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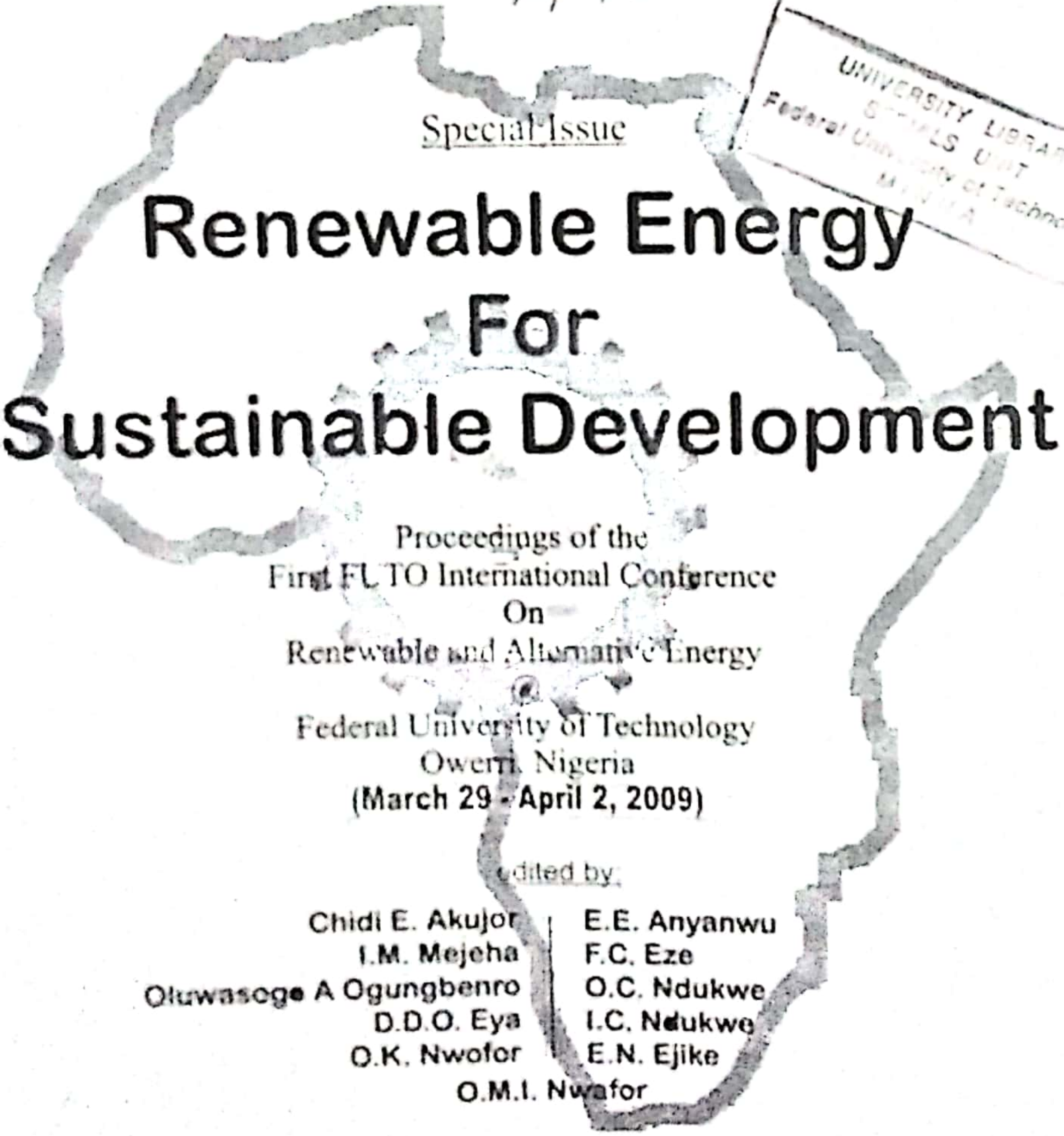

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Application of Architectural Design Techniques for Reducing Energy Consumption in Residential Buildings

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Abstract

The use of energy has become a critical factor in national and global economic development. Therefore, the need and the search for its alternative sources is more pressing in recent times especially in developing countries like Nigeria. Consequently, this has led to the world currently facing a major energy challenge with fossil fuels becoming more scarce and expensive to produce. Hence, the need to reduce overdependence on its use in other sectors such as building in order to meet the growing demands. Buildings generally account for about 40% of energy consumption because of its use to create interior comfort and lighting conditions that largely ignore the natural environment. As construction booms in many developing countries, there is a growing need for building professionals to design buildings which not only provide comfort for the occupants but also minimize the consumption of fossil fuels. This paper discusses the application of some architectural techniques such as site and building orientation, ventilation, landscaping and others for reducing energy consumption in residential buildings. It concludes that the concept of energy efficiency in buildings should be adopted and incorporated at the planning and designing stage which can be the key direction for buildings of the 21st century.

Keywords: Architecture, Buildings, Design, Elements, Energy- efficient.

1.0 Introduction

Currently, energy availability and global warming are amongst the biggest challenges confronting the planet. Energy is a vital part of every aspect of life in the modern world, hence the demand for energy is rising rapidly. Global consumption of primary energy to provide heating, cooling, lighting, and other building-related energy services grew from 86 exajoules in 1971 to 165 exajoules in 2002-an average annual growth rate of 2.2 percent per year (Price *et al.*, 2006). By 2030, global energy consumption will have grown by over 70% (EIA,2007). The world population, which has increased more rapidly than ever before over the last 50 years (Population Reference Bureau, 2005), indicates huge future demand for houses and the energy to run them. The building sector is one of the major energy consumers in the world. Buildings, as they are designed and used today, contribute to serious environmental problems because of the excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy intensive solutions sought to construct a building in order to meet its demands for heating, cooling, ventilation and lighting cause severe depletion of invaluable environmental resources.

The proportion of total energy use attributable to buildings generally ranges from 10 - 15% in undeveloped countries to more than 40% in the developed countries (Robertson, 1992). The absolute figure is rising fast, as construction booms, especially in countries such as China, India and Nigeria. The energy use by the building sector will continue to increase, primarily because new buildings are constructed faster than old ones are retired until buildings can be designed to produce enough energy to offset the growing energy demand. It is essential to act now, because reduction in consumption of energy in buildings can make a major contribution to tackling climate change and energy use. By using architectural design principles for energy savings techniques, up to 80% of a building's energy consumption for heating or cooling can be saved. Hence, buildings can be designed and built to meet occupant's need for thermal and visual comfort at reduced energy levels and resources consumption.

1.1 The Need For Energy Efficiency and Renewable Energy Use In Buildings

Presently there is a growing need for energy efficiency in buildings as energy use in buildings has grown considerably faster in developing countries than in industrialized countries over the last three decades: the annual average growth rate for developing countries was 2.9 percent from 1971 to 2002, compared to 1.4 percent for industrialized countries. Overall, 38 percent of all primary energy consumption (not counting traditional biomass) is used globally to supply energy services in buildings. Currently, there is a limited supply of fossil fuels in the world and the other demerit to the use of fossil fuels is that of burning them for energy which in turn produces CO_2, a greenhouse gas, which causes climate change. This is where sustainable energy comes in. Sustainable energy refers to a way we can use and generate energy that is more efficient and less harmful to the environment. Another way of explaining sustainable energy is that it will allow us to meet our present energy needs without compromising the ability of future generations to meet their own needs. This can be done by being more efficient in the use energy and also by increasing the amount of energy that comes from renewable sources such as the wind, sun, rivers and oceans.

The energy demand in buildings is driven by population growth, the addition of new energy-using equipment, building and appliance characteristics, climatic conditions, and behavioral factors. The rapid urbanization that is occurring in many developing countries has important implications for energy consumption in the building sector. Most of the population growth that is projected to occur worldwide over the next quarter century is expected to occur in urban areas. And as millions of apartments and houses are added to accommodate a growing population, they in turn create new demand for energy to power lights, appliances, and heating and cooling systems. In residential building, there are various factors that influence the type and amount of energy consumed in the residential structure. The most important are:

i. the type of dwelling units;
ii. the size of the structure;
iii. the number of occupants and their habitats;
iv. the weather conditions and time of year;
v. the thermal integrity of the building (level of insulation and number and location of windows);
vi. the number of appliances (e.g., washing machine, clothes dryer, swimming pools, etc.); and
vii. the type of appliances (e.g., gas versus electric heaters and ranges).

Typically, the most important factors influencing residential energy consumption are the type of house (detached single-family or multi-family structure) and the number of major appliances. A single-family home requires more energy for space heating than a multi-family unit, due to its bigger size and the amount of heat loss through external walls. It also requires more energy for operation of major appliances as it usually houses more occupants.

1.2 Concept of Energy Efficiency in Residential Building.

Energy efficiency in simple words means the extraction of maximum energy out of fuel or less energy wastage. Energy efficient buildings are those that provide the specified internal environment for minimum energy cost, normally within the constraint of what is achieveable and cost effective. This can be acheived by using innovative materials, technologies and design concepts as climatically optimised architecture is being developed to reduce the unnecessarily high-energy consumption in buildings while retaining the same level of comfort (Maznah, 2003). Energy efficient buildings (if new constructions or renovated existing buildings) can also be refered to as buildings that are designed to provide a significant reduction of the energy need for heating and cooling, independently of the energy and of the equipment that will be chosen to heat or cool the building. This can be achieved through the following means:

i. bioclimatic architecture: shape and orientation of the building, solar protections, passive solar systems
ii. high performing building envelope: thorough insulation, high performing glazing and windows, air-sealed construction, avoidance of thermal bridges
iii. high performance controlled ventilation: mechanical insulation, heat recovery.

Only when the building has been designed to minimise the energy loss, does it makes sense to start looking at the energy source (including renewable energy) and at the heating and cooling equipment. Energy-efficient home design refers to the design of homes that generally maintain the internal living environment in the human comfort zone throughout the year, without the need for energy to be consumed for cooling or heating, or, if energy is used, it is at an absolute minimum. Similarly, there is a need for only minimum energy for lighting, water heating and other services necessary for comfort and amenity.

Bioclimatic architecture takes into account climate and environmental conditions to help achieve thermal and visual comfort inside. Bioclimatic design takes into account the local climate to make the best possible use of solar energy and other environmental sources, rather than working against them. Bioclimatic design includes the following principles:

i. The shape of the building has to be compact to reduce the surfaces in contact with the exterior; the building and especially its openings are given an appropriate orien-tation; interior spaces are laid out according to their heating requirements;

ii. Appropriate techniques are applied to the external envelope and its openings to protect the building from solar heat in winter as well as in summer; passive solar systems collect solar radiation, acting as "free" heating and lighting systems; the building is protected from the summer sun, primarily by shading but also by the appropriate treatment of the building envelope (i.e. use of reflective colours and surfaces).

2.0 Potentials Of Energy Efficiency In Buildings

Energy is essential to our way of life. It provides us with comfort, transportation and the ability to produce food and material goods. Historically, energy consumption has been directly related to the gross national product (GNP), which is a measure of the market value of the total national output of goods and services.At the moment, most of the energy we use comes from fossil fuels such as oil, gas, coal and peat. Unfortunately there is a limited supply of fossil fuels in the world that are being used up at a very fast rate. However, the huge potential of energy efficiency in buildings has been recognised. Progress can begin immediately because knowledge and technology exist today to slash the energy buildings use, while at the same time improving levels of comfort. By using well-proven energy efficiency measures, 70 to 90% of a building's energy need for heating or cooling can be cut. The benefits from the energy-efficient siting and design of buildings are economic (saving money), social (reducing fuel poverty); and ecological (reducing resource exploitation and emissions). Every new development ideally should have an explicit energy strategy, setting out how these benefits are to be achieved. Therefore, a strategy for improved energy efficiency of buildings is a necessity if the energy consumption is to be reduced significantly over a limited period of time. Efficient energy use is achieved primarily by means of a more efficient technology or process rather than by changes in individual behaviour (Diesendorf 2007). Energy efficient buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help controlling global emissions of greenhouse gases. Energy efficiency and renewable energy are said to be the "twin pillars" of sustainable energy policy (The Twin Pillars of Sustainable Energy, 2007). Energy efficiency offers a powerful tool for achieving a sustainable energy future. Improvements in energy efficiency can reduce the need for investment in energy infrastructure, cut fuel costs, increase competitiveness and improve consumer welfare. Environmental benefits can also be achieved by the reduction of greenhouse gases emissions and local air pollution. Energy security can also profit from improved energy efficiency by decreasing the reliance on imported fossil fuels.

Buildings contribute substantially to the depletion of the planet's resources and the reduction of environmental quality. The building industry, both in the construction and occupation stages, is a major contributor to the total greenhouse gas emissions from industry as a whole. Today's knowledge makes it possible for building professionals to develop solutions for the built environment which can enable the conservation and enhancement of our natural environment and ecological systems. To achieve this, we need to consider the building itself as a heating and cooling system utilising existing natural, climatic and environmental energies to obtain an acceptable level of comfort and health. The design team can explore many options of the site and building layout, types of windows and shading, insulation and thermalmass levels both within the building and external to the structure in order to tap the energy required for year-round comfort.

2.1 Architectural Principle For Energy Efficient Building Design

By using appropriate architectural design, materials, building components along with the use of renewable energy, it is possible to reduce energy consumption in buildings appreciably. Hence, architects can achieve energy efficiency in the buildings they design by studying the macro-and micro-climate of the site, applying bioclimatic architectural principles to combat the adverse conditions, and taking advantage of the desirable conditions. Thus, energy efficient design has to become part of the expression of architecture and a way of life. However, there are many competing interests when incorporating these energy efficiency principles into a design, but the emphasis is to include as many of the principles of 'smart design' and 'passive solar design'(Saini,1980) that do not conflict with sound 'urban design'(Szokolay, 1982) principles of 'good manners architecture' (Szokolay, 1987). According to Majumdar (2001) some common design elements that directly or indirectly affects thermal comfort conditions and thereby the energy consumption in a building are:

i. Landscape,
ii. Ratio of built form to open spaces,
iii. Location of water bodies,
iv. Orientation,
v. Platform, and
vi. Building envelope fenestration.

However, in extreme climatic conditions, one cannot achieve comfortable indoor conditions by these design considerations only. There are certain tested and established concepts which, if applied to a design in such climatic conditions, are able to largely satisfy the thermal comfort criteria. These are classified as advanced passive solar techniques. The two broad categories of advanced concepts are:

i. Passive heating concepts (direct gain system, indirect gain system, sunspaces, etc) and
ii. Passive cooling concepts (evaporative cooling, ventilation, wind tower, earth-air tunnel, etc. see Majumdar, 2001).

Following is a discussion of some design elements that deserve consideration when designing an energy efficient house.

2.2 The Site Orientation

Energy efficient design starts with the site. The site needs to be evaluated to find out the site resources and potentials which will enhance the appearance or functionality of the design and operating costs. The site evaluation will guide the building design in harnessing the site resources important to the building design which include: vegetation, soils, water resources, important natural areas, solar access, wind/breeze direction and slope. In order to design to minimise impact on and maximise potential of site resources, the first criteria is to ensure that the sunshine is not blocked by existing or future development, trees or escarpments. As long as the sun does reach the site it does not matter which way the site faces, the house can be designed to be fully solar. Likewise, it does not matter in which direction the view faces. The view and the sun do not have to be on the same side and the living room does not have to face the street.

In exposed cold climates a southerly view can cause problems, it may require well sealed and double glazed windows and should be kept to a minimum area. In milder coastal climates southerly views can be easily accommodated and windows used to capture summer breezes. Westerly views have an undeservedly bad reputation. Provided they are properly shaded with a wide low verandah, the view of a setting sun can be very rewarding. In the tropics, the ideal bioclimatic layout of buildings is low density in dispersed patterns with access to ventilation on all sides by porches and verandahs. As Cooke (1980) shows, lower building densities have many advantages including:

i. maximum flow of air around all sides of the buildings avoiding hot spots and solar-heated recesses.

ii. allowing the use of outdoor space as an alternative or complement to indoor function

iii. providing privacy by distance so that air movement is not impeded by walls.

However, this ideal is no longer possible due to pressure of population on land resources and the resulting high cost of land means that the distance between buildings is often reduced to a minimum.

2.3 Building Orientation

The building's optimum orientation is often overlooked due to competing forces, including the orientation of the land, the streetfrontage, optimising floor to wall ratios, views and aspect. In the tropical climatic conditions, rectangular buildings with long elevations facing north and south are better so as to minimise solar heat gain. Simply noting which way is North and where the sun rises and sets provides an initial basis for determining a building's exposure to sun. In the case of building, orientation is a significant design consideration, mainly with regard to solar radiation and wind. In predominantly cold regions, buildings should be oriented to maximize solar gain; the reverse is advisable for hot regions although in regions where seasonal changes are very pronounced, both situations may arise periodically. Therefore, the building orientation and its position on the site can be advantageous for maximising the benefits of passive solar design. This design principle has considerable energy saving advantages in temperate and subtropical climates during the cooler months and for hot, humid climates in summer months.

If the major living areas are orientated to face true solar north, the benefits are free warmth and provision of daylight. And as the sun passes low in the northern sky in winter, the daylighting can reduce the need for electrical lighting, which also lowers the need for air-conditioning. Conversely, orientating the building to capture the prevailing breezes is very advantageous in subtropical and tropical climates during the hot, humid summer months. Although, wind can be desirable or undesirable however, a compromise is required between the sun and wind orientations but with careful design, shading and deflecting devices can be incorporated to exclude the sun or redirect it into the building, just as wind can be diverted or directed to the extent desired.

2.4 Building Form

A compact building form of minimum surface-to-volume ratio is best for reducing heat loss. This is because the volume of space inside a building that needs to be heated or cooled and its relationship with the area of the envelope enclosing the volume affects the thermal performance of the building. Therefore, for any given building volume, the more compact the shape, the less wasteful it is in gaining or losing heat. For instance, a rectangular building with one of the longer facades facing south can allow for increased passive solar heating, day-lighting and natural ventilation As well as reducing energy costs, sunny south-facing rooms also have high amenity value. Projections such as bay and dormer windows should be kept to a minimum, since by increasing the surface-to-volume ratio of the building, they will increase heat loss. They also tend to be more difficult to insulate effectively. Hence, in hot, dry, regions and cold climates, buildings should be compact in form with a low surface-to-volume ratio to reduce heat gain and losses respectively. The parameter, known as the surface-to-volume ratio, is determined by the building form and the building form determines the airflow pattern around the building, directly affecting its ventilation. Apart from surface-to-volume ratio, the depth of a building also determines the requirements for artificial lighting therefore, the greater or the more the depth, the higher the need for artificial lighting.

2.5 Building Envelope And Fenestration

The building envelope is the interface between the interior of a building and the outdoor environment. In most buildings, the envelope along with the outdoor weather is the primary determinant of the amount of energy used to heat, cool, and ventilate. A more energy-efficient envelope means lower enegry use in building and lower greenhouse gas emmissions. The envelope concept can be extended to that of the building fabric which includes the interior partitions, ceiling, and floors. Interior elements and surfaces can be used to store, release, control, and distribute energy, thereby further increasing the overall efficinecy of buildings. The primary elements affecting the performance of a building envelope as highlighted and explained by Majumdar (2001) are:

2.5.1 Material with low embodied energy

Heavily processed or manufactured products and materials are usually more energy intensive. As long as durability and performance will not be sacrificed, it is best to choose low-embodied-energy materials. This is because the choice of building materials is very important in reducing the energy contents of buildings. Reducing the strain on conventional energy can be achieved by low-energy buildings with low-energy materials, efficient structural design, reducing the quantities of high-energy building materials and transportation energy. The choice of materials also helps to maximize indoor comfort. Table 1 below shows the energy contents of some commonly used building materials.

2.5.2 Roof

The roof is often the leading source of heat intrusion into a house. It receives significant solar radiation and plays an important role in heat gain/losses, daylighting, and ventilation. Depending on the climatic needs proper roof treatment is very essential. In a hot region, the roof should have enough insulating properties to minimize heat gains or reducing heat transfer through ventilation of ceiling cavities.

2.5.3 Walls

Walls are a major part of the building envelope and receive large amounts of solar radiation. The heat storage capacity and heat conduction property of walls are key to meeting desired thermal comfort and air cavities in walls reduce heat transmission into the building, which is the primary aim in a hot region.

Table 1: The energy contents of commonly used building materials

Building	Elements/ materials	KWh/cum (in situ)
Cement concrete	1:5:10	402
Lime concrete with brick ballast	1:4:8	1522 (80% in brick)
Brick masonry	1:5	676
Brick masonry	1:4	709
Random rubble masonry	1:4	267
Stabilized mud with 6% lime		197
Stabilized mud with 10% lime		320
RCC roof (10 cm)		$174/m^2$
Stone slabs in RCC joists		$132/m^2$
Cement plaster	1:4	$20.65/m^2$
Cement plaster	1:6	$15.09/m^2$
Lime surk	1:4	$11.05/m^2$

Source: Gupta (1994)

2.5.4 Fenestration

Among all the elements in the building envelope, windows and other glazed areas are most vulnerable to heat gain or losses. Thus, fenestration design is primarily governed by requirements of heat gain and loss, ventilation and daylighting. Hence, their location, size, and detailing with their shading form an important part of bioclimatic design as they help to keep the sun and wind out of a building or allow them when needed. The location of windows for ventilation is determined by prevalent wind direction. At higher levels windows naturally aid in venting out hot air while thier size, shape and orientation moderate air velocity and flow in the room. Hence, small inlet and large outlet increase velocity and distribution of airflow through the room. Therefore, the house should be so positioned on the site that takes advantage of prevailing winds. In summer, the prevailing wind direction is from the south/south-east. This can provide sufficient air motion in hot humid and warm humid climate. Fenestrations having 15 to 20% of floor area are found adequate for both ventilation and daylighting in hot and dry, and hot and humid regions. Natural light is also admitted into a building through glazed openings. The important components of a window that should be considered for energy efficient house are the glazing systems and shading devices.

2.5.5 Building Finishes/ Colours

Light colours have the ability to reflect solar radiation and assist in reducing internal temperatures. The proportion of solar radiant energy that passes through a material is measured by a solar absorptance value. A solar absorptance value is expressed as a scale from 0 to 1. Dark colours readily absorb solar radiant energy and have an absorptance value at the higher end of the scale (e.g. 0.9) and light colours are at the lower level (e.g. 0.2). The external finish of a surface determines the amount of heat absorbed or relected by it. For example, a smooth and light colour surface reflects more light and heat in comparison to a dark colour surface. Lighter colour surfaces have higher emissivity and should be ideally used for warm climate. Table 2 shows the typical absorptance values for various colours as described above while Table 3 shows the reflection and absorption of solar radiation by some colours.

Table 2: Typical Absorptance Values

Colour	Typical Absorptance values
Slate (dark grey)	0.90
Yellow, buff	0.60
Red, green	0.75
Light grey	0.45
Off white	0.35
Light cream	0.30

Source: Building Code of Australia

Table 3: Reflection and Absorption of Solar Radiation by Some Colours

Materials	Solar Radiation	
	Absorption	Reflection
White wash	21%	79%
Bright aluminium	30%	70%
Yellow colour	48%	52%
Dark aluminium	63%	37%
Bright red	65%	35%
Light green	73%	37%
Black colour	97%	3%
Concrete	70%	30%
Fired clay brick-red	70%	30%
Copper sheeting	64%	36%
Red roofing tile	70%	30%
Aluminium foil	39%	61%
Asphalt	95%	5%
Plaster	81%	19%

Source: Komolafe, 1988

2.6 Internal Room Zoning

The orientation and grouping of rooms of a similar function (e.g. living areas, service areas and sleeping areas) can assist in minimising heat loss in winter or equally, maximise the benefits in summer of the local climatic conditions, such as cooling prevailing breezes.Where possible, the garage, laundry, bathroom and storerooms should best be positioned on the western wall of the building as they assist in minimising heat transfer into the living areas. Ideally, in the subtropics and tropics, bedrooms are best positioned on the southern side of the building where the solar heat gain is minimal. Bedrooms on the north and east walls require shading devices that can capture the warm winter sun.

2.7 Shading of Windows and Walls

There are many designs of windows which reduce solar radiation transmittance into buildings (Taleb and Al-Wottar, 1988; Talmatamar *et al.*, 1955).The first step in shading is to orient the building to have the least direct impact from the sun. East- and west-facing walls and windows are the most important to shade, as solar heating is most intense on these orientations, especially the summer sun. Windows facing east or west should be protected by a sufficiently wide horizontal-shading device (such as wide eaves, verandah or pergola). The next step is to prevent solar gain by means of shading devices, rejecting the solar gains by means of ventilation and absorbing solar gain in thermal mass.

An external sun-shading devices are preferred to internal and interstitial shading devices. This is because indoor shading devices reflect solar energy which has passed through the glazing into the room and back out through the glazing. Hence,they are less effective than external shades because some radiation is reflected back into the room and some absorbed by the surface of the shading device. To effectively provide external shading, eaves of 450 mm (minimum), preferably 600–900 mm wide (wider in the tropics) can be used on all elevations to partially protect top of external walls from direct solar radiation.Wall colour can also be of importance; a white wall, or a wall shaded by vegetation is effectively exposed to a low level of radiation, even when facing east or west. Eastern windows equipped with appropriate operable shutters can be protected from the sun while taking advantage of ventilation from the easterly wind (Givoni, 1994).

Fixed external shading devices such as awnings are also effective because the solar radiation is rejected before it enters the building. However, this effectiveness varies with the seasonal geometry of solar radiation, as affected by the sun's movement. All shading devices influence the view through glazed windows: an overhang, a Venetian blind, an opaque blind, fine wood lattice, bamboo screens and solar control films may all reduce the solar gain by the same amount but they will alter the view through the aperture quite differently in each case. Shading devices are of various types:

i. Moveable opaque (roller blind, curtains, etc): these can be highly effective in reducing solar gains but eliminate view and impede air movement.

ii. Louvres: May be adjustable or fixed. These affect view and air movement to some degree.

iii. Fixed overhangs.

Relative advantages and disadvantages of these shading devices have been enumerated (Majumdar, 2001) as follows:

2.7.1 Moveable blinds or curtains

The use of moveable blinds or curtains can be adopted to block the transmission of solar radiation through glazed windows, especially on the east and west walls. In hot and dry climates, when ambient air is hotter than room air, they help to reduce convective heat gain. However, in warm humid climates, where airflow is desirable, they impede ventilation. For air-conditioned buildings, where the flow of outside air is to be blocked, they can reduce cooling load.

2.7.2 Overhangs and louvres

The part of the sky through which the sun passes can be blocked through the application of overhangs and louvres. Overhangs on south-oriented windows can provide effective shading from the high-altitude sun while an extended roof shades over the entire north or south wall will shield the walls from the noon sun.

2.7.3 Landscaping

Landscaping is the most under utilised area of domestic architecture. It is probably the cheapest and the most effective way of improving year round comfort and energy efficiency. It is an important element in altering the microclimate of a place. Proper landscaping reduces direct sun from striking and heating up of building surfaces. It prevents reflected light carrying heat into a building from the ground or other surfaces. Landscaping creates different airflow patterns and can be used to direct or divert the wind advantageously by causing a pressure difference. Outside the building, the thermal environment can be greatly improved with judicious planting of shrubs and trees. Trees are the primary elements of an energy-conserving landscape. Climatic requirements govern the type of trees to be planted. However, planting deciduous trees on the southern side of a building is beneficial in a composite climate. Deciduous trees provide shade in hot season while dense shrubbery trees provides shelter from undesirable harmattan dusty winds. Additionally, the shade created by trees and the effect of grass and shrubs reduce air temperatures adjoining the building and provide evaporative cooling. Likewise, application of external paving can also play a major role in modifying the ambient temperatures when shaded and dampened in hot season and alternatively, when dry and exposed to the sun in raining season.

2.7.4 Cross Ventilation

Cross ventilation is of prime importance in tropical climates with efficient natural ventilation of dwellings during the hot season. This is because the main objective of building design in tropical climates is to avoid the overheating of the indoor temperature by keeping it at least below the outdoor temperature. Adequate ventilation in residential buildings is therefore essential to provide fresh air and to remove moisture, odours and pollutants. Good natural ventilation requires locating openings in opposite pressure zones. However, excessive ventilation during the heating season results in energy wastage and can also cause discomfort due to draughts. The thermal importance of ventilation is twofold. In hot weather, because of lower night time temperatures, cross ventilation on a hot evening will remove the stored heat of the day from the mass inside the house. This allows the mass walls and concrete floors to absorb heat from the occupant by radiation and conduction. The other function of cross ventilation is to cool the occupant directly with cool air passing over their skin thereby losing heat to the air by evaporation. To achieve this every room needs openings from at least two directions and ceiling fans as a backup when there are no breezes. Casement windows opening in different directions can scoop in the slightest of breezes, while highlights extract the rising hot air.

2.7.5 Day Lighting

Interest in day lighting became important in the 1970s with the awareness that in many large buildings the single largest energy consumer was electric lighting and not cooling. Day lighting involves the skilful use of natural light as an effective lighting source for a building during its daytime operation. According to De Herde and Nihoul (1994), day lighting design approaches include four concepts:

i. Penetration; collection of natural light inside the building,

ii. Distribution; homogenous spreading of light into the spaces or alternatively focusing of the light,

iii. Protection; reducing the direct penetration of the sun's rays into the building by shading.

iv. Control; controlling light penetration by fixed or moveable screens to avoid visual discomfort.

Day lighting has merits beyond mere energy savings. It is extremely effective at reducing peak load which will lower peak cost to the utility. The building owner benefits from reduced consumption whilst the utility benefits by being able to spread out demand in order to lower peak cost. This could help to reduce the long-term need for new power plant construction.

3.0 Conclusion

Using appropriate architectural design, materials, building components along with the use of renewable energy, it is possible to reduce energy consumption in buildings appreciably. Reducing energy consumption of building is by far the most practical and affordable way to reduce the environmental impact of residential development. Energy efficient design that removes the need for heating and cooling systems and the use of energy efficient lighting and appliances is a concept which can potentially eliminate all mechanical systems for space heating and cooling in all forms of residential buildings.Therefore, the concept of energy efficiency and utilisation of renewable energy should be adopted and incorporated at the planning and design stage. If this is done, it will be the key direction for buildings of the 21st century.

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