Minimizing Urban Heat Island Effect and Imperviousness Factor in Bangalore

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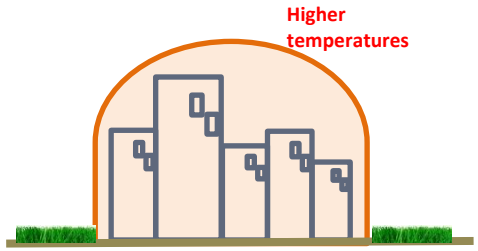
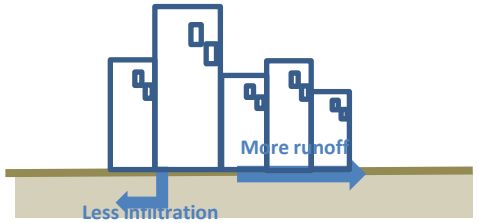
Introduction

Growth of Cities → Increase in built-up areas → Rise in temperatures compared to surrounding rural areas (UHI)

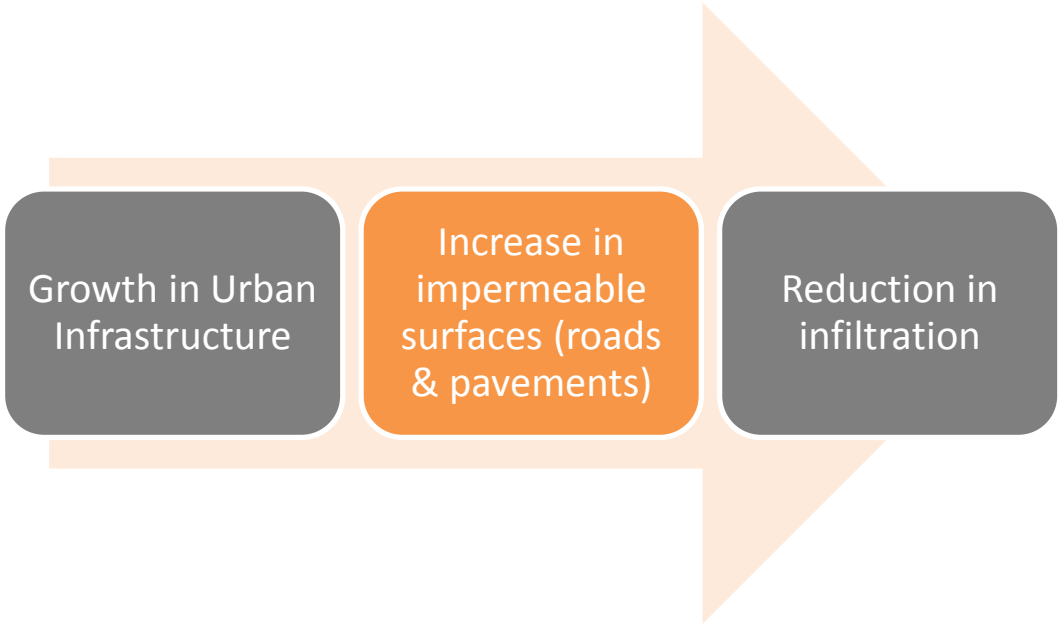


- **UHI results in**
  - **Thermal discomfort (both indoor and outdoor) and increased energy consumption in air conditioned buildings.**
  - **Increased rainfall intensities over the urban areas**

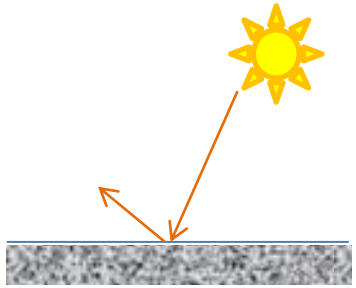


- **It is estimated that about three billion people living in the urban areas in the world grieve by this problem (Rizwan A M et al, 2007)**

Introduction



Green Roofs



Reflective Roofs

- **The two important strategies to mitigate this problem are**
  - **Reflective roofs**
  - **vegetated roofs**

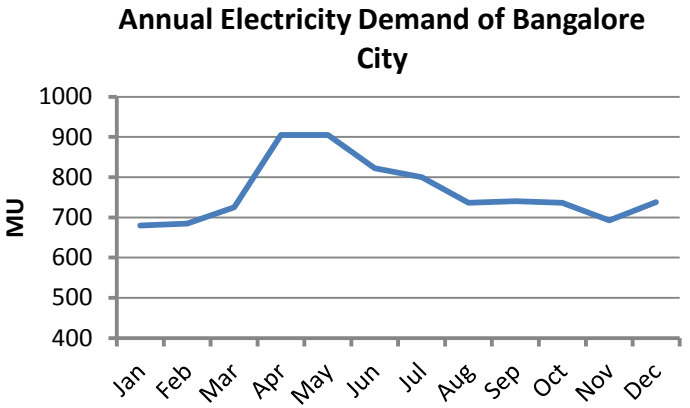
Need to UHI Mitigation

- **The UHI issue is very prominent in many of the developing tropical cities of South Asia where the ambient air temperatures and solar radiation intensities are normally high.**

- **It is estimated that 3 to 8 % higher electricity demand in cities with populations greater than 1, 00,000 is used to confront the heat due to heat island effect (Green in Practice 103- cool communities, 2012).**

- **Most of the cities in South Asia face deficit in energy supply as the gap between demand and supply go up during summers.**

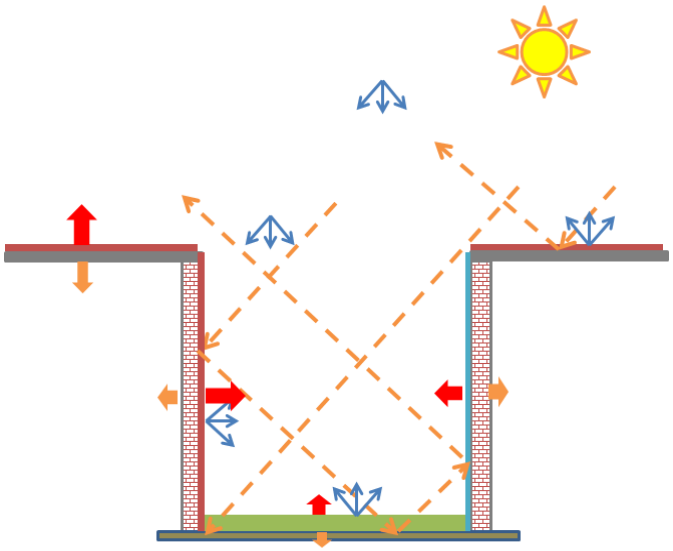
- **Currently, the Energy/ sustainability codes in India recommends about cool roofs at building level to reduce the UHI and thus help in reducing electricity demand at city level**



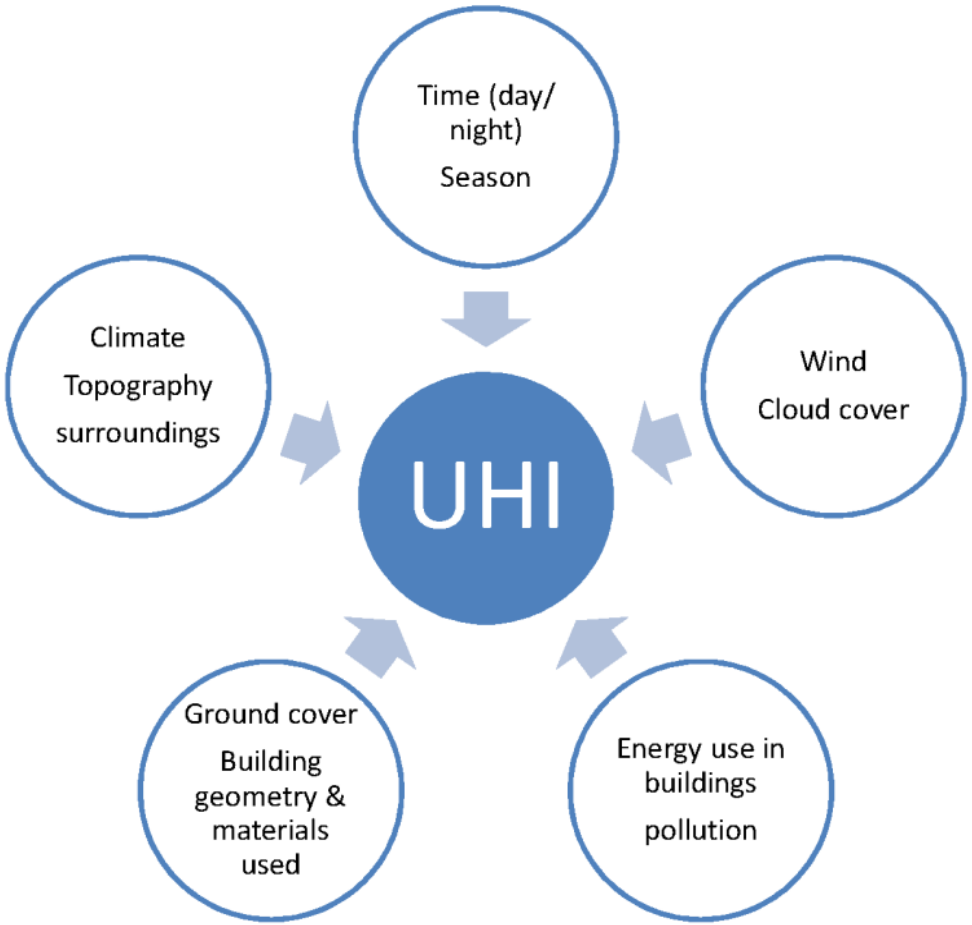
Technical Aspects of UHI

- **Solar energy falls on a surface**
  - **Gets reflected(Reflectivity)**
  - **Absorbed**
  - **Re Radiated (emissivity)**

- **Indicators**
  - **Air temperature (result of solar radiation absorbed by the absorbed by the atmosphere and the heat emitted by different surfaces)**
  - **Surface temperatures (result of solar radiation and solar reflectance of the surfaces)**



Causes of Urban Heat Island Effect

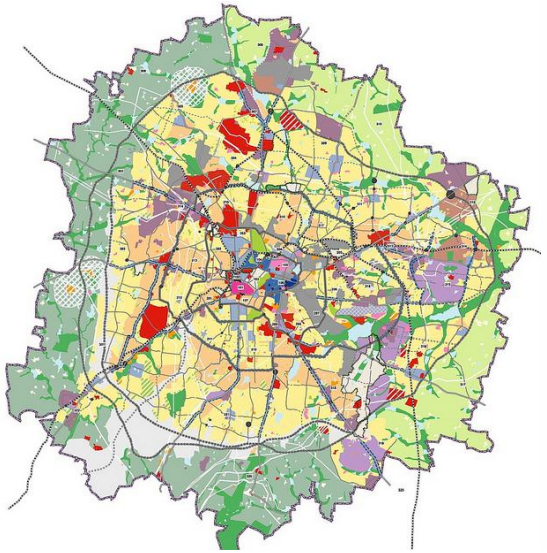


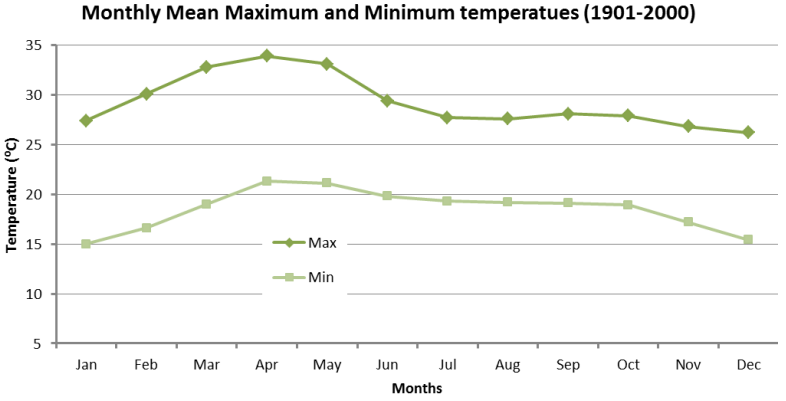
Summary of UHI studies in Asian cities

Studied City	Method	Difference in temperature found in the city	Observations/ UHI Influencing factors
New Delhi	Thermal mapping of surface temperatures using MODIS data for 3 years	7˚C in the night time	Aerosol depth/ distribution, Presence of water bodies and rivers
Chennai	Mobile survey- air temperatures	2.48 ˚C in summer and 3.35 ˚C in winter	Density of builtup areas, presence of water bodies, thermal properties of materials and anthropogenic heat
Bangalore	LST maps using satellite data for a few decades	2.5 ˚C	Parks, lakes, vegetation
Pune	Mobile measurements (DBT and WBT)	2˚C	Heat island accompanied by moisture island, Topography, Katabatic winds
Colombo	LANDSAT satellite data for surface temperatures	Max 18˚C*	Population, floor area density, forest cover
Cochin	Filed measurements- Air temperatures	Average 2.4K during Winter	High water cover
Hong Kong	Fixed station	1.5^{0}C (during night)	Surface albedo, Sky view factor
Kaulalampur	Fixed station	6.5^{0}C	Building mass, green spaces
Singapore	Fixed stations	3^{0}C	Building mass, green spaces
Tokyo	Mobile measurements	8.1^{0}C (during night)	Wind movement
Seoul	Surface temperatures (fixed station)	Max 7^{0}C	Stronger on week days than week ends

About Bangalore

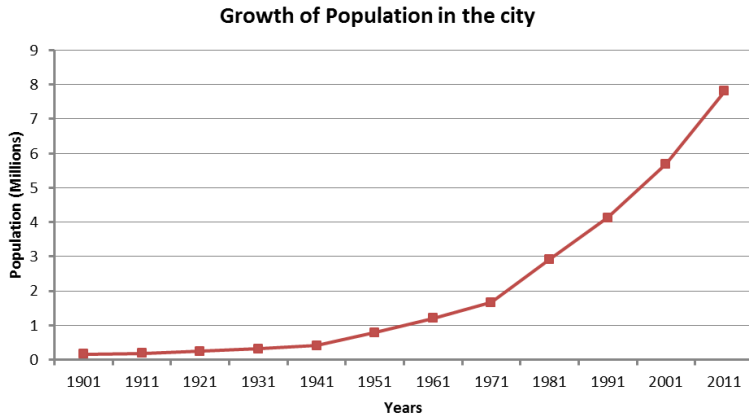
- **Known as " Garden City" for its gardens, parks and lakes**
- **Plateau with red fine loamy and clayey soils**
- **Land use**
  - **60% buildings**
  - **14% Parks & Open Spaces**
  - **21% transportation**
  - **5% unclassified**
- **Temperate climate with 38^{0}C yearly Max & 12^{0}C yearly min**
- **Maximum global radiation exceeds 1000 W/Sqm**





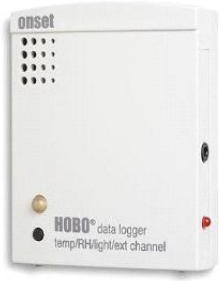
About Bangalore

- One of the fastest growing metropolitan cities in India- About 60% population growth during last two decades
- 632% growth in urban builtup areas over last four decades
- Shift in peoples life style and rapid growth in vehicle usage led to increase in energy demand
- 30% of cities energy consumption is shared by the commercial building sector includes corporate offices, IT parks, multiplexes and shopping malls



Site Selection

Fixing Instruments



Thermo-hygro data logger

IR- Thermometer

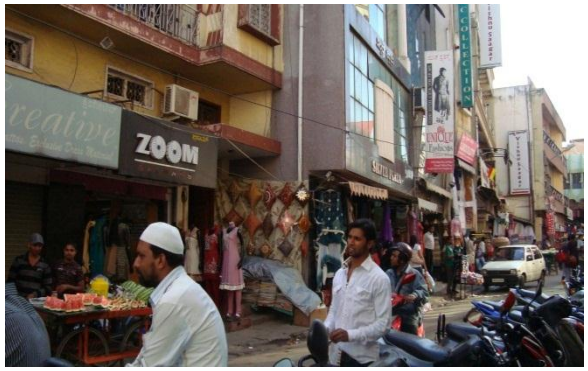
Heat Stress Meter

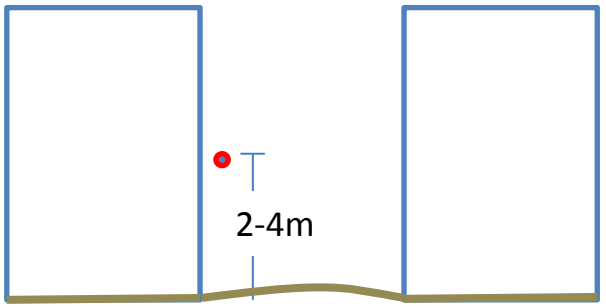
IR- Thermal Camera

Site 1: Commercial Street

- **Roof area :86%**
- **Road Area :13%**
- **Green Area/ open Area :1%**

- **City Centre**
- **Densely urban area**
- **No vegetation and open areas**

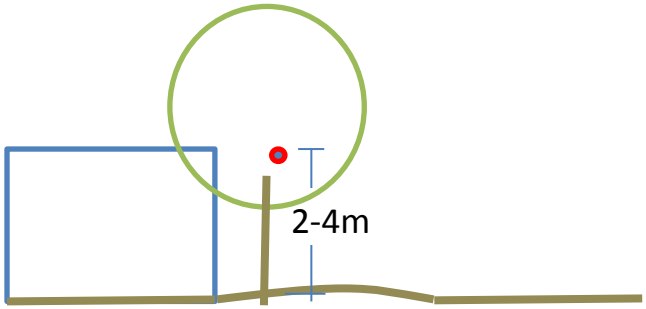


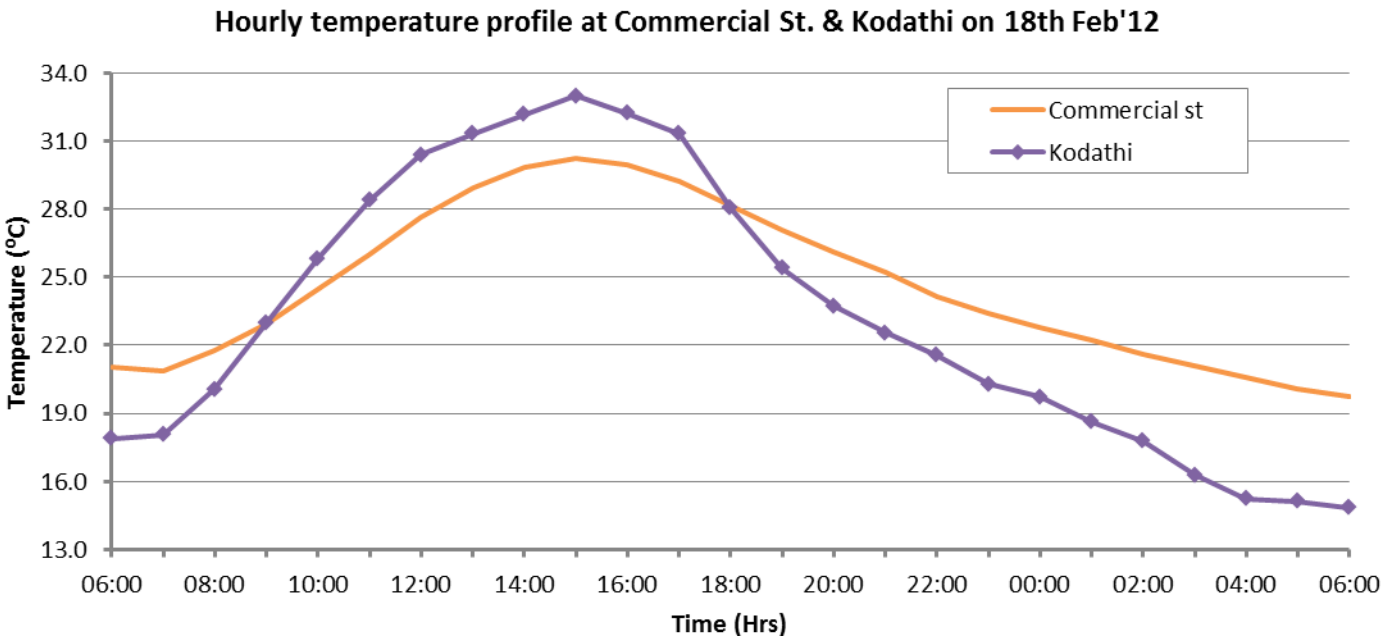


Site 2: Kodathi

- **Roof area :4.6%**
- **Road Area :7.1%**
- **Green Area/ open Area :88.3%**

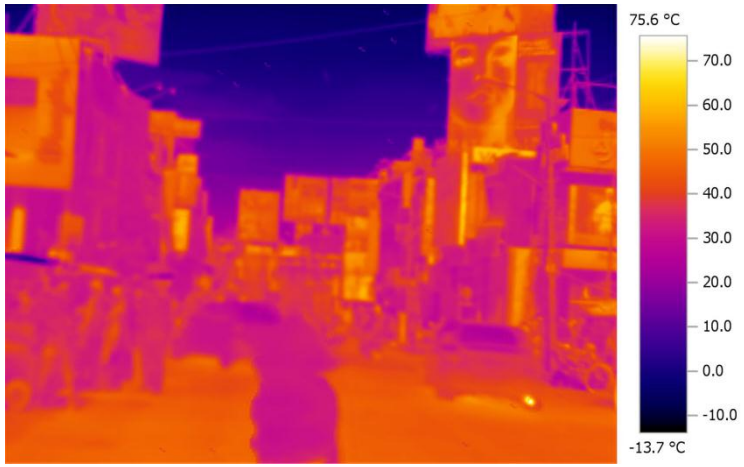
- **Suburban/ Rural**
- **Open fields/ farm lands**
- **Less built-up**





Daily mean air temperatures recorded at Commercial street and Kodathi

		Day1	Day2	Day3	Day4	Day5	Day6	Day7
Mean Air Temperature	Kodathi	24.8	23.5	23.6	24.5	24.8	23.8	23.3
	Commercial St.	25.6	24.7	25.1	26	26.3	25.6	25.3
Difference		0.8	1.2	1.5	1.5	1.5	1.8	2



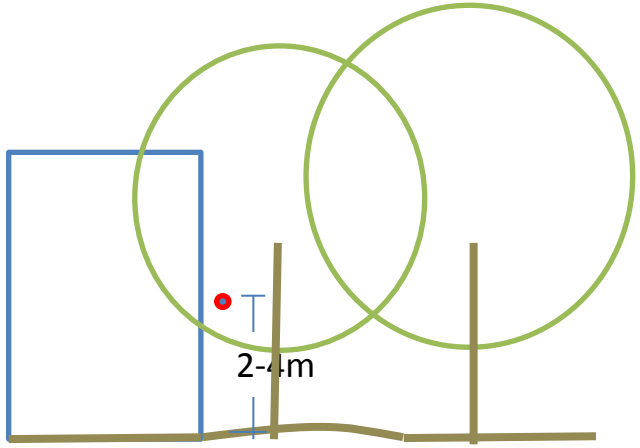
Radiant Temperature 39.7°C

Radiant Temperature 36.8°C

Site 3: IISc

- **Roof area :22.7%**
- **Road Area :0%**
- **Green Area/ open Area : 77.3%**

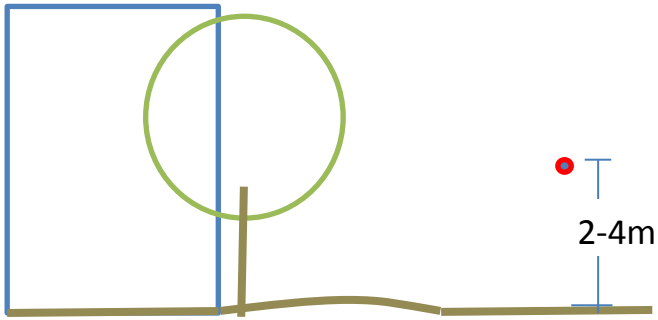
- **Urban area**
- **Highly vegetated area with all matured trees**
- **Less Built up**

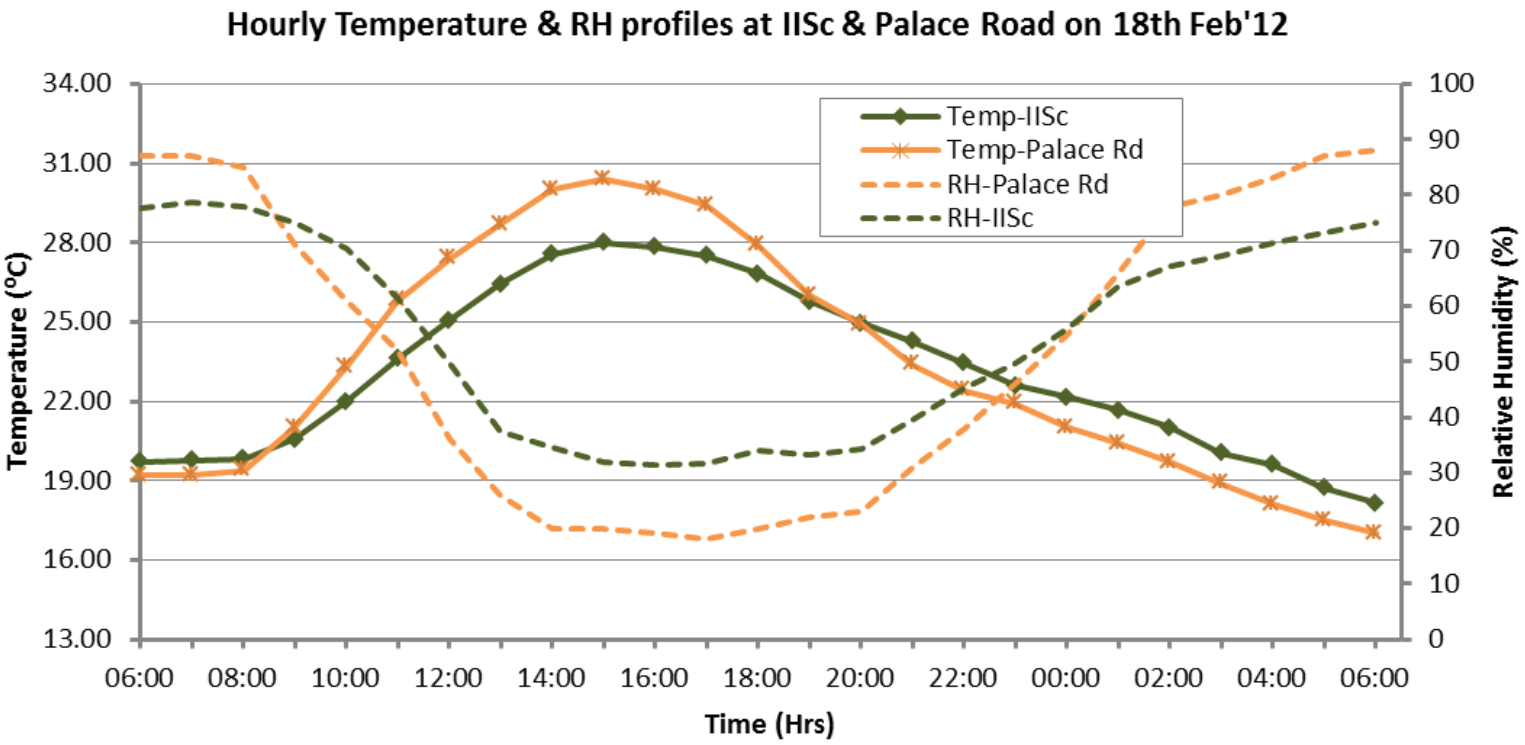


Site 4: Palace Road

- **Roof area :21.8%**
- **Road Area :15.2%**
- **Green Area/ open Area :63%**

- **Urban area**
- **Moderately developed**
- **Large open areas with less matured trees**





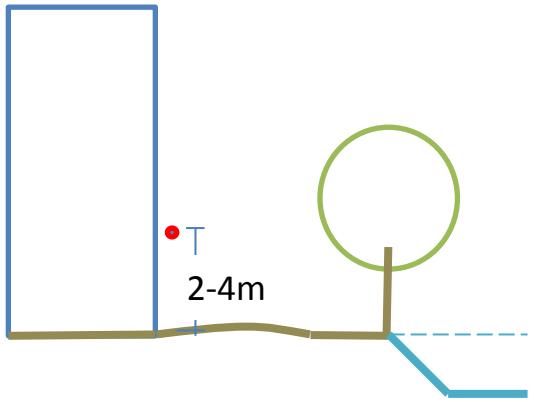
- **The maximum day time temperature recorded at highly vegetated IISc is 2.4degC lower compared to less vegetated Palace Road**

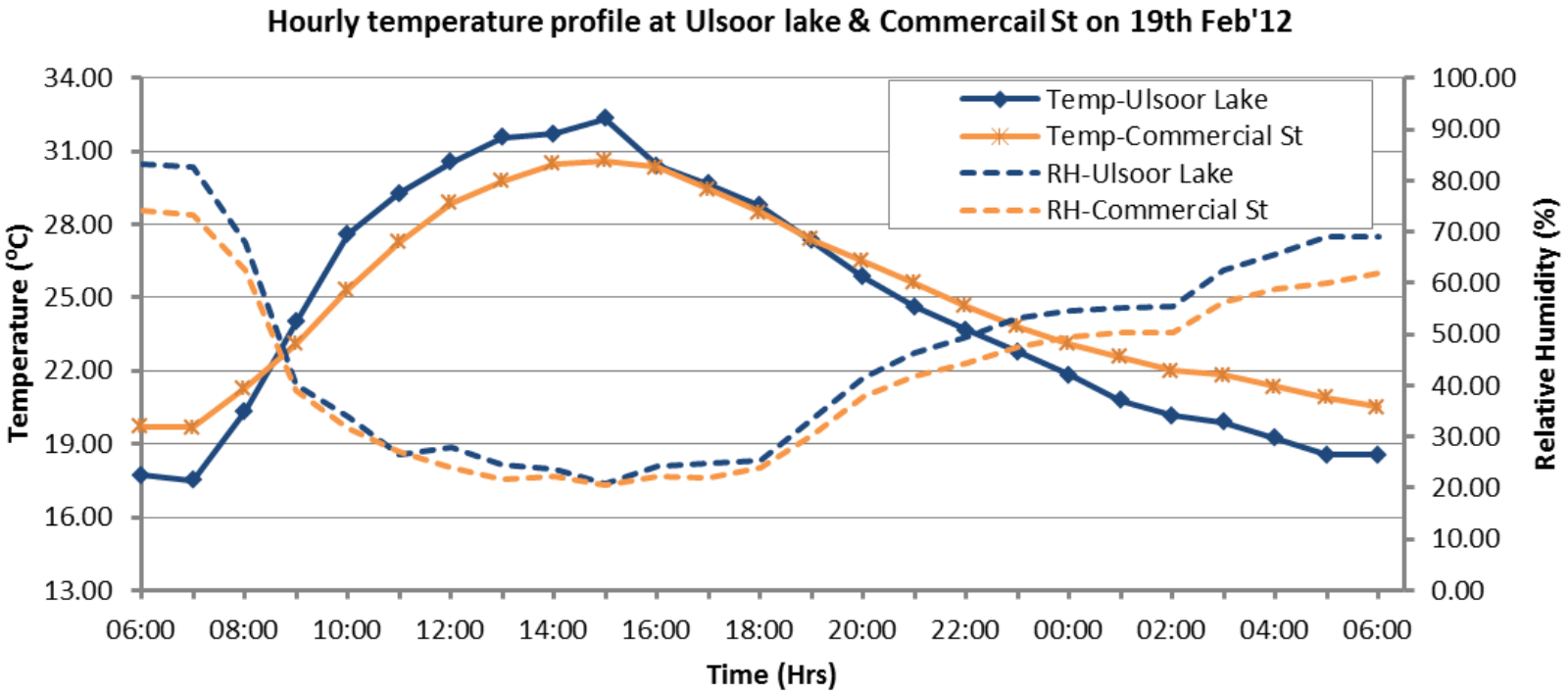
- **Night temperatures recorded at IISc are 1.5degC higher than palace road**

Site 5: Ulsoor Lake

- **Roof area :32.5%**
- **Road Area :15.8%**
- **Water body Area :34.1%**
- **Green Area/ open Area :17.6%**

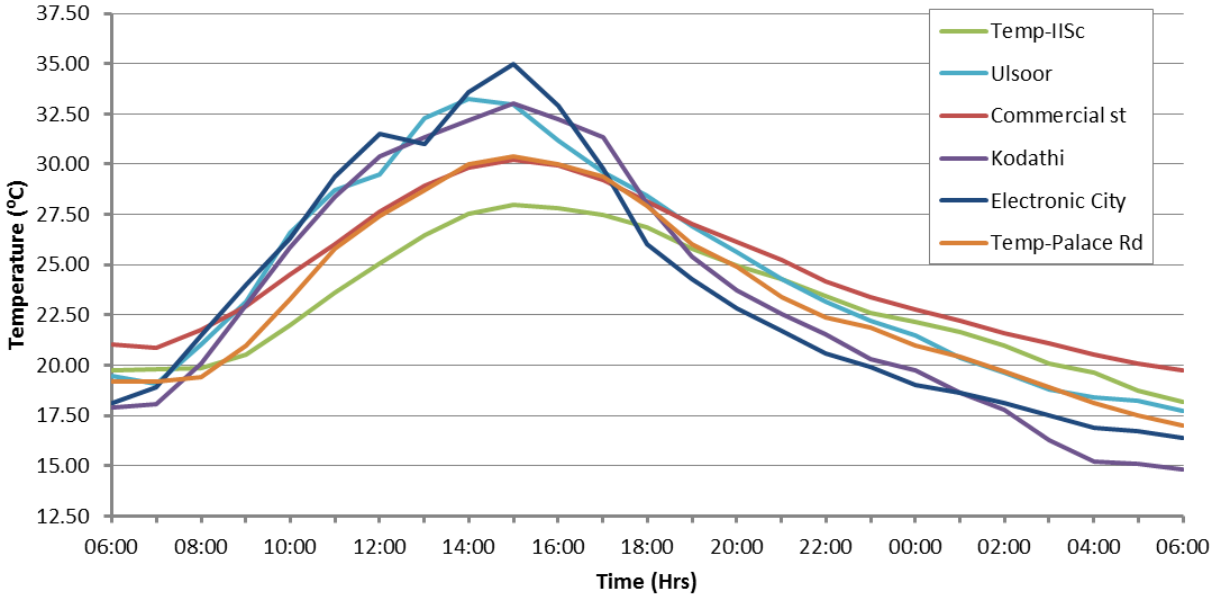
- Urban area/ city center
- Development around a water body
- Less open area and medium vegetation

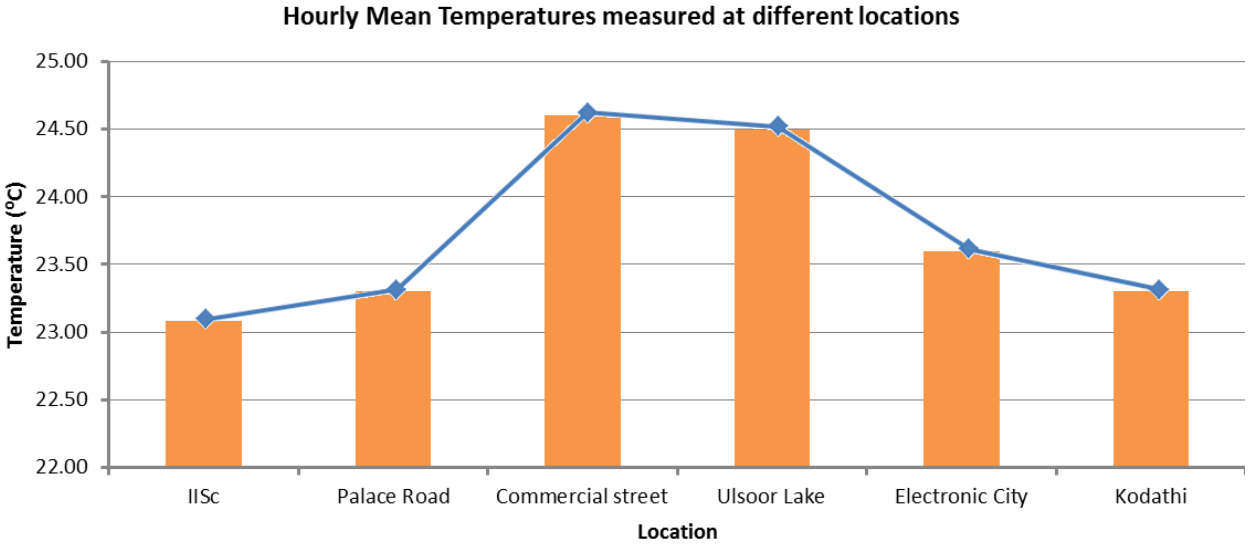




- **Almost 4 degC lower air temperatures observed at Ulsoor lake during night**

- **Higher relative humidity & lower temperatures makes the locations cooler compared to other areas**


37.50
35.00
32.50
30.00
27.50
25.00
22.50
20.00
17.50
15.00
12.50
Temperature (ºC)
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
02:00
04:00
06:00
Time (Hrs)
Temp-IISc
Ulsoor
Commercial st
Kodathi
Electronic City
Temp-Palace Rd


Hourly Mean Temperatures measured at different locations
25.00
24.50
24.00
23.50
23.00
22.50
22.00
Temperature (ºC)
IISc
Palace Road
Commercial street
Ulsoor Lake
Electronic City
Kodathi
Location

Observations

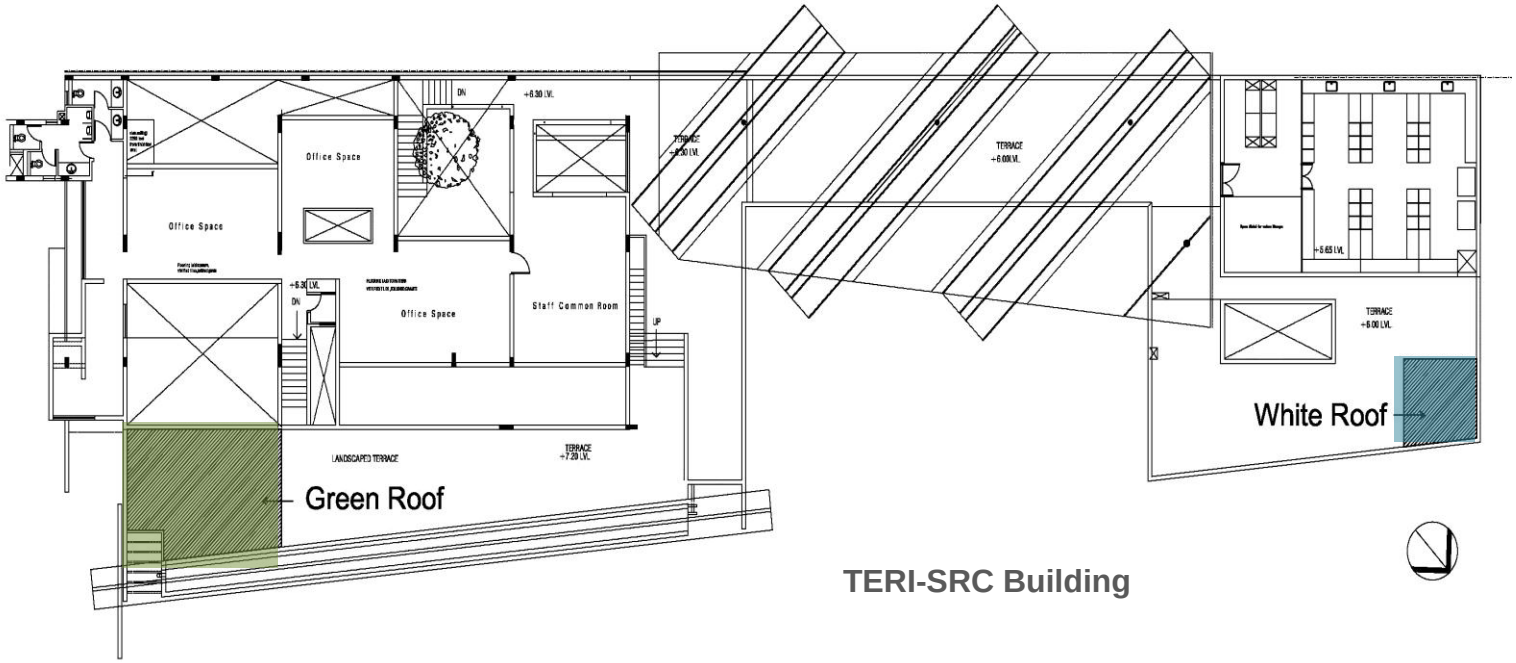
- **It is evident that though the air temperatures during daytime are lower due to less solar exposure, night temperatures increase drastically in densely developed Commercial Street.**

- **About 0.8 to 2 deg C higher mean air temperature was observed during the measured period that confirms the presence of urban heat island.**

- **Higher night temperatures (about 1.5 deg C) observed at IISc site where all matured trees are present. It is thus suggested that the small leaf trees are more effective compared to big leaf trees in this aspect.**

- **Water body located near to the city centre has a significant impact on the surrounding micro climate due to lower air temperature and higher relative humidity in the night.**

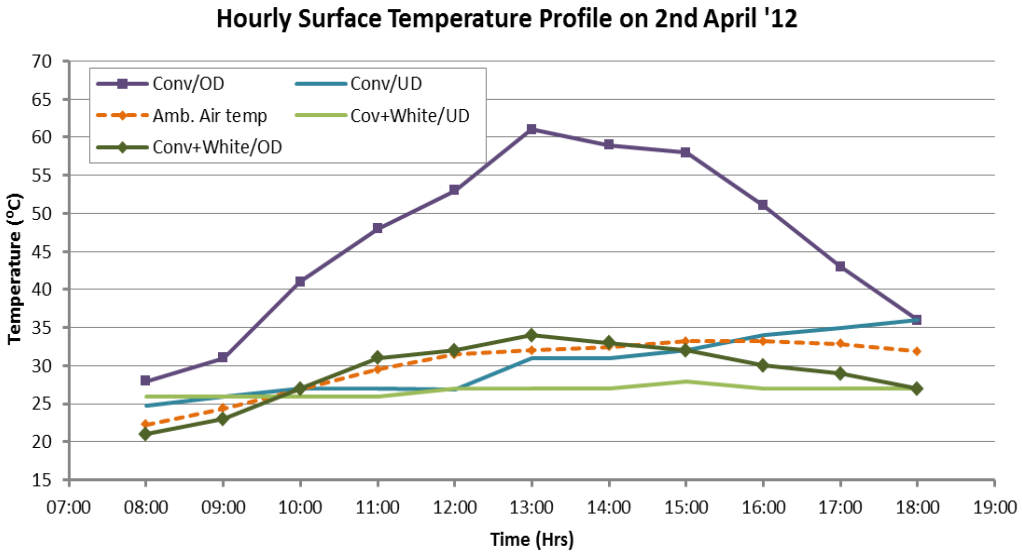
Studies on Mitigation Options



TERI-SRC Building

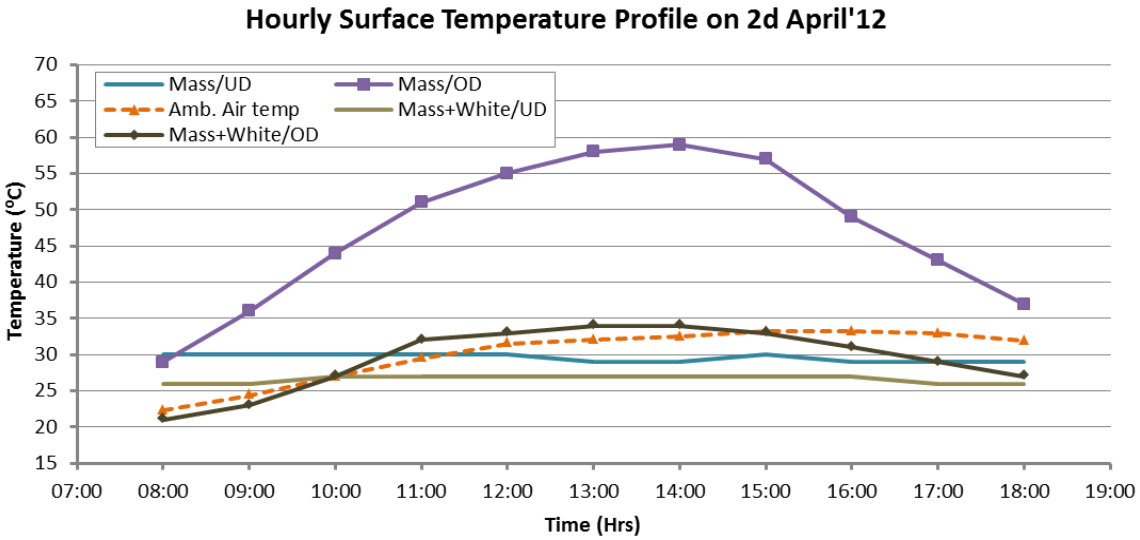
- **Hourly Air and surface temperatures monitoring**
  - **Over and under deck**
  - **Ambient & Indoor Temperatures**

Conventional RCC roof versus White roof



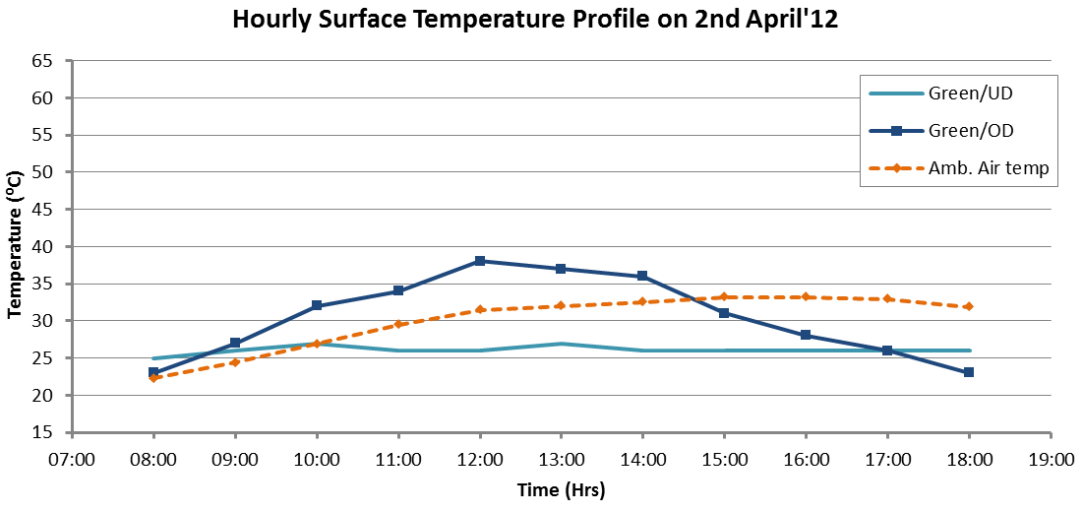
- **Maximum surface temperature over deck reduced to 34^{0}C from 61^{0}C; under deck temperature remains at 27 to 28^{0}C throughout the day**
- **77% less heat flux at peak time with white roof**

Mass RCC roof with white coat

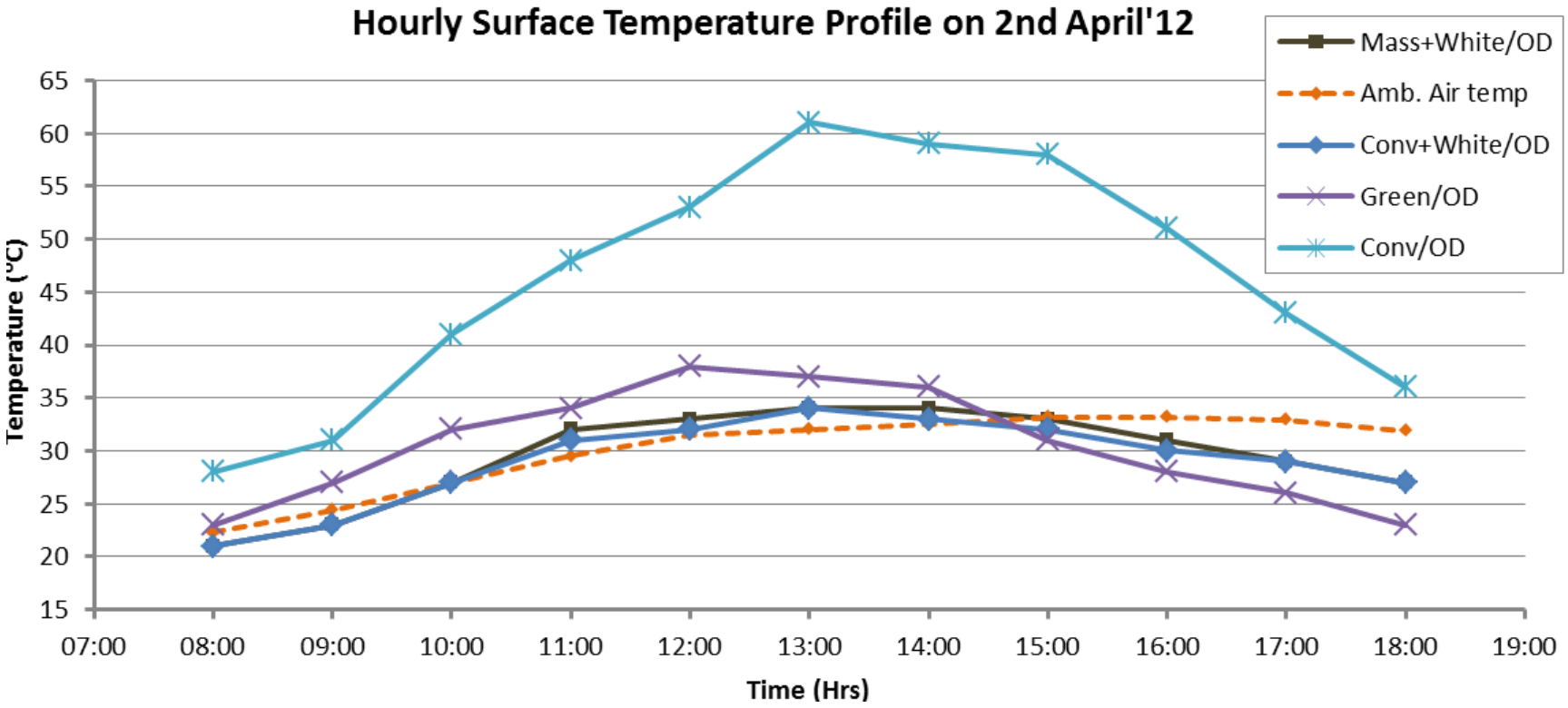


- **3 degC difference in underdeck surface temperature throughout the day**
- **Constant under deck surface temperatures throughout the day**

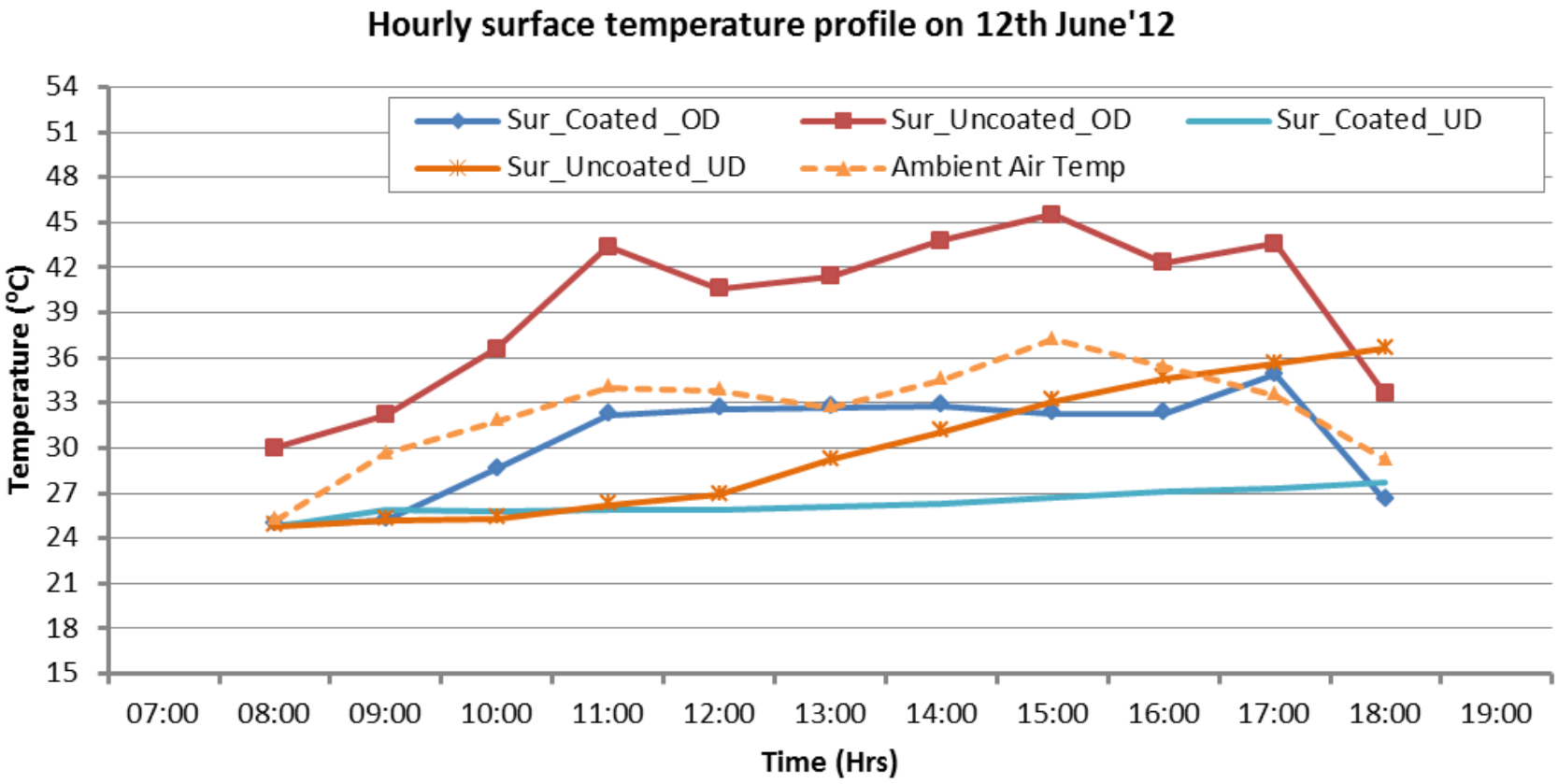
Green Roof



- **Overdeck surface temperature goes down below air temperature after watering grass in the evening**
- **Under deck surface temperature is constant at 26^0C throughout the day**


Hourly Surface Temperature Profile on 2nd April'12
Temperature (°C)
65
60
55
50
45
40
35
30
25
20
15
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
Time (Hrs)
Mass+White/OD
Amb. Air temp
Conv+White/OD
Green/OD
Conv/OD

Glossy finish white roof for easy maintenance



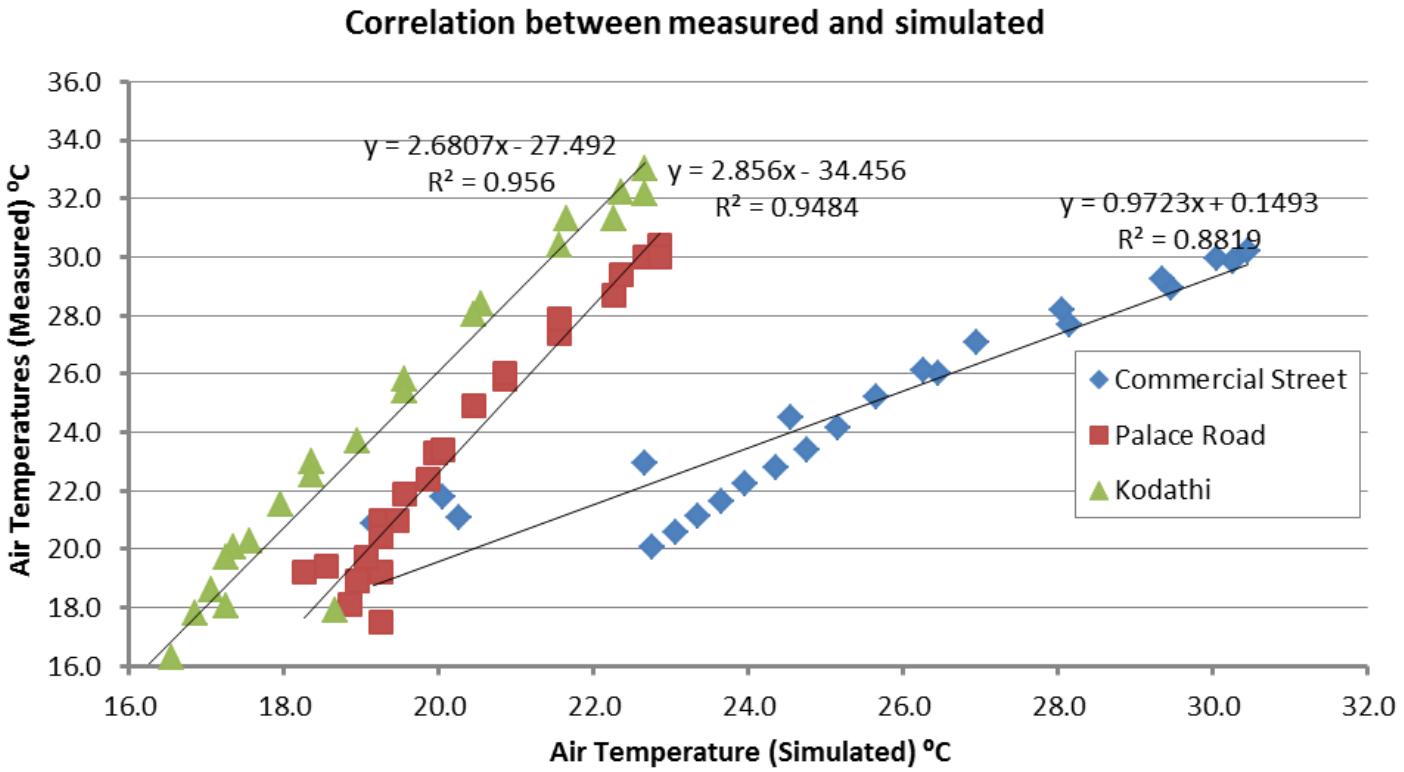
Observations

- **It is understood that the amount of heat flux in case of high reflective RCC roof is almost 77% less compare to the compare to uncoated RCC roof during the peak time.**

- **It is also observed that there is about 1.3degC notable drop in mean room temperatures when the conventional mass RCC roof painted with insulation white paint over the surface.**

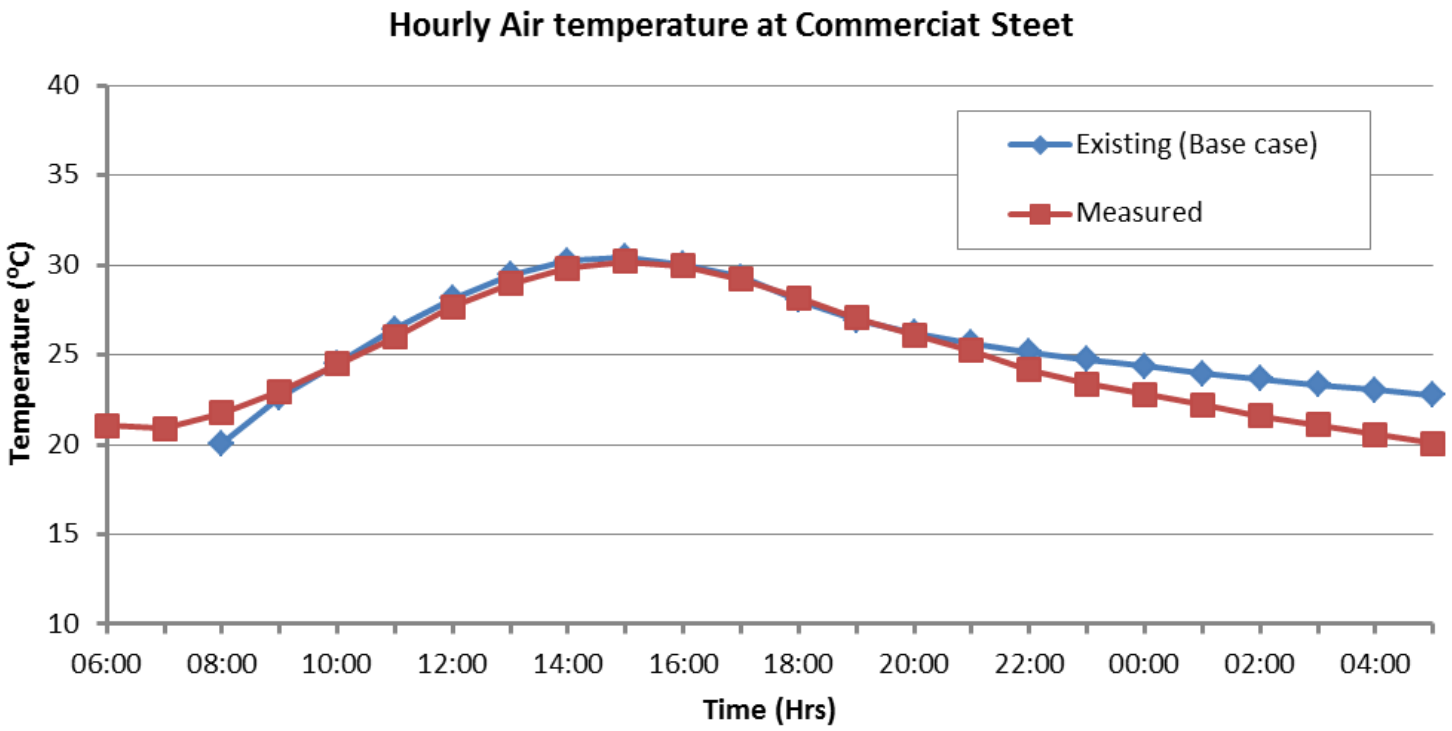
- **The application of maintenance free reflective white coatings which have insulation property due to the nano particles is highlighted in this study. These coatings don’t lose their performance when cleaned periodically.**

Validation of ENVI-met model



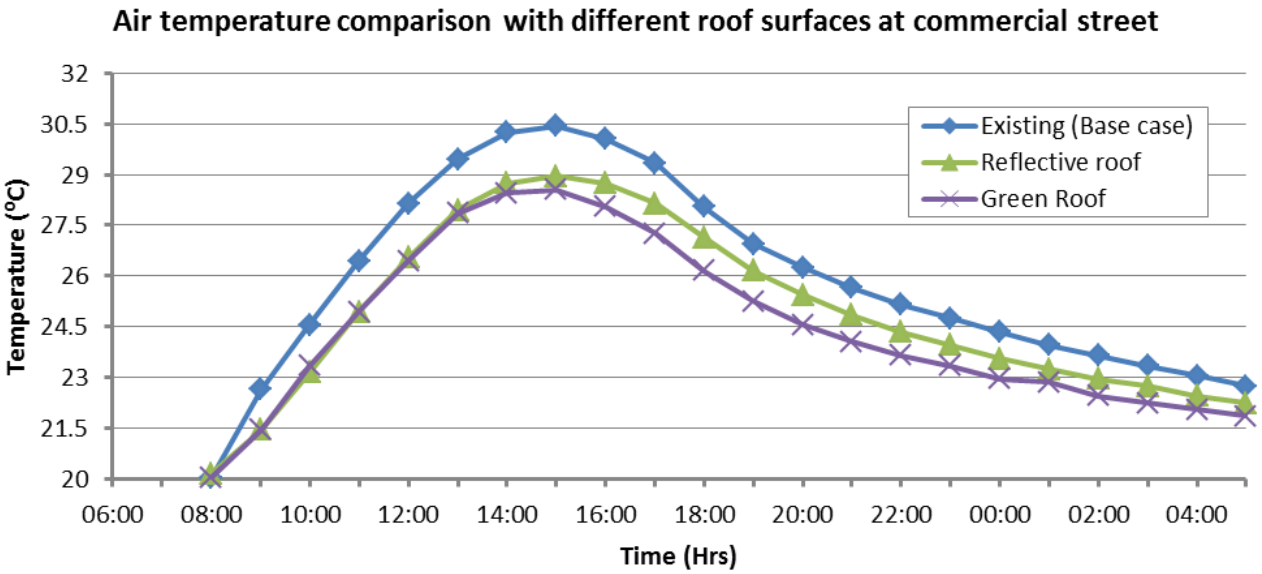
- **Good correlation and hence Validated**

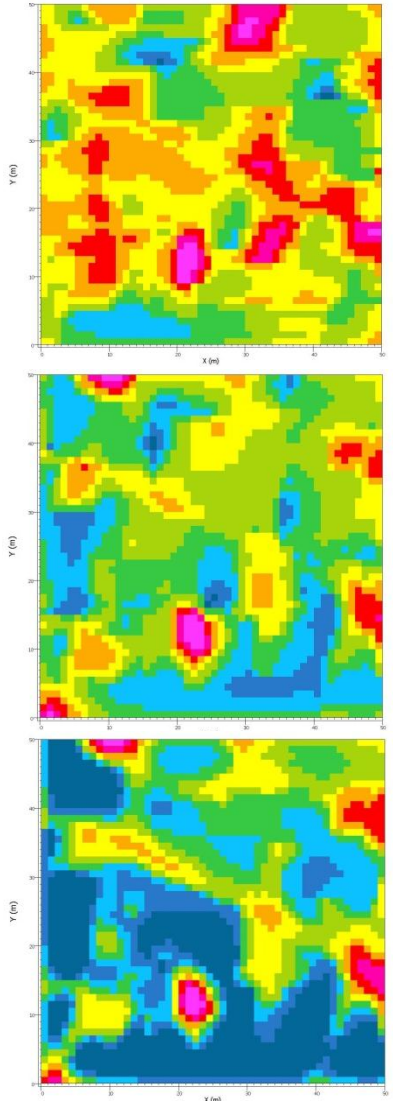
Calibration of ENVI-met model



- **Error factor +0.6°C between measured and simulated on daily average temperature**
- **Used this calibrated model for parametric runs**

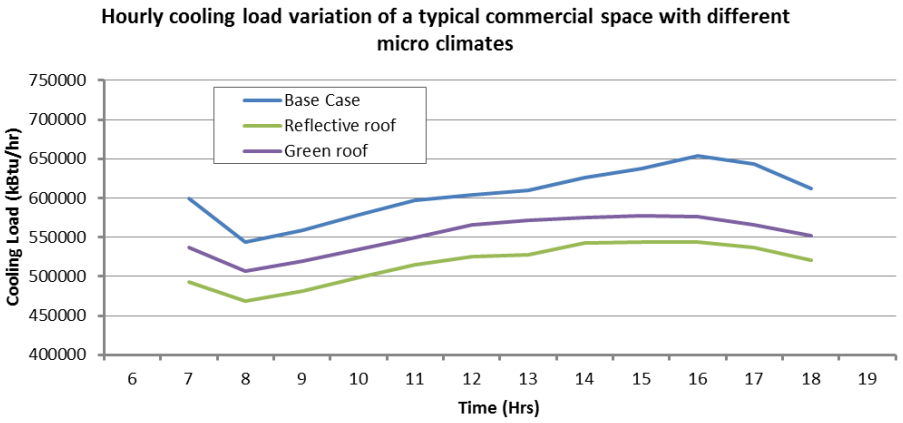
Parametric runs for UHI Mitigation measures

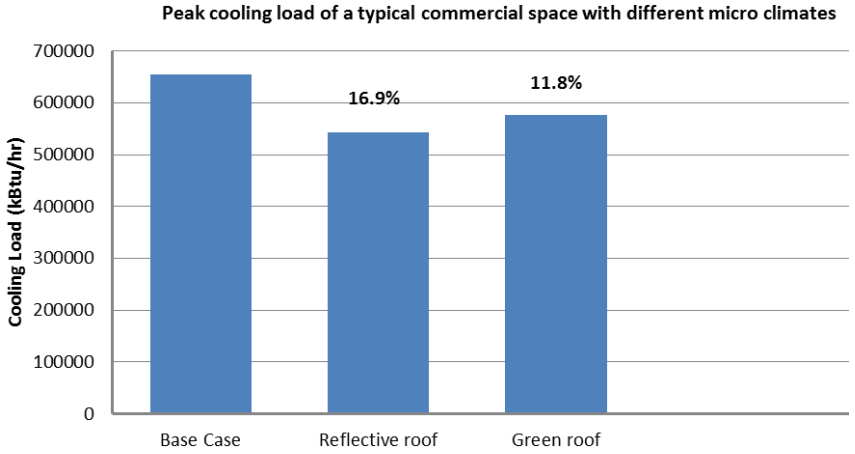




- **Reduction in peak air temperature**
  - **1.5^{0}C incase of Reflective roof**
  - **1.9^{0}C incase of Green roofs**

Cooling load reduction due to improved micro climate



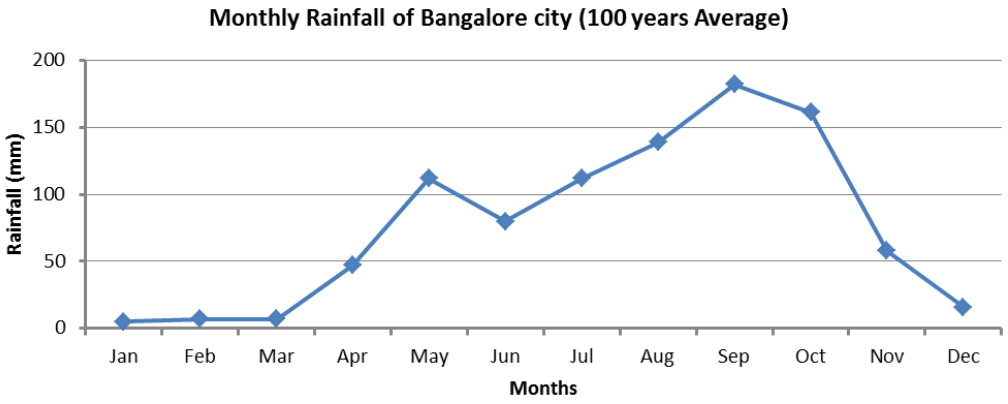


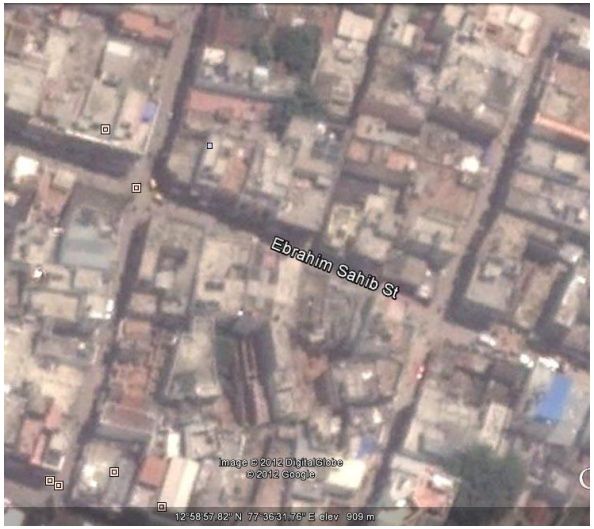
	Base Case	Reflective Roof	Green roof
Building Type	Commercial Office	Commercial Office	Commercial Office
Zone Area	40000Sft	40000Sft	40000Sft
Height	3 m	3 m	3 m
Lighting power density	1.4 W /ft^2	1.4 W /ft^2	1.4 W /ft^2
Equipment power density	0.75 W /ft^2	0.75 W /ft^2	0.75 W /ft^2
Occupants	275 ft^2 / person	275 ft^2 / person	275 ft^2 / person
Occupancy Schedule	8 hours, 5 days a week	8 hours, 5 days a week	8 hours, 5 days a week
External wall	Uninsulated 230mm Brick Wall	Uninsulated 230mm Brick Wall	Uninsulated 230mm Brick Wall
External Roof	Uninsulated 150mm RCC Roof	Uninsulated 150mm RCC Roof with reflective coat (albedo 0.9)	Green Roof with U- value 0.23W/m2
Glazing Specification	6mm clear glass	6mm clear glass	6mm clear glass

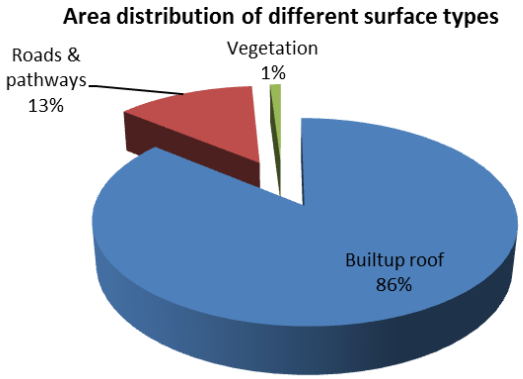
Observations

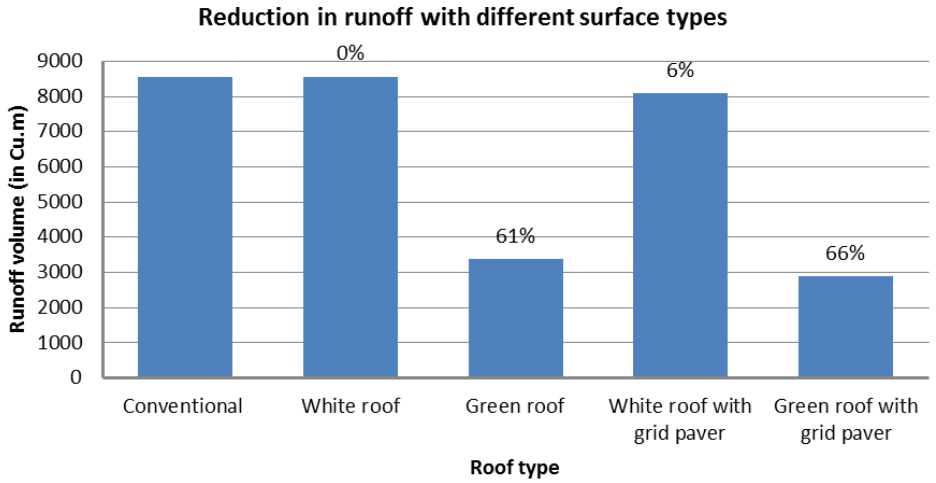
- **There is a good correlation (R^2= 0.96, 0.95, 0.89) found between measured and simulated data.**
- **It is observed that about 1.5^{0}C , 1.9^{0}C reduction in daily maximum temperature possible with reflective and green roofs respectively.**
- **The peak cooling load is reduced by 16.9 % and 11.8 % incase with the improved climates due to reflective and green roofs.**

Increasing infiltration with various surface types

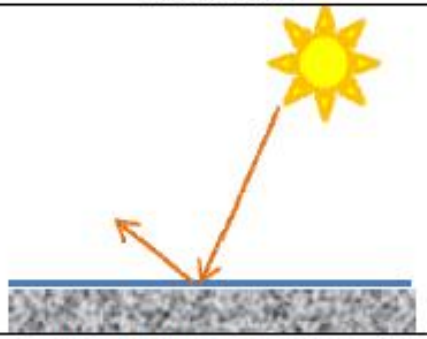
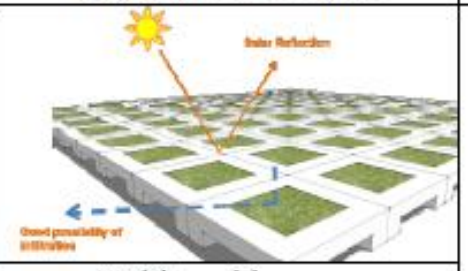








Conclusions

	Roof type	Reduction in Cooling load	Reduction in storm water runoff
1.	 Green roof	11.8%	61%
2.	 Reflective white roof	16.9%	0%
3.	 White grid paver	-	66%

Conclusions

- **Narrow streets with respect to lower solar exposure is important in case of pedestrian movement. Hence, roof is the more critical area to change its surface type and reducing the air temperatures**
- **Higher temperatures during winter nights might be helpful in providing human thermal comfort and hence reducing the energy costs.**
- **Using maintenance free insulation reflective coatings are helpful to reduce the maintenance and operational energy costs.**
- **Infiltration increases and thus significant rise in ground water table by use of grid pavers**

THANK YOU

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