Environmental Monitoring (ISSN Online: 2771-988X)
April 2022 Vol.1, No.1, pp. 1-7
DOI: https://doi.org/10.55571/em.2022.04001

Mitigations for Sustainability of the Megacities

Ghosh Biswajit
The Neotia University, D.H.Road, 24 Paragonas (S), & Jadavpur University, Kolkata
*Corresponding author's e-mail: bghosh3@gmail.com

Abstract. The megacities are facing problems like increase in population, enhancement of environmental pollution, collapsing of traffic systems, and dysfunctional of waste management. The vertical extensions in the built-in-systems welcomed urban heat island (UHI) effect and enhance 5-10% more energy consumption. Thus, mitigation of UHI can be done by; i. reduction of albedo effect by introducing rooftop integrated photovoltaic (RiPV) systems, and ii. introduction of evapo-transpiration systems like water bodies, greeneries, green roof & green wall. Long term studies showed that introduction of RiPV systems in built-in-system not only reduce the albedo effect but also compensate the additional energy demand.

Keywords. Rooftop integrated photovoltaic (RiPV) systems; Evapo-transpiration systems; Sustainability

1. Introduction

People induced towards the cities due to; i. geographical location, ii. available infrastructures for health, educations and other essential living supports, iii. access to income generation activities. As a result the cities around the globe are overpopulated and introduced loads on ecology, economy and welcomed the problem ofsustainability.

Sustainable development is about 'meeting the needs of the present without compromising the ability of future generations to meet their own needs' [1]. In its application to cities, sustainability adopts the metaphor of metabolism; a city can be defined as becoming more sustainable if it is reducing its resource inputs (land, energy, water & materials) and waste outputs (air, liquid, and solid waste) while simultaneously improving its live ability (health, employment, income, housing, & leisure activities)

To understand the trends of energy use with time in the cities it is important to understand the dynamics of the city. The metabolism of the city can be characterized by assessing its input output items where energy and materials are used as input and waste as output. The metabolism approach is a powerful metaphor for the illustration of the processes that mobilize and control the flows of energy and materials through a city. Thus, the ecological system of a city will help in taking control of the vital links between human actions and the quality of the environment.

Hence, in designing the sustainable scheme for a city, knowledge on human-induced energy and material flows with comparison to those of natural flows is essential.

Environmental Monitoring (ISSN Online: 2771-988X)
April 2022 Vol.1, No.1, pp. 1-7
DOI: https://doi.org/10.55571/em.2022.04001

The significant energy use in cities is not very well perceived in Asian countries. Although a number of studies were conducted on energy consumption across various sectors of the cities have been conducted but most of them are from the national point of view. The dynamics of energy consumptions and its impact on ecology both at local and regional level requires being addressed from the sustainable standpoint of megacities. In the present paper efforts have been made to address the need for ecological adoption of an upcoming megacity around the ancient city, Kolkata, in West Bengal, India.

2. Ecological Impact

It was mentioned in the previous section that rapid increase of population in cities and its periphery induced the growth of mega-cities. To accommodate the people and to offer their access in the economic activities has resulted in the build-up of massive infrastructures and dense settlements. The urban surfaces are converted with asphalt, concrete, and other materials, -referred as ‘impervious surfaces’- absorb more incoming solar radiation (INSOLATION) during day hours, converted it into sensible heat and store in the building materials. During night hours the impervious surface released the stored heat into the urban air, creating a warm bubble that can be as much as 1 to $3^{O}C$ (2-$5^{O}F$) higher than temperatures in surrounding outskirt of city areas [2].The change in land surface quality has primarily affected solar reflectivity, so-called albedo. The albedo is different from normal reflectivity in the sense that reflectivity might only account for visual bands, whereas albedo accounts for all the incoming solar radiation (INSOLATION) to a surface. Asphalt roads, concrete pavements and corrugated roofs, which form the major part of dense cities, have a low value of albedo. The low albedo surfaces absorb significant proportions of solar radiation and contribute in worsening the urban environment. In addition, loss of vegetation inhibits the evapotranspiration process, in which plants use heat from the air to evaporate water from their leaves. This process enables vegetation to act as a heat sink. Changes in wind patterns have also exacerbated the urban heat (UH) problem [3].

2.1. Urban Heat Island (UHI) Effect

The UHI was discovered in 1800s [4] when it was observed that the cities growing warmer than its surroundings outskirt areas particularly in summer months. Higher ambient temperatures of cities increase the demand for electricity for cooling and this leads to an increase in the production of CO_2 and other pollutants where production of electricity needs fossil fuel. The UHI is not a problem in cities during winter but imposed some other problems on ecology and economy also. Man-made changes to the urban environment are the source of the UHI phenomenon. The radiation balance within the urban system is disrupted as surfaces absorb long-wave radiation and are unable to re-radiate it. An increase in anthropogenic heat discharge, a decrease in surface evaporation, changes in the thermal characteristics of urban surfaces, an increase in traffic population and air pollution, together with the reduction in airflow and humidity caused by the sheltering effect of buildings, are the major factors behind these changes.

The energy demand is fulfilled through electricity and the combustion of fossil fuels, which ultimately discharge heat into the urban atmosphere. The single greatest source of stationary heat discharge from buildings comes through air-conditioning units. These units are very densely concentrated throughout the cities. Some waste incineration plants and industries located in the outskirt of the cities also release heat directly into the urban environment. Studies revealed that only 13% of the total energy input into transportation is converted into useful work. The rest is dissipated as heat into the environment at the site [5].

Environmental Monitoring (ISSN Online: 2771-988X)
April 2022 Vol.1, No.1, pp. 1-7
DOI: https://doi.org/10.55571/em.2022.04001

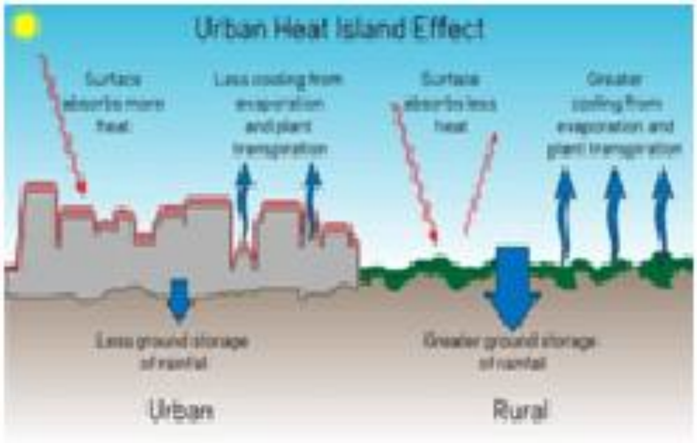

Figure 1. Possible cause behind UHI

Rapid urbanization and population growth in mega- cities has resulted in the build-up of massive infrastructures and dense settlements with scarifies of vegetated land surfaces those are converted into concrete and asphalt. The change in the natural surfaces has primarily affected the albedo (α). As mentioned in the previous section that asphalt roads, concrete pavements and corrugated roofs have a low α value. The value of α for asphalt has 0.05-0.20, and that of concrete has 0.10-0.35 [6]. Low α value surfaces absorb significant proportions of solar radiation and contribute to the worsening of the UH environment.

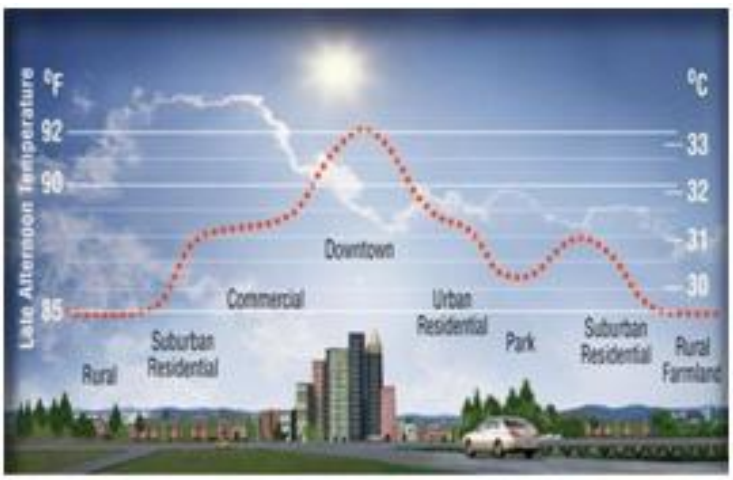

Figure 2. Ambient temperature variation due toUHI

The meager in vegetation surfaces inhibit the reduction of evapo-transpiration process, in which plants act as a heat sink. The formation of an urban canopy changes the wind pattern also and enhancing the total entropy in the city environment. The figure 1 and 2 are the pictorial representation of UHI.

2.2. Impact of UHI

Following are impact of UHI. i. Enhance energy consumption. Increased temperature in summer enhanced energy consumption to run cooling systems in the habitat places. It has been observed that enhancing 1^{O}F or 0.6^{O}C ambient temperature in the range of 25^{O}C, the cooling systems demand 5-10% more energy input. ii. Enhancement of green house gas (GHG)

Environmental Monitoring (ISSN Online: 2771-988X)
April 2022 Vol.1, No.1, pp. 1-7
DOI: https://doi.org/10.55571/em.2022.04001

composition density. In meeting the demand for more energy the fossil fuel based power plants consume more fossil fuel and enhanced GHG emission. iii. Poses danger to aquatic sys tems. Due to raise in ambient temperatures within the urban areas, temperatures over pavements and rooftops are also increases. At higher surface temperatures the heat wave enhanced water body temperature which possibly reduced dissolved O_2 concentration and welcome respiratory problem on the aquatic systems. It has been observed that pavements with temperatures of 38℃ can increase initial water temperature from about 21℃ to over 35℃ and reduced 5-10% reduced dissolved O_2 concentration [7]. iv. Discomfort and danger in human health. Higher air pollution, reduced nighttime cooling, and increased temperatures adversely affect human health. Human health is negatively impacted due to increase in general discomfort, exhaustion, heat-related mortality, respiratory problems, headaches, heat stroke and heat cramps. Exacerbated heat events or sudden temperature increases can result in higher mortality rates. Research by the Center for Disease Control and Prevention indicates that between 1997 and 2003 more than 8,000 premature deaths were registered in the USA owing to excessive heat [8]. v. Secondary impact on weather, climate & eco-systems.

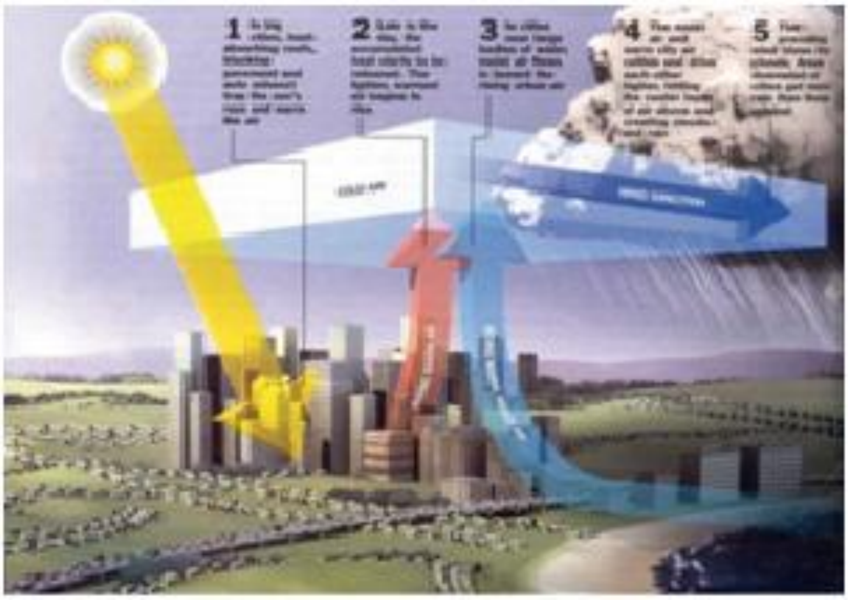

Figure 3. Possible impact of UHI on smog formation and increase rain at the city outskirt

Apart from enhancing ambient temperature, the UHI can bring forth secondary effects on the local weather and climate. This includes changes of local wind patterns, formation of fog and clouds, precipitation rates and humidity. The unusual heat caused by UHI contributes to a more intense upward wind movement that can stimulate thunderstorm and precipitation activity. The possible impact is presented in figure 3.

2.3. Mitigation of UHI

Researchers reported that possible ways and means for reduction of UHI are as follows: a. Use of appropriate materials and methods in reducing absorption of incoming solar radiation. The use of light-colored concrete and white roofs has been found to be effective in reflecting up to 50% more light and in cutting down the ambient temperature. Black and dull colors absorb copious amounts of solar heat resulting in warmer surfaces (Fig. 4). The use of light-colored concrete and white roofs can as well reduce the overall air conditioning demands. In addition to this rooftop integrated photovoltaic (RiPV) systems in conjunction with green roof surface can be a useful method in reduction of UHI (Fig. 5). b. Green roofs and vegetation cover. Green roofs present a great method in reducing the impacts of UHI. Green roofing is the practice of planting vegetations on a roof.

Figure 4. Impact of Solar INSOLATION onroofing materials

Figure. 5. Integration of green roof and RiPVsystem

Plants on the roof are excellent insulators during summer and decrease the overall UHI effect. Plants also cool the surrounding environments thereby reducing air conditioning demands. Furthermore, air quality is improved as the plants absorb CO_2 and produce fresh air.

2.4. Introduction greeneries in the cities.

The greeneries within and around cities provide an incredible way of reflecting solar radiation while at the same time decreasing the UHI effect. The trees provide shade, absorb CO_2, release O_2 and fresh air,and introduce cooling effect. d. Green parking lots.

Green parking spaces utilize green infrastructure strategies to limit the impacts of UHI effect. Impactof green roof in reducing the rooftop temperature is presented in figure 6.

Environmental Monitoring (ISSN Online: 2771-988X)
April 2022 Vol.1, No.1, pp. 1-7
DOI: https://doi.org/10.55571/em.2022.04001

Figure 6. Thermal mapping of rooftop withgreeneries & black coating

2.5. Implementation and sensitization of heat reduction policies and rules.

The state implementation of environmental policies such as Clean Air Act, Low carbon fuel standards, uses of renewable energy, and electrical vehicles can impressively regulated the anthropogenic inducers of UHI effect. Education and outreach activities can also help in bringing the awareness on economic and social benefits.

3. Results of Studies

It was mentioned that built-in- systems are the major players in contributing UHI effect. Thus, proper care require to be taken at the built-in-systems to reduce UHI and one of such care should be the introduction of PV power in the built-in-systems. The radiation balance over PV module is presented in figure 7 and PV module can act as the reflect surface to reduce UHI effect through balancing of long wave (LW) and short wave (SW) radiation by absorbing and emitting.

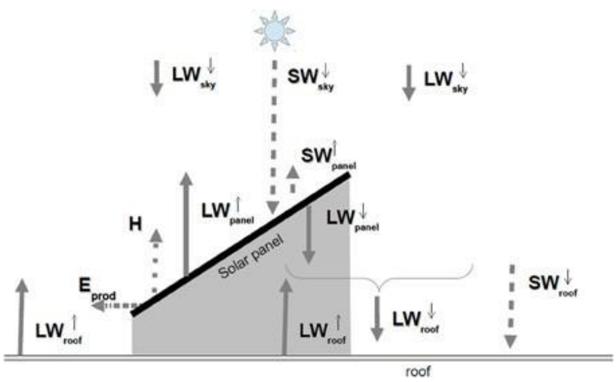

Figure 7. Radiation balance below PV module

The PV power in the built-in-systems can be introduced as a building component. The countries located in between the tropic of Cancer and Capricorn are rich in sunshine and at the same time they have the power shortage problem. Thus, power from PV has the possibility to emerge as meeting the peak load demand in these countries. The rooftop PV power has introduced in these countries normally in roof mounted PV (RmPV) mode, but roof integrated PV (RiPV) mode is more versatile than that of RmPV mode. Some detailed studies on this issue have been conducted in this region and result is presented in figure 8. The figure 8 is the experimental data on the variation of maximum roof temperature in comparison with ambient temperature, RmPV system and RiPV system. The result showed that minimum roof temperature is in case of

RiPV system. Apart from this RiPV systems have other advantages like i. introducing additional building space, ii. protecting the rooftop from external corrosion and erosion, iii. reducing the cooling load of the building and iv. generating additional power.

4. Concluding Remarks

From the studies in the previous sections it has been observed that UHI effect cannot be reduced to zero as it is an anthropogenic effect.

The UHI effect is predominating effect at the mega-cities but adoption of proper measures can reduce its effect. In reducing the heat gaining effect in the built-in systems results showed that introduction of RiPV system is one of the possible measure in this context. Thus, proper design of RiPV systems can reduce a substantial heat gain in the built-in system which ultimately reduce the UHI in mega cities and address sustainability.

Acknowledgements

The author is grateful to CSIR, Govt. of India, for providing support as ‘Emeritus Scientist’ to carry out the present studies.

Conflicts of Interest

The authors declare that there is no conflict of interest.

References

[1] UN Report on Sustainable Development https://unstats.un.org/sdgs/report/2019/The-Sustainable-Development-Goals-Report-2019.pdf
[2] Oke T. R. (1982), “The energetic basis of the urban heat island,” *Quarterly Journal of the Royal Meteorological Society*, 108 (455):1–24.
[3] Rizwan A. M., Dennis L. Y. C., and Liu C. (2008), “A review on the generation, determination and mitigation of Urban Heat Island,” *Journal of Environmental Sciences*, 20(1):120-128.
[4] Hirano Y, Kaya Y. (1998),“The effects of urban heat-island phenomenon on residential and commercial energy consumptions”, *Environ SystRes*,26:527–532
[5] Newman, P.Kenworthy, J. (1999) “*Sustainability and Cities: Overcoming Automobile Dependence”*,Island Press: Washington, DC, USA.
[6] Arnfield, A. J. (2003), “Two decades of urban climate research: a review of turbulence, exchanges of energy and water, and the urban heat island” *International journal of climatology*, 23(1):1-26.
[7] Breheny M. (1992), *Sustainable Development and Urban Form*, Pion Limited, London, UK, 1992.
[8] MacFarlane A, Waller RE. (1976), “Short term increases in mortality during heat waves”. *Nature*, 264: 434-6.