SOLAR PASSIVE DESIGN: PRINCIPLES AND PRACTICE

Understanding Climate and Atmosphere
Human impact on global weather
Energy outlook in India
Energy needs in buildings
Comfort zone
Solar passive design- Case study – solar kitchen

suhasini / auroville design consultants / csr / auroville
www.aurovilledesign.com / suhasini@auroville.org.in
A- What is climate?

Climate - the composite of prevailing weather conditions of a region, as temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds, throughout the year, averaged over a series of years.

Of the 50 kms, troposphere which at the most 12 kms thick has 80% of the mass of the total atmosphere and where all the "weather phenomena" happens.
Compared to the size of the planet, thickness of the atmosphere that most life depends on is equivalent to a layer of “varnish” on “atlas globe” in our libraries.....

A thin and fragile veil, held in place by the gravitational pull of earth.
Factors affecting global climate

A1- Atmospheric cycles - The two major driving factors of large-scale winds are the differential heating between the equator and the poles (difference in absorption of solar energy) and the rotation of the planet.

Hadley cells and prevailing winds

Solar warming of the tropics drives atmospheric circulation in three cells. Rotation of the Earth generates Coriolis forces that create the easterly trade winds below 30° latitude and polar easterlies above 60° latitude. Coriolis forces create prevailing westerlies in the mid-latitudes.
A **ocean currents** - Earth's rotation affects the oceans in a similar manner, setting up currents that flow within the ocean basins. Ocean currents are driven by surface winds, Earth's rotation, and differences in salinity.

**FACT FILE**

**Climate conveyor belts**

Driven by changes in temperature and salinity, large ocean currents are in constant motion, moving heat from the equator to the upper latitudes and then moving cold back toward the equator.

Known as ‘thermohaline circulation,’ this phenomenon includes the Gulf Stream, which moderates northern Europe’s climate. Some scientists speculate that global warming could weaken this circulation and leave some regions relatively cooler.

**SOURCE:** National Center for Atmospheric Research, Intergovernmental Panel on Climate Change

**RAINMAN Graphics Library**
A3- Biogeography – depending on the global positioning and size of the land mass, we recognize six bio-geographic realms — Nearctic, Palearctic, Neotropical, Ethiopian, Oriental, and Australian — in which animals exhibit features distinctive to that region.
A 4- planetary cycles

Milutin Milanković contribution is the "Canon of the Earth’s insolation", which characterizes the climates of all the planets of the Solar System.

The second contribution is the explanation of Earth's long-term climate changes caused by changes in the position of the Earth in comparison to the Sun, now known as Milankovitch cycles.
Atmosphere – composition and dynamics
B- human impact on global weather
B- climatic impact on humans

10.1. Humans have had a large impact on atmospheric methane concentrations (A), CO₂ (B), and estimated global and high-latitude temperature (C, left, right) during the last several thousand years.

13.1. Intervals of low CO₂ concentrations in Antarctic ice cores correlate (within dating uncertainties) with major pandemics that decimated populations in Eurasia and the Americas.
C. Energy outlook in India

Total energy consumption in India, 2011

- Coal 41%
- Petroleum 23%
- Natural gas 9%
- Solid biomass & waste 23%
- Nuclear & other renewables 5%

India's Sources of Energy 2008

- Coal & peat 42%
- Oil 23%
- Renewables & waste 26%
- Gas 6%
- Hydro: 1.6%
- Nuclear: 0.6%
- Geothermal, solar, wind: 0.2%

2006-07 shortfall between peak load and peak served was 4 GW

Predicted short fall in 2016 -17 the same is 64 GW

With the use of fossil fuel in food / shelter / transport / pharma and improved sanitation– population increase from 1.6 billion in 1900 to 6.0 billion in yr.2000

India 1900 – 27 million and in yr 2000 it is 1.05 billion
D- Energy needs in buildings

Source: CEA 2009
Growing ownership of appliances in India

By 2030, there will be 70 per cent additional stock of appliances

Source: Prayas Energy, 2011
E - Comfort zone

A: CONTEXT = ECOLOGICAL AND PHYSICAL
B: SETTLEMENT PATTERN AND SITE PLANNING
C: PASSIVE HEATING AND COOLING DESIGN STRATEGIES
D: OPENINGS, DAY LIGHTING AND NATURAL VENTILATION
E: BUILDING ENVELOPE
F: ACTIVE STRATEGIES / INTERVENTIONS

Band of appropriate design

Diagram showing relationships between building context, climate, use, efficiency systems, and small loads.
Definitions

Climatic design- “principles of solar design” as a interrelationship between architectural design, building materials, human behaviour and climatic factors.

Energy efficient design- interventions to reduce the amount of energy required to provide products and services like heating / cooling / lighting

Solar passive design - uses sunlight without active mechanical systems, converting sunlight into usable heat, causing air-movement for ventilating, orientation for reduced heat and enhanced lighting.
**embodied energy** - is the sum of all the energy required to produce goods or services, considered as if that energy was incorporated or 'embodied' in the product life-cycle including assessing the relevance and extent of energy into raw material extraction, transport, manufacture, assembly, installation, dis-assembly, deconstruction and/or decomposition as well as human and secondary resources.

**Carbon neutral** - is having a net zero carbon footprint, or achieving net zero carbon emissions by balancing the amount of carbon released with an equivalent amount sequestered or offset. It is used in the context of carbon dioxide releasing processes, associated with transportation, energy production and industrial processes.

**Carbon footprint** - "A measure of the total amount of carbon dioxide (CO₂) and methane (CH₄) emissions of a defined population, system or activity, considering all relevant sources, sinks and storage within the spatial and temporal boundary of the population, system or activity of interest. Calculated as carbon dioxide equivalent (CO₂e) using the relevant 100-year global warming potential (GWP100)"
The idea of solar passive design is to modulate the conditions such that they are always within or as close as possible to the comfort zone.

Identification of the climatic zone

Collection of Climatic data for the last decade

Study of site specific features

Identification of local / unique weather conditions and features
Cool & Monsoon Season

- Night flushing is not advisable- night time RH is very high though diurnal swings can be observed

Dry Bulb Temperature

Relative Humidity

CHENNAI

January
February
March
April
May
June
July
August
September
October
November
December

WET BULB TEMP (DEG C)

HUMIDITY RATIO

Dry Bulb Temperature

Relative Humidity

Dry Bulb Temp (degrees C)

Dry Bulb Temp

Relative Humidity (percent)

Dry Bulb Temp

Relative Humidity
Cool & Monsoon Season

- Low to moderate wind speeds during high rainfall period
- Driving rain is a concern

Wind speed (m/s)

Rainfall in Chennai
Night flushing is not advisable—night time RH is very high and marginal diurnal swings.
Summer Season

- Low to moderate wind speeds during summer months
- Scanty rainfall
Annual Solar Radiation & Sky Cover

Direct Normal Solar Radiation

- High direct normal solar radiation between January and May
- Moderate radiation during the remaining months

Sky Cover

- Semi-clear days between January and May
- Cloudy days during the remaining months

**DIRECT NORMAL RADIATION**
(Wh/sq.m)

- 53% Night Time
- 8% 4 - 158
- 14% 158 - 316
- 11% 316 - 474
- 11% > 474

**SKY COVER**
(percent)

- 0% < 10
- 5% 10 - 30
- 47% 30 - 60
- 45% 60 - 80
- 1% > 80

- Months between January and May most conducive for using solar energy
G- Solar passive design interventions – Solar Kitchen / Auroville
Solar bowl for steam generation
Balance of open spaces to built up along with layout of streets / roads to create heat venting channels by aligning with the prevailing wind directions.
G.2- Building orientation for solar gain and ventilation
Optimum solar orientation and the optimum wind orientation may not coincide

In the tropics the north-south orientation is preferable for sun exclusion as the low angle of the sun in the evening will heat up the walls if there is no vertical shading devices or external wall insulation.
Natural Ventilation is the most essential element in Hot-Humid zones, and this can be achieved with optimization of orientation.

By conventional wisdom one would assume that the highest pressure on windward is generated when the long façade is right angle to the wind direction but it has been found (Givoni-'63) that wind angle of 45° increases the average indoor air velocity and provides a better air distribution.
Solar chimneys: due to differential temperature (the slab at the top of solar vent heats up the air and draws it to the outside creating negative pressure, increasing the air flow from the outside) within a given space, one can increase the wind speed which is essential for comfort in hot and humid climate.
Roof vents to allow the hot air that rises to escape creating negative pressure to increase the air movement in the room.

Use of fans during the hottest part of the day would reverse this by drawing the hot air in.
G.3- Building envelope design and efficiency
Windows – deep set with over hangs: oriented to have max ventilation / no direct solar access/ no fixed glazing / outdoor shaded with trees / diffused natural light / solar chimney
G4- Radiation and heating:

• Conduction – heat intake through walls and roof...lower U value in building materials

• Solar radiation – heat intake from opaque surfaces, from transparent surfaces (windows), paved and surfaced area in direct sun around buildings.

• Un-shaded glazed windows especially on the east and western facades.

• Heat exchange from air

• Internal heat gain – heat output from people, lamps, computers and appliances

• Evaporation – from surfaces (sweat, walls and plants)
Shading and day lighting: is a major issue in the tropics because of the intense sky glare, in spite of careful orientation it is difficult to cut down on the glare.

Mesh screening helps to cut the glare and light shelves allow a more diffused lighting conditions. Day lighting can also act as heating systems due to the thermal aspect of day light.
Creation of transition spaces for lowering the air temperature before it enters the building

Planting of ground and tree cover to reduce reflected ground radiation
• Roof shading, reflective surfaces and insulation
G5- colors and textures - Internal materials like furniture and furnishings can store heat, high humid conditions even with temperatures between 25-35 °C. Evaporation of a small quantity of moisture from the body would form a saturated air envelope preventing any further evaporation. In these conditions thick fabrics and warm colors add to discomfort.
Thank you