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A Study to Evaluate Urban Heat Mitigation Design Strategies, In Commercial Centers.

Un estudio para evaluar estrategias de diseño de mitigación de calor urbano, en centros comerciales.

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ABSTRACT

The rapid rate of urbanization, especially continued growth and anthropogenic activities has given rise to numerous urban climate impacts across different cities round the world. In India most of the cities specifically those with commercial centers are more at risk of induced urban heat effects thanks to intense radiation during most of the year, resulting in increased atmospheric air temperature and outdoor/indoor discomfort. The auto – dependent planning of the town contributed negatively to the external thermal comfort and to people's daily social lives. One in every of the largest challenges for cities with hot climate is to search out effective solution against the induced urban heat increase and to boost the outdoor thermal. Considering the present scenario, over half of the earth's population resides in urban areas. The amount of urban inhabitants is predicted to grow exponentially, especially in developing countries. The enlarging urban population would require an extensive array of infrastructure, services, housing and jobs etc. The urban land expansion could be a threat to land supply, causing intra-growth of the traffic volumes and increment in adverse pressure on the environment and may become immensely unsustainable for any city. Thus, the need of the hour is to take measures on variety of indicators that have outreached critical levels, especially the UHI and subsequently responsible choices need to be made for the new future so-as to push human and environmental resilience as we all must heal this warming world.

Keywords: Urban Heat Island, Urbanization, Anthropogenic activities, Increased atmospheric temperature, Outdoor/Indoor discomfort, Strategies to heal the warming world.

RESUMEN

La rápida tasa de urbanización, especialmente el crecimiento continuo y las actividades antropogénicas, ha dado lugar a numerosos impactos climáticos urbanos en diferentes ciudades del mundo. En la India, la mayoría de las ciudades, específicamente aquellas con centros comerciales, corren más riesgo de sufrir los efectos del calor urbano inducido gracias a la intensa radiación durante la mayor parte del año, lo que resulta en un aumento de la temperatura del aire atmosférico y molestias en el interior y el exterior. La planificación autodependiente de la ciudad contribuyó negativamente al confort térmico exterior y a la vida social diaria de las personas. Uno de los mayores desafíos para las ciudades con clima cálido es encontrar una solución eficaz contra el aumento de calor urbano inducido y potenciar la temperatura exterior. Considerando el escenario actual, más de la mitad de la población mundial reside en áreas urbanas. Se prevé que la cantidad de habitantes urbanos crezca exponencialmente, especialmente en los países en desarrollo. La población urbana en aumento requeriría una amplia gama de

infraestructura, servicios, viviendas y empleos, etc. La expansión de la tierra urbana podría ser una amenaza para la oferta de tierra, causando un crecimiento interno de los volúmenes de tráfico y un aumento de la presión adversa sobre el medio ambiente y puede volverse inmensamente insostenible para cualquier ciudad. Por lo tanto, la necesidad del momento es tomar medidas sobre una variedad de indicadores que han superado los niveles críticos, especialmente el UHI y, posteriormente, se deben tomar decisiones responsables para el nuevo futuro a fin de impulsar la resiliencia humana y ambiental, ya que todos debemos sanar. este mundo que se calienta.

Palabras clave: isla de calor urbana, urbanización, actividades antropogénicas, aumento de la temperatura atmosférica, incomodidad exterior/interior, estrategias para curar el calentamiento global.

AIM OF THE PAPER: How urban design can control urban heat island effect in an urban area?

OBJECTIVES:

What's Urban Heat Island and the way it affects the urban areas?

To work out the consequences and impact of urban heat island effect on the town and explore the factors that affect its intensity.

How Urban Design principles can control UHI effects in a city.

To produce strategies to create a city center with UHI principles.

INTRODUCTION

WHAT'S URBAN HEAT ISLAND (UHI) AND IT'STYPES?: An urban heat island (UHI) is an urban area or metropolitan area that is primarily warmer than its surrounding rural areas because of mortal activities. The temperature variation is typically huge at the hours of darkness than throughout the day, and is most evident when winds are weak. UHI is most striking during the summer and winter. The main cause behind the urban heat island effect occurs from the modification of land surfaces. On the idea of its impacts, the urban heat island effect will be of two types: Surface UHI and Atmospheric UHI.

SURFACE – URBAN HEAT ISLANDS: The particular is generated when the heat from solar radiation is suck up by dry and exposed surfaces of the urban set-up. Its magnitude is thus obsessed with the intensity of radiation, which changes seasonally and diurnally.

ATMOSPHERIC – URBAN HEAT ISLANDS: These are formed where there's a variation between the air temperatures of urban and rural areas. These are further sub-divided into two types: Canopy Layer UHI and Boundary Layer UHI. Canopy Layer UHI occurs near the bottom surface, where people and built environment exists, i.e. from the bottom surface to the topmost level of trees and roofs. Whereas Boundary Layer UHI occur at a level ranging from the rooftops and tree tops, until the purpose where urban landscapes no longer affect the atmosphere.

HOW IT AFFECTS THE URBAN AREAS?:The sun's heat and light outreach the urban and the rural area in the same way. The difference in temperature between urban and less-developed rural areas has got to do with, how well the surfaces in each environment absorb and hold heat. Objects of various colours reflect varying amounts of sunshine. Surfaces with a greater albedo (or lighter colour) reflect sun's energy to a greater extent. Darker objects tend to absorb maximum radiation and so heat up more quickly. If you travel a rural area, you'll probably find that almost all of the region is roofed with plants. Grass, trees and farmlands covered with crops are often seen almost everywhere; that's as far as one's vision can reach. So rural areas because of presence of more pervious surfaces have an evaporative cooling effect which makes it feel cooler, whereas in a city the areas are majorly dominated by tall buildings, sidewalks, streets, parking lots and tall buildings. The above mentioned structures are generally made of materials such as cement, asphalt, brick, glass, steel and dark roofs which have lower albedo and significantly absorb maximum radiation than the rural areas. Jolma Architects (2018) stated that cities tend to empty surface water quickly into sewers, where it's trapped, and can't evaporate as easily. In rural areas groundwater drains directly through the soil and is transpired by plants. The evaporation of water in rural areas adds up a cooling effect to the local climate. Finally, things like air conditioning and vehicles add small amounts of warmth to the air in cities, contributing to the UHI effect. The impact of heat on the surrounding in urban and rural scenario can be referred in Fig:1 and the temperature analysis in different environment to justify the same can be referred in Fig:2.

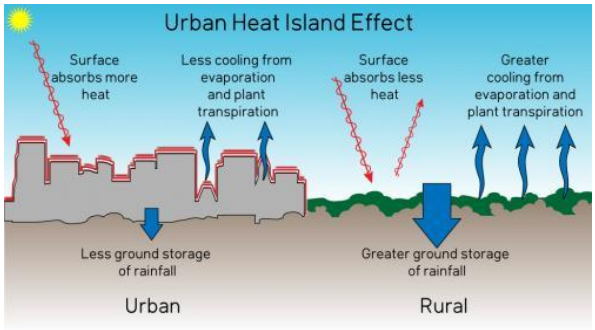


Fig1: Impact of heat on the surrounding in Urban and Rural Scenario

*Source: Skeptical Science Graphics-Urban Heat Island

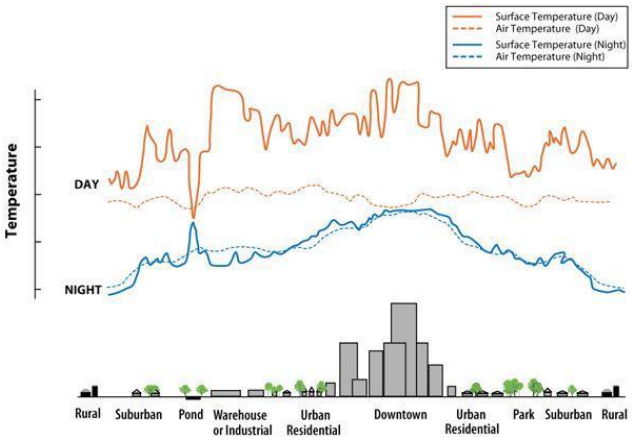


Fig 2: Temperature Analysis in different environment

*Source: The Energy and Resource Institute (TERI), 2017

URBAN HEAT ISLAND AND ALSO THE BUILT ENVIRONMENT: Urbanization has led to physical growth of urban areas, be it horizontal or vertical. Sudden development has encouraged lots of construction activities resulting in rampant deforestation. Built use like district centers or industries which is principally dominated by paved surfaces with less albedo ends up in heating up of the environment either by harmful emissions or by additional usage of cooling devices which adds up in making the urban area warmer than the rural areas. The further decline in green cover and also the increase of built-up hard surfaces as well as emissions are primary reason behind formation of urban heat islands.

The Energy and Resource Institute (TERI),(2017) has mentioned UHI mitigation strategies should aim to restrict heat built up by: 1. Reduction of usage of hard and absorptive surfaces, 2. Providing sufficient shading from solar radiation and 3. Reducing anthropogenic emissions.

GREEN AND BLUE INFRASTRUCTURE

"Green and Blue Infrastructure" has always helped in cooling the environment. It's been proven since historic times as mughals used to use a lot of greens and water bodies for surrounding the built environment because it helped in passive cooling as water can decrease the air temperature by evaporation, absorption and transport of heat. Theeuwes (2012) measured the effect of green vegetation and water surfaces within the urban areas. They found that presence of every 10% vegetative and water reduces the temperature by 0.6K and stated that trees can bring down the effect substantially. Adinna (2009) gauged the aftermath of urban heat island effect within the Enugu city of Nigeria and suggested malleable measures to keep UHI effect in check within the city. Their study deduced that utilization of dense and heavy green vegetation roofing materials and softening of pavement materials can lessen the impact in urban areas. Jolma Architects (2018) in their study to mitigate UHI through landscaping concluded that permeable paving can encourage evaporative cooling at the road level, and when utilized in conjunction with rainwater harvesting can maximize cooling effect when it's needed the foremost. Hence a lot of green infrastructure techniques are used for green roofs, permeable surfaces, green parking lots and green corridors. Street trees are always beneficial as they provide shadow to the buildings and sidewalks, effectively obstructing the radiation which will reach the surfaces with lower albedo. All of these measures will help to decrease the ambient temperature of the local microclimate and mitigate the overall urban heat island effect.

URBAN MORPHOLOGY

With rapid urbanization of cities, the morphology of urban blocks have developed from single and low-density blocks to massive and high-density ones, thus increasing more area resulting in more heat gain, thus increasing the urban heat island effect. Jeffrey Raven (2017) said not only greens which will cool the environment but we also have to look at other factors like city morphology, orientation and form of buildings and roads, building massing, creation of anthropogenic heat and relative lack of green and blue infrastructure in a very city and suggest strategies for them so as to tackle the consequences of Urban Heat Island (Joyce Klein-Rosenthal. 2017, Jeffrey Raven2017).

Jaffrey Raven (2017) gave the example of NYC which can be referred in Fig 3. in which privately-owned outdoor and indoor spaces which took the form of plazas, block arcades, gallerias, open air concourses etc. helped to direct the wind flow; and also formed a green connecting corridor for the city which helped in trapping the solar

heat radiation and hence had a greater impact in reducing the Urban Heat Island thus making the city cooler. (Joyce Klein-Rosenthal. 2017, Jeffrey Raven2017).

URBAN FORM AND LAYOUT

The orientation and height of buildings have large impact on the microclimate. The wind flow is often blocked by these large buildings hence the morphological factors can be controlled by streetscape or courtyards, plazas or ventilation corridors. C.Johnson (2015) while studying the results of UHI in an exceedingly city said, the impervious surfaces of the built form prevent the movement of air and water which are the key in the cooling processes of evaporation and transpiration. Supported his research he said that the foremost effective strategy for addressing the urban heat islands is chronicled because the development of green networks. He also suggests to retain the smaller street networks as present day cities with wide street networks as a function of more accessible transportation routes can have high magnitude of UHI than cities that retain their historic networks.

BUILT AND OPEN RELATIONSHIP

The correlation between built and open space plays an important role in mitigating the UHI. Factors like ratio of the height of the building (H) to the width of the adjacent street (W) i.e. H/W ratio and orientation of streets in the sun's and wind's direction also has a huge impact for controlling the UHI effect. The effect or UHI is especially distinct in urban canyons, which are urban enclosures formed by narrow streets and tall buildings on either sides. On one hand, during the daytime, the tall buildings can shade the canyon leading to reduction in surface temperature, but on the opposite hand the surfaces of those tall buildings may reflect and absorb the heat resulting in rise in air temperatures, *(TERI, 2017).*Joyce Klein-Rosenthal (2017)suggested choosing narrow urban canyons (where the buildings are taller relative to street width, ends up in releasing the city's trapped heat into the cool night sky); it's better to go with varied building height and massing where wider streets will be incorporated with large shading trees*(*Joyce Klein-Rosenthal. 2017, Jeffrey Raven2017). On a contrary Shima Taslima(2015)said streets with high H/W ratio leads to a more comfortable environment by relating it to the historic streets.

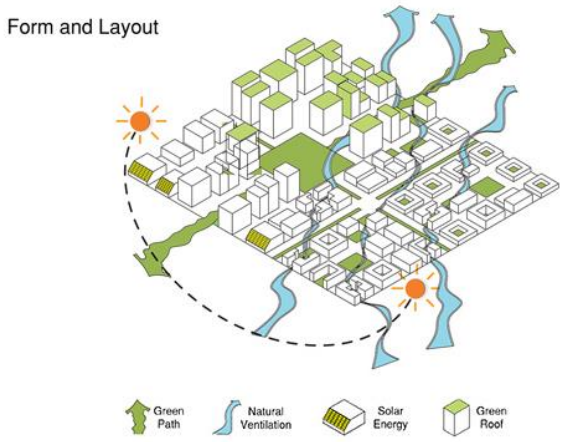


Fig 3: Image showing factors of urban morphology to control UHI.

*Source: Jaffrey Raven,2017

URBAN SURFACE CHARACTERISTICS

Urban surfaces absorb and reflect solar energy and re-emit the absorbed heat at night. Urban surfaces (roads, pavements, roofs, etc.) are made up of low-albedo surfaces which reflect less and absorb more heat as compared to rural areas. Materials like steel, glass, concrete tend to store more heat when compared to mud and soil of rural areas. Hence, there is an increased surface temperature in urban areas as compared to nearby less dense areas. The heat mitigation strategies most often used by cities which are based on new materials include high-albedo reflective roof coatings, green roofs, and reflective or permeable pavements which help in reducing temperature by 1.5°C to 2.0°C.Yasuyo Makido (2019)said that increasing the albedo of the surfaces and using green roofs helps in maintaining a cooler environment. In this world filled with concrete jungles we can even start looking at technologies which will use natural construction techniques like mud and bamboo (like ancient time but with newer techniques) and start constructing newer buildings with the same in order to achieve a cooler environment to live in.(Yasuyo Makido 2019 , Dana Hellman 2019 , Vivek Shandas 2019)

ANTHROPOGENIC HEAT MITIGATION

Heat caused due to human activity such as manufacturing, heating or cooling, lighting, transportation, heat from human and animal metabolism together add up to the anthropogenic heat, which eventually leads to increased UHI. Making a city more pedestrian friendly or promoting non-motorized vehicles at least for lanes with local markets or historic commercial lanes can help lessen the heat emission to some extent. Jan Gehl (2016) said when you encourage more people to walk more you contribute more towards a living city; it protects the surroundings and also adds towards a healthy lifestyle. When you promote pedestrianisation you come across more about the city and also encourage the social connection between people. The increasing growth of population is adding pressure on living space with consequent deterioration in environmental quality. The rapid increase in population density is because of the rise in number of migrants searching for better working opportunities, services and facilities. These sudden changes have mostly impacted the commercial centers which has been dominated by multi-storey buildings and high commercial buildings that dominate the skyline, and they have a dramatic impact on the microclimates of the city. The continuous constructions in the city are replacing the beautiful gardens and the greenery thus adding more pressure on the environment. Commercial centers usually experience the maximum number of footfall when compared to the surrounding areas thus leading to more transportation systems , more heating ventilation and air conditioning (HVAC) systems installed for thermal comfort inside the buildings as a result, such anthropogenic activities lead to heat production making it a primary problem in a city. Thus, urbanization and human activities are major factors in increasing the strength of UHI and contribute significantly as some of the major reasons behind UHI. Therefore, in commercial centers because of high-density area air temperature grows too much and lack of greenery & low albedo facades become quite important issues of Heat Island intensity.

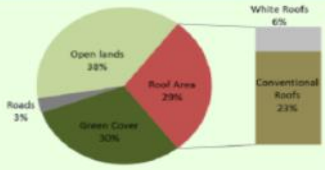
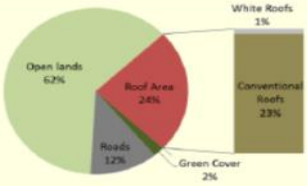
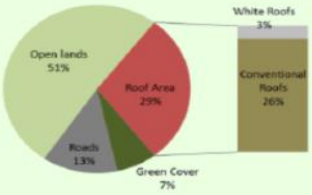
A CASE OF BANGALORE – Analysis by The Energy and Resource Institute, Teri 2017

The project aims at analyzing the local effects of urban planning and green cover on UHI within the IT industrial areas of Bangalore. Owing to its vast IT industry, Bangalore has numerous old and new IT parks in several areas of the town. From the angle of design, they could differ from each other in terms of road widths, building heights, form of vegetation, etc. The IT-park in Electronic city is one in all the greenest within the country. To assess the impact of green cover in IT developments, the above case can be analyzed against another IT-park in Marathahalli, East Bangalore and Whitefield. The 1 kilometer span includes a very high percentage of open lands, however the green cover is low.

Amongst the IT locations, it is observed that Whitefield observes the highest AT during daytime. This is often because of the actual fact that Whitefield contains a high percentage of open land surfaces with low green cover.

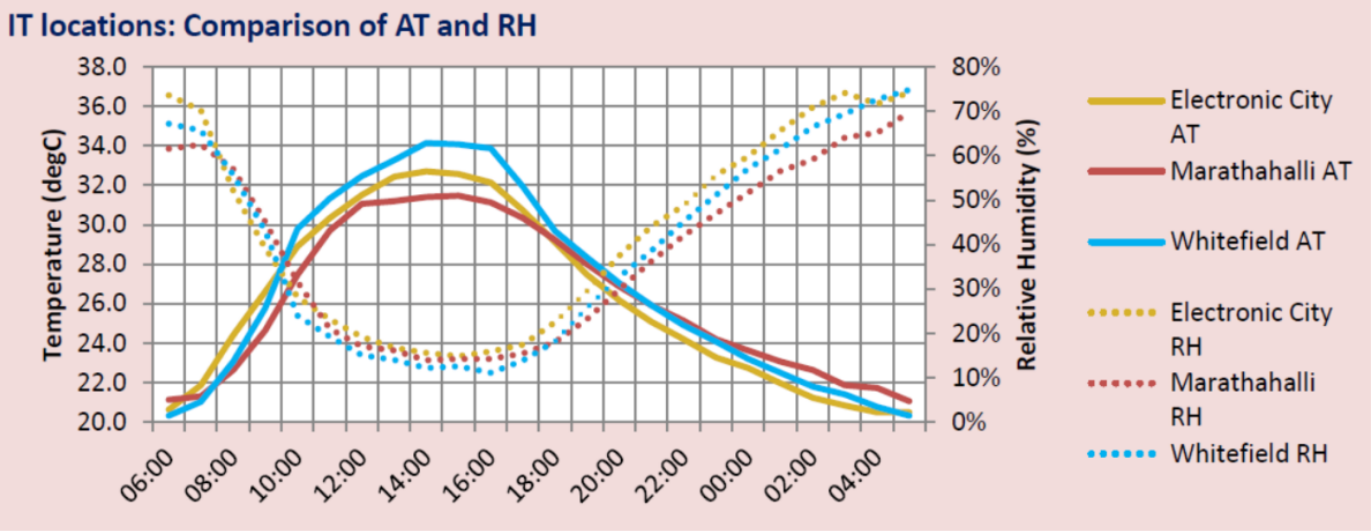
Due to a high percentage of open lands, this area shows low temperatures in the dark and a high diurnal variation. In Marathahalli, it has low AT at daytime, despite having identical RH. This ascertains that the lower daytime AT is because of a high H/W ratio. The buildings are tall and space between buildings is narrow because the surfaces are protected against direct solar radiation. Whitefield observes 4degC higher temperature during daytime compared to others, because it has wider roads with heavier traffic and because of high anthropogenic heat emitted by buildings and impervious surfaces which are not covered; thus trap the warmth making the environment warmer. From the results of Electronic City, it had been observed that the thick green cover combined with white roofs and light coloured surfaces are often very effective in lowering the daytime as well as the night-time temperatures. Existence of water bodies can further help reduce the temperature and give rise to evaporative cooling. The Summary of IT locations selected for monitoring can be referred in Table 1 which will help to further justify the above paragraph and the comparative analysis of hourly averages of air temperatures (AT) and relative humidity (RH) for IT locations can be referred in Table 2.

Table 1: Summary of IT locations selected for monitoring.

	Location name	Development type	Characteristics at Area level (for a radius of 1 kilometre)	Characteristics at Street level		Significant features
				H/W Ratio	% Green Cover	
1	ELECTRONIC CITY (South Bangalore)	Mid-rise IT offices		0.6	30%	• High green cover • Medium density • Moderate traffic
2	MARATHAHALLI	Mid-rise and high-rise IT offices, light commercial		2.33	2%	• Very low green cover • Medium density • High traffic • 2 kilometres away from nearest lake.
3	WHITEFIELD	Mid-rise IT buildings		0.49	7%	• Wider roads • Moderate green cover • Surrounded by large open spaces

*Source: The Energy and Resource Institute (TERI). 2017

Table 2: Comparative Analysis of Hourly averages of Air Temperatures (AT) and Relative Humidity (RH) for IT Locations. (Monitoring Period: 15-March-2017 to 22-March-2017).



*Source: The Energy and Resource Institute (TERI). 2017

Recommendations for Commercial locations of Bangalore: As perceived from Whitefield case, In order to lessen the start-up load that happens early morning it is suggested to possess planned open lands that can help dissolve the gathered heat to the night sky (natural heat sink). A high H/W ratio could also be useful in commercial building zones because it is effective in providing necessary shade to the horizontal and vertical surfaces of a street canyon, hence helping lessen the too much daytime heat gains into the buildings. Cool roofs or green roofs are often very effective in lowering the daytime temperatures too. It is also recommended that the light coloured paints & textures should be selected for external walls of buildings (especially taller buildings) in commercial locations. For Marathahalli and Whitefield cases, additional tree plantation in open lands and streets could lessen the temperatures further. In patches of Electronic city, strategic tree plantation can be carried out to improve shading. Low lying areas can be transformed to ponds and lakes wherever possible.

CONCLUSION

The Urban Heat Island effect is one of the consequences of urbanization which somewhere affects the environment we live in and our life as well. The major source of UHI is the huge amount of impervious urban surfaces as they consume much of the solar radiation and re-radiate less, and from the anthropogenic human activities. This study analyzed the impacts of UHI on a city and how urban design principles can play a role in mitigating it. The results indicate that maximizing the albedo of urban surfaces, increasing the amount of green and blue infrastructure in an area can subsequently maintain or reduce temperatures in any of the area studies. We observed that different areas of the cities require different site-specific applications for temperature reduction. Areas mostly dominated by built structures such as Commercial districts can be cooled by increasing the albedo of roofs and roads, curb side planting or creating green ventilation corridors, proposing urban forms with plazas or open air concourses; which will let the wind to sweep inside and increasing H/W ratio of built to street and making the neighbourhood pedestrian friendly in order to mitigate anthropogenic heat. On the other hand for the areas that already have abundant tree cover, such as high canopy vegetated neighbourhoods – efforts should be done to maintain the same. Areas with large open

spaces of soils or grounds may be successfully reduced by adding planned green spaces or more trees. No matter the different types of intervention we suggest for different areas but from the study it is noticeable that nature based solutions are both practical and promising. It has been proved that increasing urban green areas such as parks, street trees, short vegetation cover and green roofs could reduce air temperature and hence, UHI through three processes: Evapotranspiration, Increase of direct shading on urban surfaces and Improvement in air movements. Green roofs are an additional means of mitigating UHI through removing heat by evapotranspiration, decreasing heat absorption and reducing the need for air conditioning which will further reduce anthropogenic heat. Therefore it is concluded that Urban greening along with light roofs (Ecological Infrastructure) is an efficient method to mitigate Urban Heat Island as it can be applicable to most of the study areas. Ecological infrastructure not only provides cooling but also better social and biotic rewards as compared to what is currently being offered by many built urban environment. Urban Heat Island mitigation has become the need of the hour because of the changing requirements of urbanization and Urban designers, planners and policymakers have an imperative to look ahead, which has to be explored and subsequently responsible choices have to be made for the new future in order to promote human and environmental resilience as we all need to heal this warming world. A further research on this topic can be done by focusing on strategies to mitigate Surface and Atmospheric UHI separately so that urban designers and planners can get a better clarity and specific implementations to deal with UHI mitigation.

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