Asian Journal of Advances in Basic and Applied Science
2015: Vol-1: No-1: 54-69
Review Article

Low energy building design: Heating, ventilation and air conditioning

Abdeen Mustafa Omer

Forest Road West, Nottingham NG7 4EU, UK

Abstract

The move towards a de-carbonised world, driven partly by climate science and partly by the business opportunities it offers, will need the promotion of environmentally friendly alternatives, if an acceptable stabilisation level of atmospheric carbon dioxide is to be achieved. This requires the harnessing and use of natural resources that produce no air pollution or greenhouse gases and provides comfortable coexistence of human, livestock, and plants. This study reviews the energy-using technologies based on natural resources, which are available to and applicable in the farming industry. Integral concept for buildings with both excellent indoor environment control and sustainable environmental impact are reported in the present communication. 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. Special emphasis is put on ventilation concepts utilising ambient energy from air ground and other renewable energy sources, and on the interaction with heating and cooling. It has been observed that for both residential and office buildings, 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. 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. This article 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.

Key words: Built environment; energy efficient comfort; ventilation; sustainable environmental impact

Corresponding autor

Abdeen Mustafa Omer
Forest Road West, Nottingham NG7 4EU, UK
Aden.mustafa@yahoo.uk

1. Introduction

Globally, buildings are responsible for approximately 40% of the total world annual energy consumption [1]. Most of this energy is for the provision of lighting, heating, cooling, and air conditioning. Increasing awareness of the environmental impact of CO_2 and NO_x emissions and CFCs triggered a renewed interest in environmentally friendly cooling, and heating technologies. Under the 1997 Montreal Protocol, governments agreed to phase out chemicals used as refrigerants that have the potential to destroy stratospheric ozone. It was therefore considered desirable to reduce energy consumption and decrease the rate of depletion of world energy reserves and pollution of the environment. 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 [2]. 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. The provision of good indoor environmental quality while achieving energy and cost efficient operation of the heating, ventilating and air-conditioning (HVAC) plants in buildings represents a multi variant problem. The comfort of building occupants is dependent on many environmental parameters including air speed, temperature, relative humidity and quality in addition to lighting and noise. The overall objective is to provide a high level of building performance (BP), which can be defined as indoor environmental quality (IEQ), energy efficiency (EE) and cost efficiency (CE).

- Indoor environmental quality is the perceived condition of comfort that building occupants experience due to the physical and psychological conditions to which they are exposed by their surroundings. The main physical parameters affecting IEQ are air speed, temperature, relative humidity and quality.
- Energy efficiency is related to the provision of the desired environmental conditions while consuming the minimal quantity of energy.
- Cost efficiency is the financial expenditure on energy relative to the level of environmental comfort and productivity that the building occupants attained. The overall cost efficiency can be improved by improving the indoor environmental quality and the energy efficiency of a building.

An approach is needed to integrate renewable energies in a way to meet high building performance. However, because renewable energy sources are stochastic and geographically diffuse, their ability to match demand is determined by adoption of one of the following two approaches [2]: the utilisation of a capture area greater than that occupied by the community to be supplied, or the reduction of the community's energy demands to a level commensurate with the locally available renewable resources. For a northern European climate, which is characterised by an average annual solar irradiance of 150 Wm^{-2}, the mean power production from a photovoltaic component of 13% conversion efficiency is approximately 20 Wm^{-2}. For an average wind speed of 5 ms^{-1}, the power produced by a micro wind turbine will be of a similar order of magnitude, though with a different profile shape. In the UK, for example, a typical office building will have a demand in the order of 300 $kWhm^{-2}yr^{-1}$. This translates into approximately 50 Wm^{-2} of façade, which is twice as much as the available renewable energies [3]. Thus, the aim is to utilise energy efficiency measures in order to reduce the overall energy consumption and adjust the demand profiles to be met by renewable energies. For instance, this approach can be applied to greenhouses, which use solar energy to provide indoor environmental quality. The greenhouse effect is one result of the differing properties of heat radiation when it is generated at different temperatures. Objects inside the greenhouse, or any other building, such as plants, re-radiate the heat or absorb it. Because the objects inside the greenhouse are at a lower temperature than the sun, the re-radiated heat is of longer wavelengths, and cannot penetrate the glass. This re-radiated heat is trapped and causes the temperature inside the greenhouse to rise. Note that the atmosphere surrounding the earth, also, behaves as a large greenhouse around the world. Changes to the gases in the atmosphere, such as increased carbon dioxide content from the burning of fossil fuels, can act like a layer of glass and reduce the quantity of heat that the planet earth would otherwise radiate back into space. This particular greenhouse effect, therefore, contributes to global warming. The application of greenhouses for plants growth can be considered one of the measures in the success of solving this problem. Maximising the efficiency gained from a greenhouse can be achieved using various approaches, employing different techniques that could be applied at the design, construction and operational stages. The development of greenhouses could be a solution to farming industry and food security.

2. Built environment

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. Of this, approximately 30-50% is lost through ventilation and air infiltration. However, estimation of energy impact of ventilation relies on detailed knowledge about air change rate and the difference in enthalpy between the incoming and outgoing air streams. In practice, this is a difficult exercise to undertake since there is much uncertainty about the value of these parameters [4]. 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 [4]. 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. Figure 1 illustrates the typical fan and thermal conditioning needs for a variety of ventilation rates and climate conditions.

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 [5]. 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 [5]. 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 [5]. 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.

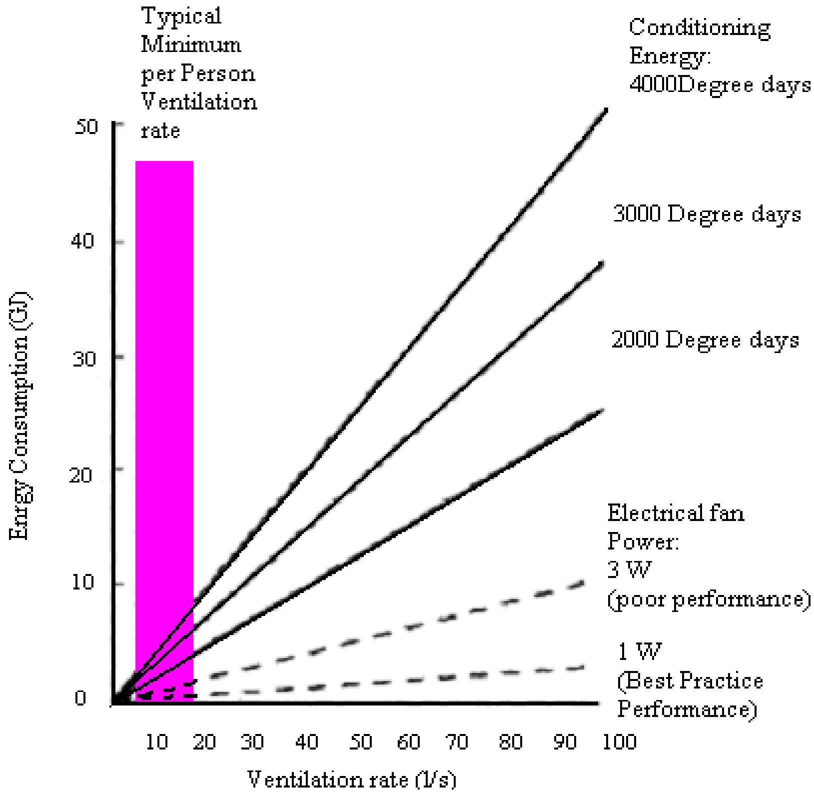


Figure1 Energy impact of ventilation

Good indoor air quality may be defined as air, which is free of pollutants that cause irritation, discomfort or ill health to occupants [6]. Since long time is spent inside buildings, considerable effort has focused on developing methods to achieve an optimum indoor environment. An almost limitless number of pollutants may be present in a space, of which many are at virtually immeasurably low concentrations and have largely unknown toxicological effects [6]. The task of identifying and assessing the risk of individual pollutants has become a major research activity [e.g., 5, 6, and 7]. In reality, a perfectly pollutants-free environment is unlikely to be attained. Some pollutants can be tolerated at low concentrations, while irritation and odour often provide an early warning of deteriorating conditions. Health related air quality standards are typically based on risk assessment and are either specified in terms of maximum-permitted concentrations or a maximum allowed dose. Higher concentrations of pollutants are normally permitted for short-term exposure than are allowed for long-term exposure [7].

Ventilation is essential for securing a good indoor air quality, but, as explained earlier, can have a dominating influence on energy consumption in buildings. Air quality problems are more likely to occur if air supply is restricted. Probably a ventilation rate averaging 7 l/s.p represents a minimum acceptable rate for normal odour and comfort requirements in office type buildings [8]. Diminishing returns are likely to be experienced at rates significantly above 10 l/s.p [8]. If air quality problems still persist, the cause is likely to be poor outdoor air quality (e.g., the entrainment of outdoor traffic fumes), poor air distribution or the excessive release of avoidable pollutants into space. However, the energy efficiency of ventilation can be improved by introducing exhaust air heat recovery, ground pre-heating, demand controlled ventilation, displacement ventilation and passive cooling [9]. In each case, a very careful analysis is necessary to ensure that the anticipated savings are actually achievable. Also, it is essential to differentiate between avoidable and unavoidable pollutant emissions. Achieving energy efficiency and optimum Indoor Air Quality (IAQ) depends on minimising the emission of avoidable pollutants. Pollutants inside buildings are derived from both indoor and outdoor contaminant sources, as illustrated in Figure 2. Each of these tends to impose different requirements on the control strategies needed to secure good health and comfort conditions.

3. Achieving energy efficient ventilation

A recent review of the International Energy Agency [10] concludes that the thermal insulation characteristics of buildings improve; ventilation and air movement is expected to become the dominant heating and cooling loss mechanism in buildings of the next century. Poor air quality in buildings sometimes manifests itself; refer to a range of symptoms that an occupant can experience while present in the building. Typical symptoms include lethargy, headaches, lack of concentration, runny nose, dry throat and eye and skin irritation [10]. Other examples of sick building syndrome have been associated with the presence of specific pollutants, such as outdoor fumes entering through air intakes [11]. Improved ventilation is one way of tackling the problem. Many standards are being introduced to ensure the adequacy and efficiency of ventilation. However, to be effective, standards need to address the minimum requirements of comfort, operational performance, air tightness, provision for maintenance and durability [11]. Also, various methods have been introduced to improve the energy performance of ventilation. These include:

3.1 Thermal recovery

Recovery of thermal energy from the exhaust air stream is possible by means of air-to-air heat recovery systems or heat pumps. In theory, such methods can recover as much as 70% of the waste heat [12]. While these methods are exceedingly popular, their full potential is, often, not achieved. This is because buildings or ductwork are often excessively leaky and, hence, additional electrical energy load is needed. To be successful, the designer must integrate such ventilation design with that of the building itself and be thoroughly aware of all the energy paths [12].

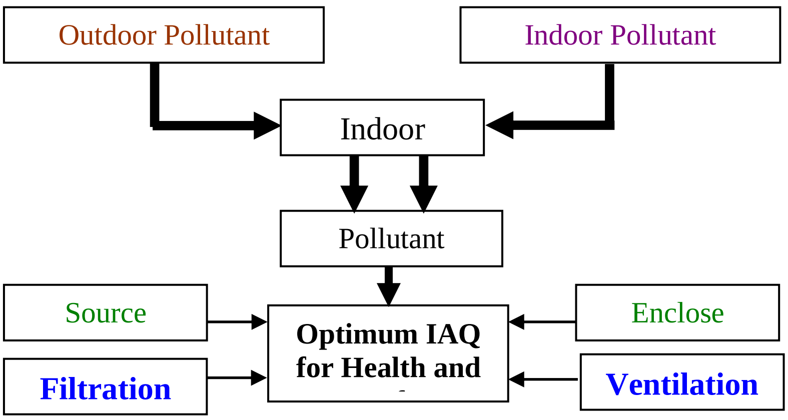


Figure 2 Strategies for controlling IAQ

3.2 Ground pre-conditioning

Ventilation air can be pre-conditioned by passing the supply air ducts under-ground. This can provide a good measure of winter pre-heating and summer pre-cooling [13].

3.3 Demand control ventilation

Demand control ventilation, DCV, systems provide a means by which the rate of ventilation is modulated in response to varying air quality conditions. This is effective if a dominant pollutant is identifiable. In transiently occupied buildings, control by metabolic carbon dioxide concentration has become popular although must be introduced with caution. For success, it is essential to ensure that no other problem pollutants are present [14].

3.4 Displacement ventilation

Displacement ventilation involves distributing clean air at low velocity and at a temperature of approximately 2K below the ambient air temperature of the space [15]. This dense air mass moves at floor level until it reaches a thermal source such as an occupant or electric equipment, causing the air to warm and gently rise. Polluted air is then collected and extracted above the breathing zone. This process reduces the mixing effect of classical dilution ventilation, thus reducing the amount of ventilation needed to achieve the same air quality in the vicinity of occupants [15]. For success, very careful temperature control is needed and there is a limit on potential cooling capacity [15].

4. Outdoors air pollution

Clean outdoor air is essential for good indoor air quality. Although air cleaning is possible, it is costly and not effective in the many offices and dwellings that are naturally ventilated, leaky or ventilated by mechanical extract systems. Some air quality problems are global and can only be controlled by international effort. Other pollutants are much more regional and may be associated with local industry and traffic. Nature, too, presents its own problems with large volumes of dust and gaseous emissions being associated with volcanic activity. Similarly, while naturally occurring, radon can penetrate buildings from the underlying geological strata. Even rural areas are not immune to pollution, where the presence of pollen, fungal spores and agricultural chemicals can result in poor health and cause allergic reactions. There are several pollution control strategies. Some of them are discussed below:

4.1 Filtration

Filtration is applied primarily to remove particulates from the air. Filtration of outdoor air cannot be readily applied to the many buildings that are naturally ventilated or excessively leaky. To be effective, filtration systems must be capable of trapping the smallest of particles and of handling large volumes of airflow. Activated carbon and other absorbing filters are additionally able to remove gaseous pollutants [16].

4.2 Positioning of air intakes

Air intakes must be located away from pollutant sources. Particular sources include street level and car parking locations [16]. Although urban air quality is normally much improved at elevations above street level, contamination from adjacent exhaust stacks and cooling towers must, also, be avoided [16]. Determining the optimum position for air intakes may require extensive wind tunnel or fluid dynamics analysis. Further information on the positioning of air intakes is reviewed by Limb 1995 [7].

4.3 Air quality controlled fresh air dampers

Traffic pollution in urban areas is often highly transient, with peaks occurring during the morning and evening commuting periods. At these times, it may be possible to improve indoor air quality by temporarily closing fresh air intakes and windows.

4.4 Building air tightness

None of the above control strategies will be effective unless the building is well sealed from the outdoor environment to prevent contaminant ingress through air infiltration. Underground parking garages must also be well sealed from occupied accommodation above. Evidence suggests that sealing is often inadequate [16].

5. Indoor pollutants

Pollutants emitted inside buildings are derived from metabolism (odour, carbon dioxide, and bacteria), the activities of occupants (e.g., smoking, washing and cooking), emissions from materials used in construction and furnishing and emissions from machinery and processes. The preferred order of control is discussed below:

5.1 Source control

Once a pollutant has entered a space, it can, at best, only be diluted [17]. Avoidable pollutants should, therefore, be eliminated. This means restricting or, preferably, eliminating potentially harmful pollutant emissions.

5.2 Enclosing and ventilating at source

Pollutants generated as part of the activity of occupants are usually highly localised. Wherever possible, source control should be applied, combined with the use of local extractors [17].

5.3 General ventilation

General ventilation of a space is needed to dilute and remove residual pollution primarily from unavoidable contaminant sources [17].

6. Ventilation of spaces in humid climate

The design of windows in modern buildings in a warm, humid climate can be influenced either by their use to provide physiological and psychological comfort via providing air and daylight to interior spaces or by using them to provide aesthetically appealing fenestration. Most spaces in modern buildings are not adequately ventilated and it is recommended that effort should be directed towards the use of windows to achieve physiological comfort. Evaluation of public housing has focused on four main aspects: economics, social and physical factors, and residents' satisfaction. However, information about the physiological characteristics of spaces in a warm humid climate will aid the design of appropriate spaces with respect to the development and adequate choice of building materials and appropriate use of suitable passive energy. In this light there is a need to examine residents satisfaction with respect to these physiological issues. Proper ventilation in a space is a primary factor in determining human health, comfort and well being of the occupants. At present, getting a proper naturally ventilated space seems to be a difficult task. This is partly due to the specific environmental problems of high temperature, high humidity, low wind velocity, and variable wind direction-usually attributed to the warm humid climate, on the one hand, and the difficulty of articulating the design constraints of security, privacy and the desire of users for large spaces on the other hand. As pointed out by most researchers in the field of passive energy design, such as Givoni [18], Koenigsberger et al. [19] Boulet [20] and Szokolay [21], the types of spaces most suited to this climate are spaces, which are cross-ventilated. This implies that these spaces must have openings at least on opposite sides of a wall, but this condition is difficult to achieve in view of the design constraints mentioned above. So in most cases, the option left to the designer is to have openings on a wall or openings on adjacent walls. The effectiveness of the above arrangement for effective ventilation of a space still depends on other parameters. Therefore, in order to optimise comfort in spaces in warm humid climate, there is a need to re-examine the factors affecting proper ventilation with respect to these design issues. In order to be thermally comfortable in interior spaces, four environmental parameters, namely air temperature, relative humidity, mean radiant temperature and air velocity, need to be present in the space in adequate proportions [21]. In a warm, humid climate, the predominance of high humidity necessitates a corresponding steady, continuous breeze of medium air speed to increase the efficiency of sweat evaporation and to avoid discomfort caused by moisture on skin and clothes. Continuous ventilation is therefore the primary requirement for comfort [18]. From the above, it is apparent that the most important of these comfort parameters in a warm, humid climate is air velocity. It should, also, be noted that indoor air velocity depends on the velocity of the air outdoors [21]. The factors affecting indoor air movement are orientation of the building with respect to wind direction, effect of the external features of the openings, the position of openings in the wall, the size of the openings and control of the openings. Cross-ventilation is the most effective method of getting appreciable air movement in interior spaces in warm, humid climates. For comfort purposes, the indoor wind velocity should be set at between 0.15 and 1.5 m/s [22]. A mathematical model based on analysis of the experimental results [23], which established the relationship between the average indoor and outdoor air velocities with the windows placed perpendicular to each other, was adapted to suit a warm, humid climate and is, usually, used to evaluate the spaces. The formula states that:

$$V_1 = 0.45 \, (1-\exp^{-3.84x}) \, V_o \quad (1)$$

Where:
V_1 = average indoor velocity
x = ratio of window area to wall area
V_o = outdoor wind speed

6.1 Air movement in buildings

Natural ventilation is now considered to be one of the requirements for a low energy building designs. Until about three decades ago the majority of office buildings were naturally ventilated. With the availability of inexpensive fossil energy and the tendency to provide better indoor environmental control, there has been a vast increase in the use of air-conditioning in new and refurbished buildings. However, recent scientific evidence on the impact of refrigerants and air-conditioning systems on the environment has promoted the more conscious building designers to give serious considerations to natural ventilation in non-domestic buildings [24]. Two major difficulties that a designer has to resolve are the questions of airflow control and room air movement in the space. Because of the problem of scaling and the difficulty of representing natural ventilation in laboratory, most of the methods used for predicting the air movement in mechanically ventilated buildings are not very suitable for naturally ventilated spaces [25]. However, computational fluid dynamics (CFD) is now becoming increasingly used for the design of both mechanical and natural ventilation systems. Since a CFD solution is based on the fundamental flow and energy equations, the technique is equally applicable to a naturally ventilated space as well as a mechanically ventilated one, providing that a realistic representation of the boundary conditions are made in the solution.

6.2 Natural ventilation

Generally, buildings should be designed with controllable natural ventilation. A very high range of natural ventilation rates is necessary so that the heat transfer rate between inside and outside can be selected to suit conditions [25]. The ventilation rates required to control summertime temperatures are very much higher than these required to control pollution or odour. Any natural ventilation system that can control summer temperatures can readily provide adequate ventilation to control levels of odour and carbon dioxide production in a building. Theoretically, it is not possible to achieve heat transfer without momentum transfer and loss of pressure. However, Figures 3 and 4 show some ideas for achieving heat reclaim at low velocities. Such ideas work well for small buildings.

6.3 Mechanical ventilation

Most of the medium and large size buildings are ventilated by mechanical systems designed to bring in outside air, filter it, supply it to the occupants and then exhaust an approximately equal amount of stale air. Ideally, these systems should be based on criteria that can be established at the design stage. To return afterwards in attempts to mitigate problems may lead to considerable expense and energy waste, and may not be entirely successful [25]. The key factors that must be included in the design of ventilation systems are: code requirement and other regulations or standards (e.g., fire), ventilation strategy and systems sizing, climate and weather variations, air distribution, diffuser location and local ventilation, ease of operation and maintenance and impact of system on occupants (e.g., acoustically). These factors differ for various building types and occupancy patterns. For example, in office buildings, pollutants tend to come from sources such as occupancy, office equipment, and automobile fumes. Occupant pollutants typically include metabolic carbon dioxide emission, odours and sometimes smoking, when occupants (and not smoking) are the prime source. Carbon dioxide acts as a surrogate and can be used to cost-effectively modulate the ventilation, forming what is known as a demand controlled ventilation system. Generally, contaminant sources are varied but, often, well-defined and limiting values are often determined by occupational standards.

6.4 Bioclimatic design

Bioclimatic design cannot continue to be a side issue of a technical nature to the main architectural design. In recent years 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.

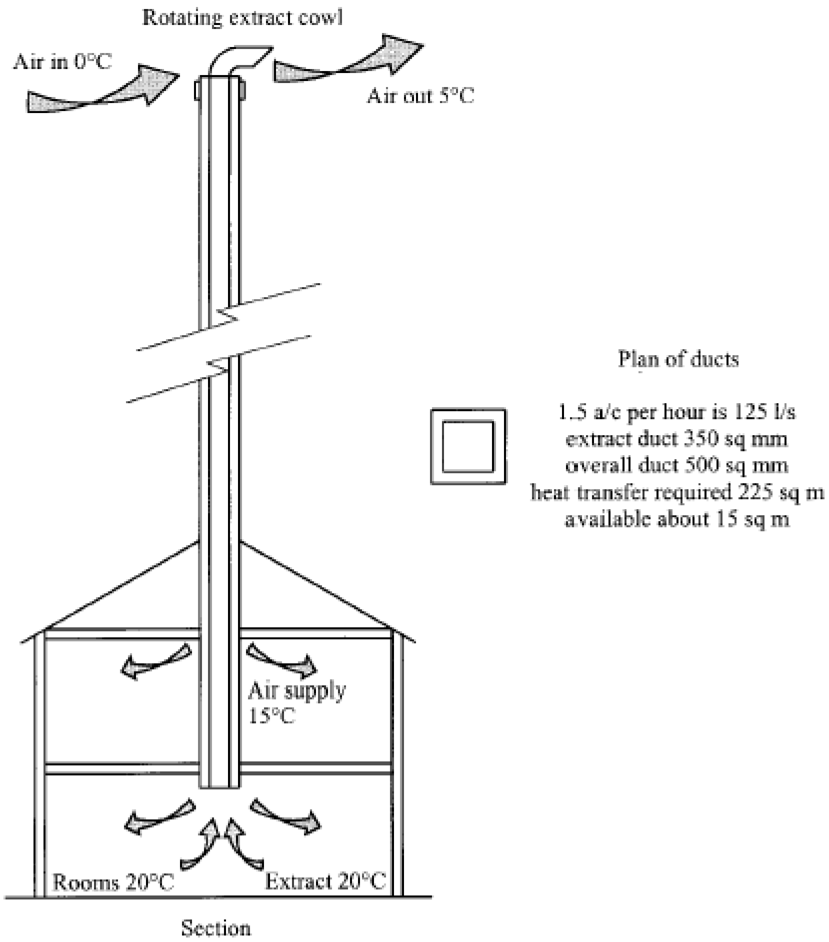
Hidden dimensions of architectural creation are vital to the notion of bioclimatic design. The most fundamental ones are:

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. 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 forms moulder.

Figure 3 Small house



Natural ventilation with heat reclaims (A very tall chimney)

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.
Heat gain in the summer is the main problem as it overheats the indoor environment of residential buildings. This forces the residents to utilise mechanical air conditioning systems

to satisfy their comfort. Under today's economic crisis, energy conversation programmes and acts for respect of environment are receiving more attention. As a contribution to such efforts and in order to overcome the heat gain in houses, it's advisable to utilise passive systems, namely, producing ventilation by a solar chimney [26]. Room air is removed by ventilation produced by the metallic solar wall (MSW) as shown in Figure 5.

6.5 Infiltration

Infiltration is the process of air flowing in (or out) of leaks in the building envelope, thereby providing (renewable) ventilation in an uncontrolled manner [27]. All buildings are subject to infiltration, but it is more important in smaller buildings as many such buildings rely exclusively on infiltration when doors and windows are closed. In larger buildings there is less surface area to leak for a given amount of building volume, so the same leakage matters less. More importantly, the pressures in larger buildings are usually dominated by the mechanical system and the leaks in the building envelope have only a secondary impact on the ventilation rates [27]. Infiltration in larger buildings may, however, affect thermal comfort and control and systems balance. Typical minimum values of air exchange rates range from 0.5 to 1.0 h^{-1} in office buildings [27]. Buildings with higher occupant density will have higher minimum outside air exchange rates when ventilation is based on outdoor air supply per occupant, typically 7 to 10 ls^{-1} [27]. Thus, schools have minimum outdoor air ventilation rates 3 h^{-1}, while fully occupied theatres, auditoriums and meeting rooms may have minimum air exchange rates of 4 to 7 h^{-1} [27]. It is in low-rise residential buildings (most typically, single-family houses) that infiltration is a dominant force. Mechanical systems in these buildings contribute little to the ventilation rate.

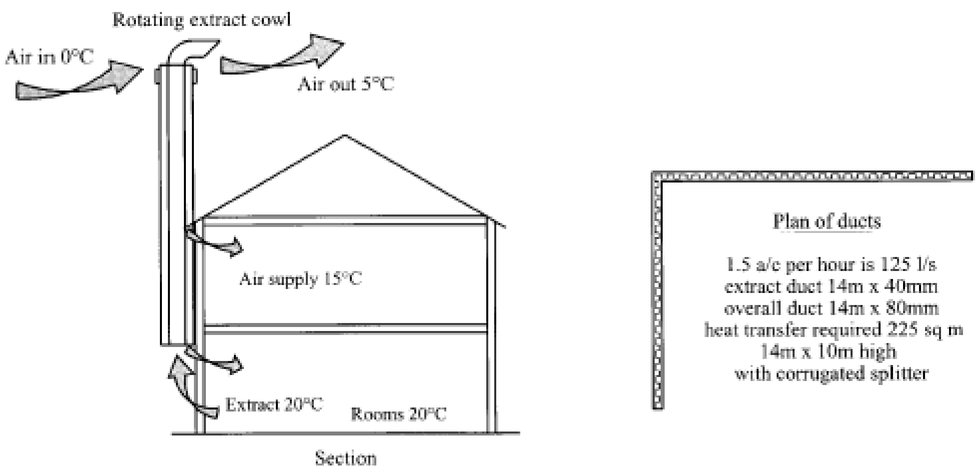


Figure 4 Ventilation duct supply and extract wraps around the building

6.6 Passive ventilation systems

Passive solar systems for space heating and cooling, as well as passive cooling techniques can significantly contribute to energy saving in the building sector when used in combination with conventional systems for heating, cooling, ventilation and lighting. The overall thermal behaviour of the building is dependent on the alternatives and interventions made on the building's shell. Passive ventilation systems share the use of renewable energy to provide ventilation with infiltration. But unlike air leakage and open windows, passive ventilation systems are designed to provide specific amounts of ventilation to minimise both energy liabilities due to excessive ventilation and periods of poor air quality due to under-ventilation [28]. However, the most common passive ventilation system is the passive stack, which is normally used to extract air from kitchen and bathrooms. In this method, prevailing wind and temperature differences are used to drive airflow through a vertical shaft. Various stack designs can be used to control or enhance the performance, based on local climate. However, careful design is required to avoid backdraughting and to insure proper mean rates. Although there is significant experience with this approach in Europe, it has been rarely used in North America [28]. Well-designed passive ventilation systems can be used to provide whole-building ventilation as well as local exhaust. Some efforts are currently underway to develop passive ventilation systems that incorporate heat recovery to minimise the need for conditioning the ventilation air [28]. These approaches aim towards a fully renewable ventilation system in that it requires no non-renewable resources for either providing the ventilation air or conditioning it.

6.7 Passive cooling

In the office environment, high heat loads are commonly developed through lighting, computers and other electrical equipment. Further heat gains are developed through solar gains, occupants and high outdoor air temperature. Passive cooling methods attempt to reduce or eliminate the need for energy intensive refrigerative cooling by minimising heat gains. This involves taking advantage of thermal mass (night cooling) and introducing high levels of air change. Night ventilation techniques seem to be the most appropriate strategy for buildings. This arises as a consequence of the large diurnal temperature range during the cooling seasons and the relatively low peak air temperatures, which occur during the day [29]. Such a combination allows the thermal mass of the building to use the cool night air to discard the heat absorbed during the day. An initial examination of the weather conditions experienced during the summer months of June to September in the UK indicates that most peak conditions of external weather fall within the ventilation and thermal mass edge of the bioclimatic chart [29, and 30]. Figure 6 shows that the summer (June to September) climatic envelope is within the heating, comfort, thermal mass and ventilation effectiveness areas of the chart.

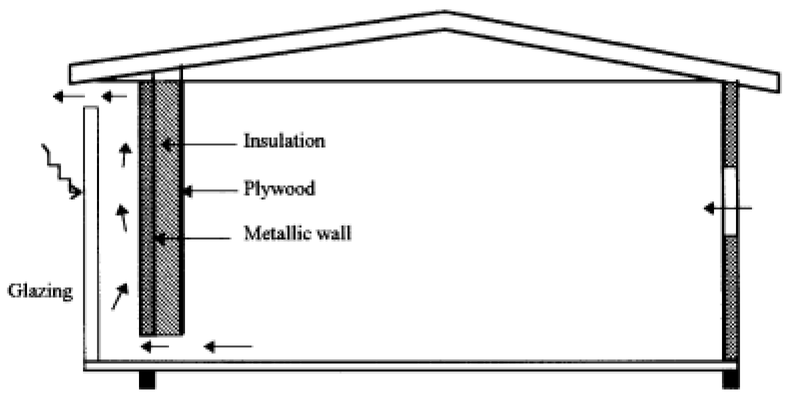


Figure 5 Schematic representations of the passive solar house and natural ventilation by metallic solar wall

The key parameters influencing the effectiveness of night cooling are summarised into the following four categories [30]:

- Internal heat gains of 10, 25 and 40 W/m^2; representing occupancy only, occupancy plus lights, and occupancy together with lights and IT load respectively.
- Envelope gains.
- Thermal response.
- Ventilation gains/losses.

Due to the complexity resulting from all the interrelated parameters affecting the effectiveness of night ventilation, it is necessary for designers to have access to a simple user friendly and yet accurate model when assessing the viability of night ventilation during the initial design stage. The followings are the key output parameters [30]:

- Maximum dry resultant temperature during the occupied period.
- Dry resultant temperature at the start of the occupied period.
- Energy savings data: solar protection is assumed good, thermal gains can be varied and the user specifies the occupancy period.
- Building fabric data: glazing ratio can be any value while thermal mass can be varied at three levels.
- Ventilation data: infiltration, day ventilation and night ventilation can be specified as necessary.
- Weather data: solar data are fixed but temperature is user specified for seven days although temperature profiles need not be the same for all days. The weather data are

specified in the form of maximum and minimum temperature for each day and hourly values are calculated by sinusoidal fitting.

However, a primary strategy for cooling buildings without mechanical intervention in hot humid climates is to promote natural ventilation. To control the energy used for the cooling of buildings in hot-arid regions with ambient air temperatures during the hottest period between 42 to 47°C, passive cooling approaches should be implemented [30]. A solar chimney that employs convective currents to draw air out of the building could be used. By creating a hot zone with an exterior outlet, air can be drawn into the house, ventilating the structure as well as the occupants. Since solar energy in such a region is immense, the hot zone created with a black metal sheet on the glazing element can draw hotter air at a slightly higher speed [30]. Applications of solar chimneys in buildings were limited to external walls. Integrating a solar chimney with an evaporatively cooled cavity could result in a better cooling effect. However, this should be applied with care since water sources are limited [31]. Figure 7 shows the combined wall-roof solar chimney incorporated into that building.

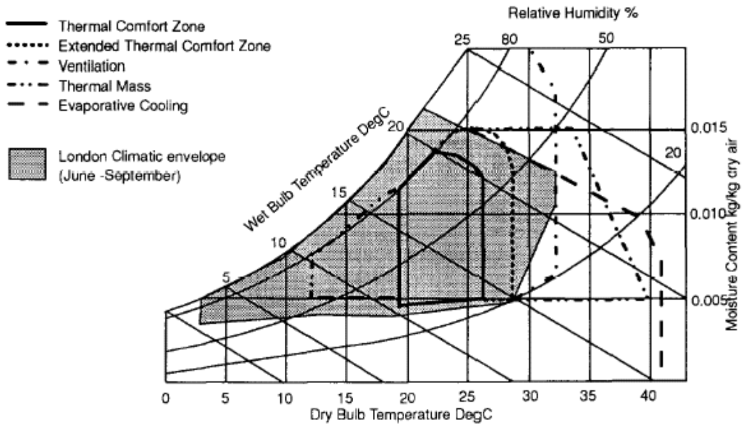


Figure 6 Bioclimatic chart with summer climatic envelope for London

The input data required are the following:

- Thermal gains Average room and ambient air temperatures are 23 and 27°C respectively. Air velocity required to achieve thermal comfort in the room should reach a maximum of 0.3 m/s [31]. Figure 8 gives the cooling load versus air change per hour. This indicates that the inclined airflow by the combined wall-roof chimney is enough to overcome a high cooling load required to cool heavy residential buildings. This suggests that night ventilation could be improved, and incorporating a combined wall-roof solar chimney increases the cooling load. However, thermal mass and ventilation should be sufficient to cover cooling requirements in typical buildings. A high percentage of the cooling requirements can be met by night ventilation before another form of cooling is used. Finally, a simplified ventilation tool for assessing the applicability of night cooling in buildings, currently under development in terms of user inputs and typical outputs.

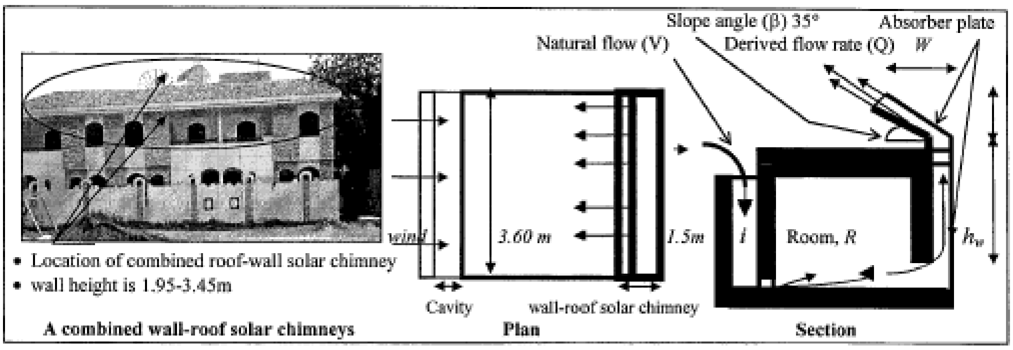


Figure 7 A combined wall-roof solar chimney incorporated into a residential building

7. Air pollutants and transmutation

Controlling the pollution of the present civilisation is an increasing concern. More importance is given to control global carbon dioxide, which is considered to be the main factor of green house effect. Though the complete experimental result on the fact is yet to be debated, the immense heat, temperature and turbulence of nuclear explosion oxidising the atmospheric nitrogen into nitric oxide, are considered to be similarly responsible for depletion of ozone layer [32]. At present, more importance is given for plantation to reduce the level of global carbon dioxide. The plantation over the whole earth surface may control only 50% of carbon dioxide disposed to atmosphere and its greenhouse effect. There are, also, explosions in the ozone layer time to time to add to the problem. Irrespective of the relative importance of each factor, the ozone layer protects us from harmful cosmic radiations and it is believed that the depletion of ozone layer increases the threat of outer radiations to human habitation if environmental pollution is not controlled or there is no possibility of self-sustainable stability in nature [32].

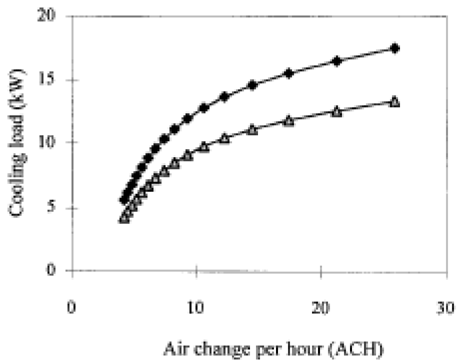


Figure 8 Cooling load by night ventilation for desired room indoor air temperatures of 23 and 25°C

The presence of ionosphere in the outer-sphere is most probably for ionic dissociation of the gases of the outer-sphere in the presence of low pressure and cosmic radiation [32]. Moreover the ionosphere contains charged helium ions (alpha particle). Therefore, it may be concluded that the explosion in the ozone and transmission of radiations through it are the possible effects of transmutation of pollutants with exothermic reaction (emission of radiations) [33, 34]. The existence of a black hole in the space, which is found in the photo camera of astrologist, is still unexplored. This black hole may be an effect of transmutation process with absorption of heat energy (endothermic reaction). The idea of transmutation of pollutants has been proposed for one or more of the following reasons:

- The experimental results support the transmutation of materials.
- To search the sinks of the remaining carbon dioxide not absorbed by plants or seawater.
- To find out the possible causes of explosion in the ozone layer other than the depletion of ozone layer.
- To investigate the possibilities of the self-sustaining stability of global environment.

To prove the portable of 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. The results of such experimental investigation may prove the probable transmutation of pollutants and self-sustaining equilibrium of the global environment.

8. Buildings and CO_2 emission

To achieve carbon dioxide, CO_2, emission targets, more fundamental changes to building designs have been suggested [35]. The actual performance of buildings must also be improved to meet the emission targets. To this end, it has been suggested that the performance assessment should be introduced to ensure that the quality of construction, installation and commissioning achieve the design intent. Air-tightness and the commissioning of plant and controls are the main two elements of assessing CO_2 emission. Air-tightness is important as uncontrolled air leakage wastes energy. Uncertainties over infiltration rates are often the reason for excessive design margins that result in oversized and inefficient plants. On the other hand, commissioning to accept procedures would significantly improve energy efficiency. The slow turnover in the building stock means that improved performance of new buildings will only cut CO_2 emissions significantly in the long term. Consequently, the performance of existing buildings must be improved. For example, improving 3% of existing buildings would be more effective in cutting emissions than, say, improving the fabric standards for new non-domestic buildings and improving the efficiency of new air conditioning and ventilation systems [36]. A reduction in emissions arising from urban activities can, however, only be achieved by a combination of energy efficiency measures and a move away from fossil fuels.

Conclusions

Thermal comfort is an important aspect of human life. Buildings where people work require more light than buildings where people live. In buildings where people live the energy is used for maintaining both the temperature and lighting. Hence, natural ventilation is rapidly becoming a significant part in the design strategy for non-domestic buildings because of its potential to reduce the environmental impact of building operation, due to lower energy demand for cooling. A traditional, naturally ventilated building can readily provide a high ventilation rate. On the other hand, the mechanical ventilation systems are very expensive. However, a comprehensive ecological concept can be developed to achieve a reduction of electrical and heating energy consumption, optimise natural air condition and ventilation, improve the use of daylight and choose environmentally adequate building materials. Energy efficiency brings health, productivity, safety, comfort and savings to homeowner, as well as local and global environmental benefits. The use of renewable energy resources could play an important role in this context, especially with regard to responsible and sustainable development. It represents an excellent opportunity to offer a higher standard of living to local people and will save local and regional resources. Implementation of greenhouses offers a chance for maintenance and repair services. It is expected that the pace of implementation will increase and the quality of work to improve in addition to building the capacity of the private and district staff in contracting procedures. The financial accountability is important and more transparent. Various passive techniques have been put in perspective, and energy saving passive strategies can be seen to reduce interior temperature and increase thermal comfort, reducing air conditioning loads. The scheme can also be employed to analyze the marginal contribution of each specific passive measure working under realistic conditions in combination with the other housing elements. In regions where heating is important during winter months, the use of top-light solar passive strategies for spaces without an equator-facing façade can efficiently reduce energy consumption for heating, lighting and ventilation.

References

1. Jeremy, L. The energy crisis, global warming and the role of renewables. Renewable Energy World 2005; 8 (2).
2. Omer, A. Low energy building materials: an overview. In: Proceedings of the Environment 2010: Situation and Perspectives for the European Union. p. 16-21. Porto: Portugal. 6-10 May 2003.
3. UNEP. Handbook for the international treaties for the protection of the ozone layer. United Nations Environment Programme. Nairobi: Kenya. 2003.
4. Viktor, D. Ventilation concepts for sustainable buildings. In: Proceedings of the World Renewable Energy Congress VII, p. 551, Cologne: Germany. 29 June – 5 July 2002.
5. Lam, J.C. Shading effects due to nearby buildings and energy implications. Energy Conservation and Management 2000; 47 (7): 647-59.
6. Raja, J., Nichol, F., and McCartney, K. Natural ventilated buildings use of controls for changing indoor climate. In: Proceedings of the 5th World Renewable Energy Congress V. p. 391-394. Florence: Italy. 20-25 September 1998.
7. Limb, M.J. Air intake positioning to avoid contamination of ventilation. AIVC. 1995.

8. [8] Miller, G. Resource conservation and management. Wadsworth Publishers. California: USA, p.51-62. 1990.
9. Erlich, P. Forward facing up to climate change, in Global Climate Change and Life on Earth. R.C. Wyman (Ed), Chapman and Hall, London. 1991.
10. ASHRAE. Energy efficient design of new building except new low-rise residential buildings. BSRIASHRAE proposed standards 90-2P-1993, alternative GA. American Society of Heating, Refrigerating, and Air Conditioning Engineers Inc., USA. 1993.
11. Molla, M. Air pollutants and its probable transmutation in the ionosphere. Renewable Energy 10 (2/3): 327-329. 1997.
12. Bahadori, M. A passive cooling/heating system for hot arid regions. In: Proceedings of the American Solar Energy Society Conference. Cambridge. Massachusetts, p.364-367. 1988.
13. Dieng, A. and Wang, R. Literature review on solar absorption technologies for ice making and air conditioning purposes and recent development in solar technology. Renewable and Sustainable Energy Review 2001; 5 (4): 313-42.
14. Lobo, C. Defining a sustainable building. In: Proceedings of the 23rd National Passive Conference. American Solar Energy Society (ASES'98). Albuquerque: USA. 1998.
15. Crisp, V., Cooper, I., and McKennan, G. Daylighting as a passive solar energy option: an assessment of its potential in non-domestic buildings. Report BR129-BRE. Garston. UK. 1988.
16. Horning, M., and Skeffington, R. Critical loads: concept and applications. Institute of Terrestrial Ecology. HMSO Publishers Ltd. London: UK. p. 23-27. 1993.
17. Humphrey's, M. Outdoor temperatures and comfort indoor. Building Research and Practice 6 (2). 1978.
18. Givoni, B. Man climate and architecture. Applied Science Publishers Ltd, p.289-306. London: UK. 1976.
19. Koenigsberger, O., and Ingersoll T., Mayhew, A., and Szokolay S. Manual of tropical housing and building. Part 1: Climate design. Longmas, p.119-130. London: UK. 1973.
20. Boulet, T. Controlling air movement: a manual for architects and builders. McGraw-Hill, p.85-138, New York: USA. 1987.
21. Szokolay, S. Design and research issues: passive control in the tropic. Proceedings First World Renewable Energy Congress, p.2337-2344, Reading: UK. 1990.
22. Borda-Daiz, N., Mosconi, P., and Vazquez, J. Passive cooling strategies for a building prototype design in a warm-humid tropical climate. Solar and Wind Technology 6, p.389-400. 1989.
23. Givoni, B. Laboratory study of the effect of window sizes and location on indoor air motion. Architectural Science Review 8: 42-46. 1965.
24. Fanger, P. Thermal comfort: analysis and applications in environmental engineering. Danish Technical Press. 1970.
25. Fordham, M. Natural ventilation. Renewable Energy 19: 17-37. 2000.
26. Awbi, H. Ventilation of buildings. Spon Publisher. London: UK. p. 9-13. 1991.
27. Givoni B. Man climate and architecture. Applied Science Publisher Ltd, p.289-306. London: UK. 1976.
28. [28] BS 5454. Storage and exhibition archive documents. British Standard Institute. London. 1989.
29. Lazzarin, R. D'Ascanio, A., and Gaspaella, A. Utilisation of a green roof in reducing the cooling load of a new industrial building. In: Proceedings of the 1st International Conference on Sustainable Energy Technologies (SET), p. 32-37, Porto: Portugal. 12-14 June 2002.
30. David, E. Sustainable energy: choices, problems and opportunities. The Royal Society of Chemistry 2003; 19: 19-47.
31. Zuatori, A. An overview on the national strategy for improving the efficiency of energy use. Jordanian Energy Abstracts 2005; 9 (1): 31-32.
32. Anne, G., and Michael, S. Building and land management. 5th edition. Oxford: UK. 2005.
33. Randal, G., and Goyal, R. Greenhouse technology. New Delhi: Narosa Publishing House. 1998.

34. Yadav, I., Chauadhari, M. Progressive floriculture. Bangalore: The house of Sarpan, p.1-5, 1997.
35. EIBI (Energy in Building and Industry). Constructive thoughts on efficiency, building regulations, inside committee limited, Inside Energy: magazine for energy professional. UK: KOPASS, p.13-14. 1999.
36. Jeremy L. The positive solution: Solar Century. Energy and Environmental Management, 2002. p.4-5.