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Analysis and benchmarking of greenhouse gas emissions of luxury hotels

Kuo-Tsang Huang[a], Jen Chun Wang[b,*], Yi-Chieh Wang[c]

[a] Department of Bioenvironmental Systems Engineering, National Taiwan University, 1, Roosevelt Rd., Sec. 4, Taipei, Taiwan
[b] Department of Industry Technology Education, National Kaohsiung Normal University, 62, Shenjhong Rd., Yanchao District, Kaohsiung City 82446, Taiwan
[c] Department of Tourism Management, Chia Nan University of Pharmacy and Science, 60, Erh-Jen Rd., Sec. 1, Jen-Te, Tainan, Taiwan

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ABSTRACT

Hotels are one of the most energy intensive building types due to their multi-usage functions and round the clock operations. We investigated the energy consumption of 58 Taiwanese luxury hotels for greenhouse gas (GHG) emissions, including carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). The average yearly GHG emission density of the investigated hotels is 132 kg-CO_2e/m^2. The results show an expected 29 kg of equivalent carbon dioxide emission (CO_2e) for each accommodated guest/night, or 50 kg-CO_2e generated for each room/night sold. A multiple regression model was established to normalize the GHG emission intensity, which includes GHG emissions potential variables and a benchmark model, plotted as a cumulative percentile distribution, in which hotels can rank their GHG emissions intensity. By comparing hotel GHG emission performances, hotel managers can determine if and where improvements should be implemented.

1. Introduction

Climate change is receiving more attention worldwide and the main cause of aggravated global warming is thought to be carbon dioxide (CO_2) and other greenhouse gases (GHGs) emitted by anthropogenic activities (IPCC, 2007). Buildings significantly contribute to the emission of GHGs (McKinsey Company, 2009). Global energy consumption has doubled from 1971 to 2010 (International Energy Agency, 2013), and the building sector is thought to account for more than one-third of the global energy consumption nowadays. The operating energy, which is defined as energy consumed during the use phase of a building, represents by far the largest share in the life cycle energy bill of a building, ranging to about 90–95% (Sartori and Hestnes, 2007). Heating, ventilating, and air-conditioning (HVAC) systems contribute to the largest share of a building's energy consumption. Since HVAC energy needs are closely related to a building's envelope design, there is a tendency to design and build energy efficient building envelopes. Taiwan's Ministry of Interior in 1995 established building energy conservation regulations to regulate the design of building envelopes.

Hotels are one of the highest energy consuming building types among non-residential building. Hotels operate round the clock, they offer various facilities and functions, and the hotel room occupants have a free reign on their room's energy consumption. These factors make hotels one of the most energy consuming building types (Dascalaki and Balaras, 2004). From the building life cycle perspective, energy use in the building operation phase is 4–6 times greater than in the hotel's construction phases (Rosselló-Batle et al., 2010). Available specific information on the energy characteristics, thermal performance, energy losses, and electric loads are important in developing energy efficient hotel systems (Xydis et al., 2009). Given that energy use is strongly linked to GHG emissions, efficient energy saving strategies during the hotel operation phase will result in savings for the hotel operators and a significant reduction in the GHG emissions.

There are five levels of star ratings in Taiwanese hotels, in which five star is the highest ranking. Both four and five star hotels are considered luxury hotels. They provide services/facilities such as (1) more than two high quality restaurants; (2) business centers; (3) separate in-room washrooms and bathrooms; (4) conference or banquet halls; (5) in-room Wi-Fi access. In addition, luxury hotels also have laundry facilities, swimming pools and/or spas, although they are not mandatory in the rating system. The difference between four and five stars lies in their qualities and details of the provided services objectively judged by the rating committee. The services and facilities provided by the four and five star luxury hotels are substantially more than those of lesser quality hotels. Furthermore, there is a clear difference between the occupants of

* Corresponding author.
E-mail address: jcwang@nknucc.nknu.edu.tw (J.C. Wang).

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the luxury hotels who are mostly foreign tourists and businessmen and hotels of less than three stars, whose primary occupants are local domestic tourists. The quality of the hotel also reflects the building costs and quality. Therefore, a large bias in constructing the benchmarking model would be apparent if hotels of less than three stars were included in the model. In addition, due to the high growth rate of international tourists which has recently soared (the annual growth rate of international tourists was 12.9% in 2014, the highest among countries in North East Asia, UNWTO, 2014), more luxury hotels have been and are currently being built. Since luxury hotels are the major contributors to the energy use in the hotel industry, the research concentrated on the GHG emissions of the four and five star luxury hotels.

The hospitality industry in Taiwan has developed rapidly in the past five years. Because of the recent thaw in political tensions between Taiwan and China, tourists from China have begun visiting Taiwan in large numbers since 2008. According to the official published data on visitor arrivals, the yearly growth rate of inbound tourists rose from 9.3% in 2009 to 26.7% in 2012 (Tourism Bureau of Taiwan, 2013a). In addition, the economic recovery from the financial crisis of 2007–2008 increased the yearly growth rate of domestic tourists from 22.8% to 26.5% during the same period (Tourism Bureau of Taiwan, 2013b). Currently, there were approximately 47 million guest/night stays in Taiwanese hotels (Tourism Bureau of Taiwan, 2013c), and the number of international tourist arrivals had more than tripled in the last decade (Fig. 1). Increased tourism has contributed to the significant growth in Taiwan's hotel industry. As of September 2013, the total number of five star international tourist hotels in Taiwan was 71 (20,461 rooms), 39 (5378 rooms) for the four star standard tourist hotels, 3230 (131,138 rooms) for three star rated hotels, and 3375 (18,104 rooms) for bed and breakfast facilities (Tourism Bureau of Taiwan, 2013c). The number of rooms rose by 11.5% and 46.5% for five star and four star rated hotels respectively since 2009. Furthermore, plans for an additional 5536 rooms for five-star hotels and 2038 rooms for four-star hotels have been registered and construction permits were acquired, with some planned hotels already under construction (Tourism Bureau of Taiwan, 2013c). The total number of hotel employees in Taiwan is 71,678 and total revenues from this sector were US$3.8 billion in 2012. The total number of employees hired and revenues earned in the hotel sector comprised 23.4% and 22.3% of the total tourism industry in 2012, respectively.

Because of the growth in tourism, CO_2 emissions generated by tourists cannot be ignored (Becken et al., 2003; Gössling et al., 2005). In Taiwan, five and four star hotels consume up to 2.6E06 GJ energy annually which accounts for 28% of the whole hotel industry and is 6.2% of the total energy used in the tourism industry. However, the expenditure of energy comprises only 3–10% of the total revenue they earn (Wang and Huang, 2013). Many studies have confirmed that energy use dominates the greenhouse gas emissions in the hotel sector (Filimonau et al., 2011; Wu et al., 2010; Yi, 2011).

2. Theory

Most of the hotel energy consumption studies adopt the term "energy use intensity" (EUI) to describe a hotel's annual energy consumption per square meter floor area with the unit being kW h/m^2 year (Bohdanowicz and Martinac, 2007; Deng, 2003; Lu et al., 2013; Priyadarsini et al., 2009; Rosselló-Batle et al., 2010; Taylor et al., 2010; Trung and Kumar, 2005; Wang, 2012; Wang and Huang, 2013). Table 1 summarizes the related worldwide studies in the recent decade. Numerous studies indicate that hotel energy usage is different from other building categories and also show that hotels located in different parts of the world have many discrepancies in their energy usage patterns (Wang and Huang, 2013). In general, hotels located in temperate areas consume less energy than those located in extremely cold and hot areas. Some studies concentrated on energy use per guest/night (Bohdanowicz and Martinac, 2007; Karagiorgas et al., 2007; Lu et al., 2013; Wang and Huang, 2013; Warnken et al., 2005). Only a few studies focused on the GHG emissions generated by energy consumption (Beccali et al., 2009; Wu et al., 2010).

Most of the previous studies focus on energy use, some of them only focus on electricity end use, and some emphasize the total energy use including electricity, gas and fuel. Only a few studies highlight GHGs generated by energy consumption. Moreover, most of the previous GHGs related studies only focus on CO_2 emissions. However, primary GHGs besides carbon dioxide (CO_2) also include nitrous oxide (N_2O), methane (CH_4), ozone (O_3), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (The Intergovernmental Panel on Climate Change (IPCC, 2011). From the energy types used in hotels, which include electricity for general use, liquid petroleum gas for water heating, and natural gas for culinary use, CO_2, CH_4, and N_2O are expected to be generated (Lai, 2015). The degree of contribution to global warming of the last two gases can be converted to equivalent CO_2 emission via emission factors given in Table 2. Therefore, the impact of various GHGs can be consolidated to an identical unit kg-CO_2e for the sake of convenience. Although the proportions of CH_4 and N_2O

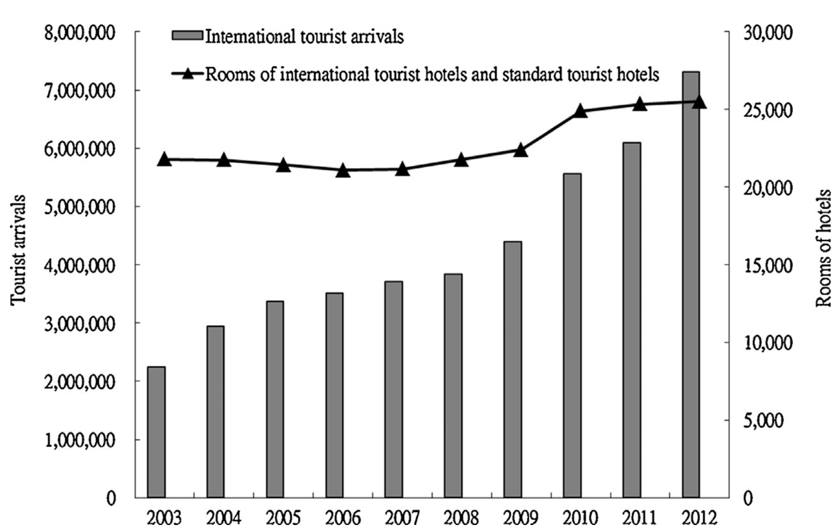

Fig. 1. The number of international tourist arrivals and rooms in five and four star hotels from 2003–2012.