CLIMATE RESPONSIVE ARCHITECTURE: CREATING GREATER DESIGN AWARENESS AMONG ARCHITECTS

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ABSTRACT

Climate has always challenged man in his quest for a better life. The elements of weather have affected all spheres of man's activities and have shaped his instinctive responses leading to largely disruptive effects to the natural environmental equilibrium. Nothing is more basic to human existence as food and shelter. The search for habitable dwellings which offer comfort, security and relief brings into focus the need for buildings which respond to particular local climatic and environmental conditions. This paper primarily aimed at creating greater design awareness among architects on designing climate responsive architectures. It strives to provide suggestions to architects (who lead the building professionals) on employing an organized approach to designs to suit specific climates. Based on the findings of the study it was recommended among others that architects should embrace a proper interpretation of location and climate parameters. Also, architectural designs must harmonize passive and active cooling/heating strategies. This may include sun shading, thermal insulation and cross-ventilation in combination with active systems, such as air conditioning.

Keywords: *Climate, Environment, Architecture, Design, Construction*

INTRODUCTION

Depending on the contexts and perceptions of the period, architecture has been defined in various ways. The Encarta dictionary (2008) says it is the art and science of designing and constructing buildings. Another description refers to the overall design of a building, structure, or system that unifies its components or elements into a coherent and functional whole (dictionary.com ,2009). Other descriptions abound but the overriding theme of most definitions is the recognition of architecture as reconciliation between man and the environment. This reconciliation requires the architect to constructively contend with the prevailing external environment into which he introduces his building. Among the several goals the architect sets out to achieve when designing a building, the creation of a comfortable living space is perhaps the most important (Saberi, Saneei and Javanbakht, 2000). This overriding need for comfort indeed determines the success or failure of any architectural design scheme, necessitating a competent understanding of local climatic conditions and working with them. From the beginning of time, man has been affected by climate and its influence over the earth. This is reflected in the efforts of the first humans who inhabited caves and built shelters to avoid the elements of weather. Turner (2003) quotes Oktay as dating the first documented architectural design with climate in mind as far back as 4BC in Greece. This is probably the origin of vernacular or climate-responsive architecture whereby the approach to design of buildings in various regions of the world employs unique local techniques that are best suited to that particular region and which encompass the cultural patterns (Turner, 2003). Due to inadequacies in the training curriculum (Sa'ad, 2001), architects are not properly equipped to effectively marry designs with local conditions resulting in designs which rely totally on active methods of thermal comfort control thereby producing buildings which lack both cost and energy efficiency.

The so-called International Style which ignores traditional age-old solutions to problems posed by local climate while relying instead on the use of high technology materials such as reinforced concrete frame and glass walls simply fails as an architectural solution. Indeed as Fathy (1986) illustrates, a 3 x 3m glass wall in a building exposed to solar radiation on a warm, clear tropical day will let in approximately 2000 kilocalories per hour. To maintain the microclimate of a building thus exposed within the human comfort zone, two tons of refrigeration capacity is required. Such a reliance on energy-consuming solutions at a time when the earth is experiencing severe climate change due to global warming (IPCC, 1997) is truly a reflection of the failure of the architect to live up to his responsibility towards the client and the environment. The architect cannot ignore the environment and local conditions in which he operates. Olotuah (2006) captures the essence of this argument by insisting that architectural education (and by extension the practice of the profession) must not only be appreciative of the various cultures of the people, but must also be informed by it. The need for climate-responsive architecture is clearly not only desirable but essential.

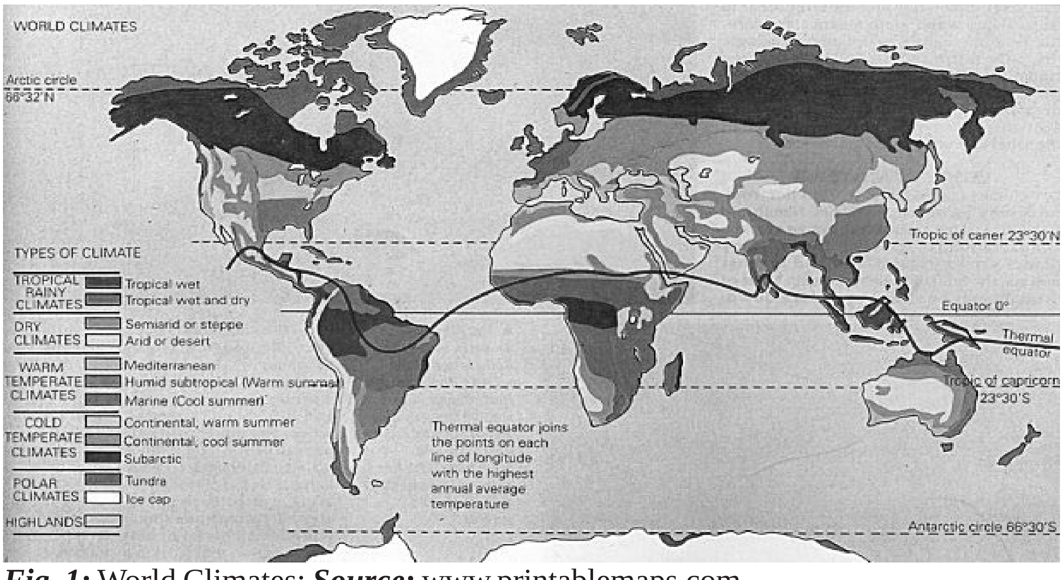


Fig. 1: World Climates: ***Source:*** www.printablemaps.com

CLIMATE AND DESIGNING FOR COMFORT

In applying climate-responsive architecture principles, it is useful to understand the basics of climate itself and its characteristics. Climate is the term used to describe the long-term weather patterns of a particular place, including factors such as rainfall and humidity (Jackson and Hudman, 1990). Depending on the combination of these factors, different climate classifications can be given to various regions of the world. The climate of any region is affected by latitude (distance from the equator) and elevation as well as nearby oceans and ocean currents.

The Köppen Climate Classification System is the most widely used for classifying the world's climates (Koch-Nielsen, 1997). It is based on the one introduced in 1900 by the Russian-German climatologist Wladimir Köppen. He divided the Earth's surface into climatic regions that generally coincided with world patterns of vegetation and soils. The Köppen system recognizes five major climate types based on the annual and monthly averages of temperature and precipitation. Table 1 shows the categorization he developed. The whole concept of comfort has been looked at and approached by different academics in different ways. Comfort is defined by Opoko (2001) as conditions in which somebody feels physically relaxed. Saini (1973) identifies comfort as being both physiological and psychological. This underscores the importance of establishing just what the conditions required for comfort are and explains the development and use of the bioclimatic chart (Fig 1).

This is a chart which identifies the comfort zone which Krishan & Arvind, (1999) define as the range of temperatures and humidities within which people feel comfortable under calm wind conditions. In general, as temperature increases, tolerance to humidity decreases, and vice versa. Wind speed, however, has a great effect on the comfort zone. Increases in wind speed up to about 40 miles per hour lower the effective temperature, a phenomenon known as the wind-chill factor. When air temperature is 20°C and wind speed is 20 miles per hour, the effective temperature is -10°C and when wind speed is 40 miles per hour, the effective temperature is -21°C. Every climate offers challenges. Hot humid climates for example present high temperatures, insolation, high humidity and small diurnal temperature range. Temperate climates on the other hand have low humidity with high diurnal range and have four distinct seasons: summer, winter, autumn and spring.

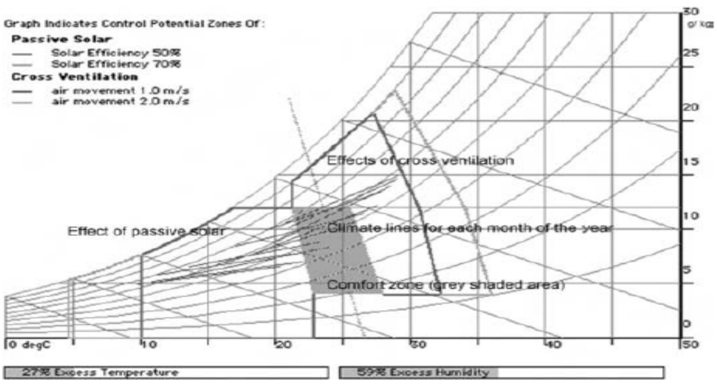


Fig. 2: The Psychometric Chart Source: Hall and Blakay (1996)

The chart can be used as a design tool, with the comfort zone in the centre. Temperature forms the horizontal axis, humidity the vertical axis. Warm climates normally sit to the right of the comfort zone.

Table 1: The Köppen Climate Classification System

Climate	Sub-group		Characteristics
Tropical humid	Af	Tropical wet	No dry season
	Am	Tropical monsoonal	Short dry season; heavy monsoonal rains in other months
	Aw	Tropical savanna	Winter dry season
Dry	BWh	Subtropical desert	Low-latitude desert
	BSh	Mid-latitude dry	Low-latitude dry
	BWk	Mid-latitude desert	Mid-latitude desert
	BSk	Mid-latitude steppe	Subtropical steppe
Mild Mid-Latitude	Csa	Mediterranean	Mild with dry, hot summer
	Csb	Mediterranean	Mild with dry, warm summer
	Cfa	Humid subtropical	Mild with no dry season, hot summer
	Cwa	Humid subtropical	Mild with dry winter, hot summer
	Cfb	Marine west coast	Mild with no dry season, warm summer
	Cfc	Marine west coast	Mild with no dry season, cool summer
Severe Mid-Latitude	Dfa	Humid continental	Humid with severe winter, no dry season, hot summer
	Dfb	Humid continental	Humid with severe winter, no dry season, warm summer
	Dwa	Humid continental	Humid with severe, dry winter, hot summer
	Dwb	Humid continental	Humid with severe, dry winter, warm summer
	Dfc	Subarctic	Severe winter, no dry season, cool summer
	Dfd	Subarctic	Severe, very cold winter, no dry season, cool summer
	Dwc	Subarctic	Severe, dry winter, cool summer
	Dwd	Subarctic	Severe, very cold and dry winter, cool summer
Polar	ET	Tundra	Polar tundra, no true summer
	EF	Ice Cap	Perennial ice

Source: Lene Edvardsen

THE CLIMATE-RESPONSIVE ARCHITECTURE

Climate-responsive architecture can be defined as architecture aimed at achieving occupant thermal and visual comfort with little or no recourse to non-renewable energy sources by incorporating the elements of the local climate effectively (Yannas, 2003). This refers therefore to architecture that reduces the negative impact on the environment & sustains the ecosystem of which it is a part. Udyavar (2006) identifies the main paradigms of Climate Sensitive Architecture as: (a) Energy Efficient Design (b) Preservation of Natural Ecosystems (c) Use of Renewable Energy (d) Water Resource Management (e) Use of Eco-friendly materials (f) Ecological Landscape Design (g) Solid Waste Management and Healthy Indoor Environment. For the architect, the process of acquiring and maintaining the knowledge and proficiency needed to create and sustain an environmentally-responsive architecture can be very tasking. Yannas argues that this requires the architect to have motivation, dedication and a considerable amount of time. There can also be conflicts with other criteria. For some designers environmental aspects are just an additional concern; for them environmental design is essentially and mainly corrective rather than generative. Such designers fail at the first hurdle to incorporate what Ehrenkrantz (1992) identifies as user needs and aspirations which include provision of environmental control and comfort among others. In practical terms climate-responsive architecture should result in structures that are planned and constructed to accommodate weather-related factors such as heavy precipitation, snow loads and temperature extremes. To get from design objectives to actualization, the architect has to incorporate environmental aspects from the outset. At the heart of this is the architectural design process itself which is so complicated that even experienced architects could not easily clarify what exactly happens in creating a new building. Table 2 below offers suggestions on some steps in design process that architects use.

Table 2: The Architectural Design Process

1. ***Study***	2. ***Sketch Design*** (giving Alternatives)	3. ***Design*** Scale: 1:100	4. ***Detail design*** Scale: 1:50-1:1
Concepts and Ideas	Concepts and Ideas	Choosing one of alternatives and giving exact plans on different levels	Detail design of: Architectural Mechanical Electrical and structural systems
Climate and comfort		Facades	
Function	Functional 2d and 3d Diagrams	Sections	
Circulation	Orientation	Perspectives	Cost estimation
Culture	Volume	Model	Perspectives
Structure	Facades	Primary decisions about mechanical, structural and electrical systems	exact models
Mechanical systems	Site layout		Thedrawings should be ready to built without any more description
Electrical systems	Simple models		

Source: Saberi,Saneei and Javanbakht (2002)

An analysis of the table shows that climate studies are the first step, in which the architect needs to study climate of the area using mostly meteorological stations data outside or in the boundaries of the city. This data is then analyzed using some approximate comfort data (winter and summer comfort zones) while at the same time looking at passive heating/cooling strategies; then combine these strategies to design in sketch and other steps, if other issues such as economical and/or aesthetic considerations allow. Environmentally-responsive architecture is an evolving concept that must be redefined and reassessed with each new project. Two major factors:

knowledge and performance targets should govern any design decisions the architect makes. These will form a strong guide and ensure that decisions reached are practical and effective. Table 3 explains these factors further:

Factor	Main sources
Knowledge	i) A good theoretical grounding is essential to provide designers with the ability to conceive ways in which building physics can translate into architecture. ii) Empirical knowledge is needed that can show how different techniques have worked in practice, and the extent to which their performance has satisfied the environmental design criteria set at the design stage. This is acquired from fieldwork, with direct observations and measurements, and by interviewing occupants after the building is completed. iii) Analytic tools and simulation techniques need to be used at different stages of design to make performance predictions on which to compare and fine-tune designs thus helping to test hypotheses derived from theoretical knowledge, as well as to draw generalized conclusions from limited measurements and observations
Environmental performance targets	i) what kind of environmental conditions need to be attained ii) What materials and construction techniques should be chosen iii) How much non-renewable energy use should be targeted for construction, operation, reuse or recycling of the building iv) How should environmental performance relate to building form and function?

If the deductions from the table are reduced to their basics, the conclusion is that the architect needs to know his onions. Olotuah (2006) poses questions for the architect to answer regarding his approach to design challenges and schemes when he asks: (i) what kind of architecture do we want to produce? (ii) What kind of architecture do we want to accept? (iii) What role is envisaged for the architect, especially in the 21st century? (iv) What kind of architecture and architectural education do we want to bequeath to the coming generation? These questions are pertinent because they seek to determine if the architect is interested in finding carefully thought-out solutions which contribute value to the profession or not. Based on the identified issues from the processes in Table 3 above, the architect should now be prepared to ascertain his design approach and objectives in a practical and direct way.

The Practical Approach: Having established that design with climate is essentially driven by PLANNING a proper projection, a practical approach is to carry out a stage-by-stage phased approach to design schemes. Haruna (2006) describes architecture as being successful if it acts well and does the thing it is required to do. If this success is to be achieved, a staged approach (referred to as Stages 1 and 2) is suggested and it involves investigation/evaluation and synthetic application of design responses.

STAGE 1: Investigation & Evaluation

Clearly, any analysis carried out will give specific results depending on the factors determined by local conditions. The deductions from the information in Stage 1 should guide the architect subsequently.

Table 4: Stage 1

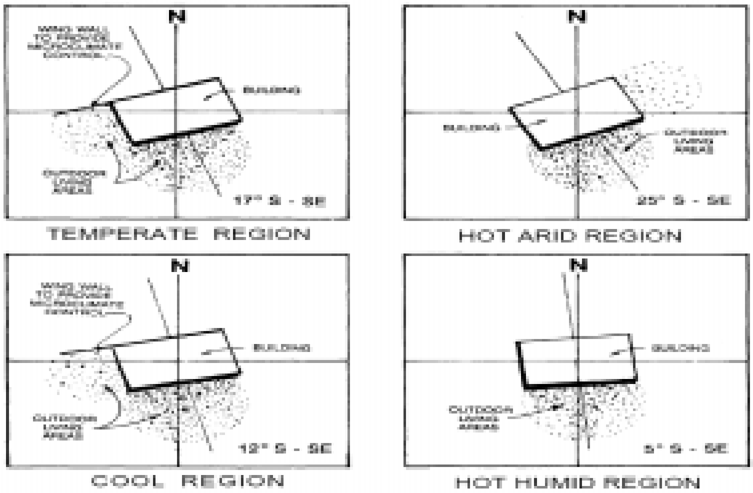
Phase	Issues to consider	Implications
Analysis	* Prevailing wind, precipitation and temperature conditions in the area. * The site's location in relation to the sun from morning to night. * The ability of terrain, vegetation and nearby buildings to block winds and air currents. * Wind direction, strength and frequency in combination with sun, precipitation and temperature. * the determined comfort level of the area based on the bio-climatic chart * Occupancy * Lux levels * Internal heat gain	* Reduced energy costs and loads during active life of building * Thermal comfort of occupants * Reduced impact (heat island) on the external environment
Planning	* Siting of buildings * Juxtaposition of buildings in relation to one another * topography and vegetation. * Orientation * Design and arrangement of building * Organisation of activities in and around buildings. * Arrangement of building parts and structures * volumes * Management, operation and maintenance. * Identification of Passive design elements such as walls, openings, roofs, etc. & the use of appropriate technology & materials	
Specifications	Use of Eco-friendly materials * Materials with low embodied energy * Materials that contain recycled content or are recyclable * Local or rapidly renewable material * Non-toxic/Low Toxic Materials	* Reduce the release of GHGs * Safeguard health of occupants * Reduced impact on the external environment
	Use of Renewable Energy Resources * Solar thermal for water heating * Solar Photo Voltaic for electricity * Wind & hybrid systems * Geothermal, tidal, micro-hydel energy Fuel cells and hydrogen	* Reduce dependence on fossil fuels * Reduce the emission of Green house gases & thus the threat of global warming * Pollution and emission-free
	Ecological landscaping * Based on knowledge of topography, drainage, geology as well as flora and fauna of the region * Bo-biologue: passive design with trees * Protection of soil and vegetationo Including water shed, waste and water management	* Prevention of soil erosion & subsequent ecological devastations * Protection of native, indigenous species of vegetation * Long term ecological sustainability of the bio-region

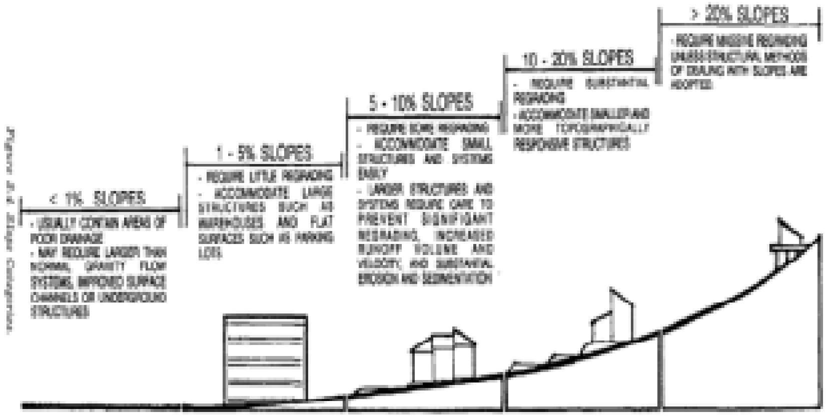
STAGE 2: Synthetic Application

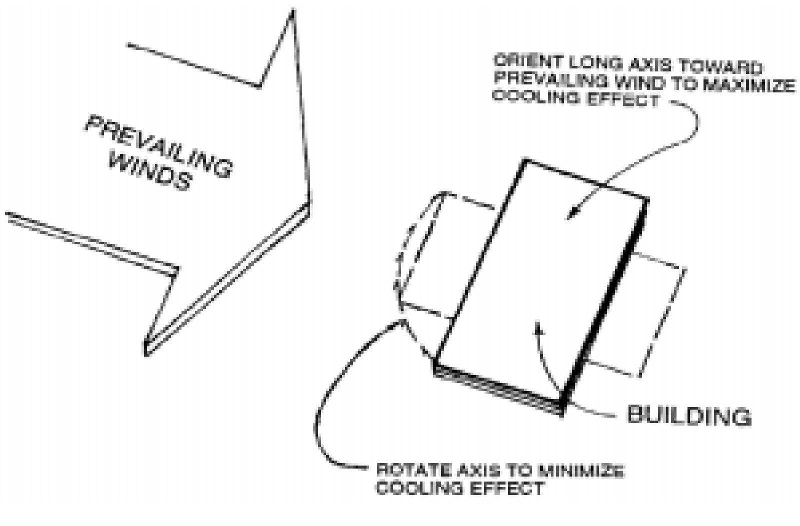
This involves the application of various measures to deal with the problems identified by the analysis and evaluation process. Basically this means taking measures to address Passive Cooling, Orientation, Shading, Insulation, Thermal Mass, Passive Solar Heating and Renewable Energy. Table 5 suggests some design applications which are appropriate for particular climates.

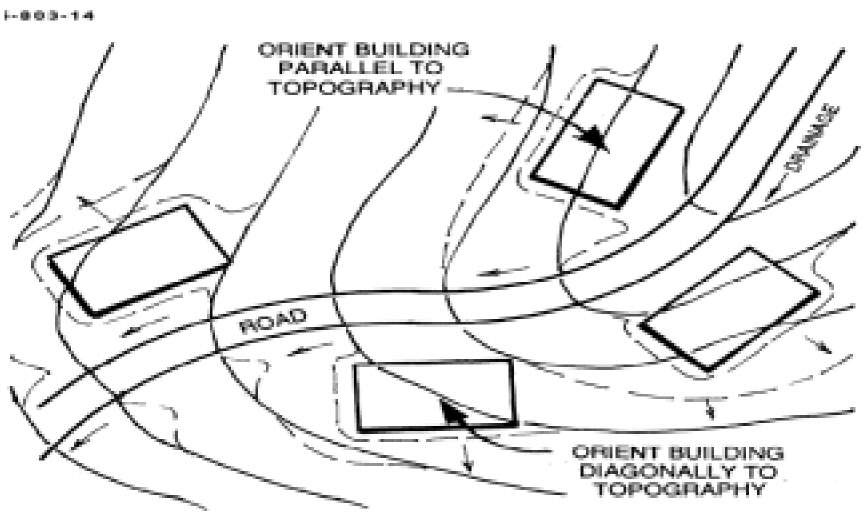
CLIMATE	SUGGESTED DESIGN RESPONSES
Tropical humid	i) Employ lightweight (low mass) construction ii) Maximize external wall areas (plans with one room depth are ideal) to encourage movement of breezes through the building (cross ventilation) iii) Ceiling fans should be used where required iv) Site buildings for exposure to breezes and shading all year. v) Shade whole building summer and winter (consider using a fly roof). vi) Use reflective insulation and vapour barriers. vii)Ventilate roof spaces viii) Use bulk insulation if mechanically cooling ix) Choose light coloured roof and wall materials x) Elevate building to permit airflow beneath floors xi) Consider high or raked ceilings xii) Provide screened, shaded outdoor living areas xiii) Consider creating sleepout spaces xiv) Design and build for cyclonic conditions.
Dry	i) Use passive solar principles with well insulated thermal mass ii) Maximise night time cooling in summer. iii)Consider convective (stack) ventilation, which vents rising hot air while drawing in cooler air. iv)Build more compact shaped buildings with good cross ventilation for summer. v) Maximise solar access, exposure to cooling breezes and cool air drainage. vi) Protect from strong, cold winter and dusty summer winds. vii Shade all east and west glass in summer. viii Provide shaded outdoor living areas.Consider adjustable shading to control solar access. ix Avoid air-conditioning. x Use reflective insulation to keep out summer heat. xi Use bulk insulation for ceilings, walls and exposed floors. xii Consider double glazing. xiii Use ponds and water in shaded courtyards to provide evaporative cooling. xiv Draught seal thoroughly. Use airlocks to entries.
Mild Mid-Latitude	1. Use passive solar design with insulated thermal mass. 2. Maximise cross ventilation 3.Evaporative cooling or ceiling fans should be used if required. 4. Consider convective (stack) ventilation, which vents rising hot air while drawing in cooler air. 5. Site home for solar access and exposure to cooling breezes. Shade all east and west glass in summer. 6. Install reflective insulation to keep out heat in summer 7.Use bulk insulation in ceilings and walls. 8. Build screened, shaded summer outdoor living areas that allow winter sun penetration.
Severe Mid-Latitude	1. Use passive solar principles. 2. High thermal mass is strongly recommended. 3. Insulate thermal mass including slab edges. 4. Maximize north facing walls and glazing, especially in living areas with passive solar access. 5. Minimize east, west and south facing glazing. 6. Use adjustable shading. 7. Use double glazing, insulating frames and/or heavy drapes with sealed pelmets to insulate glass in winter. 8.Minimise external wall areas (especially east and west). 9. Use cross ventilation and night time cooling in summer. 10. Site new homes for solar access, exposure to cooling breezes and protection from cold winds. 11. Draught seal thoroughly and provide airlocks to entries. 12.Install auxiliary heating in extreme climates. 13.Use renewable energy sources. 14.Use reflective insulation to keep out heat in summer. 15.Use bulk insulation to keep heat in during winter.
Polar	1.Insulate thermal mass including slab edges. 2.Maximise north facing walls and glazing, especially in living areas with passive solar access. 3.Minimise east, west and south facing glazing. 4.Use adjustable shading. 5.Use double glazing, insulating frames and/or heavy drapes with sealed pelmets to insulate glass in winter. 6. Minimise external wall areas (especially east and west). 7.Use cross ventilation and night time cooling in summer. 8.Site new homes for solar access, exposure to cooling breezes and protection from cold winds. 9.Draught seal thoroughly and provide airlocks to entries. 10.Install auxiliary heating in extreme climates. 11. Use renewable energy sources. 12.Use reflective insulation to keep out heat in summer. 13.Use bulk insulation to keep heat in during winter. 14 Bulk insulate walls, ceilings and exposed floors.

Illustrated Examples of Climate-responsive Design Solutions









CONCLUSION AND RECOMMENDATIONS

The challenges before architects are numerous. While in the past the factors they had to contend with in approaching design schemes were clear cut, the requirements today have greatly increased. The architect can no longer design in isolation disregarding the environmental effects of his buildings. Projections about the effects of climate change which has been caused by man's activities make it imperative for the design of buildings which are energy efficient and cause minimal negative environmental impact. The architect possesses a powerful tool which if used wisely can achieve all of the design objectives and promote the ideals of environmental sustainability. Based on the findings, the following are recommended:

- i Architects should embrace a proper interpretation of location and climate parameters.
- ii Planning regulations should require all designs to show a greater synthesis between building elements and local climate conditions.
- iii Architectural designs must harmonize passive and active cooling/heating strategies. This may include sun shading, thermal insulation and cross-ventilation in combination with active systems, such as air conditioning.
- iv The impact of buildings on the environment must be assessed and minimum acceptable requirements established before any building approvals are issued
- v Stricter enforcement of planning strategies as they concern gross floor area to control the total site coverage and building footprint

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