

# Architectural Solutions to Urban Heat Island Effect

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**Abstract**—This document has been written to acknowledge the readers with architectural solutions to urban heat island effect by taking into consideration the factors responsible for it.

**Keywords**— Urban heat island effect, urban canyon effect, urban cold island effect, black body phenomenon

## I. INTRODUCTION (Urban Heat Island Effect)

Urban heat island (UHI) effect is widely known as a heat accumulation phenomenon, which is the most obvious characteristic of urban climate caused by urban constructions and human being activities.

As urban areas developed, changes occurred in the landscape. Surfaces which were permeable and moist generally have become impermeable and dry now. This development leads to the formation of urban heat islands—the phenomenon whereby urban regions experience warmer temperatures than their rural surroundings.

Building materials absorb more heat than landscapes. 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 called “heat islands.” Heat islands can be formed the day or night, in small or large cities, and in all seasons.

## II. DEFINITION

### A. What is urban heat island effect

Urban heat island effect is a phenomenon in urban areas having higher average temperature than its rural surroundings due to the result greater urban building materials like concrete, glass, coal tar (majorly on roads) etc. Architectural structures like buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes like forests and water bodies.

If an object absorbs the sunlight it converts light energy into thermal energy due to law of conservation of energy and it is emitted back in the form of heat. The law of conservation of energy states that energy can neither be created nor be destroyed but it can only be transformed from one form to another. Dark coloured objects heat up faster in the sun because they absorb different wavelengths of light.

### B. Black body phenomenon

A black body phenomenon states that a black coloured body or surface absorbs all radiant energy falling on it and converts

them into heat energy so the objects gets warmed or heated up.

So materials like asphalt, steel, and brick are generally very dark colors—like black, brown and grey and absorb heat from the sun resulting in overall increase in the surrounding temperatures.

### C. History

The phenomenon of urban heat island effect was first investigated and described by Luke Howard in the 1810s, although he was not the one to name the phenomenon.

## III. TYPES OF URBAN HEAT ISLAND EFFECTS:

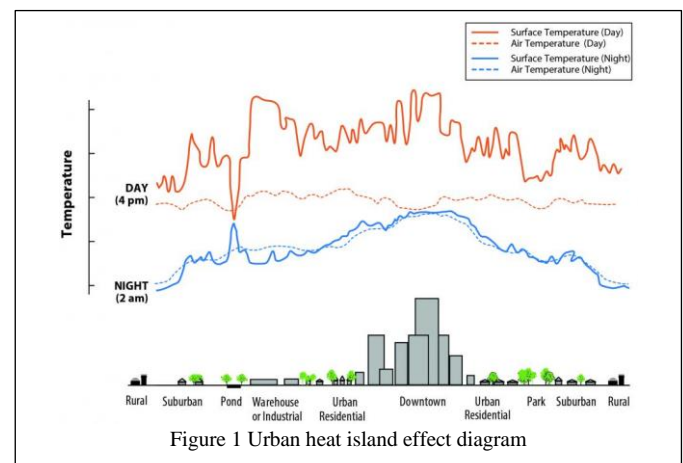
There are two types of heat islands: surface heat islands and atmospheric heat islands. These differ in the ways they are formed, the techniques used to identify and measure them, their impacts, and to some degree the methods available to cool them.

### a) Surface Heat Islands:

Roads and building surfaces absorb and reflect heat to a greater extent than vegetation areas. On a warm day with a temperature of 91°F, conventional roofing materials may reach as high as 60°F warmer than air temperatures. Surface heat islands tend to be most intense during the day when the sun is shining.

### b) Atmospheric Heat Islands:

When the air is warm in urban areas and cooler in outlying rural areas these urban heat island are formed. Atmospheric heat islands vary much less in intensity than surface heat islands.



### I. Urban Cold Island Effect:

When an urban area which is hotter in the day is cooler than surrounding rural area at night in the same ground level, this condition leads to urban cold island effect. This phenomenon was an unexpected discovery when studying the response of plants to urban environments. Snow cover in rural areas insulates plants. This phenomenon occurs in early morning because the buildings within cities block the sun's solar radiation and the wind speed within the urban centre. Both the urban heat island and urban cold island effects are most intense at times of stable meteorological conditions. The reason for this phenomenon is the less availability of water and vegetation in the urban region as compared to the surroundings.

### II. CASE STUDY

#### US Data



Figure 2 Skyscrapers in Chicago a Cause of Urban Heat Island Effect.

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.

#### New York Cityscape:

Downtown New York City is an urban heat island, a built-up area with temperatures that are higher than the rural areas surrounding it. According to the Environmental Protection Agency, the annual air temperature of a city with 1 million people can be 1.8–5.4 degree Fahrenheit (1–3 degree Celsius) warmer than its surroundings.



Figure 3 Skyscrapers New York City as a cause of urban heat island effect

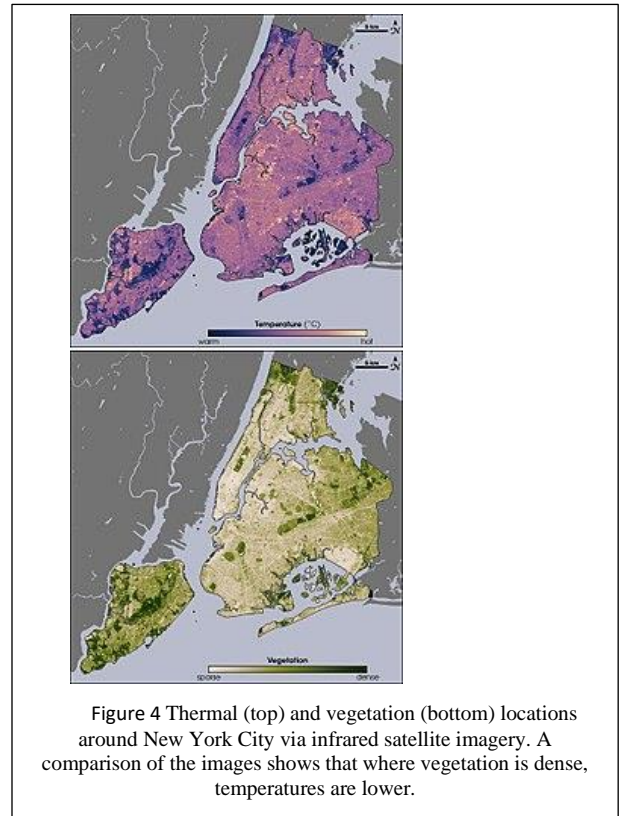


Figure 4 Thermal (top) and vegetation (bottom) locations around New York City via infrared satellite imagery. A comparison of the images shows that where vegetation is dense, temperatures are lower.

### III. Factors responsible for Urban Heat island Effect:

Heat islands form as a result of several factors:

- 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.

- Concrete

Concrete can hold roughly 2,000 times as much heat as an equivalent volume of air. As a result, the large daytime surface temperature within the Urban Heat Island is easily seen via thermal remote sensing.

- Urban geometry

In heavily developed areas, surfaces and structures obstructed by neighbouring 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. The dimensions and spacing of buildings within a city influence wind flow and urban materials' ability to absorb and release solar energy.

Tall buildings within urban areas provide multiple surfaces for absorption and reflection of sunlight. It increases the efficiency of urban heating. This is phenomenon is known as the "urban canyon effect".

- Reduced natural landscapes in urban areas

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. Trees, vegetation, and water bodies tend to cool the air by providing shade, transpiring water from plant leaves, and evaporating surface water, respectively.

- Weather and geography

Strong winds and cloud cover suppress heat island formation while 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. Geographic features also impact the heat island effect such as nearby mountains can block wind from reaching a city, or create wind patterns that pass through a city.

Another effect of buildings is the blocking of wind, which also inhibits cooling by convection and prevents pollutants from dissipating. Waste heat from automobiles, air conditioning, industry, and other sources also contributes to the urban heat island effect.

- 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.

- Pollution

Many forms of pollution change the radiative properties of the atmosphere. Urban heat island effect also increases ozone concentrations because ozone is a greenhouse gas whose formation will accelerate with the increase of temperature.

#### IV. EFFECTS

Urban heat island effect influences energy flow and material flow in urban ecological systems, alter their function and structure, exerts a series of ecological and environmental effects on urban climates, soil properties, biological habits, urban hydrologic situations, and health of the people.

Increased temperatures have been reported to cause heat stroke, heat exhaustion, heat syncope, and heat cramps.

#### V. EFFECTS OF URBAN HEAT ISLAND EFFECT IN INDIA

The difference between urban and rural temperatures had been studied from 2001-2017.

Researchers from IIT-KGP states that, "For the first time, we have found evidence of mean daytime temperature of Surface Urban Heat Island (UHI Intensity) going up to 2C for most cities, as analysed from satellite temperature measurements in monsoon and post-monsoon period." Delhi, Mumbai, Bengaluru, Hyderabad and Chennai are the most affected cities.

#### VI. SOLUTIONS TO URBAN HEAT ISLAND EFFECT

- Reducing the use of materials with high thermal mass

Concrete has a high capacity to store heat and is referred to as 'high thermal mass' materials which is one of the major causes of urban heat island effect. That is it stores heat for a longer duration of time so if we find an alternative to concrete and such materials urban heat island effect can be reduced to great extent.

The use of other highly reflective materials like glass or metals should also be reduced to assist the reduction of heat island effect and save the environment.

- Improving Urban Geometry to reduce Urban Canyon Effect caused by them

The Urban geometry should be improved by widening the streets to provide circulation and should be supported with vegetation so that the air is not blocked by the surrounding houses in the narrow streets.

Tall buildings can be supported with vertical landscaping so that they do not provide larger surface area to the building material to absorb and re-emit heat to the surroundings and increasing the overall temperature of the surrounding which results in heat island effect. This can also reduce the urban canyon effect caused by tall buildings in the urban areas.

- Reducing dark coloured covered areas

To cool down urban heat islands, some cities are 'lightening' streets. This is done by covering black asphalt streets, parking lots, and dark roofs with a more reflective grey coating. These changes can drop urban air temperatures dramatically, especially during the heat of summer. This can decrease the black body effect which is the cause of urban heat island effect.

- Increasing Shade and natural landscape in urban areas

Plant trees and vegetation which lower surface and air temperatures by providing shade and cooling through evapotranspiration. This will lower down the overall temperatures in the surroundings and lower heat island effect.

- Providing green roofs

Providing a layer of green roof or vertical and horizontal landscaping decreases the heat island effect. A green roof/rooftop garden is a vegetative layer grown on rooftop.

- Use of energy-efficient appliances and equipment to reduce heat island effect through pollution by greenhouse gases emitted by electrical appliances

The efficient use of energy efficient appliances emits less greenhouse gases in the atmosphere resulting in lowering down the heat island effect.

- *Reducing surface absorption by materials*  
Light shading structures over streets, pavements and roofs can be installed to reduce the surface absorption by materials over streets. Shading structures should not trap heat or reduce the air flow on the streets.
- *Using vernacular methods of building construction*  
The use of easily available and eco-friendly materials with custom constructional techniques can not only increase the aesthetics of the place but also reduce the urban heat island effects.

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