Energy and Buildings 42 (2010) 547–558

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Energy use, CO_2 emissions and waste throughout the life cycle of a sample of hotels in the Balearic Islands

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ARTICLE INFO

Article history:
Received 25 May 2009
Received in revised form 5 October 2009
Accepted 29 October 2009

Keywords:
Embodied energy
Life cycle
Energy use
CO_2 emissions
Waste
Hotel buildings

ABSTRACT

Tourism is the most developed economic sector in the Balearic Islands. The great rise in construction activities within the last 50 years, the increase in energy use, in CO_2 emissions and in waste production due to tourism, as well as an electrical energy production system mainly based on coal and fossil fuels is not an environmentally sustainable scenario. The aim of this study is to identify the processes that have had the greatest impact on the life cycle of a tourist building. In order to do this, the energy uses, CO_2 emissions and waste materials generated have been estimated, assuming a life cycle of 50 years, within a sample of hotels from the Balearic Islands. The results show that the operating phase, which represents between 70% and 80% of the total energy use, is the one with the greatest impact; that the energy use due to the manufacture of materials represents a fifth of the total and that electric consumption is the main cause of CO_2 emissions because of the regional energy system.

1. Introduction

The construction industry contributes significantly to the emission of greenhouse gases. In Spain it is estimated to represent 40% of the total, as opposed to 23% in Germany and 22% in France [1,2]. Construction is, in the Spanish economy, one of the industries which has experienced the greatest growth in recent years. In 2006 this sector represented 13.9% of the total employment in Spain [2]. Large town-planning expansion leads to uncontrolled consumption of material and energy resources. The use and construction of buildings are responsible for 40% of energy use, 17% of water consumption, 32% of CO_2 emissions and 25% of wood consumption worldwide [2,3]. According to the Spanish National Association of Aggregates Producers the annual consumption of aggregates for construction in Spain is about 11 tonnes per inhabitant. This amount has doubled in ten years and is much higher than the average in the European Union, which is around 7 tonnes per inhabitant and year [4]. In the case of cement, in 2007, the rate in Spain reached 1300 kg/inh (kilograms per inhabitant). This amount was over twice the average in the European Union which was about 536 kg/inh [5]. In fact, that year, cement consumption in Spain was greater than in France, the United Kingdom and Germany all together. In terms of construction and demolition debris (C&D debris), this represents 25% of the total waste materials in the EU [6]. Recycling rates for these waste materials differ greatly between countries. While in Spain this value is less than 5%, in Holland or Belgium reach levels of 90% or 87%, respectively [2,6].

The data presented above show that the present-day model of town-planning growth is unsustainable. This is the main reason why, in different countries, some National and Regional Plans have been established in recent years to minimize the amount of waste materials and to improve energy efficiency. Moreover in the last fifteen years an increasingly number of studies on buildings and the environment have been developed. Although many of them focus on the study of energy performance during the use phase [e.g. [7–11]], there are also studies that considerate the building from a life cycle perspective. Doing some analysis of the literature it has been observed that there are studies that present a method to calculate the total energy use on buildings during the life cycle [12,13]. In others apart from life cycle distribution of energy, environmental impacts like global warming potential, ozone depletion potential, nutrification potential and solid waste generation are assessed [14]. A life cycle analysis (LCA) model applied in New Zealand houses and developed at the University of Auckland [15] shows that the environmental impact follows a pattern similar to that of life cycle energy use. Peris Mora [16] emphasizes that the use of waste products in construction is a necessity to improve environmental management. In this line, Thormark [17] shows that reusing clay bricks and roofing tiles instead of using new bricks and tiles can contribute to a considerable reduction of the environmental impact of a building. This latter author shows also that in low energy buildings about

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0378-7788/$ – see front matter
doi:10.1016/j.enbuild.2009.10.024

37–42% of the embodied energy (energy use from extraction of the raw material until it is ready to be delivered from the manufacturer) can be recovered through recycling [18]. Arena and De Rosa [19] conclude that the election of less energy-intensive materials can be as effective as making use of solar energy or improve the thermal insulation of a building. There are some other studies that focus on methodologies for life cycle analysis: Erlandsson and Borg [20], for example, present the methodology problems and the development needs of LCA for buildings and constructions, and make a today practice assessment based on characterization of some generic LCA approaches. Allacker and De Troyer [21] propose a methodology to overcome the problems encountered when trying to carry out an LCA done following ISO 14040. Building lifetime considered in studies is different depending on the case, but in most it is set to 50 years.

Most of the studies that assess buildings from a life cycle perspective focus on dwellings, whereas tourist buildings have so far been less evaluated. Hotels assessments generally concentrate on energy performance. Bohdanowicz and Martinac [8], for example, present energy and water use in 184 European hotels and investigate the influence of different physical factors on resource consumption indicators. A similar assessment is presented by Shi-Ming Deng and Burnett [11,22] for a sample of hotels in Hong Kong. Few studies have been discovered about materials on construction of hotel buildings [23]. Data relating to hotels are scarce respect to other types of buildings, so some of the results will be compared with results of dwellings or office buildings.

1.1. The Balearic Islands and tourist development

The Balearic Islands have an economic system based fundamentally on tourism. With a total surface area of 4992 km^2 and a stable population of 1,030,650 inhabitants on January 1, 2007 [24], the number of tourists in this same year was over 13 million. The number of tourist establishments in operation in the Islands, today, is 2627, and the total number of beds is 425,097 [25], which almost half are concentrated in hotels. Tourist development, although necessary to maintain the economic system established in the Islands, causes deterioration of the environment and salient increases in energy use, water consumption and waste generation. These increases are produced particularly in the warm months of the year. Tourism is related to climate and it is surprising that the climate change impact literature pays little attention to tourism [26], when tourist activities impact directly and indirectly on ecosystems [27]. In a place like the Balearic Islands, appreciated as a tourist destination in many other regions, and whose main attraction are their environmental resources, it has become necessary to implement strategies that will make it possible to minimize the environmental impacts derived precisely from tourism. This is the reason that led to carrying out this study, whose main is to obtain the overall balance of energy use, CO_2 emissions and waste of a sample of hotels in the Balearic Islands for an assumed lifetime of 50 years. The choice of the indicators has been determined by a series of reasons: first of all, energy use, because it is a widely used measure of the environmental impact of buildings [28] and also for the high energy dependence that characterize the islands. Second, CO_2 emissions, because among the gases which contribute to the green-house effect (global environmental impact) the main component released by the processes linked to the building sector is the CO_2 [19]. And third, waste generation, because this indicator is closely related to the arrival of tourists.

2. Method

This study focused on the analysis of a sample of hotel buildings. This choice was determined by the fact that hotels

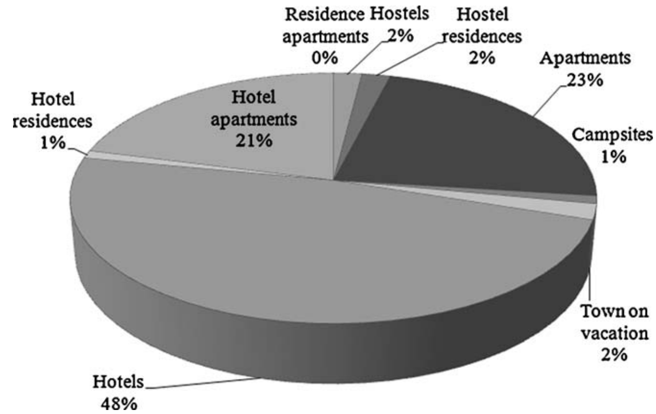

Fig. 1. Seating tourist. Balearic Islands. Year 2007 [25].

represent nearly 50% of all tourist beds in the Balearic Islands, as opposed to other types of tourist buildings such as apartments or residential tourism [25] (see Fig. 1). Data collection is no easy task when it comes to putting into process a study of these characteristics, especially if the system to be studied is as complex as a hotel building.

In order to carry out the study, four phases of the hotel life cycle were considered. The construction phase, which ranges from extracting raw materials to the building works on site (like it will be seen below, some intermediate processes will not be analysed because of a lack of data). The operation phase which covers the years the building is operating. The refurbishment phase which includes structural maintenance and operation processes throughout the time the building is in operation. And, finally, the demolition phase which encompasses all the processes involved in pulling down the building as well as transportation of waste debris to the waste treatment centers. The building lifetime is assumed to be 50 years, as it is considered an appropriate mean value in Spanish technical regulations, and also because it facilitates a comparison of the results obtained with results from other studies.

In the construction phase three hotels in the Balearic Islands were analysed. The data used for the analysis were taken from their construction projects, state of measurements, plans and installation projects. Of the hotels analysed, two were beach hotels and one a city hotel. All three were 4-star hotels. For the analysis of this phase of the life cycle the *TCQ* computer tool provided by the *Institute of Construction Technology of Catalonia* (*ITeC*) was used. Specifically, the module for Cost Estimates and Technical Conditions (*TCQ2000*) and the module for Environmental Management (*TCQGMA*) which provides the quantity of materials, the energy consumptions, CO_2 emissions, and the waste generated, from information provided by the state of measurements. The energy consumption of the machinery is attached to its power, and it is corrected by a factor depending on the type of engine and the type of fuel consumed. The aim of TCQGMA tool is that technicians can check the environmental impact derived from their decisions. In this tool items classified as materials are decomposed into constituent materials. Each constituent material has an energy consumption value and a CO_2 emissions factor assigned. Energy consumptions of the materials are calculated from establishing the amount of constituent material by the value of the energy consumption of this constituent material. CO_2 emissions are obtained using the corresponding factor of the constituent material. So building material energy consumption is associated only to material that is part of this element and which has been used in the process of manufacturing. Energy consumption of constituent materials includes: extraction of materials, transport from origin to the factory and manufacturing process (from now on, embodied energy). Transport from factory to construction and