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Low Energy Buildings Design and Human Comfort Solutions

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The use of renewable energy sources is a fundamental factor for a possible energy policy in the future. Taking into account the sustainable character of the majority of renewable energy technologies, they are able to preserve resources and to provide security, diversity of energy supply and services, virtually without environmental impact. Sustainability has acquired great importance due to the negative impact of various developments on environment. The rapid growth during the last decade has been accompanied by active construction, which in some instances neglected the impact on the environment and human activities. Policies to promote the rational use of electric energy and to preserve natural non-renewable resources are of paramount importance. Low energy design of urban environment and buildings in densely populated areas requires consideration of wide range of factors, including urban setting, transport planning, energy system design and architectural and engineering details. The focus of the world's attention on environmental issues in recent years has stimulated response in many countries, which have led to a closer examination of energy conservation strategies for conventional fossil fuels. One way of reducing building energy consumption is to design buildings, which are more economical in their use of energy for heating, lighting, cooling, ventilation and hot water supply. Passive measures, particularly natural or hybrid ventilation rather than air-conditioning, can dramatically reduce primary energy consumption. However, exploitation of renewable energy in buildings and agricultural greenhouses can, also, significantly contribute towards reducing dependency on fossil fuels. Therefore, promoting innovative renewable applications and reinforcing the renewable energy market will contribute to preservation of the ecosystem by reducing emissions at local and global levels. This will also contribute to the amelioration of environmental conditions by replacing conventional fuels with renewable energies that produce no air pollution or greenhouse gases. This study describes various designs of low energy buildings. It also, outlines the effect of dense urban building nature on energy consumption, and its contribution to climate change. Measures, which would help to save energy in buildings, are also presented.

Keywords: Renewable technologies, Built environment, Sustainable development, Mitigation measure

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Introduction

Natural resources may be renewable, non-renewable or abstract. Non-renewable resources include fossil fuels, minerals, clear-felled tropical hardwoods that are not replaced and rare animals or plants that are hunted or collected in an uncontrolled way. Renewable resources include energy from the sun and the biological and biogeochemical cycles (such as the water and energy hydrological and carbon cycle) [1]. At a more immediate level, renewable resources include forests that have been selectively felled and replanted, animal and plant populations that have been properly managed through controlled hunting, fishing and collecting, and waters with controlled inputs that can be readily recycled and reused. Abstract resources include animals, plants and the natural landscape as part of 'the countryside' used for recreation and tourism activities such as bird watching, fishing, hiking, sight-seeing, etc. Non-renewable resources are of course finite, while the other two categories are effectively infinite. Our descendants will not thank us for exhausting finite resources, nor for destroying the renewable ones.

In many countries, global warming considerations have led to efforts to reduce fossil energy use and to promote renewable energies in the building sector. Energy use reductions can be achieved by minimising the energy demand, by rational energy use, by recovering heat and cold and by using energy from the ambient air and from the ground. To keep the environmental impact of a building at sustainable levels (e.g., by greenhouse gas (GHG) neutral emissions), the residual energy demand must be covered with renewable energy. In this thesis integral concepts for buildings with both excellent indoor environment control and sustainable environmental impact are presented. Special emphasis is put on ventilation concepts utilising ambient energy from the air, the ground and other renewable energy sources, and on the interaction with heating and cooling. It is essential to avoid the need for mechanical cooling, e.g., by peak load cutting, load shifting

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and the use of ambient heat or cold from the air or the ground. Techniques considered are hybrid (controlled natural and mechanical) ventilation including night ventilation, thermo-active building mass systems with free cooling in a cooling tower, and air intake via ground heat exchangers. For both residential and office buildings, the electricity demand remains one of the crucial elements to meet sustainability requirements. The electricity demand of ventilation systems is related to the overall demand of the building and the potential of photovoltaic systems and advanced co-generation units [2].

The heating or cooling of a space to maintain thermal comfort is a highly energy intensive process accounting for as much as 60-70% of total energy use in non-industrial buildings [3]. Of this, approximately 30-50% is lost through ventilation and air infiltration [4]. However, estimation of the energy impact of ventilation relies on detailed knowledge of air change rates and the difference in enthalpy between the incoming and outgoing air streams. In practice, this is a difficult exercise to undertake as there is much uncertainty about the value of these parameters [5]. As a result, a suitable datum from which strategic planning for improving the energy efficiency of ventilation can be developed has proved difficult to establish [6]. Efforts to overcome these difficulties are progressing in the following two ways:

- Identifying ventilation rates in a representative cross section of buildings.
- The energy impact of air change in both commercial and domestic buildings.

In addition to conditioning energy, the fan energy needed to provide mechanical ventilation can make a significant further contribution to energy demand. Much depends on the efficiency of design, both in relation to the performance of fans themselves and to the resistance to flow arising from the associated ductwork.

The building sector is an important part of the energy picture. Note that the major function of buildings is to provide an acceptable indoor environment, which allows occupants to carry out various activities. Hence, the purpose behind this energy consumption is to provide a variety of building services, which include weather protection, storage, communications, thermal comfort, facilities of daily living, aesthetics, work environment, etc. However, the three main energy-related building services are space conditioning (for thermal comfort), lighting (for visual comfort), and ventilation (for indoor air quality). Pollution-free environments are a practical impossibility. Therefore, it is often useful to differentiate between unavoidable pollutants over which little source control is possible, and avoidable pollutants for which control is possible. Unavoidable pollutants are primarily those emitted by metabolism and those arising from the essential activities of occupants. ‘Whole building’ ventilation usually provides an effective measure to deal with the unavoidable emissions, whereas ‘source control’ is the preferred and sometimes only practical, method to address avoidable pollutant sources [7]. Hence, achieving optimum indoor air quality relies on an integrated approach to the removal and control of pollutants using engineering judgment based on source control, filtration, and ventilation. Regardless of the kind of building involved, good indoor air quality requires attention to both source control and ventilation. While there are sources common to many kinds of buildings, buildings focusing on renewable energy may have some unique sources and, therefore, may require special attention [7]. In smaller (i.e., house size) buildings, renewable sources are already the primary mechanism for providing ventilation. Infiltration and natural ventilation are the predominant mechanisms for providing residential ventilation for these smaller buildings.

Ventilation is the building service most associated with controlling the indoor air quality to provide a healthy and comfortable environment. In large buildings ventilation is normally supplied through mechanical systems, but in smaller ones, such as single-family homes, it is principally supplied by leakage through the building envelope, i.e., infiltration, which is a renewable resource, albeit unintendedly so. Ventilation can be defined as the process by which clean air is provided to a space. It is needed to meet the metabolic requirements of occupants and to dilute and remove pollutants emitted within a space. Usually, ventilation air must be conditioned by heating or cooling in order to maintain thermal comfort and, hence, becomes an energy liability. Indeed, ventilation energy requirements can exceed 50% of the conditioning load in some spaces [7]. Thus, excessive or uncontrolled ventilation can be a major contributor to energy costs and global pollution. Therefore, in terms of cost, energy, and pollution, efficient ventilation is essential. On the other hand, inadequate ventilation can cause comfort or health problems for the occupants. Good indoor air quality may be defined as air, which is free of pollutants that cause irritation, discomfort or ill health to occupants [8]. Since a long time is spent inside buildings, considerable effort has focused on developing methods to achieve an optimum indoor environment. In the coming century the built environment faces a period where significant adaptation will be required in order that buildings and built-up spaces remain safe.

Please present the background information, motivation, and objective of your paper in this section.

Energy Efficient Comfort

Natural living systems supply humanity with an array of indispensable and irreplaceable services that support our life on earth [8]. These include direct resources such as building products (wood), food, medicines, clothing materials, etc. Living systems also provide functional services such as maintenance of the appropriate mix of atmospheric gases, generation and preservation of soils, disposal of wastes, restoration of systems following disturbance, control of pests, cycling of nutrients and pollination of crops. Thus, not only is humanity totally dependent on the living environment but also the integrity of the planet is itself dependent on the maintenance of the natural environment and on the interactions between the living organisms and the physical/chemical components of the earth.

The methods of expressing the concentration of a constituent of a liquid or gas are:

(1) Mass/volume: The mass of solute per unit volume of solution (in water chemistry). This is analogous to weight per unit volume, typically, mg/L = ppm (parts per million).

(2) Mass/mass or weight/weight: The mass of a solute in a given mass of solution, typically, mg/kg or ppm (parts per million).

If the density of a solution = ρ = mass of solution / volume of solution (kg/L)

And,

Concentration of a constituent in mg/L = C_{A1} = mass of constituent/volume of solution (mg/L)

And,

Concentration of a constituent in ppm = C_{A2} = mass of constituent/mass of solution (mg/kg)

Then rearranging,

$\rho = C_{A1}/C_{A2}$

If $\rho = 1$ kg/L, then $C_{A1} = C_{A2}$ (1)

i.e., the concentration of a constituent in ppm mg/kg = concentration of a constituent in mg/L.

For most applications in water and wastewater environments, $\rho = 1$ kg/L. For applications in the air environment, Eq. (1) does not hold. The use of mg/L is most common in water applications as the volume of the solution is usually determined as well as the mass of the solute. The unit ppm is typically used in sludges or sediments. To prove the portable transmutation of pollutants, experimental investigations may be conducted to bombard C or CO_2 or CH_4 or other air pollutants by accelerated alpha particles in a low-pressure vacuum tube in a similar condition of ionosphere. Heating them with gamma radiation can accelerate the alpha particles [9]. The results of such experimental investigation may prove the probable transmutation of pollutants and self-sustaining equilibrium of the global environment.

The ‘greenhouse effect’ is but one of the environmental problems that have resulted either directly or indirectly from the activities of man. The role of the human population on environmental change has been simply summarised by Erlich [9] in the simplified equation:

I = PAT (2)

Where the impact I of the population on the environment results from the size of the population (P), the *per capita* affluence or consumption (A) and the damage caused by technologies (T) employed to supply each unit of consumption. As P increases, so too does T because supplies to additional people must be mined from deeper ores, pumped from deeper deposits, transported further. It is also suggested that the *per capita* consumption of commercial energy in a nation can be used as a surrogate for the AT part of the equation- a considerable proportion of the environmental damage involves use of commercial energy, from cleaning tropical forests for agriculture to mining, manufacturing, road building and extraction of fossil fuels [9].

The overall human population has more than doubled in the past 40 years although not evenly over the globe. Population growth rates are increasing exponentially in the less/underdeveloped countries while growth is slow or non-existent in most developed countries. Many resources are being depleted with little recycling, and waste products are being returned to the environment in a different form and at concentrations that are often toxic or otherwise damaging. Land use changes are taking place rapidly. The global human population lives on only about 2 per cent of the global land area, but a further 60 per cent is taken up growing crops, grazing livestock or being utilised for extraction of mineral resources and removal of forest. Much of the remaining land area is either desert or covered with ice or is too steep for use [9]. Forests, grasslands and wetlands are disappearing rapidly and deserts are expanding due to soil erosion, a decline in underground water deposits and lowering of water tables. Human activity is therefore seen as a significant cause of environmental change, mainly as a result of the conflict between maintaining and using the environment, i.e., development and exploitation of physical resources, building and urbanisation, changing land use and deposition of wastes, often at the expense of the integrity of the biotic component of the environment and biological resources.

In warm humid conditions, airflow can be an energy-efficient means to achieve indoor thermal comfort. Airflow does not create sensible cooling of air that can be measured on a thermometer; it conducts heat from our skin. This results in a cooling sensation ASHRAE [10]. This cooling sensation becomes noticeable with uniform airflow above 0.2 m/s, while airflow greater than 1.0 m/s begin to disturb loose papers. This discourages utilisation of airflow greater than 1.0 m/s in office type spaces. Airflow up to 2.0 m/s is frequently provided in industrial and storage buildings as well as living areas and bedrooms in houses in hot humid climates. Many studies, (ASHRAE [10]) have modelled the cooling sensation of uniform airflow on human thermal response. In steady airflow, the cooling sensation (CS), of airflow can be estimated in degrees Celsius using equation:

$CS = 3.67(V-0.2)-(V-0.2)^2 \ {}^{o}C$ (3)

When average airflow, V, is in m/s

Natural ventilation from breezes or difference in air temperature generated by solar chimneys can induce passive indoor airflow. The problem with a passive approach is that breezes are not always present when needed and solar chimneys rarely produce enough airflow for comfort. Fans, particularly ceiling fans, can provide a reliable source for airflow for indoor thermal comfort in warm humid environments. Unsteady airflow, with an appropriate gust frequency, can enhance the cooling sensation of airflow. Airflow provides a cooling sensation for occupants of buildings in warm humid climates. The enhanced benefits of turbulent airflow, with gust velocities within the range of 0.3 Hz to 0.5 Hz (with a peak preference at 0.47 Hz), present further opportunities to utilise large, high-volume, low-speed ceiling fans for energy efficient cooling [11]. This effect appears to be due to a peak response of human cold cutaneous thermoreceptors just beneath the skin.

As an alternative and new design philosophy, hybrid ventilation and cooling technologies (HVAC) combine the advantages of mechanical HVAC systems and natural ventilation. It has the potential to reduce energy consumption in many buildings, improve the satisfaction level of the occupants' comfort and minimise sick building syndrome (SBS). Hybrid ventilation and cooling provides opportunities for innovative solutions to the problems of energy-consuming environment control in buildings. Because hybrid systems combine natural and mechanical ventilation, they present several complex challenges to design and analysis tools, requiring a global approach that takes into account the outdoor environment, the indoor environment, the control strategy and the mechanical system [12].

Results and Discussions

Bioclimatic design cannot continue to be a side issue of a technical nature to the main architectural design. In recent years, bioclimatic design started to alter course and to become much more holistic in its approach while trying to address itself to:

- The achievement of a sustainable development.
- The depletion of non-renewable sources and materials.
- The life cycle analysis of buildings.
- The total polluting effects of buildings on the environment.
- The reduction of energy consumption, and Human health and comfort.

Hidden dimensions of architectural creation are vital to the notion of bioclimatic design. The most fundamental ones are:

TIME, which has been called the fourth dimension of architectural space, is of importance because every object cannot exist but in time. The notion of time gives life to an object and releases it to periodic (predictable) or unperiodic repetition. Times relates to seasonal and diurnal patterns and thus to climate and the way that a building behaves or should be designed to couple with and not antagonise nature. It further releases to the dynamic nature of a building in contrast to the static image that we have created for it.

AIR, is a second invisible but important element. We create space and pretend that it is empty, oblivious of the fact that it is both surrounded by and filled with air. Air in its turn, due to air-movement, which is generated by either temperature or pressure differences, is very much there and alive[13]. And related to the movement of air should be building shapes, sections, heights, orientations and the size and positioning of openings.

LIGHT, and in particular daylight, is a third important element. Architecture cannot exist but with light and from the time we have been able to substitute natural light with artificial lighting, many a building and a lot of architecture has become poorer so. It is not an exaggeration to say that the real form giver to architecture is not the architect himself but light and that the architect is but the form moulders.

Vernacular architecture is beautiful to look at as well as significant to contemplate on. It is particularly interesting to realise the nature of traditional architecture where various devices to attain thermal comfort without resorting to fossil fuels can be seen. Sun shading and cross ventilation are two major concerns in house design and a south-facing façade is mandatory to harness the sun in winter as much as possible. Natural ventilation required higher ceilings to bring a cooling effect to occupants in buildings built fifty years ago, whereas modern high technology buildings have lower ceiling heights, thus making air conditioning mandatory. Admitting the human right of enjoying modern lives with a certain level of comfort and convenience, it is necessary to consider how people can live and work in an ideal environment with the least amount of energy consumption in the age of global environment problems. People in the modern age could not put up with the poor indoor environment that people in the old age used to live in. In fact, in those days people had to live with the least amount of fuels readily available and to devise various means of constructing their houses so that they would be compatible with the local climate. It is important; therefore, in designing passive and low energy architecture for the future to learn from their spirit to overcome difficulties by having their creative designs adapted to respective regional climatic conditions and to try to devise the ecotechniques in combination with a high grade of modern science [14].

In climate-sensitive architecture, strategies are adopted to meet occupants' needs, taking into account local solar radiation, temperature, wind and other climatic conditions. Different strategies are required for the various seasons. These strategies can themselves be subdivided into a certain number of concepts, which represent actions.

Innovative daylighting systems have four key aims: to increase daylight levels deep within rooms, to improve daylight uniformity, to control direct sunlight and to reduce glare. In non-domestic buildings, lighting can be a major energy consumer. The provision of daylight therefore needs to be viewed as an important part of low energy, passive solar design. Crisp et al [15] have identified substantial potential savings (typically around 20-40% of lighting use) from exploiting daylight in such buildings. The four aims of such daylighting systems are therefore to:

1. Increase daylight levels towards the rear of deep rooms.
2. Improve daylight uniformity within a space, and hence its appearance.
3. Control direct sunlight so that it can be used as an effective working illuminant.
4. Reduce glare and discomfort for occupants.

If innovative daylighting systems are to be used for shading, they need to be designed properly. The system should reduce glare for seated occupants, controlling direct sunlight for all sun positions. This is particularly important for interiors with display screen equipment. Supplementary clear view glazing needs extra shading devices.

Laminated glass with light-directing holograms allows a great variety of applications in architecture for utilisation of solar energy, improvement of room comfort as well as design of solar light and colour effects. The angle of diffraction of light depends on the wavelength described by the following equation:

$$\sin \alpha = \lambda / g \quad (4)$$

Where:

λ is the wavelength of light

g is the constant of grating

α is the angle of diffraction

The environmental advantages are obvious. Daylighting in buildings can be improved and reductions in electricity for room illumination will be more than 50% [15]. Shading of direct solar radiation in combination with photovoltaic power generation and diffuse daylighting opens a wide field of future developments and applications.

Summary or Conclusions

With environmental protection posing as the number one global problem, man has no choice but to reduce his energy consumption. One way to accomplish this is to resort to passive and low-energy systems to maintain thermal comfort in buildings. The conventional and modern designs of wind towers can successfully be used in hot arid regions to maintain thermal comfort (with or without the use of ceiling fans) during all hours of the cooling season, or a fraction of it. Climatic design is one of the best approaches to reduce the energy cost in buildings. Proper design is the first step of defence against the stress of the climate. Buildings should be designed according to the climate of the site, reducing the need for mechanical heating or cooling. Hence maximum natural energy can be used for creating a pleasant environment inside the built envelope. Technology and industry progress in the last decade diffused electronic and informatics' devices in many human activities, and also in building construction. The utilisation and operating opportunities components, increase the reduction of heat losses by varying the thermal insulation, optimising the lighting distribution with louver screens and operating mechanical ventilation for coolness in indoor spaces. In addition to these parameters the intelligent envelope can act for security control and became an important part of the building revolution. Application of simple passive cooling measures is effective in reducing the cooling load of buildings in hot and humid climates. 43% reductions can be achieved using a combination of well-established technologies such as glazing, shading, insulation, and natural ventilation. More advanced passive cooling techniques such as roof pond, dynamic insulation, and evaporative water jacket need to be considered more closely. The building sector is a major consumer of both energy and materials worldwide, and that consumption is increasing. Most industrialised countries are in addition becoming more and more dependent on external supplies of conventional energy carriers i.e., fossil fuels. Energy for heating and cooling can be replaced by new renewable energy sources. New renewable energy sources, however, are usually not economically feasible compared with the traditional carriers. In order to achieve the major changes needed to alleviate the environmental impacts of the building sector, it is necessary to change and develop both the processes in the industry itself, and to build a favourable framework to overcome the present economic, regulatory and institutional barriers.

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