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### ROLE OF MICRO AND MACRO CLIMATIC CONDITIONS TO ACHIEVE SUSTAINABLE ARCHITECTURE.

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**Abstract:** Sustainable Architecture aims to create environment –friendly and energy efficient indoor and outdoor spaces .This entails actively harnessing renewable natural resources like Solar energy, wind energy, vegetation, water bodies, soil conditions and utilizing materials that cause the least possible damage to the global environmental conditions. The Ninth Plan of the Government of India has taken a lead by stressing the development and improvement of urban areas as economically efficient, socially equitable and environmentally sustainable entities. The rapid growth of urbanization, due to land cost in central urban area, the horizontal expansion and development became difficult hence the concept of vertical development in every town and city (i.e. multistoried residential and commercial structures) has imposed immense pressure on dwindling energy sources and other vital resources like water which are resulted to un-sustainable environments. It means it is creating a barrier between Man and Nature. One cannot prevent vertical development as it is related to fulfillment of one of its basic need but by protecting, providing, planning and designing the Micro and Macro level climatic conditions, the balance between Grey and Green Architecture can be re-established. In this paper it is explain through existing case studies the appropriate provision and existence of Natural Climatic factors which are generating the sustainable architecture from region to town and from town to house.

**Keywords:** Environment-friendly, Micro, Macro, Urbanization, vegetation, water bodies, anthropogenic, GHG's.



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## 1. INTRODUCTION

**1.1 Macro and Microclimate:** The term Macroclimate is related to global or regional climatic conditions which are going to affect the variation in temperature, humidity, precipitation, sky conditions, air movement, solar radiation, soil condition etc. around and on the Earth surface. The Micro climate is different than global or regional climate. Every city, town, village and a precinct in a town may have its own climate. The synonymous term use for Micro climate is to generate the comfortable living conditions with respect to thermal comfort and humidity. The botanist may consider the 'micro-climate' of a single plant leaf, with its temperature and moisture conditions, its population of insects and micro-organisms, on the scale of few centimeters but for the Urban Planner or Urban Geographer the term Microclimate may mean the climate of whole town or city and for an Architect site climate is synonymous to Microclimate (1). The Macro and Microclimatic conditions are depends upon the Natural climatic factors which are as follows:

a) Earth Sun Relationship

b) Global trade wind patterns:

c) Altitude, latitude, longitude:

d) Topography: i.e. slopes, orientation, exposure, mountains, valleys or hills, at or near the town or site.

e) Ground surface: Natural or man-made with its reflectance and permeability, soil conditions and its temperature.

f) Vegetation: Forest coverage percentage within a region, trees, shrubs, grass, etc. within a town or site.

g) Water bodies: Location and orientation of Oceans, Seas, Rivers, Lakes, Ponds, etc. nearer to a region, within or surrounded.

h) Urban-scape: High rise, low rise or multistoried structures generating urban heat island.

i) Anthropogenic: Emission of Greenhouses gases by Human activities.

The above climatic factors are governing the type of climatic conditions on the earth surface with tropical or temperate climatic zones at Macro and Micro level. The regional climatic data is useful to generate the Macroclimatic conditions by utilizing the favourable climatic features

and to mitigate the adverse features through appropriate planning and designing of indoor and outdoor spaces. The designer will get the positive impact of Macro level climatic conditions to generate the appropriate Micro level climatic conditions at city, town, village or site level by considering the favourable climatic features.

1.2] Global Warming and Climate Change: The climate system consist of five components: Atmosphere, Ocean, Cryosphere (ice), Biosphere and Geosphere. The fundamental processes driving the global climate system are heating by incoming short-wave solar radiation and cooling by long wave radiation into space. If the Earth had no atmosphere, the average temperature at the surface would be well below freezing. The Earth’s capacity for absorbing and assimilating most human generated pollutants is large, but limited. The pollution rate raised due to increase of human activities, leading to emission of higher level of greenhouse gases in the atmosphere. The main GHG’s are water vapour, CO<sub>2</sub>, (Carbon dioxide: 55%), CH<sub>4</sub>, (Methane: 15%), N<sub>2</sub>O (Nitrous Oxide:6%), CFC’s other CFC’s (Chlorofluorocarbons: 24%) (Fig.1). With the exception of water vapour, all other gases are generated through anthropogenic sources. However the human activities are termed anthropogenic which lead to climate change and this is referred as enhanced greenhouse, effect and more commonly known as Global Warming.

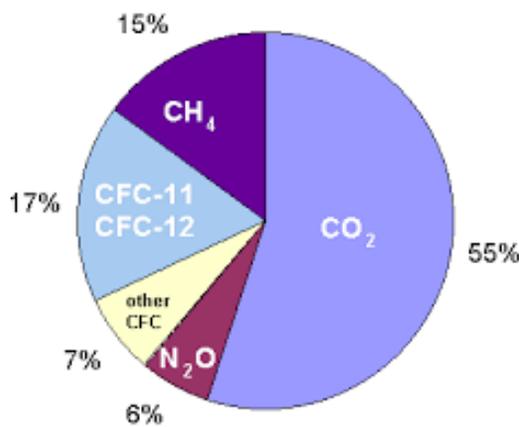


Figure 1: The greenhouse gases composition

Figure 2: Global warming from 1980 to

1990.Source: IPCC, 1990

The terms global warming and climate change are often used co-tremendously, but the two phenomena are different. **Global warming** is the rise in global temperatures due to an increase of heat-trapping carbon emissions in the atmosphere. **Climate change**, on the other hand, is a more general term that refers to changes in many climatic elements (viz. temperature and precipitation) around the world (Fig.2). These changes are happening at different rates and in different ways. The world mostly agrees that some- thing needs to be done about global warming and climate change. The first stumbling block, however, has been trying to get an agreement on a unanimous framework. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to assess the scientific knowledge on global warming. The IPCC concluded in 1990 that there was broad international consensus that climate change was anthropogenic. That report led the way to an international convention for climate change namely the United Nations Framework Convention on Climate Change (UNFCCC), signed by over 150 countries at the Rio Earth Summit in June 1992 [3].

Intergovernmental Panel on Climate Change reported that greenhouse gas (GHG) concentrations in the global atmosphere were rising as a result of human GHG's emissions, principally from fossil fuel burning. This is clearly a 'global problem'. There is yet another dimension to the global problem. While the global dependency on fossil energy for economic growth remains nearly 100% at this time, the IPCC also noted that cuts in GHG's emissions in the order of 60% to 80% were required immediately if rising atmospheric GHG's concentrations were to be stabilized just at the present raised values .If policies to reduce CO<sub>2</sub> emissions from current level are not implemented, the average global surface temperature will rise by about 2 degree C between 1990 A. D. to 2100 A.D. [3].The climate change will impact agriculture and forestry, natural terrestrial ecosystem, hydrology and water resources, human settlements, energy, human health, air quality, oceans and coastal zones, seasonal snow cover, ice and permafrost.

**2] Urban Heat Island:** Today, the towns in India seem to have acquired the status of 'Concrete Jungles' having less regard for social environmental aspect. Almost all the Cities and towns are characterized by congestion, noise, air and water pollution, squatter and other discomforts. The size and density of the built up area affect the " heat island" phenomenon, namely the creation of higher air temperature within dense urban areas as opposed to the surrounding low- rise built up areas, or open country. This phenomenon is due to the absorption of a high percentage of solar radiation by the built mass, its storage and emission of greenhouse gases by human activities. It is amplified by high density and high-rise constructions, which minimize radiative heat losses. The magnitude of the heat island also depends upon the time of the day, as well as

wind and sky conditions, coverage of vegetation and water bodies. During the day the denser parts of the city may rich temperature higher by 1-2 degree C (and even more) than the surrounding country, while during night the air temperature may be higher than 5 degree C in the denser areas of the city. The built up area enclosing wide open spaces will heat up fast during the day, but also cool fast at night, while denser areas, even if low rise will perform in a different manner (Fig 1)[11].

The situation is no better in the rural settlements. There is an indiscriminate destruction of forests, soil erosion, water pollution, desertification and degradation of hygienic conditions which have placed man and his environment quite apart, giving rise to disharmony and gloominess. The balance between man and environment could be achieved through assigning social values based on maintenance of ecological integrity and realization of local needs of various land uses such as agriculture, conservation of natural resource, water bodies, forest and vegetation, recreation, residential, public and semi-public,

### Udaipur – A Lake City

Commercial and industrial to generate sustainable comfortable living environment at Macro and Micro level (FIG 3).

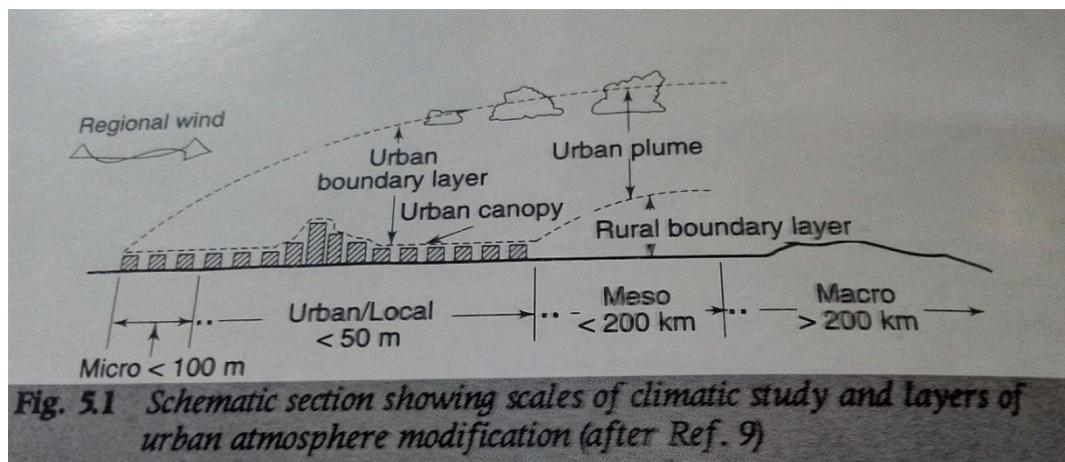


Figure 3: Local climates are influenced by the Regional Macroclimate

(Source: Isaac A Meir, Settlement Pattern and Site planning, 2001.)

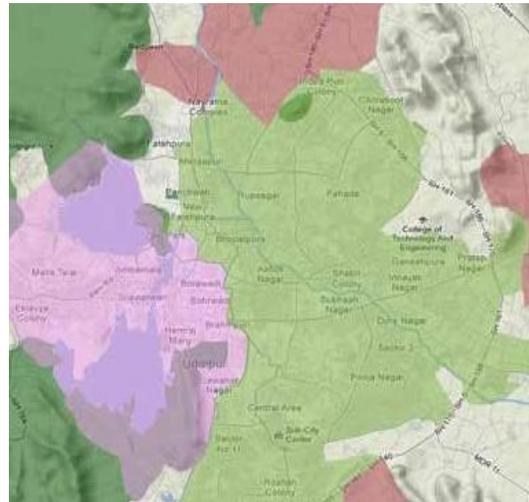
**2.1] Integrated Planning:** The environment has little to do with political boundaries established by different communities at global level. Therefore it is necessary to create a balance between

nature, technology, economy and sustainability which requires an integrated approach to environmental and urban planning at Global and regional level.

The following are the aspects of planning where integration is required

1. Functional and Organisational
2. Territorial / Spatial
3. Temporal

Functional integration refers to the integration of space, economy, environment, society and organizational system.



Territorial integration encompasses four levels of planning:

- a. National Planning
- b. Regional
- c. District/ Block planning
- d. Local planning.

The Temporal Integration which is usually neglected in planning must be considered along with other aspects of planning. Public participation has been a desired goal in development of physical plan. Very little has been accomplished in this regard. Importance towards this aspect should be given to produce a harmonious co-existence of man and nature which would bring out the integration between the various levels of planning in a coherent 'whole' which ultimately will discourage the disparities at the national, regional, local and village planning programmes (12).

## 2.2) Sustainable and Vernacular Architecture:

**Energy consumption:** Energy consumption in building is one of the most important parameters next to industrial sector in India. The building sector in India consume about 33 percent of the total electricity consumption, of which residential sector accounted for 25 percent and the rest

8 percent is accounted for commercial sector. However, the per capita energy consumption in India is one of the lowest in the world. The per capita energy consumption is just 566 kWh for India. Energy has been one of the most crucial parts of our life but most of the energy is obtained from non-renewable resources that is from coal and petroleum which are depleting at a faster rate and may exhaust in few decades. Simultaneously the energy generation through non-renewable sources emitting GHG's in the atmosphere leading to higher absorption of solar radiation enhancing global warming effect. Hence it is essential to adopt the sustainable and environment friendly renewable sources for energy generation to reduce CO2 emission.

**Sustainability:** The UNCED earth summit in Rio, June 1992 it was agreed by consensus that we must change to a pattern of sustainable development, one that respects the ecological balances of our planet. Sustainability applies to actions or developments that preserve the global environment and its non-renewable resources for present and future generations. The word sustainability relates to 'Green Architecture', 'Environmental Architecture', 'Eco-friendly Architecture' means the built and unbuilt spaces or indoor and outdoor spaces which should be based on minimal impact on the environment and use of renewable energy resources with Passive solar architecture planning and design features to generate appropriate micro climatic conditions which will enhance the quality of living environment. It means Sustainable Architecture aims to create environment –friendly and energy efficient indoor and outdoor spaces .This entails actively harnessing renewable natural resources like Solar energy, wind energy, vegetation, water bodies, soil conditions and utilizing materials that cause the least possible damage to the global environmental conditions. The Ninth Plan of the Government of India has taken a lead by stressing the development and improvement of urban areas as economically efficient, socially equitable and environmentally sustainable entities.

**Vernacular:** the Latin word 'Vernaculus' means native. "Architecture is vernacular when it exhibits all of its criteria related to the 'native context' in the sense that it can only be acceptable and recognizable within any particular society by applying some particular technology materials, social rules and systems". Oliver P (1987) states that "It is a term used to categorize methods of construction which use locally available resources to address local needs.

Vernacular architectural buildings and settlements based upon the local climate and geographical conditions are still sustainable with all respect. Study proves that the planning of Jaisalmer city which is in hot dry desert climate, a unique example of a whole city designed to respond to its hot dry desert context. Whereas the entire city through its street patterns, thermal mass and mutual shading creates a comfortable urban environment, each house

enhances the experience by way of thermal mass and courtyards. A study of street section design response to solar geometry reveals a sophisticated relationship between street width, building height and projections to create a cool shaded environment in hot summers by mutual shading. This is the example of solar passive architecture to generate comfortable living spaces by creating micro climatic conditions.

- **Micro-climate analysis:** The data indicates the energy consumption in building sector which leads to serious environmental problems because of excessive consumption of energy and other natural resources. Hence, an architect and planner can achieve energy efficiency for built and unbuilt spaces by studying the existing macro and micro climate of the region or site, applying bioclimatic architectural principles and solar passive architectural features to combat the adverse condition and advantage of desirable conditions. Following are the common planning and designing factors that directly or indirectly affect thermal conditions in tropical climatic zones.



- Vegetation (landscaping)
- Waterbodies
- Orientation
- Plan form and Built-up form
- Ratio of built form to open spaces
- Building envelop and fenestration

#### **Vegetation:**

#### **GULABH BAGH**

**Gulab Bagh** (Sajjan Niwas Garden) is the largest garden in Udaipur. It is spread over 40 hectares and has innumerable varieties of roses, from which it gets its name. It acts as a micro climate modifier.



**VEGETATION& ORIENTATION (Source: TERI)**

- Shading and evapotranspiration (the process by which a plant actively moves and releases water vapour.)from trees can reduce surrounding air temperature as much as 5°C
- Ground cover planting not only reduces glare but also can lower the temperature near the ground by approximately 6°C through evapotranspiration ( the loss of water from the soil by evaporation and by the transpiration pf the plants)
- Trees and shrubs can be selected in position to moderate the cold penetrating winter winds particularly on large exposed sides and can also assist in capturing cool summer breezes.
- A windbreak is an obstruction perpendicular to wind flow that alters the wind direction. Large dense trees and shrubs can be used as windbreaks to the northeast to counter cold winter winds and creates channel to summer breezes.
- Wind channels are designed to guide a circulation. The trees should be oriented in such a way so that the deflected wind is funneled into a desired area or space without decreasing the initial velocity. Deciduous trees with dense canopies can be used to create wind channels.

**Water Bodies:**

- Water is a good modifier of micro climatic conditions especially in hot and dry climate because its stores large percentage of solar energy incident on the water surface and a small percentage is radiated off. It takes up large amount of heat in evaporation and generates significant cooling in hot and dry climate. At the same time, while a small percentage of solar radiation incident on the land surface, a large percentage of same energy is radiated back into the atmosphere.
- The presence of water bodies in the form of rivers, lakes, ponds, streams, cascades at a regional level or adjacent to site, lower down the temperature of the surrounding air and helps for thermal balance of that region due to faster evaporative heat loss and hence it is helpful to maintain thermal comfort.
- Water conservation and management can be achieved by rain water harvesting through surface and roof channels by accumulating in lakes, ponds, etc; and after treating, it can recycle and reuse for drinking and irrigation purpose.

- The micro-climatic conditions that are generated by the Rana's and Maharana's before 600 years in Udaipur city by constructing the eight major lakes and they are interlinked with each other to conserve the limited natural water resource for drinking purpose as well as to achieve the thermal comfort in the semi-arid regions. This is the world's oldest example of "Conservation of water Management" with respect to geographical and climatic conditions (15).
- **Building form /surface-to-volume ratio:** The surface area to volume [S/V] ratio is an important factor determining heat gain and loss. The greater the surface area the more heat gain / loss through t. So small S/V ratio imply minimum heat gain and minimum heat loss. In Hot-dry climate S/V ratio should be as low as possible as this would minimize heat gain which will reduce air-conditioning energy. In cold-dry climate also S/V ratios should be as low as possible to minimize heat losses. In warm humid climates the prime concern is creating airy spaces. This might not necessarily minimize the S/V ratio.

The plan form and built form affects the airflow pattern around and through it. The air tends to flow from high pressure to low pressure spaces hence the appropriate plan form with open spaces channelizing the direction of air movements. The building openings connecting the high pressure areas to low pressure areas generates natural cross ventilation.

**Orientation:** In hot- dry climate the prime aim is to minimize the heat gain. This could be achieved by cutting off the solar radiation. The amount of direct solar radiation received on the street is determined by the street width. The solar altitude azimuth angles determines the position of the sun at all times. The street width to building height ratio determines the altitude up to which solar radiation can be cut off similarly the street orientation determines the azimuth up to which solar radiation can be cut off. The building orientation determines the amount of radiation it receives accordingly the plan and built form to be plan and design (4).

**Open spaces and Built- up form:** The open spaces are the requisite of any urban space. They have to be considered with built- form. Together they can allow for free air movement and increased heat loss or gain. The open ground with greenery and grass is useful to absorb more heat than hard ground. Shading by surrounding buildings and trees reduces heat gain. The plan form of building affects the airflow around and through it. A large perimeter/area ratio means that a small area is being bounded by a large perimeter. Greater the P/A ratio, greater the radiative heat gain during the day and greater the heat loss at night. Similarly smaller the P/A ratio, lesser will be heat gain during the day and lesser the loss at night (2).



### Passive solar features of WALMI building, Bhopal.

In the northern hemisphere by understanding sun path diagram the sun is tilted towards south in most the months of the year hence it is essential to generate plan form and built form which will receive less solar radiation on the surfaces of the building to reduce heat gain in hot and dry climate.

**Building envelope and fenestration:** The building envelope and its components are the key determinants of the amount of heat gain and loss and ventilation pattern. The primary components affecting the performance of the building are a) materials and construction techniques b) roof c) walls d) fenestration and shading e) finishes

a) **Materials and construction techniques:** The appropriate construction techniques with low energy materials are useful in reducing energy content of the building. The choice of materials with respect to climate helps to maximize indoor comfortable level. The application of sundried mud bricks retains the coolness in the summer and warmth in the foggy winter. The application of insulation on the exterior surfaces of the wall will reduce heat gain in hot and dry climate.

- b) Roof: Roof materials determines the amount of heat transfers through roof inwards or outwards. In hot and dry climates the roof material should have a low transmittance value it means it has high thermal capacity. This would ensure maximum heat gain and heat loss. In a hot and dry regions the roof must have enough insulating properties to minimize heat gains. The entire roof surface can be covered with inverted earthen pots as insulating cover. The Vermiculite concrete has been used in the RETREAT building at Gual Pahari( near New Delhi) and has reduced roof conduction by 60%.Terrace gardening is thermally comfortable in hot regions.
- c) Walls: The heat storage capacity and heat conduction property of the walls generates thermal comfort conditions .As far as materials are concerned what applies to roofs is valid for walls as well but the difference is that more direct solar radiations are incident on the roof than the walls. Cavity walls with air spaces about 5cm between the two layers reduce heat transmission in hot regions. A trombe wall is used in the cold regions of Leh.
- d) Fenestration and shading: The orientation of the fenestration determines the amount of radiation incident on the opening. The fenestration pattern and configuration involve the area, shape, location and relative positioning of the windows which would affect the air movements, daylight and glare. In hot-dry climate windows shall be small in area to receive sufficient daylight and ventilators for heat vents. Airflow need not be encouraged since daytime air is hot. Windows of larger size if provided for night time natural ventilation then it must be shaded from radiative heat gain. It would be desirable to provide every room with windows on at least two wall which will generate cross ventilation. The orientation, sizes and shading of the opening will depends upon the sun path diagram and wind direction to reduce radiative heat gain.
- e) Finishes: The external finish of a surface determines the amount of radiation absorbed or re-radiated. The surface characteristics affect heat transmission into the indoor spaces. A rough textured surface (for example a grit finish with large aggregate size) causes self-shading and it also increases the area for re-radiation. In comparison, a flat surface allows greater heat transmission but a smooth surface would be more reflective. In hot-dry climates surface of light colours with rough textures is preferable. In cold climates surface of dark colours with flat textures would absorb more heat and less re-radiation and minimum shading.

**CONCLUSION:**

Renewable energy is seen as an effective option for ensuring access to modern energy services in our vast country. Macro and micro level environmental problems associated with the generation of conventional energy have provided a strong argument for enhancing the role of renewable energy within the broad energy development plans of country. Hence to generate energy efficient, environmental friendly, sustainable architecture it is necessary to understand the existing Macro and Micro climatic conditions with respective climatic data of climatic factors and climatic elements of a site such as latitude, longitude, altitude, topography, solar charts, wind directions (prevailing and seasonal), solar radiation, precipitation, sky conditions, water bodies, vegetation, low embodied energy materials, etc; with solar passive and active architectural features and techniques for enhancing the comfortable living environment.

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