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What Are Heat Islands?

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Structures such as buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes such as forests and water bodies. Urban areas, where these structures are highly concentrated and greenery is limited, become "islands" of higher temperatures relative to outlying areas. These pockets of heat are referred to as "heat islands." Heat islands can form under a variety of conditions, including during the day or night, in small or large cities, in suburban areas, in northern or southern climates, and in any season.

A review of research studies and data found that in the United States, the heat island effect results in daytime temperatures in urban areas about 1–7°F higher than temperatures in outlying areas and nighttime temperatures about 2–5°F higher. Humid regions (primarily in the eastern United States) and cities with larger and denser populations experience the greatest temperature differences. Research predicts that the heat island effect will strengthen in the future as the structure, spatial extent, and population density of urban areas change and grow.^[1]

Causes of Heat Islands

Heat islands form as a result of several factors:

Reduced Natural Landscapes in Urban Areas. Trees, vegetation, and water bodies tend to cool the air by providing shade, transpiring water from plant leaves, and evaporating surface water, respectively. Hard, dry surfaces in urban areas – such as roofs, sidewalks, roads, buildings, and parking lots – provide less shade and moisture than natural landscapes and therefore contribute to higher temperatures.

Urban Material Properties. Conventional human-made materials used in urban environments such as pavements or roofing tend to reflect less solar energy, and absorb and emit more of the sun's heat compared to trees, vegetation, and other natural surfaces. Often, heat islands build throughout the day and become more pronounced after sunset due to the slow release of heat from urban materials.

Urban Geometry. The dimensions and spacing of buildings within a city influence wind flow and urban materials' ability to absorb and release solar energy. In heavily developed areas, surfaces and structures obstructed by neighboring buildings become large thermal masses that cannot release their heat readily. Cities with many narrow streets and tall buildings become urban canyons, which can block natural wind flow that would bring cooling effects.

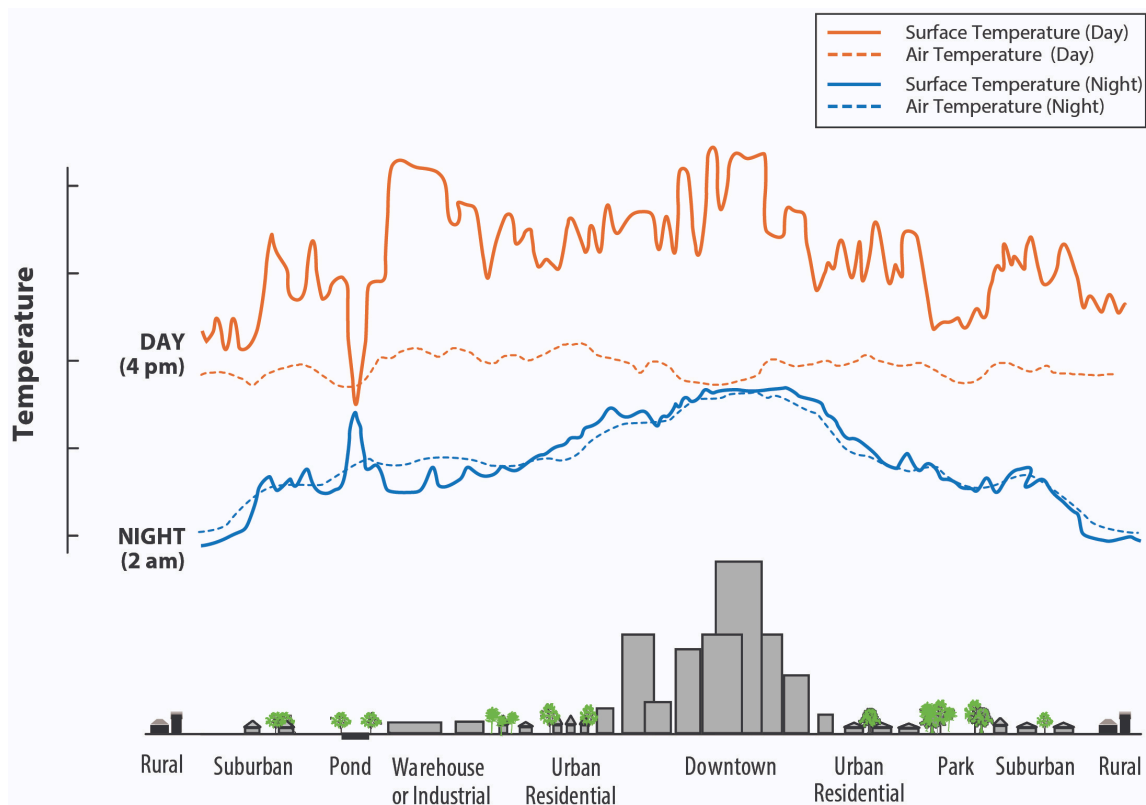
Heat Generated from Human Activities. Vehicles, air-conditioning units, buildings, and industrial facilities all emit heat into the urban environment. These sources of human-generated, or anthropogenic, waste heat can contribute to heat island effects.

Weather and Geography. Calm and clear weather conditions result in more severe heat islands by maximizing the amount of solar energy reaching urban surfaces and minimizing the amount of heat that can be carried away. Conversely, strong winds and cloud cover suppress heat island formation. Geographic features can also impact the heat island effect. For example, nearby mountains can block wind from reaching a city, or create wind patterns that pass through a city.

Characteristics of Heat Islands

Heat islands are usually measured [by the temperature difference between cities relative to the surrounding areas](https://epa.gov/heatislands/measuring-heat-islands). Temperature can also vary inside a city. Some areas are hotter than others due to the uneven distribution of heat-absorbing buildings and pavements, while other spaces remain cooler as a result of trees and greenery. These temperature differences constitute intra-urban heat islands. In the heat island effect diagram, urban parks, ponds, and residential areas are cooler than downtown areas.

Heat Island Effect Diagram



Surface temperatures vary more than atmospheric air temperatures during the day, but they are generally similar at night. The dips and spikes in surface temperatures over the pond area show how water maintains a nearly constant

temperature day and night because it does not absorb the sun's energy the same way as buildings and paved surfaces. Parks, open land, and bodies of water can create cooler areas within a city. Temperatures are typically lower at suburban-rural borders than in downtown areas.


In general, temperatures are different at the surface of the earth and in the atmospheric air, higher above the city. For this reason, there are two types of heat islands: surface heat islands and atmospheric heat islands. These differ in the ways they are formed, the techniques used to identify and measure them, their impacts, and to some degree the methods available to cool them.

Surface Heat Islands. These heat islands form because urban surfaces such as roadways and rooftops absorb and emit heat to a greater extent than most natural surfaces. On a warm day, conventional roofing materials may reach as much as 66°F warmer than the surrounding air temperatures.^[2] Surface heat islands tend to be most intense during the day when the sun is shining.

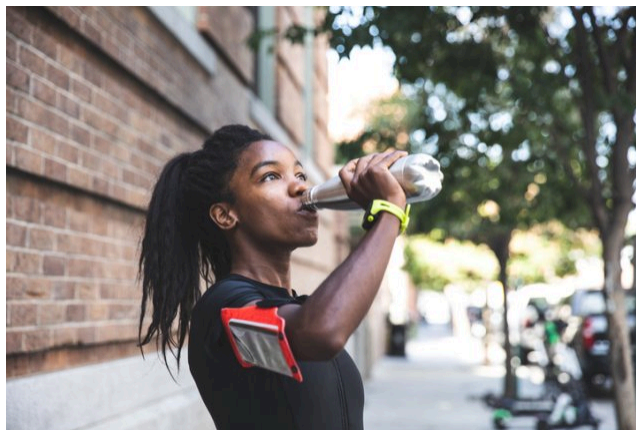
Atmospheric Heat Islands. These heat islands form as a result of warmer air in urban areas compared to cooler air in outlying areas. Atmospheric heat islands vary much less in intensity than surface heat islands.

Heat Island Impacts

Increased Energy Consumption. Heat islands increase electricity demand for air conditioning and peak energy demand. Increased electricity demand for air conditioning ranges from 1–9% for each 2°F increase in temperature, with the highest increase in countries where most buildings have air conditioning, such as the United States.^[3] This increased demand contributes to higher electricity expenses. Peak demand generally occurs on exceptionally hot afternoons, when offices and homes are running air-conditioning systems, lights, and appliances. This increased demand can overload systems and require a utility to institute controlled brownouts or blackouts to avoid power outages.

Elevated Emissions of Air Pollutants and Greenhouse Gases. To meet electricity needs, utility companies typically rely on fossil fuel power plants as a power source <<https://epa.gov/airmarkets>>. Increased use of fossil fuels increases emissions of greenhouse gases <<https://epa.gov/ghgemissions>>, such as carbon dioxide, which contribute to global climate change  <<https://nca2018.globalchange.gov/>>. These pollutants are harmful to human health and also contribute to complex air quality problems such as the formation of ground-level ozone <<https://epa.gov/ground-level-ozone-pollution>> (smog), fine particulate matter <<https://epa.gov/pm-pollution>>, and acid rain <<https://epa.gov/acidrain>>. Ground-level ozone, in particular, is formed when nitrogen oxides and volatile organic compounds <<https://epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds>> react in the presence of sunlight and hot weather. If all other variables are equal, such as the level of precursor emissions in the air and wind speed and direction, more ground-level ozone will form as the environment becomes sunnier and hotter.

Compromised Human Health and Comfort. Hot weather events contribute to heat-related deaths <<https://epa.gov/climate-indicators/climate-change-indicators-heat-related-deaths>> and heat-related illnesses <<https://epa.gov/climate-indicators/heat-related-illnesses>>. Areas experiencing heat islands further contribute to higher daytime temperatures and reduced nighttime cooling. Heat is of greatest concern for groups such as older adults, young children, populations with low-income, people who work outdoors, and people with chronic health conditions, disabilities, mobility constraints, or taking certain medications. From 2004 to 2018 the Centers for Disease Control and Prevention recorded an average of 702 heat deaths per year. ^[4]





Impaired Water Quality. High temperatures of pavement and rooftop surfaces can heat stormwater runoff, which drains into storm sewers. This runoff raises water temperatures as it is released into streams, rivers, ponds, and lakes. Water temperature affects the metabolism and reproduction of many aquatic species. Rapid temperature changes can also be stressful, and even fatal, to aquatic life. One study found that urban streams have more frequent temperature surges than streams in forested areas. Temperature surges in urban streams were as much as 18°F higher due to heated runoff from urban areas, higher discharge volumes due to impervious surfaces, and warmer baseline stream temperatures.^[5]

Reducing Heat Islands

Numerous strategies exist for reducing the severity of the heat island effect. Visit the Heat Island Reduction Solutions page <<https://epa.gov/heatislands/heat-island-reduction-solutions>> for more information.

References

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