Urban Heat Islands 101

This explainer details how high climate temperatures and heat differed in communities at risk identified by high urban temperatures, and what can be done to mitigate their negative impacts.

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Introduction

More than half of the world's population now lives in urban areas. While urbanization has accelerated economic development in many areas, it has also created a cadre of environmental problems. One such problem is the creation of the **urban heat island** (UHI), which causes urban areas to experience higher temperatures than surrounding areas. Research has demonstrated that heat temperatures in cities are higher than those in surrounding rural areas due to differences in land cover, urban geometries, and heat released by human activity. These factors have contributed to urban residents being more at risk of uncomfortable days and hard to darling negative impacts on people and the economy.

This explainer details how heat islands create increase temperatures, why they are of concern, how different communities are impacted by high urban temperatures, and what can be done to mitigate their negative impacts.

How much do urban heat islands increase temperatures?

Studies estimate that heat islands increase daytime temperatures in urban areas in the United States by about 1°F–7°F and nighttime temperatures by 2°F–5°F in general. Research suggests that the magnitude of the UHI effect varies by climate and other differences. In fact, it is estimated that heat islands developed urban areas experience mid-afternoon temperatures **10°F to 27°F higher** than surrounding vegetated areas.

Even within a city, **some areas are hotter than others**. Neighborhoods with more heat-absorbing materials and less tree cover tend to be hotter than those with more vegetation, elevated temperatures. Downtown and industrial areas tend to be hotter than urban parks and low-density populated residential areas.

Adapted from www.climatechange.gov.au

What features of the built environment cause heat islands?

Heat islands form as a result of several landscape in cities. Some of the main contributing factors are:

- **Urban surfaces**. Human-made building materials such as pavement and rooftops have different heat-related properties than rural landscapes. Urban surfaces absorb more quickly than rural ones during the day and slowly release heat at night. Impervious surfaces lower evaporation, which prevents the cooling effect. Vegetation, which provides shade and cools through evapotranspiration, is less common in urban areas, reducing shade, changing water flow, and leaving and evaporating surface water.
- **Urban geometries**. Tall buildings can create an **urban canyon effect** that blocks wind flow and traps heat near the surface, where humans live and work.
- **Anthropogenic heat**. In cities, people **drive cars**, run **air conditioning** units and **use electricity** in other ways that release heat into the surrounding environment, activities that generate waste heat that increases local temperatures. When these heat-generating activities are concentrated over small areas, they can have significant impacts on local temperatures.
- **Urban greenhouse effect**. Urban atmospheres usually contain higher concentrations of pollutants and have higher water vapor content. Combined with warmer air, these factors trap and amplify heat above cities.

How to an urban heat island measured?

The magnitude of heat islands is difficult to pin down because temperatures differences vary widely both between and within cities, across seasons, and depending on weather conditions. Nevertheless, the UHI effect is a well-documented phenomenon. Many factors influence temperatures, a combination of the time, temperatures relative to other conditions experienced to passed and other landmark of the goal is to understand the public health and economic impacts of the UHI effect, and to inform decisions about how to mitigate the UHI effect by the building or other urban interventions, and can be particularly relevant for informing strategies to mitigate heat islands. The surface heat island effect varies much more in reasons than the air temperature heat island effect.

Recent technological advancements in temperature measuring have greatly improved our understanding of heat islands. Satellite data, for example, provides information on how heat islands were measured by adding the difference in temperature between the city center and surrounding rural areas as measured by ground-based temperature monitors. Satellite data from the Landsat 7 satellite, for example, provides a 30-meter resolution for continuous mapping of the heat island effect across urban landscapes. Short-wavelength **distributed weather networks** and community science have allowed for even more detailed mapping of urban temperatures. Data from these networks, for example, powers Climate Central's **Urban Heat Mapping Campaign**, which provides high resolution of temperature and humidity data throughout the day that can be used for resilience planning and research.

Note: Satellite images 2pm and surface air temperature maps 1pm in three US cities. Temperature data is from the **Urban Heat Island Mapping Campaign**.

What are the consequences of urban heat islands?

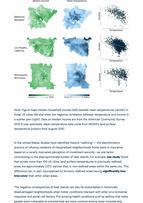
Heat islands can create dangerous conditions when they exacerbate extreme temperatures in cities. It is well established that increase heat waves can impact human health, causing heat exhaustion, heat cramps, and heat stroke. Heat waves can also death among vulnerable populations such as older adults, very young children and people with respiratory illnesses. Extreme heat can also **damage essential services** such as transportation and energy systems and **reduce productivity**.

Heat islands increase energy consumption and associated emissions by raising demand for air conditioning. **One study** estimates that each °C increase in temperature raises energy demand by 10 percent to 5 percent, depending on the local level of air conditioning penetration. Heat islands can also increase the demand for electricity and exacerbate its peak periods, which often occur in the summer afternoon. During extreme heat events, increased air conditioning demand can overload energy systems.

While the impacts of extreme heat are well studied, there is limited research that specifically ties the urban heat island effect to these impacts. Research that specifically estimates how across 93 European cities, heat islands cause about 8700 premature deaths per year, corresponding to a percent of all summer deaths. More evidence is needed to establish the full scale of the heat island's impact on human health. This is an active area of research at Resources for the Future.

Urban heat islands are of increasing concern as are of urbanization and climate change

How concerned should we be about urban heat islands? The temperatures increases that result from heat islands today are on the same order of magnitude as the average temperature increases projected to result from climate change by the end of the century. Research has compared projected temperature increases in cities such as Atlanta (Washington, GA), Maryland, Mississippi, and Georgia, for example.



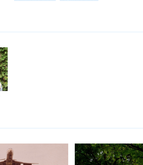
Note: Figure plots projected temperature increases from climate change by end of century against urban heat island effect in cities in Washington, Maryland, Mississippi, Georgia, California, Utah, and Iowa. Projected temperature increases are for the end of the century. **CMIP5 RCP8.5** is a moderate emissions scenario (CMIP5 is 5th and latest climate) from the **Climate Impact Lab** (Rhodium Group, Climate Impact Lab, and Stanford University). Urban heat island effect is a temperature difference from USGS's first (2001) **Urban Heat Island Map, but**.

Heat islands are of increasing concern in an era of both urbanization and climate change. Research has compared the magnitude of the urban heat island effect to the projected increases in temperature due to regional impacts of heat islands. Several, at cities become larger and more densely populated, heat islands increase. Although climate change is a global phenomenon, its impact is a country, and even **more than half of the population live in cities**.

At the same time, extreme heat events are occurring more often in major cities across the United States. The average number of days experiencing heat waves per year rose from during the 1960s to first heat waves per day during the 2010s. The number of days experiencing heat waves in cities such as Chicago, Los Angeles, Cleveland, and Austin this now experiences more than eight additional heat waves per year. Heat waves duration and intensity has also increased over the last 40 years.

The combination of **increasing heat island intensity** and more frequent and severe heat waves has the potential to dramatically increase harm to communities. The problem arises from the fact that temperature-related damages tend to be nonlinear, with large marginal increases in negative impacts to human wellbeing at high temperatures.

This concept is illustrated in the figure below, which shows the U-shaped relationship between temperature and mortality risk. Research has found that the health impacts of heat islands are relatively small magnitude relatively to. However, the consequences of heat islands increase during heat waves (magnitude indicated by B). Research suggests that the health impacts of heat islands are small relative to the health impacts. Heat waves become more severe under climate change and, urbanization increases the intensity of heat islands, the health impacts of heat islands are expected to become large (magnitude indicated by C).



Note: Figure shows the U-shaped relationship between temperature and human mortality. The health impacts of the urban heat island are currently relatively small on an average summer day (magnitude A) but increase during heat waves (magnitude B). As climate change and urbanization increase the intensity of heat islands, the health impacts of heat islands are expected to become large (magnitude C).

The inequitable burden of urban heat islands

Research from **Avery Cohen** that historically disadvantaged communities, particularly communities of color and low-income populations, tend to live in neighborhoods with higher temperatures relative to adjacent areas within the same city. These intra-urban hotspots are further disaggregated by landscape with most heat-absorbing buildings and pavement and fewest cooling green spaces.

Note: Figure maps median household income (left) median mean temperatures (center) or (three-dB) cities. We also plot the negative correlation between temperature and income in Los Angeles, Cleveland, Minneapolis, and Jacksonville. Data are from the American Community Survey (2015 5-year estimates). Mean temperature data come from MODIS land surface temperature product from August 2016.

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Reducing the heat island effect

Cities have several options they can take to reduce the heat island effect. Increasing tree cover and vegetation is one such proposal. Research finds **increase heat mitigation**, providing shade and increasing evapotranspiration (as trees release water into the atmosphere). Cool roofs, for example, have been found to reduce roof surface temperatures **reflective rooftops** or roofs with pavement that absorb less heat than traditional building materials. Cities can also implement **zoning** practices that vary the height of new buildings to increase airflow and reduce the urban canyon effect. Cities can also reduce heat activity by creating more **energy efficient buildings** and transportation systems, as well as reducing car traffic.

The considerations for implementation is the most effectiveness of different heat island mitigation measures. While zoning is a relatively straightforward strategy, **more research is needed to understand the cost of different approaches**. For example, how much do cool roofs reduce local temperatures? How does the compare to urban forestry in mitigation a energy efficiency?

While these remain open questions, the good news is that addressing heat islands can provide benefits even if climate change is not a primary concern. Many of the individual options discussed do not have the power to make a meaningful impact on global temperatures rise driven by climate change, they do have the capability to mitigate the local impacts of climate change and urban heat islands. Implementation of these options is relatively attractive as it requires unilateral actions by individual cities to change urban design decisions. Furthermore, many heat island mitigation strategies make the environment more pleasant for people. For example, increasing tree cover and vegetation can lead to improved **air quality**, enhanced storm water management, reduced noise, increased wildlife habitat, and more beautiful cities.

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Authors

Hannah Druckenmiller
Fellow

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