Heat Mitigation
Solutions Guide
for Mobile Homes

ASU Knowledge Exchange for Resilience
Arizona State University

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Knowledge Exchange for Resilience, Arizona State University

About this Solutions Guide

People who live in mobile homes are **6 to 8 times** more likely to die of heat-associated deaths.

According to the Centers for Disease Control and Prevention (CDC), more people die in the U.S. from heat than from all other natural disasters combined. According to the Environmental Protection Agency (EPA), more than 1,300 deaths per year in the United States are due to extreme heat. Arizona, California and Texas are the three states with the highest burden, accounting for 43% of all heat-related deaths according to the CDC.

Although only 5% of housing in Maricopa County, Arizona, is mobile homes, approximately 30% of indoor heat-related deaths occur in these homes. Thus, the residents of mobile homes in Maricopa County are disproportionately affected by heat. Mobile home residents are extremely exposed to heat due to the high density of mobile home parks, poor construction of dwellings, lack of vegetation, socio-demographic features and not being eligible to get utility and financial assistance.

We researched numerous solutions across different domains that could help build the heat resilience of mobile home residents. As a result we found **50 different solutions** for diverse stakeholders, budgets and available resources. The goal of this toolbox is to present these solutions and to explain how to apply them in order to get the most optimal result and build heat resilience for mobile home residents. These solutions were designed as a coordinated set of actions for everyone — individual households, mobile home residents, mobile home park owners, cities and counties, private businesses and nonprofits serving mobile home parks, and other stakeholders — to be able to contribute to heat mitigation for mobile home residents.

When we invest in a collective, coordinated suite of solutions that are designed specifically to address the heat vulnerability of mobile homes residents, we can realize a resilience dividend in maintaining affordable, feasible, liveable housing for the 20 million Americans who choose mobile homes and manufactured housing as their place to live and thrive.

To cite this guide:

Varfalameyeva, Katsiaryna, Patricia Solís, Lora Phillips, Elisha Charley, David Hondula, and Mark Kear (2021). Heat Mitigation Solutions Guide for Mobile Homes. Knowledge Exchange for Resilience Solutions Series. Tempe: Arizona State University. Available from https://keep.lib.asu.edu/collections/160080.

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Why is it important to address the heat exposure of mobile home residents?

According to the CDC, more people die in the U.S. from heat than from all other natural disasters combined. According to the EPA, more than 1,300 deaths per year in the United States are due to extreme heat. Heat deaths in Maricopa County have been increasing for the last six years. Since 2006 there have been a total of 1,696 heat-associated deaths, and 35% of them were indoor heat deaths (Fig. 1). Prior research shows that the recent increase in heat-related deaths cannot be explained by weather patterns.

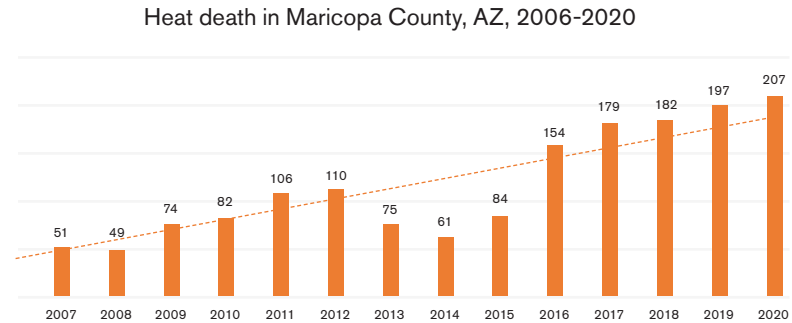


Figure 1. Trend and number of heat-related deaths in Maricopa County, 2006-2020

Although only 5% of housing in Maricopa County is mobile homes, approximately 30% of indoor heat-related deaths occur in these homes. Thus, the residents of mobile homes in Maricopa County are disproportionately affected by heat. Given that this pattern cannot be explained by weather patterns (Fig. 2), there must be additional factors that make heat so deadly for mobile home residents specifically.

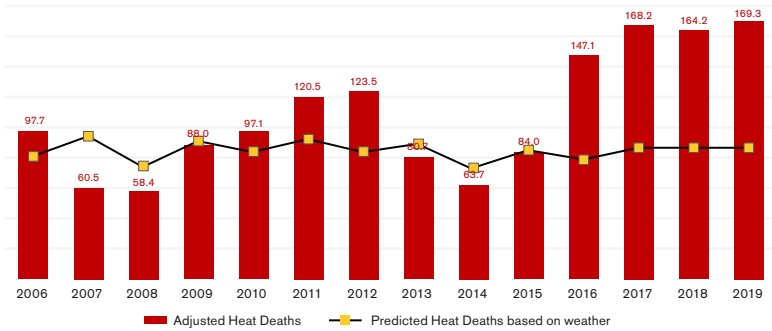


Figure 2. Weather patterns and heat-related deaths in Maricopa County, 2006-2019

Residents of mobile homes experience very low heat resilience due to the following reasons:

1. **Extremely high density of mobile home parks.**
   Mobile home parks often resemble parking lots full of RVs or mobile homes. Their density is three to five times higher than the density of single-family communities. All dwellings in the parks are located close to each other without yards.

2. **Poor construction of mobile homes.**
   Mobile homes are not designed to be permanent housing, and for that reason they have lower construction standards than single-family homes. In addition, aging mobile homes require a lot of maintenance and repairs, which a majority of residents cannot afford. Mobile homes in the Phoenix Metro Area have very poor construction, including low insulation, thin walls, holes between windows and doors, old and thin roofs and floors. As a result, these mobile homes get very hot inside in a short period of time and require a lot of energy to cool down.

3. **Age of the structure.**
   Two-thirds of all mobile homes in Maricopa County were built before 1990, which increases the likelihood that they do not comply with the energy efficiency standards that were issued in 1990 for all residential buildings. This resulted in poor construction that has been degrading over time.

4. **No vegetation.**
   Mobile home parks are parking lots with very high density where residents have no space to plant trees. In addition, unique relationships between park owners and residents prevent increasing vegetation since residents rent the lot under their homes and have no legal right to plant anything.

5. **Socio-demographic factors.**
   Mobile home households have significantly lower incomes, higher rates of poverty, an older population and lower housing value, but they have higher rents compared to the single-family households. As a result, mobile home residents more often experience financial hardship, in which electric bills, air conditioning repairs, or energy efficiency improvements are extremely unaffordable. Very often this puts mobile home residents into a challenging situation where they need to choose between essential purchases like food or cooling down their home and not suffering from heat exhaustion. Oftentimes, they face this tradeoff while simultaneously working to manage age-related pre-existing health conditions that also increase their heat risk.

6. **Social isolation.**
   Mobile home residents are more likely to live alone than residents of single-family or multi-unit homes. Additionally, some mobile home residents do not have friends or relatives nearby, and although mobile home residents express a great willingness to help their neighbors, very few report interacting with their neighbors on a regular basis. In Maricopa County specifically, many mobile home parks also cater to snowbirds who arrive in the winter and leave before summer begins, meaning that mobile home parks are less populated during the hottest portion of the year. These conditions force many mobile home residents to manage heat and heat costs alone, increasing their risk of heat-related illness or death.

7. **Policy regulations that exclude mobile home residents from getting assistance.**

   Because of their unique renter-owner situation (i.e., owning the mobile home but renting the land it is parked on), and the fact that their homes have wheels (even if they are immobilized), mobile home households are excluded from many programs such as weatherization and utility assistance. In situations where the mobile home park is the direct utility consumer, mobile home households are also excluded from utility provider-sponsored programs. Even though these households are in need of this support, they are ineligible for these programs because they do not own the land, are very often not direct customers to the utility companies, and simply because they live in a mobile home.

The issue of extreme heat vulnerability among mobile home residents is important to address due to high heat-related mortality rates for this group. According to the State Department of Health Services, in 2020 alone, there were a record 521 heat-related deaths in the state of Arizona. In addition, the consequences of heat exposure impose a huge cost on the county. In 2020, the estimated financial toll of all heat-associated health impacts ranged from $360,180,000 to $1,800,900,000. Hospitalization alone from heat-related illness also imposes a huge cost on the county. In 2018, the estimated cost of these hospitalizations was $24,160,675.

Even though heat is the deadliest hazard in the U.S., its consequences have not received due attention relative to other hazards. However, awareness is growing. Numerous local, regional and national news outlets have recently provided coverage of heat-related hazards, particularly among mobile home residents, including: The Arizona Republic, Arizona Mirror, ABC 15 News, Cronkite News, Los Angeles Times, High Country News, The New York Times, The Washington Post and National Geographic. Thus, it is more timely than ever before to develop and improve adaptive capacity to heat for all groups of people, starting with the most vulnerable populations.

50 ways to mitigate heat

Heat mitigation requires a strategic approach because the issue of heat exposure is complex and further complicated by the many factors that make mobile home households especially vulnerable to heat. Therefore, the goal of this toolbox is to address heat mitigation from all possible angles. We propose five main areas where solutions should be implemented: technical and built solutions, natural solutions, policy-related solutions, community-based solutions, and innovative financial opportunities. This chapter provides a list of all 50 solutions, along with their description.

Technical and built solutions

The goal of this group of solutions is to increase heat resilience by improving the quality of construction and the built environment around mobile homes. All of these solutions should be applied directly on site. Some of the solutions are designed to be applied to a single mobile home, while others should be applied to the mobile home park.

Improve insulation and construction of mobile homes:

1. **Air sealing the home** – Reduce air leakage for mobile home structures by inserting new windows and doors, improving insulation and sealing holes.

2. **External insulated finishing or stucco systems** – Improve insulation of mobile homes by adding additional layers of stucco.

3. **Skirting** – Insulate underneath the mobile home. Various materials can be used, including vinyl, brick, concrete, metal, plywood, foam and reil rock.

Increase sun protection:

4. **Curtains** – Add curtains on windows inside mobile homes.

5. **Window films & window tinting** – Add films or tint to mobile home windows.

6. **Shutters or other external window covering (e.g. cardboard)** – Attach to windows outside mobile homes.

7. **Shade awnings** – Protect homes and lots from direct sun exposure. Awnings use an angled design to provide versatile, cost-efficient heat reduction.

8. **Shade sails** – Shading structures can be a temporary solution if solar panels are not installed on mobile homes. All structures include: the shade structure, installation, powder coating, high density polyethylene cover, cable, hardware, anchor bolts, template and rebar cages.

9. **Reflective coatings (white coat)** – Special white coating on mobile home roofs that is weather-resistant for year-round, eco-friendly protection.

10. **Passive Daytime Radiative Cooling (PDRC)** – Innovative roof coating that radiates heat to the cold outer space, which decreases the temperature of the mobile home itself and the environment around it.

Improve air conditioning:

11. **Heat pumps (especially mini-split versions)** – Alternative to traditional air conditioning units. The main advantages of mini-splits are their small size and flexibility for zoning, or heating and cooling individual rooms. Ductless mini-split systems are easier to install than some other types of air conditioning systems. Mini-splits have no ducts, so they avoid the energy losses associated with the ductwork of central forced air systems.

12. **Portable air conditioning** – Known to be cost effective, as it has low electricity use. It is portable and compact due to its lightweight design, so it is easy to carry around the house or car if needed. This cooler is also noise-free.

13. **Swamp coolers** – Swamp coolers are alternatives to traditional portable air conditioners. They consume less energy than traditional air conditioners, and they use the natural power of evaporation to cool the atmosphere in low-humidity areas. Evaporative coolers cool outdoor air by passing it over water-saturated pads, causing the water to evaporate. The 15°F- to 40°F-cooler air is then directed into the home, pushing warmer air out through windows.

Sustainable energy use:

14. **LED lights** – Update and install energy efficient lighting.

15. **High-efficiency appliances** – Update and install new appliances in mobile homes.

16. **Solar (PV) canopies** – Provide direct shade to mobile homes and generate power for HVAC equipment.

17. **Solar pavement** – Hungarian tech company Platio uses recycled plastic to build solar panels into pavements, which can power buildings and charge electronic devices. Watch this video to learn more: https://youtu.be/SNOIm9YFJPM, or visit their website at https://platiosolar.com/

Change the physical environment of the park:

18. **Outdoor evaporative cooling (misters)** – Build water systems around mobile homes. Misters are both energy- and water-efficient, with easy professional and cheap DIY installation options.

19. **Proximity of structures to each other for shading and ventilation** – Improve or change the distance between mobile homes, allowing natural ventilation.

20. **Site orientation optimization for cooling** – Change or improve the location of mobile home units to account for wind and sun angles.

21. **Cool pavements** – Apply cool pavement coating on roads and sidewalks to reduce the temperature. Learn about a cool pavement pilot project by ASU researchers here: https://tinyurl.com/ayf5p8bw

22. **Mechanical trees** – This technology, developed by ASU professor Klaus Lackner, mimics real trees to remove carbon dioxide from the air faster than nature, helping reduce global carbon emissions. This will result in a temperature reduction around mobile home parks in the long term. Learn more in The State Press: https://tinyurl.com/29c8t2eu

Natural solutions

This group of solutions is focused on using natural resources such as different types of vegetation to improve the heat resilience of mobile home parks. To provide a meaningful impact, these ideas should be applied to the whole park.

23. **Green or living walls** – Implement vertical forms of vegetation (e.g., vines) to provide shade (and possibly evaporative cooling) to the mobile home park. They provide benefits similar to those of trees, but they may be more feasible because they can be installed without having to alter the ground surface.

24. **Replacing pavement and asphalt with soil and plants** – Where possible (e.g., driveways), replace pavement and asphalt (which absorbs and re-emits heat, increasing ambient temperatures) with gravel, soil, vegetation or a combination.

25. **Trees** – Plant trees throughout mobile home parks to provide additional shade (and possibly evaporative cooling). Landlord and tenant cooperation is needed for trees, as the landlord has to allow trees, and tenants have to maintain them.

Policy-related solutions

These solutions are based on an analysis of the policies and regulations that govern mobile home parks. The implementation of these solutions will require high-level decision makers' participation. The results of these recommendations will be visible on a city, county and state level.

26. **Cooling centers within mobile home parks** – Permanent or pop-up cooling centers could be set up within or near mobile home parks. These centers would especially benefit residents who are less mobile, and mobile home parks often already have an established common space.

27. **Free or subsidized transportation options** – Provide a regular free or subsidized transportation service to and from mobile home parks in order to help residents access existing cooling centers.

28. **Door-to-door wellness checks by government employees and community groups** – Have dedicated individuals or teams regularly check on vulnerable residents of mobile home parks in order to ensure that they are not unnecessarily exposed to extreme heat conditions and that they are accessing helpful resources that are available to them.

29. **Improve the building envelope program and tailor this program to mobile homes** – Review (and revise) existing policies and programs aimed at supporting or subsidizing the weatherization and retrofitting of dwellings to make them more energy-efficient and less susceptible to extreme heat conditions.

30. **Outreach and education programs with mobile home parks** – Outreach and education should focus on: 1) existing resources for mitigating the impacts of extreme heat (e.g., cooling centers, personal actions, assistance programs, etc.) and 2) overview of tenants' rights in relation to the utilities and landlords (e.g., utility shut-off rules). Communication needs to be bilingual. Outreach and education programs could be led by institutional actors, but there is also potential to draw on community knowledge and connections. Education programs often work especially well when knowledge is shared among familiar actors, underscoring the importance of developing educational programs that draw on existing residents' knowledge, expertise and skills.

31. **Revise utility assistance programs, policies and regulations to reclassify "mobile"** – Policies could be modified to reclassify "mobile." Just because a home has axles and wheels does not necessarily mean that it is truly mobile, but classifying these homes as such makes them ineligible for many grants and programs. Mobile homes are not currently eligible for many utility assistance programs that can help to reduce utility burden or subsidize helpful technologies and retrofits. Through modifications to existing programs, policies and regulations, these "loopholes" can be closed.

32. **Draft statewide legislation that institutes utility shutoff protection** – Such legislation would prohibit utility companies from terminating service to certain residents (e.g., vulnerable residents of mobile home parks) during extreme heat conditions.

33. **Develop or increase shade via zoning requirements** – Enact zoning laws that require mobile home parks to have a certain amount of shading.

34. **Create public regulatory policies and financial or tax incentives that facilitate the creation of resident-owned cooperative housing** – Provide a pathway to land ownership for mobile home residents in order to avoid some of the complications and misalignment of incentives that exist when one entity owns the land, and residents lease their lots, dwellings or both from this entity.

35. **Utility conversion program** – Modify the electric meter system to be submetered at the individual dwelling level rather than master metered at the community level.

36. **Energy efficiency standards and requirements** – Revise and update energy efficiency requirements for mobile homes. Given that mobile home residents generally express that they want to increase the energy efficiency of their homes but cannot afford to do so, this solution would be most effective if paired with a cost-share or financing arrangement. Current mobile home owners should also be grandfathered in under new energy efficiency regulations so that they are not removed from their homes if cost is a prohibitive factor for making improvements. Since many mobile home residents are not able to finance their home improvements, this solution should be paired with other programs, tools and financing arrangements to lower the cost for residents.

37. **Home improvement loans** – Provide loans specifically for mobile home residents with low interest and easy qualifying criteria (Kear et. al. 2019).

Equity efforts and social or community programs

38. **Social infrastructure and community engagement** – Implement programs and resources to support and enhance social cohesion within mobile home parks. Possible ways to bring residents together include bingo nights, art nights, game nights or small classes held at a central location (e.g., a resident's home, an on-site community center, a local library or park). Well-maintained social infrastructure facilitates community engagement by providing welcoming and convenient places for people to congregate.

39. **Heat-resilient community center** – The community center incorporates solutions that increase both social connectedness and heat resilience. Some things that increase social connectedness are vegetable gardens, outdoor cooking areas, social events, playgrounds and seating. Shaded areas with misters, aluminum benches, shaded houses and vegetation instead of asphalt increase heat resilience.

40. **Information campaign via AARP bulletin** – Partner with AARP to ensure that the most vulnerable residents of mobile home parks (e.g., the elderly and those on a fixed or low income) are receiving pertinent information about the risks of extreme heat, as well as information regarding what resources, support and solutions are available to mitigate their heat risk. AARP could also be a powerful voice in lobbying for meaningful regulatory and legislative changes (e.g., utility shut-off ban, utility subsidies, etc.)

41. **Early detection warning system to notify friends, family and caretakers when a home is getting too hot** – Implement monitoring and communication systems that alert mobile home residents and their social networks of upcoming or existing dangerous heat conditions within their homes or communities and suggest steps for minimizing the danger.

42. **Educate public health officials and emergency responders about the unique vulnerability of mobile home residents** – Provide information about mobile home residents' unique vulnerability to extreme heat and the disproportionate health impacts extreme heat has on mobile home park residents. Develop policies and protocols for giving extra care and attention to mobile home parks during extreme heat events.

43. **Mutual aid networks and neighborhood associations** – The human infrastructure characterized by "people helping people" is comprised of formal and informal entities that are hyperlocal and created by and for neighbors where they live. This constitutes a potentially critical resource that could utilize greater investment, especially when it comes to the opportunity to take advantage of the often friendly atmosphere in park-wide settings.

Innovative financial products and opportunities

44. **Support for small-dollar home lending markets** – This should include chattel lending for both new and already sited homes. The goal of such support should be to reduce the cost of buying a manufactured home titled as personal property and to reduce practices such as contract selling, which are common, often predatory and largely unregulated.

45. **Greater consumer protections for mobile home buyers comparable to those available to real estate buyers** – Most households who purchase a mobile or manufactured home do so without the same legal safeguards and consumer protections enjoyed by mortgagees. For example, the Real Estate Procedure Settlement Act (1974) does not apply to personal property loans. Even formal personal property loans do not have the same disclosure requirements about loan costs, do not require appraisals, and homes purchased with them can be repossessed without a regular foreclosure or eviction process (Bourke and Siegel 2020). Those borrowing to purchase newer homes must rely on high-cost chattel loans, while those purchasing existing homes in mobile home parks have fewer options still. Typically, they must buy "on contract", entering into agreements, similar to those offered to households in redlined neighborhoods that combine "all the responsibilities of homeownership with all the disadvantages of renting" (Coates 2014).

46. **Expansion of tenure forms that preserve the affordability that comes from owning one's home separately from land but without the insecurity** – Three potential approaches here are cooperative ownership of land — or land trust — nonprofit or public ownership of land.

47. **Right of first refusal** – This would obligate community owners to sell to residents if they are able to match the terms of another offer.

48. **Greater lending support for residents who would like to create a cooperative park** – For example, currently, community development financial institutions, like ROC USA Capital, do not receive the same level of support from government-sponsored enterprises (Fannie Mae and Freddie Freddie Mac) through Duty to Serve as corporate lenders and purchasers often do.

49. **Support for real estate conversions** – Many states allow for the conversion of personal property in parks into real estate, but the practice is rare. For many this could confer the advantages of traditional homeownership on mobile home owners in parks.

50. **Tailor home improvement lending products for housing titled as personal property** – Currently, many only apply to manufactured housing titled as real estate or mortgagees. Programs tailored to housing titled as personal property should be created.

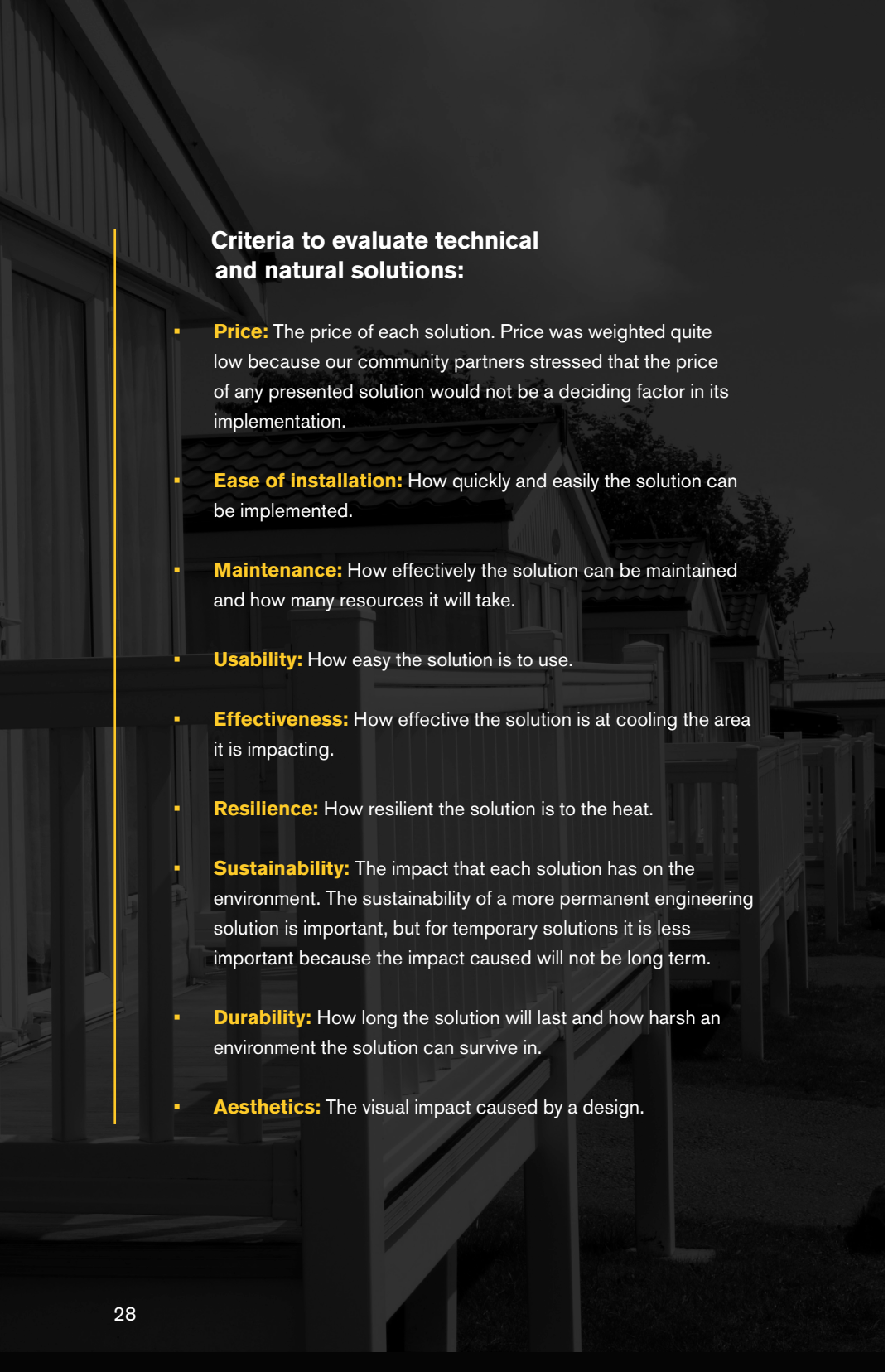
Guidelines and decision matrix to select solutions and estimate their efficiency.

Even though there are numerous ways to mitigate heat, the issue itself still exists partly because of the poor selection and implementation of solutions. All solutions mentioned above have different levels of benefits they can provide. In addition, they all require different resources to be implemented. Since there is a significant number of heat mitigation solutions, the decision of which solutions to pursue should be based on the following guidelines to ensure the most optimal use of resources and maximum benefits. To support decision-making, we developed a multistage process to evaluate and select solutions that will provide the most optimal results.

Since solutions exist within different groups and provide benefits on different scales, it may seem challenging to evaluate which suite of solutions will be the most feasible and effective. To support the decision making process, we developed helpful evaluation criteria based on the most important factors for successful heat mitigation. In our approach, we divide solutions into two groups for evaluation, based on the different criteria used to measure them: (1) technical and natural solutions and (2) policy and community-based solutions. Thus, each group of solutions can be analyzed using appropriate criteria.

Technical and natural solutions evaluation

To analyze the technical and natural solutions, we developed nine evaluation criteria based on our knowledge and expertise. First, using an analytic hierarchy process (AHP) we developed a decision matrix to represent the weight each criterion has in comparison to other criteria, as some criteria are more important than others. Below, there is a description of each criterion to evaluate solutions. The AHP decision matrix can be found in the appendix as Table A-1.



Criteria to evaluate technical and natural solutions:

- **Price:** The price of each solution. Price was weighted quite low because our community partners stressed that the price of any presented solution would not be a deciding factor in its implementation.
- **Ease of installation:** How quickly and easily the solution can be implemented.
- **Maintenance:** How effectively the solution can be maintained and how many resources it will take.
- **Usability:** How easy the solution is to use.
- **Effectiveness:** How effective the solution is at cooling the area it is impacting.
- **Resilience:** How resilient the solution is to the heat.
- **Sustainability:** The impact that each solution has on the environment. The sustainability of a more permanent engineering solution is important, but for temporary solutions it is less important because the impact caused will not be long term.
- **Durability:** How long the solution will last and how harsh an environment the solution can survive in.
- **Aesthetics:** The visual impact caused by a design.

Next, using the weighting factor from the AHP decision matrix, we evaluated each solution to find the most optimal ones. Based on our knowledge and expertise, we evaluated each solution on a five-point scale according to our nine criteria, and we then multiplied the scores by the weighting factor. This allowed us to select the most optimal solutions. A scoring rubric for each criterion and a table with all evaluated solutions can be found in the appendix as Table A-2 and Table A-3 accordingly. Below are the final tables (Tables 1 and 2) presenting all evaluated solutions, including their scores, benefits and approximate price to implement.

Table 1. Cost and benefit of evaluated technical solutions

Technical solutions	Score	Cost	Benefits
External insulated finishing or stucco systems	4.718	$5,000–$7,000 for 1 mh	Better insulation, lower temperature inside, less energy to cool down, smaller electric bill
PDRC	4.597	Unknown	Roof absorbs less heat, lower temperature inside, less energy to cool down, smaller electric bill
Air sealing the home	4.596	$350–$600	Better insulation, lower temperature inside, less energy to cool down, smaller electric bill
Cool pavements	4.201	$0.1–10 per sq ft	Reduce the temperature of the urban environment
Swamp coolers	4.484	$250	More efficient models cool down better and use less energy
Skirting	4.475	$1,500 for 1 mh	Better insulation, lower temperature inside, less energy to cool down, smaller electric bill
Shade sails	4.443	$20,000 for 1 mh	Additional shading, dwelling consumes less heat, lower temperature inside, less energy to cool down, smaller electric bill

Table 1 continued. Cost and benefit of evaluated technical solutions

Technical solutions	Score	Cost	Benefits
Window film	4.275	$50 for one window	Dwelling heats up less, lower temperature inside, less energy to cool down, smaller electric bill
Solar (PV) canopies	4.210	$430,000 for 40 mh	Additional shading, dwelling absorbs less heat, lower temperature inside, less energy to cool down, additional electricity from solar, smaller electric bill
LED lights	4.202	$40 for one light	Efficient energy use, smaller electric bill
Mechanical trees	4.201	Unknown	Reduce carbon dioxide emissions, reduce the temperature of the urban environment
Curtains	4.193	$50–$100 for one item	Dwelling heats up less, lower temperature inside, less energy to cool down, smaller electric bill
Shutters or other external window covering	4.193	$50–$200 for one item	Dwelling heats up less, lower temperature inside, less energy to cool down, smaller electric bill
Shade awnings	4.193	$250 for one (Walmart)	Dwelling heats up less, lower temperature inside, less energy to cool down, smaller electric bill
Reflective coatings	4.153	$1.50 per sq ft	Roof absorbs less heat, lower temperature inside, less energy to cool down, smaller electric bill
Portable air conditioning	4.081	$150	More efficient models cool down better and use less energy
Misters	3.887	$2,000 for 1 mh	Reduce the temperature of the urban environment
Proximity of structures to each other for shading, ventilation	3.750	Difficult to estimate	Natural cooling of the whole park Natural cooling of the whole park
Site orientation optimization for cooling	3.750	Difficult to estimate	Natural cooling of the whole park
Heat pumps	3.719	$600	More efficient models cool down better and use less energy
High efficiency appliances	3.355	Varies based on type	Efficient energy use, smaller electric bill

Table 2. Cost and benefit of evaluated natural solutions

Natural solutions	Score	Cost	Benefits
Trees	4.532	$200 for one tree	Reduce the temperature of the urban environment
Replacing pavement and asphalt with soil and plants	4.411	$5–$35 per sq ft	Reduce the temperature of the urban environment
Green or living walls	4.330	$75–$125 per sq ft	Reduce the temperature of the urban environment

Policy solutions, community-based solutions and innovative financial products and opportunities evaluation

For policy and community-based solutions we developed another set of evaluation criteria along with an AHP decision matrix. Below there is a description of each criterion to evaluate solutions. The AHP decision matrix can be found in the appendix as Table A-4

Criteria to evaluate policy solutions, community-based solutions and innovative financial products and opportunities:

- **Time to develop:** How fast the policy or community actions can be developed.
- **Price:** The price of each solution.
- **Ease of development:** How difficult it is to develop and apply the policy, how many stakeholders and decision makers should be involved.
- **Effectiveness:** How well the solution works for heat mitigation.
- **Resilience:** How well the solutions help to build heat resilience.
- **Support of other solutions:** How the policy correlates with other solutions and how many opportunities to implement other solutions it can offer.
- **Maintenance:** How effectively the solution can be maintained and kept, how many resources it will take.

Consistent with the previous group of solutions, each solution has been evaluated on the five-point scale according to the seven criteria above. Then the scores were multiplied by the weighting factor. This allowed us to select the most optimal solutions. A scoring rubric for each criterion and a table with all evaluated solutions can be found in the appendix as Table A-5 and Table A-6 accordingly. Below is a final table presenting all evaluated solutions, including their score and benefits.

Table 3. Benefits of evaluated policy and community-based solutions

Policy and community-based solutions	Score	Benefits
Energy efficiency standards and requirements	4.512	Improve the construction of mobile homes, better insulation of the homes
Revise or update utility assistance programs and policies to reclassify “mobile”	4.512	Affordable electricity for mobile home residents, reduce heat deaths
Improve the building envelope program, and tailor this program to mobile homes	4.386	Improve energy efficiency, less susceptible to extreme heat conditions
Develop or increase shade via zoning requirements	4.268	Provide additional shading, reduce heat exposure
Utility conversion program	4.260	More efficient electricity use, smaller electric bills
Educate public health officials and emergency responders about special vulnerability in mobile homes	4.252	Educate and improve social awareness about heat, opportunity to develop other solutions
Draft statewide legislation that institutes utility shutoff protection	4.205	Provide electricity during heat waves, prevent heat deaths
Home improvement loans	4.071	Affordable housing, improve building conditions of mobile homes

Table 3 continued. Benefits of evaluated policy and community-based solutions

Policy and community-based solutions	**Score**	**Benefits**
Create policies and financial incentives that facilitate the creation of resident-owned cooperative housing	3.953	Provide a pathway to land ownership for mobile home residents, open opportunities for other solutions
Early detection warning system to notify friends, family and caretakers when a home is getting too hot	3.449	Prevent heat deaths
Heat-resilient community center	3.378	Provide heat-resilient environment, prevent heat deaths
Free or subsidized transportation options	3.126	Provide heat-resilient environment, prevent heat deaths
Mutual aid networks	3.126	Provide heat-resilient environment, prevent heat deaths
Social infrastructure and community engagement	3.126	Provide heat-resilient environment, prevent heat deaths
Put information into AARP bulletin to raise awareness	3.126	Create heat-resilient environment, educate and improve social awareness about the heat, opportunity to develop other solutions
Outreach and education programs with mobile home parks	3.063	Create heat-resilient environment, educate and improve social awareness about the heat, opportunity to develop other solutions
Small or pop-up cooling centers within communities	2.937	Provide heat-resilient environment, prevent heat deaths
Door-to-door wellness checks by government employees and community groups	2.929	Prevent heat deaths

Table 4. Benefits of evaluated innovative financial products and opportunities

Innovative financial products and opportunities	**Score**	**Benefits**
Expansion of tenure forms	4.512	Provide additional protection and open room for other solutions
Support for real estate conversions	4.386	Increase affordability of mobile homes
Greater consumer protections for mobile home buyers	4.378	Provide additional protection and open room for other solutions
Tailor home improvement lending products for housing titled as personal property	4.323	Increase affordability of mobile homes, provide financial protection and stability
Support for small-dollar home lending markets	4.197	Provide additional protection and open room for other solutions
Greater lending support for the creation of cooperative mobile home parks	4.071	Increase affordability of mobile homes, provide financial protection and stability
Right of first refusal	3.992	Provide additional protection and open room for other solutions

This chapter described the approach to evaluate solutions for successful heat mitigation. This issue is so complex that it requires a multifaceted approach across different categories of solutions. The evaluation process allows us to distribute resources more effectively by picking the most optimal solution instead of one that just seems cheap or easy to implement. Since there are numerous stakeholders with different resources and goals, they will pick the most optimal solution out of the scope of solutions that are relevant for them. Thus, the next step is to pick solutions based on the evaluation results.

4

How to build a set of solutions

Since multiple factors contribute to heat vulnerability, one single solution cannot guarantee optimal heat mitigation. Moreover, there is no one solution that can solve the entire issue of heat exposure of mobile homes. Unfortunately, implementation of only one solution may actually be a waste of resources, since it will not provide significant benefits on its own. Another challenge is that stakeholders have different reach, goals and capacity, which usually dictates the scale of cost and benefits they can bear. In addition, the application of some solutions by one group would benefit from the application of other solutions by a different group. Thus, the most successful heat mitigation process will happen via collective decision-making. This requires a complex approach to implementing multiple solutions. As such, we propose creating packages of solutions depending on available resources and the capacity of stakeholders implementing the solutions.

The concept of collective decision-making in the framework of heat mitigation actions looks something like Figure 3. Green space represents the most common approach and thinking in solving problems, where costs and benefits involve the same stakeholder. Most of the design solutions will be in this space. The orange area represents solutions with small-scale costs but a larger, more diffuse scale of benefits. An example of this is a household property tax that is aggregated for the benefit of neighborhoods and cities. Yellow represents solutions with large-scale costs and benefits for distinct people and places. An example of this is assistance and aid programs (Solís, Varfalameyeva, 2021).

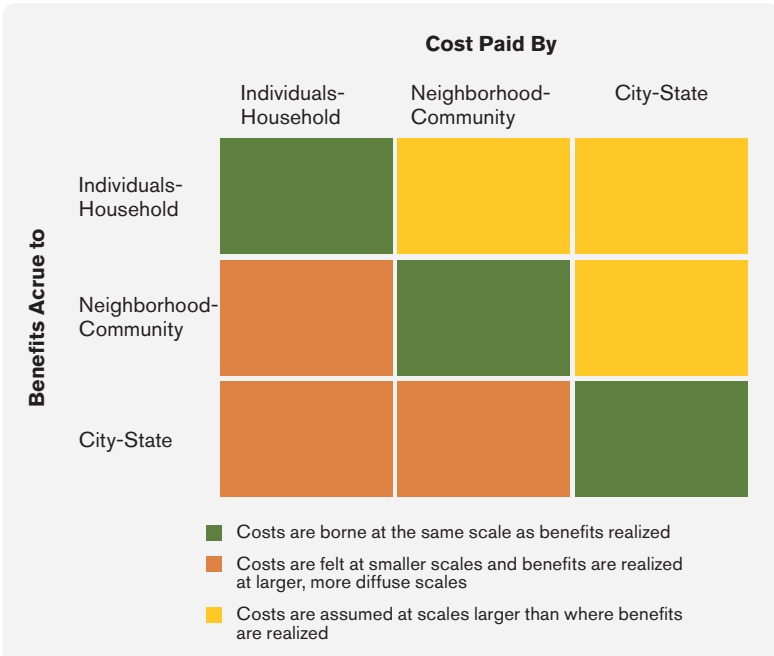


Figure 3. Scales of decision making (see Solís, Vanos & Forbis, 2017).

The creation of solutions packages should be based not only on the decision matrix, but also on the scale of the solutions (i.e., the individual-household scale, the neighborhood-community scale, or the city-state scale). All provided solutions belong to a different scale depending on who implements them, who bears the costs, and who shares the benefits. Thus, the first step to creating a package of solutions is to decide the scale. The following table (Table 5) illustrates groups of solutions at different scales along with their efficiency scores.

Table 5.1. Representation of solutions on different scales according to cost-benefit relationships along with their scores

Spatial congruence matrix of broader solutions set for heat-resilient mobile homes

Individual-Household	**Individual-Household**
	4.718 – External insulated finishing or stucco systems
	4.596 – Air sealing the home
	4.484 – Swamp coolers
	4.475 – Skirting
	4.275 – Window films
	4.202 – LED lights
	4.193 – Curtains
	4.193 – Shutters or other external window covering
	4.193 – Shade awnings
	4.081 – Portable air conditioning
	3.719 – Heat pumps
	Neighborhood-Community
	4.597 – Passive Daytime Radiative Cooling (PDRC)
	4.153 – Reflective coatings (white coat)
	3.449 – Park-controlled early detection warning system to notify friends, family and caretakers when a home gets too hot
	2.937 – Small or pop-up cooling centers within communities
	City-State
	3.126 – Free or subsidized transportation options to help community members access cooling centers
	3.126 – Share information in AARP bulletin to raise awareness
	2.929 – Door-to-door wellness checks by government employees or community groups

Table 5.2. Representation of solutions on different scales according to cost-benefit relationships along with their scores

Neighborhood-Community	**Individual-Household**
	3.449 – Personal heat warning systems or personal alert notifications using internet of things devices
	Neighborhood-Community
	4.532 – Trees 4.443 – Shade sails 4.411 – Replacing pavement and asphalt with soil and plants 4.330 – Green or living walls 4.210 – Solar (PV) canopies 4.201 – Cool pavements 4.201 – Mechanical trees 3.887 – Outdoor evaporative cooling (misters) +Solar pavements
	City-State
	4.386 – Improve the building envelope program, and tailor this program to mobile homes 3.378 – Resilience hubs and heat-resilient community centers 3.063 – Outreach and education programs with mobile home parks

Table 5.3. Representation of solutions on different scales according to cost-benefit relationships along with their scores

City-State	**Individual-Household**
	4.205 – Utility moratorium on shut-offs during hottest summer days
	Neighborhood-Community
	3.126 – Social infrastructure and community engagement 3.126 – Mutual aid networks
	City-State
	4.512 – Revise or update utility assistance programs and policies to reclassify “mobile” 4.512 – Energy efficiency standards and requirements 4.268 – Develop or increase shade via zoning requirements 4.260 – Utility conversion program 4.252 – Educate public health officials and emergency responders about special vulnerability in mobile homes 4.205 – Draft statewide legislation that institutes utility shutoff protections 4.071 – Home improvement loans 3.953 – Create policies and financial incentives that facilitate the creation of resident-owned cooperative housing

Different packages of solutions will provide the desired cost and benefit for different scales. First, those who are going to implement the solutions — stakeholders — should determine what scale of resources they have and what scale of benefits they want to get. After this, they should pick solutions appropriate to their scale of cost and benefits. The combination of the solutions into one package should be based on the evaluation of each solution presented earlier in the guide. As such, we suggest combining the most optimal solutions with higher scores. However, based on the resources available for implementation, the number of solutions inside the package can vary. As an example, we built packages of solutions for two different scales — individual mobile home owners and renters, as well as mobile home park owners.

Packages of solutions

This is a situation in which individual mobile home owners or renters in the community improve their own units. They bear the costs and the benefits. To motivate and assist owners and renters in making these changes, the funds could be subsidized or provided by someone else (e.g., park owner, community organization). At this scale, we selected all the solutions based on Table 5. We calculated the cost of the solutions for a medium-sized 2,000-square-foot. mobile home with four windows. Package 1 provides the largest possible benefit through the application of all solutions at their maximum level. In addition, we built three other more affordable packages by excluding less efficient solutions or by applying some solutions on a smaller scale. Table 6 illustrates four packages of solutions along with their associated costs. Regardless of the solutions package, individual mobile home owners and renters get significantly improved construction of their mobile homes, resulting in smaller utility bills, as less energy will be needed to cool down the homes.

Scale 1: Individual mobile home owners and renters

Table 6. Packages of solutions for individual mobile home owners and renters

Solutions			
Package 1	**Package 2**	**Package 3**	**Package 4**
Air sealing the home at the maximum level	Air sealing the home at the maximum level	Air sealing the home at the minimum level	Air sealing the home at the minimum level
Foam insulation	Foam insulation with cheaper materials	Foam insulation with cheaper materials	—
Swamp coolers	Swamp coolers	Swamp coolers	Swamp coolers
Skirting	Skirting with cheaper materials	Skirting with cheaper materials	—
4 Window films and window tinting	2 Window films and window tinting	—	2 Window films and window tinting
3 LED lights	3 LED lights	3 LED lights	3 LED lights
4 Curtains	2 Curtains	—	2 Curtains
4 Shutters or other external window covering	2 Shutters or other external window covering	—	2 Shutters or other external window covering
4 Shade awnings	2 Shade awnings	2 Shade awnings	2 Shade awnings
Portable air conditioning	—	—	—

Cost			
$10,420	**$5,770**	**$4,970**	**$1,620**
—	The costs were reduced by eliminating some improvements, by reducing the scale of application of some improvements, and by using cheaper materials.	The costs were reduced by eliminating some improvements, reducing by half the scale of application of some improvements, and by using cheaper materials.	The costs were reduced by eliminating some improvements, reducing by half the scale of application of some improvements, and by using cheaper materials.
Effectiveness			
100%	**90%**	**62%**	**62%**
Benefits: Better insulation, dwelling heats up less, lower temperature inside, less energy to cool down, smaller electric bill			

Scale 2: Mobile home park owners

This is a situation in which mobile home park owners apply heat-resilient solutions to the entire park. They bear the cost, but the benefit will be divided between owners and residents. To motivate owners to make these changes, the funds could be subsidized or provided by community organizations or sponsors. At this scale we also selected all of the solutions based on Table 5 and calculated the cost of the solutions for a medium-sized mobile home park with 250 mobile homes. Package 1 provides the largest possible benefit through the application of all solutions at the maximum level. In addition, we built two other more affordable packages by excluding less efficient solutions or by applying some solutions for half of the park. Table 7 illustrates three packages of solutions along with their associated costs. The whole park and each individual resident of the park will benefit from these investments. Solutions at this scale will improve the urban environment of the park by reducing the temperature of the urban environment through less heat exposure and additional shading and vegetation and less heat. As a result, individual mobile homes will require less electricity to cool down.

Scale 2: Mobile home park owners

Table 7. Packages of solutions for mobile home park owners

Solutions		
Package 1	**Package 2**	**Package 3**
Solar (PV) canopies	Solar (PV) canopies	Solar (PV) canopies for 50% of the park
Shade sails	Shade sails	Shade sails for 50% of the park
Reflective coatings (white coat)	Reflective coatings (white coat)	Reflective coatings (white coat)
Outdoor evaporative cooling (misters)	Outdoor evaporative cooling (misters)	Outdoor evaporative cooling (misters)
Cool pavement	Cool pavement	Cool pavements with cheaper materials
Trees	Trees	Trees
Replacing pavement and asphalt with soil and plants	Replacing pavement and asphalt with soil and plants using cheaper materials	Replacing pavement and asphalt with soil and plants using cheaper materials
Green or living walls	Green or living walls	Green or living walls for 50% of the park
Solar pavements	—	—

Table 7 continued. Packages of solutions for mobile home park owners

Cost		
$13,130,860	**$6,430,860**	**$3,802,680**
—	The costs were reduced by eliminating some improvements, by reducing the scale of application of some improvements, and by using cheaper materials.	The costs were reduced by eliminating some improvements, by reducing the scale of application of some improvements, and by using cheaper materials.
Effectiveness		
100%	**82%**	**60%**
Benefits: Reduce the temperature of the urban environment, additional shading, dwelling consume less heat, lower temperature inside, less energy to cool down, additional electricity from solar, smaller electric bill		

The same exercise can be performed to combine solutions for other scales. However, it is important to note that one group of solutions could require support from another group of solutions. For example, to use the solar energy from solar canopies it will be necessary to support this solution with broader policies.

5

Solution application

Mobile homes in Maricopa County

There are 92,031 mobile homes in Maricopa County, which is 5.2% of the total housing stock. These homes are located in approximately 686 mobile home parks spread throughout different parts of the Phoenix Metropolitan Area, usually on the outskirts or in less valuable areas (Fig. 4). There is a cluster of mobile home parks in the Mesa area, on the right corner of the map, where we selected several parks for collaboration and for our first pilot projects.

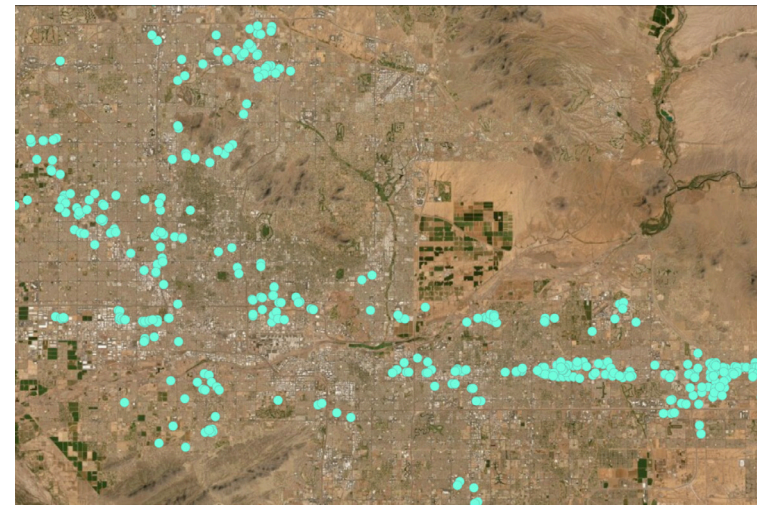


Figure 4. Mobile home parks around Phoenix Metropolitan Area, 2020

Mobile home park model example

This chapter provides an example of how the described approach could be applied in a particular case. Students have been working on collaborating and developing solutions for specific parks. One of the parks is Parkhaven Estates mobile home park located at 306 S Recker Rd, Mesa, AZ 85206. This 900,000 square feet mobile home park was built in 1980 as a 55+ community. The approximate capacity of this park is 288 spots total where 250 of those are mobile homes, and the rest are RVs. It also has a leasing office and community center with a pool (Fig. 5).

As with many other mobile home parks, Parkhaven Estates has high heat vulnerability due to factors that include:

- **High density** – Houses are located extremely close to each other without any back or front yards.
- **A lot of impervious surfaces** – The whole area of the park is covered with roads.
- **Very little vegetation** – There is a very low number of trees near the leasing office and along Recker Rd. Approximately 99% of the park has no trees or any other form of vegetation.
- **Lack of shading** – There are no forms of additional shading around mobile homes.
- **Construction of the mobile homes** – Many of the mobile homes are older models that were not constructed to modern energy efficiency standards

To pick the solutions set for this park, it was assumed that the mobile home park owner would invest into solutions with the goal of providing benefits for the community. For this scale, we selected the top three solutions from different categories: trees, shade sails and solar (PV) canopies. Then we calculated the cost to implement these solutions for the whole park.

1. **Trees**
   A Chicago study found that increasing tree cover by 10% could lower total heating and cooling energy use by 5–10% ($50–$90 per dwelling unit) (McPherson et al., 1997). Thus we need at least 900,000*10% = 90,000 square feet of tree coverage. One tree with a small canopy covers an area of 400 square feet.; therefore we should plant 90,000/400 = 225 trees minimum. The cost will be $200*225 = **$45,000**.

2. **Solar canopies**
   These structures are designed to be similar to carports in that they cover several mobile homes at once. The approximate size of one structure is 19,000 square feet, which will cover approximately 14 mobile homes. One solar canopy structure will fit 1,000 solar panels that will produce 320 kW of energy and power 40 mobile homes (one home needs ~25 panels). Thus, to power this park we need six structures, which will cost $430,560*6 = **$2,583,360**. As a benefit, 84 mobile homes will have shading structures on top of them, and the whole park will have solar electricity.

3. **Shading structures**
   After applying solar canopies there will be 166 mobile homes left without shade coverage. For this project we decided to use shading structures that could cover two mobile homes at once. This means that we need 166/2 = 83 shading structures. This will result in a $20,000*83 = **$1,660,000** investment. As a benefit, all mobile homes will have additional shading which reduces heat in the house, the amount of energy required to cool the house down and utility costs.

The total investment to improve the heat resilience of the Parkhaven Estates mobile home park will be $4,288,360. The main benefits will be solar energy, reducing cooling energy use by 5–10% and saving $50–$90 in utility costs per dwelling unit (Fig. 6).

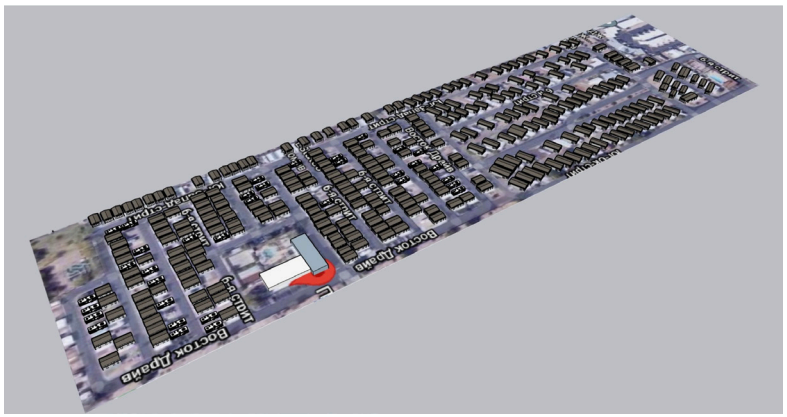


Figure 5. Parkhaven Estates mobile home park 3D model before implementing solutions

Figure 6. Parkhaven Estates mobile home park 3D model after implementing solutions

The implementation of these solutions, however, requires support from other stakeholders. Park owners, for instance, could be incentivized to make these changes through updated regulations or subsidies, and financial assistance or financing tools could address cost challenges. Beyond the goal of decreasing heat-related illness and death in mobile homes, stakeholders can also be incentivized by the positive externalities associated with implementing solutions. For example, if utility companies invest in solar canopies, they may reap the future benefit of buying electricity from the park.

Although the cost of implementing solution packages may seem steep, it is a necessary investment to protect some of Maricopa County's most vulnerable residents. To that end, **it is essential that any solutions that get implemented do not increase mobile home residents' vulnerability.** For instance, if costs are passed down to residents in the absence of financial assistance, some residents may end up homeless due to not being able to afford improvements or lot rental costs. Further, indoor heat-related deaths in mobile homes may actually increase if residents are forced to shift limited funds towards improvements or rent, thus limiting what they can afford in terms of utility use. Balancing mobile home residents' capacity with their need for heat mitigation underscores the complex nature of heat mitigation; solutions may not achieve the desired objective if they are not supported by financing, policies and regulations aimed at limiting negative externalities.

Candidate site for the pilot project

With the goal of starting to implement solutions, we selected La Rancheria mobile home park in Phoenix as the candidate site (Fig. 7). This park has 109 mobile homes and was built in 1955 as a 55+ community. It is a highly populated park, as 44% of households have three to four members, and the same percentage of households have more than five members living in a home. However, 60% of households have only one member employed, and only 30% of households have two members employed. Almost all residents of the park — 98% — are of Hispanic ethnicity. Around 80% of residents rent their mobile homes.

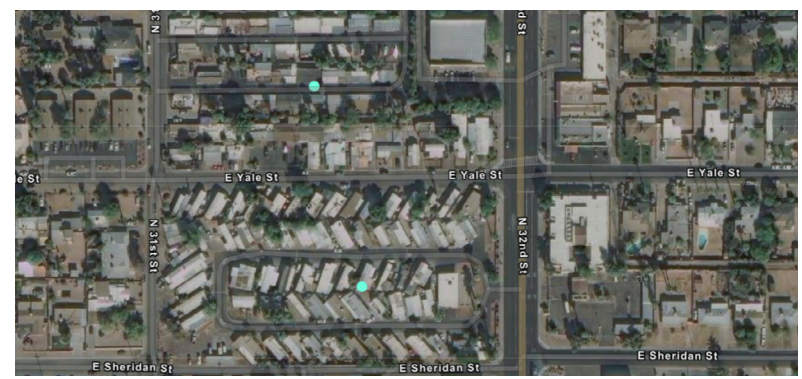


Figure 7. La Rancheria mobile home park, Phoenix

Taking into account that residents of this community have no personal funding for home improvements, and since the majority of mobile homes are owned by the park, the investments into heat-resilient solutions should be made by the park owner and other interested investors. In light of this, we combined packages of solutions from both levels — individual homeowner and park owner. We revisited all of the solutions and picked the most appropriate for this park. For instance, we excluded natural solutions, as there is no space in this park for additional vegetation. We combined the most optimal solutions from both solution sets and calculated the implementation cost, which can be found in Table 8. Improving the construction of mobile homes, along with creating a cooling environment, will significantly increase the heat resilience of this community.

Table 8. Heat-resilient solutions for La Rancheria mobile home park, Phoenix

Solution	Cost for the whole park
Solar (PV) canopies for 50% of the park	$1,291,680
Shade sails for 50% of the park	$500,000
Reflective coatings (white coat)	$162,500
Outdoor evaporative cooling (misters)	$200,000
Cool pavements with cheaper materials	$43,000
Air sealing the home at the minimum level	$35,000
Foam insulation with cheaper materials	$300,000
Total Cost	**$2,532,180**
Effectiveness	**80%**

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Appendix

Table A-1. AHP decision matrix for technical and natural solutions

Design Criteria

	Price	Ease of installation	Maintenance	Useability	Effectiveness
Price	1	0.5	0.33	0.25	0.2
Ease of installation	2	1.0	0.67	0.50	0.4
Maintenance	3	0.6	1.00	0.75	0.6
Useability	4	2.0	1.33	1.00	0.8
Effectiveness	5	2.5	1.67	1.25	1.0
Resilience	4	2.0	1.33	1.00	0.8
Sustainability	3	1.5	1.00	0.75	0.6
Durability	2	1.0	0.67	0.50	0.4
Aesthetic	1	0.5	0.33	0.25	0.2
Total					

Design Criteria

Resilience	Sustainability	Durability	Aesthetic	**Total**	**Weighting factor**
0.25	0.33	0.5	1	4.370	**0.040**
0.50	0.67	1.0	2	8.730	**0.081**
0.75	1.00	1.5	3	12.20	**0.113**
1.00	1.33	2.0	4	17.47	**0.161**
1.25	1.67	2.5	5	21.83	**0.202**
1.00	1.33	2.0	4	17.47	**0.161**
0.75	1.00	1.5	3	13.10	**0.121**
0.50	0.67	1.0	2	8.730	**0.081**
0.25	0.33	0.5	1	4.370	**0.040**
				108.27	**1.000**

Table A-2. Scoring rubric for technical and natural solutions

	Score				
Criteria	**1**	**2**	**3**	**4**	**5**
Price	very expensive	medium price	affordable	cheap	free or very cheap
Ease of installation	professional assistance needed, difficult to install	somewhat difficult	not difficult	easy	very easy
Maintenance	high regular, requires other resources	regular, requires other resources	low regular	low	not needed
Useability	professional assistance needed, difficult	somewhat difficult	not difficult	easy	very easy
Effectiveness	low effectiveness or none	slightly effective	somewhat effective	very effective, decrease temp	extremely effective, provides extra benefits
Resilience	not resilient	low resilience	somewhat resilient	very resilient	extremely resilient
Sustainability	not sustainable, dangerous	not sustainable	somewhat sustainable	very sustainable	extremely sustainable, improves the environment
Durability	very fragile, easily destroyed by heat	will last less than one year	will last several seasons	will last more than five years	extremely durable
Aesthetic	decreases aesthetic of the buildings	slightly decreases aesthetic of the buildings	doesn't influence	slightly improves	significantly improves

Table A-3. Evaluated technical and natural solutions

		Air sealing the home		Curtains		Shutters or other external window covering		External insulated finishing or stucco systems		Heat pumps		High efficiency appliances	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total
Price	**0.040**	3	0.120	4	0.160	3	0.120	3	0.120	3	0.120	2	0.080
East of installation	**0.081**	1	0.081	5	0.405	3	0.243	4	0.324	4	0.324	3	0.243
Maintenance	**0.113**	5	0.565	5	0.565	5	0.565	5	0.565	4	0.452	4	0.452
Useability	**0.161**	5	0.805	5	0.805	5	0.805	5	0.805	4	0.644	4	0.644
Effectiveness	**0.202**	5	1.010	2	0.404	3	0.606	5	1.010	4	0.808	3	0.606
Resilience	**0.161**	5	0.805	4	0.644	4	0.644	5	0.805	3	0.483	3	0.483
Sustainability	**0.121**	5	0.605	5	0.605	5	0.605	4	0.484	3	0.363	3	0.363
Durability	**0.081**	5	0.405	5	0.405	5	0.405	5	0.405	5	0.405	4	0.324
Aesthetic	**0.040**	5	0.200	5	0.200	5	0.200	5	0.200	5	0.120	4	0.160
Total	**1**		**4.596**		**4.193**		**4.193**		**4.718**		**3.719**		**3.355**

Table A-3 continued

		Air sealing the home		Curtains		Shutters or other external window covering		External insulated finishing or stucco systems		Heat pumps		High efficiency appliances	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total
Price	**0.040**	3	0.120	4	0.160	3	0.120	3	0.120	3	0.120	2	0.080
East of installation	**0.081**	1	0.081	5	0.405	3	0.243	4	0.324	4	0.324	3	0.243
Maintenance	**0.113**	5	0.565	5	0.565	5	0.565	5	0.565	4	0.452	4	0.452
Useability	**0.161**	5	0.805	5	0.805	5	0.805	5	0.805	4	0.644	4	0.644
Effectiveness	**0.202**	5	1.010	2	0.404	3	0.606	5	1.010	4	0.808	3	0.606
Resilience	**0.161**	5	0.805	4	0.644	4	0.644	5	0.805	3	0.483	3	0.483
Sustainability	**0.121**	5	0.605	5	0.605	5	0.605	4	0.484	3	0.363	3	0.363
Durability	**0.081**	5	0.405	5	0.405	5	0.405	5	0.405	5	0.405	4	0.324
Aesthetic	**0.040**	5	0.200	5	0.200	5	0.200	5	0.200	5	0.120	4	0.160
Total	**1**		**4.596**		**4.193**		**4.193**		**4.718**		**3.719**		**3.355**

Table A-3 continued

		Shade awnings		Shade sails	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total
Price	**0.040**	3	0.120	2	0.080
East of installation	**0.081**	2	0.162	1	0.081
Maintenance	**0.113**	5	0.565	4	0.452
Useability	**0.161**	5	0.805	5	0.805
Effectiveness	**0.202**	4	0.808	4	1.010
Resilience	**0.161**	4	0.644	4	0.805
Sustainability	**0.121**	4	0.484	5	0.605
Durability	**0.081**	5	0.405	5	0.405
Aesthetic	**0.040**	5	0.200	5	0.200
Total	**1**		**4.193**		**4.443**

Site orientation optimization for cooling		Skirting		Solar (PV) canopies		Swamp coolers	
Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1 –5)	Total
1	0.040	3	0.120	1	0.040	4	0.160
1	0.081	3	0.243	1	0.081	4	0.324
5	0.565	5	0.565	3	0.339	4	0.452
5	0.805	5	0.805	5	0.805	5	0.805
3	0.606	4	0.808	5	1.010	4	0.808
4	0.644	5	0.805	5	0.805	5	0.805
4	0.484	5	0.605	5	0.605	5	0.605
5	0.405	4	0.324	5	0.405	5	0.405
3	0.120	5	0.200	3	0.120	3	0.120
	3.750		**4.475**		**4.21**		**4.484**

Table A-3 continued

		Window film		Cool pavements	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total
Price	**0.040**	4	0.160	1	0.040
East of installation	**0.081**	5	0.405	1	0.081
Maintenance	**0.113**	5	0.565	4	0.452
Useability	**0.161**	5	0.805	5	0.805
Effectiveness	**0.202**	3	0.606	4	0.808
Resilience	**0.161**	4	0.644	5	0.805
Sustainability	**0.121**	5	0.605	5	0.605
Durability	**0.081**	5	0.405	5	0.405
Aesthetic	**0.040**	2	0.080	5	0.200
Total	**1**		**4.275**		**4.201**

Mechanical trees		Green or living walls		Replacing pavement and asphalt with soil and plants		Trees	
Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1 –5)	Total
2	0.080	2	0.080	2	0.080	3	0.120
1	0.081	2	0.162	2	0.162	4	0.324
4	0.452	3	0.339	3	0.339	3	0.339
5	0.805	5	0.805	5	0.805	5	0.805
4	0.808	5	1.010	5	1.010	5	1.010
5	0.805	5	0.805	5	0.805	5	0.805
5	0.605	5	0.605	5	0.605	5	0.605
5	0.405	4	0.324	5	0.405	4	0.324
4	0.160	5	0.200	5	0.200	5	0.200
	4.201		**4.330**		**4.411**		**4.532**

Table A-4. AHP decision matrix for policy and community-based solutions

Policy criteria

	Time to develop	Price	Ease of development	Effectiveness
Time to develop	1	0.5	0.33	0.25
Price	2	1.0	0.67	0.50
Ease of development	3	1.0	1.00	0.75
Effectiveness	4	2.0	1.33	1.00
Resilience	3	1.5	1.00	0.75
Support of other solutions	2	1.0	0.67	0.50
Maintenance	1	0.5	0.33	0.25
Total				

Policy criteria

Resilience	Support of other solutions	Maintenance	**Total**	**Weighting factor**
0.33	0.5	1.00	3.92	**0.063**
0.67	1.0	2.00	7.83	**0.126**
1.00	1.5	3.00	11.25	**0.181**
1.33	2.0	4.00	15.67	**0.252**
1.00	1.5	3.00	11.75	**0.189**
0.67	1.0	2.00	7.83	**0.126**
0.33	0.5	1.00	3.92	**0.063**
			62.17	**1.000**

Table A-5. Scoring rubric for the policy and community-based solutions

Score

Criteria	**1**	**2**
Time to develop	requires more than 12 months	requires 6–12 months
Price	very expensive	medium price
Ease of developing	requires many decision-makers to be involved	somewhat difficult
Effectiveness	low effectiveness or none	slightly effective
Resilience	does not contribute to resilience	slightly effective
Support of other solutions	doesn't correlate with other solutions	potential support for other solutions
Maintenance	high regular, requires other resources	regular, requires other resources

Score

3	**4**	**5**
requires 3–6 months	Requires up to two months	can be developed right away
affordable	cheap	free or very cheap
not difficult	easy	very easy
somewhat effective	very effective, decreases temperature	extremely effective, provides extra benefits
somewhat improved resilience	improved resilience	significantly improved resilience
supports only one solution	provides some support for other solutions	crucial to implement other solutions
low regular	low	not needed

Table A-6. Evaluated policy and community-based solutions

		Small or pop-up heat relief centers within communities		Free or subsidized transportation options		Door-to-door wellness checks by government employees or community groups		Improve the building envelope program, and tailor this program to mobile homes		Outreach and education programs with mobile home communities		Revise and update utility assistance programs and policies to reclassify "mobile"	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total
Time to develop	**0.063**	3	0.189	4	0.252	4	0.252	3	0.189	4	0.252	3	0.189
Price	**0.126**	3	0.378	3	0.378	3	0.378	5	0.630	4	0.504	5	0.630
Ease of developing	**0.181**	3	0.543	3	0.543	4	0.724	3	0.543	3	0.543	3	0.543
Effectiveness	**0.252**	3	0.756	3	0.756	3	0.756	5	1.260	3	0.756	5	1.260
Resilience	**0.189**	4	0.756	4	0.756	3	0.567	5	0.945	4	0.756	5	0.945
Support of other solutions	**0.126**	1	0.126	2	0.252	1	0.126	4	0.504	1	0.126	5	0.630
Maintenance	**0.063**	3	0.189	3	0.189	2	0.126	5	0.315	2	0.126	5	0.315
Total	**1**		**2.937**		**3.126**		**2.929**		**4.386**		**3.063**		**4.512**

Table A-6 continued

		Draft statewide legislation that institutes utility shutoff protection		Develop or increase shade via zoning requirements		Create policies and financial incentives that facilitate the creation of resident-owned cooperative housing		Utility conversion program		Energy efficiency standards and requirements		Home improvement loans	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total
Time to develop	**0.063**	3	0.189	2	0.126	1	0.063	3	0.189	3	0.189	2	0.126
Price	**0.126**	5	0.630	5	0.630	3	0.378	3	0.378	5	0.630	2	0.252
Ease of developing	**0.181**	2	0.362	2	0.362	2	0.362	3	0.543	3	0.543	3	0.543
Effectiveness	**0.252**	5	1.260	5	1.260	5	1.260	5	1.260	5	1.260	5	1.260
Resilience	**0.189**	5	0.945	5	0.945	5	0.945	5	0.945	5	0.945	5	0.945
Support of other solutions	**0.126**	4	0.504	5	0.630	5	0.630	5	0.630	5	0.630	5	0.630
Maintenance	**0.063**	5	0.315	5	0.315	5	0.315	5	0.315	5	0.315	5	0.315
Total	**1**		**2.937**		**4.268**		**3.953**		**4.260**		**4.512**		**4.071**

Table A-6 continued

		Social infrastructure and community engagement		Heat-resilient community center		Put information into AARP bulletin to raise awareness		Early detection warning system to notify friends, family, caretakers, etc. when a home is getting too hot		Educate public health officials and emergency responders about special vulnerability in mobile homes		Mutual aid networks	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1 –5)	Total
Time to develop	**0.063**	3	0.189	3	0.189	4	0.252	3	0.189	5	0.315	3	0.189
Price	**0.126**	5	0.630	3	0.378	3	0.378	2	0.252	4	0.504	4	0.504
Ease of developing	**0.181**	3	0.543	3	0.543	3	0.543	2	0.362	4	0.724	3	0.543
Effectiveness	**0.252**	3	0.756	4	1.008	3	0.756	4	1.008	5	1.260	3	0.756
Resilience	**0.189**	3	0.567	5	0.945	4	0.756	5	0.945	3	0.567	4	0.756
Support of other solutions	**0.126**	1	0.126	1	0.126	1	0.126	4	0.504	5	0.630	1	0.126
Maintenance	**0.063**	5	0.315	3	0.189	5	0.315	3	0.189	4	0.252	4	0.252
Total	**1**		**3.126**		**3.378**		**3.126**		**3.449**		**4.252**		**3.126**

Table A-6 continued

		Support for small-dollar home lending markets		Greater consumer protections for mobile home buyers		Expansion of tenure forms	
Criteria	**Weighting factor**	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total
Time to develop	**0.063**	3	0.189	4	0.252	3	0.189
Price	**0.126**	5	0.630	4	0.504	5	0.630
Ease of developing	**0.181**	3	0.543	4	0.724	3	0.543
Effectiveness	**0.252**	5	1.260	5	1.260	5	1.260
Resilience	**0.189**	4	0.756	5	0.945	5	0.945
Support of other solutions	**0.126**	4	0.504	4	0.504	5	0.630
Maintenance	**0.063**	5	0.315	3	0.189	5	0.315
Total	**1**		**4.197**		**4.378**		**4.512**

Right of first refusal		Great lending support to create a co-operative park		Support for real estate conversions		Tailor home improvement lending products for housing titled as personal property	
Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total	Score (1–5)	Total
4	0.252	3	0.189	3	0.189	3	0.189
5	0.630	2	0.252	4	0.504	4	0.504
5	0.905	3	0.543	3	0.543	3	0.543
3	0.756	5	1.260	5	1.260	5	1.260
4	0.756	5	0.945	5	0.945	5	0.945
3	0.378	5	0.630	5	0.630	5	0.630
5	0.315	4	0.252	5	0.315	4	0.252
	3.126		**4.070**		**4.386**		**0.252**

The story of this guide

Timeline and discovery process of this project

- **December 2018 – Utility assistance network analysis and discovery**
  The “aha” moment happened when we discovered that mobile home residents fell between the cracks of utility assistance programs.

- **Summer 2019 – Schmidt Futures project**
  Measuring, surveying and calculating the scope of the heat and health problem.

- **January 2020 – Interpretation meeting with mobile home owners and study participants**
  Checking back and sharing the results with participants.

- **May 27, 2020 – Heat Resilience Solutions Meeting with stakeholders**
  Socializing the results more broadly among actors who might be able to mitigate and respond.

- **Summer 2020 – Innovation challenge with Walton Solutions students summer interns**
  Digging deeper into recommendations by participants and stakeholders to assess discrete solutions.

- **August 2020 – April 2021 – EPICs student teams**
  Working at the park scale to assess solutions and design sets of ideas in actual park conditions.

- **June – August 2021 – Mobile Home Solutions Guide**
  Compiling everything we have learned in a way that can be used by multi-sector actors.

- **Now – Launching pilot phase effort**
  Mobilizing a community of actors to create prototype solutions based on this exchanged knowledge.

Partners and stakeholders

Sponsor

VIRGINIA G. PIPER CHARITABLE TRUST

Funding support also received from

NASA

NSF

The Nature Conservancy

SCHMIDT FUTURES

ASU Academic Unit Partners

ASU Arizona State University

Knowledge Exchange for Resilience

Decision Theater

Geospatial Research and Solutions

Healthy Urban Environments

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Speaking Up for Home and Hope

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Maricopa County Public Health
WeArePublicHealth.org

a new leaf
HOUSING · HEALTH · COMMUNITY SERVICES

The University of Arizona

wildfire
Igniting Community Action to End Poverty in Arizona

With special thanks

To the families and residents of the parks who co-created this knowledge about the effects of heat, who shared their innovative strategies to stay cool, and inspired this collection of ideas and solutions.