Climate Resilience in Building Design and Urban Heat Island Effect

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Introduction

- One of the primary purposes of man's shelter is protection against adverse climatic environments, but each building changes the climate not only inside but outside its walls ; when buildings are congregated the result is a degree of modification, which cannot be reversed in anyway unless positive climatic input is used.
- Increases in world population and the proportion of peoples living in cities introduce many problems to the socio-economic organizations and stabilities of many parts of our planet.
- The accelerated rate of growth of our cities in all parts of the world must be purposefully planned if we are to avoid a mass of structural and functional design failures.
- Climate is an essential element in this planning.

Climate Resilience

- **Flooding**

– Flood resistance & resilience

- **Extreme weather**

– Designs to reduce impacts of high winds, snow & driving rain

- Urban Heat Island effect

– Measures to reduce overheating & demand for mechanical cooling

- **Water stress and drought**

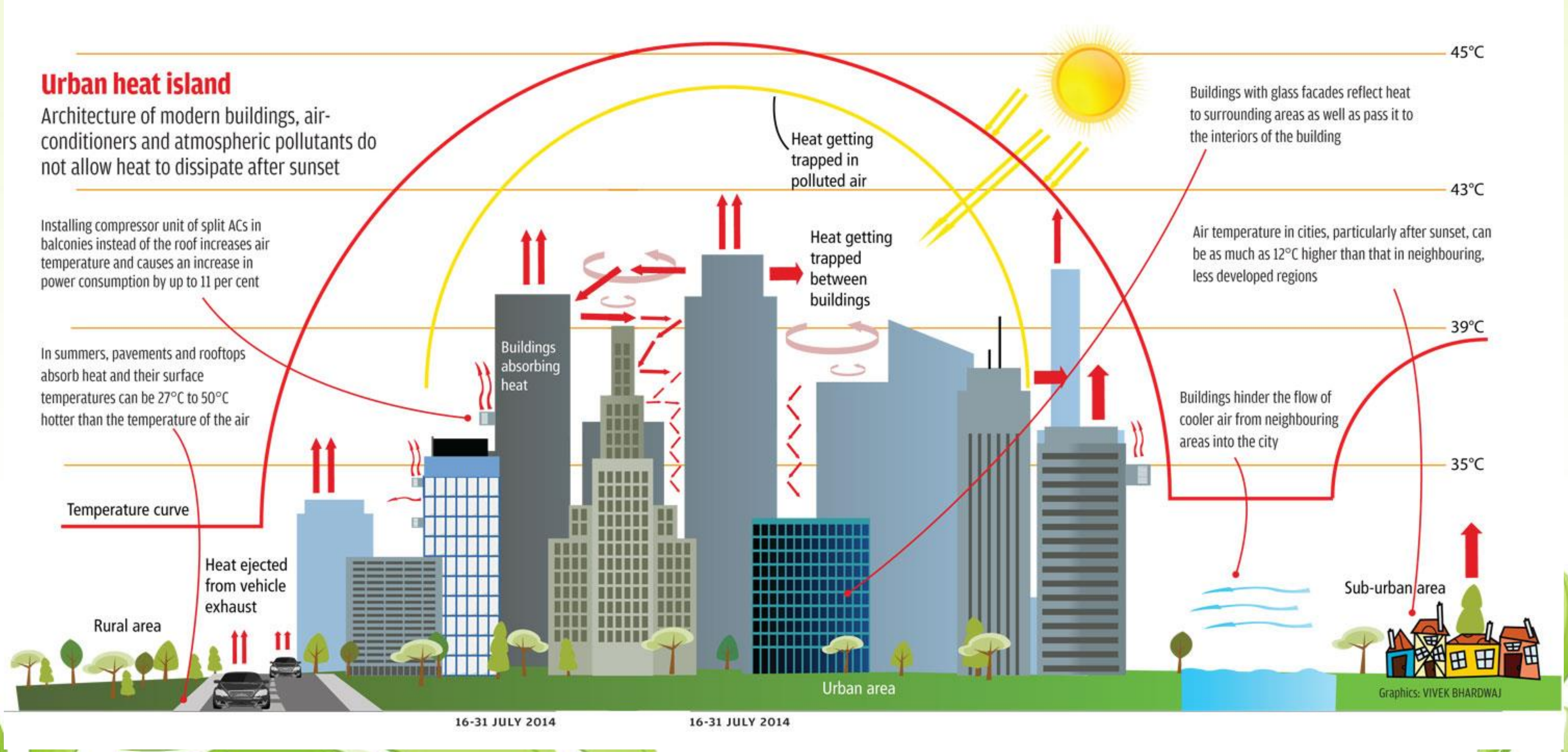
– Measures to reduce water demand, recycle and reuse

- **Earth Quake Resistance**

Urban Heat Island Effect

- The increase of the urban population has also led to rapid changes in land use and land cover within cities.
- During recent years there are evidence of increased change in traffic congestion and pollution.
- These physical changes affect the quality of the environment, contributing to other phenomenon such as an increase in air temperature.
- It is observed that air temperatures in densely built urban areas are higher than the temperatures of the surrounding rural country.
- This increase in temperatures within urban areas is known as the 'urban heat island' (UHI) phenomenon.

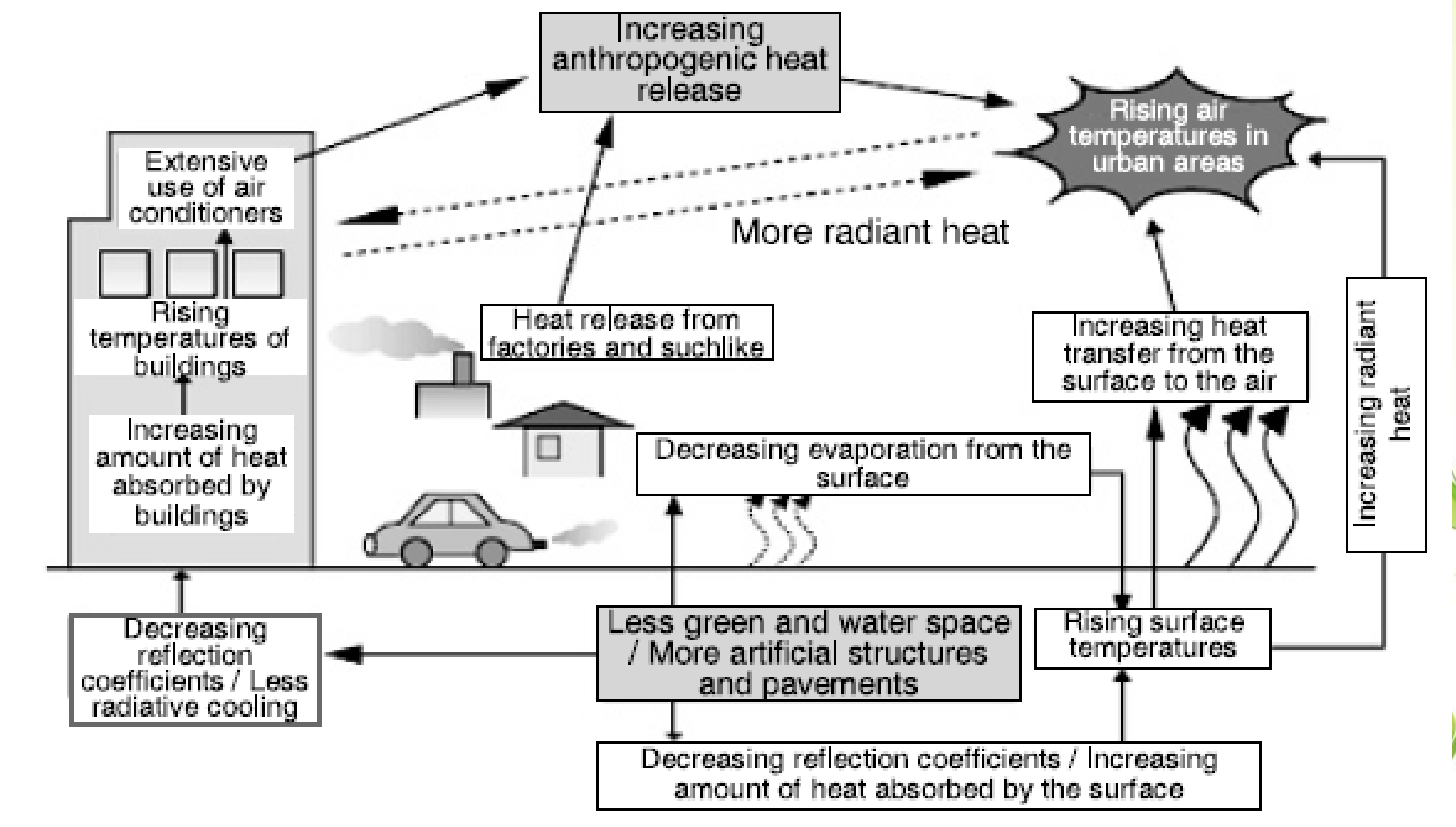
Introduction



Factors affecting Urban heat island effect

- Climate
- Geography
- Size and spread of Urban Sprawl
- Geometry and density of buildings
- Reduced Vegetation
- Anthropogenic heat : generated by human activity e.g. released by combustion of fuels from mobile or stationary sources.

Causes of Urban heat island effect



Impacts of Urban heat island effect

- Impact on Climate: Rising temperatures
- Impact on Energy Consumption: increased use of air conditioners and fans
- Impact on livable Environment: loss of flora and fauna
- Impact on health of occupants : increased mortality rates
- Air Pollution: More carbon-di-oxide emissions
- Economic impacts : Increased energy consumption has direct impacts on economy

City	Delhi	Bangalore	Pune	Chennai	Thiruvananthapuram	Guwahati	Ahmedabad	Bhopal	Nagpur	Visakhapatnam
CAUSAL FACTORS										
Landuse Planning	■	■	■		■	■	■			■
Building Morphology	■	■	■	■		■	■	■	■	■
Surface Characteristics								■		
URBAN LIFESTYLE				■						
MEASURED IMPACTS										
Temperature Increase	■	■	■	■	■	■	■	■	■	■
Energy Use& CO2 Emissions										
Air Quality										
Health Impacts										
Economic Impacts										
MITIGATION MEASURES										
Landuse Planning									■	
Building Morphology										
Surface Characteristic		■						■		
URBAN LIFESTYLE										

■ Identified factors in particular study.

Causal factors

- Anthropogenic heat:
- Generated by transportation, cooking, and air-conditioning use and emitted into the local atmosphere. Standby generators used for electricity production and use for home appliance or building equipment may also contribute.
- Air pollution:
- Emitted by transportation use, cooking, and generators used for home appliances, and other electrical equipment. Includes noxious gases and pollutants that retain heat in the atmosphere and prevent it from being released

Causal Factors

- Solar exposure: affecting radiant temperature
- Most directly influenced by building density but also by land use zoning allocation of the built mass as well as the character of vegetation cover on open ground.
- The building density is manifest in the extent of ground coverage, the allowable floor area ratio, and the ratio of the height of buildings to the width between them.
- This influences the shading of the solar heat during the day affecting gain and radiative heat loss at night due to the related parameter of sky view factor.

Causal Factors

- Wind speeds: affecting convective transfer
- Again, the built areas, their density, and texture, affect the larger wind patterns in a region, modulating it to produce the localized wind patterns which influence the flushing of stored heat.
- Vegetation cover : affecting surface moisture
- Based on the allocation of green areas, coverage of open areas, and character of the green cover, the comprising vegetation affects the ambient moisture content due to evapo-transpiration affecting heat retention by the local atmosphere

Linking causal factors to solutions

- Anthropogenic heat:
- By using energy efficient appliances
- By using solar passive design principles
- Air pollution:
- Reducing the number of private vehicles
- Designing diverse modes for public transport
- Solar exposure:
- Designing building byelaws according to climatic zones
- Wind speeds:
- Regulating wind speeds with building densities
- Vegetation cover :
- Improvising the percentage of green space requirements

Mitigation strategies for Urban heat island effect

An appropriate solution is adequate vegetation, natural ventilation, and high albedo or high solar reflectance materials in urban areas can reduce UHI effects .
This can be done at three scales :

Building Group Scale

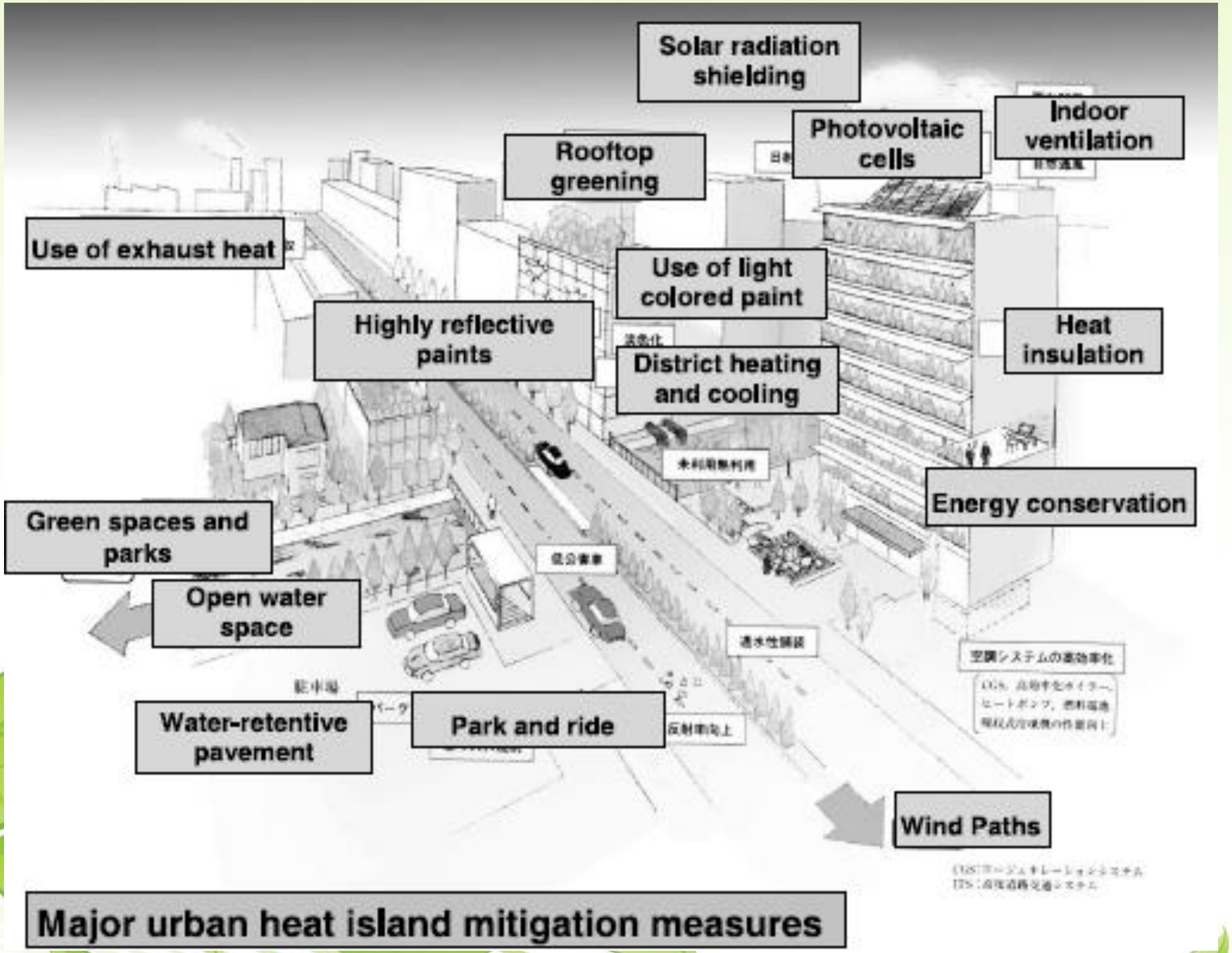
Building Scale

Building Component Scale

BUILDING GROUP SCALE

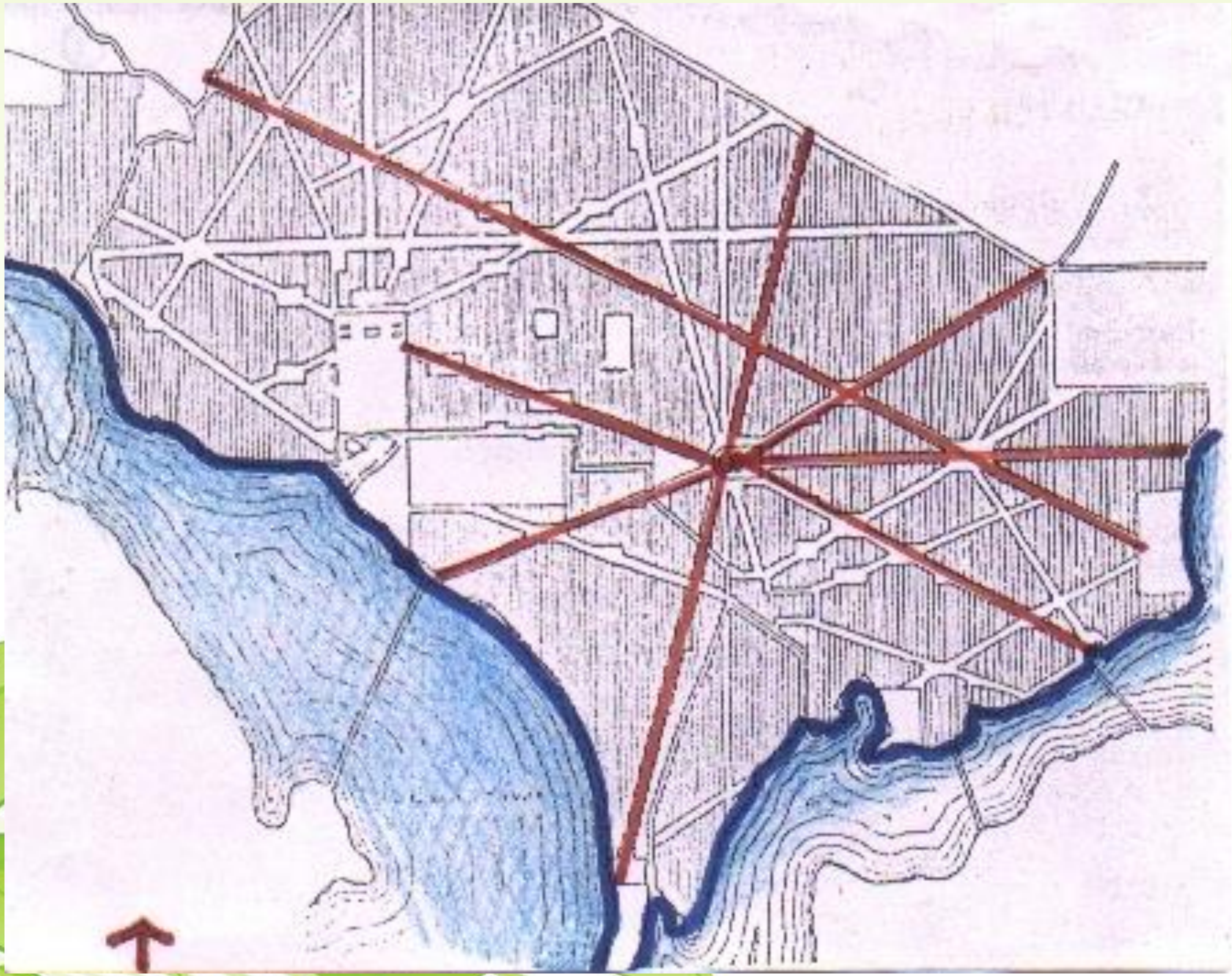
- Providing appropriate landscape for heat gain reduction and shading in open spaces
- Providing appropriate orientation of building and site for preventing sun Radiation
- Encouraging air movement and natural ventilation
- Interwoven plantation and water bodies for cooling
- Radial Ventilation corridors for flushing heat in the core areas
- Green infrastructure planning and implementation for low impact development

Mitigation measures at urban scale



Interwoven plantations for cooling in urban areas

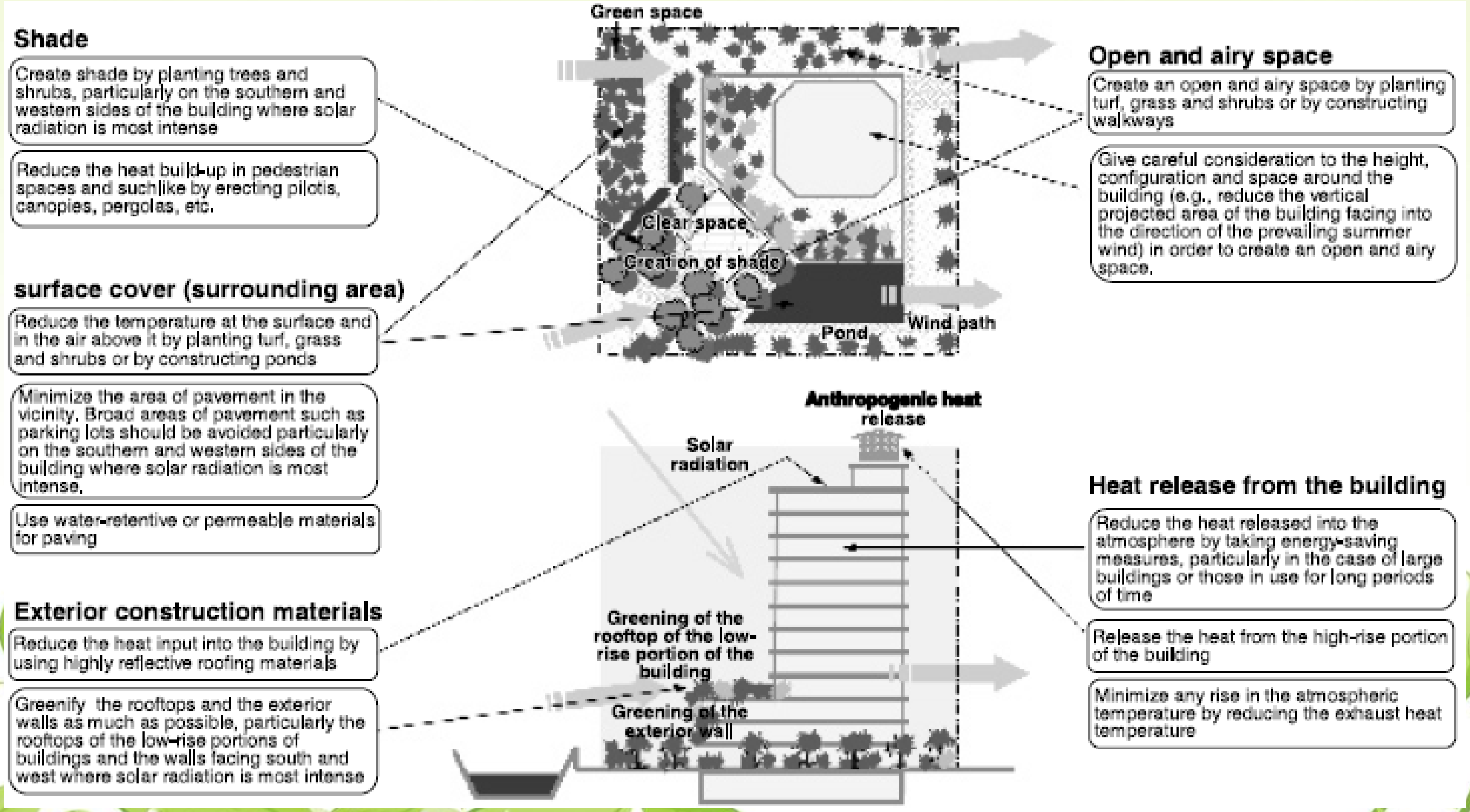
1856 Plan of Washington DC



BUILDING SCALE

- Designing Solar passive buildings for cross ventilation
- Providing green spaces and vegetation in different layers of buildings
- Using albedo materials on external surfaces of buildings
- Providing punctures at various levels, or at mid-span, variation of building height and arrangement of openings in building to face the prevailing wind can create natural ventilation

Mitigation measures at Building scale



BUILDING COMPONENTSCALE

- Protect from solar radiation : Green Roofs, Green Walls, Shading Devices
- Minimize heat infiltration : Designing building envelope, Insulation, Reflective materials
- Reduce Anthropogenic Heat : Energy efficient lighting and equipments
- Maintain Thermal Comfort : Applying passive strategies like evaporative cooling , cross ventilation

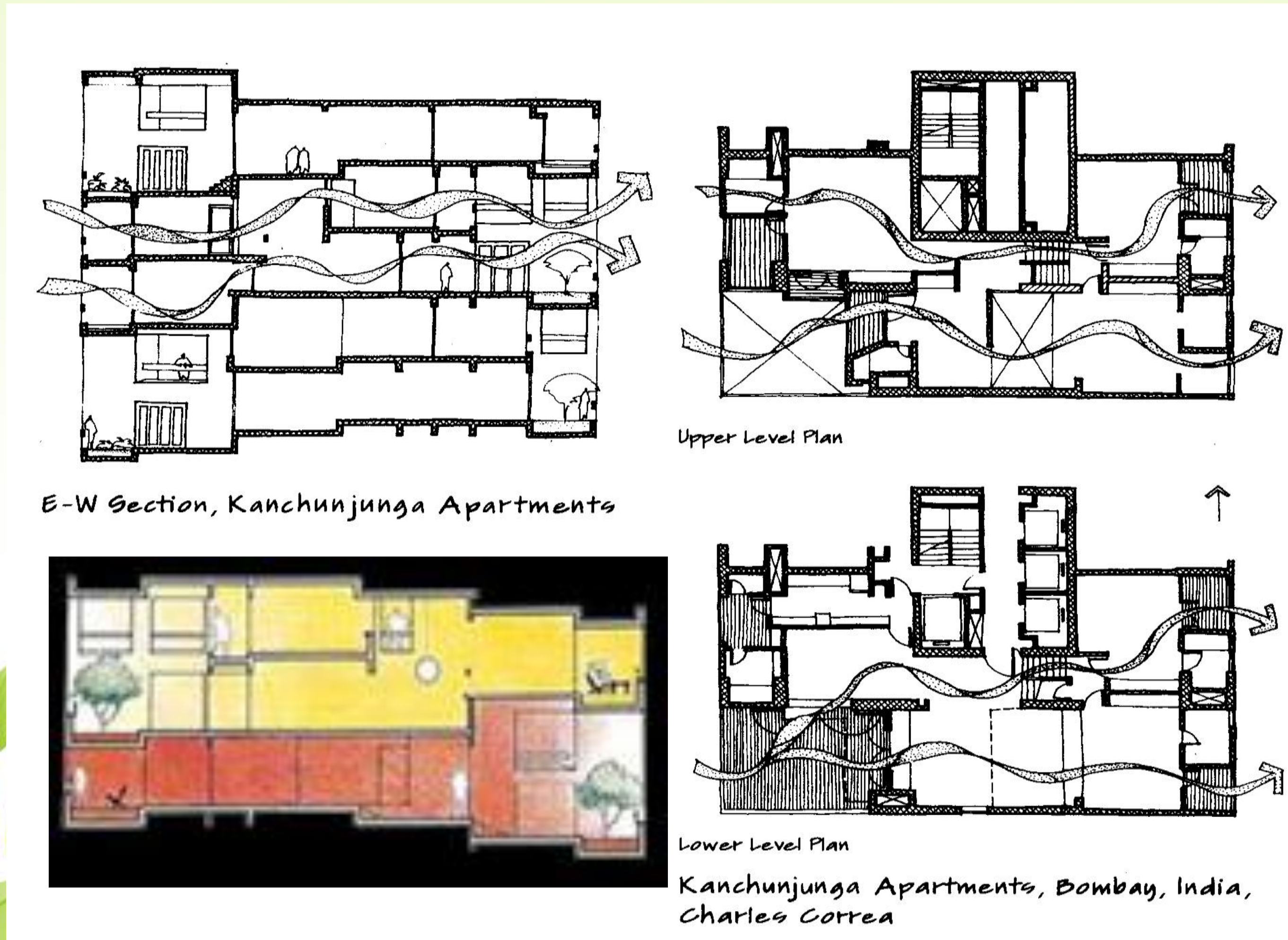
Green Roof

- A green roof is a vegetative layer grown on a rooftop.
- As with trees and vegetation elsewhere, vegetation on a green roof shades surfaces and removes heat from the air through evapo-transpiration.
- These two mechanisms reduce temperatures of the roof surface and the surrounding air.
- The surface of a vegetated rooftop can be cooler than the ambient air, whereas conventional rooftop surfaces can exceed ambient air temperatures

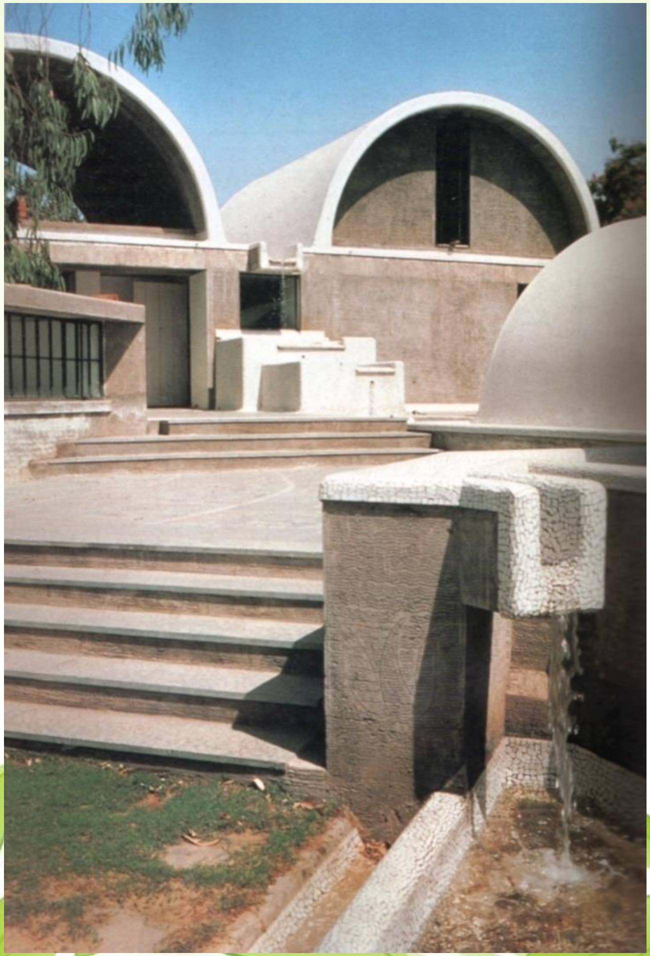
Temperature difference between conventional roof and green roof

Cross ventilation in Kanchunjunga

Cross ventilation in Kanchunjunga



Solar Reflectance Index



The surface temperature of a material is dependent on its reflectance & absorptance properties.

Solar Reflectance Index (SRI) is a measure of a materials ability to reject solar heat, as shown by its temperature rise in full sun.

Standard Black (refle.0.05, emit.0.90) has an SRI of 0 & std. White (refle. 0.80, emit. 0.90) has an SRI of 100.

Materials with higher SRI values are cooler.

In hot climates, select materials with an SRI above 50.

SRI Values of Roofing Materials

Solar Reflectance Index of Roofing Materials :

Roofing Materials	Solar Reflect.	Infrared emitt.	Temp. rise °C	SRI
Asphalt				
Premium white	0.36	0.91	33	41
Grey	0.22	0.91	41	23
Light Brown	0.19	0.91	42	19
Dark Brown	0.08	0.91	48	4
Black	0.05	0.91	50	0
Metal				
Steel, galvanised	0.61	0.04	31	46
Aluminium	0.61	0,25	27	56
Tiles				
Metal, white	0.67	0.85	16	82
Clay, red	0.33	0.90	34	41
Concrete, red	0.18	0.91	43	23
Cement, unpainted	0.25	0.90	39	31
Coatings				
White polymer	0.70 - 0.85	0.86 - 0.91	5 - 13	88 - 107
Light yellow	0.79	0.91	9	99
Grey	0.40	0.91	31	47
Dark blue	0.12	0.91	46	9
Aluminised	0.61	0.25	27	56

References

- Akbari, H. 2005. Potentials of urban heat island mitigation. Pages 11 – 22 in Proceedings of the Internatinal Conference on Passive and Low Energy Cooling for the Built Environment. May 2005, Santorini, Greece
- A Report on ‘Scoping study for policy initiatives to minimize urban heat island for low carbon urban growth

- Oke, T.R. 1988b. Street design and the urban canopy layer climate. Energy and Buildings 11, 103-113
- US EPA, 2008. Reducing Urban Heat Islands: Compendium of Strategies. http://www.epa.gov/heatisland/resources/compendium.html
- Urban Climatology and its relevance to Urban Design by T.J.Chandler

Thank-you for your patience

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