Available online at www.sciencedirect.com
ScienceDirect
Building and Environment 42 (2007) 605–613
BUILDING AND ENVIRONMENT
www.elsevier.com/locate/buildenv

Enabling the hybrid use of air conditioning: A prototype on sustainable housing in tropical regions

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Received 24 February 2005; received in revised form 5 May 2005; accepted 10 October 2005

Abstract

This paper demonstrates how the use of active or passive means only does not give the appropriate answers to a tropical design when considering housing. The author discusses about the idea of both modes of operation being used simultaneously or in parallel, and how this concept has been developed for one experimental building prototype in tropical areas of Brazil (Northeast region). Quantification is given through extensive parametric simulations which have been conducted using different environmental simulation programmes—TAS (EDSL, UK), ESP-r (ESRU, UK) and photovoltaic (PV)-Design PRO-G (Sandia Labs, USA). Thermal comfort levels along with energy use were assessed and compared, in terms of degree hours of overheating/under heating and cooling energy use. The prototype design has also taken into account the appropriate use of resources through sustainable design features: efficient use of energy, water and materials. The results have demonstrated that for regions such as the warm-humid tropics, the use of a mixed running strategy have optimized energy performance and provided better levels of thermal comfort in a much more effective way. For some cases, cooling energy savings up to 80% were feasible on a hybrid mode, where thermal comfort was improved up to 65%. It has also demonstrated the integration of energy efficiency and a PV grid-connected system, while enabling those daytime electrical needs to be accomplished by the photovoltaic component.

Keywords: Tropical architecture; Thermal simulation; Free-running; Air conditioning; Sustainable buildings; PV grid-connected systems

1. Energy consumption in the tropics: an increasing demand

Over the last years the high demand in the use of air-conditioning (A/C) systems in the residential sector have contributed to the increase in energy consumption levels. This is basically due to the low costs of electricity and household A/C systems allied to a social lifestyle change, demanding better comfort levels. Sales of A/C equipment have increased considerably over the past few years in all different regions of the world [1] especially small packaged A/C systems that can be easily installed by homeowners.

The elevated levels of thermal stress in these regions, combined with higher urban densities (which basically impairs the use of natural ventilation for some periods of the year) along with the use of houses not only for leisure purposes, but also as a work environment (requiring privacy, less noise and distance from pollution), are the most significant reasons to justify the use of A/C in the residential sector. But understanding A/C systems as the major consumers of energy, in addition to being a potential source of hazardous CFC emissions (through ozone depleting CFC refrigerants), makes their growth prohibitive, as their usage could offset the energy savings being achieved by more efficient use of lighting and/or heating. Pressures to install A/C units will escalate further, in anticipation of the effects of global warming. It is therefore important to consider how they could be made more efficient, and more importantly: whether any viable alternatives exist.

1.1. Resources efficiency

Resource efficiency is a central principle of our world today. If we think about providing for today's six billion people as well as the generations of tomorrow, resources of

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0360-1323/$ - see front matter
doi:10.1016/j.buildenv.2005.10.003

all types–physical, financial and human should not be squandered. We understand that energy is essential both to facilitate production and for its contribution to quality of life, the services it helps deliver—heating, cooling, light motive power, mobility, etc., and to enhance economic prosperity, personal comfort and leisure. Some of the most challenging environmental problems that mankind faces in the 21st century are directly linked with the production, transport, storage and use of energy. Therefore, the importance of resources efficiency has grown dramatically in recent years, as preserving the environment is a key strategy to make the world's ecosystem more economically and environmentally sustainable.

This research project (*BR Ecoproject*) is concerned with the appropriate use of resources through sustainable features, demonstrating throughout the design process how energy use can be minimized in this particular context.

2. Description: the BR Ecoproject

Originally, the Guarajuba Ecohouse project [2], started with the idea of designing a zero cooling energy house for the tropics (Brazil), where the chosen location was the Northern beaches of the state of Bahia-Brazil, which is an area of fast spread of luxury residential condominiums, all set up to be fully air conditioned. It is located around 70 km from the city of Salvador, the capital of Bahia. The development of this idea is now the *BR Ecoproject*, in which alternative solutions to minimize energy needs are generated, along with possible applications of the proposed concepts to extended locations of equally or greater environmental importance within the area. The initial base case is maintained (warm-humid climate), but this research project aims to expand and establish a systematic process of designing/implementing demonstration houses, in which conservation of natural resources can be applied and its technical processes of implementation and use can be assessed and available to the community in general.

The energy use and costs of a building depend on the complex interaction of many parameters and variables that can be effectively evaluated with hourly building energy simulation tools. Fabric, shape, openings, orientation, operation modes, control strategies and internal gains, are all features that are parts of an integrated design. No design feature can be added or deleted without affecting other elements of the whole building package. In terms of sustainability, it is extremely important also to understand that the social and economical aspects are essential to the development of a successful sustainable design, along with the consideration of environmental, cultural and political aspects. The BR Ecoproject, has focused on the environmental/energy aspects of the design, along with the appropriate emphasis on the economical feasibility of the idea and the associated social support of the community. For this case, we had two communities, which were identified. One, was the community in which the site was located: the luxurious condominiums, near the beach. The other was the fisherman village, which is located just across the motorway (Monte Gordo) and which does not have access (or spaces) to commercialize their products so effectively to this seasonal community of tourists and residents that come for holidays and vacations.

Based mostly on the initial concept of a zero energy house, the idea gained support from the Monte Gordo community (fisherman village located just 1 km from the original site), because also of the extensive problems of energy supply in the area since the 2001 shortages of power in Brazil. The initiative also attracted much interest as it would provide a possible space for the community closer to the upper class condominiums, where production of artcrafts (made by the women at the village) could be distributed. This was also seen as a space and opportunity for the local fishermen to sell directly their products and advertise it to the tourists and local residents, enhancing the possibilities of economical balance/sustainability in the area for the Monte Gordo community. An intense migration still happens to Salvador (the capital), given the lack of local jobs, education and general services.

Initiatives like this, are intended to give incentives for development and establishment of practices already in place at such communities, enabling a social and economical development, which respects and protects its environment.

2.1. Design approach and features

A free running design should ensure that the indoor temperature does not rise higher than the outdoors, and an air-conditioned design should minimize cooling loads. The strategies to achieve these aims are different and depend on a wide variety of elements, but can overlap. The energy use and costs of a building depends on the complex interaction of many parameters and variables that can be effectively evaluated with hourly building energy simulation tools. Fabric, shape, openings, orientation, operation modes, control strategies, internal gains, each feature is part of an integrated design. No design feature can be added or deleted without affecting other elements of the whole-building package.

The dual mode project [3] was mounted to define the desirable attributes of both free-running and conditioned buildings, in order to find the extent and nature of such an overlap. The dynamic thermal simulation tool, ESP-r, developed by the Energy Systems Research Unit (ESRU)–University of Strathclyde, UK, had been used for the extensive parametric simulations. The performance of both conditioned and free running modes are presented. Conditioned results were measured in terms of energy requirements for (heating–cooling—kW/h) and free running results were quantified in terms of degree hours of overheating/underheating (°C).

An initial test cell was used to determine which parameters would be tested and permutated on the house design. A total of 6720 simulation runs were undertaken