ABSTRACT

‘Development’ and ‘Climate change’ are inextricably linked. With the onset of urbanization, there is a rampant replacement of the natural green-cover by the urban materials like concrete, asphalt, etc. which have significantly altered the surface energy budget and have fostered the growth of ‘Urban Heat Islands’ (UHIs). UHIs are defined as metropolitan areas which are significantly warmer than their surroundings and are associated with high energy consumption and high air pollution having adverse impact on the human health and economy. The present research work attempts to holistically juxtapose the process of urbanization and micro-climatic changes over megacity Delhi and brings out its impact on building energy consumption along with various building envelope modifications for mitigating the UHI effect.

The Land Use / Land Cover (LU/LC) study done using the IRS LISS-III satellite data for the years 1997, 2000, 2004 and 2008 revealed that Delhi experienced substantial changes particularly in the built-up category which witnessed an overall increment of 17% of the total area i.e. from 540.5 sq km to 791.6 sq km during 1997-2008. Alarmingly, the study forecasts that, by 2021, the share of the built-up area would further increase from the present 53% to around 68%. The temperature trend analysis done for the Land Surface Temperature (LST) and Surface Air Temperature (SAT) revealed that the minimum temperatures have increased significantly while the maximum temperatures have either decreased or remained constant. Consequently a significant decrease in the Diurnal Temperature Range (DTR), which is a typical characteristic of the urbanization process, was categorically observed. Based on the inferences drawn from the LU/LC changes and the overall warming trend, the task of micro-mapping the UHIs of megacity Delhi was undertaken using remote sensing data and the extensive field campaign. The study infers that the maximum UHI intensity in Delhi was around 8.3°C and locations like Sitaram Bazar, Connaught Place, Bhikaji Cama and few others were identified as the major UHIs. Moreover, it was observed that the high UHI intensity zones almost remain unchanged but new zones of moderate UHI intensity appeared. At a broader level, South-West and North-West Delhi, which registered highest and second highest decadal population growth rate and major LU/LC transformations to built-up areas, witnessed major shifts i.e. the UHI intensities increased in the nighttime and decreased in the daytime. Interestingly, the shift pattern of the UHI intensity in case of North-East and Eastern Delhi, which are the two most populous
zones of Delhi registering high population growth rate, was different from that of the South-West and North-West Delhi. In these zones, both the nighttime and daytime UHI intensities increased signifying the role of anthropogenic heat emissions in the heat island intensity pattern.

Linking the changing meteorological conditions viz.-a-viz. the UHI effect with the building energy consumption especially for the space-cooling, the study revealed that altered meteorological conditions have significantly increased the power consumption viz. at IIT Delhi, the changing meteorological conditions during 2008-2009 increased the annual power consumption for space cooling by 16.6% and subsequently the total power consumption increased by 7.67%; at Palam airport, the changing meteorological conditions during 2007-2011 increase the annual power consumption for space cooling by 41.6% while the total power consumption increased by 25.5%. Further, for similar thermal comfort conditions, in comparison to medium dense forest like Sanjay Van densely built-up canopies like Sitaram Bazar exhibit enhanced demand of power to a tune of 44%.

The potential of various building envelope modifications for reducing the power consumption for space-cooling thereby mitigating the UHI effect, was investigated using building energy simulation. Specifically focussing on the walls, the study relooked to simple mitigation measures like ‘increasing the thickness’ of the wall and constructing a ‘cavity wall’ on one hand while also described the potential of earthen materials like ‘Rammed earth’ and natural materials like ‘Bamboo-concrete composite’ named as ‘bamcrete’. Considering ‘brick’ as a wall material, the comparative analysis reveals that cavity wall offers the highest reduction in the power consumption for space cooling. The thermal performance of Rammed earth was quite encouraging however looking to the high minimum thickness (300 mm) required for construction, its applicability might be restricted to areas where land availability is not critical. ‘Bamcrete wall panels’ have high potential for mitigating the UHI effect as the reduction in the power consumption for space-cooling by 6 inch (152.4 mm) bamcrete wall panel was very near to that of a 12 inch (304.8 mm) rammed earth wall. The study reconfirms the strong potential of the whitening of the roof and more specifically the installation of a roof-top garden in reducing the power consumption for space cooling of the top-storey.