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Design and Operation of Low Energy Consumption Passive Human Comfort Solutions

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Abstract

The use of renewable energy sources is a fundamental factor for a possible energy policy in the future. Considering the sustainable character of most 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. Consumption of the primary energy will be reduced by following natural or hybrid ventilation, some Passive measures compared to air-conditioning. Fossil fuels dependency will be reduced by the utilization of renewable energy in agricultural greenhouses and buildings. Thus, promotion of the novel renewable applications and its fortification resulting in the preservation of the ecosystem. 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. Present study described about various low energy building designs and explains the effects of dense urban building on energy consumption and in the climatic changes. Moreover, this study outlines some measures to save energy in buildings.

Keywords: Renewable technologies, Built environment, Sustainable development, Mitigation measures.

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

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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. Utilization of energy from the ground and ambient air effectively minimizes the energy demand resulting in the reduction of energy usage. 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 utilizing 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 and the use of ambient heat or cold from the air or the ground. Intake of the air through ground heat exchangers, night ventilation are the considered hybrid ventilation techniques. 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. Emissions from metabolism and the regular/essential activities of the inmates are the main causes for unavoidable pollutants. to dealt with the unavoidable emissions, 'Whole building' ventilation is the effective measure whereas 'source control' is the practical, measure for avoidable pollutant sources [7]. However, engineering judgment based on source control, filtration, and ventilation were used in the removal and control of pollutants to attain optimum indoor air quality. Scrutiny of the both source control and ventilation is necessary for the good indoor air quality regardless of the kind of building involved. 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. Often to maintain the thermal comfort, ventilation air must be adapted by heating or cooling. Hence, it became an energy liability. certainly, ventilation energy prerequisites can surpass half of the adapted load in some spaces [7]. Global pollution and energy costs were due to excessive or uncontrolled ventilation. Hence, adequate ventilation is necessary in terms of cost, energy, and pollution. Moreover, discomfort and health problems occur due to this inadequate ventilation [7]. 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 quality of indoor air is defined as the air, that is free from pollutants-which is the main reason behind illness to occupants, causes irritation and discomfort [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.

Environment pollutions

The multifaceted role of present-day environmental engineers demands a greater understanding of the functioning of living systems and their interaction with the environment on which the work of the engineer is based. As shown in figure 1 the physical and chemical (abiotic) components are one part of the natural environment, while the biotic components are living organisms that provide well-being for the human species and the earth.

Table 1 lists the significant directives. The list is meant to give an idea of the range of directives and is not meant to be comprehensive. The significant 'environments' are: water, air and land (soil). The criteria air pollutants (ambient air standards) and some limits and associated directives are listed in table 2. It is noted from table 2 that not all criteria pollutants have EU ambient limit values.

The direct and indirect effect is to be described on:

- Material and cultural heritage.
- Human beings, fauna and flora.
- Soil, water, air, climates and landscape.

Other areas addressed in directives that are of relevance to environmental engineering/science include: Noise, habitats, and general.

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.

Methods of Expressing Concentration

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,

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

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

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, ρ = 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

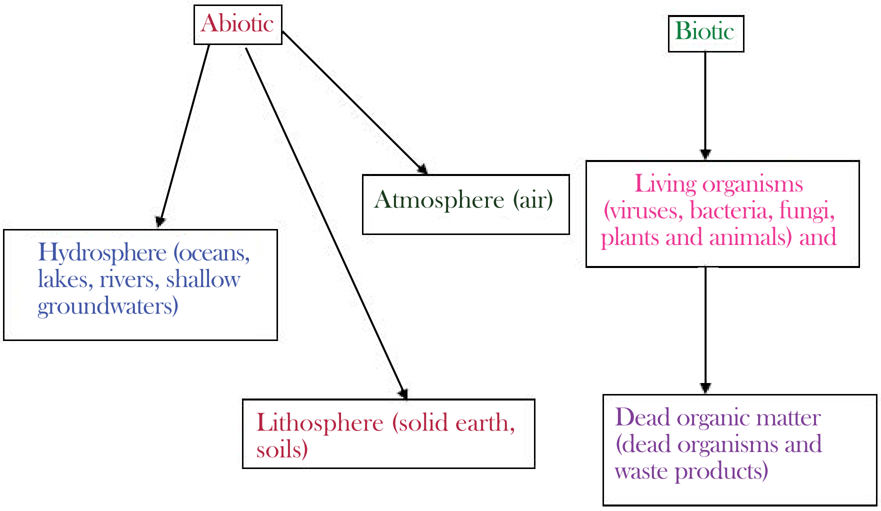

Figure 1: The major components and subcomponents of the natural environment.

Table1: Significant EU environmental directives in water, air and land environments.

Environment	Directive name
Water	Surface water for drinking Sampling surface water for drinking Drinking water quality Quality of freshwater supporting fish Shellfish waters Bathing waters Dangerous substances in water Groundwater Urban wastewater Nitrates from agricultural sources
Air	Smokes in air Sulphur dioxide in air Lead in air Large combustion plants Existing municipal incineration plants New municipal incineration plants Asbestos in air Sulphur content of gas oil Lead in petrol Emissions from petrol engines Air quality standards for NO_2 Emissions from diesel engines
Land	Protection of soil when sludge is applied

Table 2: EU criteria pollutant standards in the ambient air environment.

Pollutant	EU limit
CO	30 mg/m^2; 1h
NO_2	200 μg/m^2; 1h
O_3	235 μg/m^2; 1h
SO_2	250-350 μg/m^2; 24h 80-120 μg/m^2; annual
PM_{10}	250 μg/m^2; 24h 80 μg/m^2; annual
SO_2+PM_{10}	100-150 μg/m^2; 24h 40-60 μg/m^2; annual
Pb	2 μg/m^2; annual
Total suspended particulate (TSP)	260 μg/m^2; 24h
HC	160 μg/m^2; 3h

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.

People, Power and Pollution

Population consists of a group of individuals of the same species living in a area at the same time. Each population is genetically distinct to some degree from other separate populations of the same species. They have a size and a birth, death and hence population growth rate. Populations of different species live together, many interacting with each other, forming a community, e.g., in a pond-a natural community of plants, animals and microbes forming a distinctive living system.

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 summarized by Erlich [9] in the simplified equation:

$$I=PAT \qquad (2)$$

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 utilized 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 because of the conflict between maintaining and using the environment, i.e., development and exploitation of physical resources, building and urbanization, changing land use and deposition of wastes, often at the expense of the integrity of the biotic component of the environment and biological resources.

Energy-Efficient Comfort

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 [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 utilization 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, [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:

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

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 utilize 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 minimize 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 considers the outdoor environment, the indoor environment, the control strategy and the mechanical system [12].

Wind Towers

Operation of conventional wind towers or Baud-Geers has achieved summer comfort in hot arid regions [13]. Wind towers maintain natural ventilation through buildings due to wind or buoyancy effects. The tower structure is cooled externally through radiative transfer with the sky, and internally with the cool ambient air, circulated through the building and the tower during the night. During the day, the warm ambient air is partially cooled by the tower structure before entering the building. When passed over moist surfaces air is cooled evaporatively. However, sensible and evaporative cooling potentials of conventional wind towers, which depend on the tower design, are limited. Another disadvantage of the conventional wind tower is the admittance of dust into the building. Two modern designs of wind towers are considered which eliminate the above disadvantages. One design incorporates one-way dampers in the tower head and a wetted column in the tower. This design, which is particularly suitable in areas with good winds, evaporatively cools the hot-dry ambient air before admitting it into the building. The other design incorporates evaporative cooling pads at the tower entrance. This design is particularly suitable in areas with very little or no winds.

With the advent of mechanical or chemical cooling systems, the use of Baud-Geers in new buildings has been greatly reduced. The use of evaporative or desert coolers and mechanical air conditioners is now very common. The major advantage of wind towers or Baud-Geers is that they are passive systems, requiring no energy for their operation. Major disadvantages of the conventional wind towers may be summarized as follows:

- Dust and insects can enter the building.
- A portion of the air admitted in the tower is lost through other tower openings and never enters the building. When the tower has only one opening facing the wind, all the air entering the tower enters the house.
- The amount of coolness which can be stored in the tower mass is generally limited (due to small mass and low specific heat of the energy-storing material) and may not be enough to meet the cooling needs of the building during hot summer days.
- The evaporative cooling potential of the air is not fully utilized.
- Baud-Geers do not find any application in areas with very low wind speeds.

Modern designs of wind towers are briefly discussed below

Wind towers with evaporative cooling column: This design consists of three distinct improvements. The height and the total cross-sectional area of the column can be selected to produce a desired airflow rate and temperature to meet the level of thermal comfort needed in a building.

- A tower head, which accepts wind blowing in any direction and prevents the air from leaving the other tower openings.
- A column with a substantial increase in the heat and mass transfer areas.
- Full utilization of the potential of evaporative cooling of air by wetting the wall areas of the column.

Wind towers with evaporative cooling pads placed at the tower entrance: In areas with little or no winds, the entire opening area of the wind tower head can be covered with evaporative cooling pads. The air circulation through the tower and the building is accomplished through buoyancy effects. This design finds applications in areas with low winter heating needs [13].

With environmental protection posing as the number one global problem, man has no choice but reducing 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 the 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.

Bioclimatic Design

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: 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 aperiodic 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 antagonize nature. It further releases to the dynamic nature of a building in contrast to the static image that we have created for it.

Air: 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. And related to the movement of air should be building shapes, sections, heights, orientations and the size and positioning of openings.

Light: Light and 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 realize 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 Eco techniques in combination with a high grade of modern science [14].

Relationship between Climate, Building and Occupants

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:

- Increase daylight levels towards the rear of deep rooms.
- Improve daylight uniformity within a space, and hence its appearance.
- Control direct sunlight so that it can be used as an effective working illuminant.
- 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:

$\sin \alpha = \lambda / g$ (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.

Health and the built environment

Two opposing trends threaten engineers. The first is concern for global pollution. Not only energy use but also energy sources will be defined in terms of atmospheric contamination. The second is demand for a performance specification for a more satisfactory indoor climate. The engineers of today are facing two kinds of environmental forces. The first is a respect for the global external environment, which knows no natural boundaries and is now near saturation with pollution and may be affecting our climate in a harmful way. The second is a rising expectation of better indoor conditions, which in the past has meant a more energy intensive building through air conditioning. Safety issues and avoidance of exposure to toxic materials are being reinforced by concern for long-term health and welfare. The second trend is the continued increase in energy use as our population rises and our productivity increases. Rising standards of living require more fuel to keep us cleaner and warmer and enable us to travel long distances for recreation. More effective use of energy is now essential.

The four more important types of harm from man's activities are global warming gases, ozone destroying gases, gaseous pollutants and microbiological hazards (Table 3). The earth is some 30oC warmer due to the presence of gases but the global temperature is rising. This could lead to the sea level rising at the rate of 60 mm each decade with the growing risk of flooding in low-lying areas (Figure 2). At the United Nations Earth Summit at Rio in June 1992 some 153 countries agreed to pursue sustainable development [16]. A main aim was to reduce emission of carbon dioxide and other greenhouse gases (GHGs). Reduction of energy use in buildings is a major role in achieving this. Carbon dioxide targets are proposed to encourage designers to look at low energy designs and energy sources (Figure 3).

A main core with several channels will be able to handle heating and cooling simultaneously, provided that the channels to some extent are thermally insulated and can be operated independently as single units, but at the same time function as integral parts of the entire core. The shapes and numbers of the internal channels and the optimum configuration will obviously depend on the operating characteristics of each installation some possible configurations. Loading of the core is done by diverting warm and cold air from the heat pump through the core during periods with excess capacity compared to the current need of the building [16]. The cool section of the core can also be loaded directly with air during the night, especially in spring and fall when nights are cold and days may be warm.

The activities and operations of the occupants, their patterns of use and misuse, can have a significant effect on the energy performance of the intermediate and internal environments. The management and control of three interfaces: external to internal, external to intermediate and internal to intermediate can also have significant effect particularly in response to seasonal, daily and hourly variations in solar energy availability, its regulation and distribution. Other facilities management function can also have major energy implications, particularly maintenance, cleaning, replacement, refurbishment and adaptation.

As our knowledge of satisfactory conditions develops so we can control the physical environment to provide satisfaction. Performance based design will specify how many shall be satisfied. Target figures suggest satisfaction for 90% of the occupants is high quality, down to 70% for poor quality designs [16]. Such performance values are being applied to a whole range of indoor factors such as air quality (Figure 4), thermal comfort, and noise levels.

Comfort Temperatures and Climate

Nearly half the world's energy use is associated with providing environmental conditioning in buildings and about two thirds of this is for heating, cooling and mechanical ventilation. Whilst in cooler climates, the energy used for heating has been reduced by the application of conservation

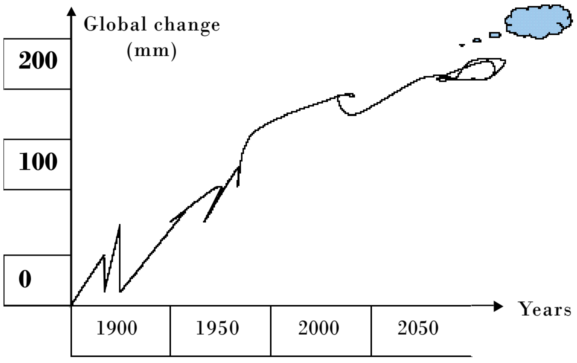

Figure 2: Change in global sea level.

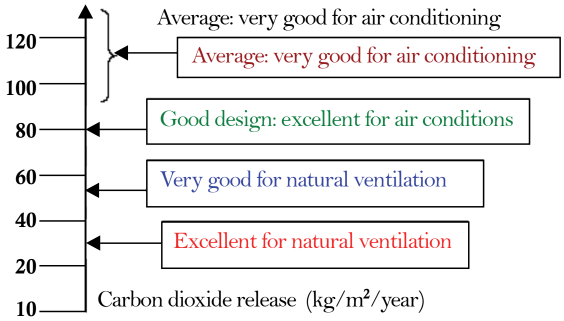

Figure 3: Designing for atmospheric pollution.

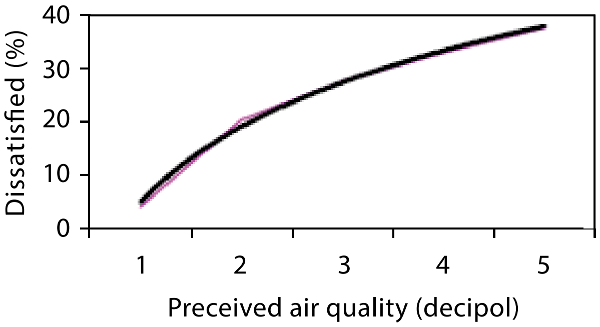

Figure 4: Designing to a satisfaction level.

Table 3: The external environment.

Damage	Manifestation	Design
NO_x, SO_x	Irritant	Low NO_x burners
	Acid rain land damage	Low sulphur fuel
	Acid rain fish damage	Sulphur removal
	Global warming	Thermal insulation
CO_2	Rising sea level	Heat recovery
	Drought, storms	Heat pumps
	Increased ultra violet	No CFC's or HCFC's
O_3 destruction	Skin cancer	Minimum air conditioning
	Crop damage	Refrigerant collection
	Pontiac fever	Careful maintenance
Legionnellosis Irritant	Legionnaires	Dry cooling towers

technologies; energy requirements for cooling are on the increase. The application of passive cooling techniques to buildings in warm climates creates the need for appropriate comfort criteria. The perceived need for mechanical cooling is to achieve accepted standards of thermal comfort, usually defined (directly or indirectly) by temperature limits. There is, however, growing controversy as to what these standards are. For example, in a compilation of results from 47 field studies, predominantly in warm and hot climates, Humphrey's (1978) [17] found that the preferred comfort temperature in buildings was a function of the average monthly outdoor temperature:

$$T_n = 0.534\ T_o + 11.9 \qquad (5)$$

Where:

Tn is the indoor comfort temperature, and T_o is the mean of the local daily maximum and daily minimum outdoor temperatures at the appropriate season of the year.

Fanger's theory [18] relates the sensation of hot or cold (Predicted Mean Vote, PMV), and subsequently the discomfort or dissatisfaction (Predicted Percentage Dissatisfied, PPD), to the imbalance between the heats produced by the bodies' metabolism, and the heat loss to the environment. Obviously this imbalance cannot exist indefinitely, and the sensation of discomfort is a signal to the person to take some action to restore heat balance

$$PMV= (0.303\ \exp^{-0.36M} + 0.028)\ (M\text{-}H) \qquad (6)$$

and

$$PPD=100\text{-}95\ \exp\text{-}\ (0.0335PMV^4 + 0.218\ PMV^2) \quad (7)$$

Where,

M is the metabolic rate and H is the heat loss to the environment.

The result of using Fanger's equations seems to predict the need for much more closely controlled conditions than one usually finds in free-running buildings, in which people still seem to be comfortable. For example, the ISO 7730, based upon Fanger's equations, recommends an optimal operative temperature of 24.5°C ± 1.5°C for light sedentary work with light summer clothing.

The storage concept is based on a modular design that will facilitate active control and optimization of thermal input/output, and it can be adapted for simultaneous heating and cooling often needed in large service and institutional buildings [18]. The conceptual integration of various warm/cold energy sources combined with thermal energy storage system is illustrated as shown in figure 5. A main core with several channels will be able to handle heating and cooling simultaneously, provided that the channels to some extent are thermally insulated and can be operated independently as single units, but at the same time function as integral parts of the entire core. The shapes and numbers of the internal channels and the optimum configuration will obviously depend on the operating characteristics of each installation some possible configurations.

Energy Savings

The admission of daylight into buildings alone does not guarantee that the design will be energy efficient in terms of lighting. In fact, the design for increased daylight can often raise concerns relating to visual comfort (glare) and thermal comfort (increased solar gain in the summer and heat losses in the winter from larger apertures). Such issues will clearly need to address in the design of the window openings, blinds, shading devices, heating systems, etc. Simple techniques can be implemented to increase the probability that lights are switched off. These include: (1) making switches conspicuous (2) locating switches appropriately in relation to the lights (3) switching banks of lights independently, and (4) switching banks of lights parallel to the main window wall.

Large energy savings cover a wide range of issues including:

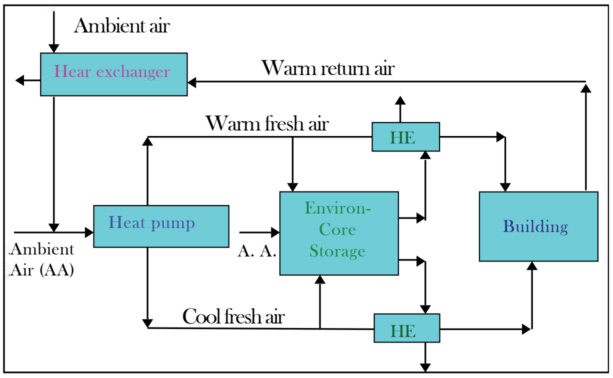

Figure 5: Flow sheet of combined heating and cooling with air-source heat pump and energy recovery from return air in combination with Environ-core thermal storage.

- Guidelines on low energy design.
- Natural and artificial lighting.
- Solar gain and solar shading.
- Fenestration design.
- Energy efficient plant and controls.
- Examining the need for air conditioning.

The strategy:

- Integration of shading and daylighting: an integral strategy is essential and feasible where daylighting and shading can be improved simultaneously.
- Effect of shading on summer comfort conditions: solar shading plays a central role in reducing overheating risks and gives the potential for individual control but should be complimented with other passive design strategies.
- Effect of devices on daylighting conditions: devices can be designed to provide shading whist improving the daylight conditions, notably glare and the distribution of light in a space, thus improving the visual quality.
- Energy savings: energy savings from the avoidance of air conditioning can be very substantial, whilst daylighting strategies need to integrate with artificial lighting systems to be beneficial in terms of energy use.

In summary, achieving low energy building requires a comprehensive strategy that covers; not only building designs, but also considers the environment around them in an integral manner. Major elements for implementing such a strategy are as follows:

Efficient use of energy

Various parameters are essential to achieving sustainable development. Some of them are as follows:

- Climate responsiveness of buildings.
- Good urban planning and architectural design.
- Good housekeeping and design practices.
- Passive design and natural ventilation.
- Use landscape as a means of thermal control.
- Energy efficiency lighting.
- Energy efficiency air conditioning.
- Energy efficiency household and office appliances.
- Heat pumps and energy recovery equipment.
- Combined cooling systems.
- Fuel cells development.

Utilize renewable energy

To encourage all sectors of the population to participate in utilizing and adoption of renewable energy technologies:

- Photovoltaics.
- Wind energy.
- Small hydros.
- Waste-to-energy.
- Landfill gas.
- Biomass energy and biofuels.

Reduce transport energy

To achieve technical development the following should be addressed:

- Reduce the need to travel.
- Reduce the level of car reliance.
- Promote walking and cycling.
- Use efficient public mass transport.
- Alternative sources of energy and fuels.

Increase awareness

Successful applications of renewable technologies also require:

- Promote awareness and education.
- Encourage good practices and environmentally sound technologies.
- Overcome institutional and economic barriers.
- Stimulate energy efficiency and renewable energy markets.

Integrated energy systems need to be implemented at two levels:

- Integration of various thermal energy sources into concurrent systems for heating, cooling and production of hot water.
- Physical integration of such systems into the building structure.

However, integrated energy systems for buildings face a number of barriers, of which the most significant are:

- Lack of expertise, information and demonstration systems.
- Immature products and service delivery chains.
- Utilities that still favor central generation and the market power created by such infrastructure.
- Electricity markets that do not yet account for environmental externalities.

In practice, low energy environments are achieved through a combination of measures that include:

- The application of environmental regulation and policy.
- The application of environmental science and best practice.
- Mathematical modelling and simulation.
- Environmental design and engineering.
- Construction and commissioning.

- Management and modifications of environments in use.

The following initial requirements for the air quality in the archives were established by the consultant in conservation and international recommendations:

- Air temperature between 17oC and 19oC.
- Relative humidity between 50 and 60%, with lower values in the photographic archives.
- Low levels of natural light and total exclusions of direct sunlight in archives, reading-rooms and complementary spaces.
- Exclusion of ultra-violet radiation from natural and artificial lighting.
- Air filters to exclude particles larger than 0.01 microns (this requirement was relaxed, considering the high cost, additional energy requirements and problems of maintenance).
- Filters of active carbon to reduce the content of ozone, Sulphur dioxide and oxides of nitrogen.

Conclusion

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 defense 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 utilization and operating opportunities components, increase the reduction of heat losses by varying the thermal insulation, optimizing 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. It would be beneficial if there is a close consideration on the advancements in the passive cooling techniques such as evaporative water jacket, dynamic insulation and roof pond. The building sector is a major consumer of both energy and materials worldwide, and that consumption is increasing. Most industrialized 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 favorable framework to overcome the present economic, regulatory and institutional barriers.

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