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Greenhouse gas emissions of amusement parks in Taiwan

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ABSTRACT

This study investigated the greenhouse gas emissions of amusement parks in Taiwan. The energy use of 26 parks evenly distributed throughout Taiwan was audited. An average of 583,000 people was found to visit each site annually. In addition, average annual energy consumption of 7699 MW h per site was observed, translating into 4096 t of carbon emissions per year. Every visitor generated an average of US$29.4 in revenue and 7.4 kg-CO_2eq. The parks offering luxury services, such as 4-or 5-star accommodation and luxury food products, or many large-scale motorized water- or ground-based attractions consumed more energy than did ecology- and education-oriented parks. We categorized the parks into five categories, and found significant discrepancies among them in energy use. Two models for predicting annual carbon emissions and average carbon emissions per visit were developed, with the adjusted coefficient of determination being 0.934 and 0.792. This paper concludes by proposing several guidelines to assist park operators in reducing carbon emissions and improving energy efficiency.

1. Introduction

According to the data reported by the United Nations World Tourism Organization (UNWTO), average annual increases of 4.6% and 4.4% were observed for international tourist arrivals and tourism revenue, respectively, in the years following 2010 as the world economy recovered from the 2009 global financial crisis. Regionally, tourist arrivals and revenue increased by 19.3% and 19.7%, respectively, between 2012 and 2015 in Asia Pacific. Tourism revenue in Northeast and Southeast Asia increased by 12% representing the greatest increase in the Asia-Pacific region. Because of an increase in visitors from China, international tourist arrivals in Taiwan increased by 14.5% from 2013 to 2015, which is the second highest rate for that period of anywhere in Northeast Asia. A growing number of people from China are traveling abroad, with the rate increasing by 27.1% and 26.2% in 2014 and 2015, respectively. China surpassed all other countries for four consecutive years (2012–2015) in number of tourist departures [1]. The annual growth rate of inbound tourists in Taiwan was 23.9%, 9.6%, and 27.1% in 2012, 2013, and 2014, respectively. In 2015, the number of inbound tourists reached 10.4 million, with 5.6 million of these from China. By contrast, in 2008, the first year in which Chinese tourists were allowed to visit Taiwan, the number of inbound Chinese tourists was only 330,000. A 17-fold increase in the number of tourists from China was recorded in the 7 years from 2008 to 2015 [2].

From an environmental perspective, the development of tourism has been confirmed as being closely related to increased greenhouse gas emissions and thus to global climate change [3–6]. In Australia, studies have shown that climate change predicted to affect several major cities will profoundly influence the tourism industry, and these results have drawn considerable attention from Australian authorities [7]. Although scholars disagree regarding the level to which climate change will affect tourism [8], some locations whose GDPs heavily rely on tourism, such as Spain, Turkey, other European Union countries, Macau, Taiwan, and China. have presented evidence that tourism development will lead to large increases in carbon emissions [9–14]. Carbon dioxide emissions from tourism and travel activity are usually accredited to the destination country regardless of whether it is an island or intercontinental country [9,15]. Although the GDP contribution of the tourism industry is roughly equivalent to that of traditional industries, and despite tourism and amusement park activity emitting less carbon than does traditional industry activity, carbon emissions from tourism-related businesses have gained widespread attention in island countries with limited natural resources such as Taiwan [15–19]. In the Mediterranean island country Cyprus, rapid tourism industry growth led to a severe need to control carbon emissions [20]. Crete, a Greek island in the Mediterranean Sea, faces the same problem, and is seeking to harvest solar energy to power the hospitality industry [21]. In the thriving tourism destination Tibet, tourism activity accounts for 6–14% of all carbon emissions. For politically stable Southeast Asian countries, tourism development, energy consumption, and economic growth are positively correlated [22]. The thriving tourism business in Macau has led to high GDP growth, but has also resulted in high energy consumption, with carbon emissions increasing by 100.31% from 2000 to 2010 [12,23].

The development and use of natural resources for tourism-related activity also affects environmental conservation [24–27]. Among all carbon emissions from tourism activity, those related to traveling, such as plane emissions, contribute 18–32%, those related to the accommodation sector contribute 15–33%, and the remainder are from recreation and leisure activities such as dining and shopping [28]. Numerous studies have suggested the promotion of in-depth tourism or city tourism for reducing carbon emissions from long-haul travel [29–31]. Some research has provided energy-saving measures for hotel management and government [32,33].

The carbon emissions caused by tourism development have drawn attention worldwide, particularly in island and geographically isolated countries with limited natural resources. In Taiwan, an island that imports almost all of its energy, how the prospering tourism industry affects energy consumption and carbon emissions is of increasing concern. Fig. 1 shows the number of tourists visiting various types of tourist sites in

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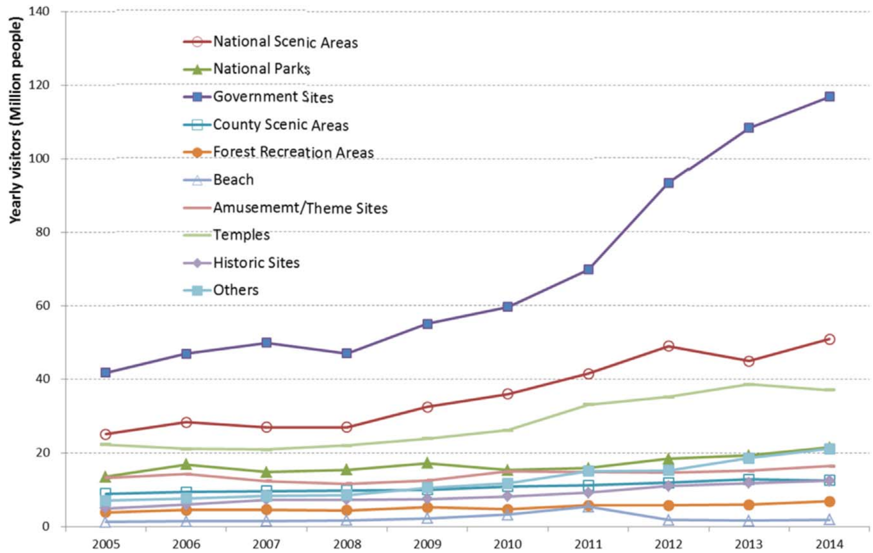

Fig. 1. Visitors to tourist sites in Taiwan from 2005 to 2014 according to data from the Tourism Bureau, Taiwan.

recent decades, with most exhibiting an increasing trend. The annual average growth rates of national scenic areas, national parks, government sites, county scenic areas, forest recreation areas, beaches, amusement and theme parks, temples, historic sites, and other sites from 2005 to 2014 were 8.2%, 5.2%, 12.1%, 3.9%, 6.5%, 3.9%, 2.4%, 5.8%, 10.7%, and 12.9%, respectively. The annual growth rate of the total number of visitors during this period was 8.5%. The total number of visitors increased greatly from 142 million in 2005 to 298 million in 2014 [34]. Regarding energy consumption, among all types of tourist sites, amusement and theme sites are the types necessitating the most attention. Compared with other types of tourist sites, amusement and theme sites contain more complex spaces that are employed for a variety of purposes. Amusement parks differ from each other considerably. Some focus on ecological tourism and education, whereas others focus on leisure. Some offer only simple facilities to provide tourists with ecological information, whereas others provide luxurious accommodation and delicacies for tourists in wild environments. Different tourism operations entail substantial differences in energy consumption and greenhouse gas emission.

2. Background and methodology

2.1. Determining the carbon emission coefficients of various greenhouse gases

The primary greenhouse gas (GHG) emissions are carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), ozone (O_3), sulfur hexafluoride (SF_6), hydrofluorocarbons, and perfluorocarbons [35]. Among these, hotels using nonrenewable energy typically generate CO_2, CH_4, and N_2O; therefore, GHG emissions auditing should focus on these three gases instead of CO_2 only. Table 1 summarizes the GHGs generated by different types of energy consumption according to local rates of energy efficiency. The use of both electric power and fossil fuels indirectly and directly generates GHGs, which not only pollute the environment but also contribute to global warming. According to a 2012 report by the Taiwan Bureau of

Table 1
GHG emissions for different energy sources.

Energy	Unit	GHGs	Emission factor[a]	kg-CO_2e[b]
Liquefied petroleum gas (LPG)	liter	CO_2	1.75 kg-CO_2/liter	1.75
		CH_4	2.78E−05 kg CH_4/liter	5.84E−04
		N_2O	2.78E−06 kg N_2O/liter	8.62E−04
Liquefied natural gas (LNG)	m^3	CO_2	2.66 kg-CO_2/m^3	2.66
		CH_4	1.24E−04 kg CH_4/m^3	2.60E−03
		N_2O	2.49E−05 kg N_2O/m^3	7.72E−03
Heavy fuel	liter	CO_2	2.98 kg-CO_2/liter	2.98
		CH_4	1.16E−04 kg CH_4/liter	2.44E−03
		N_2O	2.31E−05 kg N_2O/liter	7.16E−04
Light fuel	liter	CO_2	2.73 kg-CO_2/liter	2.73
		CH_4	1.44E−04 kg CH_4/liter	3.02E−03
		N_2O	1.44E−04 kg N_2O/liter	4.46E−02
Electricity	kWh	CO_2-eq.	0.532 kg-CO_2e/kWh	0.532

[a] Per unit energy emits GHG [37]. The factors are calculated by Bureau of Energy, Taiwan according to the local energy efficiency.
[b] Kilogram of carbon dioxide equivalent. The conversion factors are 1 kg-CO_2=1 kg-CO_2e, 1 kg CH_4=21 kg-CO_2e, and 1 kg N_2O =310 kg-CO_2e, respectively [35].