Resource Use and Waste Generation by the Tourism Industry on the Big Island of Hawaii

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Supporting information is available on the *JIE* Web site

Summary

A survey of the tourism industry on the island of Hawaii (the Big Island) in the state of Hawaii in the United States was conducted to collect baseline information on major resources (energy, food, and water consumption) and waste generation from five tourism sectors: accommodations, food and beverages (restaurants), golf courses, tourism services (tours), and rental cars. The questionnaire was developed and 50 establishments from the target sectors participated in this survey. Resource consumption and waste generation were calculated by the number of establishments, employees, and visitors. Using these factors and island-wide statistics (the number of establishments, job counts, and visitors), this study estimated the current status of island-wide water, food, and energy consumption and waste generation by these five sectors of the tourism industry. The estimate shows that the tourism sectors surveyed for this study account for 21.7% of the island's total energy consumption, 44.7% of the island-wide water consumption, and 10.7% of the island-wide waste generation. Using a per guest emission factor (such as per employee, guest room, and seat) provided in this study, the owners and managers of tourism establishments can calculate a baseline for each resource input and output. This is essential information to improve the industry's efficiency and result in economic savings.

Introduction

The tourism industry annually attracts about 6 million visitors to the state of Hawaii (Hawaii Tourism Authority 2010), and it accounts for one-quarter of the state's gross domestic product and one-third of its jobs (DBEDT 2010; Thomas 2009). The island of Hawaii (the Big Island) welcomes more than one million tourists annually. The highest growth (67%) in daily visitors on the Big Island was registered between 1990 and 2007 (DBEDT 2008). It is widely known that the tourism industry is an economic engine for the Big Island. Tourism utilizes a significant share of the total electricity and fuel used on the island; however, the total amount and detailed breakdowns have not been quantified. The economic growth of the island must be carefully assessed and managed to mitigate negative impacts on its environment and sustainability. For this purpose, this study focuses on examining the flow of major materials and resources within individual enterprises in key sectors of the tourism industry on the Big Island. In particular, this article aims to

- identify major players in the tourism industry;
- collect data on the input of materials (food and water), output of materials (waste), and consumption of energy (electricity, fuel, and gas) from identified players; and
- estimate the current status of the major materials and perform an energy assessment of the tourism industry on the Big Island.

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The results of this study can be used to encourage individual enterprises to improve their efficiencies by providing baselines and best practices regarding environmental impacts from key sectors of the tourism industry.

Methods and Materials

Literature Survey

Gössling (2002) estimated the global environmental consequences of tourism for five major aspects of leisure-related impacts on the environment, including the changes in land cover, land use, and energy use. He investigated the land cover conversion for the construction of accommodations (hotels, hostels, bed and breakfasts, bungalows, and farms), traffic infrastructure (airports, roads, railways, ports, and marinas), and leisure activities (golf, skiing, and amusement parks). He also attempted to quantify the energy use and carbon dioxide (CO_2) emissions for transportation (such as car and air travel) and accommodations and activities (such as heli-skiing, scenic flights, diving, scenic boat cruises, sailing, guided walks, adventure activities, and rafting). Gössling and colleagues (2012) reviewed direct freshwater consumption by the tourism industry on a global scale to assess the tourism sector's current water demand and identify management challenges. This review study included recommendations for managing the tourism industry's water footprint. Hunter and Shaw (2007) applied ecological footprint (EF) analysis to estimate EF values for international tourism activities, including comparison of specific tourism products. Their study suggested that "some (eco)tourism products may, potentially, make a positive contribution to resource conservation at the global scale"(46).

For this study, available reports and statistical data from the Department of Business, Economic Development, and Tourism (DBEDT) were collected after the preliminary interview with an economist from DBEDT. However, most reports focused on the number of visitors, their expenditures, the purpose of their trip, accommodation type, and other characteristics (Latzko 2004; DBEDT 2008, 2010, 2011; Hawaii Tourism Authority 2010, 2011). Little information is available on the energy and resources used by the tourism sector.

In the State of Hawaii, fossil fuels account for about 90% of total energy consumption; Hawaii's Renewable Portfolio Standard (RPS) mandates that 20% of the energy should be supplied by renewable sources by 2020 and 30% by 2030 (Yalcintas and Kaya 2009). Table S1 in the supporting information available on the Journal's Web site shows the composition of each energy source to the total electricity generated on the island (DBEDT 2011). The Big Island currently generates nearly one-third of its electricity from renewable resources, with the largest contribution from wind and geothermal.

Kaya and Yalcintas (2010) calculated the energy intensity index for the State of Hawaii by dividing energy consumption per capita by the income per capita. They found that tourist arrival numbers did not change the energy consumption directly between 1991 and 2006, but a change in tourism arrival numbers correlates per capita income with a phase lag of a few months to a year.

Tabatchnaia-Tamirisa and colleagues (1997) explored the linkage between energy use and tourism in the State of Hawaii using the 1987 Hawaii input–output table developed by the DBEDT (1993). They found that tourists account for a significant amount of the total energy and fuel demand, in particular, 22% of electricity, 33% of gasoline, 68% of aviation fuel, and 18% of other fuels. This study evaluated the energy use by tourists, but because of methodological constraints, the energy intensity of certain activities was not quantified (e.g., shipping, dining, entertainment, and rural and marine adventures). In order to encourage energy conservation in each sector of the tourism industry, a more detailed breakdown of energy used by the tourism activity or facility needs to be investigated.

Konan and Kim (2003) developed an applied general equilibrium model to simulate visitor scenarios and transportation demand in the State of Hawaii. They found that the tourism industry dominates the state economy, with small increases in visitor expenditures contributing significantly to the gross state product. Following this study, Konan and Chan (2010) estimated petroleum consumption and greenhouse gas (GHG) emissions associated with combined demand from residents and visitors in the State of Hawaii. They used an input–output analysis of the expenditure patterns of different consumer types to attribute GHG emissions to demand and revealed that visitors generated more than 22% of the state's total emissions in the baseline year 1997.

Okazaki and colleagues (2008) investigated food waste and recycling in the State of Hawaii by collecting a total of 5,033 surveys from food establishments, including restaurants, liquor dispensers, schools, medical facilities, hotels, and retail stores. They showed that the number of food service employees and the number of meals served per day can be used as an indicator of the establishment's size, and both were found to correlate positively with the amount of food waste recycled. Based on survey results, they estimated the total amount of food waste generated by all food establishments in the State of Hawaii.

Target Establishments

In 2008, 78.2% of the visitor days (visitor arrivals multiplied by the length of stay) of the State of Hawaii were from the United States and 11.2% from Japan (DBEDT 2010; Hawaii Tourism Authority 2010). Table 1 summarizes activities in which tourists participated and the establishments associated with each activity. Tour service establishments provide sightseeing activities, and retail establishments mainly provide shopping activities. Accommodations often provide both recreation and entertainment activities. During their stay in the State of Hawaii, 76.8% of U.S. visitors rented a car, while only 18% of the Japanese visitors rented a car (DBEDT 2010). Golf courses attracted 12.7% of the visitors from the United States and 8.8% of the visitors from Japan (table 1).

Based on table 1, the current study selected five target sectors: accommodations, restaurants, golf courses, car rentals, and tours. The retail sector was excluded in this study because,

Table 1 Activity participation by visitors, job counts of tourism industry sectors, and visitor expenditures on the Big Island

		Activity participation by visitors in 2009 (%)		*Establishment types (sectors) of tourism industry*					
	Activity	*United States*	*Japan*	*Accomm-odations*	*Restau-rants*	*Golf courses*	*Car rentals*	*Tours*	*Retail*
Sightseeing	Helicopter/plane tour	10.4	3.3					•	
	Boat/submarine/whale watching	27.5	15.5					•	
	Tour bus excursion	11.8	39.8					•	
	Private limousine/van tour	4.5	14.0					•	
	Self-guided	77.1	53.6				•		
Recreation	Swimming/sunbathing/beach	82.6	59.5	•					
	Surfing/body boarding	22.4	6.6	•				•	
	Snorkeling/scuba diving	49.9	15.5	•				•	
	Jet skiing/parasailing/windsurfing	4.6	3.3					•	
	Golf	12.8	8.7			•			
	Running/jogging/fitness walking	39.6	20.7	•					
	Spa	11.7	7.8	•					
	Backpacking/hiking/camping	24.9	8.6	•					
	Sports event/tournament	4.2	2.4	•		•			
Entertainment	Lunch/sunset/dinner/evening cruise	25.6	50.0	•	•			•	
	Lounge act/stage show	23.8	23.3	•					
	Nightclub/dancing/bar/karaoke	12.5	5.5	•	•				
	Fine dining	54.2	74.0	•	•				
	Family restaurant/diner	73.9	46.9	•	•				
	Ethnic dining	43.2	12.6	•	•				
	Prepared own meal	52.6	14.7	•					•
Shopping	Department stores	42.4	48.3						•
	Designer boutiques	34.8	56.3	•					•
	Hotel stores	41.9	40.5	•					
	Swap meet	31.8	15.5						•
	Discount/outlet stores	34.4	40.3						•
	Supermarkets	71.8	58.5						•
	Convenience stores	63.2	70.8						•
	Duty free	13.2	63.8						•
	Local shops/artisans	70.7	31.0						•
Job counts in 2009	State of Hawaii	Total:	597,700	35,000	55,350	NA	NA	NA	66,250
	(%)		(100.0)	(5.9)	(9.3)				(11.1)
	the Big Island	Total:	63,400	5,750	5,150	NA	NA	NA	8,850
	(%)		(100.0)	(9.1%)	(8.1)				(14.0)
Visitor expenditures in 2009	State of Hawaii (millions of dollars)	Total:	9,993.2	3,653.1	1,381.2	NA	645.3	207.3	2,226.2
	(%)		(100.0)	(36.6)	(13.8)		(6.5)	(2.1)	(22.3)
	the Big Island (personal daily spending in dollars)	Total:	147.7	57.6	19.7	NA	14.4	16.1	25.3
	(%)		(100.0)	(39.0)	(13.3)		(9.7)	(10.9)	(17.1)

Sources: Activity participation by visitors (DBEDT 2010); job counts (DBEDT 2010); visitor expenditures (Hawaii Tourism Authority 2010). NA = not available.

Table 2 Survey data collection in 2010

Establishment type		*Number of establishments on the Big Island*	*Number of valid samples*	*Sampling ratio (%)*
Accommodations[a]	Hotels	31	9	29.0%
	Condominiums	19	2	10.5%
	Bed and breakfasts	95	0	0.0%
	Other (individual vacation unit, timeshare, etc.)	298	0	0.0%
	Subtotal	**443**	**11**	**2.5%**
Restaurants[b]		173	24	13.9%
Golf courses[c]		21	4	19.0%
Tours[d]		63	9	14.3%
Car rentals[e]		9	2	22.2%
	Total	**709**	**50**	**7.1%**

Sources: [a]Hawaii Tourism Authority (2011).
[b]Dining Guide, http://hawaii.diningguide.com/.
[c]Hawaii Golf Course Coalition and each golf course's official Web sites.
[d]List of tour establishments.
[e]Web site for each car rental establishment.

compared to the five selected sectors, it is difficult for the retail sector to distinguish between purchases made by visitors and those by residents. In terms of visitors' personal expenditures on the Big Island, four of the five sectors account for 72.9% of the total expenditures in 2009 (accommodations 39.0%, restaurants 13.3%, car rentals 9.7%, tours 10.9%) (table 1).

Survey Methodology

As summarized in table S2 in the supporting information on the Web, the questionnaire used in this study was separated into three parts: (1) general information (such as year founded, number of employees, land cover, acreage, building and construction type, gross floor footage, number of guest rooms, number of visitors, and annual sales), (2) inputs (food, energy, and water consumption), and (3) outputs (wastes, including wastewater). In collaboration with a local counterpart, the questionnaire survey was conducted from mid-August to December 2010, following a pretest in early August.

The snowball sampling technique was used to collect samples from five target sectors. In this method, the researcher asks survey participants to provide referrals to other potential respondents. This sampling method is effective in reaching participants, but the representativeness of the sample is not guaranteed and the participants may share similar traits and characteristics. During the pretest phase of the questionnaire, the author found it difficult to identify establishments that would agree to provide in-depth and quantitative information about their business operations. Thus, each time the author and the local assistants met with participants, the participants were asked to nominate further potential contact persons or establishments. Consequently, 50 valid samples were collected from the target sector enterprises (table 2). Nearly one-third of the hotels participated in this survey, but samples could not be collected from bed and breakfast and other accommodation types, including individual vacation units and timeshares, because of the limitation in collecting private information and the lack of tracking data for resources and wastes. Sampling ratios of restaurants, golf courses, tours, and car rentals were 13.9%, 19.0%, 14.3%, and 22.2%, respectively. According to Yamane's (1967) formula for calculating samples sizes ($n = N/(1 + N(e))^2$), where n is the sample size, N is the population size, and e is the level of precision, 50 samples out of 709 establishments (table 2) means an 86.4% confidence level ($e = 0.136$).

Survey participants were asked to answer quantitative questions regarding energy, water, and materials on the basis of their energy bills (such as electricity, gas, oil, and wood pellets), water and sewer bills, and bills or records indicating waste disposal or recycling from the most recent (January–December) 12-month period. To encourage participation and ensure the accuracy and credibility of sample data, the investigator and local assistants personally visited more than 30 participants. The rest of the survey responses were collected through multiple follow-ups via e-mail or confirmation calls. In addition, a food inventory for restaurants was developed through in-depth interviews with six restaurants (five Japanese restaurants and one local fusion-style restaurant).

Resource Consumption and Waste Generation

The sample data were analyzed to determine the average amount of energy, food, and water used as well as the waste generated by the type and size of the establishment. The number of visitors, employees, guest rooms (units), golf course holes, and car rentals were used to determine specific consumption and waste generation, depending on the establishment type. The number of visitors (users) is the common operation indicator for all types of establishments (DBEDT 2011; Hawaii Tourism Authority 2010). The number of available units (guest rooms) was used as a key indicator in the accommodation sector (Hawaii Tourism Authority 2011). The length of stay and occupancy rate are also important indicators for understanding the characteristics of the accommodation business

(Hawaii Tourism Authority 2010); however, it was difficult to collect data on the occupancy rates of individual establishments because the rate directly reflects the business condition of an establishment. The size of a restaurant was often characterized by the number of meals it served and the number of its employees (Okazaki et al. 2008). The size of a golf course was often represented by the land area, which is closely related to the number of holes (Saito 2010). For example, an 18-hole course in general requires approximately 50 to 60 hectares (ha) of land (Gössling 2002).[1] The business size of tour services can be measured by the number of visitors, employees, tour vehicles, and trips. The number of car rentals, traveling distance per rental, and vehicle fuel efficiency (intensity) were used to estimate the energy use of rental car travel (Becken et al. 2003).

In order to identify key variables to understand and quantify resource use and waste generation by the tourism industry on the Big Island, this study explored the relationships between the variables described in the previous paragraph and resource use conditions through correlation analysis. Ideally the overall amount should be estimated by using the significantly correlated variables. However, due to the lack of reliable data on some key variables, the island-wide status was estimated based on the number of establishments, employees, guest rooms, golf course holes, and car rentals. For example, when quantifying the input and output for hotel accommodations, specific units (for energy, water, food, and waste) per employee were calculated as the average value from the collected samples multiplied by the number of island-wide employees in the accommodation sector. Similarly, specific units per guest room and the number of island-wide guest rooms were also used as estimates for accommodation.

Results and Discussion

Specific Water and Energy Consumption and Waste Generation

Table 3 shows specific resource consumption and waste generation derived from the survey. The results are listed on per establishment, per employee, and per visitor (per guest) bases. Energy consumption is given in oil equivalents, which represent energy generated by burning 1 metric ton of oil. Rental cars show the highest energy consumption, while their waste generation per visitor is the lowest. The results revealed that water consumption by accommodations and golf courses far exceeds water consumption by the other sectors, primarily due to filling swimming pools and irrigating green spaces. Furthermore, accommodations showed the highest per establishment and per visitor food consumption and waste generation values, while restaurants showed the highest per employee food consumption and waste generation values.

Correlation Analysis

Table 4 shows the Pearson's correlation coefficients for energy consumption, water consumption, waste generation, and basic operation indicators such as the number of employees, square footage, number of seats, and number of annual guests for accommodations, restaurants, and tours. The sample sizes of golf courses and car rentals are too small to test correlation.

The number of employees indicates six significant positive correlation coefficients (energy for accommodations, energy and waste at restaurants, and energy, water, and waste for tours) across all three sectors, which means the probability (P) of there being no significant relationship is less than 0.05 (5%). In general, the greater the number of employees in an establishment, the greater the amount of energy and water consumed, and waste generated.

The number of seats in a restaurant establishment shows a significant positive relationship ($P < 0.01$) with energy use, water use, and waste for restaurants. The scatter plots in figure 1 clearly demonstrate this relationship with a linear regression equation to estimate the amount of energy consumption, water consumption, and waste generation (y) by each operation indicator (x), such as the number of employees and seats for restaurants. (Note that for figure 1, the y-intercept was set at zero, while for table 4 the y-intercept was determined by best fit. Because of this, the Pearson coefficients for restaurants from table 4 are not necessarily coherent with the R^2 values given in figure 1.)

In addition to the number of employees, the number of guest rooms at accommodations are more useful to estimate water consumption. Similarly, the number of annual guests are a better indicator to explain water consumption and waste generation values for tour enterprises, while the number of annual trips is more important to estimate their energy use (table 4).

Restaurant Food Inventory

The restaurant food inventory varies depending on the type and size of a restaurant. Table 5 shows the food inventory and the inputs from the six restaurants surveyed. Food input and output were calculated using the number of employees, seats, and annual guests. The annual food input per employee ranged from 1.91 to 4.71 tonnes, per seat from 0.38 to 1.47 tonnes, and per guest from 0.24 to 2.46 kilograms (kg).[2] Using the six samples, average food input per employee, per seat, and per guest was 3.11 tonnes, 0.66 tonnes, and 1.16 kg, respectively, while the average food output was 1.08 tonnes, 0.23 tonnes, and 0.40 kg, respectively.

If we exclude a sample of non-Japanese restaurants (restaurant E in table 5), average food input per employee, per seat, and per guest was 3.92 tonnes, 0.88 tonnes, and 1.31 kg, respectively, and the average food output was 1.81 tonnes, 0.41 tonnes, and 0.60 kg, respectively. This suggests that food input and output for Japanese restaurants may be larger than for non-Japanese ones, but more samples from non-Japanese establishments need to be collected to demonstrate this statistically.

Figure S1 in the supporting information on the Web illustrates the average composition of food types served per guest (1.16 kg). Dairy, dry, and bakery goods such as flour, miso (soybean paste), and eggs account for 48%, followed by fruits and

Table 3 Specific resource consumption and waste generation derived from the survey samples

	Category	*Unit*	*Accommodations*	*Restaurants*	*Golf courses*	*Tours*	*Car rentals*
Per establishment	Energy	tonnes of oil equivalent/year	890.5 (±652.6)	381.2 (±166.2)	178.7 (±103.7)	34.3 (±18.0)	4,522.0 (±7,339.1)
	Water	kL/year	879,704.3 (±1,017,177.9)	2,621.6 (±1,681.6)	801,553.7 (±634,400.7)	195.8 (±152.4)	609.5 (±247.5)
	Food	kg/year	214,092.5 (±16,409.2)	84,363.7 (±53,625.2)	13,607.8	2,379.5 (±2,698.8)	NA
	Waste	kg/year	360,740.3 (±307,785.0)	87,647.4 (±36,884.8)	108,721.2 (±129,118.1)	11,270.4 (±9,534.7)	63,013.2 (±56,488.4)
Per employee	Energy	tonnes of oil equivalent/year	2.6 (±0.7)	13.5 (±5.1)	1.9 (±1.4)	2.1 (±1.8)	85.3 (±60.1)
	Water	kL/year	2,155.1 (±2,025.5)	79.8 (±43.7)	8,437.4 (±13,472.1)	11.9 (±13.2)	11.5 (±152.5)
	Food	kg/year	413.7 (±8.7)	3,109.0 (±956.0)	68.0	80.2 (±58.2)	NA
	Waste	kg/year	883.7 (±21,365.5)	3,558.5 (±669.2)	1,144.4 (±2,665.2)	784.0 (±368.0)	1,188.9 (±5,109.9)
Per visitor (per guest)	Energy	kg of oil equivalent/year	14.5 (±5.7)	5.9 (±2.8)	3.6 (±1.8)	3.4 (±2.8)	40.0 (±67.1)
	Water	L/year	14,452.8 (±3.1)	38.3 (±29.8)	15,981.5 (±8,525.5)	20.9 (±40.0)	2.0 (±151.6)
	Food	kg/year	2.3 (±0.01)	1.2 (±0.8)	0.3	0.1 (±0.2)	NA
	Waste	kg/year	5.9 (±5.4)	2.0 (±0.8)	2.2 (±1.9)	1.4 (±0.8)	0.6 (±5.0)
Per guest room	Energy	tonnes of oil equivalent/year	2.3 (±1.7)	–	–	–	–
	Water	kL/year	2,029.8 (±765.1)	–	–	–	–
	Food	kg/year	197.6 (±268.9)	–	–	–	–
	Waste	kg/year	832.3 (±1,588.3)	–	–	–	–
Per hole	Energy	tonnes of oil equivalent/year	–	–	7.4 (±4.0)	–	–
	Water	kL/year	–	–	33,398.0 (±38,134.7)	–	–
	Food	kg/year	–	–	378.0	–	–
	Waste	kg/year	–	–	4,530.0 (±7,509.2)	–	–

Notes: (±) means 90% confidence range. Tonnes is metric tons. kL = kiloliters; kg = kilogram; NA = not applicable.

vegetables (16%), seafood (13%), and breads, noodles, and rice (10%).

The average food waste generated from the five samples was 29.9 tonnes/year per establishment (=149.6/5; table 5). According to results from surveys conducted in 2004 and 2005 by Okazaki and colleagues (2008), food waste generated per restaurant in the State of Hawaii was reported to be 35.2 tonnes/year. This suggests that food waste generation per restaurant on the Big Island may be smaller than the state average, or it has dwindled due to the slowdown in the world economy.

Of the six restaurants that provided detailed food inventory information, only one restaurant (A in table 5) recycles 90% of its food waste for pig slop. Restaurant E in table 5 answered that they do not track food waste because they do not separate food waste from other waste.

Resource Consumption and Waste Generation

The resource use and waste generation (table 6 and figure 2) on the Big Island were estimated based on the resource input and waste output in table 3 and on island-wide statistics for the number of establishments, employees, and other business operations derived from the *State of Hawaii Data Book 2010* (DBEDT 2011). Two different specific units were used

Table 4 Pearson's correlation coefficient for energy consumption, water consumption, waste generation, and basic operation indicators for accommodations, restaurants, and tours

Type		*Valid N*	*Number of employees*	*Square footage (square meters)*	*Number of guest rooms (units)*	*Number of annual guests (2009)*
Accommodations	Energy	7	0.935**	0.925**	0.746	0.275
	Water	5	0.851	0.897*	0.979**	– 0.705
	Waste	5	0.507	0.494	0.120	0.531
Type		*Valid N*	*Number of employees*	*Square footage (square meters)*	*Number of seats*	*Number of annual guests (2009)*
Restaurants	Energy	18	0.651**	0.333	0.656**	0.271
	Water	9	0.656	0.559	0.860**	– 0.021
	Waste	16	0.929**	0.649**	0.874**	0.509*
Type		*Valid N*	*Number of employees*	*Square footage (square meters)*	*Number of annual trips*	*Number of annual guests (2009)*
Tours	Energy	7	0.823*	0.574	0.839*	0.540
	Water	7	0.919**	0.600	0.369	0.934**
	Waste	8	0.849**	0.236	0.277	0.981**

Notes: N = number of samples. Significance level of Pearson's correlation coefficient *$P < 0.05$, **$P < 0.01$.

for accommodations (number of employees and number of guest rooms), restaurants (number of establishments and number of employees), and golf courses (number of establishments and number of holes). Since there are no official statistics for the number of car rentals, the lower estimate assumed 50% of the visitors under the category of "true independent" for the travel method from the *State of Hawaii Data Book 2010* (DBEDT 2011) used rental cars with an average party size of 2.09. The higher estimate assumed that 100% of "true independent" visitors used rental cars with the same party size.

Figure 2 shows that energy consumption from restaurants contributes 58% of the total energy consumption by these five tourism sectors, followed by car rentals (20%) and accommodations (17%). Water used by accommodations and golf courses together accounts for more than 98% of the total water consumption for these five tourism sectors. Food consumption by restaurants accounts for 85% of the total food consumption for these five tourism sectors. It was estimated that 62% of the waste generation from these five tourism sectors was generated from restaurants, 27% from accommodations, and 7% from golf courses.

According to the *State of Hawaii Data Book 2010* (DBEDT 2010), total electricity production on the Big Island is 1,227 million kilowatt-hours (kWh), and 17.7% of it (217,645 megawatt-hours [MWh],[3] equivalent to 105,503 tonnes of oil) is consumed by the five tourism sectors evaluated in this study (table 6). The five tourism sectors account for 21.7% of the island's total energy consumption. This includes electricity, liquid fuels, and propane gas. Water consumption by the five tourism sectors was estimated to be 44.7% of the island's total water consumption, probably due to the excessive water use by the accommodations sector and golf courses. In contrast, waste generation from the five tourism sectors accounted for 10.7% of the island's total waste generation. These estimates suggest that the five tourism sectors surveyed have a much larger impact on the island's total water use than on its energy consumption and waste generation.

The DBEDT (2005) reported on the statewide visitor demand for infrastructure services through an input–output analysis that attributes total infrastructure demand to residents, visitors, and other consumers of the output of the State of Hawaii (table 6). According to this report, visitors use 18.8% of energy consumed, 35.5% of water consumed (including for sewerage), and generate 14.8% of the solid waste. The tourism industry is therefore a heavy user of water and sewerage on both the Big Island and in the State of Hawaii. Another study on the State of Hawaii using input–output analysis revealed that visitors consumed 33.5 trillion British thermal units (BTU),[4] which accounts for 22.5% of the total energy consumption of the state (Konan and Chan 2010). My estimation showed that the energy use by visitors on the Big Island was 21.7% of the total (table 6). However, we need to be careful in interpreting these percentages because, while the DBEDT (2005) and Konan and Chan (2010) computed both direct energy use and indirect use through interindustry relations, my study focused on the direct use of resources by selected tourism sectors. It did not consider indirect resource demand and waste generation through the consumption of goods and services outsourced by the tourism industry (i.e., taxis, laundries, commercial fishing, and food production and processing). Another problem concerning the comparison lies in the difference in the estimation baseline year. The DBEDT (2005) and Konan and Chan (2010) used the 1997 input–output tables for their calculations because

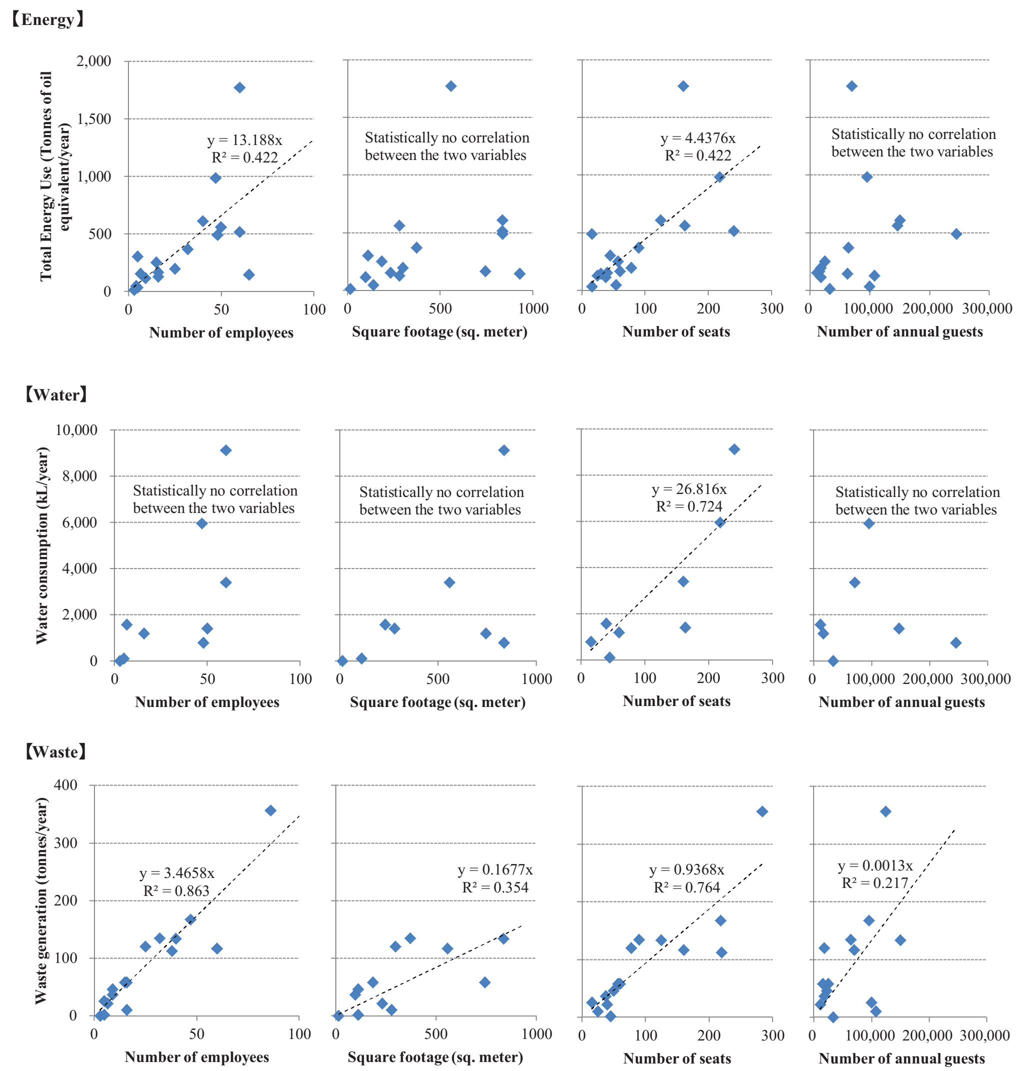

Figure 1 Scatter plot of energy, water, waste, and basic operation indicators for restaurants. kL = kiloliters; y = dependent variables (total energy use, water consumption, and waste generation); x = independent variables (number of employees, square footage of the restaurant, number of seats, and number of annual guests).

a more recent input–output and energy dataset from 2002 was not suitable for the analysis owing to the exclusion of key energy sectors in its aggregation.

The resource use and waste generation on a per visitor per day basis on the Big Island were also computed and compared with those for the State of Hawaii (table 6). This suggests that visitors on the Big Island consume more energy and water than do those in the State of Hawaii; however, the amount of solid waste is more or less the same in both places. Konan and Chan (2010) also calculated per visitor per annum energy use for the State of Hawaii at 213 million BTU (excluding air transportation), which is equivalent to 14.7 kg oil equivalent per visitor per day. This is slightly higher than that of the Big Island as estimated by my study (table 6), which does not include indirect energy consumption. Based on an international review of tourism accommodations, Gössling and colleagues (2012) concluded that water consumption ranges from 84 to 2,000 liters (L) per visitor per day on a global scale,[5] and from 303 to 1,514 L per visitor per day in the United States. Estimated water use on the Big Island was 3,623 L per visitor per day (table 6), which is far greater than consumption in the United States because it includes consumption by golf courses, which account for nearly 45% of the overall water use on the Big Island.

Summary and Conclusion

A survey of the tourism industry on the Big Island was conducted to collect baseline information on major resources (energy consumption, food consumption, and water consumption) and waste generation from five tourism sectors: accommodations, restaurants, golf courses, tours, and rental cars. Visitor expenditures by these sectors (excluding golf courses) accounted for 72.9% of the total tourism expenditures in 2008 (table 1).

Table 5 Food inventory and specific input of the six selected restaurants on the Big Island

Inventory (unit)	Type of input	A Japanese: seafood and sushi	B Japanese: bistro	C Japanese: sushi	D Japanese: bistro	E Local fusion style	F Japanese: sushi (takeout)	Total
(a) Food	Beef/pork/poultry items (tonnes/year)	11.3	2.0	1.9	2.0	10.3	2.4	29.9
	Seafood items (tonnes/year)	31.9	1.3	4.2	1.9	8.7	7.4	55.3
	Fruits and vegetables (tonnes/year)	19.8	1.6	3.9	3.4	38.0	1.3	68.0
	Bread, noodles, rice, etc. (tonnes/year)	17.7	2.5	3.8	2.4	6.9	10.9	44.2
	Condiments (tonnes/year)	12.2	2.0	4.9	0.8	5.5	0.0	25.4
	Dairy, dry, bakery goods (tonnes/year)	113.6	26.2	12.6	16.4	37.4	1.5	207.7
	Food total	206.5	35.5	31.3	26.9	106.9	23.5	430.6
(b) Nonfood	Disposable nonfoods and cleaning supplies (tonnes/year)	16.7	0.8	11.3	14.6	32.2	0.0	75.6
	Total input (tonnes/year)	223.3	36.3	42.6	41.5	139.0	23.5	506.2
(c) Basic operation indicators	Number of employees	47	9	15	6.5	56	5	139
	Number of seats	218	38	57	40	284	16	653
	Number of annual guests (2009)	95,000	18,000	24,831	10,920	124,311	99,125	372,187
(d) Specific food input (d = a/c)	Per employee (tonnes/employee)	4.39	3.95	2.09	4.13	1.91	4.71	3.11
	Per seat (tonnes/seat)	0.95	0.93	0.55	0.67	0.38	1.47	0.66
	Per guest (kg/guest)	2.17	1.97	1.26	2.46	0.86	0.24	1.16
(e) Specific nonfood input (e = b/c)	Per employee (tonnes/employee)	0.36	0.08	0.75	2.25	0.57	NA	0.55
	Per seat (tonnes/seat)	0.08	0.02	0.20	0.37	0.11	NA	0.12
	Per guest (kg/guest)	0.18	0.04	0.46	1.34	0.26	NA	0.20

Notes: kg = kilogram; NA = not applicable. Specific food input equation d = a/c signifies dividing the amount of food input (a) by the basic operation indicators (c) for each of the restaurants (i.e., number of employees, seats, or annual guests). Specific nonfood input equation e = b/c signifies dividing the amount of nonfood input (b) by the basic operation indicators (c) for each of the restaurants.

Fifty establishments from the target sectors participated in this survey.

Resource consumption and waste generation was calculated by the number of establishments, employees, and visitors (table 3). Correlation analysis revealed that, in general, the higher the number of employees in an establishment, the greater the amount of energy and water consumed, and the greater the amount of waste generated (table 4). In addition, the food inventory and the input and output amounts were surveyed for six restaurants (table 5). The average food input per employee, per seat, and per guest was 3.11 tonnes, 0.66 tonnes, and 1.16 kg, respectively, while the average food output was 1.08 tonnes, 0.23 tonnes, and 0.40 kg, respectively. Using these factors and island-wide statistics (the number of establishments, job counts, visitors, guest rooms, and golf course holes), the current island-wide resource use and waste generation by the tourism industry was estimated (table 6). The estimates show that the tourism sector surveyed for this study accounts for 21.7% of the island's total energy consumption, 44.7% of the island-wide water consumption, and 10.7% of the island-wide waste generation.

Using a per guest emission factor (such as per employee, guest room, seat) in table 3 and regression formulas including correlation and regression analysis, tourism establishment owners and managers can calculate a baseline for each resource input and output and thereby understand their relative performance. This information is essential for improving the industry's efficiency and will also lead to economic savings. Many options have been suggested to reduce inputs and outputs (Yalcintas and Kaya 2009), introduce renewable energy (Keffer et al. 2009), and implement integrated resource and solid waste management (County of Hawaii, Department of Environmental

Table 6 Estimation of water and energy use and waste generation for the five tourism sectors on the Big Island

		Input					*Output*
		Energy					
Type	*Estimation base (see table 3 for specific units used for estimation)*	*Electricity (MWh/year)*	*Fuel: gasoline, diesel, propane (tonnes of oil equivalent/year)*	*Total (tonnes of oil equivalent/year)*	*Water (1,000 kL/ year)*	*Food (tonnes/ year)*	*Waste generation (tonnes/ year)*
Tourism industry surveyed							
Accommodations	Employee basis	107,424	5,109	14,347	12,068	2,317	4,949
	Guest room basis	197,937	9,413	26,436	23,535	2,291	9,651
	Average	152,680	7,261	20,392	17,802	2,304	7,300
Restaurants	Establishment basis	40,010	63,580	65,955	454	14,614	15,163
	Employee basis	29,504	67,916	70,453	415	16,519	18,504
	Average	34,757	65,748	68,204	434	15,390	16,834
Golf courses	Establishment basis	40,010	1,986	3,752	16,833	286	2,283
	Hole basis	20,005	1,094	2,814	12,624	143	1,712
	Average	30,007	1,540	3,283	14,729	214	1,998
Tours	Establishment basis	5,958	2,957	2,162	12	150	710
Car rentals	Rental basis: low case	291	15,570	15,595	0.79		217
	Rental basis: high case	583	31,140	31,190	1.58		435
	Average	437	23,355	23,392	1		326
Total	Lower estimate	161,298	88,310	100,874	25,121	17,224	22,752
	Higher estimate	273,991	113,412	133,993	40,835	18,893	31,583
	Average (a)	217,645	100,861	117,433	32,978	18,058	27,167
Big Island total (b)[a,b]		1,227,000	440.481	545,984	73,795	NA	254,920
Percentage of tourism industry (a/b × 100)		17.7%	22.9%	21.7%	44.7%	—	10.7%
Share of visitors' demand in the State of Hawaii[c]		27.0%	15.0%	18.8%	35.5%	NA	14.8%
Visitor days on the Big Island in 2010 (the number of visitor arrivals × length of stay) (c)[d]				9,102,156			
Daily per visitor demand (a/c × 1,000)		23.9	11.1	13.0	3.6	1.9	3.0
	(unit)	(kWh)	(kg of oil equivalent)	(kg of oil equivalent)	(kL)	(kg)	(kg)
Daily per visitor demand in the State of Hawaii [c]		33.6	3.5	6.4	1.3	NA	3.3

Notes: MWh = megawatt-hour; kL = kiloliter; kWh = kilowatt-hour; kg = kilogram. The "Percentage of tourism industry" is found for each of the inputs and outputs via the formula a/b x 100; this signifies dividing the tourism industry average for each input or output (a) by the Big Island total input or output (b), then multiplying this number by 100. The "Daily per visitor demand" is found for each of the inputs and outputs via the formula a/c x 1,000; this signifies dividing the tourism industry average input or output (a) by the number of visitor days on the Big Island (c) and multiplying this number by 1,000.

Sources: [a]DBEDT (2010).
[b]County of Hawaii, Department of Environmental Management (2009).
[c]DBEDT (2005) (these values for the state of Hawaii were used to capture characteristics of energy, water, and food consumption and waste generation on the Big Island). [d]Hawaii Tourism Authority (2010).

Management 2009). However, without an understanding of the current performance of each establishment compared with a baseline or average, it is difficult to formulate an effective strategy and structure investment options at each site. When a manager finds current energy or water use to be much higher than the baseline, specific reasons for this overuse need to be identified and countermeasures implemented. The results of the correlation analysis (table 4) can also provide valuable information for those concerned with conservation measures. For example, water use at an accommodation can be explained

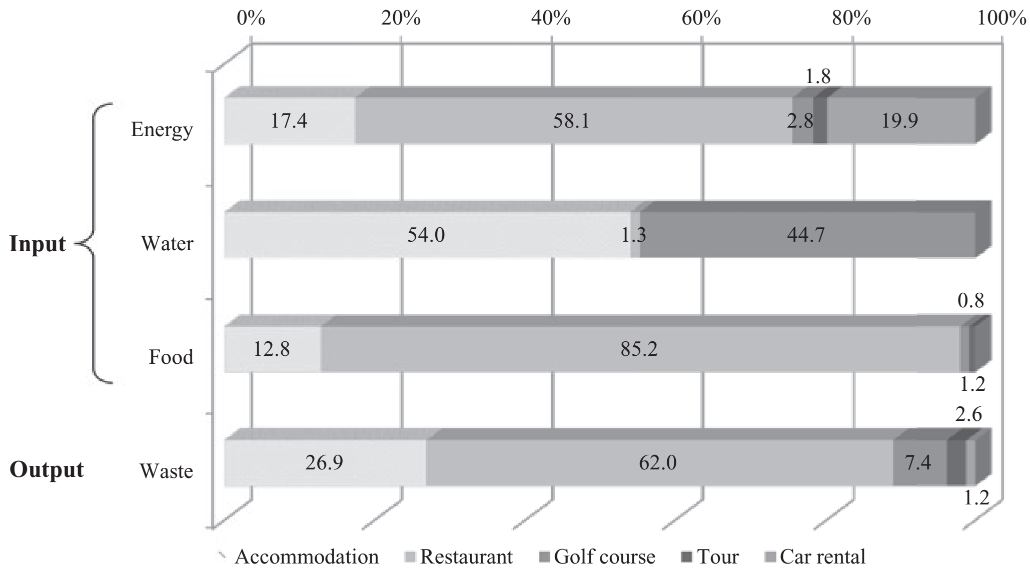

Figure 2 Composition of resource inputs and outputs by types of tourism establishment (average case).

better by the number of guest rooms than by other variables. This suggests that the improvement of water efficiency in guest rooms (i.e., by installing water-saving equipment) would be effective. Such information can also be used to make management decisions that would lead to economic savings for the industry.

It is important to note that indirect resource use and waste generation on the Big Island is not assessed in this study. Thus the results may underestimate actual input and output. Another limitation of this study is in the sampling of establishments. The collection of data from 50 establishments provides detailed information on the direct input and output of each establishment, but we need larger samples to improve the accuracy and credibility of information on overall resource use and waste generation on the Big Island (table 6). Statistical sampling methods were unsuccessful during the survey, mainly because of a high individual concern regarding information protection and the lack of strong incentives to contribute to such a survey that requires an extensive collation and examination of bills and accounting files. Additional studies are needed to increase the number of establishments surveyed and expand the sectors sampled. Practical measures to minimize resource inputs and outputs need to be identified and solutions need to be implemented as best practices within each tourism sector. In addition, interisland comparisons need to be conducted to examine whether tourism is a benefit or a curse from a sustainability perspective.

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Notes

1. One hectare (ha) = 0.01 square kilometers (km^2, SI) ≈ 0.00386 square miles ≈ 2.47 acres.
2. One tonne (t) = 10^3 kilograms (kg, SI) ≈ 1.102 short tons. One kilogram (kg, SI) ≈ 2.204 pounds (lb).
3. One kilowatt-hour (kWh) ≈ 3.6 x 10^6 joules (J, SI) ≈ 3.412 x 10^3 British Thermal Units (BTU). One megawatt-hour (MWh) = 10^3 kilowatt-hours.
4. One British Thermal Unit (BTU) ≈ 1.055 x 10^3 joules (j) ≈ 0.2522 kilocalories.
5. One liter (L) = 0.001 cubic meters (m^3, SI) ≈ 0.264 gallons (gal).

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Supporting Information S1: This supporting information contains one figure (S1) on the mean food input per guest at the six selected restaurants and two tables, one on electricity generation in the State of Hawaii in 2009 (table S1) and the other on common questionnaire items used in this study (table S2).