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SECOND CYCLE DEGREE IN ENVIRONMENTAL ENGINEERING
CURRICULUM OF EARTH RESOURCES ENGINEERING

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GREEN TECHNOLOGIES IN URBAN RESILIENCE HEAT WAVE)

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1. Abstract and Introduction

Urban resilience is the ability of an urban system to survive, adapt, grow, and mitigate through any kind of risks and Natural Disasters and respond to emerging challenges such as Earthquakes, Floods, Wild fires, Solar flares and Heat waves.

Due to the effects of climate change, there has been a noticeable and continuous increment in the Average temperatures of urban areas with increasing duration of hot days and intensities.

From the United States to Europe and China to Japan, extreme temperatures have soared for weeks, killing hundreds of people, sparking wildfires in Spain, Portugal, France, Italy, and Greece and displacing thousands of residents, as many seek refuge in public cooling centers (1).

Extreme heat is one of the deadliest health risks, according to the research of international records of Maximiliano Herrera all time high temperature records has exceeded in 24 of the world’s nations and territories in 2019, surpassing 2016’s 22 heat records.

Due to the rapid increase in the population and rise in Industrialization and Urbanization the globe is currently experiencing numerous environmental and economic issues. This phenomenon results in the replacement of natural cover with pavements and other Infrastructures absorption and retaining of heat. These Human activities lead to the formation of Urban Heat Islands that result to increase in intensity of Heat waves and due to which High amount of energy usage for Air conditioning and ventilation and other the use of other cooling appliances.

The Urban Heat Islands effect results in increasing Heat related Mortality and Morbidity. Constant and prolonged exposure to extreme heat can affect the body’s ability to maintain its core temperature which can cause serious heat stroke and dehydration of the body. Due to lack of awareness, heat stress symptoms like headaches, vomiting, dizziness and low blood pressure are miscomprehended as other health issues. During Extreme heat condition the inability of maintaining the body’s core temperature can affects on the cardiovascular and respiratory systems. If the body temperature rises too high the heart won’t be able to pump adequate circulation that leads to unconsciousness and failure of organs.

Extreme Heat can cause the rise in mortality rate up to 14% and also economically it can reduce productivity of work force and damage infrastructures.

This Thesis aims to introduce the Planning and designing at a cities level using approach of green strategies to reduce the impact of heat waves and resist extreme heat events and avoid retaining of heat islands.

In the past, technological factors have not been as important as it is now to achieve sustainability through urban planning. Currently, the difficulties are greater, and technology is required not only to address technical problems with energy, water, materials, and construction, but also to develop significant city sectors like transportation, infrastructure, communications, and housing, making these sectors sustainable using green technology**.** (2)

The various aspects of green technology that can be incorporated into the spatial planning process help in finding new ways to achieve sustainable development by reducing the negative impacts of various economic and human activities on the environment and ecosystems and guiding development towards adoption of green and eco-friendly ways of life in cities and urban areas. (3)

The phrase "green technology" developed to refer to a method of resolving these issues with a focus on sustainable growth on all fronts.

These innovations in environmentally friendly technology frequently deal with issues like energy efficiency, recycling, health and safety, renewable resources, and more. Numerous technological advancements that reduce adverse environmental effects and propose fresh strategies for achieving sustainable development are referred to as "green technologies." (4)

It appears to be a very efficient instrument for contemporary urban planning, taking into account all planning factors, including Infrastructure, Industry, Energy, Telecommunications, and other key areas in cities.

Objective:

This thesis intends to bring planning and designing at a city level using a green approach to mitigate the effects of heat waves, withstand extremely hot weather, and prevent the formation of heat islands.

Methodology:

Among the strategies with the greatest potential for green urban resilience are:

a) Green Roofs and Facades
b) Increasing Canopy and Vegetation
c) Light colored and heat resistant materials for Pavements and Road surfaces.
d) Shaded Streets, Pedestrian galleries and corridors
e) Self-Ventilating and Self-Shading structures.
f) Cooling Centers.

2. Statistical of Heat Islets

Luke Howard in 1833 noticed the anthropogenic effects on local weather, which results in the formation of Urban Heat Island (UHI). Cities have been growing bigger day by day we can now see the negative effects they have on the environment more clearly.

Figure 1 *An illustration of an urban heat island. Image credit: NASA/JPL-Caltech*

Urban Heat Island (UHI) can be defined as the excess heat in urban areas compared to its rural surroundings, UHIs have been observed and reported in a diverse range of cities, large or small, in warm or cold climates. (5)

The urban heat island effect, a well-documented phenomenon, can drastically raise summer temperatures to even more extreme levels. The Environmental Protection Agency (EPA) states that a city's annual mean air temperature with one million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. At night, the difference can be as high as 22°F (12°C). Heat islands can affect communities by increasing peak energy demand during the summer, including air conditioning costs, air pollution, greenhouse gas emissions, heat-related illness and mortality, and water quality. (6)

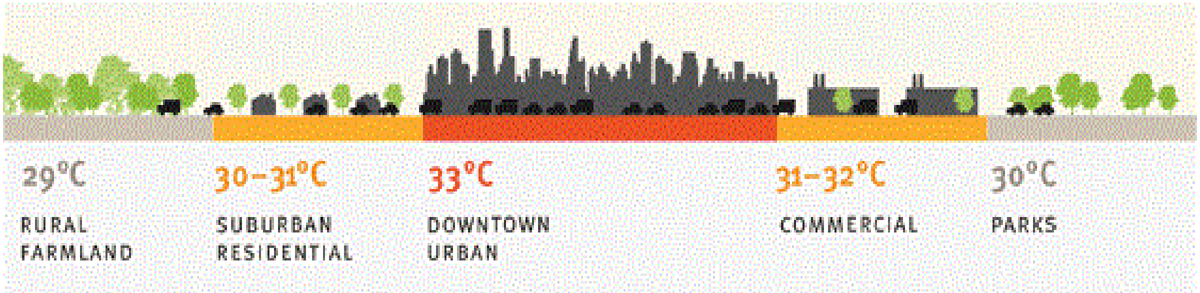

Figure 2 *Diagram Photo Credit: The Architect's Newspaper*

3. Causes of Heat waves

- Due to the increase in the use of concrete surfaces in urban areas which results in the capturing and storing the energy from sunlight and due to the rough urban surfaces and tightly packed grid layouts that cause decrease in air flow which results in the lower heat transport through wind reducing natural ventilation and trapping heat between.

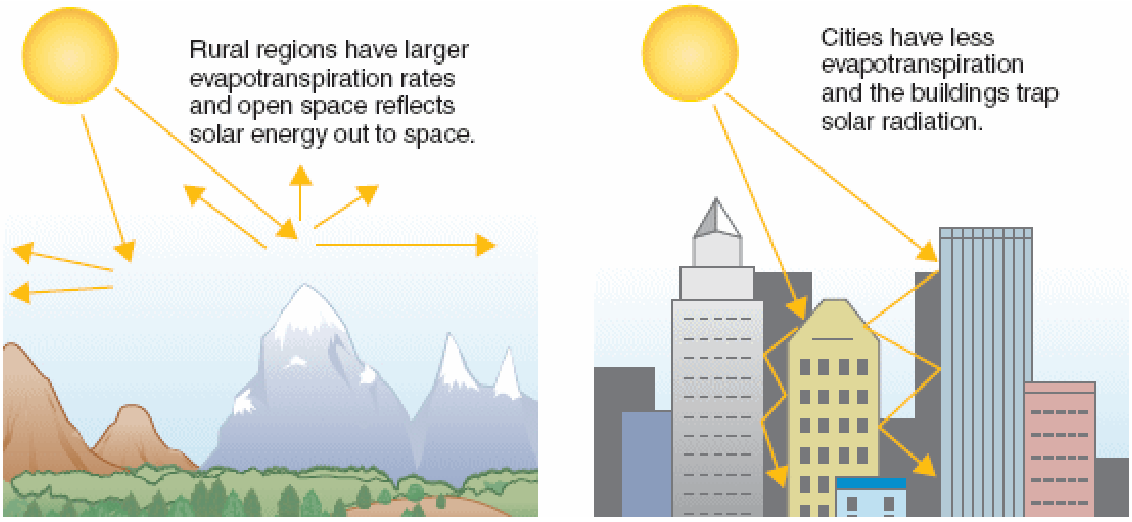

Figure 3 *Diagram illustrating Reflection and Heat trapped between Rural and Urban areas Source:cimss.ssec.wisc.edu/climatechange/globalCC/lesson7/UHI2*

- Due to Replacing of trees and plants with building materials like asphalt, concrete and other impermeable surfaces (Buildings, Roads and pavements, etc.) and scattered vegetation decrease in the process of evapotranspiration, Plants use the underground moisture through roots and store moisture in their leaves and stems. This moisture travels to small holes on the underside of leaves and eventually the liquid moisture is turned into water vapour and is released into the atmosphere. This process is called transpiration. It serves like a natural air conditioner.

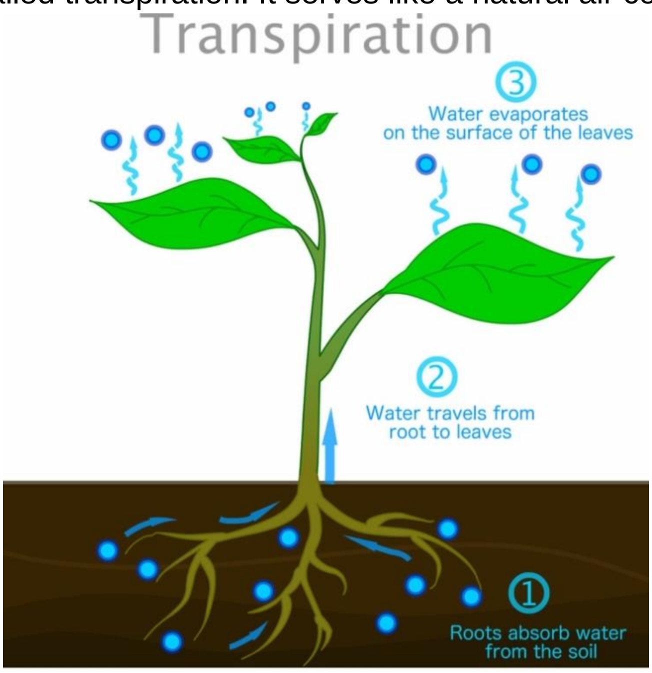

Figure 4 *Represents Transpiration process*
Source: https://www.justtrees.co.za/blog/2022/07/29/a-closer-look-at-transpiration/

- Materials such as asphalt, steel, and brick are often very dark colours like black, brown and grey. A dark object absorbs all wavelengths of light energy and converts them into heat, so the object gets warm. Thus, dark objects such as building materials absorb heat from the sun.

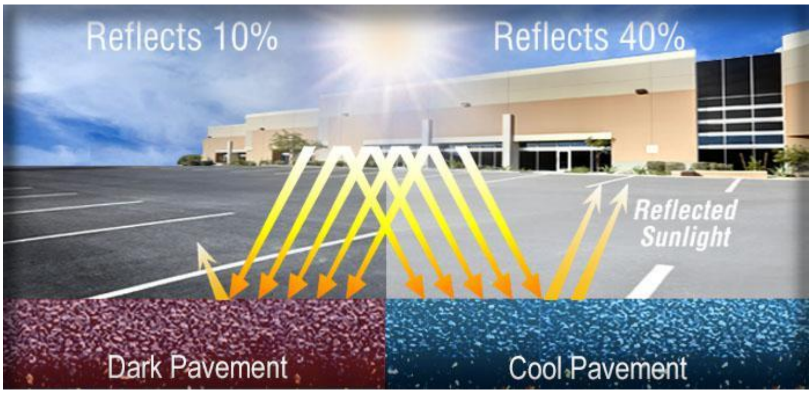

Figure 5 ***Diagram illustrating how Cool Pavement coating will increase solar reflectivity. Source: www.geographyrealm.com/can-painting-city-streets-reduce-urban-heat-island-effect/***

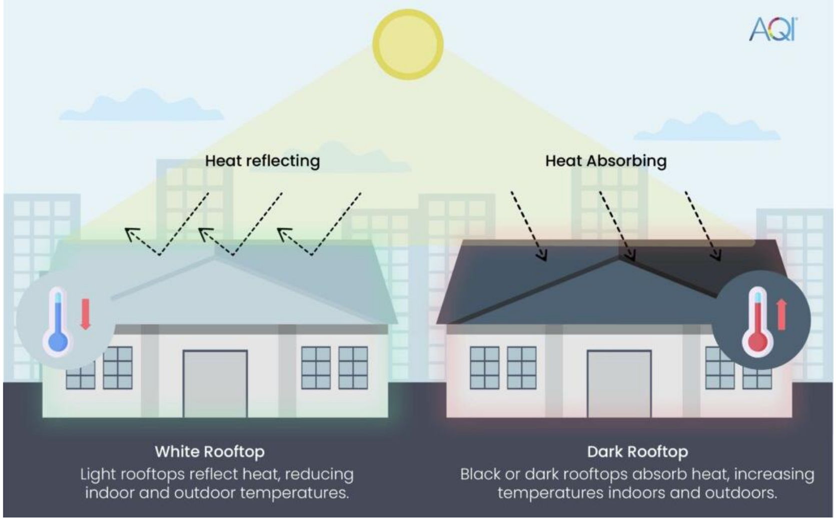

Figure 6 ***Source:www.aqi.in/blog/urban-heat-island-effect-causes-and-cities-rising-temperatures/***

- Due to the heat produced by anthropogenic activities through Air conditions and Vehicles adds extra heat to higher temperatures in urban areas through emitting the excess heat to the urban air.

Figure 7 ***Source: https://www.enertime.com/en/applications/waste-heat-recovery***

The figure below shows the magnitude of the urban heat island as a temperature difference between a city and its surroundings, for clear sky and light wind conditions, plotted as a function of city population. The different slopes of the relationship differ for cities in different parts of the world. This difference results from differences in the urban characteristics, the characteristics of the rural surroundings, and the prevailing climate. More typically, heat island intensities are in the range of 1° C to 3° C (2° F to 5° F) degrees, even for large cities, indicating the importance of wind and cloud effects. Seasonally, heat islands in temperate climates are a maximum during summer and fall when weather conditions are more favourable. (7)

UHI occurs both during the day and night, but according to Oke (1987), the maximum intensity of heat island occurs 3–5 h after sunset. This is because cities retain much of its heat in roads, buildings, and other structures that prevents them from cooling down. The phenomenon has been well documented since the beginning of last century. (8)

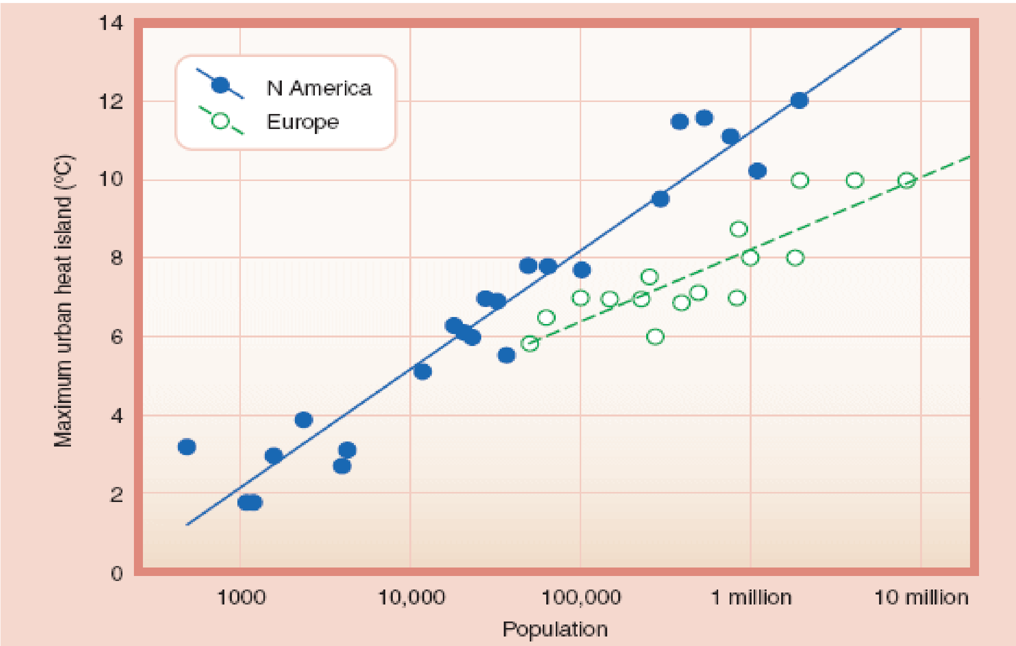

Figure 8 ***represents the magnitude of the urban heat island as a temperature difference between a city and its surroundings.***

UHI Intensity is known to be the strongest in the urban canopy layer, i.e., the region between the ground level and the mean roof height, where it is strongly influenced by local site characteristics such as building geometry and construction materials. (9)

But it is also detectable in the boundary layer, which resides above the urban canopy, typically up to two kilometres.

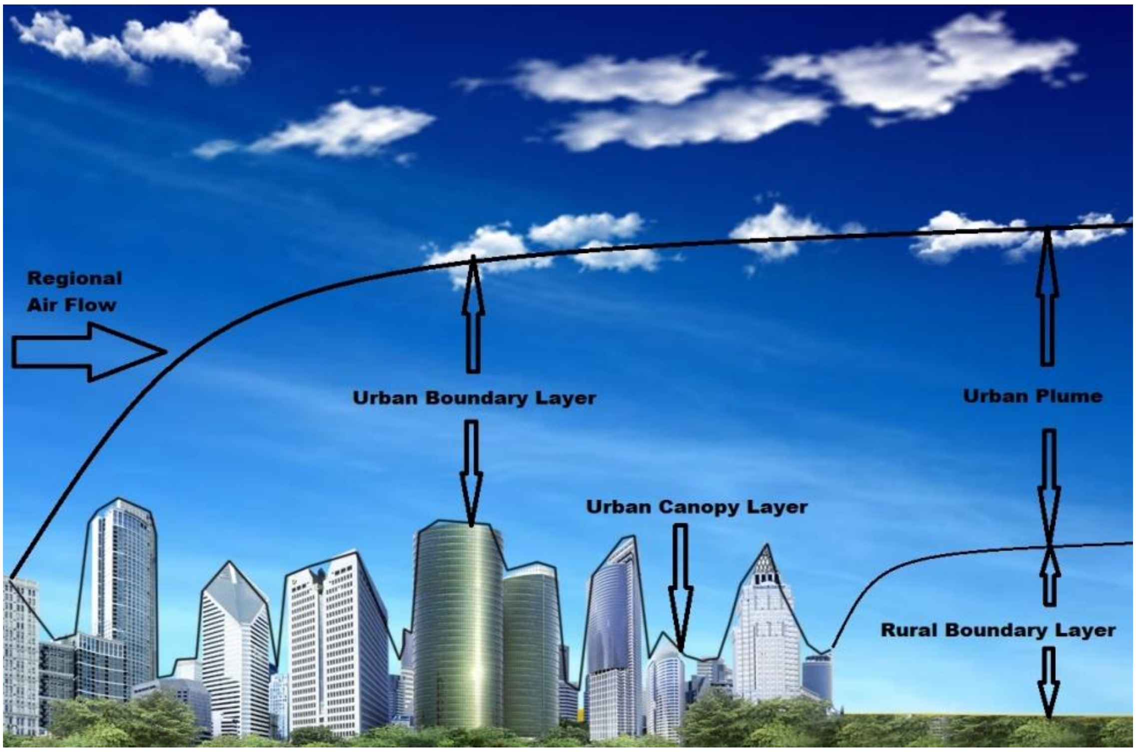

Figure 9 ***Urban Canopy Layer and Boundary Layer***

It has been consider that the urbanisation has resulted in to two distinct heat islands. There are two layers of the atmosphere: one is controlled by processes that operate at the microscale, and the other by processes that operate at the local or Mesoscale. The first layer in which is the air confined between the urban roughness components such as Buildings and other Infrastructures may be referred to as the Urban canopy layer.

The Second layer whose characteristics are affected by the presence of an urban area at its lower boundary is referred as Urban Boundary layer. This is a local or mesoscale term that describes the region of the planetary boundary layer whose properties are influenced by the presence of an urban area at its lower boundary. The modified layer is intended to form an internal boundary layer that is advective in nature. This layer may get detached from the surface in the downwind area when a new rural boundary layer forms underneath; this is known as the urban plume. The temperature inversion that frequently caps the top of the urban boundary layer corresponds in some ways to the upper limit of urban pollution.

4. Impacts of Heat waves

1. Increased Energy Demand: The heat island effect causes higher temperatures in urban areas, increasing demand for air conditioning and cooling, resulting in increased energy consumption and higher electricity costs for residents and businesses. (10)

This could result in brownouts and blackouts. Utilities occasionally require switching to emergency generators to satisfy their demand and free up electricity. Brownouts and blackouts can quickly increase the number of persons affected by an extended heat wave because many hospital cooling systems are not connected to backup power generators Brownouts and blackouts can result in darkness in urban areas because lights in houses, buildings, and streets stop working. Appliances such as computers, televisions, and other electrical equipment may malfunction or shut off as a result of power outages. Uncomfortable conditions might emerge from a loss of temperature control in regions where electricity operates heating and cooling systems. Communication infrastructure, such as landlines, mobile networks, and internet services, can be affected by power outages. Refrigerators and freezers may lose electricity during a protracted power outage, resulting in food spoilage in Food storages. Power outages may pose a safety concern by affecting vital services like hospitals, emergency services, water supply, and transportation networks.

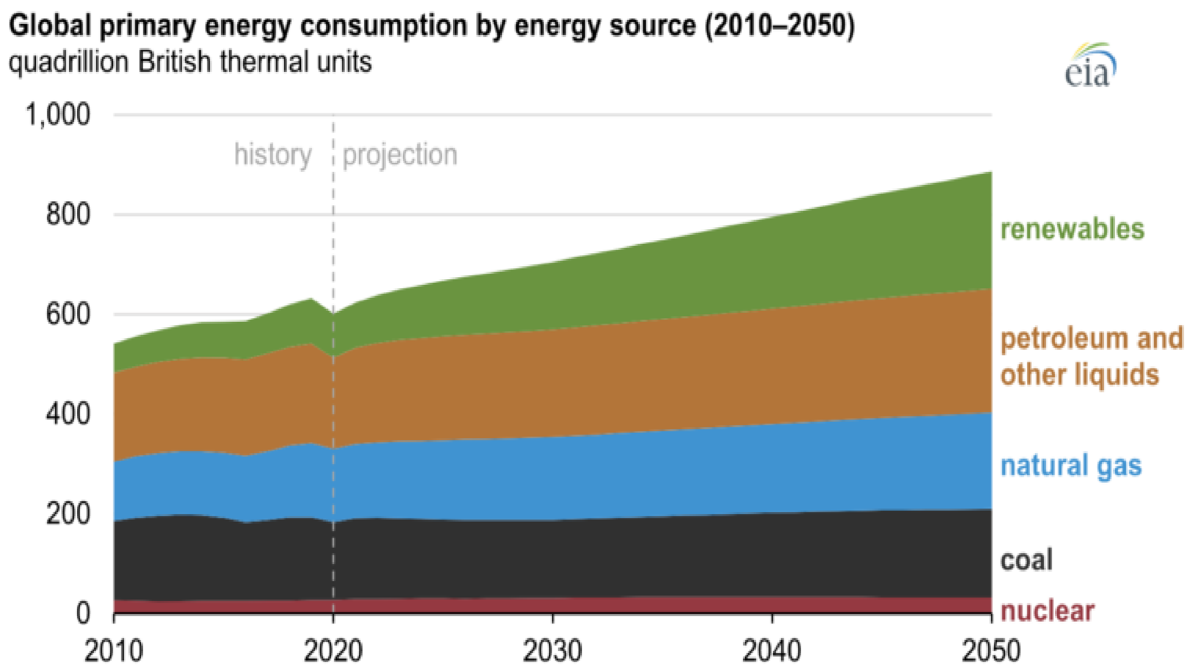

Figure 10 ***EIA Expects Energy Demand to Increase Almost 50 Percent Worldwide by 2050***

Source : Energy Information Administration

2. Reduced Air Quality: High levels of air pollution are frequently associated with urban heat islands. The combination of heat and pollutants can cause smog and other dangerous pollutants to build, aggravating respiratory symptoms and jeopardizing overall air quality. (10)

When we breathe in air pollutants, they can enter our bloodstream and lead to a variety of breathing and lung disorders, which can result in hospitalisations, cancer, or even a premature death. (11) They can also cause or worsen itchy eyes and coughing.

The World Health Organisation (WHO) provides information on main air pollutants such as lead, nitrogen oxides, sulphur oxides, ground-level ozone, and particle pollution that can seriously affects many environmental elements such as Groundwater, soil, and air, that can be severely harmed by air pollution. it seriously endangers all living organisms

Studies on particulate matter (PM) and health, focused on either short-term (acute) or long-term (chronic) PM exposure, have demonstrated a connection between PM and unfavourable health outcomes. Typically, chemical reactions between the various pollutants result in the formation of particulate matter (PM) in the atmosphere. The size of the particles has a significant impact on how far they travel.

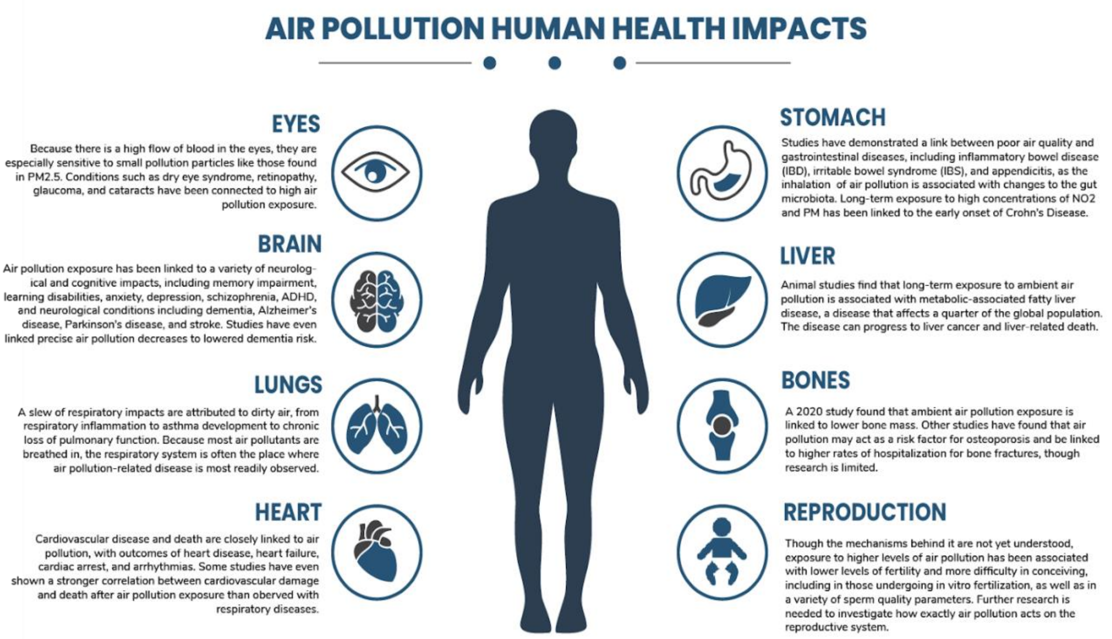

Figure 11 ***Source: https://www.clarity.io/blog/deep-dive-health-impacts-of-air-pollution***

3. Human Health Risks: Global health is at risk from excessive heat, whether it manifests as long-term average temperatures that are rising or as heat waves. It currently kills more people in the United States than all other natural disasters combined, and a changing climate will undoubtedly make it worse Summer days that are hotter than usual make it more likely that people will get sick or die compromising the body's capability to control its temperature. Heat cramps, heat exhaustion, heatstroke, and hyperthermia are just a few of the ailments that can develop because of loss of temperature regulation. Increased sickness and death are linked to even little deviations from seasonal normal temperatures. Extremes in temperature have the potential to exacerbate a variety of chronic disorders, including those connected to diabetes, as well as cardiovascular, respiratory, and cerebral diseases.

4. Urban Heat-Related Mortality: Heat waves associated with urban heat islands can result in an increased number of heat-related deaths. The intense and prolonged heat can strain the human body's ability to regulate temperature, leading to heat exhaustion and heatstroke. (10) Extreme heat events are one of the leading weather-related causes of death in the United States from 1999 to 2009; (12) extreme heat exposure caused more than 7,800 deaths Excessive heat in urban environments poses health risks. Heat-related illnesses, heat strokes, and dehydration become more prevalent during heat waves. (10) Heat waves are especially hard on children, the elderly, outdoor workers and athletes, economically disadvantaged groups, and those already suffering from chronic illnesses, often resulting in more trips to the hospital. (13)

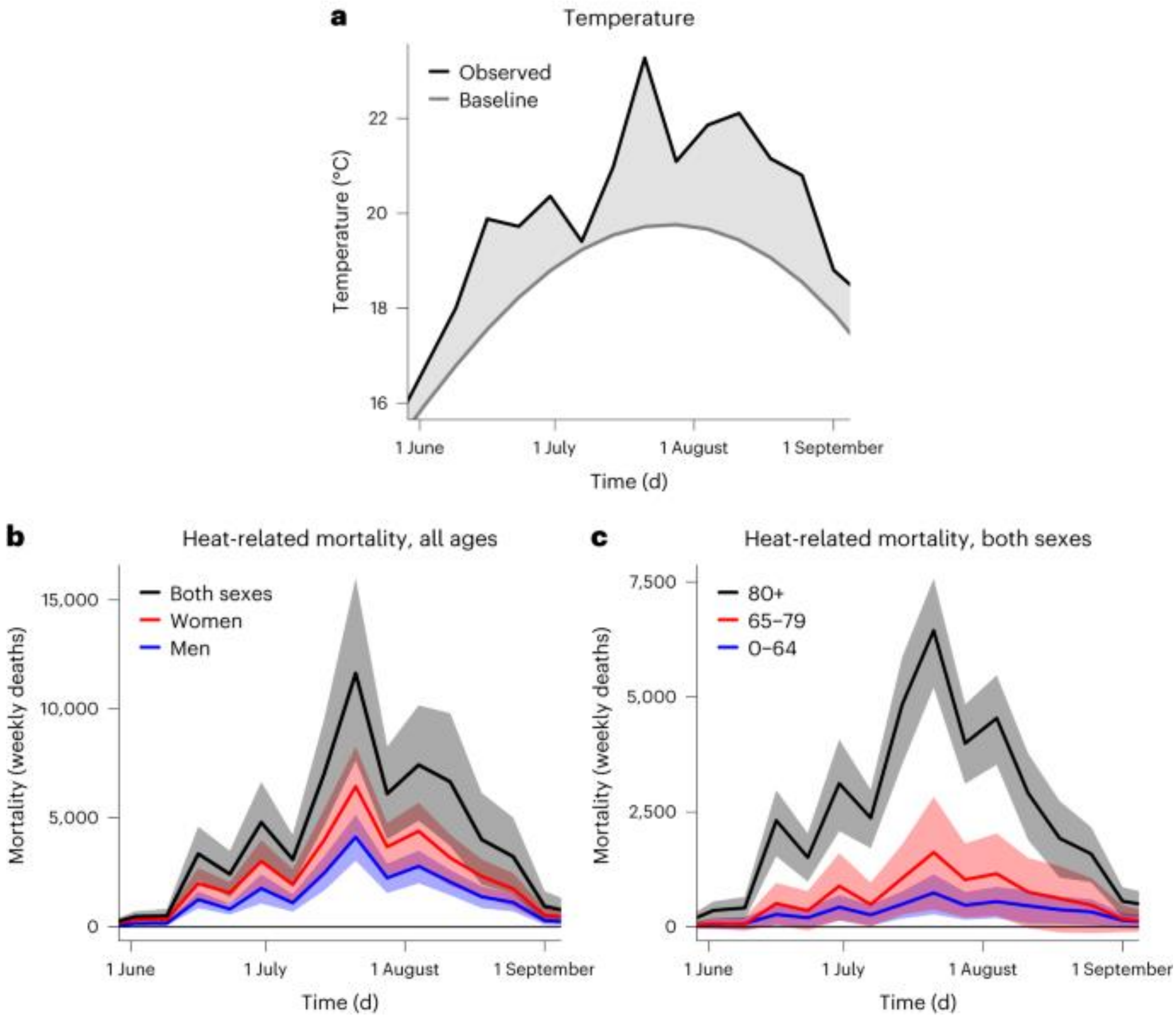

Figure 12 ***Above graphs shows Weekly temperature and heat-related mortality numbers in Europe during the summer of 2022.***
Source: Ballester, J., Quijal-Zamorano, M., Méndez Turrubiates, R.F. et al. Heat-related mortality in Europe during the summer of 2022. Nat Med 29, 1857–1866 (2023).

5. Environmental Consequences: The altered microclimate within urban areas affects the local ecosystem. It can disrupt plant and animal habitats, reduce biodiversity, and impact the natural balance of ecosystems. Additionally, higher temperatures contribute to increased water evaporation and can strain water resources in urban areas. (10)

Figure 13 *Impacts of Heat waves*
Source:www.aqi.in/blog/urban-heat-island-effect-causes-and-cities-rising-temperatures

5. Measure to understand the Vulnerability

1. **Using Lowry's system differences between urban and rural areas (based on data from two different points, Urban and Rural).**

The Lowry's schema (1977)

Mu = C + Lu + U

Mu = temperature recorded in the Urban area;
C = Regional Climate component;
Lu = climate component resultant from the specific Urban localization;
U = urban modification

Mr = C + Lr

Mr = temperature recorded in the rural surroundings;
Lr = climate component resulting from the specific rural localization

Mu -Mr = Lu - Lr + U

If Lu = Lr ,
Then Mu - Mr = U

2. **Urban transects of Air Temperature Measurement (often using vehicles fitted with digital thermo-hygrometers).**

Figure 14 *Thermo-hygrometers*
Source: www.digispot.co.uk/htd-625--thermo-hygrometer-305904-p.asp

Temperature is monitored along a straight transect from the edge of the city to the centre. Mobile transects across the full cities are challenging due to heavy traffic levels and long-time sampling concerns. As a result, the route is selected based on the topography and variety of soil cover. Heat islands are clearly delineated during evening hours.

A thermo-hygrometer range is used to measure the air temperature. It is connected to an automatic data which is set up to take readings every 0.5 seconds and store one on average every second. Prior to taking temperature readings, the average temperature readings from the sensor were compared to temperatures recorded by an automated weather station.

The thermo-hygrometer is housed on a meteorological structure that is 1.5 to 5 metres above the ground and 30 cm above the vehicle's roof. Only data recorded at speeds greater than 40 km/h-1 are taken into account in order to prevent influence from heat emissions, Along with the meteorological observations, time and geographic coordinates are recorded. These data were utilised to eliminate data points while the vehicle was stopped (for example, at stoplights).

To more precisely time the nocturnal cooling rates over the region, air temperature and humidity are monitored on both the outbound and return routes. Additionally, to account for altitude-related temperature variations along the trip, an adiabatic gradient is employed to correct the temperature data. Averages were computed for each 500 m of transect following data collection. Then, relative to equivalent readings in the city centre, differences in air temperature and absolute humidity were estimated.

Figure 15 ***Source: Impacts of the Microclimate of a Large Urban Park on Its Surrounding Built Environment in the Summertime by Majid Amani-Beni, Biao Zhang , Gao-Di Xie and A. Jacob Odgaard.***

3. Satellite and aircraft-based remote sensing.

Typically, surface measurement is performed through remote sensing that can identify and measure the wavelengths emitted from the surface. (14) The wavelength intensifies with surface temperature. Thermal wavelengths fluctuate as temperature rises, as shown in the below figure

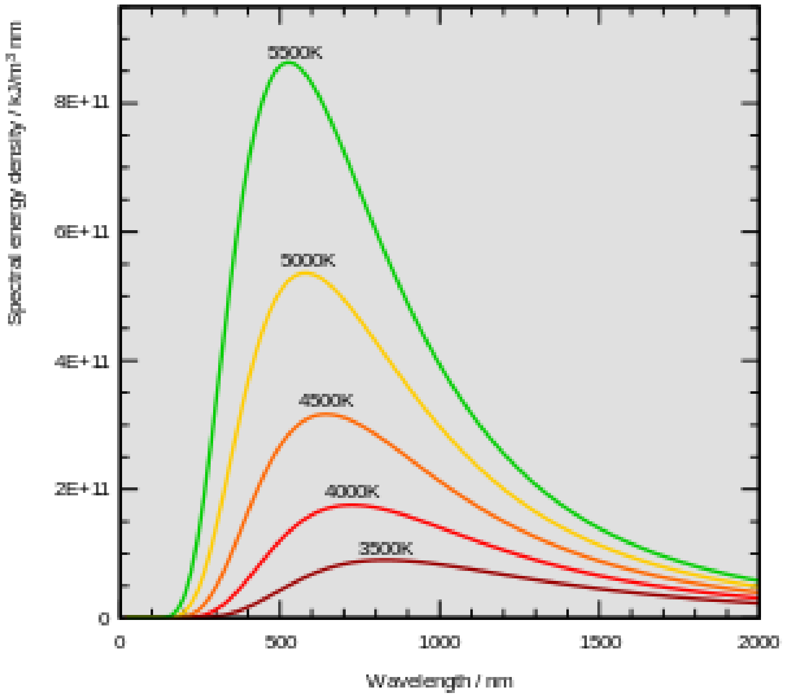

Figure 16 ***Thermal Wave length Source: Wikipedia, 2023***

Surfaces can become super-heated on a hot summer day, increasing in temperature 50-90°. (14) In densely populated Urban places with little or no vegetal surfaces, the increased temperature has the potential to raise the ambient air temperature. The measurement of surface UHI may be challenging due to this temperature change.

One of the drawbacks of remote sensing is its inability to record emissions from vertical surfaces, such as the side of a building wall. Since remote sensing equipment is made to collect data from horizontal surfaces like streets, rooftops, and treetops, this creates a hurdle. The sensor collects data from an aerial perspective, which may not always be the most accurate representation of the UHI. The second issue is that data from remote sensors shows radiation that has twice passed through the atmosphere. The wavelength has travelled from the sun to the earth, reflected from its surface back into the atmosphere to an orbiting or high flight sensor, and is now being measured by the sensor. The data must be updated by adding solar reflectance and temperature in order to account for this error.

Analyses of the observations over the short term

Following figure 17 displays the cumulative frequency distribution of UHI values for the Summer reference week participating cities. Figures 18 and Figure 19 represents respectively, the hourly values of urban temperature and hourly UHI values for a reference summer day.

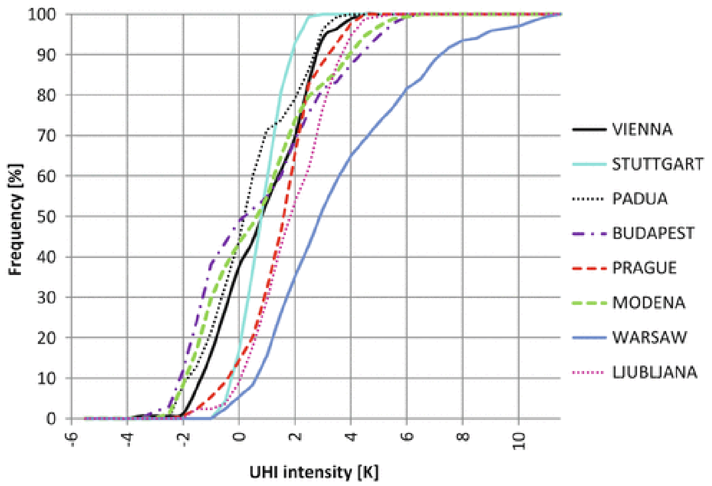

Figure 17 *Cumulative frequency distribution of UHI intensity for a one week summer period*

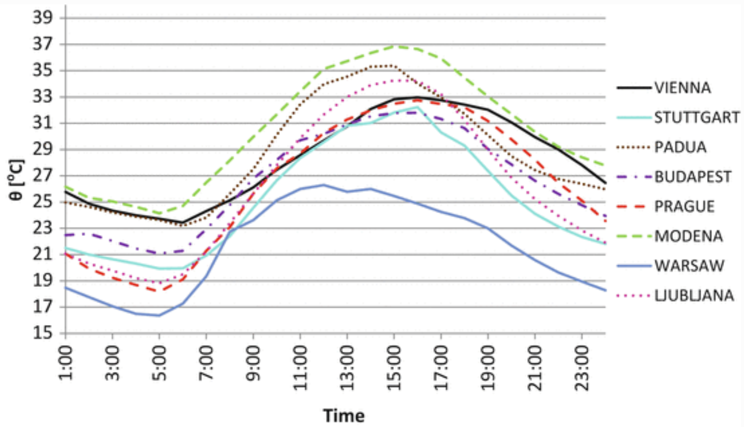

Figure 18 *Mean hourly urban temperature for a reference summer day*

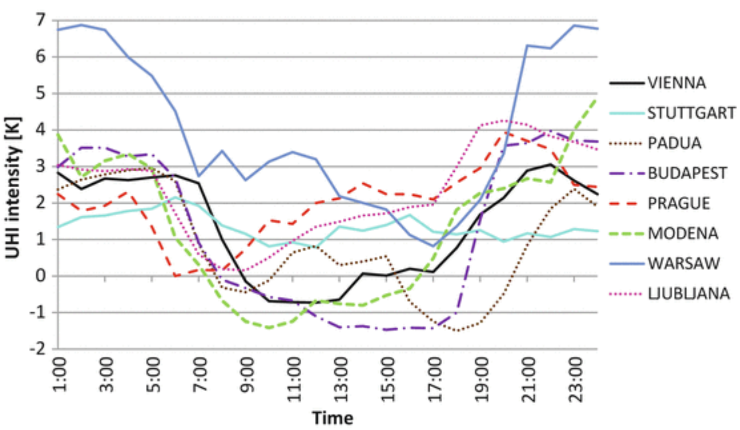

Figure 19 *Mean hourly UHI intensity distribution for a reference summer day*
Source: Methodologies for UHI Analysis,Urban Heat Island Phenomenon and Related Mitigation Measures in Central Europe Ardeshir Mahdavi, Kristina Kiesel & Milena Vuckovic

The reference week data shows the presence and sizeable magnitude of the UHI effect in participating cities, particularly at night (Fig 19). However, there are significant differences in the time-dependent UHI patterns between the participating cities. For instance, in Warsaw, the intensity of the UHI varies from 1 K during the day to approximately 7 K at night, while in Stuttgart the levels are more stable and range between 1 K and 2 K. The cumulative frequency distribution curves of Fig. 17 show the differences in UHI pattern as well. A greater UHI magnitude is indicated by a movement to the right.

Analyses of the observations over the long term

The (mean annual) temperatures for urban and rural areas over a 30-year period are shown in Figures 20 and 21, respectively. The trend in the long-term UHI intensity during the same time period is depicted in Figures 22 and 23. Both urban and rural temperatures appear to be trending rising according to historical temperature records (see Figs. 20 and 21). In line with regional and global temperature trends, all of the chosen cities with the exception of Budapest have experienced a consistent rise in rural temperatures of up to around 2.5 K. Given that this particular weather station was installed in 2000, the short sample size of the data set may be to blame. During the same 30-year period, the average annual urban temperature increased between 1 K (Stuttgart) and 3 K (Warsaw).

This tendency may have been influenced by a number of variables, including population growth, energy consumption, anthropogenic heat production, and physical changes to the urban environment (such as an increase in high-rise structures and impermeable surfaces). It should be noted that while temperatures have risen in both urban and rural areas, the intensity of the UHI has remained mostly stable. While Stuttgart and Prague data show a minor decline, our data indicate growing UHI intensity trends in Warsaw and Ljubljana (Figs. 22 and 23).

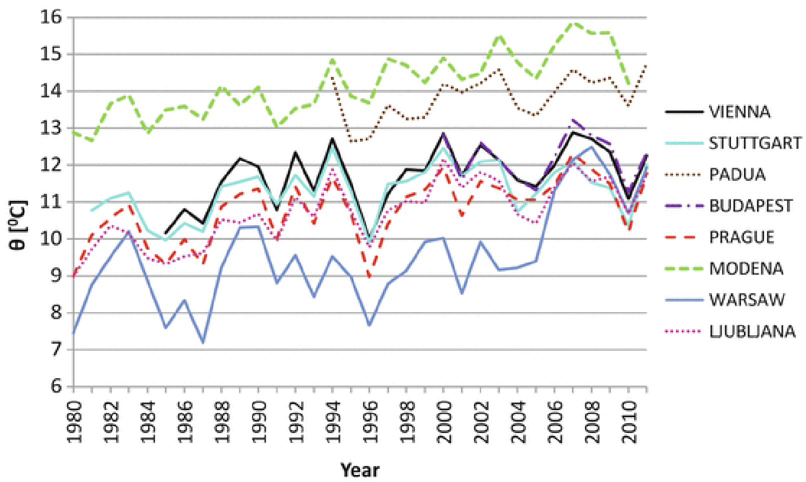

Figure 20 ***Development of (mean annual) urban temperatures over a period of 30 years***

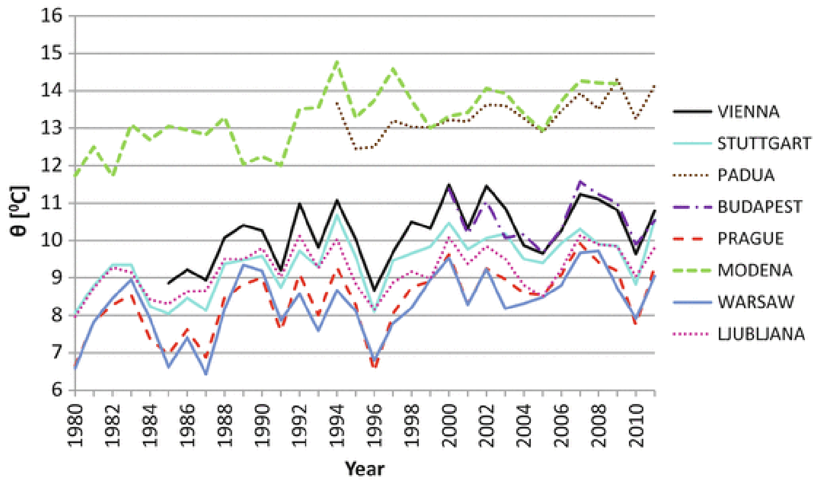

Figure 21 ***Development of (mean annual) rural temperatures over a period of 30 years***

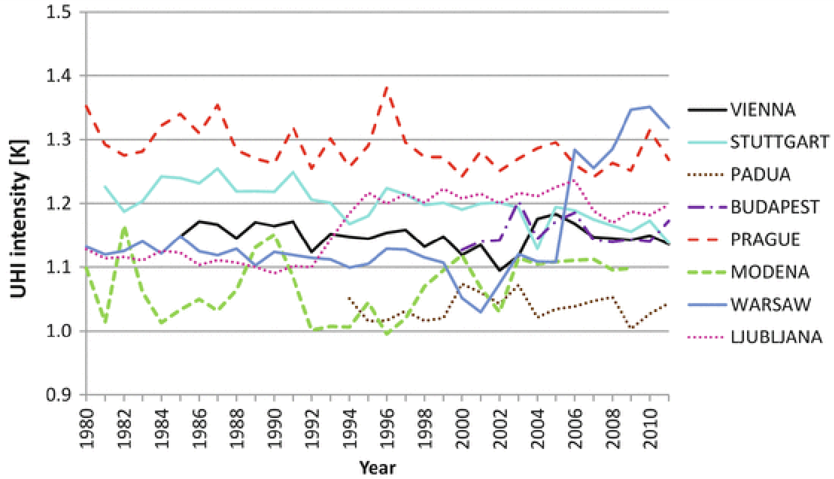

Figure 22 ***Long-term development of the UHI intensity over a period of 30 years***

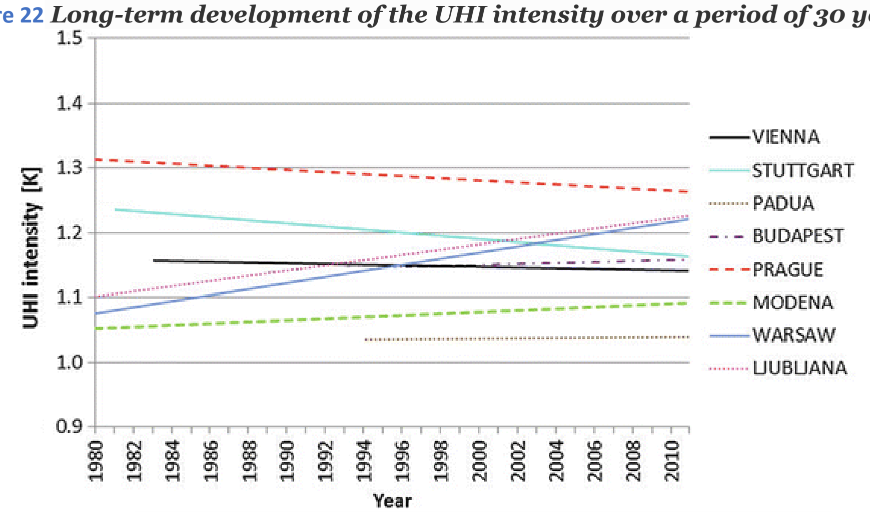

Figure 23 **Long-term UHI intensity trend over a period of 30 years**

Source: Methodologies for UHI Analysis,Urban Heat Island Phenomenon and Related Mitigation Measures in Central Europe Ardeshir Mahdavi, Kristina Kiesel & Milena Vuckovic

Above mentioned Observations were funded by the EU that looked at the scope of the UHI phenomenon in many Central European cities. The goal of this analysis is to promote and shared awareness of the effects of UHI and to develop and assess suitable adaptation and mitigation strategies.

6. Mitigation Strategies
A. Green Roofs and Green Facades

The practice of installing Green roofs and facades dates back to ancient times, and the so-called Hanging Gardens of Babylon are one example of how greenery has been incorporated into architecture.

The approach for creating more sustainable cities includes using green roofs and facades, which are effective for managing urban heat, with the main goal of reducing energy consumption for air conditioning in the summer and boosting thermal insulation in the winter and managing runoff water because of their capacity to absorb heat (sunlight) and water. In several places throughout the world, Green walls and Green rooftops is attracting increasing amounts of attention and Value. If widely adopted in the cities, Green roofs and facades can reduce the UHI Effect and hence greenhouse gas (GHG) emissions, and thus contributing significantly to both the sustainability and aesthetical environment of cities.

Hard, impermeable materials like concrete or brick building facades and asphalt roadways work to raise city temperatures, which makes residents of those areas to live in uncomfortable condition and forced them to pay more for air conditioning.

By utilising evapotranspiration, a natural mechanism that helps lower heat through a mix of plant respiration and water evaporation, the usage of vegetated roofs and facades can help mitigate this issue. Plants' stomata open due to heat and release water when heated. Evaporative cooling causes the temperature to drop as a result.

Additionally, since the temperature in their vicinity is often lower than the surroundings, vegetated roofs and green spaces aid in the vertical mixing of air. The heat island effect is decreased as warm air rises over the hard surfaces and is replaced by fresh air. According to research, urban canyon settings with vertical greenery systems can significantly benefit from a maximum temperature decrease of 8.4 degrees Celsius in humid regions. (15)

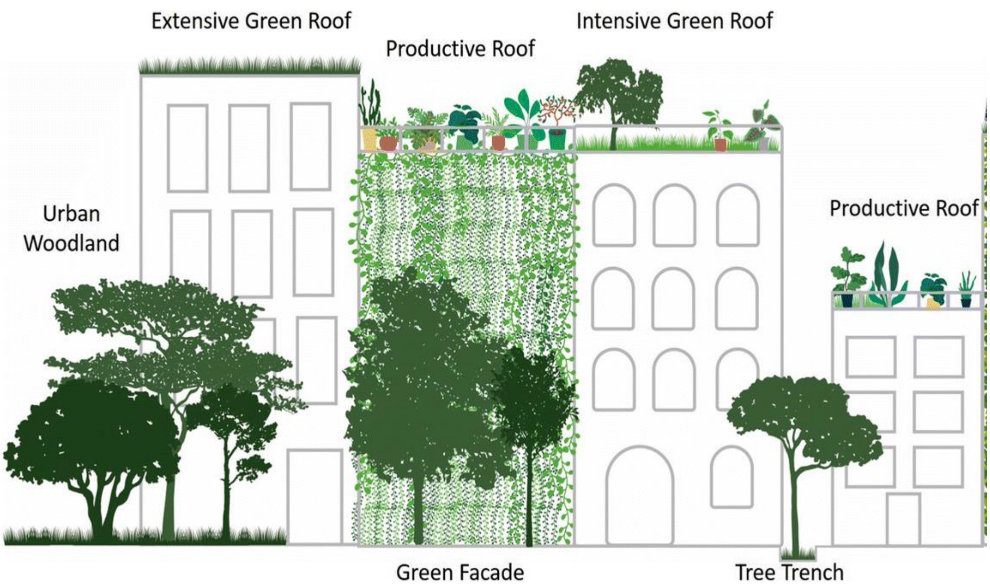

Figure 24 ***Integration of nature-based solutions in the built environment***
Source: Green Roofs Towards Circular and Resilient Cities. Cristina S. C. Calheiros & Alexandros I. Stefanakis

Green Facades: Stanley Hart White initially popularized the concept of a living green wall in 1938. He created a patent for a design that allows plants to grow vertically.

Green facades are structural components that have climbing plants that are rooted in the ground. Various Nets, Fences and Metal tube structures that promote plant’s vertical growth are used to construct green facades on structure’s exteriors and avoid any structural damage.

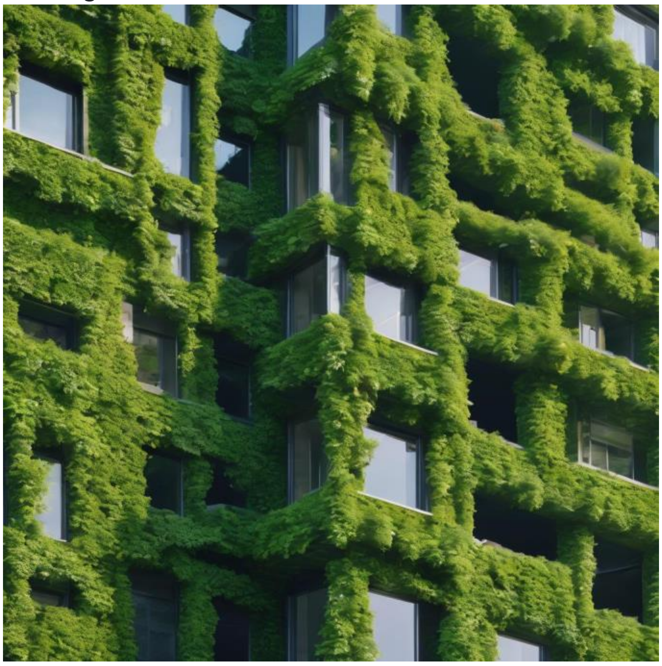

Figure 25; ***Green Facade***

<u>Green Roofs</u>: A roof that is partially or entirely covered with plants is referred to as a "Green roof" or "Living roof." Plants, such as Decorative plants or Flowers or even food crops, from grasses, small shrubs to trees, are grown in the area above the building, which is known as the Green roofs.

Figure 26; ***Green Roofs***

In order to understand the possible internal temperature difference that can be achieved using the green walls, an experiment was conducted by the University of Bari in Italy in the year 2016.

From June 2014 to April 2015, the experimental test was conducted at the University of Bari's experimental farm in Valenzano In order to develop a vertical wall prototype in scale, three vertical walls were constructed and furnished with a sealed structure on the rear. The walls had the following measurements: 0.20 m in thickness, 1.55 m in height, and 1.00 m in width. They were facing south. Perforated bricks measuring 20 cm in thickness, 25 cm in height, and 25 cm in length were used to build the walls. (16)

Pandorea jasminoides variegated and Rhyncospermum jasminoides, two different evergreen climbing plants, were utilised to cover two walls, while a third wall was left bare and served as a control shown in below figure. The transplantation took place on June 18, 2014. An iron net is used as the support for the climbing plants, and it is positioned around 15 cm from the wall. The drip watering technique was utilised for all of the plants.

Figure 27 *Source : Green control of microclimate in buildings . University of Bari,Italy*

The temperature of the walls, on the surface exposed to solar radiation and on the inner surface protected by the sealed structure and the temperature inside the sealed volume, and the temperature of the outside air were measured and collected using sensors and a data logger. The data were recorded in the data logger at a frequency of 60s, averaged every 15 minutes. Thermistors were positioned as shown in figure 37 to measure the surface temperatures of the inside wall, the exterior plaster exposed to sunlight, and the interior temperature. Using a Hygroclip sensor from Rotornic, Zurich, Switzerland, which was appropriately shaded from sun radiation, the outside air temperature was detected.

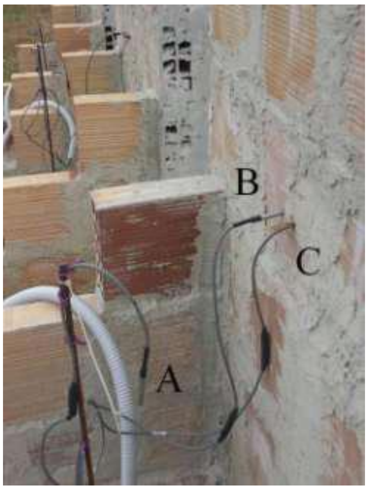

Figure 28 ***Location of the temperature sensors: sensor for the indoor temperature inside the volume behind each wall***

Results:

The plants sufficiently covered the walls starting in mid-August 2014, according to the field observations, even if Pandorea jasminoides variegated was more common than Rhyncospermum jasminoides. A difference of up to 4 °C was noted between the highest temperatures measured for the control and the walls covered with plants. In the summer, the presence of vegetation reduces the amount of solar radiation absorbed by the walls, lowering the temperature of the plaster of the external walls covered with climbing plants relative to the control wall.

The average values of the daily maximum and minimum surface temperatures of the outside plaster of the walls exposed to solar radiation from October 2014 to February 2015 are shown in Tables 1 and 2. The average maximum surface temperatures of the control, or the wall devoid of plants, were consistently higher during the study period than the average maximum surface temperatures of the vertical walls covered with Rhyncospermum jasminoides and Pandorea jasminoides variegated.

Table 1 Average values of the maximum daily external air temperature and surface temperature of the external plaster of the three walls exposed to solar radiation from October 2014 to February 2015.

Exposition period	Maximum temperatures			
	Rhyncospermum jasminoides external wall (°C)	Pandorea jasminoides variegated external wall (°C)	control external wall (°C)	external air (°C)
october 2014	24.0	22.5	25.1	23.9
november 2014	20.3	19.1	20.7	20.2
december 2014	16.2	14.6	16.4	15.1
january 2015	15.1	13.7	15.4	14.2
february 2015	13.6	12.5	14.1	14.1

Table 2: Average values of the minimum daily external air temperature and surface temperature of the external plaster of the three walls exposed to solar radiation from October 2014 to February 2015.

Exposition period	Minimum temperatures			
	Rhyncospermum jasminoides external wall (°C)	Pandorea jasminoides variegated external wall (°C)	control external wall (°C)	external air (°C)
october 2014	14.2	14.3	13.1	14.0
november 2014	12.2	12.5	10.9	12.1
december 2014	7.3	7.5	5.9	7.0
january 2015	5.4	5.3	4.0	5.4
february 2015	5.1	5.3	3.7	5.4

The greatest temperatures that were measured for the control and the wall covered in plants differed by 2.7 to 4.4 °C. The minimum surface temperature of the control wall had average values that were consistently lower than the temperatures measured for the walls with plants. The presence of plants improves the wall's thermal insulation throughout the winter. The range of 2.4 to 2.8 °C was found between the lower temperatures recorded for the control and the wall covered in plants (Fig. 38).

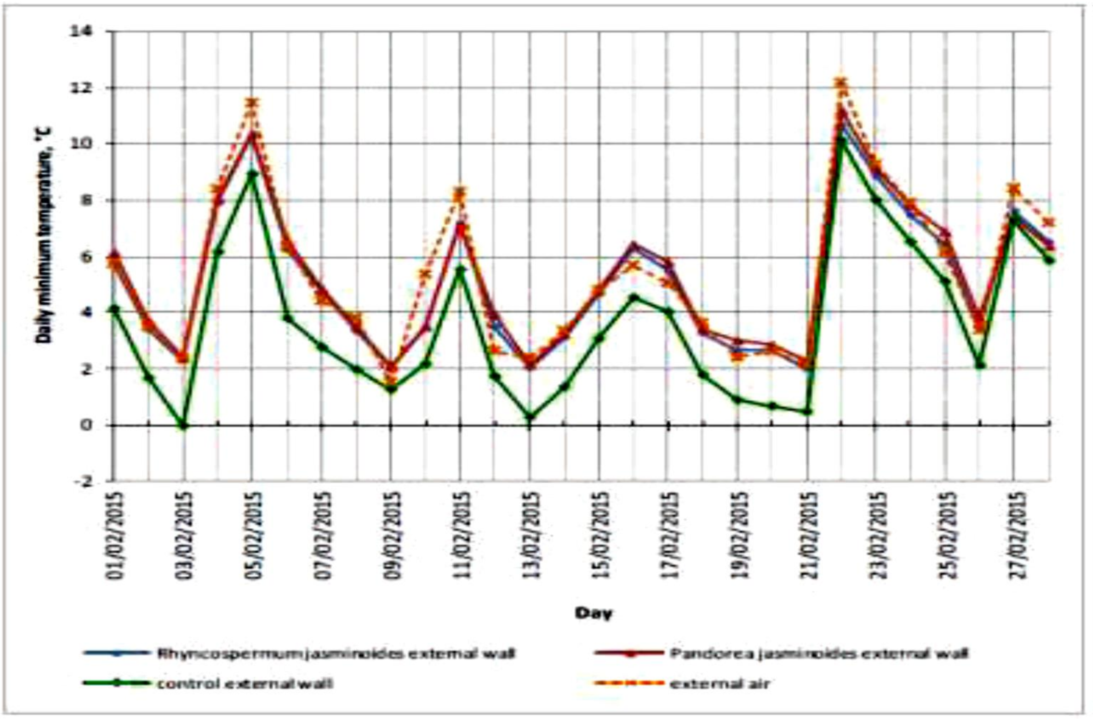

Figure 29 ***Daily minimum surface temperature of the external plaster of the three walls exposed to solar radiation and daily maximum external air temperature measured***

On vegetated vertical systems, the experimental test was carried out while accounting for both warm and cold times. By lowering the external surface temperature during the daytime hours by up to 4.4 °C when green walls were used during the summer months, it was possible to reduce the heat gain caused by solar radiation. Utilizing green walls during the colder months improved the thermal insulation capabilities of the walls by preserving the exterior surface temperature at night up to roughly 2.8 °C higher than the surface temperature of the wall without vegetation.

i. Implementation Examples

We will discuss some of the most innovative green roofs and facades designs ever created, and what makes them unique.

Examples of Green Facades:

1. CaixaForum Living Wall, Madrid

Figure 30; *Caixa Forum museum*
Source: Inhabitat.com/wp-content/blogs.dir/1/files/2012/08/Vertical-Living-wall-Madrid-lead.jpg

Caixa Forum Living Wall designed by Patrick Blanc. He invented Le Mur Vegetal, or Plant Wall. It is a thick layer of flora that can grow against any surface or even in mid-air. It functions by completely eliminating dirt and replacing it with hydroponically growing plants in felt pockets coupled to a stiff plastic base.

Blanc's wall.is completely covered by the Green plants and shrubs, Located in front of the rusting steel. The vertical garden is situated in the centre of Madrid's cultural area, which is home to numerous institutions.

Instead of the typical ferns and mosses, Blanc's wall features a range of plants that were specifically picked to thrive in the hot temperature of Madrid. The little oasis' living wall, which features more than 15,000 plants from over 250 species, immediately attracted a crowd. Climbing shrubs, Ivy, tufts of green, red, and yellow colour inside the mass of flowering plants that grow covers the wall. Wall is kept self-irrigated with Water drips that feed the plants and provide a calming mist on visitors seated around. Sitting next to the wall, the temperature feels several degrees cooler, demonstrating the wall's strong cooling impact. The wall of Blanc demonstrates that green walls may flourish in even the warmest and warmest and driest climes, green walls may grow, providing not only a rich environment but also cooling relief from the heat.

2. Stefano Boeri's Bosco Verticale or vertical forest, Milan.

Figure 31 ***Bosco Verticale (Vertical Forest), Milan***

Two residential skyscrapers that make up the Bosco Verticale (Vertical Forest) complex were created by the Boeri Studio (Stefano Boeri, Gianandrea Barreca, and Giovanni La Varra) and are situated in Milan, Italy's Porta Nuova neighbourhood. They stand 116 metres (381 feet) and 84 metres (276 feet) tall respectively, and the property also includes an 11-story office building.

The Vertical Forest is the first example of a new type of architectural biodiversity that emphasises not only the humans but also interaction between humans and other living beings like plants and Birds, Bosco Verticale is made up of two towers that are 80 and 112 metres high, respectively, and are home to 800 trees 480 first- and second-stage trees, 300 smaller trees, 15,000 perennial and/or ground-covering plants, and 5,000 shrubs, overall 94 different plant species are present in total, 33 are evergreens , 60 are trees and shrubs, and 59 of which are good for birds. providing 30,000 square metres of woodland and undergrowth of vegetation.

A control system consisting of a filtration unit, pressure regulator, and drain valve ensures the water supply to specific plants. The electrically powered irrigation system also considers the vegetation's actual water needs. To provide the best possible water flow, each valve functions separately from the others. The watering of the cultivation substrate is provided with an automatic air vent valve and a drip wing.

The Bosco Verticale has a vibration-dampening energy dissipation system despite being constructed on a site with optimum lithological characteristics and no groundwater influence. This technology must be used in order to stop the spread of potential seismic waves and, in particular, vibrations brought on by train traffic on the M2 and M5 metro lines, which are situated to the north and east of the site, respectively.

A centralised drip irrigation system is used to irrigate the trees. The water utilised is recycled from groundwater or graywater generated by the building. Once gathered in a cistern, the groundwater runs through a visible irrigation tubing network that, due to its low resilience to cold temperatures, automatically shuts off the water flow at temperatures below 0 degrees Celsius. A number of remotely monitored sensors that are able to identify any errors carry out this control.

Figure 32 ***The irrigation system of the vegetation in the Bosco Verticale, illustrated in the first figure; Source: Wikipedia***

All of these approaches get past the still primarily anthropocentric and technical idea of "sustainability" while advancing towards a new biological diversity. A few years after it was built, the Vertical Forest gave rise to a habitat that has been populated by several animal species, including over 1,600 bird and butterfly specimens, creating an outpost of spontaneous flora and fauna recolonization in the metropolis.

The project also serves as a tool for preventing urban sprawl brought on by a desire for natural space. Each tower is about equal in size to 50,000 square metres of single-family homes. The plant-based shield, unlike facades made of glass or stone, the plant-based shield filters the sun's light instead of magnifying and reflecting the sun's light, generating a comfortable internal environment. The green curtain "regulates" humidity, creates oxygen, and absorbs CO_2 and micro particles all at once. This unique combination of properties has earned the project numerous prestigious awards, including the International Highrise Award from the Deutschen Architekturmuseums in Frankfurt (2014). and the CTBUH Award for the best tall building in the world from the Council for Tall Buildings and Urban Habitat at Chicago's IIT (2015).

3. Villa M hotel, Paris

Figure 33 *www.dezeen.com/2022/06/12/villa-m-triptyque-philippe-starck-coloco-paris-hotel*

The new mixed-use Villa M project in Montparnasse, south of Paris, was created by the French-Brazilian firm Triptyque Architecture by Olivier Raffaëlli and Guillaume Sibaud, partners at Triptyque. There is a hotel and as well as a co working area and a Dynamic healthcare-focused centre. Moreover, it is dramatically covered in vegetation. The architecture of Villa M is meant to bring nature back to the city, with the main objective being to give residents a new urbane experience with the introduction of a "nature-city."

Its architecture distinguishes out with its living Facade, whose geometry is constructed by iron framework beams, intended to contain medicinal herbs plants, fruit trees, and medium- to large-sized perennial species. The building, which is made up of prefabricated pieces like in a building game, has a minimalist, light appearance and was created as an exoskeleton.

At Villa M, a total of 93 species have been planted, which have been carefully placed in a Botanical Table organised by plant type and varied heights. Sixty-five different species of medicinal herbs, perennials, and herbaceous plants are used in the design.

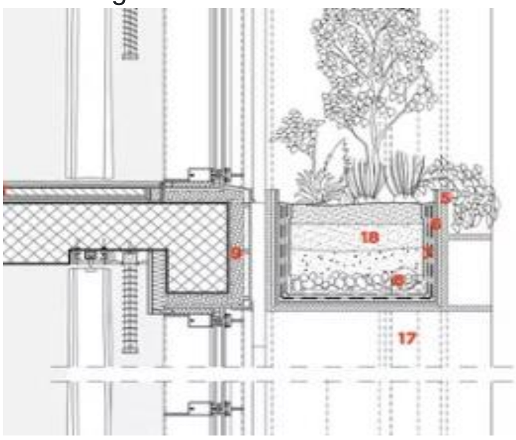

Figure 34 *Section by Triptyque Architecture*

With a simple system of planters constructed almost as a separate structure in front of the building, Villa M seems to be a really pleasant middle.

Villa M, a tropical structure that spreads vertical gardens and live architecture, likewise with its tropical building and its huge glazing and geometric metallic construction.

Examples of Green Roofs:

1. **Meera Sky Garden House, Singapore.**

   Every floor of the four-story Meera Sky Garden House, a private property designed by Guz Wilkinson and located on the Singaporean island of Sentosa, has a view of or access to greenery with total Area of 852 sq. meters and Gross floor Area of 654 sq. meters. Each level of the building has a roof garden, and it mixes solid and glass walls to maximise cross ventilation and provide privacy while minimising the need for air conditioning.

   The goal was to make each roof garden act as a base for the floor above, giving the impression that each Floor is a single-story home set in a garden thanks to the layered appearance it was possible with such a big building and the restricted space of Sentosa island.

Figure 35 ***Meera Sky Garden House – Cove Grove, Sentosa Island, Singapore***
Source: www.dezeen.com/2011/03/09/sky-garden-house-by-guz-architects

The void in the Centre and mostly shallow volumes of Sky Garden House, especially on the top levels, maximize cross ventilation and reduce the demand on Artificial Cooling.

The room in the basement level has a wide acrylic window that floods it with diffused natural light, significantly lowering energy usage. The vast shaded portions of glazing on the majority of spaces minimize the dependency on artificial lighting during daytime hours while restricting solar gain. In Singapore's tropical environment, the gardens on each floor generally extend over the floor below, giving shade and preventing warmth.

Reduced depth of interior spaces and more cross ventilation are benefits of the open air stairwell's design, which runs through the middle of the structure. When natural cross ventilation is used to its fullest and mechanical ventilation is used as needed, a high level of indoor air quality that is essential to occupant health is produced.

Water retention in garden areas will also help to decrease the strain on the surface water system during peak rainstorms in Singapore's tropical environment.

2. **California Academy of Sciences, San Francisco.**
   The Golden Gate Park environs and San Francisco's hills served as inspiration for the 2008-built California Academy of Sciences building, which was designed by architect Renzo Piano. The 2.5-acre living roof of the LEED Double Platinum building features 1.7 million native plants, solar panels, weather stations, and serves as an outdoor Classroom.

Figure 36 *CALIFORNIA ACADEMY OF SCIENCES (CAS) LIVING ROOF*
Source: www.calacademy.org/exhibits/living-roof

The living roof is possibly the best example of how Architect Renzo Piano envisioned the Academy. He stated that the intention was to "lift up a portion of the park and place a building underneath."

The building's automatic systems and skylights use information from weather stations on the roof to regulate the temperature of the rainforest, the inside piazza and the amount of natural light that reaches the exhibitions below. A sizable glass canopy around the Living Roof has an elegant band made of 60,000 solar cells sandwiched between two sheets of glass. Approximately 213,000 kilowatt-hours of energy are produced annually by these solar panels, which can provide up to 10% of the electrical requirements of the California Academy of Sciences. The usage of solar energy is anticipated to stop 405,000 pounds of greenhouse gas emissions from entering the atmosphere. The green roof lowers low frequency noise by 40 dB and keeps interior temperatures roughly 10° F cooler.

The planetarium and rain forest exhibits are housed in the two main domes. The domes are covered in a pattern of automatic skylights that open and close to provide ventilation. While the piazza's facade and the glass-covered ceiling inside offer views of Golden Gate Park to guests, the building's exterior closely resembles the park from above.

The California Academy of Sciences is a masterwork of environmentally friendly construction, fitting in well with its surroundings while utilising a wide range of cutting-edge features and methods to reduce its environmental impact. The CAS has won numerous honours, including the 2009 Honour Award in the General Design Category of the ASLA Professional Awards, the 2008 Green Roofs for Healthy Cities Award of Excellence, and the 2005 Silver Holcim Award for Sustainable Construction, given in recognition of the CAS's creative "green" design of their new facility.

3. Espace Bienvenüe, Marne-la-Vallée, France

French architect Jean-Philippe Pargade built a sizable campus for the Pôle Scientifique et Technique Paris-Est, a research and civil engineering centre also known as Espace Bienvenüe, in Marne-la-Vallée, a city east of Paris. A more than 650-foot-long wavy concrete structure that is the site's main point is covered in an accessible garden terrace that was created in cooperation with landscape architect David Besson-Girard.

Figure 37 *Espace Bienvenüe Source: https://laud8.wordpress.com/*

With a total surface area of close to 40,000 m2, Bienvenüe includes 25,000 m2 of offices, 10,000 m2 of laboratories (chemical, optical, and materials), a test slab (50 x 10 m), a conference centre with a 250-seat auditorium and meeting spaces, and a restaurant with seating for 1,700 people.

A series of restricted depth buildings with patios optimises the amount of natural light that enters the offices, labs, and training rooms. A high level of inertia (concrete envelope with externally applied insulation and concrete slabs without raised floors, planted roof terraces, glazing with reinforced insulation efficiently protected from the sun by mobile sunbreakers on the south façade that can be controlled by the occupants) minimises the need for heating and cooling. (17)

When the outside temperature is less than 26°C in the middle of the season, the system allows for manual cooling by requiring the occupants to manually open the windows. Chiller beams are utilised to keep the space chilly above that point. With a COP of 4.26 and an EER of 4.15, these beams use a reversible thermodynamic system that utilises the water table and is sized to meet the heating and cooling requirements.

Figure 38 ***ESPACE BIENVENÜE - PARIS-EST SCIENTIFIC AND TECHNICAL POLE***
Source: Press Kit Jean-Philippe Pargade Architects.

High performance fresh air/exhaust air exchangers, variable speed motors, and flow rates regulated by a timer and CO2 sensors are used in a dual flow CMV to ventilate the space.

Compact fluorescent luminaires that are controlled by presence detectors provide artificial lighting. Equipment performance levels are monitored by a centrally located building management system, which also maximises effectiveness. All the developments that support sustainable development are incorporated into the architectural strategy. It emphasises how the environment, energy management, servicing and maintenance, and hygrothermic and visual comfort are related.

The low-energy goal has received special attention, and the structure now bears the BBC label. The building's orientation and insulation (the south facade is largely open to the campus and catches solar energy; the north facade is more closed and provides an insulating wall with a strong thermal inertia), natural ventilation, rainwater collection, and insulating materials will all work together to achieve this goal.

Geothermal energy drawn from a groundwater body serves as the building's primary source of heating and cooling. Thus, the project's inspiration comes from the perfect alignment of its content laboratories conducting the most cutting-edge research in terms of sustainable development and its container the highly environmentally, energetically, and ecologically efficient architecture that surrounds and organises it.

ii. Benefits

Systems with green roofs and walls have a number of advantages, including the ability to reduce storm-water damage and pollutants and enhance the environmental quality of metropolitan areas. If widely used in cities, Green roofs and facades can also reduce greenhouse gas (GHG) emissions and the UHI Effect, which will considerably improve the sustainability and aesthetics of urban environments. (18) Additionally, green roofs and facades add to the fire protection, reduce noise, and additional uses, such as recreational areas.

Green roofs, walls and facades benefits at economic, ecological and societal levels.

Because plants absorb sunlight, which is split into 30% reflection and 50% absorption, the atmosphere is made colder and more pleasant. This reduces the amount of service required by the air conditioner, which results in energy savings for the indoor climate. Additionally, this has a favourable impact on the city's temperature as well as the climate in the area right around your building. Overall, it results in a 3°C drop in temperature in the city. (19)

Green roofs and facades contribute to better air quality in general. A study found that green roofs can lower sulphur dioxide emissions by up to 37%, nitrous acid emissions by 21%, and dust particles by 0.2 kg per square metre annually. The vegetation on green roofs, walls and facades filters airborne particulate matter and produces oxygen from CO2. (20)

Green roofs and facades enhance a building's Aesthetic Appeal and breathe life into the design. The problem of the lack of green space in urbanised areas is frequently thought to be resolved by green roofs and facades.

Green roofs and facades add to the roof's fire protection. Moisture is abundant in plants by nature. You can add a natural fire-resistant layer to your home or office building with a green roofs and facades.

Green roofs and facades support wildlife, which in turn helps improve the habitat. Despite not being able to completely replace ground habitats, they are ideal for luring birds and other species to create a thriving eco-friendly ecosystem. Different ecosystems can be supported by each green roof, mostly depending on the type of flora present. A study of 11 green rooftops in Switzerland identified an astounding 172 different species, according to the report. (20)

A Building structures have a lot to deal with all year long and is constantly under attack from the elements. Buildings will need to be able to withstand not only wind and rain, but also ultraviolet light and changing temperatures. As a result, it's typical for both homes and businesses to think about a different roofing option. This possibility is provided by green roofs and facades, which have been shown to double or even treble the lifespan of your roofing. Greenery serves as a barrier, preserving the waterproof membrane below and extending the useful life of your rooftop.

Green roofs and facades add value to the property A decrease in energy expenditures, an extension of the lifespan of your roof, and a more natural and sustainable aesthetic all contribute to an increase in property value.

Any building must have sustainable drainage in order to prevent floods in the event of excessive rain. Water control has historically been aided by a system of pipes connected to the sewage system. However, as much as 75% of water is draining off into metropolitan areas as a result of growing urban growth. (20) Green roofs are a fantastic alternative. Prior to being naturally released back into the environment, water is retained in substrate and plants due to the water absorbing properties of the plants; this cleans the rainfall storm water, slows its release into the sewage system, and allows it to evaporate through the vegetation. All of this minimises the peak demand on the sewage system, stabilises the groundwater level, and lowers the chance of flooding.

The green roofs and facade market has advanced significantly in recent years, and many projects have endured for more than ten years as they address the energy issue, combat climate change, and create sustainable communities. Thus, these horticultural marvels have the ability to turn even the most uninteresting, unwelcoming space into a wonderful, welcome vertical garden, giving new meaning to the term "green architecture."

B. Increasing Canopy and Vegetation

Plant surfaces without any shade were much cooler than all artificial materials by at least 11 °C on average and up to 2.9°C; this outcome is in line with other research that found that growing plants might be an effective urban cooling method due to their lower surface temperatures. (21)

Figure 39; *Photo by WDG Photo, Shutterstock*

According to the Research experiment carried out by the National University of Singapore. The temperature was reduced by 1.76 °C during the cold season and 2.18 °C during the warm season for 50% increase in the permeable surface. (22)

Vegetation can contribute to reduce temperatures and UHI effects in two ways:

1) Through shadowing with solar radiation being absorbed or can be reflected by their leaves.
2) Through localised Evapotranspiration. Transpiration is the process by which plants and trees draw water by their roots from the soil and release it into the air through their leaves in order to cool their surroundings. And the evaporation of rainwater that has collected on leaves and soil, vegetation may provide cooling. This transfer of water from soil and plants into the atmosphere, called Evapotranspiration is the major way that trees contribute to lowering high urban temperatures.

Due to increase in temperature by UHI effects, local urban atmosphere is need of water from its plants because warmer air can hold more water.

If we consider a plants and vegetation as a straw, it draws moisture from the earth and releases it into the atmosphere. (According to Sam Zipper, lead author and former PhD candidate at UW-Madison), the urban heat island effect is essentially extending the dimension of a straw. Stored water from Urban Trees and plants are anticipated to deplete faster as dimension of straw becomes larger, increasing the requirement to refill and meet the demands of the atmosphere.

According to the Article by Directorate-General for Environment of European commission, increasing the amount of trees in European cities to 30% could lower the number of deaths caused by the urban heat island effect.

According to the research article “Temperature and human thermal comfort effects of street trees across three contrasting street canyon environments”.by Coutts, A.M., White, E.C., Tapper, N.J.

In order to compute the effects of Trees canopy on both the interstreet and intrastreet air temperature and Human thermal comfort, three different streets in Australia that differ from one another in terms of tree canopy coverage and canyon topography CBD a deep urban canyon. OPN a shallow urban canyon with little tree canopy cover and TRD a shallow urban canyon with dense tree canopy cover were chosen. (23)

Figure 40 ***Location and photos of each street: Bourke St. (CBD) (East and West), Gipps St. (OPN), and George St. (TRD)***
Source: Article by Coutts, A.M., White, E.C., Tapper, N.J.

In order to record both interstreet and intrastreet microclimate variability, many monitoring stations were put in place on each street.

Each Street had a number of monitoring stations spread all around utilising high-quality scientific equipment. Each monitoring station recorded data of air temperature relative humidity, wind speed, solar radiation and the temperature of a black globe. The black globe thermometers were used to calculate the mean radiant temperature. To prevent damage or disturbance, stations were placed between 3.5 and 4.0 metres up on existing light poles.

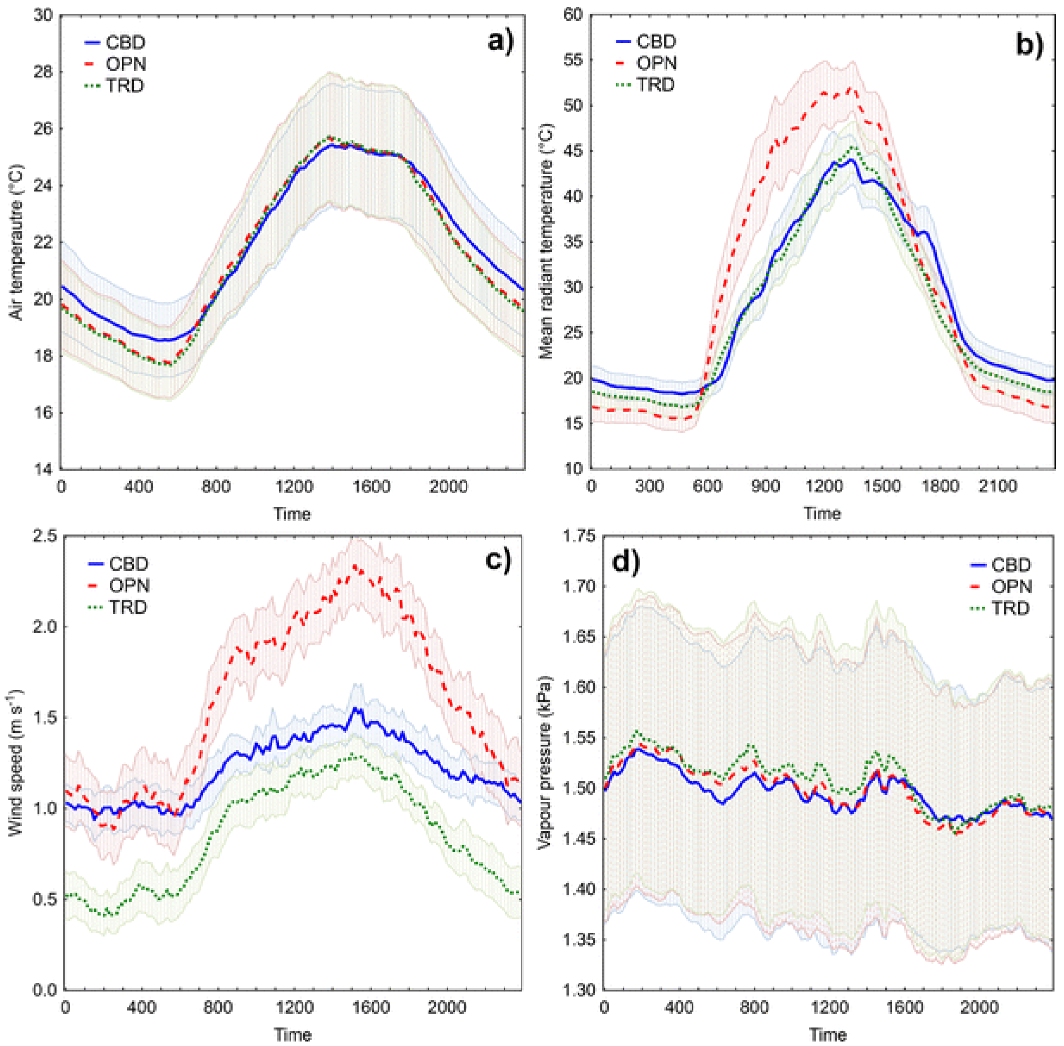

Figure 41 ***Environmental components influencing human thermal comfort for each street, averaged across all monitoring stations: January 2012 mean diurnal values for a air temperature, b mean radiant temperature, c wind speed, and d vapor pressure. Error bars are 95 % confidence interval*** (23)

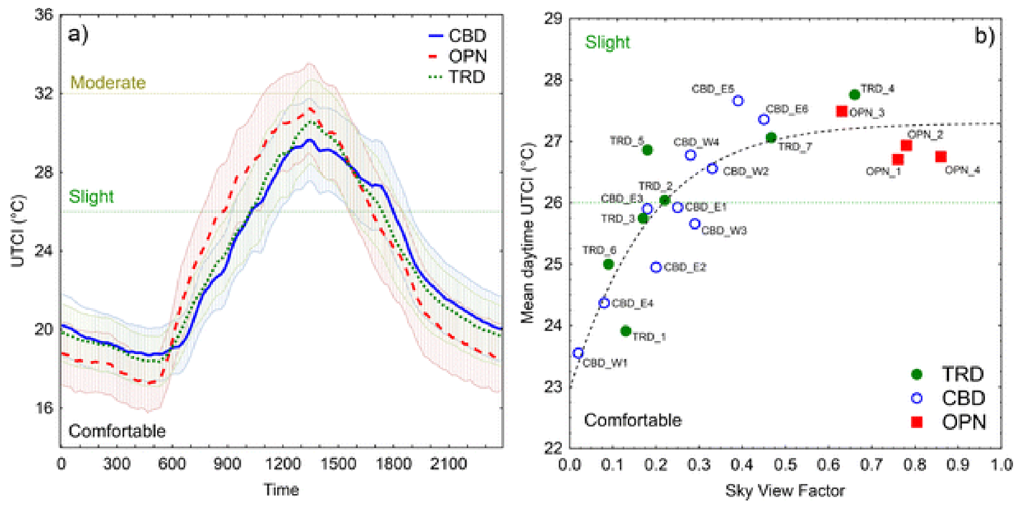

Figure 42 ***a Mean Universal Thermal Climate Index (UTCI) for each street, averaged across all monitoring stations in January 2012. Error bars are 95 % confidence interval. The levels of thermal stress from the associated assessment scale are also presented; b relationship between sky view factor (SVF) and mean daytime UTCI in January 2012*** (23)

There was a noticeable variation in canyon temperature of up to 0.8 °C at night between the TRD and the more developed CBD site, which was statistically significant. This was caused by the higher H:W and more imperviousness at CBD.

Due to the huge impervious surface cover's ability to retain radiation that was absorbed during the day and the lower long wave radiative cooling, the deep urban canyon of the CBD cooled more slowly than the shallow urban canyon of the TRD.

The CBD street canyon may have been warmed by by human activities from vehicles and buildings. Although the total Sky view factor (SVF) at CBD and TRD was similar, it is important to observe that this difference in night time was noticeable, and a larger amount of the lowered SVF at CBD was caused by buildings (Table 2). This shows that a reduced SVF caused by a building affects heat retention more than a reduced SVF caused by a tree canopy.

Figure 43; ***Aerial view of the streets highlighting individual station locations and tree canopy coverage in Bourke St. (CBD), Gipps St. (OPN), and George St. (TRD)*** (23)

The most notable difference between the shallow TRD site and the deep canyon CBD site was the greater nightly temperature at CBD (Fig. 44), with variations of up to 4.8 °C before morning. This emphasises the limited longwave cooling caused by the buildings in the CBD's lower SVF, which is known to be a significant source of the canopy layer UHI. The increased frequency of threshold minimum night time temperatures of 24 °C at CBD is also highlighted by this.

However, due to lower SVF from the structures that make up the deep canyon and, to a lesser extent, from the trees, as well as the absorption of solar radiation by urban materials, the CBD location saw a daytime temperature difference of up to 2.0 °C. These factors are sometimes cited as the origins of the urban cool island throughout the day. The lower daytime temperature at the CBD site occurs despite a lower vegetation cover and lower leaf area index of the trees, emphasising once again how little of an impact street trees have their compared to the area's building typology. Due to shade, HTC's low SVF also causes a decrease in UTCI throughout the day.

Deep roadway canyons, on the other hand, are the least advantageous at night since the heat retention causes a poorer HTC (high temperature, and high UTCI). In TRD, the street trees thus create a more agreeable thermal environment during the day while having little to no negative effects on HTC at night.

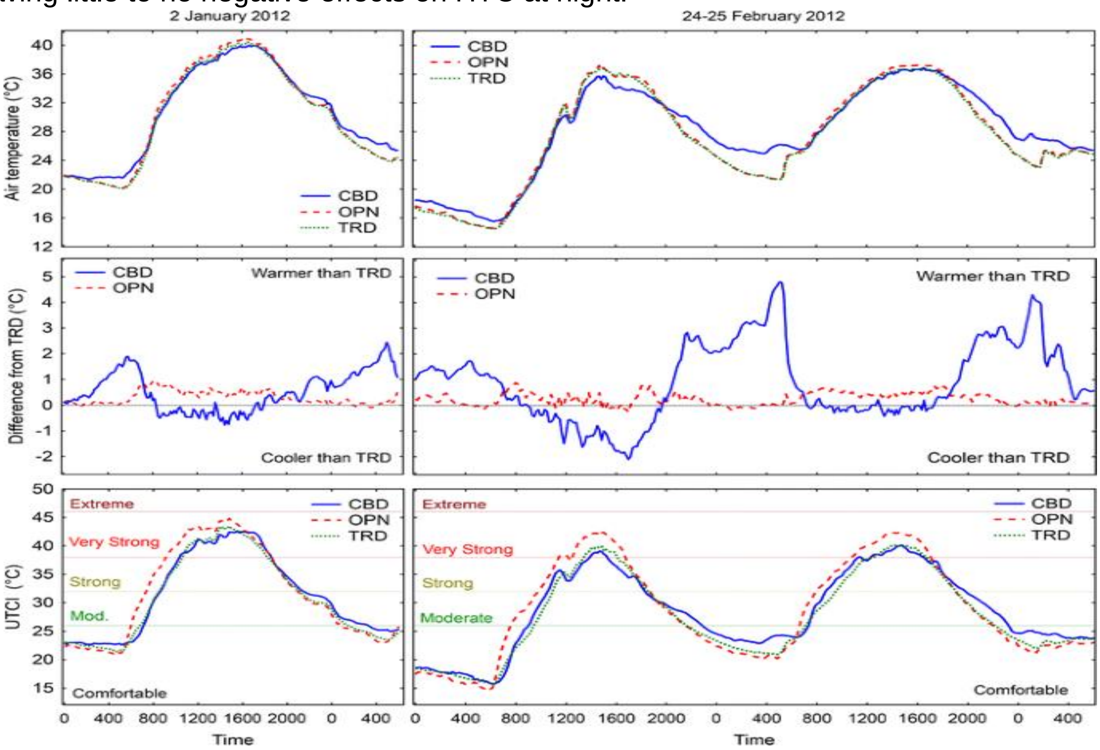

Figure 44 *Mean air temperature for each street during heat events on 2 January 2012 and 24–25 February 2012, differences in air temperature for CBD and OPN in comparison with TRD (Difference from TRD), and UTCI for each site and the corresponding grades of heat stress* (23)

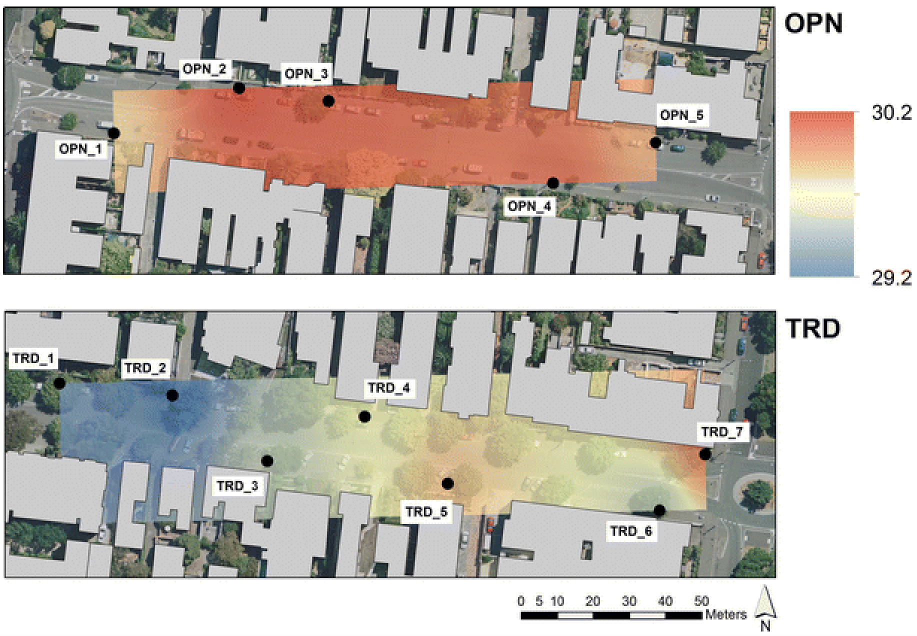

Figure 45; *Mean daytime temperature for individual stations at OPN and TRD during the heat event over 4–12 March 2013. A spatial surface was derived using inverse distance weighted interpolation tool in order to aid visualization.*(23)

Here, the buildings and trees had a significant impact on the microscale fluctuations in temperature. While the trees in TRD decreased the mean midday temperature of individual monitoring sites by up to 1.0 °C, OPN showed a geographically more constant t a during the day (Fig. 45).

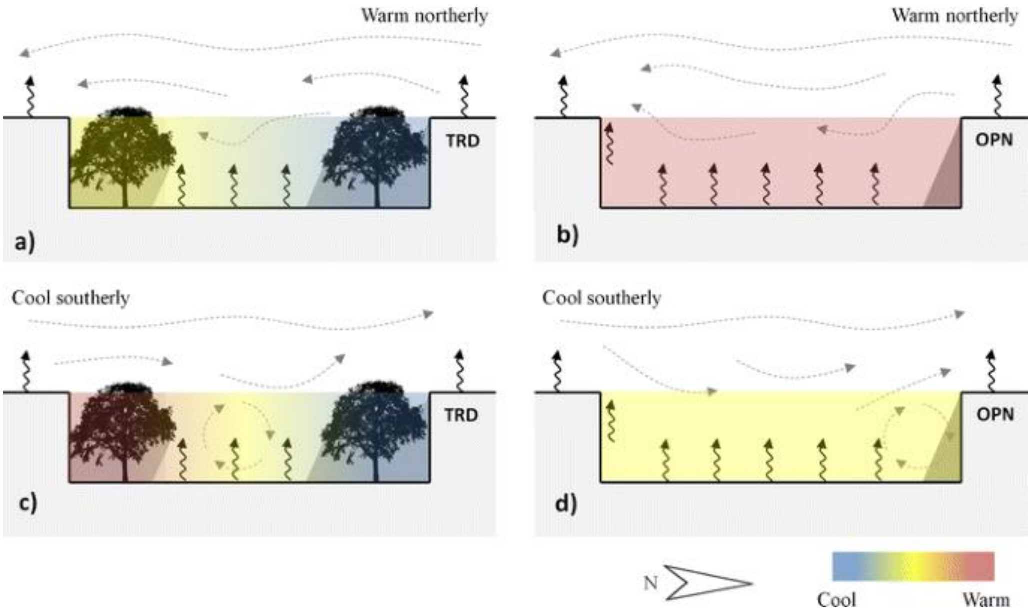

Figure 46 ***Relative differences in mean daytime air temperature in TRD (a and c) and OPN (b and d) during January 2012 under northerly (a and b) and southerly (c and d) wind directions. The sun is to the north.*** (23)

Within-canyon variability in temperature for OPN and TRD The presence of trees, surface heating from solar radiation, geometry, and flow conditions all affect the temperature. (23)

A zone of comparatively cold air is created on the north side of the street when there is a warm northerly wind because of the shading provided by the trees and buildings. However, surface heating in the street warms the southern side of the street wall and floor, and buoyancy carries heat upward (Fig. 46 a). The trees on the south side of the street also provide shade.

On the south side of the street, in cool southerly winds, a zone of comparatively warm air is produced by surface heat and heat storage by the canopy. This improves the buoyancy- and canyon-induced mixing and heat transmission, as well as the entrainment of cooler air (from the north side of the street) (Fig. 46c). In contrast, geometry had less of an impact on the air temperature distributions within the treeless canyon of OPN and was more exposed to the prevailing northerly/southerly wind conditions (Fig. 46b and d)

Therefore In cities with warm climates and Mediterranean climates, protecting and preserving urban street trees is essential to gaining their microclimate benefits. By lowering daytime temperature during heat events and consequently boosting daytime HTC during hot conditions, tree canopy cover contributes to microclimate benefits. This supports the case for increased funding for tree planting, care, and protection.

i. Implementation Examples

<u>Charlotte, North Carolina</u>:

It is delighted to be called "The City of Trees" and esteemed for its thriving urban forest. Charlotte has one of the greatest percentages of tree canopy in the United States, with 47% of the city visible from above. The city of Charlotte gains more than $335 million in annual benefits and services from its trees, in addition to the aesthetic advantages they offer. Charlotte is incredibly well-positioned to accomplish manageable canopy targets. (24)

Figure 47; *Drone aerial of Uptown Charlotte. Credit: USA Skyline / Shutterstock / Kevin Ruck*

In order to make sure that this canopy is preserved and maintained for future generations, the City of Charlotte and TreesCharlotte actively worked throughout 2016 to determine the biggest obstacles facing this crucial city asset as well as the most comprehensive approaches to achieving the city's 50% canopy goal by 2050. A clear route ahead has been defined through twelve action steps thanks to the participation of more than 40 organisations, nearly 3,000 public citizens, and the urban forestry knowledge and national perspective offered by Davey Resource Group. (24)

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One can experience a significant portion of city's towering canopy by passing along Queens Road West at Myers Park, which is adorned with majestic willow oaks. Similar tree lined streets may be seen in other neighbor hoods, which helped Charlotte earn American Forests' 2013 recognition as one of the top 10 cities for tree health, tree management plans, and citizen involvement in tree preservation.

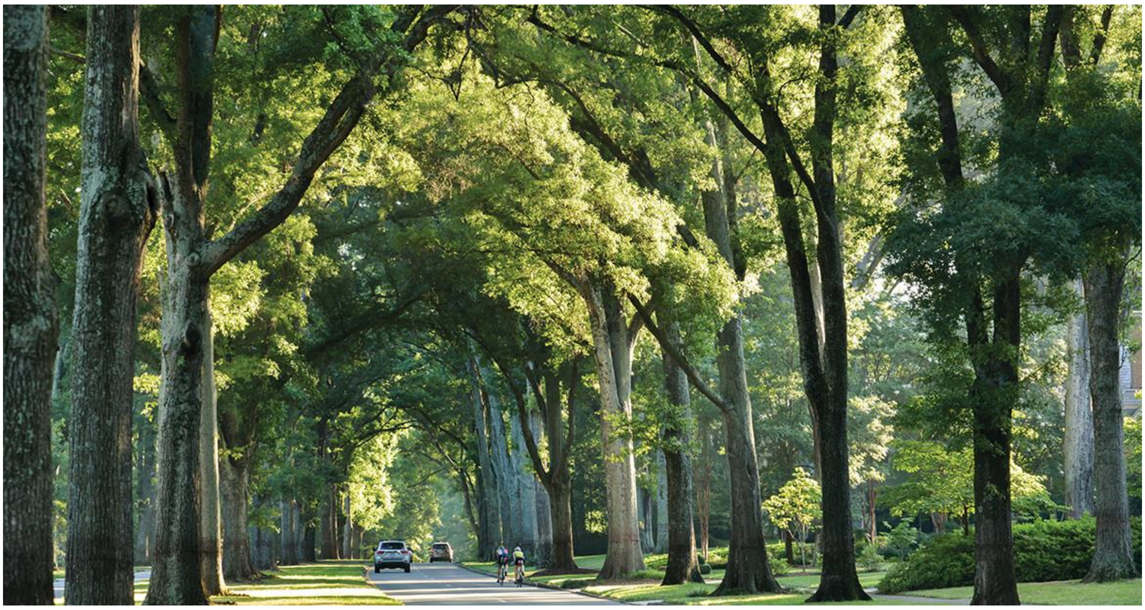

Figure 48 ***Charlotte's Beloved Willow Oaks on Queens Road West. Source: www.ourstate.com/charlotte-trees-queens-road-west/***

In Charlotte, there are also "tree save areas," which are places where a tree canopy already exists and is quantified in square feet. (25) A minimum of 10% of the lot must be set aside as a tree preserve area for residential constructions. A tree saving area must occupy 15% of the property in commercial developments. Within ten feet of any tree-free area, no structure may be built. Without a permit from the city, developers are not allowed to harm tree-protected areas. (25) The city may insist that the developer "mitigate" the loss even if a permit is granted. (25)

Developers are subject to a $50 per tree penalties if they don't plant the required quantity of trees. Up to a $1,000 fine, every day up to the required planting takes place counts as a new offence. (25) In addition, a developer is accountable for the tree's market value, up to a maximum of $20,000, if damage they inflict leads in the complete loss of a tree.

Residential property values have improved by more than $4 million thanks to greenery's attractiveness. (26)

Urban trees aid in lowering energy costs, enhancing air quality, reducing storm water runoff, and reducing air pollution.

According to Charlotte city officials, trees prevent at least 9,000 pounds of air pollution and 35 million pounds of carbon dioxide. (26)

An estimated 2.7 million gallons of storm water produced by construction are intercepted by trees every year. (26) City dwellers save $1.04 million annually on heating and cooling costs, with willow oaks being the primary beneficiary. (26)

Charlotte's tree canopy not only improves the quality of life for everyone, but also significantly contributes to food supply. (26)

According to District Manager Ray Betz of the Davey Tree Expert Company in Charlotte, North Carolina's $78 billion agriculture sector depends on pollinators like bees for many crops used in daily life. Among them are strawberries, blueberries, apples, and squash. Actually, a third of the fruits and vegetables are pollinated by North Carolina pollinators. (26)

Baltimore, Maryland:

A city-wide evaluation conducted in 2007 in Baltimore, commonly known as Charm City, revealed a concerning lack of proper canopy cover. Due to this, the TreeBaltimore effort was started with the declared objective of increasing the tree canopy 40% by the year 2037 increase of 13%. Instead of expecting city agencies to handle all of this work on their own, TreeBaltimore offered grassroots organizations technical support, capacity building, and standards and procedure direction. (27)

Figure 49 ***A side-by-side view of the tree canopy in McElderry Park and Roland Park neighbourhoods in Baltimore. The Baltimore Tree Trust works to restore Tree Equity by increasing canopy cover in neighbourhoods like McElderry Park, so they may experience the benefits trees provide. Source: chesapeaketrees.net***

BTT has currently installed 9,500 trees. They were able to intersperse tree plantings with more casual activities that elevated resident-led dialogues about trees by gradually increasing the scope of their plantings. Residents' suggestions for community forestry plans were taken into account as the organisation expanded and earned greater credibility. The Harris Creek Watershed in East Baltimore, which had the lowest tree canopy cover in the city before, has seven neighbourhoods, and BTT was able to significantly raise it within a few years. (27)

Since 2008, the Baltimore Tree Trust has been planting trees in areas with low incomes. The organisation had a modest staff of roughly 30 people. In order to move closer to their objective of planting 10,000 trees per year and growing their team to 90 individuals, the group is hoping to receive significant grants and support from the U.S. Forest Service this year. (28)

The TreeTrust also interacts with locals by canvassing their homes, handing out brochures, and showing up at festivals in order to clarify any misunderstandings they may have about trees. Many people were having misconceptions about roots damaging water supplies or heaving up pavements.

Figure 50 ***Trees in the Baltimore Tree Trust nursey located in Druid Hill Source :(Kaitlin Newman/The Baltimore Banner)***

The Tree Trust obtains many of its trees through TreeBaltimore, a municipal programme run by Baltimore City Recreation and Parks that, in the previous year, gave 5,300 subsidised trees to between 30 and 40 different organisations. The effort discovers that it has been more challenging to acquire native, understory trees out of all the trees. (28)

Baltimore still has a ways to go before reaching a 40% tree canopy, and it is difficult to increase the tree cover in Maryland's largest city by land size (80 square miles) and population (620,000). However, this 1% net gain corresponds to 200 acres more of tree canopy for the city, bringing with it more advantages. (27)

The Chesapeake Bay Programme has committed to continuously expanding the urban tree canopy's capacity in order to improve the watershed's habitat, water quality, and air quality. By 2025, 2,400 acres of additional urban tree canopy will be added. (28)

According to data analysed by the Forest Service with assistance from the City of Baltimore and the University of Vermont between 2007 and 2015, the percentage of trees in Baltimore City climbed from 27 to 28 percent the canopy increased by 4%, but it decreased by 3% as a result of diseases, storms, and development. However, Baltimore's 1% net gain corresponds to 200 acres more of tree canopy for the city, bringing with it more advantages. (28), (29)

The current cost of the services Baltimore's trees provide by shielding buildings from the summer sun and winter winds, we can save $3.3 million year on energy costs and $10.7 million annually by storing 527 tonnes of carbon. It costs $3.8 million a year to remove 700 metric tonnes of air pollution (carbon monoxide, nitrogen dioxide, sulphur dioxide, etc.) and $1.6 million a year to remove 244 metric tonnes of ozone due to carbon, a damaging gas that significantly contributes to the greenhouse effect. The main component of smog and a major cause of asthma is ground-level ozone. It is plausible to estimate that a single tree provides $57,000 in environmental and economic benefits over its lifetime.

ii. Benefits

Beyond reducing urban heat islands, using plants and trees in urban areas has other advantages, such as:

1) Reduced energy use: Plants and trees that shade buildings immediately reduce the need for air conditioning. Adding Vegetation to urban areas can have a cooling effect that may reduce the impact of UHI. In more than 600 European towns, trees were shown to have a cooling capability that ranged from 1.1°C on average to 2.9°C, according to a prior study. (31)
2) Greenhouse gas emissions are reduced and air quality is improved because trees and vegetation consume less energy, which results in less air pollution and greenhouse gas emissions. Additionally, they clean the air and adsorb and store carbon dioxide.
3) Improved storm water management and water quality: By absorbing and filtering rainwater, vegetation lowers runoff and raises the quality of the water.
4) Reduced pavement maintenance is possible because trees' shadow can delay the deterioration of the pavement.
5) Increased quality of life: Plants and trees can reduce noise, add aesthetic value, and serve as home for a variety of animals.

C. Light colored and heat resistant materials for Pavements and Road surfaces

In order to reduce solar radiation absorption and increase their ability to reflect solar radiation, high albedo surfaces have high solar reflectance and infrared remittance. Pavements can be made more breathable and cooled in specific ways. to assist in heat island reduction.

The main source of energy on our planet is sunlight. If it is introduced through a tiny hole and then transferred to a prism, it will experience the breakdown or distribution into red, orange, yellow, purple, blue, and green colors. Each light color has unique properties.

An object's color is determined by the color it emits; in contrary, other hues of light entering will be absorbed. As a result, when color of light bumps against the surface of a colored item, the object absorbs the energy.

There has been numerous research on the impact of color on the absorption of solar thermal radiation. Since each color of light has a unique wavelength, it may penetrate and absorb matter differently.

Among those, the brown color has the greatest external temperature. The black color is the most important one since it naturally absorbs the heat.

The rate of an object's radiative heat transfer can be influenced by a number of things. Temperature on the surface of an item that emits and absorbs radiation, emissivity (absorption) of the surface of the irradiated object, reflection, absorption, transmission, and the angle of view between the emitting and radiated surfaces are all elements that affect the rate of radiation heat transfer. The radiation phenomenon's rate of heat transmission is influenced by the surface quality of the objects absorbing and generating radiation.

This is possible because an object's surface features can have an impact on its emissivity (emitting power). Compared to bright dominating colors (red, blue, yellow, and white), dark dominant colors like black and green are better at absorbing heat.

In order to determine how much solar radiation is absorbed by an object with different colored surfaces an experiment has been carried out by the Universitas Negeri Semarang, Semarang, Indonesia. This study was carried out in a reasonably large space during the day when the sun was at its brightest.

Digital thermometers, stopwatches, plastic cups, and acrylic boxes coated in stickers of various colors were the instruments and materials used in this investigation.

Increase in the temperature was measured using a digital thermometer. The sizes of all the acrylic boxes utilized in this study were same regardless of the material's type or thickness. These had colored stickers applied to them, and the colored stickers were put together in a way that produced liquid temperature measurements, resulting in measurements that were essentially equal. The liquid was then poured into a plastic cup with the same volume and placed into each acrylic box.

A glass with liquid inside of it had a thermometer sensor installed into the middle of it.

The liquid's temperature should be the primary focus of the temperature measurement, not the glass wall's temperature.

Figure 51 ***Experimental Tool Circuit Source: Paminto et al. / Physics Communication***

There were 15 samples used in the experiment, and temperature readings were taken every 5 minutes. To ensure that the measurement results are roughly the same, they were covered in colorful stickers that were put together in a way to provide liquid temperature measurement.

An independent variable that will impact the amount of solar radiation absorption is the color of an object's surface. The experiment was conducted when the ambient air temperature was 32 °C and the relative humidity was 7 %. Only six colors in the visible light spectrum were processed from the data.

White and black, the two common colors, were only used for comparison. Below Figure 52 displays the outcomes of the investigations into the rise in liquid temperature.

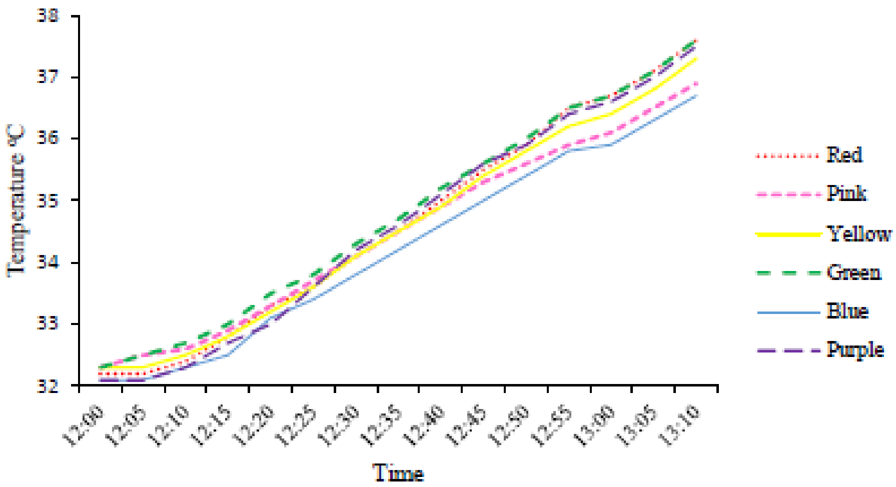

Figure 52 ***Temperature rise of the liquid enclosed in a colored acrylic box***

According to the measurement results, the liquid within the box made of black coated acrylic changed temperature by an average of 35,2°C. Black and white found out to exhibit the biggest and lowest temperature increases, respectively, among the eight hues seen. I made sure to highlight that these two hues are merely being used for comparison. According to the findings of 15 times of recording, the liquid's average temperature rise for the six colors used in this investigation was as indicated in Figure 53.

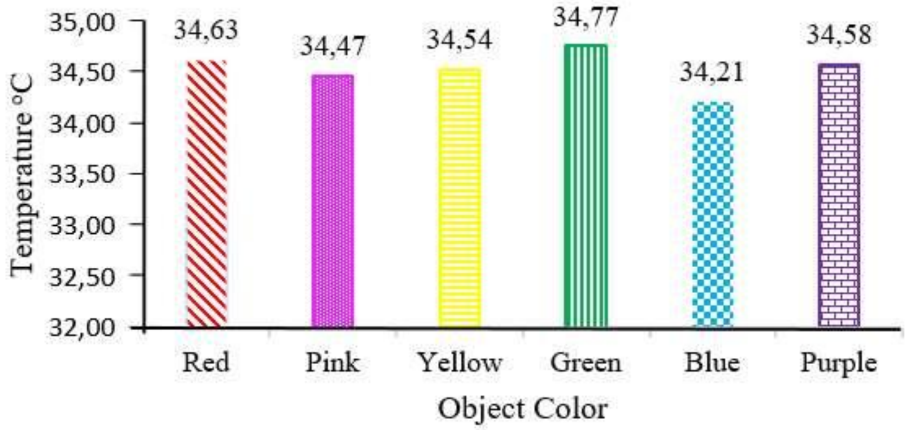

Figure 53 ***Increase in the average temperature of a liquid***

The average value of the highest temperature increase, according to the experiment's outcomes, is green, about 34, 77°C.The color blue has the lowest average value having an average temperature of 34,21°C.

According to the results of the study, it can be deduced that the working hypothesis, which reads: There is a relationship between the color of an object's surface and solar radiation absorption, as evidenced by an increase in the temperature of the liquid that is covered, Different levels of solar energy are absorbed by various colored surfaces, which affects how hot liquids and air are. They come in the following colors, from maximum to lowest absorption of solar heat: black, green, red, purple, yellow, pink, blue, and white. The dark surface is excellent at absorbing heat. This is so that black, which has a rapid temperature fluctuation, may quickly absorb the majority of the heat.

The impact of the urban heat island is getting stronger. The reduced albedo (reflective power) of urban surfaces and the eradication of vegetation in favor of buildings and pavements are among its contributing elements.

Concrete and asphalt structures that absorb solar radiation have surfaces that are several degrees hotter than the surrounding air. Later, as the air comes into contact with heated surfaces, the air temperature likewise rises. Heat islands not only make people uncomfortable thermally, but they also cause more cooling energy to be used. They also raise energy demand, expenses, and the rate at which hazardous pollution forms.

Cool materials with high solar reflectance and emittance values are needed to reduce the urban heat island phenomena.

The surface temperature of the building or pavement is lowered by increasing either reflectance or emittance, which reduces the amount of heat entering the structure. Since a colder surface has lower heat convection intensity, these strategies also function by lowering the ambient air temperature.

Cool surface coatings, reflective tiles, and other cool materials are currently offered commercially for use on buildings and other surfaces in metropolitan environments; nevertheless, they are all white or light in color.

The solar reflectance index (SRI) is a measurement that may be helpful. It is a composite value of thermal emittance and solar reflectance that was determined using the (ASTM E1980) equation. In reality, the SRI value for black surfaces would be close to 0, whereas the SRI value for white surfaces would be near to 100%. Darker materials typically have a lower solar reflectance than lighter ones. (32)

i. Implementation Examples

Phoenix's cool pavement programme:

Since 2021, Phoenix's cool pavement programme has been discussed on a number of occasions. Today, an expert is commenting on the technology's performance. The cool pavement coating Phoenix employs is a water-based asphalt solution that is put on top of an existing asphalt pavement, according to the City of Phoenix website.

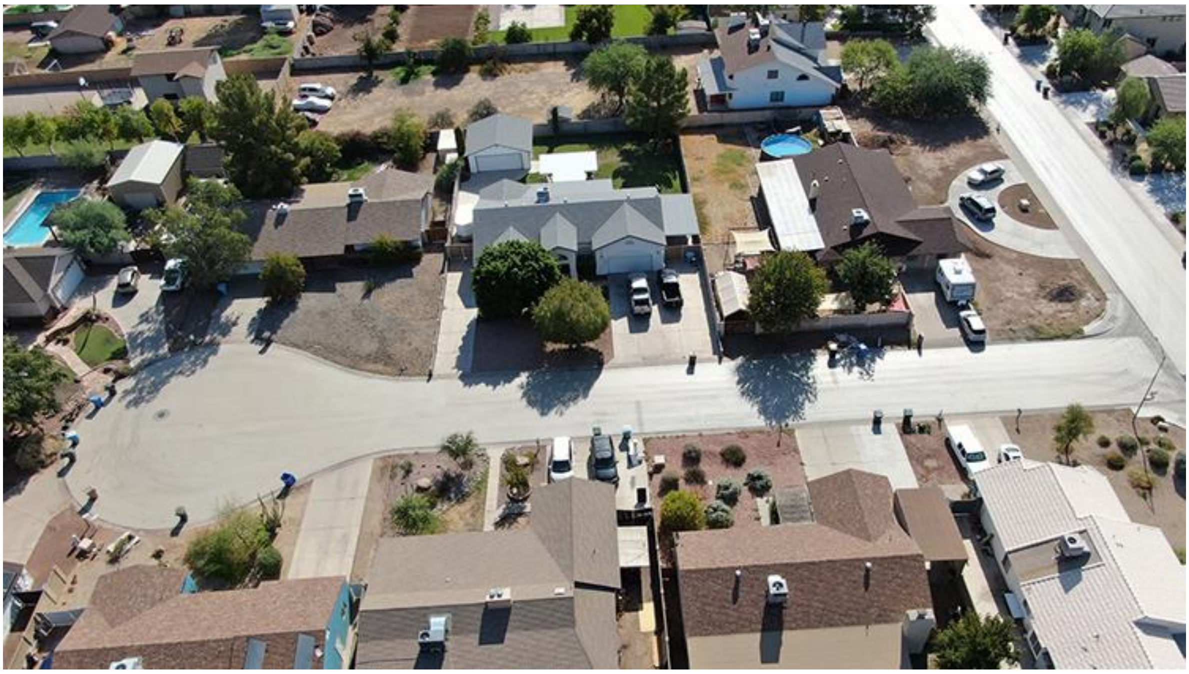

Figure 54 ***Phoenix Shares Results***
Source: City of Phoenix

The coating is made out of asphalt, water, soap (which acts as an emulsifier), mineral fillers, polymers, and recyclable materials, according to the Phoenix’s official website. A section of the website stated that it was "compatible with conventional asphalt" and included no dangerous chemicals.

A cool pavement pilot programme in the City of Phoenix came to an end in 2021. Since then, the city's street maintenance programme includes cool pavement.

The Department and Office of Sustainability revealed the outcomes of the Cool Pavement Pilot Program's first year during a webcast presentation and panel discussion on September 14, 2021. In collaboration with Arizona State University (ASU), the programme and analysis of the cool pavement procedure are being carried out. (33)

Researchers from ASU's Global Institute of Sustainability and Innovation, Healthy Urban Environments, and the Urban Climate Research Centre found that reflecting pavement surfaces have significantly lower surface temperatures than conventional roadway paving in One year of their study.

Figure 55 ***Phoenix's cool pavement program on various occasions since 2021 Source: FOX10***

According to the study's first year's findings include the following:

- Compared to conventional asphalt, cool pavement demonstrated lower surface temperatures throughout the day.

- At noon and in the afternoon, cool pavement had an average surface temperature that was 10.5 to 12 degrees Fahrenheit cooler than standard asphalt. At daybreak, surface temperatures were typically 2.4 degrees Fahrenheit cooler. (33)

- In places with cold pavement, sub-surface temperatures were on average 4.8 degrees Fahrenheit lower. (33)

- At six feet in the air, the average night time air temperature was 0.5 degrees Fahrenheit lower over cool pavement than it was on the untreated surfaces.

- Due to surface reflectivity, the human experience of heat exposure at noon and in the afternoon was 5.5 degrees Fahrenheit higher, yet similar to walking on a regular concrete sidewalk. (33)

- Over a period of ten months, the surface solar reflectivity decreased in all eight neighborhoods, falling from a range of 33 to 38 percent to a range of 19 to 30 percent. Asphalt that has not been treated has a reflectivity of only 12%. (33)

Los Angeles cool pavement programme:

Figure 56 *Cool pavement installed along 54th Street in South LA. Source: LAcurbed*

A not-so-popular method of reducing heat from the ground up is being tested by the Los Angeles Bureau of Street Services, or StreetsLA: a so-called cool pavement coating that reflects infrared light from the sun to limit heat absorption.

Since 2017, 181 lane-miles of the solar-reflective coating have been installed by StreetsLA in collaboration with a number of contractors. (34)

According to Ana Tabuena-Ruddy, assistant director and chief sustainability officer of StreetsLA, the bureau installed cool pavement in recent years in portions of Pacoima, Reseda, Wilmington, East Hollywood, Westchester, Palms, Korea town, Lake Balboa, Chatsworth, North Hills, and Atwater.

Pacoima, a low-income, primarily Latino town in the San Fernando Valley, had coating installed in important sections last summer. This summer, during the sweltering months of July and August, it was put to the test.

In a public-private collaboration, Pacoima, Climate Resolve, and StreetsLA In 10 neighborhood blocks, the parking lot and basketball court at Hubert H. Humphrey Memorial Park, and the playground at Hillery T. Broadous Elementary School, GAF roofing installed more than 700,000 square feet of beautiful, cool pavement. (34)

According to GAF, the coating's manufacturer, the pavement lowers ambient air temperature up to 6 feet from the ground by 1.5 degrees on typical sunny days and up to 3.5 degrees on particularly hot days by reflecting the infrared spectrum of sunlight. Downwind of the coated regions, the cooling effects also apply. (34)

However, with triple-digit temperatures in Fahrenheit, the coating is just a modest defense against the risks of high heat. To keep citizens comfortable, experts claim that cities need a web of overlapping solutions. (34)

ii. Benefits

The advantages of cool pavements include the following, besides lowering heat islands:

- Energy savings and pollution reductions: Cool pavements reduce the temperature of the ambient air, requiring less energy from air conditioners to cool buildings. By lowering the demand of electric for street lighting at night, cool pavements also save energy.
- Increased health and comfort: The air in the city is cooled by cool pavements, which lowers the risk of heat-related illnesses, slows the growth of smog, and improves the comfort of outdoor activities. Cooler pavements and air assist pedestrians as well.
- Improved safety for drivers: Pavements with light colours reflect street lights and car headlights more effectively at night, improving visibility for drivers.
- Improved visibility at night: Reflective pavements can increase visibility at night, thus lowering the need for lighting and saving money and energy.
- Better air quality. Cool pavements can reduce smog-producing atmospheric chemical processes by lowering urban air temperatures.
- Reduced emissions from power plants: Cool pavements help power plants emit fewer greenhouse gases and other air pollutants because they save energy on things like street lights and the usage of air conditioning in neighboring buildings.
- Quality of storm water: The damage to nearby watersheds is improved by cool pavements because they reduce surface temperatures. (35)
- Climatic change was slow down. Cool pavements can lower surface temperatures because they reduce the amount of heat absorbed at the Earth's surface. Surface temperature drops like this can temporarily counteract greenhouse gas-induced warming.

It is challenging to compare the prices of cool pavements with those of traditional paving materials. Any pavement application has different costs depending on the region, the contractor, the season, the materials selected, the site's accessibility, the locality of the materials, the underlying soils, the project's size, anticipated traffic, and the intended pavement life.

D. Shaded Streets, Pedestrian galleries and corridors

In hot desert cities, shade is crucial for constructing pedestrian-friendly outdoor areas. Pedestrians encounter severe heat more frequently, with temperatures frequently reaching 90° Fahrenheit (32° Celsius), and occasionally 110° F (43° C), as the world gets hotter and more urban. (32)

Because of this, urban walking is unpleasant, undesirable and hazardous, which promotes poor health, isolation, traffic issues, dependence on automobiles, and sprawl. Hot-climate cities should make plans for pedestrian thermal comfort to solve this. This can be done by building integrated networks of shade ways (shaded sidewalks) and pedways (enclosed, climate-controlled walkways) in urban villages (tiny communities where most services and activities can be easily accessed without a car). These can be expensive than simple pavements, but they can significantly increase walking comfort and are much less expensive than road infrastructure. Numerous economic, social, and environmental advantages can be had from them.

According to the research conducted by Arizona State University researchers a Thermally Comfortable Pedestrian Route need to have the following percentage of shade coverage for their Quantification.

Optimal shade coverage on walking corridors (as measured during the warmest times of the day) should be greater than or equal to 62% in order to create a route that is secure for walking throughout the summer. (33)

Optimal shade coverage should be more than or equal to 30% to create a walking route that is secure for 95% of the summer afternoon hours. This shadow coverage would have resulted in hazardous conditions for at least an hour on an average of 12 days during the previous ten years, according to historical meteorological data. (33)

Target shade coverage should be more than or equal to 20% to create a walking route that is secure for 90% of the summer afternoon hours. According to weather records, this shade coverage would have resulted in hazardous conditions for at least an hour on 25 days on average over the previous ten years. (33)

As a result, following a path that takes a pedestrian 20 minutes (including waiting periods) to complete 20% is the minimum permissible shade coverage, 30% for good shade coverage and 60% has excellent shade coverage. (33)

It is possible to use shade types that maximise shadow under the worst possible conditions. Trees and flora, canvas/sails, awnings, vertical panels, solar panels and building shade are a few options. To maximise thermal comfort, shade could go alongside other cooling methods.

Make sure pedestrian pathways around the project site have possibilities to occur in shady conditions, especially in the late afternoon, by modelling and/or by checking the shade % in order to achieve a Thermally Comfortable Pedestrian Route (TCPR) as indicated above.

Types of shades that can be provided are mentioned as follows:

a. Trees planted on either side of the pavement provide shade all day long.

Figure 57 ***Peoria, AZ Source: Kristian Kelley***

b. Little construction is needed for simple fabric shading devices, which in this case are supported by columns. Canopy is readily removed during the cooler months, changed out for seasonal colour or replaced when maintenance is required.

Figure 58 ***Source: Kristian Kelley***

c. Tall sculptures should take use of their height to provide shade, but designers should find inventive methods to structure them so that they generate as much shadow as possible throughout the day. For a relatively brief period around noon on a sunny day, when there is less foot traffic in the region, these examples only offer shade on a few chairs, but they serve as a distinguishing feature for the neighbourhood.

Figure 59 ***Source: Kristian Kelley***

d. At all times of day, a perforated screen running parallel to the road provides shade on one side. In order to provide safety the perforation is required to allow views into the shaded area.

Figure 60 ***Source: Kristian Kelley***

e. At junctions, overhead perforated steel shade structures offer comfort to people waiting for the traffic light to change. These constructions must be built and placed so that they do not obstruct the vision of traffic signals.

Figure 61 ***Source: Kristian Kelley***

f. Some older urban structures have colonnades that create elegant walking lanes.

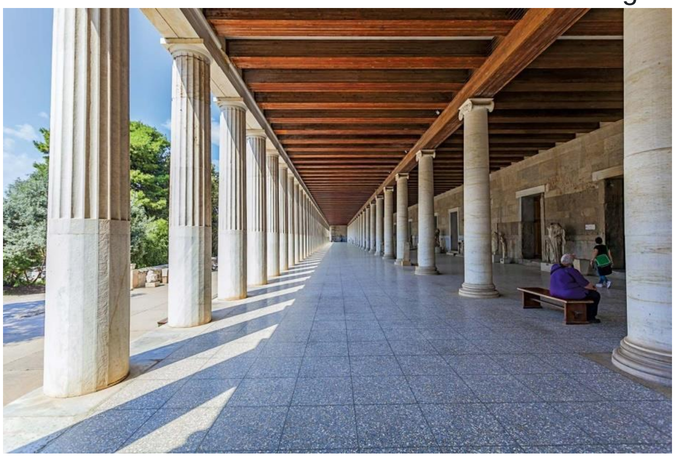

Figure 62 ***Traditional Building with Colonnade Source: (Britannica)***

i. Implementation Examples

(Colonnades) Porticoes of Bologna:

Colonnades of Bologna are the best example of the Shaded Streets or Pedestrian galleries as no other city in the world have more colonnades (Porticoes) than Bologna.

Along with the numerous towers, the porticoes of Bologna are a significant part of the city's architectural and cultural legacy and serve as a representation of the city. The porticoes of Bologna, about 62 km long, 40 km of which are in the old city centre alone, have been designated a UNESCO World Heritage Site and are what distinguish the city from others in the world. (34)

The list of twelve porticoes presented by UNESCO includes those of piazza Maggiore and Pavaglione, that of San Luca, Santa Caterina, the portico of MamBo (Museum of Modern Art of Bologna), the porticoes of via Farini, those of Piazza Cavour, Piazza Santo Stefano and Via Zamboni. To these are added the porticoes of the Baraccano, those of via Galliera, of the Certosa and the porticoed building of the Barca district. (35)

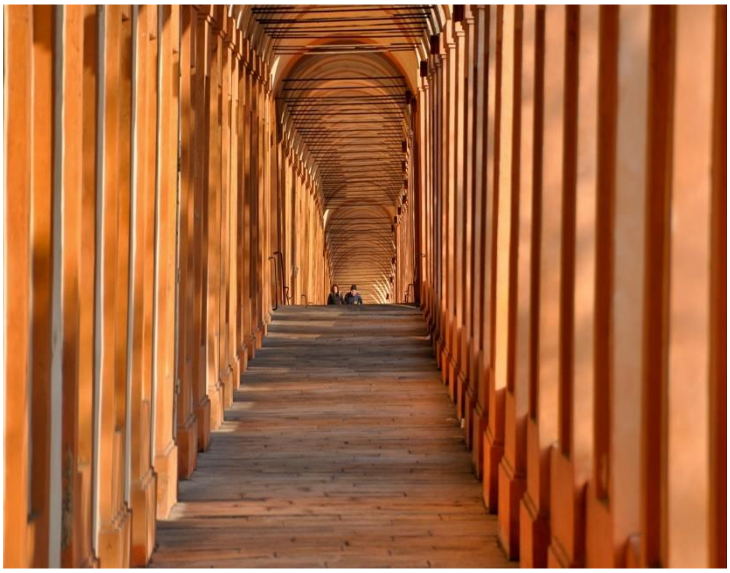

Figure 63 *Portico of San Luca, Bologna Source: interno19.com*

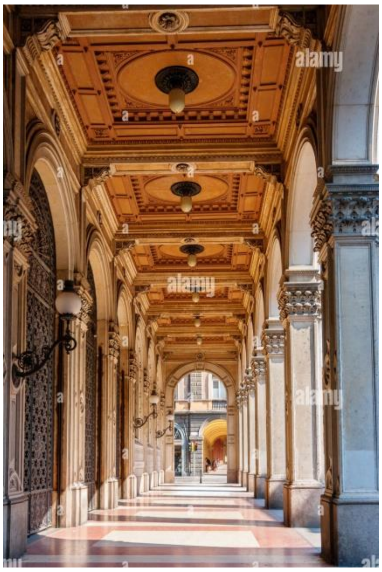

Figure 64 **Bologna Arcade** *Source:* Alamy Stock

The longest portico in the world and in the city is that of San Luca. (36) It links the Sanctuary of the Madonna di San Luca with Porta Saragozza, one of the 12 gates of the old walls constructed in the Middle Ages that encircled a 7.5 km (4.7 mi) portion of the city. (37)

The population increased including teachers and students with the founding of the University of Bologna Alma Mater Studiorum since 1088. From this point on building porticoes were started.

Which was once done abusively in the early Middle Ages, when the residents of the city started to build private properties on public property. In order to extend their living areas, the protrusion was first barely noticeable, and it was enough to insert a straightforward shelf as a support element.

The tiny reinforcements designed up until that point proved to be inadequate as the dimensions then significantly grew. In order to prevent the projecting construction from collapsing, genuine columns had to be added, which led to the creation of the well-known porticoes.

The Porticoes were built of wood during the Middle Ages and were later rebuilt using bricks or stones.

Every new house was required to have a porch beginning in 1288 through the publication of a municipal notice, and existing homes were required to construct one. Even the height and width were set since each porch needed to allow a man to ride a horse through.

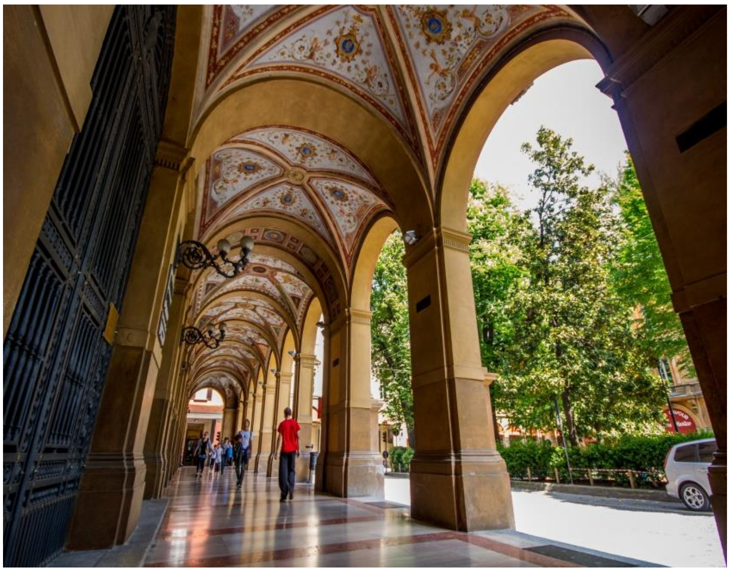

Figure 65; *Piazza Cavour Source: bolognawelcome.com*

The colonnades, which are located halfway between "inside" and "outside," have always promoted social interaction and commercial activity.

They made the streets safe to walk in by allowing people to hide beneath them to shield themselves from the sun and also during other weather conditions like rain, snow etc., allowing both locals and visitors in Bologna to move through the city without any discomfort.

Furthermore, the Artisans who had their own workshop on the ground floor might increase the space available, which could be used for both processing and displaying the items.

Medellín's green corridors, Colombia :

Medellín is the Colombia's second-largest city after Bogotá, 30 "Corredores Verdes," or green corridors, have been established in Medellín since 2016 to cover the entire city of 20-km network with a system of connected vegetation shade. This ambitious project increases the number of green spaces and enhances their connectivity, boosts urban biodiversity, lessens the urban heat island effect of the metropolis, scavenges air pollutants, and sequesters a considerable amount of carbon dioxide. The Green Corridors project serves as an example of how integrated, nature-based policies, such as broad urban tree planting, can have a substantial positive impact on individuals' lives and well-being.

A substantial urban heat island effect was present in Medellín as a result of the city's 50 years of fast urban growth. The city launched a three-year "greener Medellín for you" plan in response to this phenomenon, fundamentally altering the way in which cities are built.

The Joaquin Antonio Uribe Botanical Garden in Medellín taught 75 residents from underprivileged backgrounds to become city gardeners and planting technicians as part of the $16.3 million effort. In the 30 corridors, which total 65 hectares, they have assisted in the planting of 8,800 trees and palms. More than 90,000 types of smaller plants have been planted alongside 596 palms and trees in one of the city's busiest thoroughfares. (38)

Figure 66 *Oriental Avenue in Medellín (Source: Getty Images)*

Another significant issue was the air pollution brought on by the widespread usage of motorcyclists. The high quantities of fine particulate matter, such as PM2.5 and PM10, in Medelln and other significant cities in Colombia, were of concern.

Medellín green corridors helps in allowing growing plants to absorb carbon dioxide, capturing particulate matter (PM2.5) to improve air quality, Medellín, however, can reach 55 g/m3 of PM2.5, enough to alert the authorities, during the dry season, when the city experiences its worst period of air conditions due to less rain, which typically helps to dissipate the pollution. It is commonly known that breathing in PM2.5, which are minute airborne particles, increases the risk of developing respiratory illnesses. can reach 55 g/m3 of PM2.5, enough to alert the authorities, during the dry season, when the city experiences its worst period of air conditions due to less rain, which typically helps to dissipate the pollution. It is commonly known that breathing in PM2.5, which is minute airborne particles, increases the risk of developing respiratory illnesses. (40)

Figure 67 ***Medellín green corridors Source: seforall.org***

During the course of three years, the city's average temperature decreased by 3.5°C (from 31.6°C to 28.1°C) and its average surface temperature by 10.3°C (from 40.5°C to 30.2°C). (38)

Increasing urban biodiversity by fostering more wildlife-friendly habitats, these Green Corridors offer Medellín a variety of ecosystem services. These quick results show why natural approaches are becoming more and more well-liked in the field of sustainable urban planning.

This project, which benefits the city in many ways, is a good illustration of how nature can both improve urban living and solve a variety of problems. Without the effort of city planners and community involvement, the project would not have been possible. so that it can keep absorbing air pollutants from the highways and reducing the impact of the urban heat island.

The 2019 Ashden Award for Cooling by Nature was also given to the Green Corridors project.

ii. Benefits

- Enhanced user’s wellbeing and comfort: Increases in pedestrian traffic boost public health and fitness by encouraging walking. Less fortunate individuals might greatly benefit from shadeways and pedways that satisfy their user needs because they frequently rely on foot transit and are susceptible to heat.
- Consumer savings: Residents of walk able urban villages often own half as many vehicles, drive half as much, and spend half as much on transportation as residents of automobile-dependent places. Each person may potentially save thousands of dollars each year. (34)
- Higher property values: A greater capacity to walk and access high-quality public transport services tend to raise the value of residential and commercial properties (Boyar, 2016). According to one study, a 10-point improvement in Walk Score is linked to a 5%–8% increase in commercial values (Alfonzo 2015), while being close to excellent transit stations can result in even greater advantages (Smith and Gihring 2022).
- Increased tax income and local business activity: According to ALR (2013), businesses in walk able commercial districts typically have a higher customer and sales volume. According to a significant study, increasing walkability can boost local sales by up to 80% (Alfonzo 2015). Revenues from sales and property taxes may rise as a result.
- Reduced traffic issues: The cost of driving can be decreased by increasing walkability. Residents of urban villages typically take half as many car journeys as those in places with a high automobile population, which reduces traffic congestion, infrastructure costs, crash risk, and pollution emissions. (34)

E. Self-Ventilating and Self-Shading structures

Self-Ventilation Regardless of the weather outside, the design of the structure, or the intended usage, complete indoor climate control is now technologically achievable because to the introduction of boilers and chillers. In all climates, tightly enclosed and maintained at a constant temperature.

The idea that comfort and satisfaction can be assured by maintaining a steady condition underlies this energy-intensive method. However, the construction sector frequently fell short of meeting inhabitants' needs for comfort. According to several surveys, in the US and Europe, 56 to 89 % of government employees and up to 43 % of residents are unhappy with their HVAC systems.

The rising of warm air and the descending of cool air causes air movement. Warmer air rising from the surface of the land causes an area of low pressure. As air rises, it cools, goes toward water's surface where it falls, builds up a pressure area, and pushes cold air in the direction of the land. The wind is produced by the movement of these regions.

Buildings required apertures so that air could flow through them and keep them cool, Utilizing ecologically beneficial technologies that do not require any automated or mechanical solutions. It is not only more environmentally friendly but also more economical because it depends on Natural outside factors like the wind and the temperature of the interior space and its surroundings.

Self-Shading: Facades serve as the main defence against climatic conditions in hot and arid places, which are plagued by high temperatures, direct sun radiation, drought, and other challenging climatic circumstances. Additionally, studies have shown that in desert regions, where direct sunshine strikes the walls for lengthy stretches of the day, the heat gained via the walls is greater than that gained through the building envelope as a whole.

The wall's ability to shade themselves lowers the surface temperature that is exposed to direct sunlight, which lowers the amount of heat that is passed through them. This function offers a natural remedy for lowering temperatures in hot areas, which opens up the prospect of lowering building temperatures and so lowering energy demand for cooling.

These solutions provided by nature could provide us with excellent ideas for how to deal with the high temperatures in arid environments, which would then improve the thermal efficiency of the structure by adding additional layers to the façade or shielding it through self-shading techniques.

In hot and arid regions, nature has created remedies for the problem of high temperatures such as Termite settlements and Cactus plant.

The self-shading concept is effectively used by termites to create their habitat from the outside by those that are widespread in hot zones and woods in high temperate regions. At a height of up to four meters, the termite colony resembles branched towers. The termite settlement's mass is distinguished by its pronounced buttresses, which extend the area of its outside surfaces and maintain its stability. These buttresses aid in shading the surface and speed up the cooling process by allowing air to circulate over the settlement's outside surface.

Cactus ribs alter the thermal performance of the cactus coating by protecting the exposed area from sunlight. Other areas of the cactus could be shielded from direct sunlight by its surface ribs; this process is can be called as self-shading.

The capacity of cactus to adapt to hot temperatures and sun radiation has been the subject of numerous research. Additionally, according to certain research, the surface of a cactus can give 16% more shade than a spherical surface. (28)

These solutions provided by nature could provide us with excellent ideas for how to deal with the high temperatures in arid environments, which would then improve the thermal efficiency of the structure by adding additional layers to the façade or shielding it through self-shading techniques.

Three factors affect the quantity of heat is conducted through the walls: 1) The measure of the overall rate of heat transfer across a certain building section is called the u-value, 2) A = wall area, 3) T = (T1 - T2) = temperature differential on both sides of the wall (facing the outside and the room) at the point when the amount of heat is being calculated. Consequently, the following equation can be used to define thermal transmittance: = A U (T1 - T2) T. Therefore, using materials with a low u value or lowering surface temperature are two options to limit the quantity of heat transported through the same area of the wall. Thus, T will drop as shadowing lowers the external surface temperature. The amount of heat that is transported to buildings is thereby decreased.

To limit the quantity of heat transported by walls following method can be implemented:

1) Creating shadow areas caused by the interception of prominent wall elements by the sun.

2) Increasing the exposed area to cooling and minimizing the surface temperature.

3) The quantity of heat transported through the wall can be reduced by conduction.

4) The temperature of the inner surface declines, and thus the temperature transported to the room by convection also drop.

5) Thermal comfort improves within the space while lowering energy use.

i. Implementation Examples

Examples of Self Ventilating and Self Shading Structures:

1. **Badgir Windcatcher, Medieval Persia:**

A windcatcher, wind tower, or wind scoop in Persian Badgir is a historic architectural element used to promote cross ventilation and passive cooling in structures.

From the ancient Persians and Egyptians to the Babylonians and Arabs, civilizations have sought to adapt their architecture to the harsh, hot conditions of their locations by inventing natural ventilation mechanisms. Wind catchers can be found throughout the Middle East and Egypt, as well as in Pakistan and India.

Neglected by modern architects in the final decades of the twentieth century, they were reintroduced in the early twenty-first century to promote ventilation and reduce electricity demand for air-conditioning. Building a windcatcher typically costs less to build than a comparable building with traditional heating, ventilation, and air conditioning (HVAC) systems. Maintenance expenditures are also reduced.

Figure 68 *Source: BBC.com An ancient engineering feat that harnessed the wind Credit: (Shervin Abdolhamidi)*

Usually, structures are made of incredibly thick ceramics with exceptionally high insulating ratings. Moreover, communities are typically densely packed, with high walls and ceilings in comparison to Western architecture, optimizing shade at ground level. Small windows that do not face the sun reduce the heat of direct sunlight.

The windcatcher can guide airflow in two ways: by using the pressure of the wind blowing into it, or by employing buoyancy forces from temperature gradients (stack effect). Wind pressure plainly increases with increasing wind speed and it is more relevant than buoyancy under most conditions when the wind catcher is functioning properly.

A windcatcher has a covering and has multiple directional openings (often four) at the top. By closing all except one facing the oncoming wind, air is dragged upwards by the Coanda effect, in the same manner that opening the one facing the wind would force air down the shaft. This creates significant cooling ventilation within the structure below, but it is insufficient to reduce the temperature below ambient on its own. it would just suck hot air in by any cracks or windows in the structure below. As a result, it appears that the key to generating cold is that there are few cracks at the base of the thick structure below, with a significant air gap above the qanat a water management system used to provide a reliable supply of water to human settlements or for irrigation in hot, arid, and semi-arid climates.

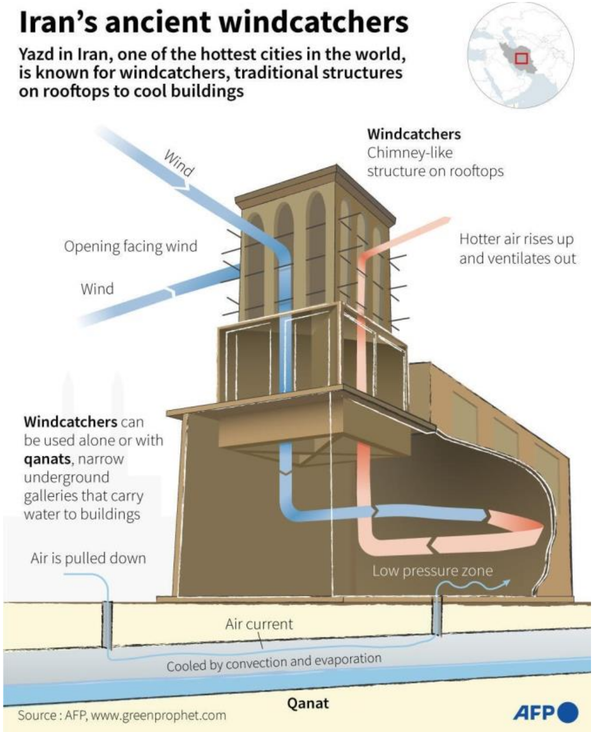

Figure 69 ***Persian's ancient windcatchers***
source: Anibal MAIZ CACERES, Julia Han JANICKI / AFP

A Qanat, which is completely isolated from the sun, also collects the cold, sinking air of the night, which is held within and unable to rise to the less dense surface air. A windcatcher, on the other hand, can generate a pressure gradient that draws some air upwards through a house. This cool, dry night air is drawn through a lengthy tube of water, where it evaporates some of the water and air is cools down.

A windcatcher acts as a solar or thermal chimney in a windless environment or waterless home, using convection of air heated by passive solar radiation. It produces a pressure gradient, allowing less dense hot air to rise and escape through the top. In the heat of the day, the windcatcher can cool lower-level spaces in mosques and houses to cooler temperatures. The windcatcher has been so effective in Persian architecture that it has also been utilized as a refrigerating device.

Windcatchers can be utilized for both mitigation and adaptation to climate change because they "reduce the buildings' energy consumption and carbon footprint. A window windcatcher can cut a building's total energy consumption by 23.3%. (29) Windcatchers can reduce indoor temperatures by 8-12 degrees when compared to outdoor temperatures. (30)

2. Eastgate Centre, Harare, Zimbabwe.

A renowned Self Ventilating structure is the Eastgate building in Harare, Zimbabwe. Zimbabwean Architect Mick Pearce, who completed the complex in 1999, used Biomimicry in his design, harnessing the inventiveness of termites to create a natural cooling system for Zimbabwe's largest commercial structure.This shopping centre.

Termites in Zimbabwe construct massive towers within which they cultivate a fungus that serves as their principal food source. The fungus must be kept at 87 degrees Fahrenheit, whereas outdoor temps range from 2°C at night to 40°C during the day. The termites accomplish this shocking achievement by opening and closing a number of heating and cooling vents throughout the mound throughout the day.

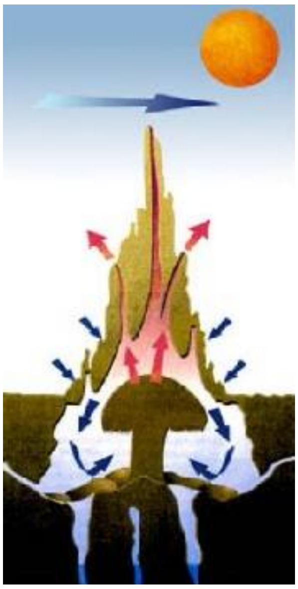

Figure 70 *Termite Mound* Figure 71 ***Eastgate Centre in Zimbabwe***
Source: livinspaces.net

Termites were not only for Mick Pearce, the architect, was also interested in cacti. One of the ways a cactus can withstand high temperatures is that its various wrinkles, ridges or ribs, and spikes raise the warmth of its surface. This allows it to release its heat more easily at night. This concept was also used by the Eastgate building, which has façade broken up by concrete shapes and projections, deep balconies, and plants.

Mick Pearce uses natural elements as well as traditional patterns and stones to create a building that is distinctly Zimbabwean in design. The glass and steel of modern metropolitan Highrise buildings are used in the interior. The exterior is purposely chosen to be more acceptable for an African city.

The Eastgate Centre, which is mostly composed of concrete, features a ventilation system similar to Termite mounds. The building mass either warms or cools the outside air that is brought in, depending on which is hotter, the building concrete or the air. It is then vented through the building's floors and offices before escaping out the top chimneys. The complex also has two side-by-side structures separated by an open space covered in glass and open to the local breezes.

Fans on the first floor continuously take air from this open space. It is then forced up to the vertical supply portions of ducts in the centre spines of the two buildings. Fresh air replaces old air that rises and escapes through exhaust vents on each floor's ceiling. It eventually enters the exhaust part of the vertical ducts before being flushed out of the building by chimneys.

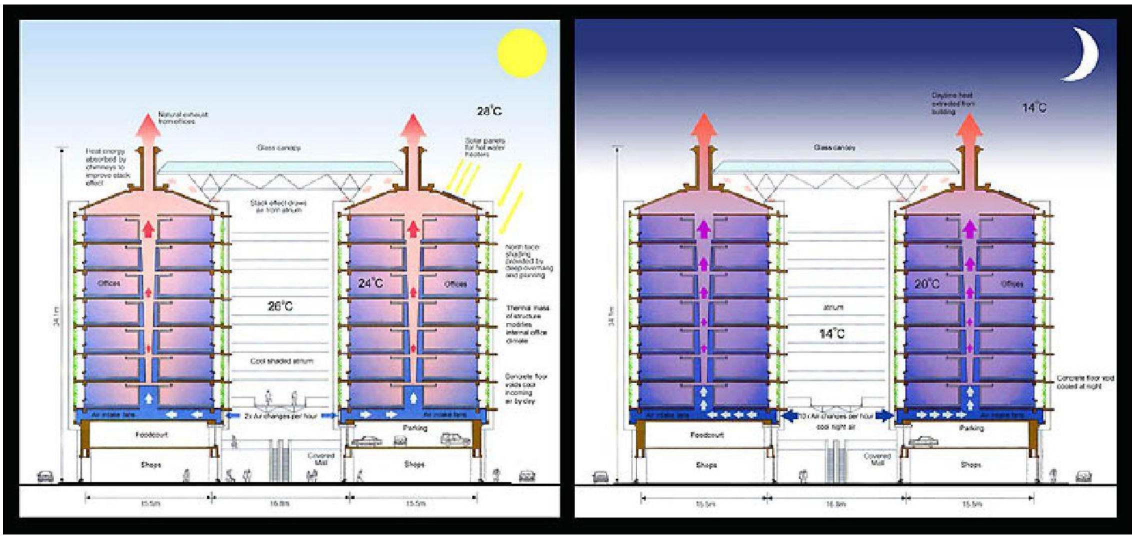

Figure 72 ***Eastgate Centre ventilation system Source mickpearce.com/Eastgate.***

Pearce was given a set of regulations by the engineering firm Ove Arup.They stated that no direct sunlight should fall on the external walls and that the window-to-wall area on the north façade [direction of summer sun] should not exceed 25%. They requested a balance of artificial and natural light to reduce energy use and heat gain. They claimed that due to noise pollution and unpredictable wind pressures and temperatures, all windows must be sealed and ducted ventilation must be used. Above all, windows must function as light filters, reducing glare, noise, and providing security. Therefore, Windows with adjustable blinds are used in the design; Architect Pearce used large overhangs to keep direct sunlight off the windows and walls. Deep Over hangings are used in a design which is a typical African method for totally sheltering the walls from the hot summer heat while enabling the lower winter sun to warm the building in the morning.

The Eastgate Centre consumes less than 10% of the energy of a comparable-sized conventional building. These economies have a direct impact on the bottom line: Eastgate's owners have saved $3.5 million on an air-conditioning system that did not need to be installed. Aside from being more eco-friendly and better for the environment, these savings are passed on to tenants, whose rentals are 20% lower than those in neighbouring buildings.

Eastgate's success can already be quantified by comparing its annual energy consumption to that of comparable conventional Harare buildings. The bar chart demonstrates that Eastgate uses less than half the energy needed in traditionally air-conditioned buildings while providing extremely good comfort levels for inhabitants.

3. District C, Telefónica Headquarters, Madrid.

For the first time in the company's history, the new Telefónica Headquarters, known as Distrito C, will house all of the company's employees - 14,000 people - in a single corporate site to the north of Madrid, at the end of a new urban development known as "Las Tablas."

Figure 73 *District C, Telefónica Headquarters*
Source: archello.com/

This district is made up of twelve office buildings: four ten-story structures at either end and eight four-story structures in the middle. This property also includes a public shopping centre and numerous other buildings that provide other functions. The goal of Distrito Telefónica is to centralize all of the company's resources in order to save money on its management structure. Las Tablas is a huge, low-density residential subdivision. Rafael de La-Hoz, a local architect, created Distrito C keeping in mind the scorching Spanish heat.

A particular form of glass, manufactured specifically for this project, Super dual Distrito C which appears transparent from the inside and opaque and clear from the outside gives a bright-dark contrast to the shadow cast by the system of vertical sunshades that structurally connects the two façades, making it visible to the eye, has been put throughout to reflect the heat from the sun. Protruding panels serve as sun visors and provide character to the buildings. A covered corridor that shades people below connects each of the four cubes. The world's largest rooftop photovoltaic installation-15,300 solar panels capable of gathering 4 million kW hours per year, located on top of the walkway.

The landscaping around the complex comprises native flora that require little water; the water required comes from rainwater collection devices on the roofs of each building. Telefonica has been able to consolidate and simplify its operational processes, as well as cut local travel expenses, after opening its Distrito C headquarters in 2007.

The architecture of Telefónica's complex results in significant savings in air conditioning and heating (15% in the winter and 34% in the summer) as well as a reduction in CO_2 emissions of 5,000 tons per year. The use of glass façades results in a 42% reduction in lighting expenditures. It has received awards such as Premio a la Obra Internacional" at the XI Bienal Internacional de Arquitect ura Argentina BA07 and Premio Aedip 2009.

4. Al Bahr Towers in the UAE

The Al Bahr towers is one of the innovative examples for self-shading structure, located in Abu Dhabi's business district, are two nearly identical 26-story, 150-meter-tall structures. The Al Bahar Towers aim to give a contextually and culturally appropriate design while also utilizing current technologies to reach the greatest feasible efficiency requirements. Following an international competition, the Aedas firm was selected to design the new Abu Dhabi Investment Council headquarters.

Figure 74 *Al Bahr Towers Source: Terry Boake*

The two towers are largely intended for office usage, but they also incorporate additional space such as 10 auditoria, prayer rooms, plant rooms, and a gymnasium. They are connected by a two-story basement that serves primarily as a parking garage and houses numerous big plant rooms, a safe vault, and different back-of-house sections. A 100 m wide curved roof forms a shallow dome over the entrance podium between the towers, its front partially glazed and presenting a striking entrance to the structures. Visitors enter this fully conditioned atrium and have the option of proceeding immediately to either tower.

Aedas Architects and Arup Engineers collaborated to build an extraordinary façade that takes cultural elements from the "mashrabiya," a traditional Islamic lattice shading mechanism that also pays homage to traditional Arab architecture and design. The geometric patterns that make up the massive screen contain over 1000 dynamic pieces that constrict and extend throughout the day depending on the position of the sun.

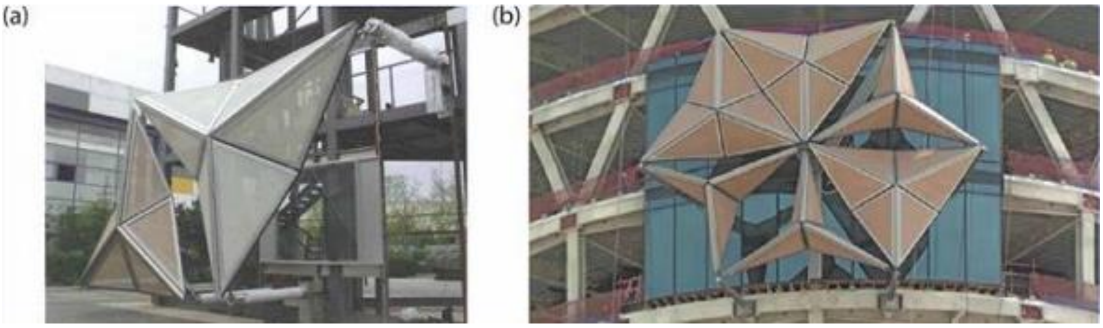

Figure 75 *(a) A full-scale prototype of the mashrabiya undergoing mechanical testing at Yuanda's facilities in Shenyang (Aeadas Architects Ltd) and (b) the onsite benchmark for six mashrabiyas. Source: www.glassonweb.com*

A dynamic and reactive shade screen reduces solar gain even more by serving as a "Mashrabiya": a second skin that filters light and reduces glare. The system is powered by photovoltaic panels that generate renewable energy. Except for the area of the façades facing north, the massive lattice almost fully surrounds the two towers. "By night, all the screens fold, revealing more of the façade. As the sun rises in the East in the morning, the mashrabiya across the length of that side of the building begins to close, and as the sun moves around the building, the entire vertical strip of the mashrabiya moves with it.

The towers' revolutionary shade screen, controlled by computer, functions as a curtain-wall, positioned two metres from the outside façade of the structures in an independent frame. Each triangle is covered in micro-perforated glass fibre and is programmed to adjust to sun movement to reduce solar gain and glare.

Figure 76 *Dynamic and sensitive shading elements source: issuu.com*

The screen is predicted to minimize solar gain by more than 50% and to lessen the need for air conditioning. Furthermore, its capacity to filter light has allowed architects to be more selective in their glass selection. It has enabled to use a more natural tinted glass, allowing more light into the interior and reducing the need for artificial lighting. It is a modernization of an ancient technique that also responds to the Emirate's desire to play a leading role in the field of sustainability.

Each tower's south-facing roofs contain solar cells, which generate around 5% of the total energy required from renewable energy sources and are utilized for water heating. The towers were among the first in the Gulf to get LEED Silver certified.

Internal, open-air gardens along the South façade provide shade and serve to mitigate the impacts of sun exposure. These places also serve a purpose for employees, who use them for meetings and breaks.

The podium houses a variety of shared facilities, such as prayer rooms, restaurants, and an auditorium, while allowing differentiated access for different categories of users, such as members of the public, staff, and VIPs, who can use a discrete entrance from the upper deck's garden area.

There are two subterranean parking levels with a total capacity of 80 vehicles, as well as a "mezzanine" area integrated into the podium that serves as a personnel conference room.

While the Gulf region's subsidized energy prices make any meaningful cost-benefit analysis difficult, the Al Bahar Towers project is expected to contribute to a broader discussion of problems such as "cost of use" and "total lifetime cost."

An observation deck is open to the public on the top floor, at a height of 120 meters.

The project received the CTBUH Innovation Award in 2012 and was named one of the "Innovative 20" tall structures that "challenge the typology of tall buildings in the twenty-first century." It was also named one of the "25 best inventions of the year" in the November 2012 issue of Time. It also received the 2013 Society of Facade Engineering Awards and the 2013 Middle East Architect Awards for best overall building and best commercial building.

Benefits

Self-Ventilating and Self shading Designs have significant benefits ranging from wellness to indulging biophilic design.

- Self-shading stops heat gain and glare to keep buildings cool and pleasant while still allowing for natural light.
- By blocking out direct sunshine, self-shading helps maintain a space comfortable and energy-efficient.
- Self-ventilation helps remove humidity and unpleasant odours that might accumulate within a structure.
- Fresh air also has a buoyant, uplifting effect that makes people feel energised and optimistic. maintaining a secure, healthy, and comfortable environment for both living and working
- Reducing the dependency on artificial cooling through air conditioners which uses a lot of energy that is produced by Burning fossil fuels which releases carbon dioxide into the atmosphere, which is more popularly known as a greenhouse gas and plays a significant role in the ozone depletion.
- By reducing the release of extra heat into the urban air by air conditioning that contributes to higher temperatures to Urban Heat Island effects.
- Due to the reduction in artificial lighting and cooling, they also provided the additional economic benefit of large energy savings.

F. Cooling Centers

Cooling centers are public or private locations like libraries, museums, or parks to offer residents a place to get some relief from the heat. Walkways with shade are cool pathways. Cities must use various methods, such as billboards, phone applications, or text messaging, to raise public awareness of the locations of these centers before and during Heat waves. These can also be mapped by cities using internet tools, as already in use in the cities like Washington D.C., Toronto, and New York's Cooling Centre Finder which is only accessible during heat waves.

Figure 77 *Los Angeles Central Library, a designated cooling centre. Source: Wikipedia*

Health is impacted by long-term temperature increases, intense heat events, drought caused by heat, high nocturnal temperatures, and urban heat islands. One health effect that will be directly impacted by climate change is illness brought on by the heat. Heat cramps, heat exhaustion, heat stroke, and even death are all potential side effects. Excessive heat poses a major threat to our health. Despite being the worst type of extreme weather, heat waves nevertheless have a poor reputation for danger. Even a healthy person during the temperature above 40 °C can be effected by the heat due to cahnge in Body’s core temperature.The elderly, small children, nursing mothers, individuals who work outdoors or have physically demanding jobs, those who are homeless, and those with chronic illnesses are particularly vulnerable. Remember them; they are in very real danger.

The use of a heat-alert system, real-time data and surveillance to monitor health outcomes during heat events, built environment strategies (such as tree-planting and cool roofs), zoning regulations, heat safety education campaigns, wellness checks, and hydration stations are just a few of the tools and programmes that can be used to protect the public from extreme heat.

Implementing cooling centers is one adaptation strategy that has the potential to be successful and is frequently implemented. Heat-related morbidity and mortality can be avoided by having access to air conditioning. Low-income communities could have limited access to air conditioning or might be reluctant to use cooling equipment because of the possibility of expensive electricity expenses during the hottest parts of the day. For these people, cooling centers can offer a cool setting.

i. Implementation Examples

<u>COOLATHENS# and EXTREMAS:</u>

The number of extremely hot days and heat waves in Athens is rising this summer. Climate change is making them more intense, frequent, and long-lasting. Through a number of measures, the Municipality of Athens is getting ready for a "Cool Athens" and protecting itself from it.

Figure 78 *Athens Source: captainbobcat.com*

Few people, particularly in the Mediterranean countries, are aware that excessive heat poses a major threat to our health. Despite being the worst type of extreme weather, heat waves nevertheless have a poor reputation for danger.

The elderly, small children, nursing mothers, individuals who work outdoors or have physically demanding jobs, those who are homeless, and those with chronic illnesses are particularly vulnerable. Remember them; they are in very real danger!

The city of Athens provided and regularly maintains the application's detailed map of the cooling centres for municipal buildings in partnership with many municipal Agencies.The Athens Coordination Centre for Migrant and Refugee Issues (ACCMR) and international and local NGOS worked together to put Near Field Communication (NFC) tags referencing the "Cool Athens" campaign.

The European Commission's (EC) Directorate-General for European Civil Protection and Humanitarian Aid provides 75% of the project's funding. 25% of the cost is covered by the partners' personal contributions. The success of the project is due to the development of close linkages between various groups, such as policymakers, scientists, and stakeholders, which leads to better-informed and more effective Disaster Risk Reduction initiatives as well as continued collaboration on enhancing community resilience. The EC's financial assistance gave us the means to launch EXTREMA on a European scale. EXTREMA is being marketed as a success story by global city networks starting in Athens. (49)

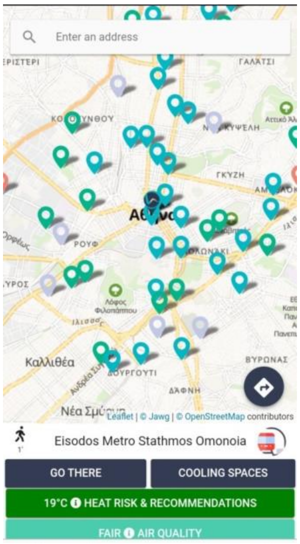

Figure 79 Source: EXTREMAglobal .com

The EXTREMA initiative seeks to increase urban resistance to temperature extremes. These occurrences can result in a large number of unnecessary fatalities, and climate change is expected to make them more frequent.

EXTREMA calculates the temperature, humidity, and discomfort index for each square kilometre of the city using real-time satellite data, other models, and city-specific data. Every five minutes, temperature estimations are updated.

On a local level, EXTREMA is coordinated by the National Observatory of Athens (Public Research Centre), which also works with ARATOS-Systems, the City of Athens, and the National Kapodistrian University of Athens' Medical School. The city of Athens' Resilience and Sustainability Department (RSD) and DAEM SA-IT firm, working with many municipal agencies

EXTREMA collects, analyses, manages, and disseminates in-situ and space data related to extreme temperature, which helps us better comprehend the risk of climate change. These can aid in creating prevention strategies and plans that are more effective.

EXTREMA has also enhanced cross-border and city-to-city cooperation for reducing the danger from climate change, particularly with regard to heat waves. Six constituencies—Athens, Paris, Rotterdam, Milan, Lisbon, and the Island of Mallorca—have endorsed EXTREMA services, shared knowledge, and worked to lessen the effects of the heatwave by improving the abilities of the populace to anticipate heat, react appropriately, and provide them with a network of cooling centres (including parks, indoor and outdoor spaces, air-conditioned municipal buildings, fountains, water games, and more).

New york Cooling centers:

Figure 80 *NJ Cooling centers*

When the National Weather Service issues a heat advisory with an anticipated heat index of 95 degrees or higher for two or more days or 100 degrees for any period, New York City opens cooling centres. People can find cooling centres within air-conditioned buildings that provide relief from the heat. (49)

Cooling centres can be found in the following places sucha as NYCHA resources,Libraries, Senior facilities,Communal buildings

If anyone cannot access a cold environment during a heat wave, and especially if they are at risk for heat-related disease, they can use a cooling centre.

Partners of the New York City Agency are in charge of managing the cooling centre facilities, and they choose the accessibility levels and operating hours for each location. Places have different laws and regulations.

The Cooling Center's management can decide whether to enforce face coverings and social seclusion.

ii. Benefits

Cooling centers have been shown to be effective in reducing heat-related illnesses and deaths during heat waves. Research has found that they can help lower body temperatures, prevent dehydration, and provide a safe environment for vulnerable populations, such as the elderly and those without access to air conditioning.

They often offer amenities like air conditioning, water, and sometimes even medical assistance

7. Conclusion

The fundamental theories, most recent methodologies, and strategies to reduce urban heat islands (UHIs) were examined and summarized in this thesis together with past research on the subject. The various factors that affect the development of UHI have been researched and reported. To comprehend the origin, determination, and mitigation of UHI, methods and tools are used. Different techniques' advantages were examined. The chief sources of UHI, according to the research, are heat from direct sunshine combined with heat from people. The main causes of UHI production include shifts in land use and cover, as well as rising impervious surface areas, which raise the intensity of UHI.

Surfaces made of heat-resistant, light-colored materials can lower UHI, provide cooling, and improve occupants' thermal comfort. However, patterns of Land Cover and Land Use, seasons, and time of a day, day/night all have an impact on the intensity of UHI. Data on surface temperatures were gathered through earlier studies. The research offers practical suggestions for lowering UHI as well as a workable strategy for sustainably addressing urban climate issues. Additionally, it was determined that methods for calculating UHI reductions with modifications to planning and design parameters are necessary.

We are learning just how much our urban areas struggle to handle heat as prolonged periods of high temperatures become more regular and intense around the world as a result of climate change.

Most of our cities weren't built to withstand this kind of weather. To stop the threat of extreme heat to lives and livelihoods, however, they must be modified as temperatures rise in response to growing greenhouse gas levels and the urban heat island effect.

The urban heat island effect puts cities at special danger during heat waves. Buildings and roadways with dark-colored, man-made surfaces tend to trap heat from the sun. As a result, urban areas frequently have temperatures that are several degrees higher than the nearby countryside. Our cities' built environments expose them to heat waves.

Additionally, the high temperatures can be fatal, especially for those who already have underlying medical issues such a respiratory disease. Because cities frequently experience increased air pollution levels due to intense sunlight, cities can also become oppressive. Additionally, hot offices reduce productivity, which hurts the economy.

In order to make our urban cities resilient towards the Heat waves, we must remodel and adapt our cities because we cannot simply knock them down and rebuild them in a manner better suited to our changing environment.

The temptation to rely only on air conditioning would result in significantly higher electricity use. Due to the electricity load created by people trying to keep their homes and workplaces at a pleasant temperature during the summer, even wealthy nations occasionally experience blackouts. Additionally, installing and running air conditioning can be unaffordable for those with lower wages, aggravating the disparity in access to resources for climate change between the wealthy and the poor.

Air conditioning systems, of fact, merely transport heat from inside buildings to the surrounding region, raising the temperature outside. We need to adopt a new strategy.

We must stop the sun's rays from causing the issue in the first place rather than scrambling to remove excessive heat from our metropolitan structures. Tinted glass blinds, or shutters must be used in offices and residences to block sunlight.

We must move towards the Green technologies by planting more trees, which can block sunlight and prevent pavement from getting heated and filter particulate matter in the air such as in Colombia's Medellin. Creating a Green shade network and Increase percentage of vegetation cover in urban areas like the efforts taken by Charlotte, North Carolina and Baltimore.

In order to increase Green canopy efforts must be put in designing the Green roofs and facades and try find the new methods to make the cost of building green roofs and facades less expensive and easy to maintain like we have seen in Bosco verticale, of Milan and Maya hotel of Singapore and others.

It should become standard to use the certain materials for construction that reflect the sun's rays rather than absorb them.

New and retrofitted old buildings will need to be designed to increase ventilation with natural flows of air to keep internal temperatures down. These are features of well-designed cities in hot countries, which we must adopt. We need building regulations that force developers to design buildings so that they do not overheat.

We should also put efforts while designing structures with self-ventilating system like we have seen in Medieval Persia, Badgir and East gate center.

Use of the Monitored and automated computerized sun blocking systems like in Al bahar tower or design the architectural geometries of the structure with extended shade like in the Telefónica Headquarters.

In order to reflect heat back into the atmosphere and prevent heat from being trapped in the urban layers like in Phoenix and Los Angeles, road pavements and roofs will need to be constructed using fewer heat-absorbing and light-colored materials.

But city dwellers and workers must also alter their attitude in order to safeguard themselves from the hot and muggy conditions. Even fit and healthy persons may be at risk if they overexert themselves in temperatures above 40C (104F). So we just have to get used to avoiding direct heat when it's appropriate. More towns will need to ban building and other heavy labor during the hottest part of the summer, following the lead of those that are closest to the equator.

Every city must set up "cool spaces" where the population can find relief during hot weather, following the lead of other communities that have already been running Cooling Centers like Paris, Athens, New york, Toronto..

Additionally, our communities need to build up their social support networks so that the elderly and others who are most at risk from the heat may receive assistance and guidance. The top priority for cooling-down procedures must be care facilities.

Our cities most urgently require integrated heat risk-management policies that coordinate the efforts of numerous public and commercial entities on both the local and national levels. They may need to appoint chief heat officers to coordinate action, as Miami, Phoenix, and Athens did.

Using Green technologies for making our urban areas resilient towards future rise of temperature and duration during Heat waves could be the only solution for us without burning any fossil fuels and releasing more greenhouse gasses. It might take us long way but in the right Direction.

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