop ready" tools. |
| August 13, 2020 | ASU-Tempe Bi-Weekly Meeting for **Macro Data** | Second bi-weekly meeting |
| August 20, 2020 | ASU-Tempe Bi-Weekly Meeting for **Micro Data** | Kick-off of bi-weekly meetings for micro data discussion |
| August 27, 2020 | ASU-Tempe Bi-Weekly Meeting for Macro Data | Third meeting |
| September 3, 2020 | ASU-Tempe Bi-Weekly Meeting for **Micro Data** | Second meeting |
| September 10, 2020 | ASU-Tempe Bi-Weekly Meeting for Macro Data | Fourth meeting |
| September 17, 2020 | ASU-Tempe Bi-Weekly Meeting for **Micro Data** | Third meeting |
| September 24, 2020 | ASU-Tempe Bi-Weekly Meeting | Fifth meeting |

| | | |
|---|---|---|
| | for Macro Data | |
| October 1, 2020 | Core HUE Macro (DEVELOP) + Micro meetings | Combined meeting discussing the integration of micro and macro data. |
| October 1, 2020 | ASU-Tempe-NASA DEVELOP Meeting | Stephanie Detrick meets and talks with NASA DEVELOP students about GIS database compatibility with City Information Infrastructure |
| October 8, 2020 | ASU-Tempe-NASA DEVELOP Bi-Weekly Meeting for Macro Data | Co-develop a game plan for the DEVELOP team matching their goals for education with the City goals for analysis |
| October 15, 2020 | ASU-Tempe Bi-Weekly Meeting for **Micro Data** | Discussion with Transportation Planning on how existing micro data applies to current projects<br>Barriers to get this knowledge into city decision-making<br>Possible intervention points to add this data into decision-making |
| October 22, 2020 | ASU-Tempe-NASA DEVELOP Bi-Weekly Meeting for Macro Data | Update from Develop Team<br>Discussion of the Rough Draft of the Decision Tree<br>Discussion of Data Insertion Points, Knowledge Gaps and How to bridge them |
| October 29, 2020 | ASU-Tempe Bi-Weekly Meeting for **Micro Data** | Show Parks and Transit/Mulituse Path Design Map<br>Show "Rule of Thumb" table in Educational document<br>Discuss Potential for Data Interventions to create thermal health (Fill out "Rule of Thumb" table)<br>Waterfall Chat - How do we use data in decision-making to create thermal equity? What data are we missing that should be added as an intervention point? |
| November 5, 2020 | ASU-Tempe-NASA DEVELOP Bi-Weekly Meeting for Macro Data | Discuss in detail transferring the data from DEVELOP to Tempe, Show decision maps and draft insertion points<br><br>Update from DEVELOP and feedback for them to refine and finalize their work<br><br>Draft Decision-making slides for Placement decisions for review and comment<br><br>General discussion and next steps |
| November 12, 2020 | ASU-Tempe Bi-Weekly Meeting for **Micro Data** | Overview of schedule including Dec. 9, 2020 workshop<br>Present initial draft of heat and health insertion points in decision-making for Multi Use paths and discuss early thoughts for Parks for review and revision<br>Next steps, what would City staff like achieve on Dec. 9, 2020 – share our proposed agenda |
| November 19, 2020 | ASU-Tempe-NASA DEVELOP | NASA DEVELOP students to present their findings to Stephanie |

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| (RECORDED) | Bi-Weekly Meeting for Macro Data | Deitrick and additional city staff for integrating heat and health data into infrastructure placement decisions |
| December 3, 2020 | ASU-Tempe Meeting for Macro + Micro Data | Preparation for 12/9/2020 workshop |
| December 7, 2020 | Tempe-ASU HUE City Workshop Practice Session I | |
| December 8, 2020 | Tempe-ASU HUE City Workshop Practice Session II | |
| December 9, 2020 (RECORDED) | Tempe-ASU HUE Resilience to Extreme Heat Workshop | 7 City Staff<br>8 ASU participants |
| December 10, 2020 | ASU-Tempe Bi-Weekly Meeting for **Micro Data** | |
| March 26, 2021 (RECORDED) | Tempe-ASU HUE Resilience to Extreme Heat Workshop IIa | First of two spring 2021 workshop II |
| April 21, 2021 | Tempe-ASU HUE Resilience to Extreme Heat Workshop IIa | Second of two spring 2021 workshop II |

## Appendix B: List of terms

Below we present a list of terms that the City of Tempe aims to socialize among city staff, collaborating researchers and professionals to facilitate communication and a shared understanding by consistently using the same term when exploring potential strategies to create equitable urban cooling. For each term, we present WHAT the term entails and HOW this term can be implemented in planning processes and become part of the institutions (formal and informal rules, regulations, norms, and protocols).

**Emergency management**

What: Heat preparedness and heat relief can be centered in emergency management practices to reduce heat illness, hospitalizations and heat caused deaths.
How: Community resilience approaches can be used to make sure residents, government, nonprofits and businesses work together to reduce the risk of heat and other shocks.

**Green building**

What: Buildings that are built with cool materials, shade and other cooling design choices.
How: LEED, Living Buildings and the International Green Construction Code can be used to ensure buildings are incorporating sustainability and resilience.

**Green infrastructure**

What: Green infrastructure is defined through the Clean Water Act. Section 502 defines green infrastructure as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." In simple terms, green infrastructure uses stormwater to provide additional water to vegetation in right of ways, residential and commercial projects.
How: The City of Tucson adopted **standards** to ensure all development incorporate bioswales, rain barrels, and water capture technologies are available.

**Sustainable infrastructure**

What: Shade and cooling built around transit shelters, bike paths, parking lots and parks.
How: Envision certification can be used for many of these projects. SITES certification can be used for parks. Heat equity data can be used to place and design this infrastructure.

**Urban forestry**

What: The practice of using trees to provide cooling and shade throughout the city.
How: Urban forestry master plans describe how cities can use trees in parks, streets and private property.

**Urban Sustainability Directors Network & Resilience**

The City of Tempe, being a member of the Urban Sustainability Directors Network, also endeavors to adopt and socialize the terms developed by USDN with regards to building resilience against extreme events. To support the City of Tempe's efforts, we are listing these terms here as well. The City is engaged in planning a variety of heat mitigation actions and associated buildings that are related to the USDN terminology around "Resilience Hubs". These include for instance: Cooling Centers, Community Centers, Envision Hub, Resilient Energy Hub, cool commercial centers, cool parks. This overview will help understanding how these heat mitigation actions relate to the USDN terminology. This list of terms is presented from the broadest umbrella term to the most specific item.

**Resilience**

The ability of our community to anticipate, accommodate, and positively adapt to or thrive amidst changing climate conditions or hazard events and enhance quality of life, reliable systems, economic vitality, & conservation of resources for present & future generations.

**Resilient Neighborhoods**

These are neighborhood-specific strategies, including big city-led elements such as zoning and land use changes and smaller community-led elements like maker spaces and citizen science projects, that support the vitality and resilience of neighborhoods year-round and in the event of disruption. Resilient Neighborhoods can bring together Resilience Hubs, Resilient Spaces and Resilient Power projects.

**Resilient Spaces.**

Resilient Spaces can include neighborhood and community spaces that are intended to enhance community resilience but are not a Resilience Hub. These can include community gardens, community-managed open spaces, community-supported green infrastructure, tool-banks, microgrids or other similar community-serving spaces that are intended to enhance community resilience.

**Resilience Hub.**

Resilience Hubs are community-serving facilities augmented to support residents, coordinate communication, distribute resources, and reduce carbon pollution while enhancing quality of life year-round. Hubs can meet a myriad of physical and social goals by utilizing a trusted physical space such as a community center, recreation facility, or multi-family housing building as well as the surrounding infrastructure such as a vacant lot, community park, or local business. They provide an opportunity to effectively work at the nexus of community resilience, emergency management, climate change mitigation, and social equity while also providing

opportunities for communities to become more self-determining, socially connected, and successful before, during, and after disruptions.
Resilience Hubs are focused on shifting power to the community and are intended to provide services and programming to communities year-round. Resilience Hubs have 5 areas that need to be addressed:

- 1) Programming & Services,
- 2) Operations,
- 3) Power, (see also Resilient Energy Systems, below)
- 4) Structure, and
- 5) Communications

Resilience Hubs are intended to serve communities year-round. The Hub serves the community in 'Normal (or Everyday) Mode' that is the mode when there is no disruption or active recovery after a disruption. Moreover, the Hub serves the community during a shock and disruption (Disruption Mode) and in the aftermath of a shock (Recovery Mode). Thus, Resilience Hubs operate in all three modes:

- Normal/Everyday Mode,
- Disruption Mode, and
- Recovery Mode.

See http://resilience-hub.org/what-are-hubs/ for additional context and information.

**Resilient Power Systems.**
Resilient power ensures reliable backup power to a facility during a hazard event while also improving the cost-effectiveness and sustainability of operations year-round. Thus, Resilient power systems are different from Resilience Hubs: resilient power systems are just focused on providing reliable backup power to a facility, and they lack the wider social change context that Resilience Hubs endeavor.

USDN thinks about Resilience and associated concepts described above using three overarching concepts:

**Broken Systems**. North America's governments were founded on faulty assumptions, designed to serve only a subset of the population and to extract from natural and human resources to benefit that subset. This design has resulted in over-extraction of resources and racial inequity. As a result, people of color and indigenous populations are impacted first and worst by a rapidly changing climate. Investing in solutions that center human needs is necessary to mitigate those disproportionate impacts. These broken systems still exist today, and to solve the climate and racial inequity crises, solutions need to acknowledge and repair those systems.

**Corrective Action**. Implementation and support of Resilience Hubs are prime examples of how local governments and partners can work to counter these broken systems. Resilience Hubs provide an opportunity for local governments to shift power to residents and community-based organizations to determine their own needs, identify how to meet those needs, and build relationships that will increase their influence on future decision-making processes. Local governments can provide support.

**Targeted Universalism**. A targeted universal strategy is inclusive of the needs of both dominant and marginalized groups but pays particular attention to the situation of the marginalized group. Targeted universalism rejects a blanket approach that is likely to be indifferent to the reality that different groups are situated differently relative to the institutions and resources of society.

In addition to the City of Tempe's list of terms and the USDN's list of terms, this project also started to heavily use some terms and so we list those terms as well. However, this is work in progress and more definitional work needs to be done.

**What are the levels of city decision-making where heat data can be used?**

**Placement:** This includes 1) the processes undertaken to pick the best place for urban heat strategies and 2) the ultimate installation of cooling infrastructure in the urban landscape. This happens:

- Regionally when cities collaborate with Maricopa County for heat hazard mitigation.
- Municipally within specific zip codes in city limits that have the highest heat vulnerability.

**Neighborhood:** The Neighborhood is the environment where people are connected by traveling through corridors to get to places. This demonstrates how people interact with infrastructure in their everyday use between placement and design.

- Cool Place: A place with sites where people congregate to get cool.
- Hot Spot: A place that is too hot to safely be at is a hot spot.
- Cool Corridors: Safe and cool walkways where people travel.
- Hot Corridor: A place that is too hot and unsafe to travel is a hot corridor.

**Design:** This is determining 1) how infrastructure is orientated at the site to create shade and 2) what materials are used for a cool touch experience.

- Site: Infrastructure that collectively forms a place
- Touch: Materials and shade that impact personal experience

**What are the main ways this project worked with data?**

- **Air Temperature**: This is the most common temperature measure. If you check your phone, that is air temperature.
- **Surface Temperature**: This measures the warmth absorbed or given off by materials like handrails, benches, and other touch materials.
- **MRT**: Mean Radiant Temperature quantifies the heat load on the human body. MRT is the sum of different kinds of radiation that hits the human body from all directions. This includes longwave radiation that is emitted from hot surfaces, such as an asphalt parking lot in the summer that radiates heat at the human body. It also includes shortwave radiation from direct sunlight in places without shade. This measurement is better in showing the difference between sun and shade - with 60-degree difference observed between direct sun and shade.