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Design thermal comfort in Greenhouses Environment

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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. Among these are greenhouses, which are necessary for the growth of some plants (i.e., vegetables, flowers, etc.) in severe climates. However, greenhouses require some air conditioning process to control their temperature and relative humidity to suit specific plants. To achieve this, a novel air humidifier and/or dehumidifier systems using mop fans had been designed and employed in an experimental greenhouse to evaluate its performance under a controlled environment. This device helped to reduce the energy consumption of the greenhouse whilst providing a pleasant environment for the plants inside the greenhouse. The system was designed taking into account the meteorological conditions, which affect the environment inside the greenhouse. The performance of the system was monitored over a period of time by measuring the temperature and relative humidity of the greenhouse. Results of the monitoring have shown that the system was able to provide comfortable conditions (temperatures of 16-26^{o}C and relative humidity of 65%) suitable for the plants grown in the experimental greenhouse. It also enabled the minimisation of temperature variation and, hence, avoided the hazard of any sudden climatic change inside the greenhouse.

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 building, which is 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.

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. The main advantages of solar greenhouse are summarised as follows:

- In the climatic conditions of Europe, the collector system equipped with linear raster lenses is able to absorb, on average, 12% of the total incoming global solar energy on the collector and convert this energy into heat at a temperature of between 30 to 50°C. The system, therefore, consumes approximately 50% less energy for heating purposes than would a traditional normal greenhouse.
- The system provides suitable, perhaps ideal, conditions for the cultivation of high quality vegetables, and even during periods of maximum solar energy absorption on the collectors, there still remains sufficient light for good vegetable growth under the area of the collectors.
- Due to the almost continuous high humidity levels and to the applied nutrient solution being rich in organic matter and microorganisms, organic matter is hardly mineralising in the soil, hence, does not degrade in patches. On the contrary, organic matter content in the soil increased during cultivation.

- In comparison with a traditional greenhouse, the system does not overheat inside. Therefore, less ventilation is necessary, which brings the benefits of smaller losses of water. Furthermore, the system saves energy, allows the efficient recycling of water and nutrients, and provides suitable growth conditions with a smaller range of extreme humidity, temperature and light allowing the cultivated plants to face less stress and have a higher quality.
- Due to the relatively low temperature in the greenhouse, additional heating might be required. Therefore, vegetables will adapt to low radiation levels, and low temperatures and, consequently, quality is preserved even during failure of control system.

This study describes various designs of low energy buildings. It also, outline the effect of dense urban building nature on energy consumption, the problems related to inadequate ventilation in buildings, and its contribution to climate change. Measures, which would help to save energy in buildings, are also presented.

DISCUSSIONS

A novel mop fan has been implemented for studying the thermal behaviour in the greenhouse after evaporative cooling (fan) using a liquid desiccant potassium formate introduced at the inlet of a flexible fibre impeller. A novel air humidifier and/or dehumidifier systems using mop fans (indoor temperature and humidity) has been employed to enhance the performance of the system, hence, reducing energy consumption, decreasing load in the greenhouse, and reducing manufacturing cost. The system has been designed taking into account the meteorological conditions to control the environment inside the greenhouse. To supervise the growing of plants, outdoor and indoor temperatures, and relative humidity were measured. The indoor temperature measurements were made at the top and bottom of the greenhouse (in the middle and near the door). The system has allowed providing temperatures inside the experimental greenhouse favourable to most greenhouse plants (the comfort level for active healthy growth is 16-26^{o}C). In the experimental greenhouse, the system has allowed a relative humidity range between 30%-65%, which is favourable to the plants. It, also, enabled the reduction of the difference between minimum and maximum temperatures so as to avoid sudden climatic variations. Recent advances in thin film coatings for greenhouse glass products provide a means of substantially reducing heat gain without proportionally reducing daylight transmittance. It means that the energy expenditures due to lighting can be minimised, while plants can enjoy more natural light and maintain visual contact with the outside environment. In recent years, research activities in the field of using desiccant-based air conditioning systems are finding applications in humidity control devices. With some modifications, these systems may be used for recovering water from ambient air in arid areas. Desiccant-based water recovery from atmospheric air systems has great potential for use in solar energy applications. The system involves night absorption of water vapour from ambient air and simultaneous desiccant regeneration and water vapour condensation during the daytime. The results of the experimental tests are encouraging, further research and development is necessary to get commercially interesting products. It is, also, interesting to develop further studies about the utilisation of additional coatings that could reduce the heat loss in winter and limit the heat penetration in summer.

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. Plants, like human beings, need tender loving care in the form of optimum settings of light, sunshine, nourishment, and water. Hence, the control of sunlight, air humidity and temperatures in greenhouses are the key to successful greenhouse gardening. The mop fan is a simple and novel air humidifier; which is capable of removing particulate and gaseous pollutants while providing ventilation. It is a device ideally suited to greenhouse applications, which require robustness, low cost, minimum maintenance and high efficiency. A device meeting these requirements is not yet available to the farming community. Hence, implementing mop fans aids sustainable development through using a clean, environmentally friendly device that decreases load in the greenhouse and reduces energy consumption.