National Workshop on Dream of Green City

September, 21st and 22nd 2006

Organized by

Dnyandeep Education Foundation, Sangli

Technical Session:

Design of Green Buildings

This Session:

Design of Buildings for Thermal Comfort

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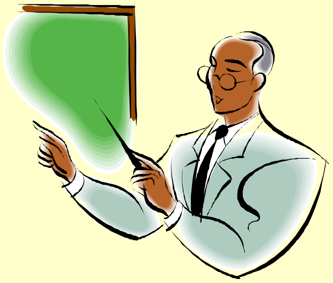


It took several hundred thousand years for the world's population to reach it's First Billion (10^9) around 1800 AD.

But only 130 years were needed to add the Second Billion, and less than 30 more for the Third around 1960.

In mid-seventies the Fourth Billion was reached and the last quarter of the century, 2 more Billions have been added, totaling to well over 6 Billions.

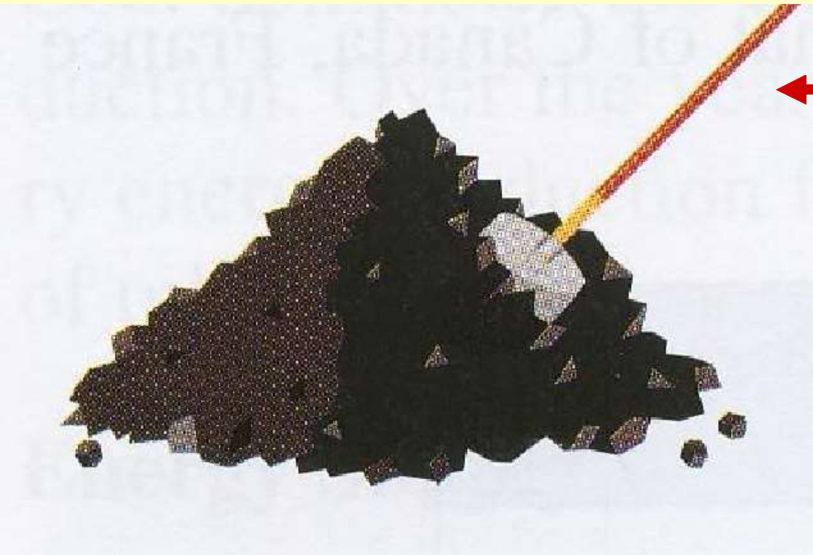

THE ONE PLANET

Our planet has evolved, for eons, with a fixed arrival rate of renewable energy from the sun.

Suddenly, in geological time, our planet is experiencing

Population Growth

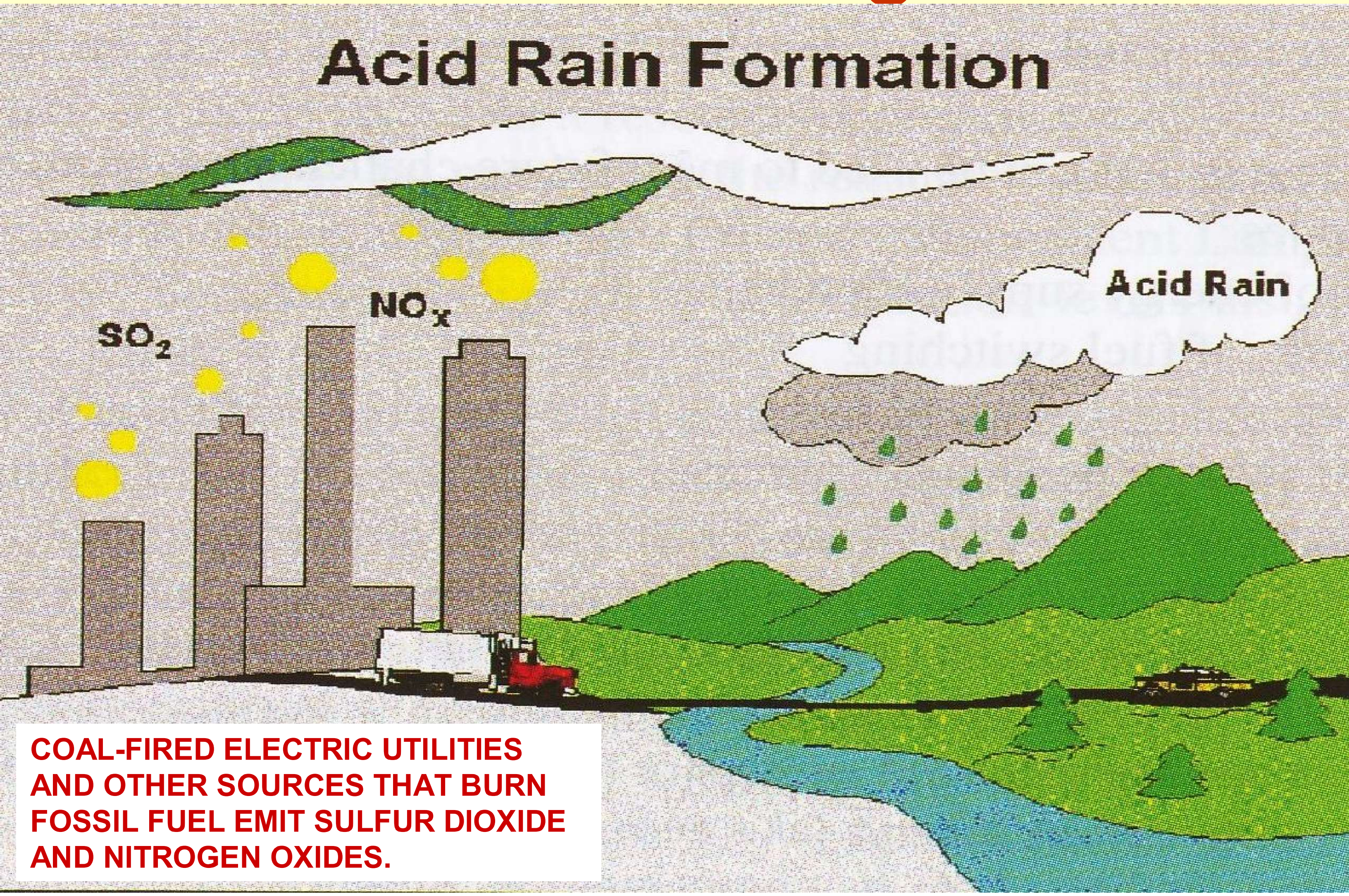
Non-renewable Energy Resource Depletion



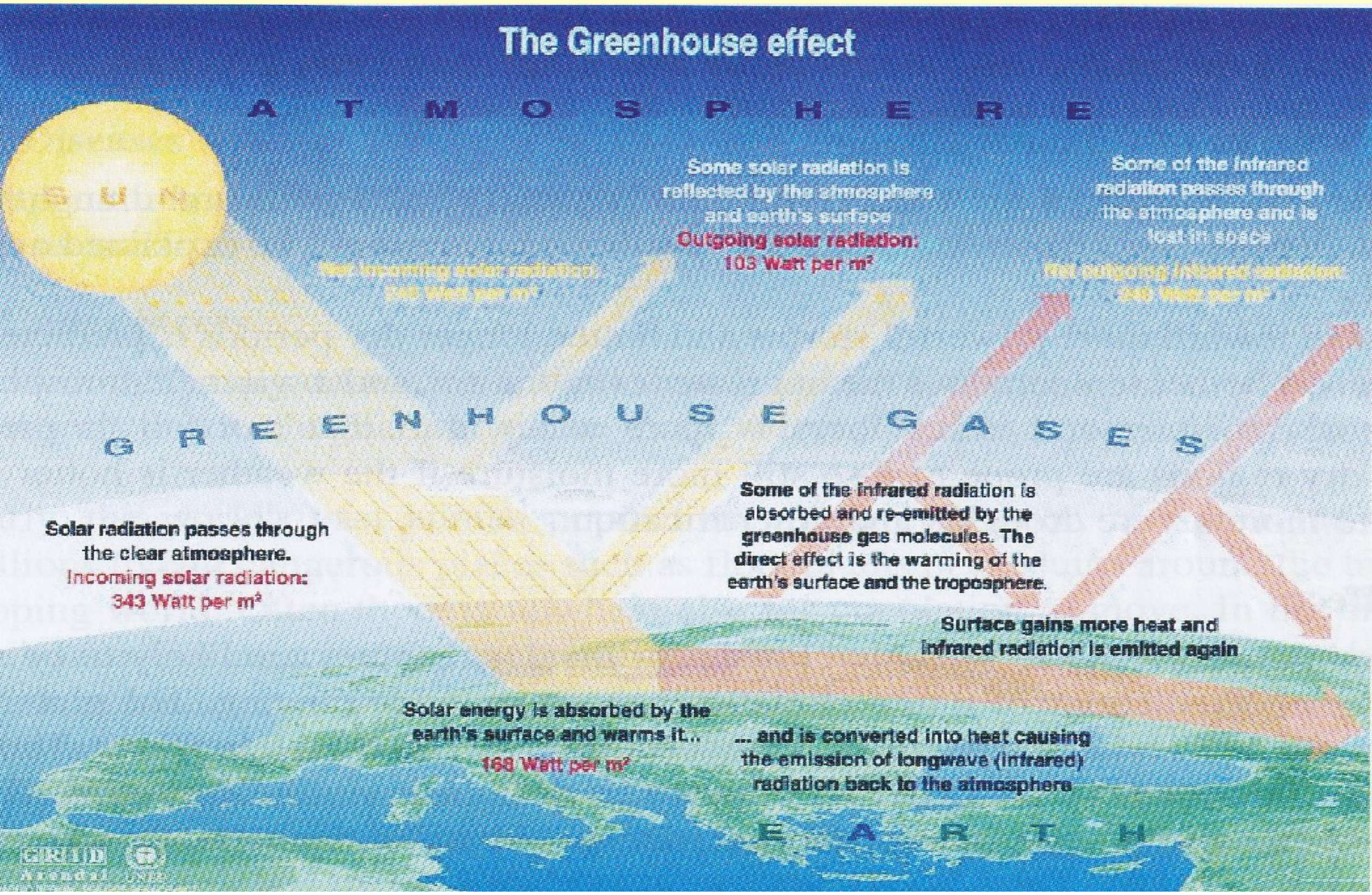
COAL

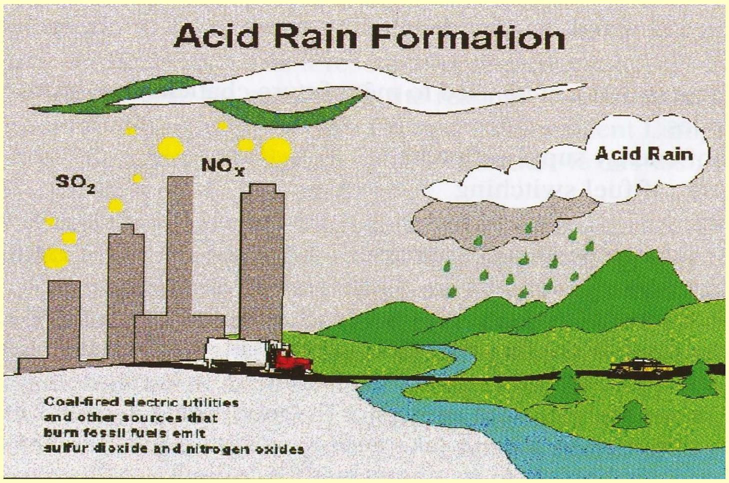
OIL

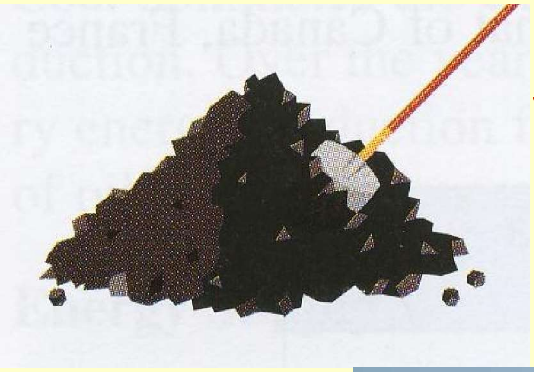
Environmental Degradation



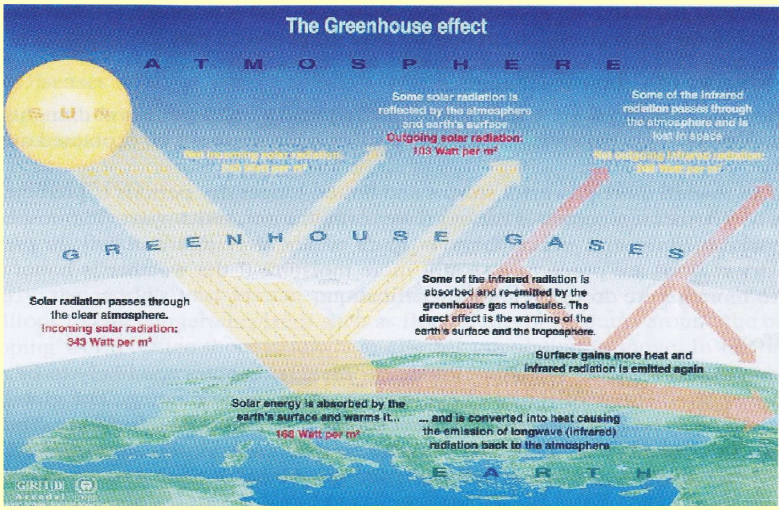
Global Warming







WORLD PROBLEMS



The expansion of urban areas is accelerating throughout the world, and each of the inhabitants of this area is consuming more resources than did his / her grand parents.

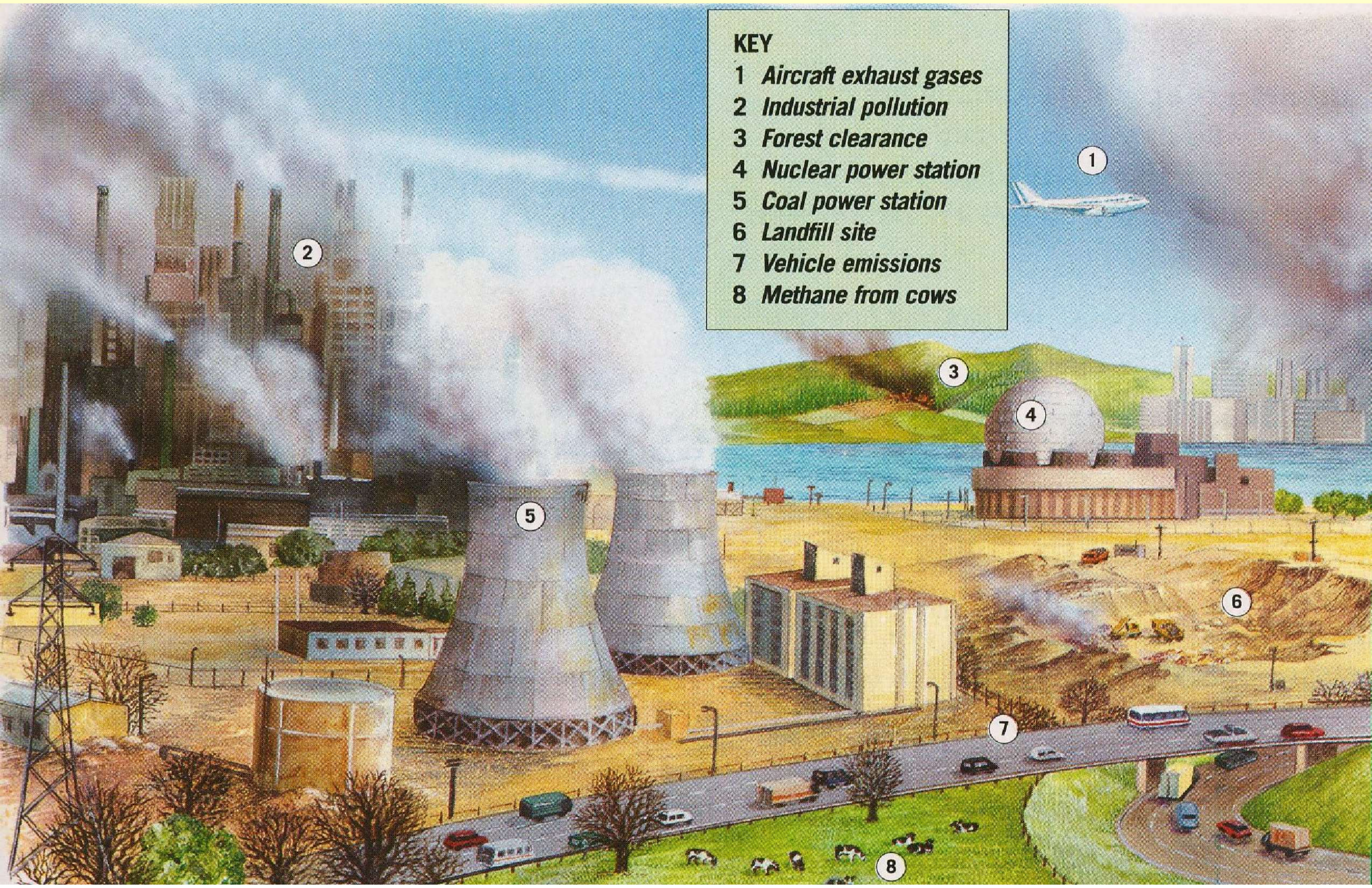
These changes and modifications of earlier situations are giving rise to many problems, such as

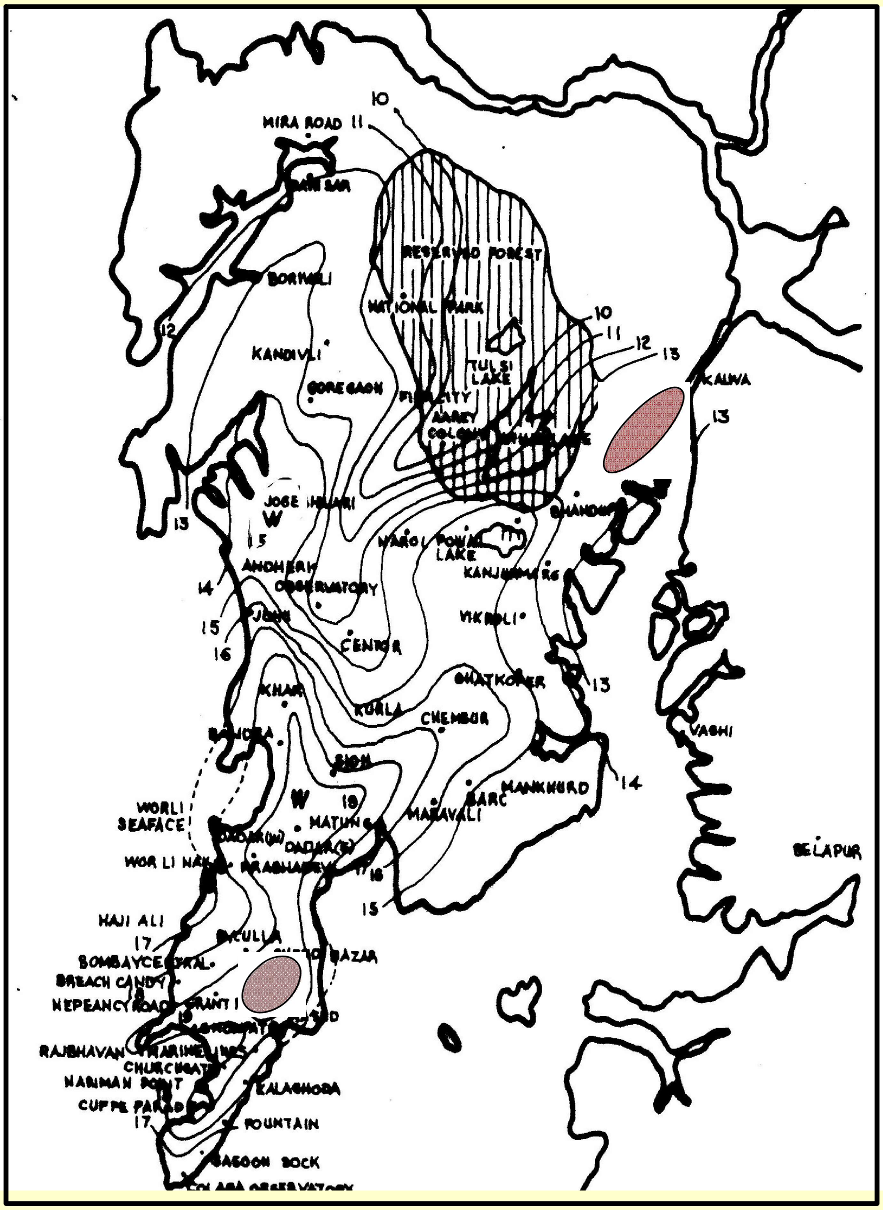
Socio -Economic

NINE / ELEVEN, NEW YORK

OVER CROWDING, PUNE

Eco-Environmental





And Meteorological problems

URBAN

HEAT ISLAND

INTENSITIES

OVER MUMBAI

In some areas of change once local problems are now regional or even global in extent.

Eventually, our planet must live within a fixed budget of renewable energy and material resources.

The question is how best we can move towards this sustainable goal with our present attitude of consumerism and over use.

Architecture and Urban Planning in their widest sense consume energy, modify environment and manipulate ecology.

It seems that these issues should be of professional concern to all the stake holders whose main goal is to improve the quality of life.

It is therefore imperative that we produce design solutions that are sustainable, eco-sensitive, energy-efficient, climate-responsive, user-friendly and cost-effective.

Our buildings are, after all, temporary occupants of the site. The arrival of a building usually produces rapid and dramatic changes to the biological and climatic systems that evolved on the site.

Buildings are guests, Sites are hosts; how might they most productively co-exist?

The site offers the building, earth for support, for a potential heat source and heat sink, and for the growth of plants, if permissible. At some level an eco-system of life is already established.

Sounds on site depend on the context, urban or rural. Water is some where below the site, flows across it, falls on it as rain, and perhaps collects on its surface. Wind moves erratically across the site.

Solar energy arrives in diurnal and seasonal cycles. The over all arrival rate of sun, wind and water is steady, although great variation can occur over shorter time spans.

The building arrives, bringing with it people and vehicles, a flow of material in to and out of the building, sounds are generated by activity and utility services are imported such as electricity, water & natural gas.

The building offers the site electric light by night as also a changed micro-climate in the immediate vicinity of it’s envelop. It also offers a continuous flow of heat and water containing waste or nutrients, depending on one’s view point. In our society this water outflow is more often whisked off, for treatment elsewhere.

“Architecture occurs at the meeting place of interior and exterior forces of use and space. These interior and environmental forces are general and particular, generic and circumstantial. Architecture as a wall between the interior and the outside becomes the spatial record of this resolution and its drama.”

- Robert Veanturi, Complexity and Contradiction in Architecture

Energy & environment have emerged as crucial issues, as a result of such crises as

Chernobyl Disaster

Draught

Flooding

This long list of symptoms points to a larger illness.

"He will manage the cure best, who foresees what, is to happen from the present condition of the patient."

- Hippocrates

On a more general level, the definition of the role of Building Design and Urban Planning in Energy Conservation has to be redefined.

Energy is costly, pure energy like electricity is inherently costlier.

Energy demand is outstripping the supply

Increased energy generation is depleting the exhaustible natural resources, and degrading the environment.

In the long run, energy costs would equal or exceed the environmental costs, which our society will have to pay dearly.

On the other hand, energy is vital for economic development which forms the foundation of social well being and political stability.

In this scenario, energy conservation becomes not only imperative but also an obligation dictated by the basic human instinct of self- preservation.

This can be done only by applying scientific methodology, which will enable us to make quantitative assessment of qualitative performance of materials, systems and resources.

Our responsibility to improve the quality of life also beacons us to develop scientifically & mathematically based methods of responding to Thermal, Luminous, Acoustics & Aqueous environments. The procedure can be described in the following way:

1. Analysis Techniques

To understand the problem & its context. This would characterize the important variables & establish their relative importance

2. Design Strategies

Which are form generating & which also concentrate on revealing the relationships between the architectural form, space and energy.

3. Evaluation Procedures

To evaluate the performance of the design.

Since we are focusing on Design of Green Cities, we will zoom in on Design Strategies for Building Group Scale.

They deal with a range of scale that extends beyond a single building to a cluster, block, town or city.

The major Architectural & Planning elements they address are

buildings, streets & open spaces

which are primary components of the design process.

The strategies are mostly concerned with the relationships between these components. They are among the most neglected by Architects and Planners.

These strategies reveal at least one of the five criteria given bellow:

They must

- deal with energy.
- primarily, be passive in nature.
- reveal major form & organizational relationship.

- have potentially major impact on the appearance of the building.
- Some strategies, if ignored at this stage, would require redesign later.

The strategy statements are not directives; they do not say that one must do this to conserve energy.

They do say that if one does this that will probably be the result. The strategy that fits the designer's other concerns should be selected.

There is no single right way to do something without the agreement of the people involved & affected; therefore, the strategies are stated as possibilities, not as absolutes.

ORGANISATIONAL CHARACTERISTICS

RADIAL ORGANISATIONS:

STRATEGY NO. 1:
Radial Ventilation Corridors:

Radial Ventilation corridors of streets or open spaces can take advantage of cool air drainage & night thermal currents. (cooling)

Cities significantly influence regional wind patterns in 2 ways:

First, when winds are calm, the urban heat island effect, active mostly at night causes centripetal wind patterns moving from fringe areas towards dense areas. These winds are stronger than surrounding country side.

Second, the areas of high development density produce and store more heat during the day and retain it longer. At night, with temperature inversion these areas start radiating heat. The warmer polluted city air then tends to rise creating negative pressure that sucks cooler air from perimeter.

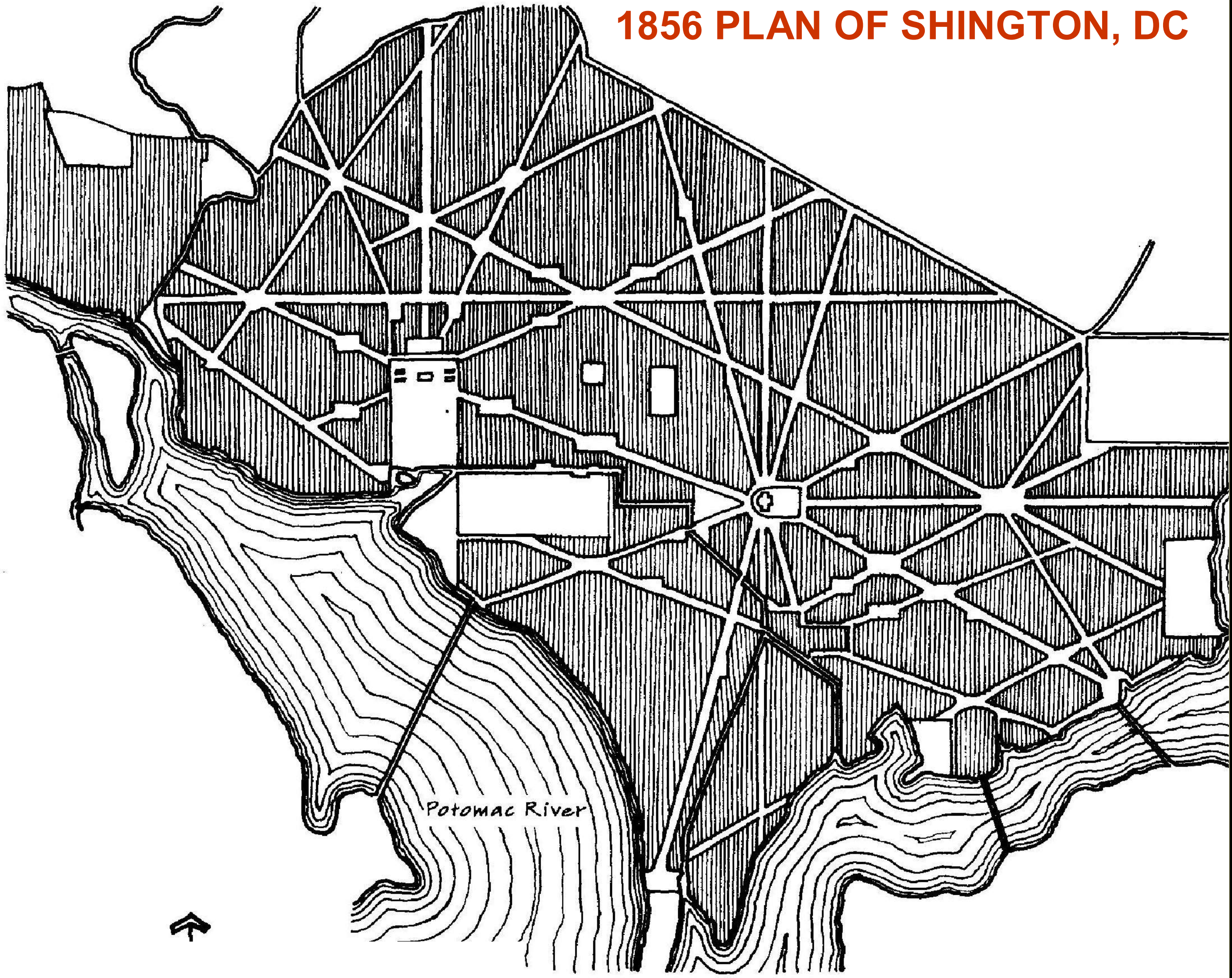
Both these effects can potentially be utilized to help flush dense areas of heat and pollutants.

Two main urban design elements are required :

1. A band of undeveloped, preferably vegetated land at the perimeter that can serve as cool air source and

2. Wide corridors to provide a pathway for the cool air to move from perimeter to centre.

1856 PLAN OF SHINGTON, DC



1856 Plan of Washington, DC

ELONGATED ORGANISATIONS:

Strategy No. 2:

East- West Oriented Settlement Form

E-W elongated building groups spaced in the N-S direction maximize solar gain while ensuring solar access to each bldg (heating).

Placement of a building, such that it has access to sun without shading other buildings, has important implications for form & arrangement of groups of buildings.

The appropriate spacing between buildings is determined by the profile angle of the low altitude winter sun.

Multiply the height of the building, H, by the value X , form the table to determine the spacing, S, that will provide optimum winter exposure for a cluster of buildings.

(Ref. Table no.1)

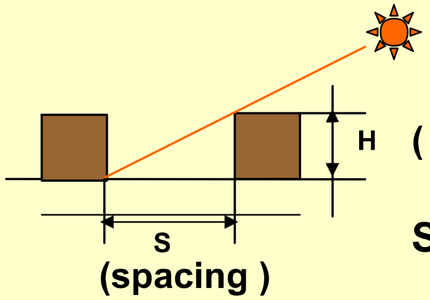
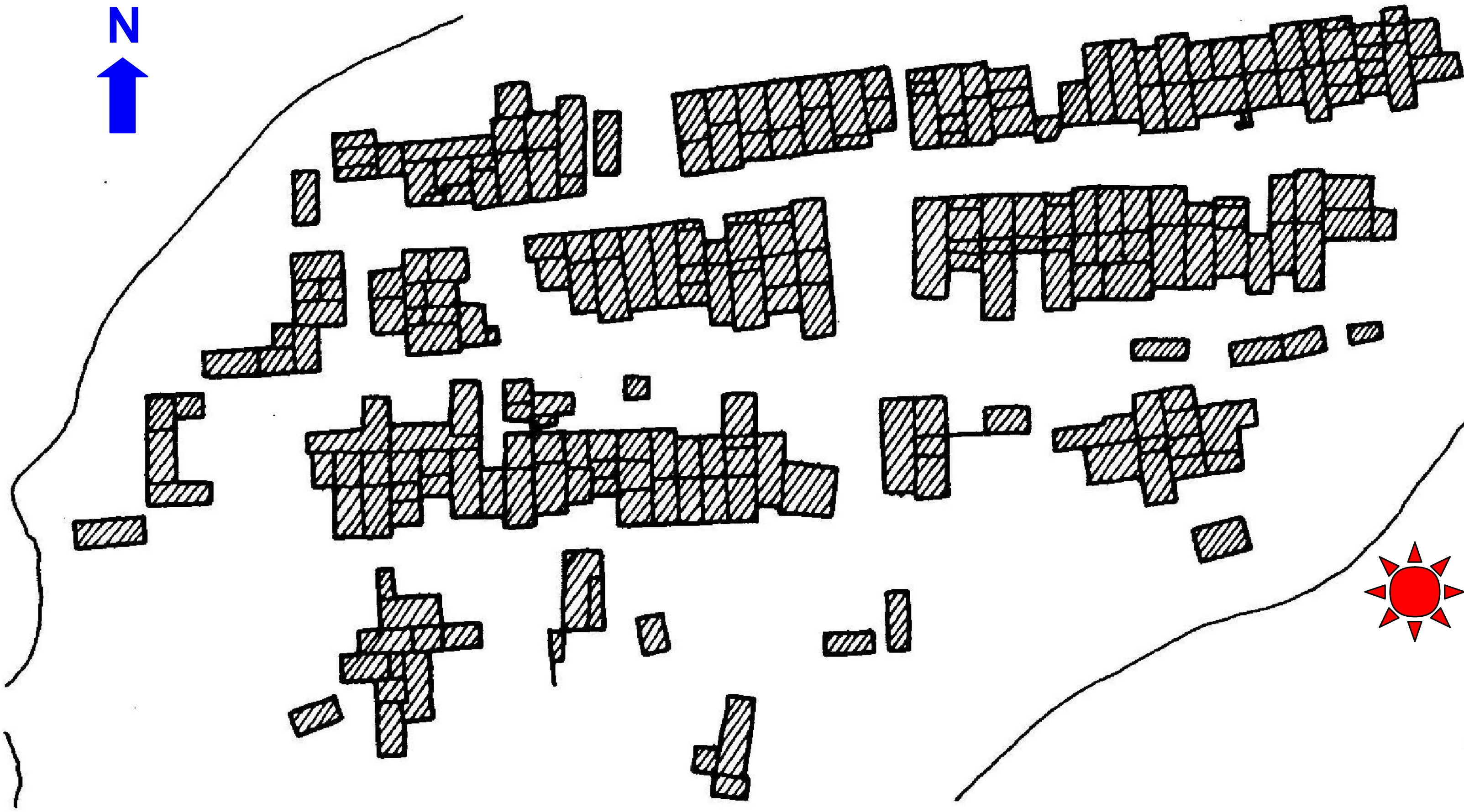


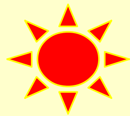
Table no. 1.	Values of "X" For Building Spacing													
Lat.	9 AM		10 AM		11 AM		12 NOON		1 PM		2 PM		3 PM	
^{0} N.	Dec	J/N	Dec	J/N	Dec	J/N	Dec	J/N	Dec	J/N	Dec	J/N	Dec	J/N
8	0.8	0.7	0.7	0.6	0.6	0.5	0.6	0.5	0.6	0.5	0.7	0.6	0.8	0.7
12	0.9	0.8	0.8	0.7	0.7	0.6	0.7	0.6	0.7	0.6	0.8	0.7	0.9	0.8
16	1.1	0.9	0.9	0.8	0.8	0.7	0.8	0.7	0.8	0.7	0.9	0.8	1.1	0.9
20	1.3	1.1	1.1	0.9	1.0	0.9	0.9	0.8	1.0	0.9	1.1	0.9	1.3	1.1
24	1.5	1.2	1.2	1.1	1.1	1.0	1.1	1.0	1.1	1.0	1.2	1.1	1.5	1.2
28	1.7	1.4	1.4	1.2	1.3	1.1	1.3	1.1	1.3	1.1	1.4	1.2	1.7	1.4
32	2.0	1.7	1.6	1.4	1.5	1.3	1.5	1.3	1.5	1.3	1.6	1.4	2.0	1.7
36	2.4	2.0	1.9	1.7	1.7	1.5	1.7	1.5	1.7	1.5	1.9	1.7	2.4	2.0

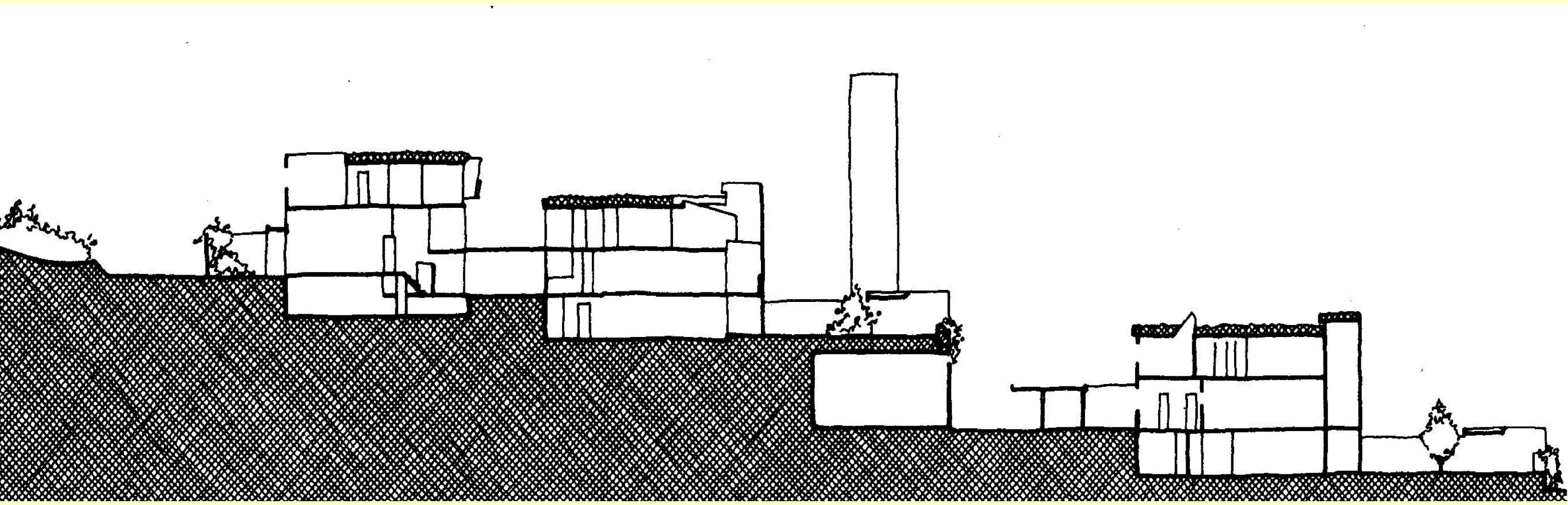
E-W elongated bldg groups spaced in the N-S direction

Example: PUEBLO ACOMA, NEW MEXICO



Spacing reduces substantially, if site is sloping southwards.

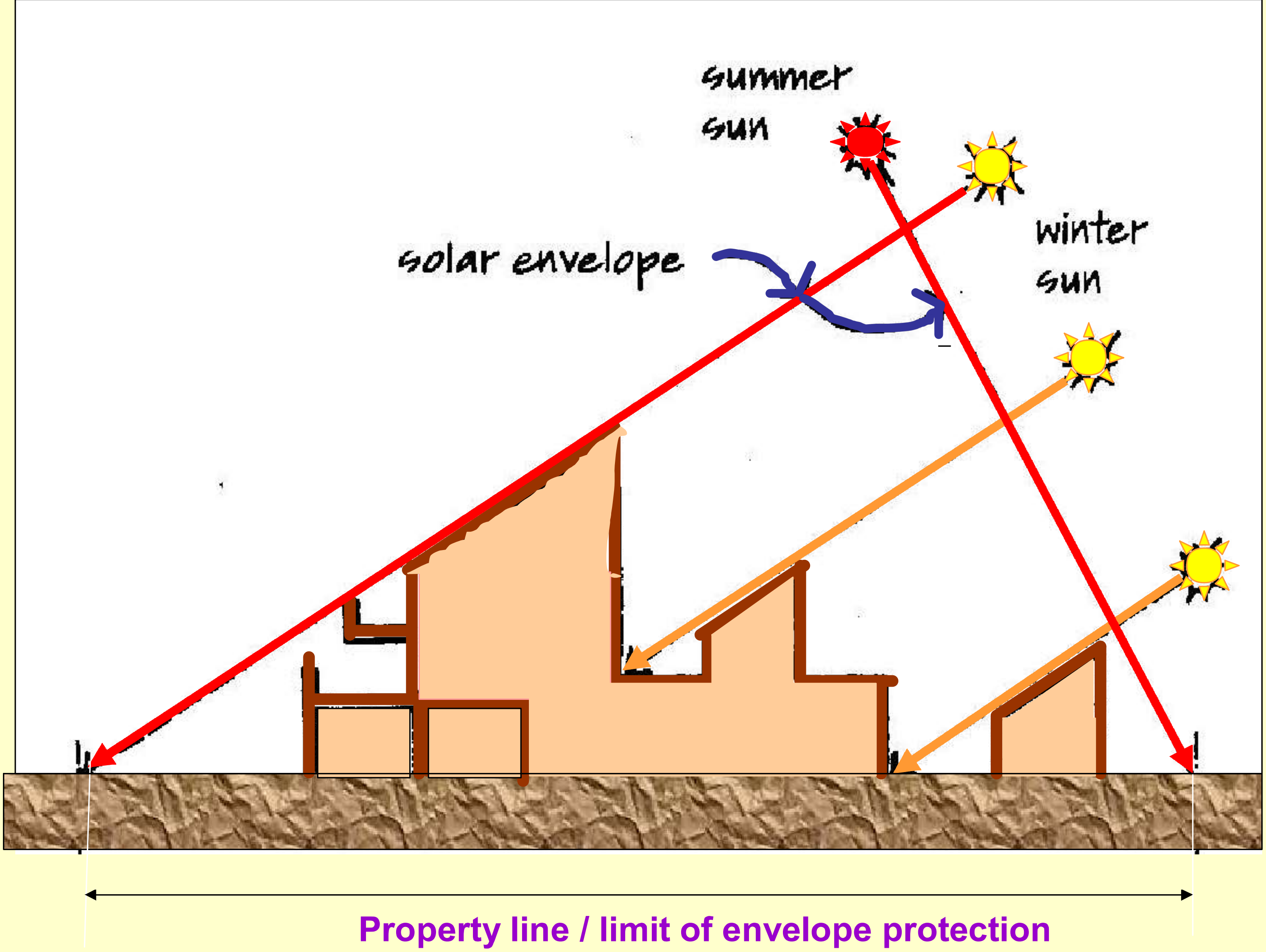




Example: Seidlung Halen, Bern, Switzerland, Atelier 5

The ideal massing to collect sun on site can be in conflict with the ideal massing to protect solar access to neighbouring sites.

To achieve both solar collection and protect solar access, massing for on-site collection should be within the solar envelope.



SOLAR COLLECTION WITHIN SOLAR ENVELOPE

COMPACT ORGANISATIONS:

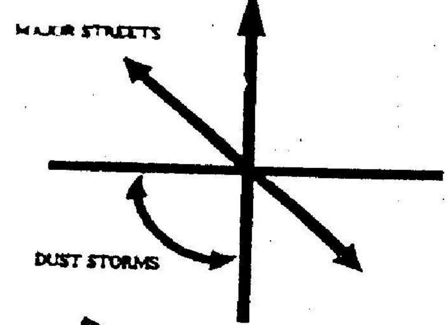
STRATEGY NO. 3:
MUTUAL SHADING

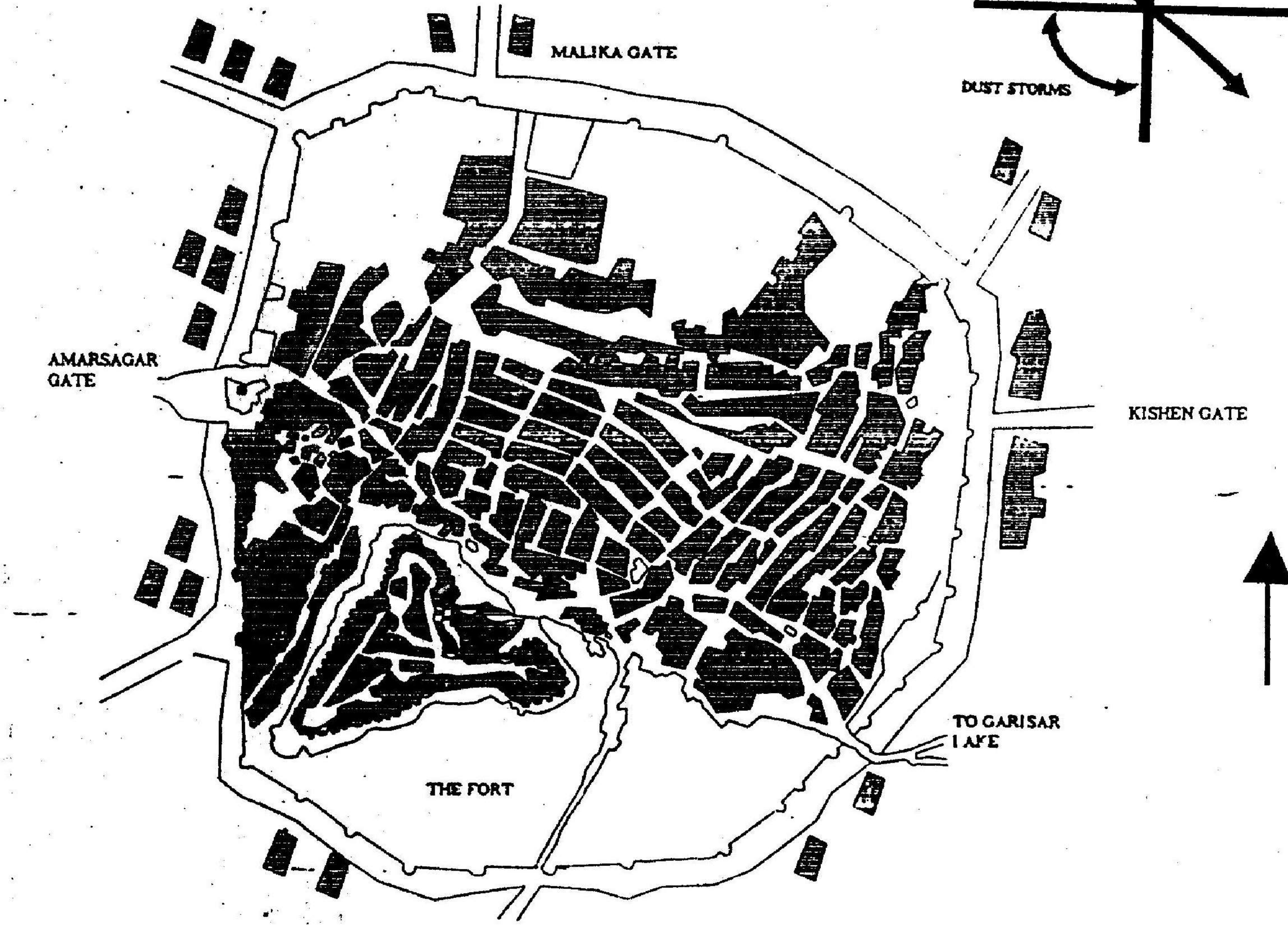
Shared shade- Buildings can be arranged to shade each other and adjacent exterior spaces (cooling)

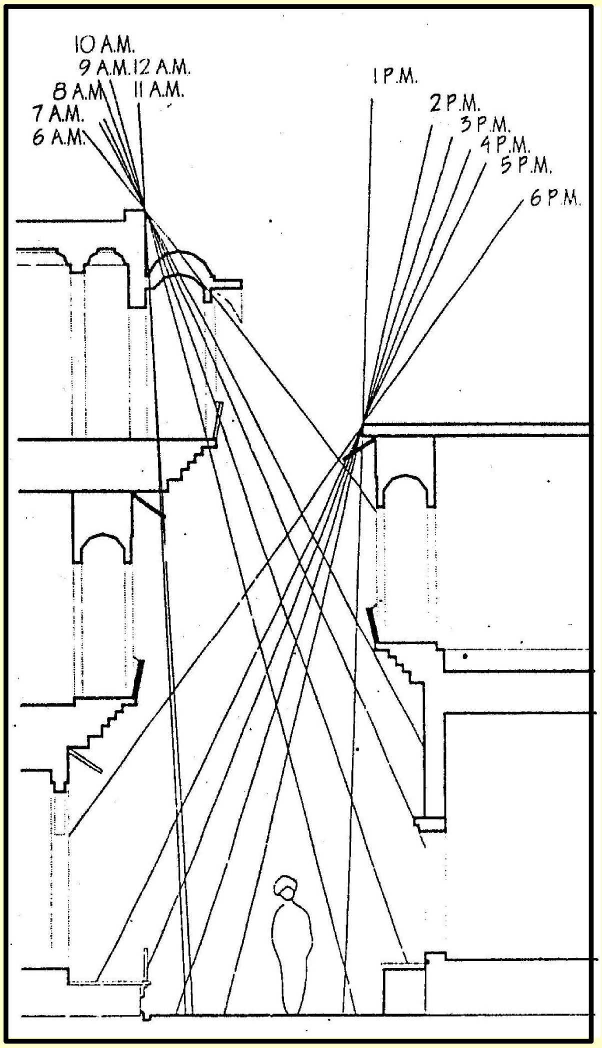
Narrow streets with tall buildings are characteristic of vernacular layouts of hot- arid cities.

They create more shade than wide streets & are useful for shading E & W facade on N & S oriented streets.

JAISALMEER TOWN



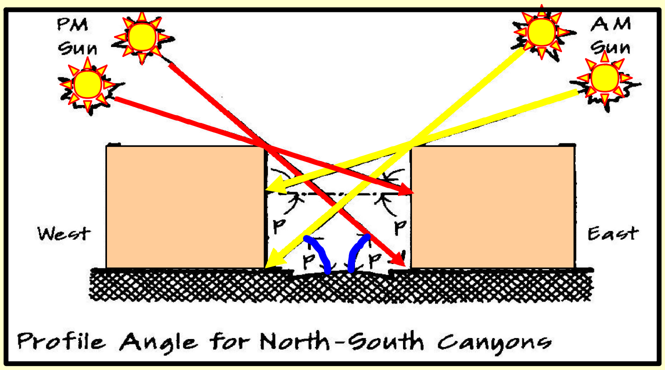




At mid-day, unless the ratio of building height to street width is 4 : 1 or greater, it is difficult to achieve shade.

When the sun is high, horizontal elements like roofs, pergolas, or tree canopies are extremely effective.

STREET SECTION – JAISALMEER, INDIA.



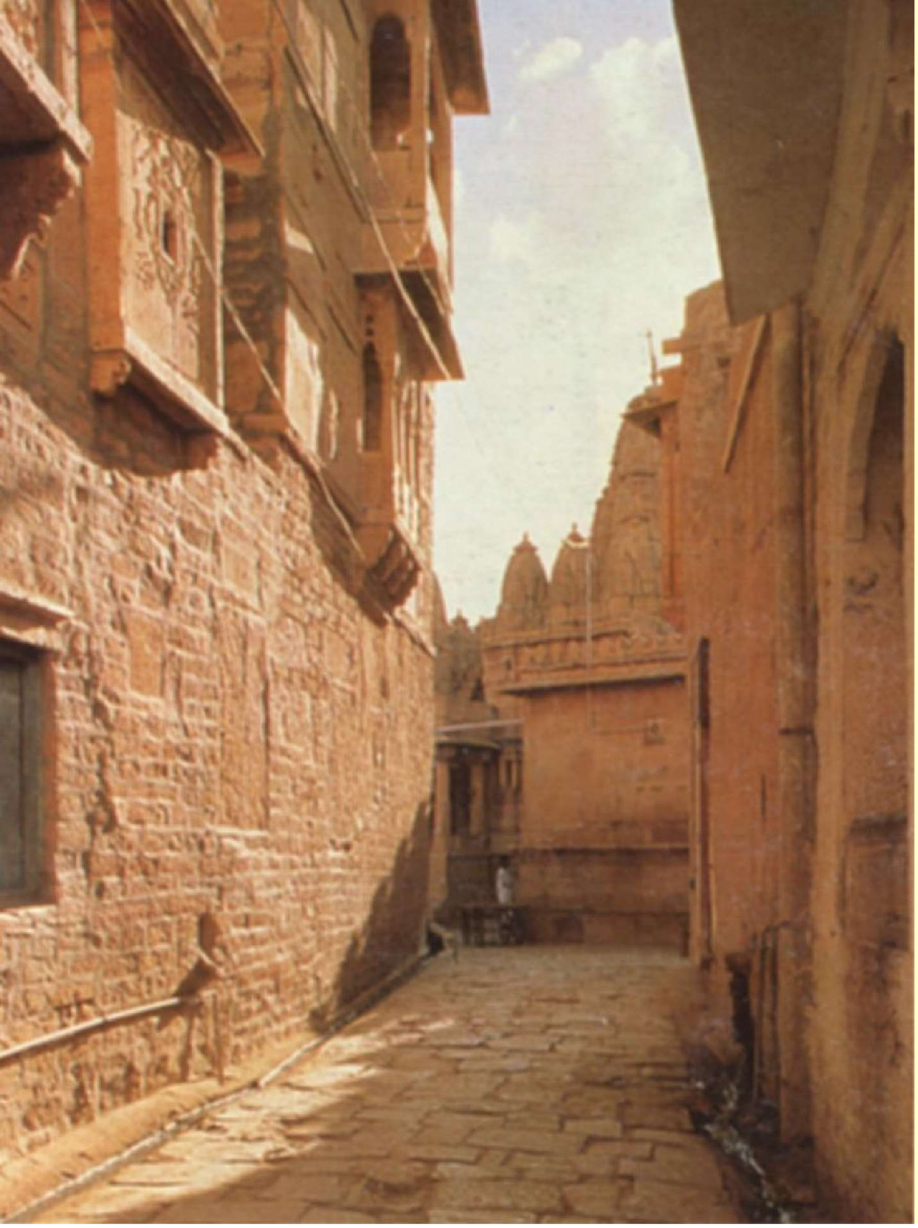
Amount of shade cast by a building on to the street & opposite building is a function of street orientation & width, the building height & the sun angle.

Profile Angles (degrees) for Shading Design in Section of N-S Streets

Lat ⁰ N	6am / 6pm	7am / 5pm	8am / 4pm	9am / 3pm	10am / 2pm	11am / 1pm	12noon
8	3	18	33	47	61	76	90
12	5	20	34	48	62	76	90
16	7	21	35	49	62	76	90
20	8	22	36	49	63	76	90
24	10	23	36	49	63	76	90
28	12	24	37	50	63	76	90
32	13	25	37	50	63	76	90
36	14	26	37	49	62	76	90

In hot climates, narrow shaded North-South streets are more appropriate for pedestrian circulation, outdoor living areas and shopping.

East-West streets, difficult to shade, may be wider and thus appropriate to vehicular traffic, while being shaded by arcades, awnings or other element scale shading devises.



Jaisalmeer Pedestrian Street

Asiad Village, Raj Rewal

GRID ORGANISATIONS:

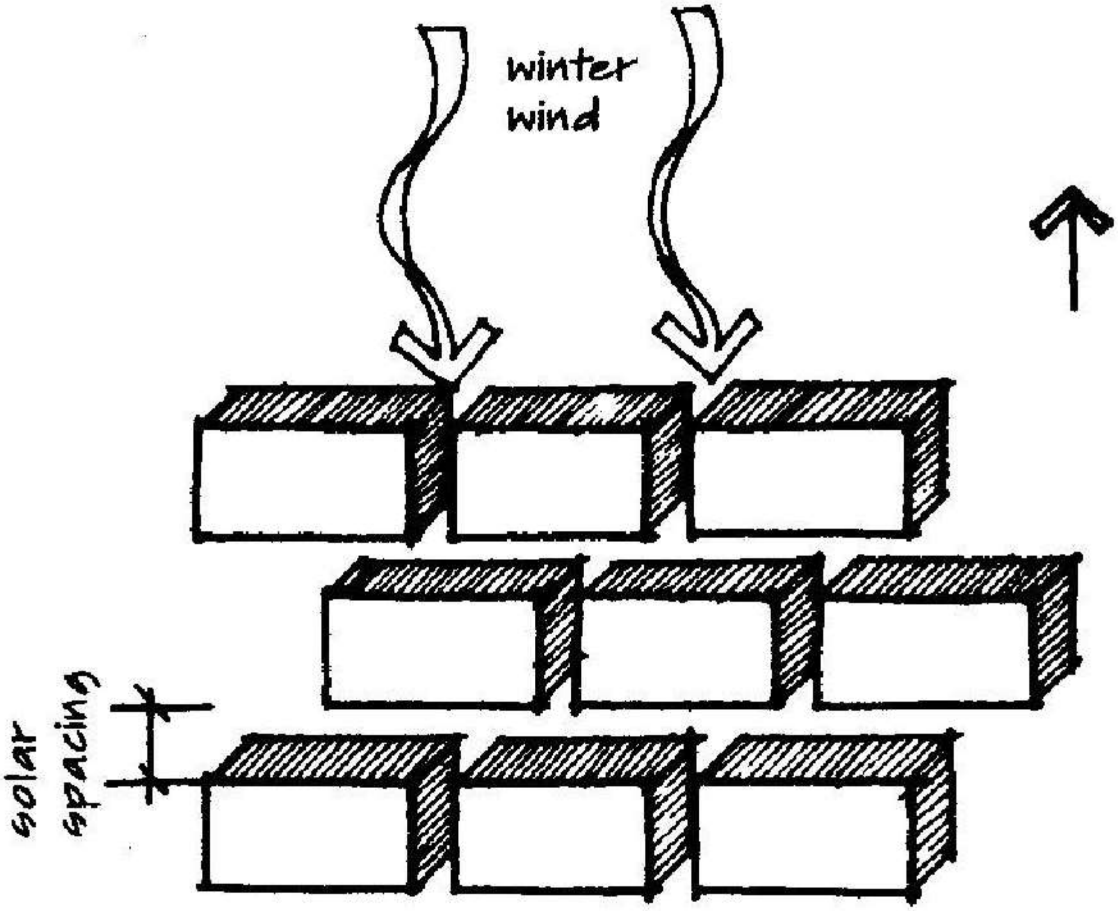
STRATEGY NO. 4:
Balanced Urban Patterns of Streets & Blocks

Streets & blocks can be oriented & sized to integrate concerns for light, sun and shade according to the priorities of climate.
(heating, cooling & day-lighting)

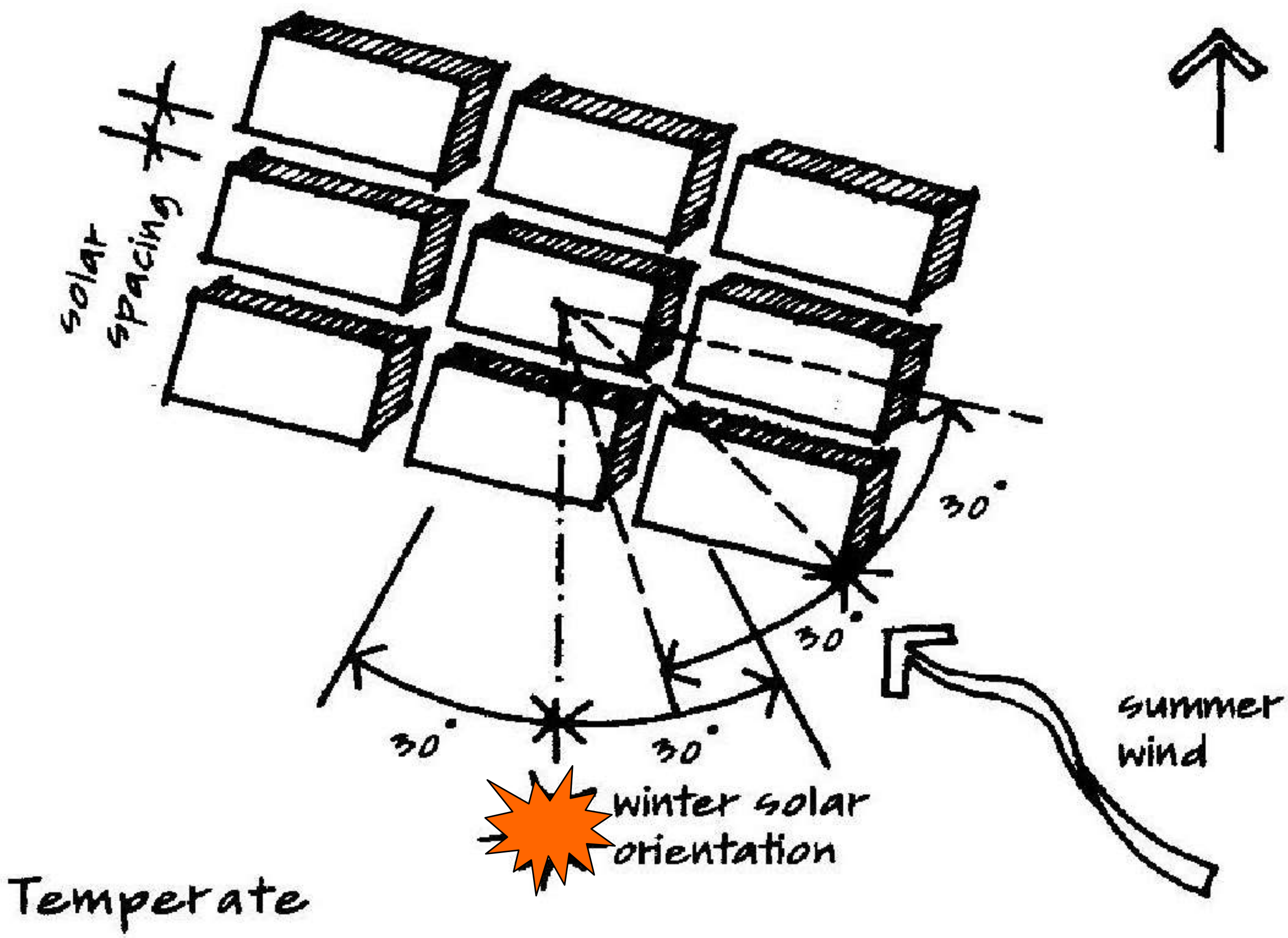
Orientation & layout of streets has major effect on micro-climate around buildings & on access to sun & wind for use in building.

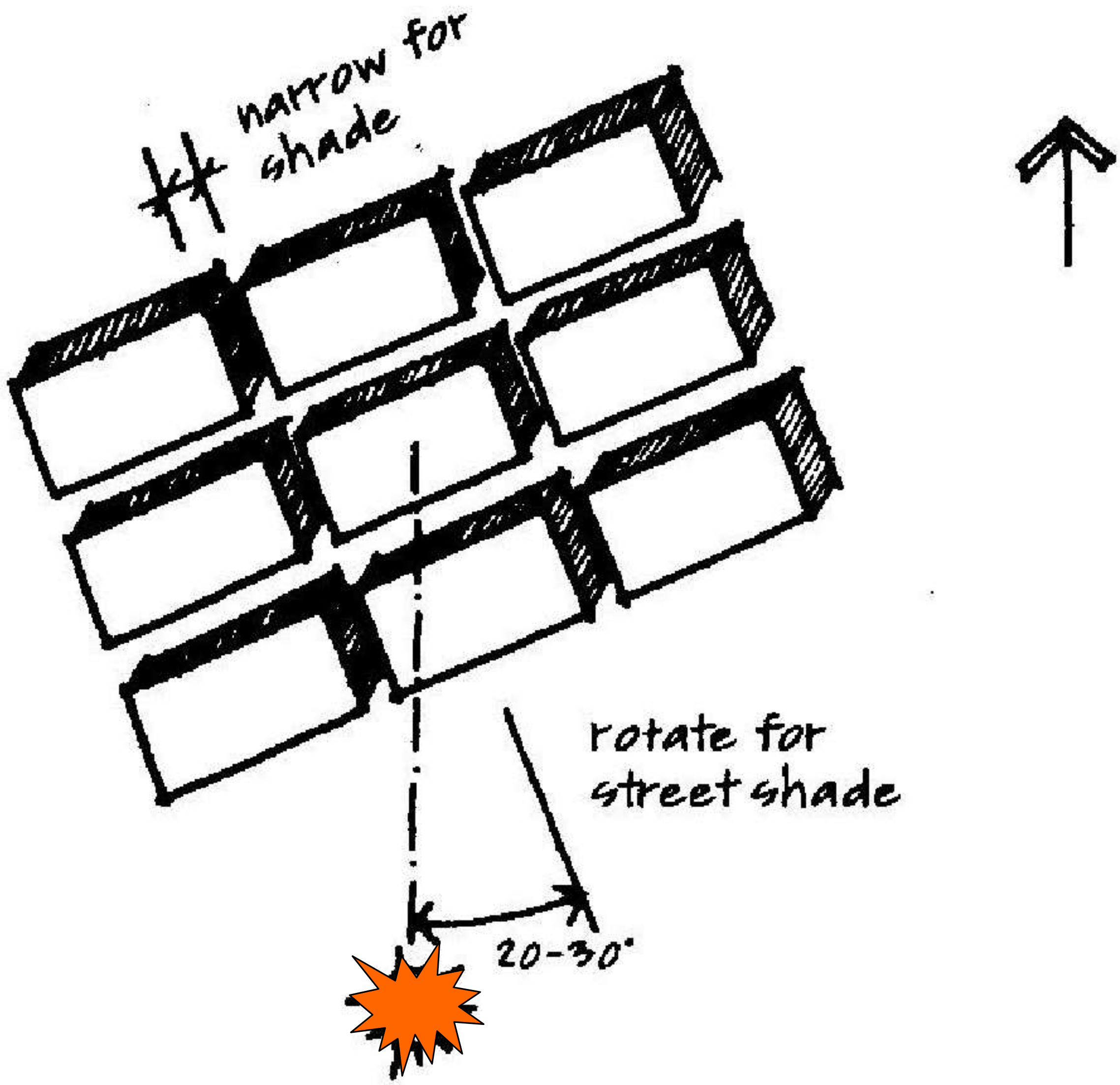
Depending on climate & heat load of buildings, different combinations of strategies may be appropriate. Diagrams show potential generic solutions for a range of climates.

Recommended Urban Patterns in Different Climates

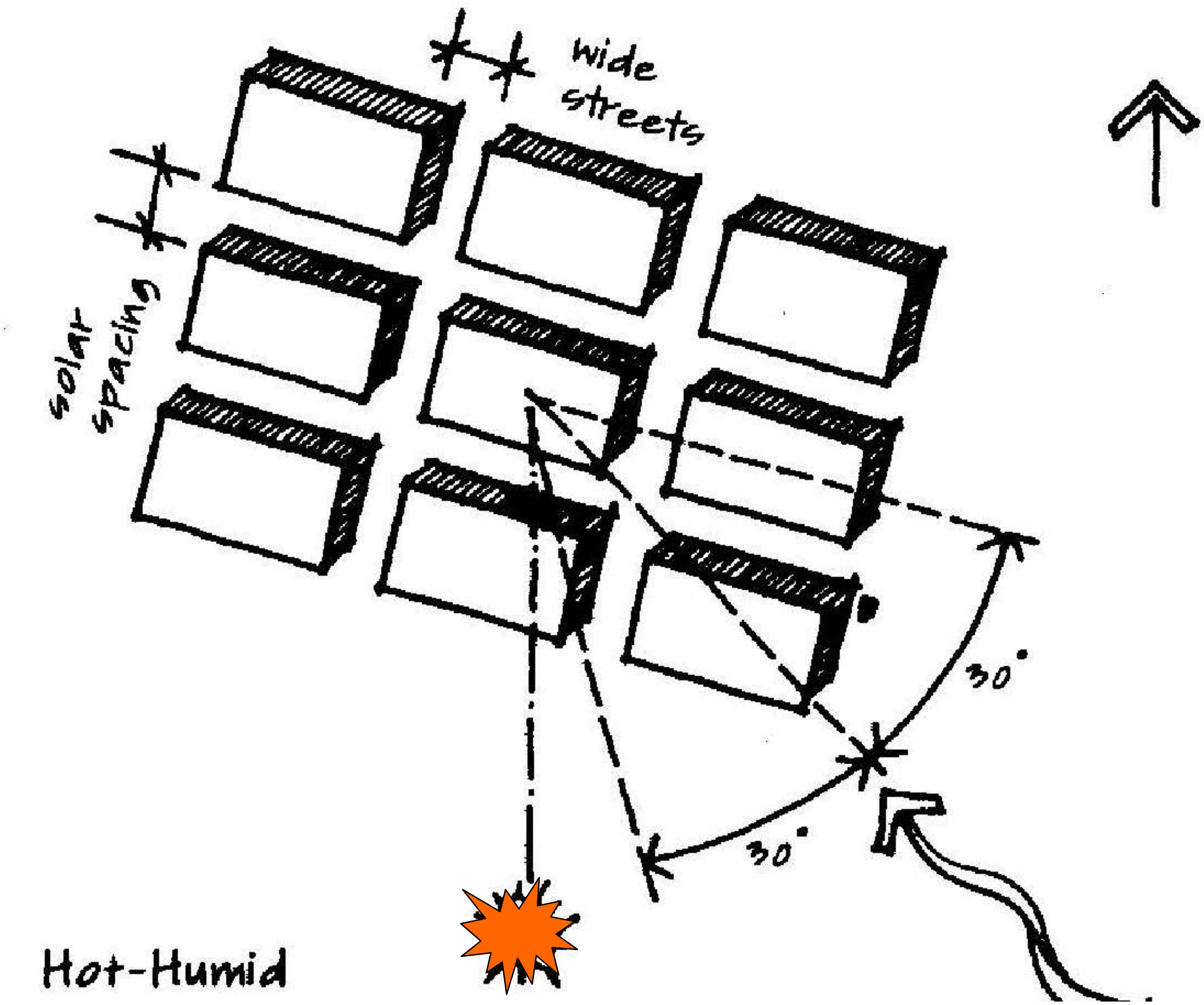


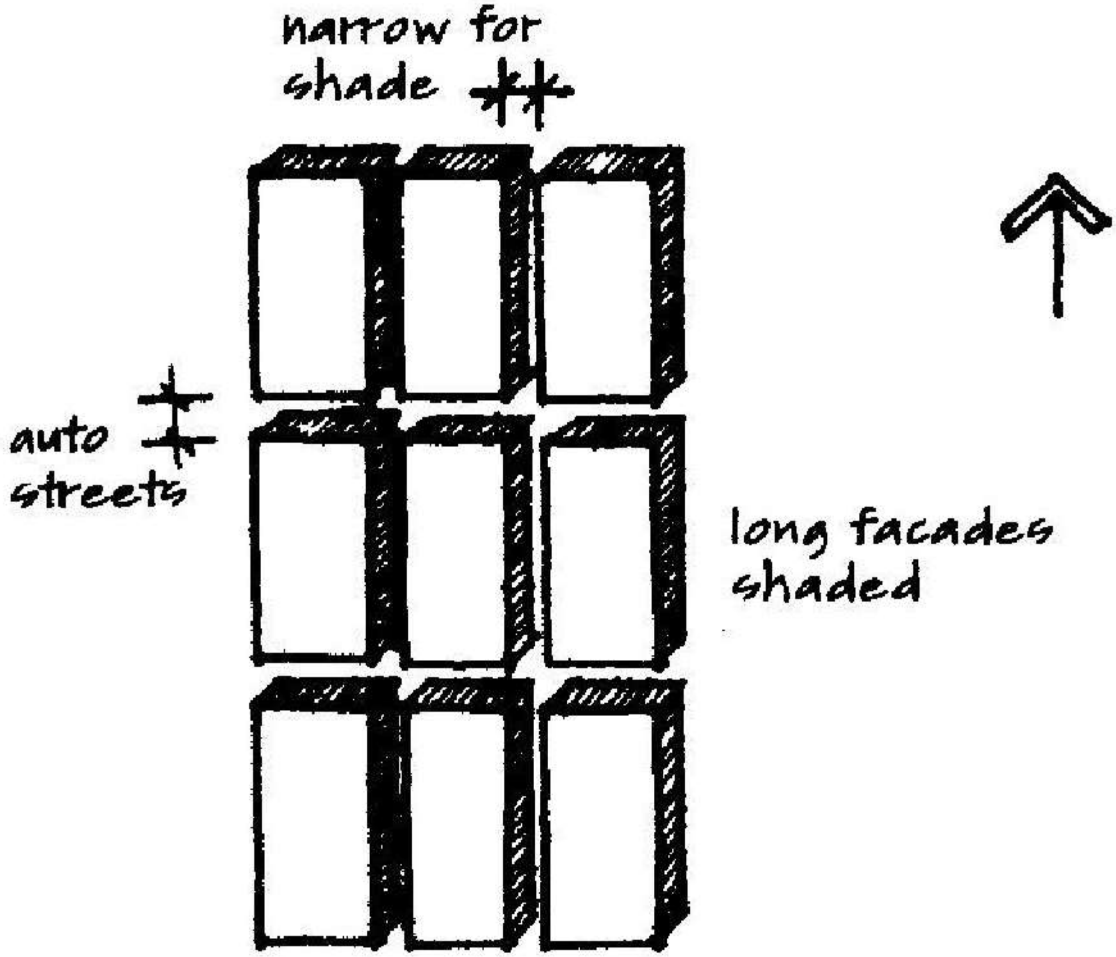
Cold/Cool


solar spacing
30°
30°
30°
30°
summer wind
winter solar orientation
Temperate

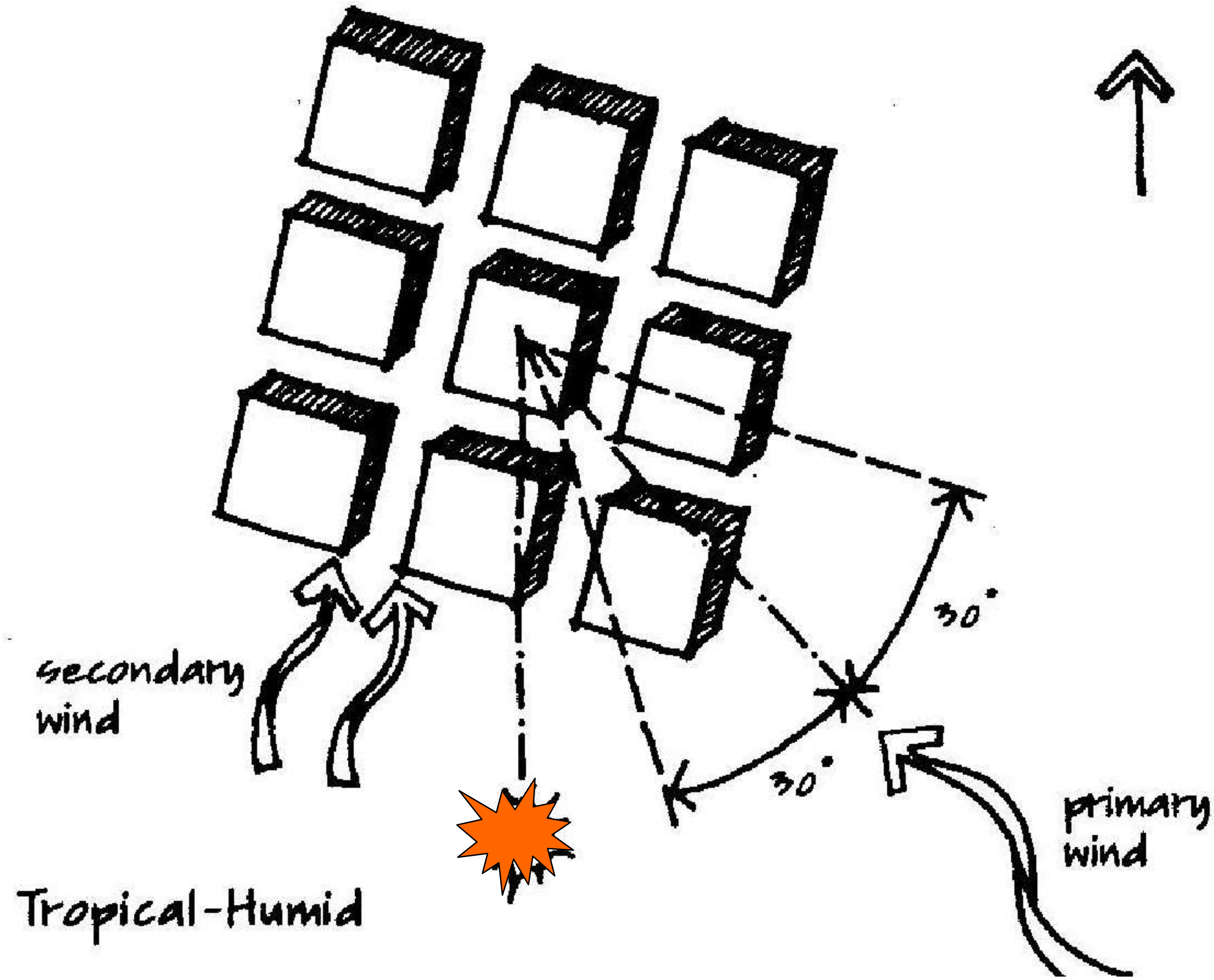


Hot-Arid


wide streets
solar spacing
30°
30°
Hot-Humid



Tropical-Arid


secondary
wind
30°
30°
primary
wind
Tropical-Humid

The table of Street Orientation and Layout by Climatic Priority for specific recommendations by climates.

Building Type IDL Bldgs	SDL Bldgs.	Response 1ST Priority	2nd Priority	Comment
-	Cold	Lee	Sun	Strict cardinal orientation for sun. Discontinuous streets in direction of winter winds. Space E/W streets for solar access for spring and fall
Cold	Cool	Sun	Lee	Cardinal orientation for sun. Discontinuous streets in direction of winter winds. Space E/W streets for solar access at solstice.
Cool	Temperate	Winter sun, Summer wind	Winter Lee, Summer shade	Orient + / - 30^0 from cardinal for sun. Adjust orientation $20\text{-}30^0$ oblique to summer wind. Space E/W streets for solar access, if needed. Elongate blocks E/W.
Temp. Arid	Hot - Arid	Summer shade	Summer wind, Winter sun	Narrow N/S streets for shade. Rotate from cardinal to increase street shading. Space E/W streets for solar access, if needed. Elongate blocks E/W.
Temp. Humid	Hot Humid	Summer wind	Summer shade, Winter sun	Orient streets $20\text{-}30^0$ oblique to summer wind. Modify orientation by rotating from cardinal to increase street shading. Space E/W streets for solar access. Elongate blocks E/W. Wide streets for wind flow.
Hot Arid, Tropical Arid	Tropical Arid	Shade all seasons	Night wind Day Lee	Narrow N/S streets for shade. Elongate block N/S, if E/W facades shaded. Wider auto streets run E/W.
Hot Humid, Tropical Humid	Tropical Humid	Wind all seasons	Shade	Orient streets $20\text{-}30^0$ oblique to predominant wind. Respond to secondary wind direction. Maximise street widths for wind flow, but not paving.

INTERWOVEN ORGANISATIONS:

STRATEGY NO. 5:

Interwoven Buildings & Planting

Organizations of interwoven buildings & planting can be used to reduce ambient air temp. (cooling)

Temperature in densely built up areas, is frequently several degrees higher than in surrounding rural areas, due to heat generation from fuels, increased absorption & storage of solar radiation, poorer radiant sky cooling & reduced wind speed due to surface roughness.

Planted areas can be as much as 6 - 8^0 C lower than built up areas due to a combination of evapo-transpiration, reflection, shading & storage of cold.

When parks are located in dense areas, localised air circulation patterns are created as heated air rises over dense areas of heat island peaks, which is replaced by cooler air from the vegetated areas.

(Chandler, 1976, p. 43)

Chandigad

Studies show that the cooling effect of planting is greatest in the blocks near the open space, but extends into built up areas to a distance of 200 – 400 M.

More smaller open spaces, evenly distributed will have a greater cooling effect than a few large parks.

Studies suggest that for a city of 1 million, temperatures do not start decreasing until the planted surfaces are 10 to 20% of city area.

The study also suggest that cooling rates due to vegetation cover are a function of surface area and that 30% surface area covered with vegetation produces 66% of possible cooling achieved by evapo-transpiration.

Increased water use to irrigate the plantation is an issue in some cities. Trees use less water and provide more cooling than turf, replacing turf with trees is an improvement on both accounts.

(Akbari et al, 1992, p. 55)

DISPERSED & COMPACT ORGANISATIONS

STRATEGY NO. 6 :
Loose & Dense Urban Patterns

Loose urban patterns maximise cooling breezes in hot climates (Cooling), while dense urban patterns minimise winter winds in cool climates (Heating).

Air movement in streets can be either an asset or liability, depending on season & climate. Wind is desirable in streets of hot climates to cool people & remove excess heat from streets;

it also becomes a potential resource to cool buildings by cross ventilation. This is important all time in humid climates & at night in arid climates.

On the other hand, wind reduces pedestrian comfort in cool season & increases infiltration heat losses of buildings.

For summer cooling, streets oriented 20-30^0 to summer winds maximise air flow through an urban area. To reduce wind flows in streets, wind breaks can be used to block undesirable cold winter winds or hot dusty desert winds.

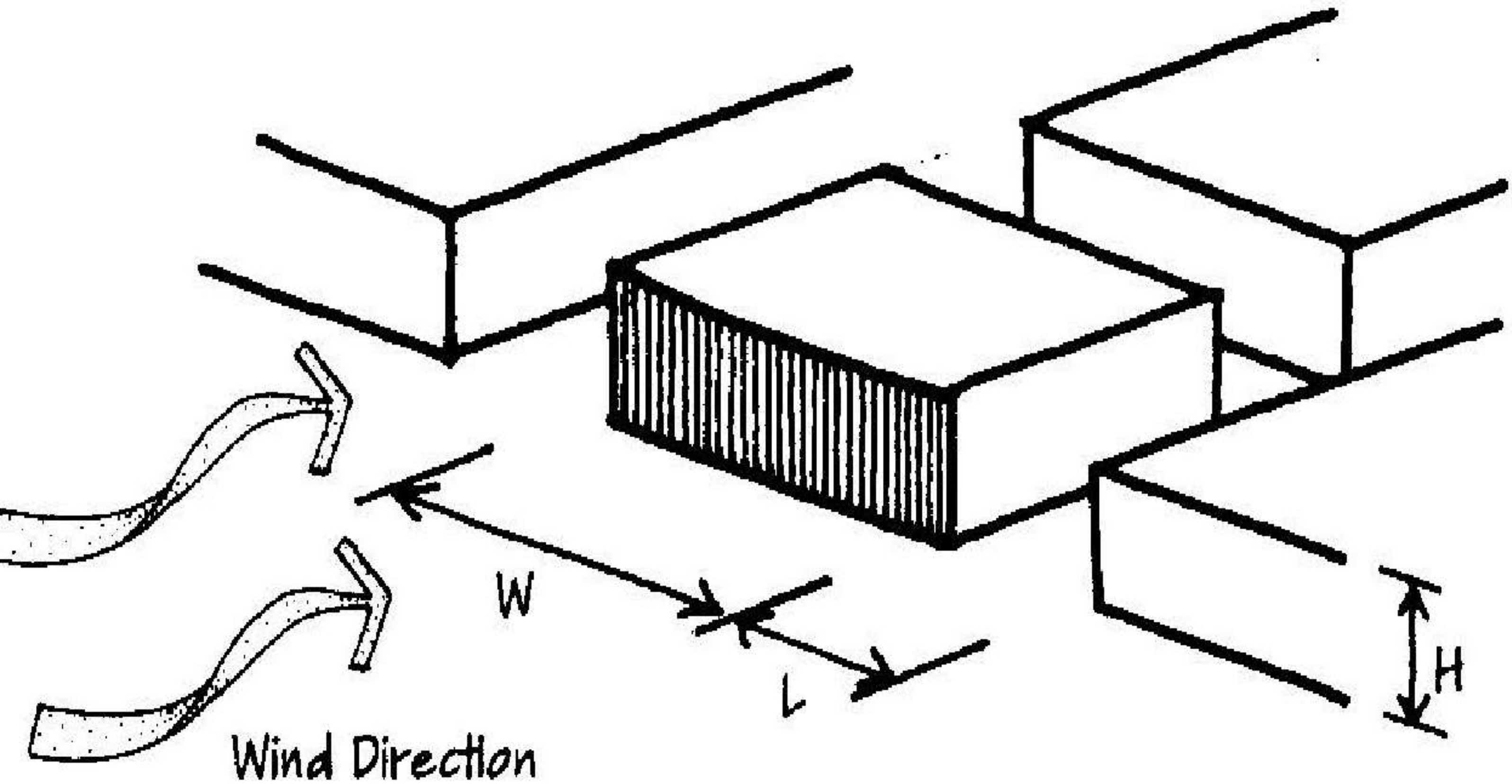
For regular organisations of buildings in an urban pattern, tall buildings on narrow streets yield the most wind protection, while shorter buildings on wider streets promote more air movement.

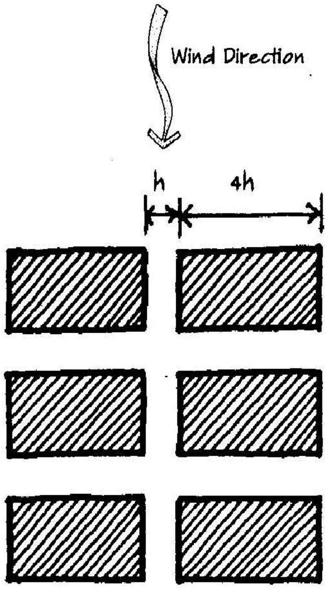
To predict wind velocity in streets refer graph, which shows wind speed in streets as a function of Blockage Ratio (Rb) of a given building group (Wu,‘94,pp.103-107). Blockage Ratio is defined as :

$$R_b = \frac{(W \times H)}{(W + L)^2}$$

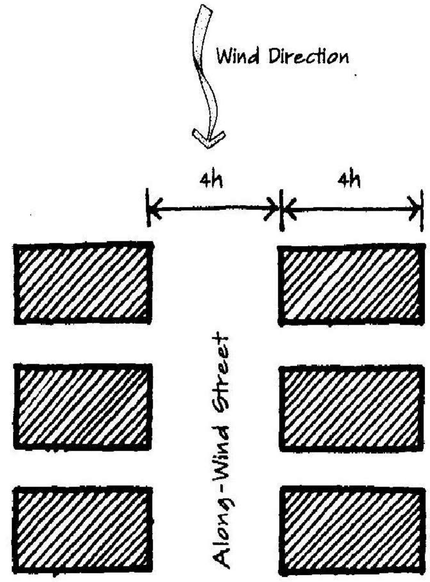
To determine wind speed in streets oriented parallel to wind, first find blockage ratio using either formula above or from calculated ratios from one of building groups shown in matrix.

BLOCKAGE RATIO VARIABLES

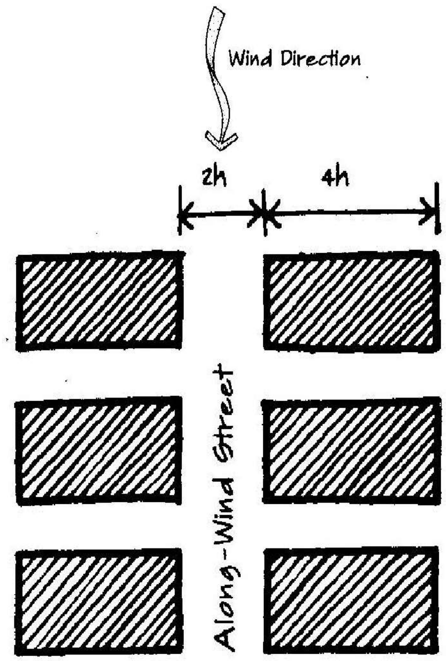




H	R_b
0.5 h	0.08
h	0.16
2h	0.32
4h	0.64



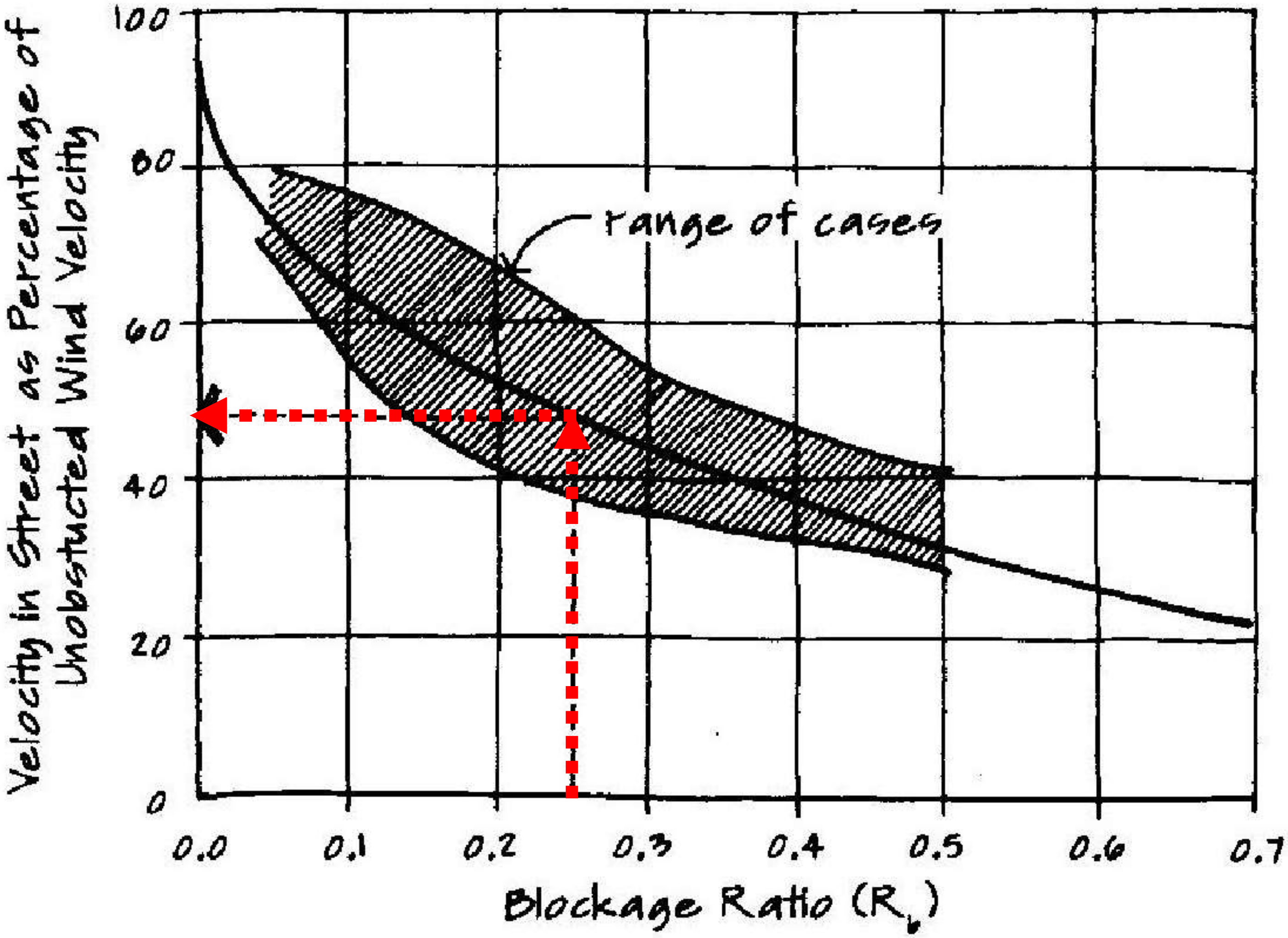
H	R_b
0.5 h	0.03
h	0.06
2h	0.13
4h	0.25



H	R_b
0.5 h	0.03
h	0.11
2h	0.22
4h	0.44

BLOCKAGE RATIOS FOR DIFFERENT ORGANIZATIONS OF BUILDINGS AND STREETS.

Enter graph on horizontal axis with blockage ratio, move vertically to intersect curve, & move horizontally to read on vertical axis predicted average wind speed in street as a fraction of open prevailing unobstructed wind speed. High fractions are desirable for cooling & low fractions for heating



Predicting Wind Velocity In Streets

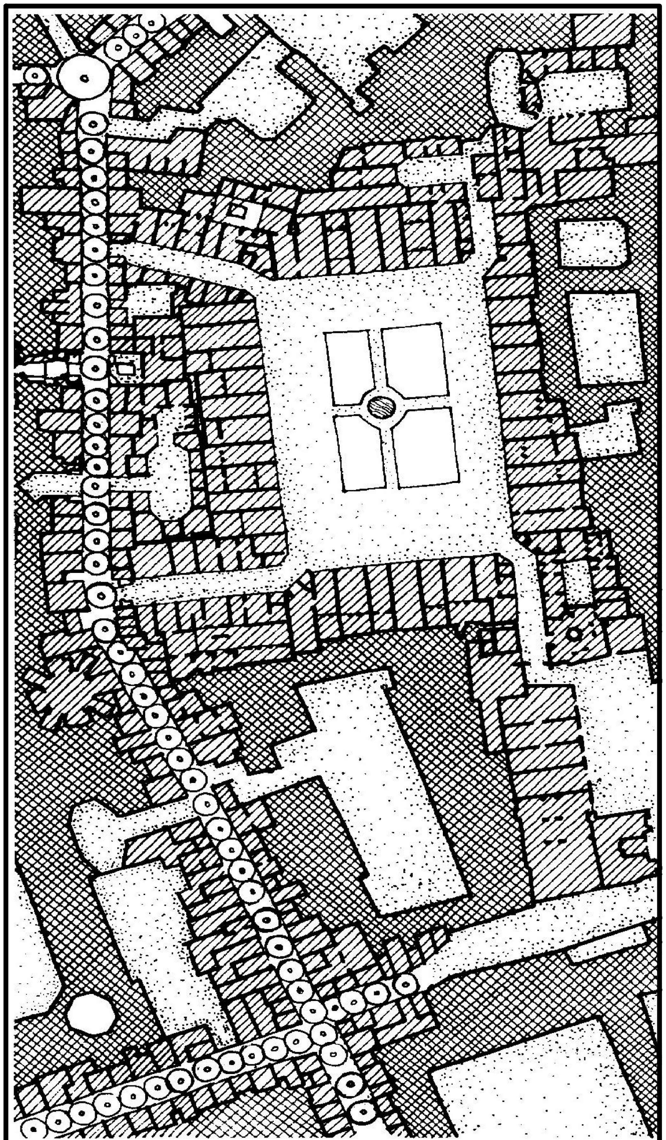
In cool climates, major streets should be oriented perpendicular to winter winds and street net work should use a discontinuous organisations, with many ‘T’ intersections to slow and block wind flow in the streets.

SHAPE AND ORIENTATION

STRATEGY NO. 7 :
Overhead Shades.

A layer of overhead shades can protect out door spaces & buildings from the high sun.
(Cooling)

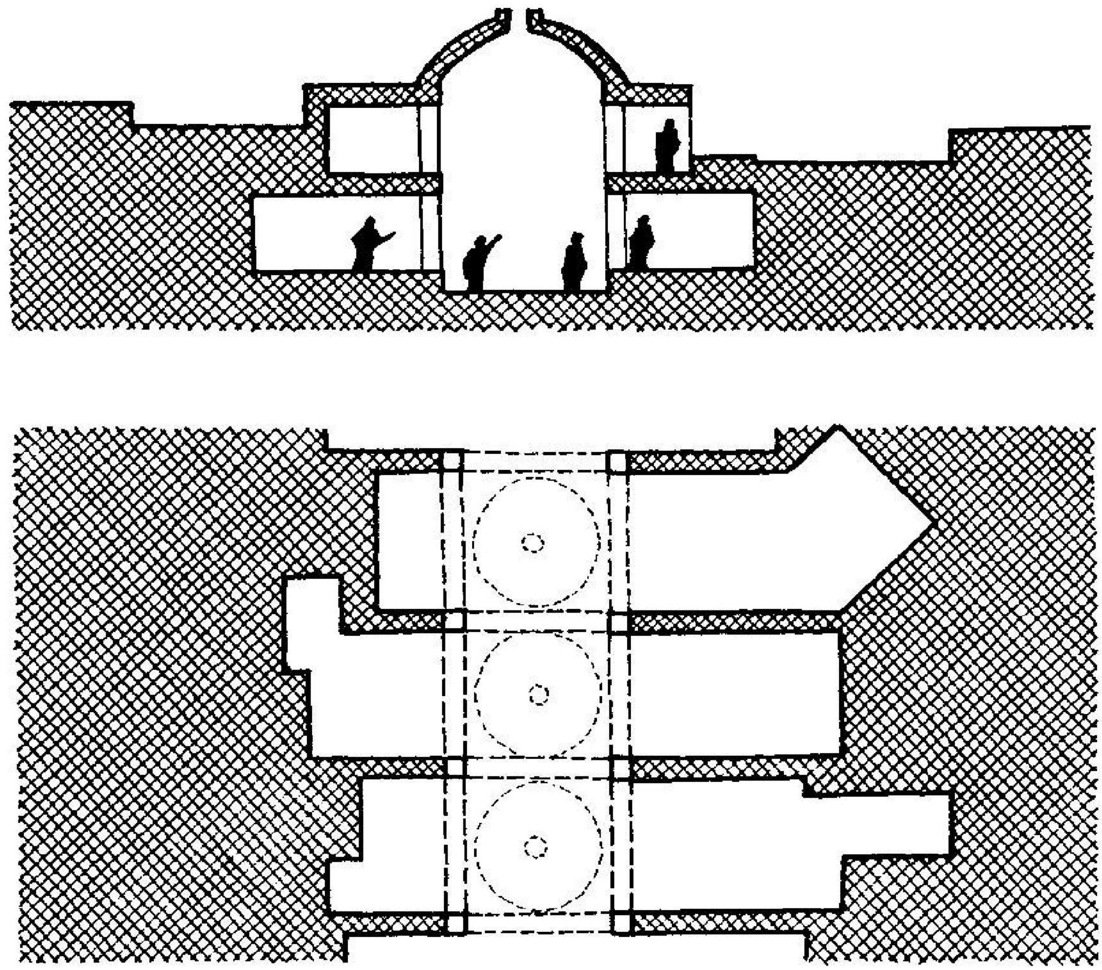
In hot climates, pedestrian streets can be quite uncomfortable unless shaded. Heat absorbing massive elements of paving and facade, high sun angle and intense solar radiation levels all contribute to the potential for extreme conditions.



Partial Plan of Bazaar, Isfahan, Iran

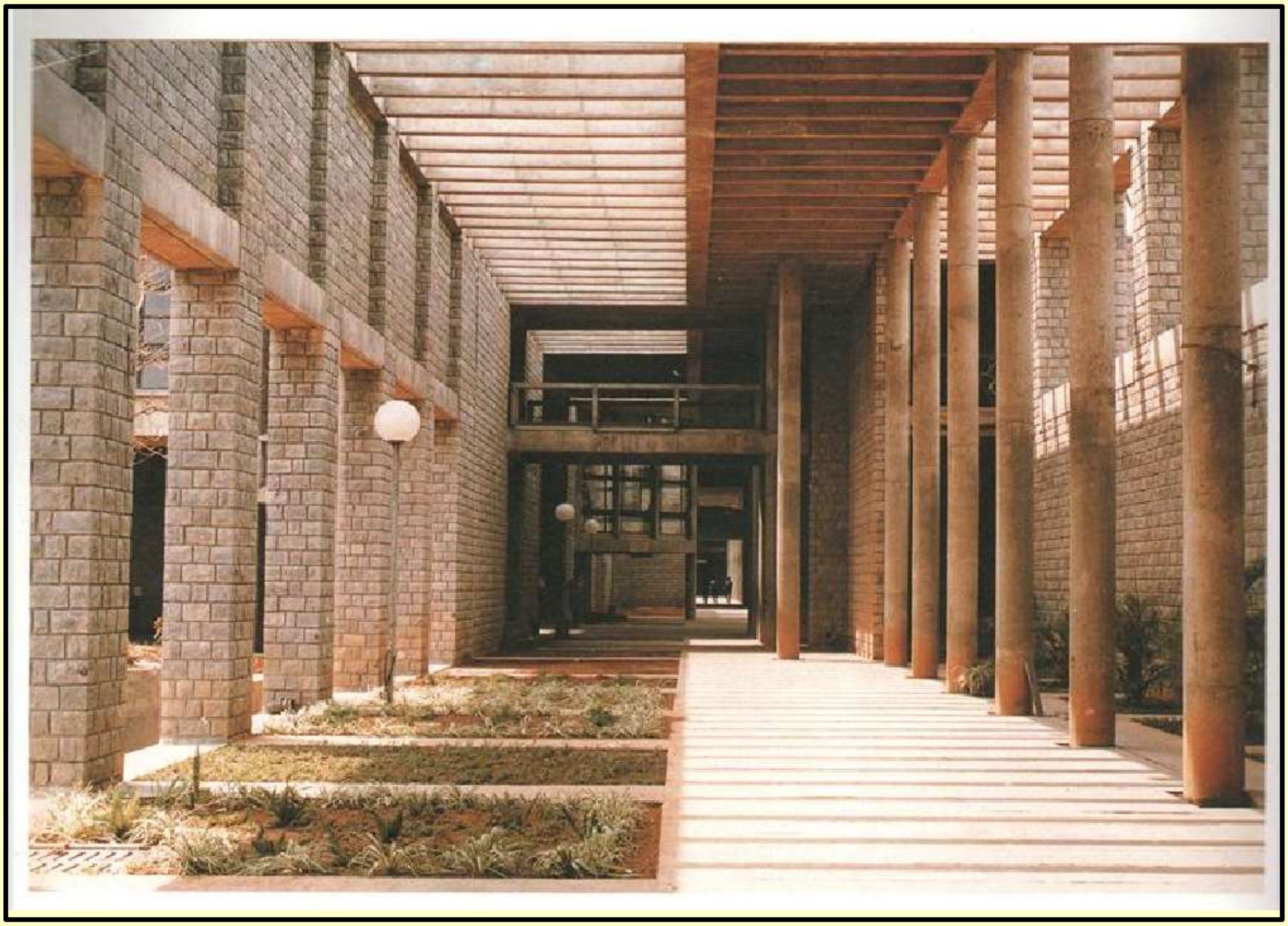
In many hot climates, both humid & arid, groups of buildings may be linked by shaded pedestrian streets or pedestrian may be protected by arcades at edge of streets & open spaces.

In hot arid climates day time protection from hot, possibly dust laden winds is also important, thus circulation can be mostly enclosed.



Typical Plan and Section of Bazaar

Conversely, in hot humid climates, shading should not block ventilation.



SHADED PEDESTRIAN STREET, IIM BUILDING BANGALORE. B.V.DOSHI.

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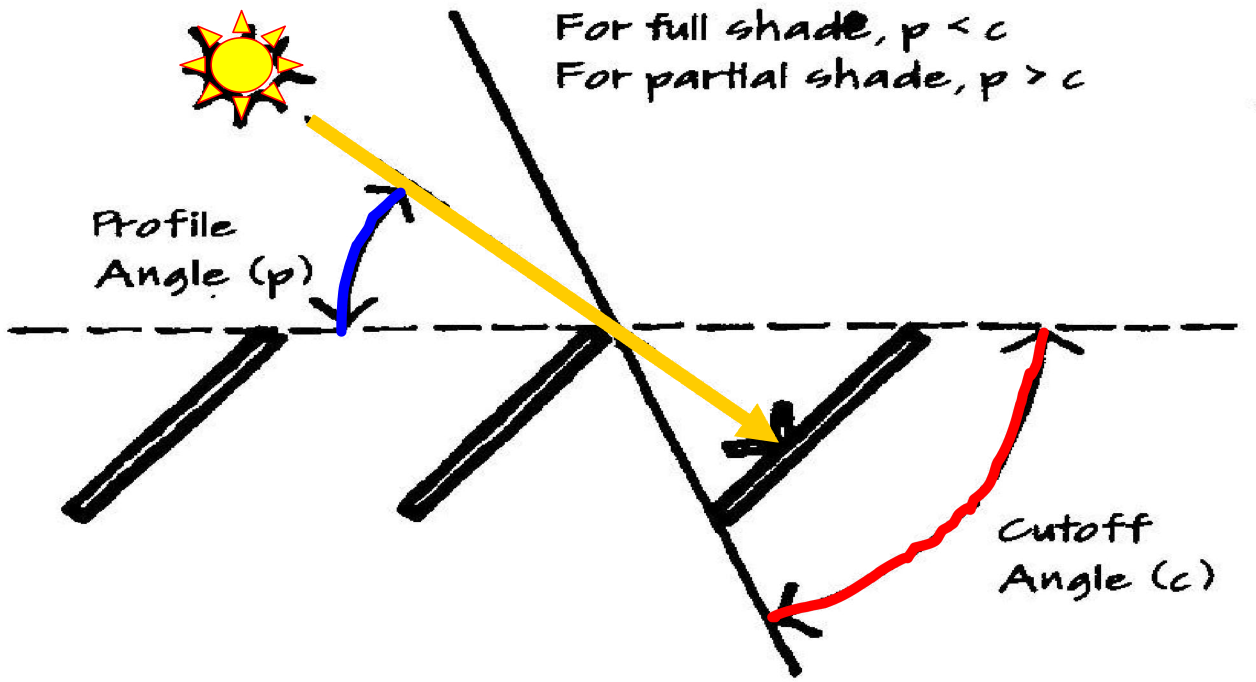
Overhead louvers for shading can shade while admitting light. They must be sized and configured to protect space below.

Louvers can be set at various angles and orientations as long as the cut off angle is greater than the profile angle.

The profile angle is the sectional angle normal to the shading device that will provide full shade. If less than 100% shade is desired, use a cut off angle less than the profile angle.

When the solar azimuth is equal to the orientation of the shading element, the profile angle is equal to the solar altitude.



Geometry of Overhead Louvered Sunshades

For shading between 8 am and 4 pm, for horizontal louvers oriented to south, profile angle is 90^0 (straight over head) for latitudes up to 40^0. In this orientation profile angle is highest in early morning and late afternoon.

For horizontal louvers oriented East-West (along N-S direction) maximum governing profile angle is 90^0 for all latitudes. As a general rule, assuming full sun exposure and no shading of louvers from obstructions:

To provide shading by fixed over head louvers, cut off angle of louver design should be greater than 90^0.

THANK YOU