STUDY OF VARIABLES AFFECTING ELECTRICITY CONSUMPTION AND GREENHOUSE GAS EMISSION OF HOTELS IN THAILAND

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ABSTRACT

The hotel sector accounts for significant environmental impacts in terms of resource consumption and pollution. This study aims to estimate greenhouse gas emissions from hotel electricity consumption in Thailand. Data were collected from 187 hotels recorded in the list of the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand. The complete data sets for the year 2011 were received from 63 hotels (33.69%) which were classified as large commercial hotels. The nine physical hotel parameters and four operational hotel parameters were collected from the sampled hotels by questionnaires. The factors affecting electricity consumption of hotel in Thailand were investigated by Pearson correlation. The results indicated that the electricity consumption intensity was 26.82 kWh/m^2/month, 2,934.20 kWh/guest room/month and 191.03 kWh/room-night/month. The carbon emission intensity was 14.69 $kgCO_2/m^2$, 1,607.06 $kgCO_2$/guest room and 104.63 $kgCO_2$/room-night. Among all factors, the number of workers was the most significant factor affecting electricity consumption in units of kWh/m^2 at a 99% confidential level. The predictive models were then proposed and used to explain the relationship between electricity consumption and hotel parameters. The impacts of six mitigation measures for the reduction of GHG emission from electricity consumption of hotels in Thailand were evaluated by expert scoring method. Among all measures, hotel staff management was the most appropriated mitigation for energy conservation and GHGs reduction by hotels in Thailand.

Keywords: electricity consumption, greenhouse gas emission, hotels, Thailand, correlation, regression analysis

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CHAPTER 1
INTRODUCTION

1.1 Rationale/ Problem Statement

As a major sub-sector of the tourism industry, the hotel sector accounts for a significant amount of overall resource consumption, as well as for a substantial portion of the environmental impacts it generates (Gossling, 2002). In the United States of America, hotel facilities rank among the top five in terms of energy consumption in the commercial/service building sector (minor only to food services and sales, health care and certain types of offices) (U.S. Energy Information Administration, 1998). There are important reasons that can explain the reason for energy use in hotels. Hotels do not have fixed operating hours, especially high class hotels, while most commercial buildings define their operating hours. For examples, restaurants may close, say, at 11 P.M., but guestroom services will continue. Some public spaces like lobby are lighted and conditioned around the clock. Not surprisingly, hotels are found in many countries to be among the most energy intensive building categories. Although no collective data was available on the energy consumption in the hotel sector, it was estimated that 97.5 TWh (351.1 PWh) of energy was used in hotel facilities worldwide in 2001 (Gossling, 2002).

Hotels usually encompass multiple functional areas that may have very different requirements for energy use. Therefore, energy in a few different forms (e.g. electricity, diesel, and LPG) is often needed in a hotel. The fuel mix of a building is largely determined by the climate it is located in. Generally, buildings in cold climates consume more gas or oil for heating, while their counterparts in the tropics may need more electricity for cooling. The electricity consumptions in worldwide hotels (the percentage of electricity consumption compared to the total energy consumption in hotels) were reported as follows: 77-91% in Singapore's hotels (Priyadarsini *et al.*, 2009), 73% in Hong Kong's hotels (Shiming and Burnett, 2002), 59-78% in Mauritius's hotels (Mohee and Bhurtun, 2012), 73.41% in New Zealand's hotels (Becken, 2000), 68.33% in Greek's hotels (Xydis *et al*, 2009), 66-89 % in Saudi Arabia's hotels (Alamoudi, 2009), 66% in Australia's hotels (Commonwealth of Australia, 2002) and 48.3-49.3% in

Europe's hotels (Bohdanowicz and Martinac, 2007). Apparently, electricity has been the main energy used in worldwide hotels. Not surprisingly, many studies pointed that hotel electricity consumption was a major source of hotel emission. For example, GHG emission from electricity consumption of hotels in Singapore accounted for 93.64% (Priyadarsini *et al*., 2009), Australia for 91% (Commonwealth of Australia, 2002) and Taiwan for 79.14%of GHG emission from electricity use (Huang *et al*., 2010). Additionally, Bush *et al.* (1997) presented hotels are part of the commercial sector, which consumes around 6% of total energy in Australia but is responsible for around 12% of total energy related greenhouse gas emissions.

As discussed previously, hotels were found in many countries to be among the most energy intensive building categories, especially, electricity which was related to GHG emission. Hotel electricity consumption and environmental impact can be large, especially in greenhouse gas emission. Although hotel buildings were the one of the most energy intensive sectors in the building stock, the greenhouse gas emissions related to them were also substantial. Accounting for GHG emissions by hotel electricity consumption was a good tool measuring their environmental impact and demonstrating their commitments towards sustainable development. As expected, there were lots of factors contributing to their high electricity consumption, some of which were related to hotel designs and operations, such as extensive use of incandescent lamps in lobbies and restaurants, continuous air conditioning or heating of large common spaces. For these factors, energy savings can often be realized by incorporating energy efficient technologies or making changes to hotel operations. A good understanding of these factors and the ways they affect hotel electricity consumption may prove valuable in new designs, retrofitting projects as well as energy management programs. As can be seen in the energy source breakdown, electricity often accounts for the largest percentage of GHG emission in hotels. Not surprisingly, the largest GHG reduction potential is often found in electricity saving.

Although the number of Thailand hotels has increased to 258 hotels (7,081.2 rooms) per year (Tourism Authority of Thailand, 2007), Thailand's average annual energy demand increased by 4.3% in the last decade (Wibulswas, 2004). GHG emissions by the energy sector increased by 27.9% of total emissions or 6.4% per year in 2004 (Office of Natural Resources and Environmental Policy and Planning: ONEP, 2010). The World Resources Institute (WRI) presented that Thailand was ranked 25th out of 186 countries globally in terms of the level of GHG emissions (Nairam, 2009). None of the above studies has drawn a relatively complete picture of energy use in Thailand hotels. Besides, the above studies were conducted either in cold or temperate climates; whereas, research on energy performance of hotels in the tropics has been relatively rare. Therefore, this study will be the second comprehensive energy performance study in tropical hotels after the study of Xuchao *et al*. (2010) in 29 Singapore hotels and will be the first comprehensive energy performance study in Thailand. It is expected that some empirical experiences can be lent to similar studies in other tropical countries. This necessitates a comprehensive study to draw a whole picture of Thailand hotel industry energy performance. The purpose of this study, therefore, is to bridge this gap by doing a detailed investigation of the energy use conditions in tropical hotels. Effective measures can subsequently be taken in the areas where inefficiencies have been discovered. Thus, this study aims to investigate the data of electricity consumption and estimate the GHG emissions from hotels electricity consumption in Thailand. The national figures of GHG emissions from electricity consumption in hotel industry will be proposed. Additionally, the appropriate GHG mitigations will be studied.

1.2 Literature Reviews

1.2.1 Data collection and number of sampled hotels

In many studies with a similar nature and objectives, no sampling process or response rate was reported, probably because the sampling has been done out of convenience rather than systematically. For the others, their response rates were basically comparable to that of the current study. The international studies on energy consumption were shown applied 1-610 sample hotels (Table 1.1). The number of sampled hotels ranked from 1.38 to 36.43% of total hotels. The most survey of sampled hotels was conducted with a questionnaire (Table 1.2).

Table 1.1 Number of the sample hotels

References	Countries	Data for the year	Number of sampled hotels
Priyadarsini *et al*. (2009)	Singapore	1993	29 from 102 (28%)
Becken (2005)	Fiji	March 2004	25 from 116 (21.60%)
Ali *et al*. (2008)	Jordan	August 2006	80 from 222 (36.43%)
Alamoudi (2009)	Saudi Arabia	2000-2008	80
Warnken and Bradley (2002)	Australia	2002	11
Commonwealth of Australia (2002)	Australia	2000	51 from over 3,700 (1.38%)
Becken *et al*. (2006)	New Zealand	2002	1
Huang *et al.* (2010)	Taiwan	-	1
Xydis *et al*. (2009)	Greece	2002	1
Taylor *et al.* (2009)	UK	2009	A newer and an older hotel
Hotel Energy Solutions (2011)	Europe	a	a
Bohdanowicz and Martinac (2007)	Europe	2004	Hilton (73) and Scandic (111)
Mohee and Bhurtun (2012)	Mauritius	2001-2002	3 from 67 (4.48 %)
Shiming and Burnett (2002)	Hong Kong	1995	16 (20%)
Adelphi consult (2009)	Thailand	-	125
Treerattanapan (2011)	Thailand	2008 to half-year of 2011	1

Note: - is not available

a is the study of 610 hotels across Europe, carried out in 2002 and 2003 by Bohdanowicz and colleagues at the Royal Institute of Technology, Sweden. The studying of implementation of the EU Environmental Management and Audit Scheme (EMAS) in 115 hotels, carried out in Spain in 2005, Total Quality Management (TQM) in 301 hotels carried out in Spain in 2005-2006, 158 hotels in Greece carried out in 1996, 64 hotels carried out in the city of Plymouth in the UK in 1998, 40 hotels in Ankara, Turkey, carried out in 2006-2007 (included for comparison), and the studying of tourists' attitudes to renewable energy use in four Australian hotels (included as it provides relevant information and was a useful comparison).

Table 1.2 Data collection

References	Countries	Data for the year	Tools
Priyadarsini *et al*. (2009)	Singapore	1993	Questionnaire, visits and interviews
Becken (2005)	Fiji	March 2004	Questionnaire
Ali *et al*. (2008)	Jordan	August 2006	Questionnaire
Alamoudi (2009)	Saudi Arabia	2000-2008	Questionnaire
Warnken and Bradley (2002)	Australia	2002	Questionnaire, websites, brochures and interviews
Commonwealth of Australia (2002)	Australia	2000	Ask to submit energy consumption report
Becken *et al*. (2006)	New Zealand	2002	Interviews
Huang *et al.* (2010)	Taiwan	-	Questionnaire
Mohee and Bhurtun (2012)	Mauritius	2001-2002	Electricity bill
Adelphi consult (2009)	Thailand	-	Questionnaire, websites and reports
Treerattanapan (2011)	Thailand	2008 to half-year of 2011	Electricity and LPG bill, questionnaire and interviews

Note: - is not available

1.2.2 Characteristics of hotels

Many international studies about energy consumption in various sampled hotel, characteristics of the sample hotels, many variables such as gross floor area (GFA), the number of guest rooms, building age, star rating and so on, a shown in Table 1.3.

Table 1.3 Hotel characteristics and factors affecting hotel energy use

References	**Singapore**	**Hong Kong**	**Mauritius**	**Australia**	**Australia**	**Europe**	**Japan**	**Thailand**	**San Francisco, California**
	Priyadarsini *et al*. (2009)	Shiming and Burnett (2002)	Mohee and Bhurtun (2012)	Warnken and Bradley (2002)	Commonwealth of Australia (2002)	Bohdanowicz and Martinac (2007)	The Energy Conservation Center (2009)	Treerattanapan (2011)	Kammerud *et al*. (2012)
Data for the year	1993	1995	2001-2002	1995-2000	2000	2004	2003	2008 to half-year of 2011	1993
Types of energy use	Electricity, diesel and natural gas	Electricity, diesel and gas	Electricity, diesel and LPG	Electricity and gas	Electricity, natural gas, LPG and diesel	Electricity	Electricity and others	Electricity and LPG	Electricity
GFA	√*	X	X	X	√*	√*	√*	X	X
Number of floors	√	X	X	X	X	X	X	X	X
Number of guest rooms	√*	X	X	X	√	X	√	X	X
Building ages	√	X	X	X	X	√	X	X	X
Number of years after the last major retrofit	√*	X	X	X	X	X	X	X	X
Number of workers	√*	X	X	X	X	X	X	X	X
Workers density	√*	X	X	X	X	X	X	X	X
Occupancy rates (OR)	√*	X	√	√*	√*	√*	X	X	X
Star rating	√*	√	X	√	X	X	X	X	X
Number of occupied room-nights	√*	X	X	X	√	√*	X	√*	√*
Outdoor air temperature	X	√*	√*	√*	X	√*	X	X	X
Geographical location	X	X	X	X	√	√	X	X	X
Number of guests	X	√*	X	X	X	X	X	X	√
Number of food covers	X	√*	X	X	X	√*	X	X	√
In-house laundry load	X	X	X	X	X	√	X	X	X
Water consumption	X	X	X	X	√*	X	√*	X	X
Peak demand	X	X	X	X	X	X	X	X	√*

Note: √ is factors did not affecting energy use

√* is factors affecting energy use

X is factors that did not study

1.2.3 Factors affecting energy use in hotels

Typically, the variables investigated with regard to energy consumption a shown in Table 1.3. Linear regression was used for investigation factors affecting energy use (Table 1.4). Although many variables may have some influences on total hotel energy use, in practice only a few variables were generally considered depending on data availability. Additionally**,** a number of international study of 1,292 hotels from Europe, Spain, Greece, UK, Turkey and Australia since 1996 to 2007 found that typically variable investigated with regard to energy consumption are hotel standard, hotel floor area (or number of guestrooms or beds), heating and cooling degree days, guest-nights (occupancy), (warm) food covers sold, presence of heated swimming pool, presence of food preparation facilities, comfort level, chain affiliation, corporate (management and staff) and customer awareness (Hotel Energy Solutions, 2011a). It found that typically variable investigated with regard to energy consumption are hotel floor area (or number of guestrooms), guest-nights or occupancy, outdoor air temperature and food covers sold.

Table 1.4 Data analysis

References	Countries	Data for the year	Data analysis
Xuchao *et al*. (2010)	Singapore	1993	Linear regression and correlation
Warnken and Bradley (2002)	Australia	2002	Linear regression (Comparing benchmark figures for electricity consumption within and between accommodation types by using ANOVA and Dunnett's T3 post hoc analysis)
Commonwealth of Australia (2002)	Australia	2000	Linear regression
Bohdanowicz and Martinac (2007)	Europe	2004	Linear regression and correlation

Table 1.4 Data analysis (Cont')

References	Countries	Data for the year	Data analysis
Mohee and Bhurtun (2012)	Mauritius	2001-2002	Linear regression and correlation
Shiming and Burnett (2002)	Hong Kong	1995	Regression and correlation
Treerattanapan (2011)	Thailand	2008 to half-year of 2011	Linear regression and correlation
Kammerud *et al*. (2012)	San Francisco, California	1993	Linear regression and correlation

Note: - is not available

Priyadarsini *et al*. (2009) reported that regression analyses were conducted to correlate energy consumption with GFA, the number of guest rooms, the number of occupied rooms per year, and the number of workers. Most of these capacity indicators are well correlated with electricity, fossil fuel energy (gas cum diesel) and total energy consumption, but GFA is still the best correlated variable, which is manifested by higher R^2s (Table 1.5).

Table 1.5 R^2s of linear models correlating energy use with primary factors (Priyadarsini *et al*., 2009)

Capacity indicator\Energy	Electricity	Fossil fuel	Total
GFA	0.86	0.73	0.90
No. of guest rooms	0.72	0.53	0.72
No. of room-nights per year	0.71	0.48	0.70
No. of workers on main shift	0.81	0.70	0.85

In order to identify the secondary drivers, which result in the variations of energy use intensity (EUI) across the hotels, Pearson correlations of EUI with a total of

21 potential secondary drivers were calculated, as shown in Table 1.6. Some of these potential drivers are data collected directly from the hotels such as standard guest room area, building age, while others are derived variables like percentage of retail area in GFA. The highest figures are seen in STAR3 (dummy variable, differentiating three-star from four- and five-star hotels), WKDENS (worker density which is the number of workers on main shift per 1000 m2 of GFA), RETROFIT (number of years after the last major retrofit) and WORKER (number of workers on the main shift), all significant at the 0.01 level; three correlations, FLOOR (number of floors), SDRMAREA (area of standard guest room) and AUDIT (dummy variable, energy audit performed during the last 5 years), are significant at the 0.05 level, while the others are insignificant. The correlation coefficients show that three of them are most highly correlated with hotel building EUI: worker density (number of workers on main shift per 1000 m2 of GFA), years after the last major energy retrofit, and star rating (differentiating three-star hotels with four- and five-star ones). The relationship of hotel star rating and EUI has been discussed before, the other two factors are detailed as follows.

Table 1.6 Pearson correlations between EUI and secondary energy drivers (Priyadarsini *et al*., 2009)

Variable name	Description	Pearson correlation
GFA	Gross floor area	0.165
FLOOR	Number of floors	0.437*
ROOM	Number of guest rooms	0.298
GFARM	Gross floor area per guest room	- 0.003
SDRMAREA	Area of a standard guest room	0.430*
AGE	Building age	- 0.205
RETROFIT	Number of years after the last major retrofit	0.529**
WORKER	Number of workers on the main shift	0.473**
OCPRATE	Yearly occupancy rate	0.254
PTDINING	Percent of GFA for dining facilities	0.017
PTCONVEN	Percent of GFA for convention centers and offices	- 0.004

Table 1.6 Pearson correlations between EUI and secondary energy drivers (Priyadarsini *et al*., 2009) (Cont')

Variable name	Description	Pearson correlation
PTRETAIL	Percent of GFA for retail shops	- 0.268
BOILER	Diesel boiler used	0.217
DISCOOL	District cooling system used	0.217
BMS	Building management system used	0.309
WKDENS	Worker density	0.669**
AUDIT	Energy audit performed in the last 5 years	0.367*
LAUNDRY	Presence of laundry facilities	0.366
STAR5	Five-star hotel	0.354
STAR4	Four-star hotel	0.166
STAR3	Three-star hotel	- 0.673**

Note : * Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Xuchao *et al*. (2010) studied the correlations between the monthly electricity consumption and factors of 29 Singapore hotels and found that worker density and the 3-star hotel were affecting the hotel monthly electricity consumption. The value of R^2 = 0.73.

Shiming and Burnett (2002) studied the correlations between the monthly electricity consumption and the factors of 16 Hong Kong hotels, and found that outdoor air temperature and the number of guests were affecting the hotel monthly electricity consumption. The value of R^2 = 0.93.

Bohdanowicz and Martinac (2007) studied the correlations between energy use and the factors of the 73 Hilton and 111 Scandic hotels in Europe. The total energy consumption of hotels correlates significantly with floor area. The value of R^2 > 0.7 obtained for the correlation between energy use and the floor area is in good agreement with findings from other studies. The energy consumption of Scandic hotels depends to a large extent on the number of guest-nights sold. The value of R^2 > 0.67. Food covers were found to be an important factor influencing energy consumption at Hilton and

Scandic hotels. As expected, the coefficients of correlation were higher in the case of energy use, R^2 = 0.66. For Scandic hotels the coefficient of correlation was 0.51 for energy consumption. Eventually, Table 1.8 showed the predictive energy models of total annual energy consumption.

Treerattanapan (2011) collected energy consumption data from a hotel (30 air-conditioned rooms and 38 electric fan rooms) in Trang Province, Thailand from 2008 to the middle year of 2011 and found that both monthly electricity and LPG consumption correlated with the number of occupied rooms using simple regression model in order to forecast their future requirement (Table 1.8).

Kammerud *et al*. (2012) studied the electricity consumption of the hotel in 1993, located in downtown San Francisco, is a 1.5 million ft^2 facility that opened in 1989. The hotel is oriented towards convention business, with 1,500 guest rooms and about 80,000 ft2 of meeting space. The hotel has a 5-story low-rise section and a tower rising to 40 floors. In this study it examines electricity use by the hotel and found that daily total electricity energy use appears to be most heavily influenced by occupancy. However, no strong causal relationships have been observed to specific functions parameters that are available (e.g., meals served or number of guests) (Table 1.8).

Among the models developed previously, a few deserve special the attention, due to the relatively large samples used. The hotel energy use correlated with number of hotel rooms, the presence of revenue-generating food and beverage and/or banquet facilities (0 is no, 1 is yes), and total heating or cooling degree days. The coefficients vary depending on the type of hotel as presented in Table 1.7. The model developed within the framework of the US EPA Energy Star rating has the following form (US EPA, 2001; Matson and Piette, 2005), as shown in Table 1.8.

Table 1.7 Coefficients developed for different types of hotels (Matson and Piette, 2005)

Type of hotel	C_0	C_1	C_2	C_3	R^2
Upper upscale	11.87840	0.942549	0.633806	-	0.842
Upscale	8.034322	1.217668	0.156245	0.307686	0.869
Midscale w F&B	8.598854	1.024112	-	0.357193	0.689
Midscale ww F&B	9.497230	1.121501	-	0.155450	0.601
Economy	7.728508	0.933250	0.466603	0.448884	0.879

A similar approach was used in the APEC study (1999) where the final regression model proposed for representing EUI in hotels is shown in Table 1.8.

The predictive model and the R^2 of linear models correlating energy use with affecting factors is shown in Table 1.8.

Table 1.8 The predictive model and the R^2

References	Countries	Data for the year	Energy use	The predictive model	R^2
Xuchao *et al*. (2010)	Singapore	1993	kWh/ m^2	predictedE = 309.77+ 23.28 (worker density) -135.66 (3-star hotel)	0.73
Shiming and Burnett (2002)	Hong Kong	1995	kWh	predictedE = 258728.7 + 17884.5 (outdoor air temperature) + 6.8 (guest)	0.93
Bohdanowicz and Martinac (2007)	Europe	2004	MkWh	predictedE^a = 0.227 (floor area) + 0.003 (guest-nights sold) + 0.003 (food covers sold) + 0.006 (laundry) + 1142.24	0.751
				predictedE^b = 0.177 (floor area) + 244.6 (health club) + 0.003 (guest-nights sold) + 0.009 (food covers sold) – 66.86	0.751
Treerattanapan (2011)	Trang Province, Thailand	2008 to half-year of 2011	kWh	predictedE^c = 20.63 (fan rooms) +14.50 (air-condition rooms) +203.49	0.756
Kammerud *et al*. (2012)	San Francisco, US	1993	MWh	E^d = 5.5 +18.0(peak demand)	0.96
US EPA (2001) and Matson and Piette (2005)	-	-	kBTU/ year	ln(predictedE^f) = C_0 + C_1(ln(rooms)) + C_2(food facilities) + C_3(In(DD))	0.601-0.879
APEC (1999)	-	-	-	Log(predictedE^f) = 7.37 – 0.385(log(Floor Area All located Per Lodging Room)) + 0.824(Electricity Demand Metering) + 0.329(log(Worker Density))	0.38

Note:

E is the monthly total electricity consumption

E^a is the total annual energy consumption of 73 Hilton hotels

E^b is the total annual energy consumption of 111 Scandic hotels

E^c is the monthly total energy consumption

E^d is electric energy (daily total load)

E^f is energy use

Worker density is worker density defined as number of workers on main shift per1000 m^2 of GFA

3-star hotel is a dummy variable, which is 1 if the hotel is a 3-star development and 0 if it is a higher class hotel (4-or 5-star)

Outdoor air temperature is the monthly mean outdoor air temperature (C^0)

Guest is the monthly total number of guest

Floor area is the total hotel floor area (m^2)

Guest-nights sold is the number of guest-nights sold

Food covers sold is the number of food covers sold

Laundry is amount of laundry washed on-site (kg)

Health club is a dummy variable, variable assuming the value of 1 for hotels with an on-site health club and 0 for those without

Fan rooms is the number of electric fan rooms

Air-condition rooms is the number of air-condition rooms

Peak demand is daily peak loads (W)

Rooms is number of hotel rooms

Food facilities is presence of revenue-generating food and beverage and/or banquet facility (0 is no, 1 is yes),

DD is total heating or cooling degree days (base 18^{o}C)

Floor area all located per Lodging Room is a derived variable indicating hotel standard and occupancy levels

Electricity demand metering is variable not causing any change in EUI but strongly correlated to other building characteristics, i.e. size

Worker density is likely to be an indicator of OR and level of services provided to the guests

1.2.4 Energy use, EUI and electricity consumption by hotels

Table 1.9 shows the total energy use, the EUI, electricity consumption and the percentage of electricity consumption from the sample hotels. The EUI units were in energy use per visitor-night or guest-night, in energy use per m^2 and in energy use per guestroom. The EUI ranked from 202.78 to 693.61 kWh/m^2/yr, 143.93 to 29,459.17 kWh/room and 8.76 to 122.22 kWh/visitor-night or kWh/guest-night. Electricity consumption intensity (ECI) ranked from 137.65 to 226.75.0 kWh/m^2/yr, 86.38 to 28,000.1 kWh/room and 4.49 to 89.5 kWh/visitor-night or kWh/guest-night. The percentage of electricity consumption from the sample hotels ranked from 48.27 to 91%.

Table 1.9 Total energy use, EUI, electricity consumption and the percentage of electricity consumption from the sample hotels

References	Countries	Data for the year	Number of sampled hotel	Total energy use	EUI	Electricity consumption	The percentage of electricity consumption
Priyadarsini *et al.* (2009)	Singapore	1993	29	427 kWh/m^2/yr	427 kWh/m^2/yr	-	91[a] 77[b]
Shiming and Burnett (2002)	Hong Kong	1995	5-star (9)	566.39 kWh/m^2/yr (2,039 MJ/m^2/yr)	566.39 kWh/m^2/yr (2,039 MJ/m^2/yr)	266.75 kWh/m^2/yr	73
			4-star (4)	596.67 kWh/m^2/yr (2,148 MJ/m^2/yr)	596.67 kWh/m^2/yr (2,148 MJ/m^2/yr)		
			3-star (3)	506.39 kWh/m^2/yr (1,823 MJ/m^2/yr)	506.39 kWh/m^2/yr (1,823 MJ/m^2/yr)		
Becken (2005)	Fiji	March 2004	Resort hotel (15)	1,856,666.67 kWh (6,684,000 MJ)	122.22 kWh/visitor-night (443 MJ/visitor-night)	-	-
			Motel/ Hotel (4)	219,444.44 kWh (790,000 MJ)	9.44 kWh/visitor-night (34 MJ/visitor-night)	-	-
			Budget accommodation (3)	143,055.56 kWh (515,000 MJ)	16.94 kWh/visitor-night (61 MJ/visitor-night)	-	-
Mohee and Bhurtun (2012)	Mauritius	2001-2002	1	105,000 kWh (378,000 MJ)	504.81 kWh/room (1,817.31 MJ/room)	297.84 kWh/room (1,072.21 MJ/room)	59
			1	155,277.78 kWh (559,000 MJ)	1,085.86 kWh/room (3,909.09 MJ/room)	846.97 kWh/room (3,049.09 MJ/room)	78
			1	27,777.78 kWh (100,000 MJ)	143.93 kWh/room (518.13 MJ/room)	86.38 kWh/room (310.98 MJ/room)	60
Bohdanowicz and Martinac (2007)	Europe	2004	Hilton (73)	364.3 kWh/m^2/yr	364.3 kWh/m^2/yr	179.59 kWh/m^2/yr 28,000.1 kWh/room/yr 89.5 kWh/guest-night	49.3
			Scandic (111)	285.0 kWh/m^2/yr	285.0 kWh/m^2/yr	137.65 kWh/m^2/yr 14,000.2 kWh/room/yr 47.8 kWh/guest-night	48.3
Xydis *et al.* (2009)	Greece	2002	1	514,602.78 kWh (1,852,570 MJ)	4,678.21 kWh/room (16,841.54 MJ/room)	3,196.99 kWh/room (11,509.18 MJ/room)	68.33

Table 1.9 Total energy use, EUI, electricity consumption and the percentage of electricity consumption from the sample hotels (Cont')

References	Countries	Data for the year	Number of sampled hotel	Total energy use	EUI	Electricity consumption	The percentage of electricity consumption
Becken *et al.* (2006)	New Zealand	2002	1	1,441,182 kWh	800.66 kWh/room/month	695,732 kWh	48.27
Becken (2000)	New Zealand	2000	15	1,430,277.78 kWh (5,149,000 MJ)	202.78 kWh/m^2/yr (730 MJ/m^2/yr) 50.33 kWh/guest-night (183 MJ/guest-night)	1,050,000 kWh (3,780,000 MJ)	73.41
Bloy *et al*. (1999)	US	-	158	347.33 kWh/m^2 (1,250 MJ/m^2)	347.33 kWh/m^2 (1,250 MJ/m^2)	-	-
	Hong Kong	-	-	297.22 kWh/m^2 (1,070 MJ/m^2)	297.22 kWh/m^2 (1,070 MJ/m^2)	-	-
	Singapore	-	-	388.89 kWh/m^2 (1,400 MJ/m^2)	388.89 kWh/m^2 (1,400 MJ/m^2)	-	-
	Chinese Taipei	-	-	347.33 kWh/m^2 (1,250 MJ/m^2)	347.33 kWh/m^2 (1,250 MJ/m^2)	-	-
Alamoudi (2009)	Saudi Arabia	2000-2008	5-Star (25)	-	-	77-98 kWh/guest-room/day	89
			4-Star (23)	-	-	44-77 kWh/guest-room/day	75
			3-Star (17)	-	-	30-40 kWh/guest-room/day	76
Alamoudi (2009)	Saudi Arabia	2000-2008	2-Star (15)	-	-	15-27 kWh/guest-room/day	66
Warnken and Bradley (2002)	Australia	1995-2000	Hotels (11)	53.11 kWh/guest-night (191.19 MJ/guest-night)	53.11 kWh/guest-night (191.19 MJ/guest-night)	44.16 kWh/guest-night	83.15
			Eco-resorts (5)	45.71 kWh/guest-night (164.56 MJ/guest-night)	45.71 kWh/guest-night (164.56 MJ/guest-night)	29.93 kWh/guest-night	65.48
			Caravan parks (6)	8.76 kWh/guest-night (31.54 MJ/guest-night)	8.76 kWh/guest-night (31.54 MJ/guest-night)	4.49 kWh/guest-night	51.26

Table 1.9 Total energy use, EUI, electricity consumption and the percentage of electricity consumption from the sample hotels (Cont')

References	Countries	Data for the year	Number of sampled hotel	Total energy use	EUI	Electricity consumption	The percentage of electricity consumption
Commonwealth of Australia (2002)	Australia	2000	Accommodation hotel (10)	221.11 kWh/m^2 (796 MJ/m^2)	221.11 kWh/m^2 (796 MJ/m^2)	-	-
			Business hotel (28)	349.72 kWh/m^2 (1,259 MJ/m^2)	349.72 kWh/m^2 (1,259 MJ/m^2)	-	-
			Casio hotel (2)	492.22 kWh/m^2 (1,772 MJ/m^2)	492.22 kWh/m^2 (1,772 MJ/m^2)	-	-
			General hotel (1)	404.44 kWh/m^2 (1,456 MJ/m^2)	404.44 kWh/m^2 (1,456 MJ/m^2)	-	-
			Resort hotel (10)	693.61 kWh/m^2 (2,497 MJ/m^2)	693.61 kWh/m^2 (2,497 MJ/m^2)	-	-
			All hotel (51)	364.72 kWh/m2 (1,313 MJ/m2) or 29,459.17 kWh/room (106,053 MJ/room) or 116.94kWh/Occ room (421 MJ/Occ room)	364.72 kWh/m2 (1,313 MJ/m2) or 29,459.17 kWh/room (106,053 MJ/room) or 116.94 kWh/Occ room (421 MJ/Occ room)	218.83 kWh/m2 (787.8 MJ/m2)	66
Adelphi consult (2009)	Thailand	-	125	-	-	343.33 kWh/month/room	-
Treerattanapan (2011)	Thailand	2008 to half-year of 2011	1	4.22 kWh/month/m^2 (15.19 MJ/month/m^2) 22.69 kWh//daily occupied room (81.69 MJ/month/daily occupied room)	4.22 kWh/month/m^2 (15.19 MJ/month/m^2) 22.69 kWh//daily occupied room (81.69 MJ/month/daily occupied room)	6,243.89-9,99233 kWh/month (22,478.00-35,972.4 MJ/month)	81
The DEDE, Thailand (2008)	Thailand	-	1-100 rooms	12.5 kWh/month/m^2 (45.0 MJ/month/m^2) 62.92 MJ/month/daily occupied room (226.5 MJ/month/daily occupied room)	12.5 kWh/month/m^2 (45.0 MJ/month/m^2) 62.92 MJ/month/daily occupied room (226.5 MJ/month/daily occupied room)	-	-

Table 1.9 Total energy use, EUI, electricity consumption and the percentage of electricity consumption from the sample hotels (Cont')

References	Countries	Data for the year	Number of sampled hotel	Total energy use	EUI	Electricity consumption	The percentage of electricity consumption
The DEDE, Thailand (2008)	Thailand	-	101-200 rooms	19.28 kWh/month/m^2 (69.4 MJ/month/m^2) 70.17 MJ/month/daily occupied room (252.6 MJ/month/daily occupied room)	19.28 kWh/month/m^2 (69.4 MJ/month/m^2) 70.17 MJ/month/daily occupied room (252.6 MJ/month/daily occupied room)	-	-
			201-300 rooms	24.69 kWh/month/m^2 (88.9 MJ/month/m^2) 79.14 MJ/month/daily occupied room (284.9 MJ/month/daily occupied room)	24.69 kWh/month/m^2 (88.9 MJ/month/m^2) 79.14 MJ/month/daily occupied room (284.9 MJ/month/daily occupied room)	-	-
			301-600 rooms	25.11 kWh/month/m^2 (90.4 MJ/month/m^2) 98.17 MJ/month/daily occupied room (356.1 MJ/month/daily occupied room)	25.11 kWh/month/m^2 (90.4 MJ/month/m^2) 98.17 MJ/month/daily occupied room (356.1 MJ/month/daily occupied room)	-	-
			>600 rooms	33.58 kWh/month/m^2 (120.9 MJ/month/m^2) 121.14 MJ/month/daily occupied room (436.1 MJ/month/daily occupied room)	33.58 kWh/month/m^2 (120.9 MJ/month/m^2) 121.14 MJ/month/daily occupied room (436.1 MJ/month/daily occupied room)	-	-

Note: - is not available

a is Singapore's hotel that electricity (91%) and gas (9%) were consumed.

b is Singapore's hotel that electricity (77%), gas (8%) and diesel (15%) were consumed.

1.2.5 GHG emissions of hotels

The GHG Protocol Corporate Standard (Scope 1 and 2) and the IPCC Guidelines were used for the calculation of GHG emissions by hotel energy use (Table 1.10). Table 1.11 showed total GHG emissions, the CO_2 emissions indicators (CEI) and the percentage of GHG emission from electricity consumption by the sample hotels. Total GHG emissions from energy use ranked from 20,916.67 to 1,109,400 $kgCO_2$/month. The CEI units were in CO_2 per visitor-night, in CO_2 per m^2 and in CO_2 per guestroom. The CEI ranked from 4.83 to 109.42 $kgCO_2/m^2$/month and 265 to 638 $kgCO_2$/guest room/month. The percentage of GHG emission from electricity consumption ranked from 79.14 to 93.64%.

Table 1.10 Calculation of GHG emission from hotel energy use

References	Countries	Data for the year	Calculation of GHG emission
Xuchao *et al*. (2010)	Singapore	1993	The GHG Protocol Corporate Standard, scope 1 and 2
Warnken and Bradley (2002)	Australia	2002	IPCC Guideline
Huang *et al.* (2010)	Taiwan	-	The GHG Protocol Corporate Standard, scope 1 and 2
Adelphi consult (2009)	Thailand	-	2006 IPCC Guideline

Note: - is not available

Adelphi Consult (2009) reported CO_2 emissions by the tourism industry in the Koh Chang clustered area, Thailand. It was found on that an average tourist in the Koh Chang clustered area is emitting 19.74 kg CO_2eq per day. This is more than the average per capita GHG emission for Thailand (12 kg CO_2eq per day) (Henzler *et al*., 2010) (Fig. 1.1) and the GHG emission level per person in the case hotel in Taiwan, 5.18 kg CO_2eq per day (Huang *et al*., 2010), which is lower than an average tourist on the popular European island of Majorca, Spain, emits (27 kg CO_2eq per day) (WWF, 2002 and Sisman, 2007) (Fig. 1.1) and the average per capita GHG emissions for Taiwan (31.95 kg CO_2eq per day) (Huang *et al*., 2010).

Table 1.11 Total GHG emissions, the CEI and the percentage of GHG emissions from electricity consumption by the sample hotels

References	**Countries**	**Data for the year**	**Number of sampled hotels**	**Total GHG emissions**	**The CEI**	**The percentage of GHG emissions from electricity consumption**
Xuchao *et al*. (2010)	Singapore	1993	29	579,706.52 $kgCO_2$/ month	18.48 $kgCO_2/m^2$/ month	93.64 (17.30 $kgCO_2/m^{2/}$ month)
Becken (2005)	Fiji	March 2004	Resort hotel (15)	391 $tonnesCO_2$	27$kgCO_2$/ visitor-night	-
			Motel/ Hotel (4)	40 $tonnesCO_2$	2$kgCO_2$/ visitor-night	-
			Budget accommodation (3)	22 $tonnesCO_2$	4$kgCO_2$/ visitor-night	-
Becken *et al*. (2006)	New Zealand	2002	1	20,916.67 $kgCO_2$/ month (251 $tonnesCO_2$)	139.44 $kgCO_2$/ room	-

Table 1.11 Total GHG emissions, the CEI and the percentage of GHG emissions from electricity consumption by the sample hotels (Cont')

References	Countries	Data for the year	Number of sampled hotels	Total GHG emissions	The CEI	The percentage of GHG emissions from electricity consumption
Huang *et al.* (2010)	Taiwan	-	1	23,628.33 $kgCO_2$/ month (283.54 $tonnesCO_2$/ yr)	4.83 $kgCO_2$ $/m^2$/month (57.95 kg CO_2/m^2/ yr)	79.14 (224.41 tonnes CO_2/yr)
Commonwealth of Australia (2002)	Australia	2000	51	-	109.42 $kgCO_2$ $/m^2$/month	91
Adelphi consult (2009)	the Koh Chang clustered area, Thailand	-	125	1,109,400 $kgCO_2$/ month (1,109.4 $tonnesCO_2$/ month)	638 $kgCO_2$/ month/ room	(193 $kgCO_2$/month/ room)
Adelphi consult (2009)	Phangnga Province, Thailand	-	4	-	-	(335 $kgCO_2$/month/ room)

Note: - is not available

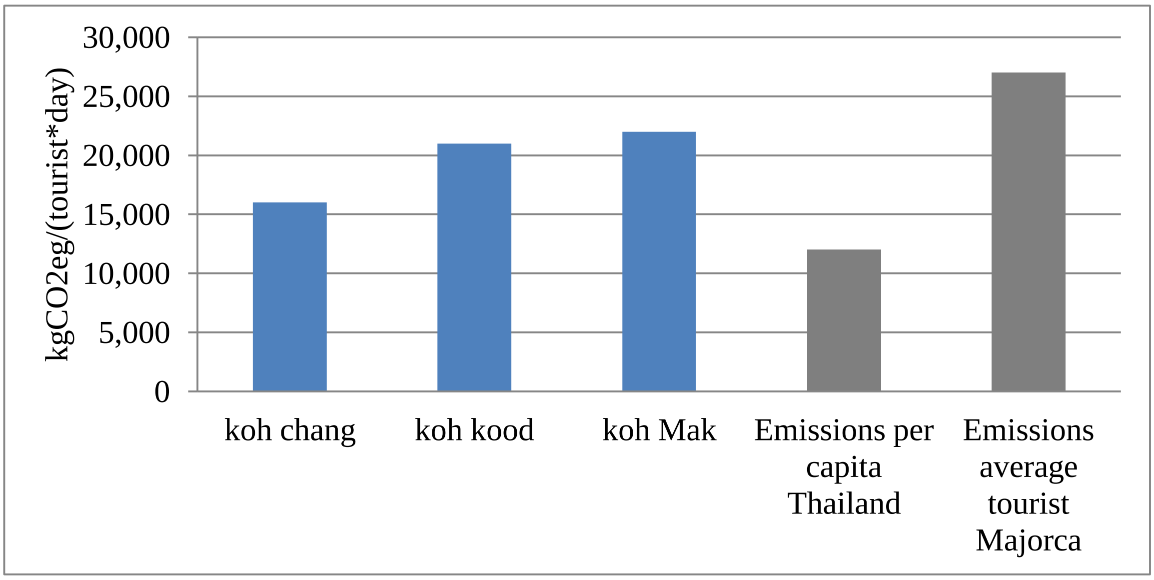

Figure 1.1 The average tourist emissions in the Koh Chang clustered area (Henzler *et al*., 2010)

1.2.6 Mitigation for GHG emission from energy use of hotels

1) Case study of 18 hotels of the Hotel Energy Solution (HES) project

Hotel Energy Solutions (2011b) reported examples of best practices in the hotel sector regarding the integration of energy efficient (EE) solutions. It has been produced within the framework of the Hotel Energy Solution (HES) project. Eighteen examples of small-to-medium size hotels which located in Italy, Portugal, Bulgaria and Switzerland. Examples of description of energy conservation measures in place showed in Table 1.12 to 1.17, make a first assessment, involve hotel staffs, involve hotel guests, protect the building from the extreme temperature, improve equipment efficiency and integration of renewable energies.

2) Case study of Hotel Caravane Serail, Southern Tunisia

Hotel Caravane Serail is a 50-employee, 399-bed hotel located in Nefta, Southern Tunisia, at the gateway to the Sahara Desert. Approximately 300,000 guests per year stay at the hotel, 95% of whom comes from outside Tunisia. Electric consumption reduction of Hotel Caravane Serail has been done by developing a preventive maintenance program, turning equipment off when it is not in use and using energy saving equipment. (Regional Activity Center for Cleaner Production: CP/RAC, 2012) (Table 1.12 and 1.16).

3) Walker (2009) suggested that reducing energy needs to be accomplished by installing motion sensors in public areas and occupancy sensors in guestrooms, installing energy-efficient lighting, dimmers, to reduce energy consumption, installing LEDs (light emitting diodes) exit signs, installing Energy Star appliances, increasing building insulation, using natural day lighting whenever possible and tightening the property shell, with added or better insulation, eliminating leaks, and replacing windows (Tables 1.14 to 1.16).

4) Case study of 125 hotels of the Koh Chang clustered area, Thailand

Henzler *et al*. (2010) suggested that the different mitigation measures have different impacts on emissions. The largest reduction potential lies within the electricity use of hotels and restaurants, which is responsible for about 54 % of the total emissions. With acceptable effort 20 to 40 % of these could be avoided within a foreseeable period if energy saving aspects is included in the planning and purchasing process as well as operations. Different instruments could be used to support the mitigation process such as policies (e.g. building code), market-based instruments (e.g. fuel or emission tax), subsidies or grants (e.g. for use of renewable energies or improvement of building envelope), campaigns (e.g. information about influence of behavior on energy efficiency) and certification and labeling of minimum standards (e.g. as part of a sustainable tourism standard). The mitigation of energy reduction, protect the building from the extreme temperature and improve equipment efficiency, were shown in Table 1.15 and 1.16.

5) Case study of 610 hotels from Sweden and Poland

Hotel Energy Solutions (2011a) reported that most of the data was available from surveys carried out by Bohdanowicz (2006) in hotels in Sweden and Poland, in chain and affiliated hotels (average size: 133 rooms), and in independent hotels (average size: 57 rooms). Reported in two separate papers, the total number of hotels sampled in these surveys was 610. The data for Sweden and Poland (Fig. 1.2 and Tables 1.14 and 1.16) showed that the energy conservation and efficiency measures comprise energy efficient lighting (just over 70 percent of hotels), energy efficient equipment (between 40 - 60 percent of hotels), and providing leaflets to encourage guests to save energy (between 20 - 40 percent of hotels).

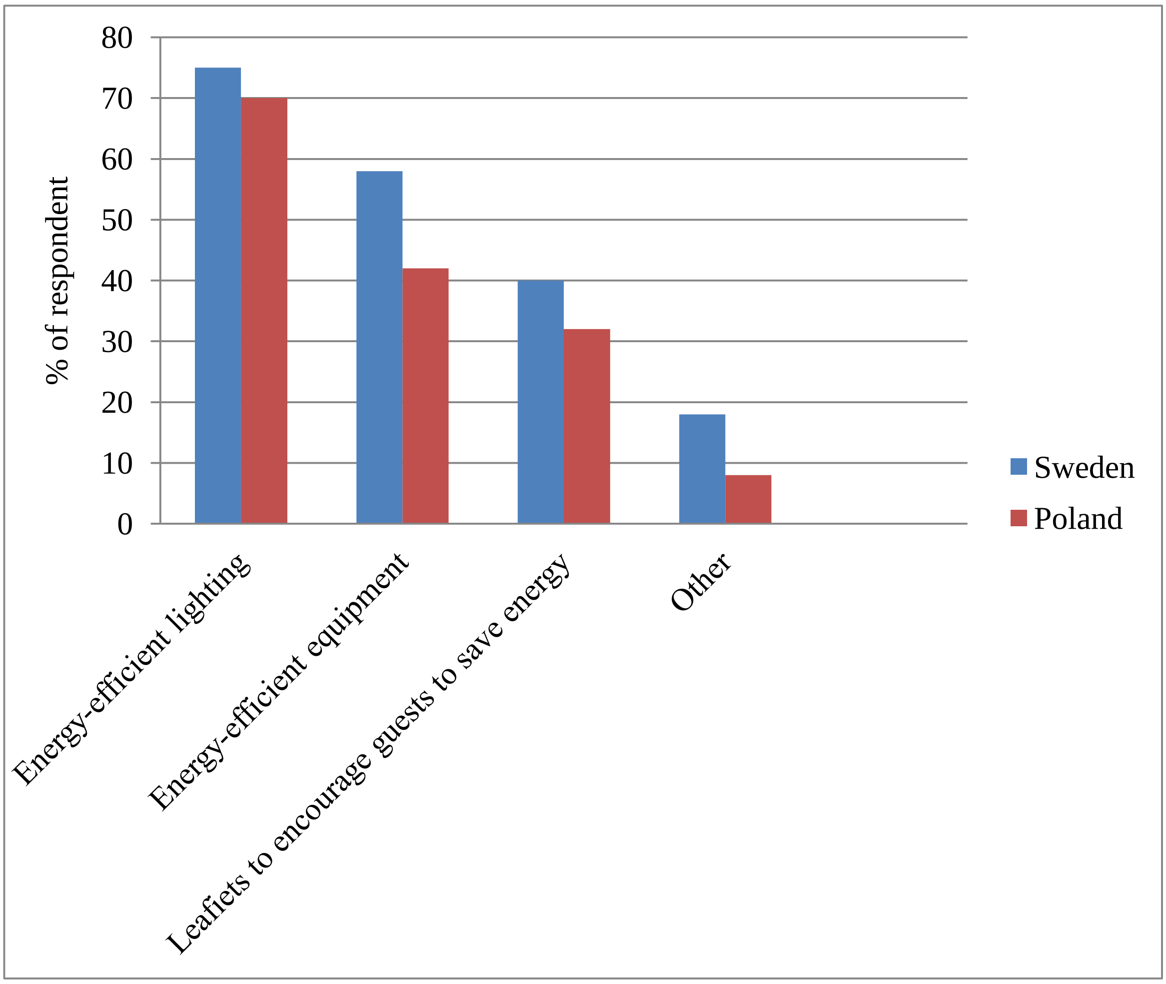

Figure 1.2 Energy consumption and efficiency measures undertaken by hotels

(Hotel Energy Solutions, 2011a)

6) The examples of mitigation for energy use reduction in buildings of IPCC

IPCC (2007) pointed that the two main reduction options for electricity use are: (1) electricity savings in the industry and buildings sector, and (2) substitution in the power sector tending towards low carbon electricity technologies. The examples of mitigation for energy use reduction in buildings a shown in Tables 1.15 to 1.17.

7) Case study of 158 hotels in Greece

Hotel Energy Solutions (2011a) reported a study of 158 hotels in Greece (140 hotels in Athens, and 18 hotels in other parts of Greece) by Santamouris *et al.* (1996). The main areas where energy efficiency savings can be made, are shown in Tables 1.15 and 1.16.

8) Case study in a hotel from Hong Kong

Shiming and Burnett (2002) suggested that energy management programs based on the experiences in implementing energy management in a number of hotels in Hong Kong. The key elements of a successful energy management program are listed as follows in Tables 1.12, 1.13 and 1.16.

9) Case study in a hotel of Trang Province, Thailand

Treerattanapan (2011) analyzed the energy consumption in lighting and air-conditioning systems in a hotel in Trang Province, Thailand, with 30 air-conditioned rooms and 38 electric fan rooms, and proposed the energy management guide in a small-scale hotel as shown in Tables 1.12 and 1.16.

10) Case study in hotels from Japan

The Energy Conservation Center (2009) presented the operating procedures for Energy-Conservation Projects in the Japanned hotel business in March 2008. The mitigations are shown in Tables 1.12 to 1.17.

11) Case study of a hotel from New Zealand

Becken *et al.* (2006) studied a 150-room hotel in a major tourist resort town with its major business operations covering accommodation, food and beverage. The hotel encourages to adopt an environmental charter, and promotes energy, waste and water management. The hotel has already reduced energy use from lighting; but a more stringent review of the lighting facilities could reveal additional options to switch to energy efficient light bulbs, further reducing energy costs. Currently all ceiling lights are switched off when the room key is retrieved. This could be extended to include all desk and night cabined lights as well. Extending the use of energy-efficient light bulbs into the guest rooms provides another option for reducing electricity consumption. An overview of mitigation options identified that could help reduce energy efficiency is provided in Tables 1.13, 1.16 and 1.17.

12) Case study of 3 hotels from Hong Kong

Three case studies in Hong Kong were carried out to identify the green measures undertaken in ISO 14001-certified hotels. A total of 113 measures were identified, nearly half of which concern energy conservation. The results of multiple regression showed that R^2 for different utilities varied. The explanatory power of equation was strong for electricity consumption, moderate for fuel gas consumption, and weak for both gas and water consumption (Chan, 2009). Core electricity reduction practices were adopted by these three studied hotels. Contrary to many claims that environmental works entailed high investment, only four measures were identified as higher capital investment (Tables 1.15 and 1.16).

Table 1.12 Make a first assessment

References	Mitigation
Hotel Energy Solutions (2011b)	- Energy consumption monitoring - Carbon assessment
CP/RAC (2012)	- Developing a preventive maintenance program
Shiming and Burnett (2002)	- Carrying out energy audits on a regular basis, preferably once every year, and installing or adding suitable electricity and gas sub-meters for monitoring energy use in various electricity end-uses and in kitchens, thus facilitating the breakdown of the total energy use to identify major energy users - Making a clearly defined energy use policy and an action plan
The Energy Conservation Center (2009)	- Establishment of energy management organization, and employee education - Energy conservation targets, and investment budget setting - Grasp status of implementation of energy conservation - Measurements and recording of monthly usage (electricity, gas, oil, and water) - Preparation of statistics, including graphs showing differences from the previous months of the year - Grasp of energy intensity (MJ/m^2/year) - Establishment of management standards

Table 1.13 Involving hotel staff

References	Mitigation
Hotel Energy Solutions (2011b)	- Staff information and involvement - Rational heating policy - Equipment maintenance - Staff training and Regular servicing - Maintenance of equipment - Customer feedback
Santamouris *et al.* (1996)	- Provide information and warning labels for staff
Shiming and Burnett (2002)	- Educating and training engineering staff - Establishing a well-defined operation and maintenance program for engineering staff
Becken *et al.* (2006)	- Staff training

Table 1.14 Involving hotel guests

References	Mitigation
Hotel Energy Solutions (2011b)	-Information to guests
Walker (2009)	- Installing Energy Star appliances
Bohdanowicz (2006)	- Providing leaflets to encourage guests to save energy
Santamouris *et al.* (1996)	- Provide information and warning labels for guests

Table 1.15 Protecting the building from extreme temperature

References	Mitigation	Economic savings	Potential
Hotel Energy Solutions (2011b)	- Window insulation - Building materials - Envelope insulation - Bio-climatic principles - Fresh ventilated air - Building insulation - Prevention of air infiltration at doors and windows - Building waterproofing - Automatic control of heating/cooling - Ventilation control	-	-
Henzler *et al.* (2010)	[a] - Upgrade building envelope (e.g. double glazing, insulation of walls and roof, shading of roof and windows)	-	-30 %
Walker (2009)	- Tightening the property shell, with added or better insulation, eliminating leaks, replacing windows - Increasing building insulation	-	-

Table 1.15 Protecting the building from extreme temperature (Cont')

References	**Mitigation**	**Economic savings**	**Potential**
IPCC (2007)	[a]- Integrated design of commercial buildings including technologies, such as intelligent meters that provide feedback and control - Improved insulation	-	-
Santamouris *et al.* (1996)	- Reduce the overall heat transfer coefficient, by insulating to the level set in the building code - Replace window frames that form a thermal bridge, and/or install double glazed windows - Energy conservation from cooling - Reduce external loads from incident solar radiation by providing proper shading of the building - Reduce internal loads by using of high efficiency lighting systems	-	-
The Energy Conservation Center (2009)	- Blocking of solar radiation on the windows (e.g. shading curtains and light-shielding films) - Blocking of solar radiation on the roof (heat reflection coating)	-	-
Chan (2009)	- Solar control window film	-	-

Note: - is not available

a is mitigation before 2030

Table 1.16 Improve equipment efficiency

References	Mitigation	Economic savings	Potential
Hotel Energy Solutions (2011b)	- Efficient lighting - Lighting control - Automatic control of electricity in guest rooms - Regulation of space heating - Efficient boiler - Individual thermostatic controls in guest rooms - Efficient heating equipment - Water heater insulation - Hot water pipe insulation	-	-
CP/RAC (2012)	- Turn equipment off when not in use - Using energy saving equipment	1.828 C/year	
Henzler *et al*. (2010)	[a] - Limiting room temperature [a] - Use latest technology (refrigerator, AC, Light bulbs)	-	-5%
Walker (2009)	- Installing motion sensors in public areas and occupancy sensors in guestrooms - Installing energy efficient lighting, dimmers - Installing LED (light emitting diode) exit signs - Using natural day lighting whenever possible	-	-

Table 1.16 Improve equipment efficiency (Cont')

References	Mitigation	Economic savings	Potential
IPCC (2007)	- Efficient lighting and day lighting - Improved cook stoves - Alternative refrigeration fluids, recovery and recycling of fluorinated gases - More efficient electrical appliances and heating and cooling devices - Passive and active solar design for heating and cooling	-	-
Bohdanowicz (2006)	- Use energy efficient lighting - Use energy efficient equipment	-	-
Treerattanapan (2011)	- Replacing the magnetic ballasts with electronic ballasts - Using T5 lamps for lighting - Using high efficient-LPG stoves - Re-schedule turning off the computers during unused period	-	-
Shiming and Burnett (2002)	- Adopting technically advanced energy efficient equipment including lights, chillers and energy efficiency motors, etc	-	-

Table 1.16 Improve equipment efficiency (Cont')

References	Mitigation	Economic savings	Potential
Santamouris *et al.* (1996)	- Use of indirect evaporative coolers instead of compression refrigeration systems - Use of alternative cooling technologies, such ground cooling with ground-air heat exchangers - Use night ventilation techniques - Use ceiling fans - Use improved fluorescent lamps - Use super metal halide fluorescent lamps - Use electronic fluorescent ballasts - Use improved luminaries - Install occupancy sensors - Use daylight effectively within the building - Use high-efficiency equipment when replacing old equipment throughout the hotels - Use high efficiency combustion systems obtaining increased efficiency through proper maintenance of the heating system	-	-

Table 1.16 Improve equipment efficiency (Cont')

References	Mitigation	Economic savings	Potential
The Energy Conservation Center (2009)	- Temperature control for chilled water, cooling water, and hot water - Adjustment of the flow rate and pressure of pumps and fans - Steam leakage and insulation management - Management of air ratio and exhaust gas of combustion equipment - Control of steam pressure and blow-down - Cooling water quality control (electrical conductivity) - Control of opening of valves and dampers (e.g. automatic valves) - Proper temperature setting - Turning off air-conditioning for rooms not in use of unoccupied - Adjustment of appropriate outside air intake volume - Review of operating hours - Effective operation of total heat exchanger - Local cooling and local exhaust - Indoor air quality control (e.g. CO_2) - Installation of (manual or automatic) inverter device to ventilation fans - Suspending either of the operation of a 4-pipe air conditioning system, if used - Control of ventilation in car parking space (CO concentration control)	-	-

Table 1.16 Improve equipment efficiency (Cont')

References	Mitigation	Economic savings	Potential
The Energy Conservation Center (2009)	- Optimization of demand - Usage control - Voltage adjustments - Power factor management - Optimum illumination control - Switching off lights when they are not necessary (use of daylight) - Cleaning of lighting fixtures and change to more energy-saving fixtures - Replace incandescent lamps to fluorescent lamps - Adoption of energy-saving FFE (furniture, fixture, and equipment) - Adoption of inverter control - Adoption of human motion sensors to escalator - Maintain the place around the condensing units for air-conditioning and chillers - Utilization of heat from hot spring - Installation of boilers using waste materials as fuel - Use late-night electricity - Co-generation	-	-

Table 1.16 Improve equipment efficiency (Cont')

References	Mitigation	Economic savings	Potential
Becken *et al.* (2006)	- New appliances (When buying new appliances, e.g. kitchen appliances, energy efficiency should be considered) - Increase lighting efficiency - Alternative fuel sources for the boiler (wood, waste or pellet fuel)	-	- - Up to 80% less electricity consumption -
Chan (2009)	- Solar control window film - Sensors of air-conditioning system - Key tag controlled switches - Energy-saving light bulbs	-	-

Note: - is not available
a is mitigation before 2030

Table 1.17 Integration of renewable energies

References	Mitigation
Hotel Energy Solutions (2011b)	- The solar grid-connected PV system - The solar installation and high performance wood burning fireplace insert - Geothermal heat pump
IPCC (2007)	[a]- Solar photovoltaic integrated in buildings - Passive and active solar design for heating and cooling
The Energy Conservation Center (2009)	- Utilization of solar heat - Wind, solar, and small hydro power generation
Becken *et al*. (2006)	- Solar water heating

Note: - is not available

a is mitigation before 203

1.3 Research Objectives and Scope of Study

1.3.1 Research Objectives

The major objectives of this research were:

1) To investigate electricity consumption and calculate GHG emissions related to the electricity consumption of hotels in Thailand,

2) To analyze factors affecting electricity consumption of hotels in Thailand,

3) To propose mitigation options for the reduction of GHG emissions from electricity consumption of hotels in Thailand.

1.3.2 Scope of Study

For this study, the survey strategy was chosen because the objective was to have a comprehensive understanding of the whole population, rather than that of a particular hotel building. The sampled hotels were conducted in 187 hotels recorded in the list of the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand. The hotels consume commercial energy including electricity and steam as from January 1 to December 31 of the past year in total volume of 20 million megajoules or more of electricity energy equivalent. They were believed to have the largest potential in making energy savings.

All data in this study was collected in the year 2011. Based on the literature review, physical characteristics (number of guest rooms, number of floors, GFA, star rating, Green Leaf Certification, locations, regions, hotel types classified by hotel functions and the Thailand Hotel Act B.E 2547) and operational characteristics (number of workers, OR, monthly room-nights and guests) was analyzed by the commercial statistic software SPSS version 16.0. A correlation and linear regression model were used to describe the relationship between the variables and electricity consumption from the sampled hotels. The physical and operational characteristics that affecting electricity use in hotels were identified, and detailed statistical analyses were conducted to understand their influences on hotel electricity consumption.

Hotel electricity consumption was converted to GHG emissions by Tier 1 of the 2006 IPCC Guidelines. Although there were also non-carbon dioxide greenhouse gases, mainly methane (CH_4) and nitrous oxide (NO_2), they were not calculated. In other words, only CO_2 emitted from electricity consumption of hotels was converted to GHG emission. Emission factor from the use of electricity in Thailand of Thailand Greenhouse Gas Management Organization (TGO), 0.5477 (tCO_2/MWh), was used for calculation.

The most significant factors affecting electricity consumption were designed for GHG mitigation. The six mitigation measures for the reduction of GHG emission from electricity consumption of hotels in Thailand were designed such as first assessment, hotel staff management, hotel guest management, heat protection techniques for building, improvement of equipment efficiency and integration of renewable energies

CHAPTER 2
THEORIES

2.1 Energy consumption in hotels

2.1.1 Architecture and energy consuming activities in hotels

Basically speaking, the space of a hotel can be divided into three clearly defined areas according to purpose (European Commission, 1994). These are as follows:

1) The guest room area, containing the bedrooms and toilet/shower or bathrooms. These are individual spaces, often with large glazing areaи, with variable and non- simultaneous utilisation and occupation,

2) The public general service area, including the reception hall, sitting rooms, bars, restaurants, meeting rooms, swimming pools, saunas, etc. These are large spaces with high external thermal exchanges (heat losses, solar gains) and internal loads (due to occupancy, decorative lighting and etc.) with variable variation,

3) The service areas, including the kitchens, offices, store rooms, laundry, staff facilities, machine rooms, and other technical sections. These are rooms and other technical sections. These areas are characterised by conditions which require specific technical treatment (Lighting, ventilation, etc.).

The main energy consuming activities and systems in a hotel are heating, air conditioning and ventilation, lighting, hot water production, electricity (lifts, etc.), cooking and preparing meals (especially warm ones), swimming pools and other energy-consuming activities by guests (Hotel Energy Solutions, 2011a and European Commission, 1994).

2.1.2 Energy sources in hotels

A hotel is a building designed to provide rest and comfort. Energy in different forms are used by many hotel facilities and services to help create an atmosphere of comfort (European Commission, 1994). Globally, the building sector was responsible for more electricity consumption than any other sector, 42%, so to a significant extent, and implicates the electricity sector at large (Baumert *et al*., 2005).

The main energy sources in the 184 hotels in Europe were electricity, LPG, fuel oil, diesel, gas, district heating and district cooling. The Commonwealth of Australia

(2002) stated that electricity was the most common form of energy used by the 50 hotels, 66%. The energy sources in hotels were electricity (66%), nature gas (27%), LPG (6%) and diesel (1%). Alamoudi (2009) studied energy use in 4 Saudi Arabian hotels and found that electricity was the main energy source, 66-89 % of total energy use (Fig. 2.1).

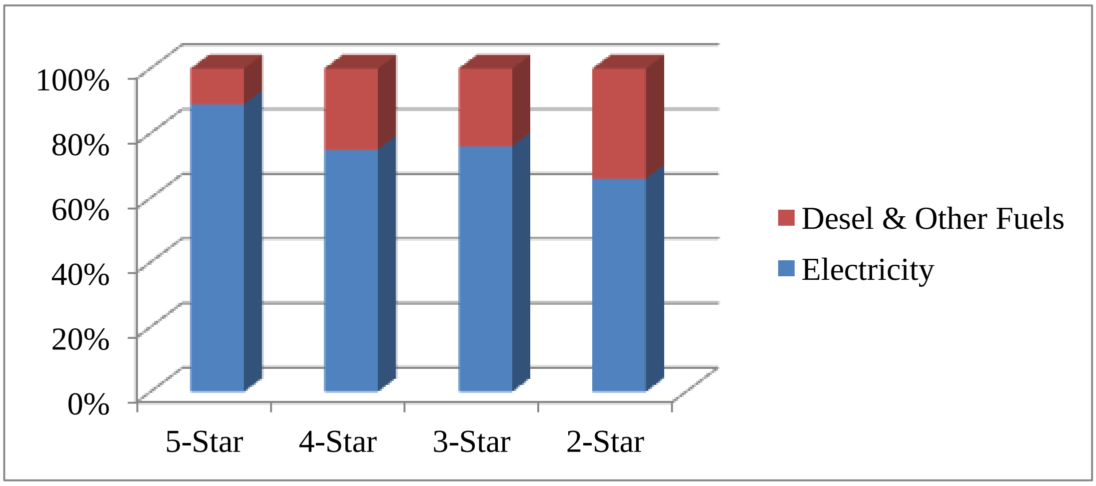

Figure 2.1 Energy use share in the four hotels category in Saudi Arabia (Alamoudi, 2009)

Xuchao *et al.* (2010) statted that electricity is the main energy source, with a proportion of 91% in hotels that only use electricity and gas. For other hotels that also consume diesel for hot water or steam generation, the percentage of electricity drops to 77%.

In Thailand, Adelphi Consulting (2009) reported that electricity consumption from hotels in Koh Chang, Koh Kood and Koh Mak were 440, 270 and 320 kWh/month/room, respectively. The average was 343.33 kWh/month/room. LPG consumption from hotels in Koh Chang, Koh Kood and Koh Mak were 4, 5 and 3 kg/month/room, respectively. The average was 4 kg/month/room. Fuel consumption from hotels in Koh Chang, Koh Kood and Koh Mak were 3, 30 and 4 liter/month/room, respectively. The average was 12.33 liter/month/room.

2.1.3 Energy end-use

The Commonwealth of Australia (2002) showed that the Cairns Hilton provided the best breakdown of energy consumption against end-use categories (Fig. 2.2). The hotel uses LPG for producing steam for the laundry and for heating domestic hot water, and uses electricity for all remaining services. The hotel is located in a hot and humid climate and, as can be expected, uses a large proportion of energy for cooling and dehumidification.

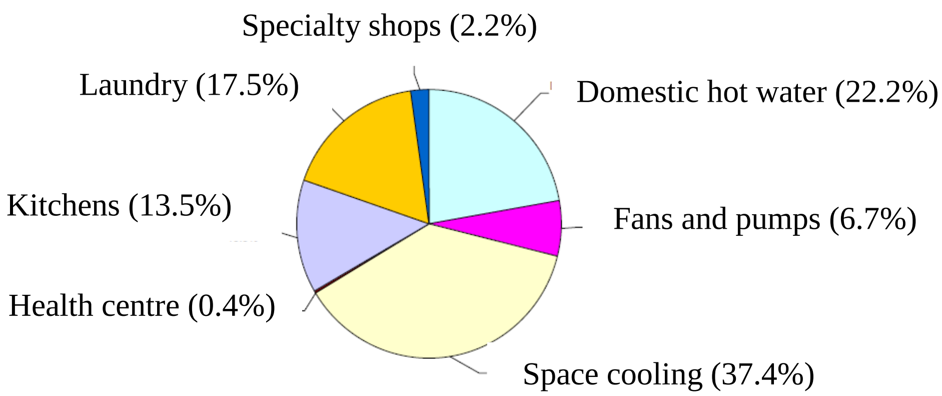

Figure 2.2 Energy end-use of Cairns Hilton hotel (Commonwealth of Australia, 2002)

The Commonwealth of Australia (2002) presented the data which is from a number of hotels in the current study. The data is of varying quality and usefulness but is included as a guide to performance. Each pie represents a different hotel and the title indicates what the climate zone of the hotel is. Energy end-use in a temperate zone and in a hot humid zone hotel showed in Figs. 2.3 and 2.4.

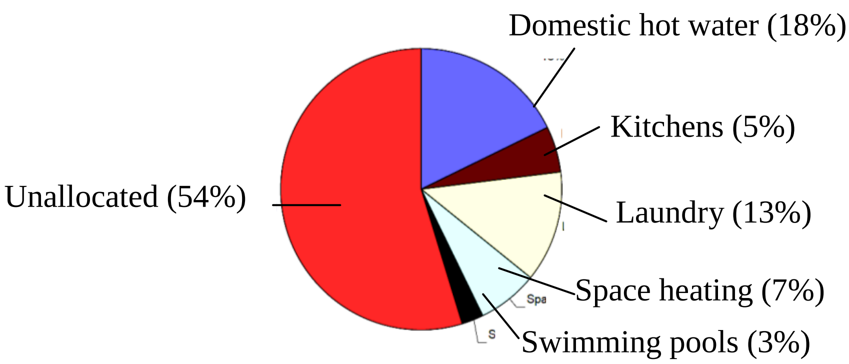

Figure 2.3 Energy end-use in a temperate zone hotel (Commonwealth of Australia, 2002)

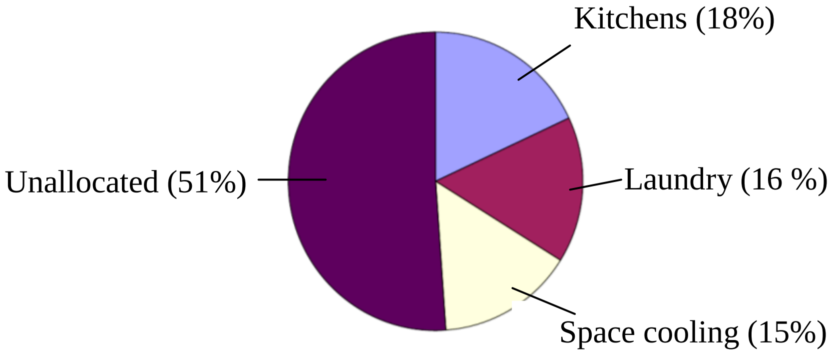

Figure 2.4 Energy end-use in a hot humid zone hotel
(Commonwealth of Australia, 2002)

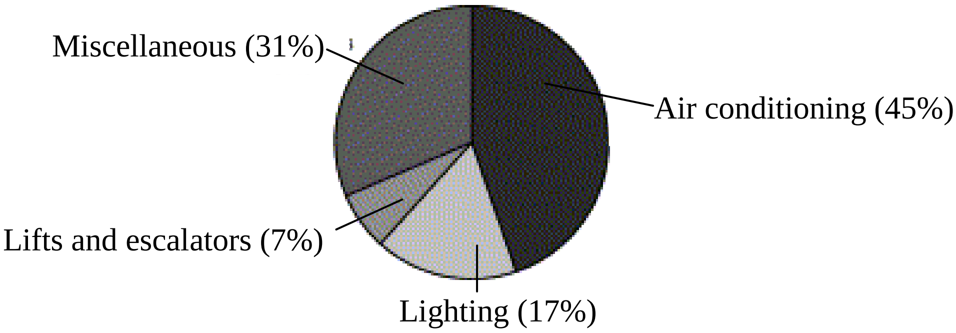

Figure 2.5 The average percentage breakdown of the total electricity use in the 16 Hong Kong hotels (Shiming and Burnett, 2002)

Fig. 2.6 gives a break-down of general energy use in American hotels. It provides energy end-use of electricity and natural gas. The majority of electricity was used for lighting (44%), while the natural gas was used for water heating (68%).

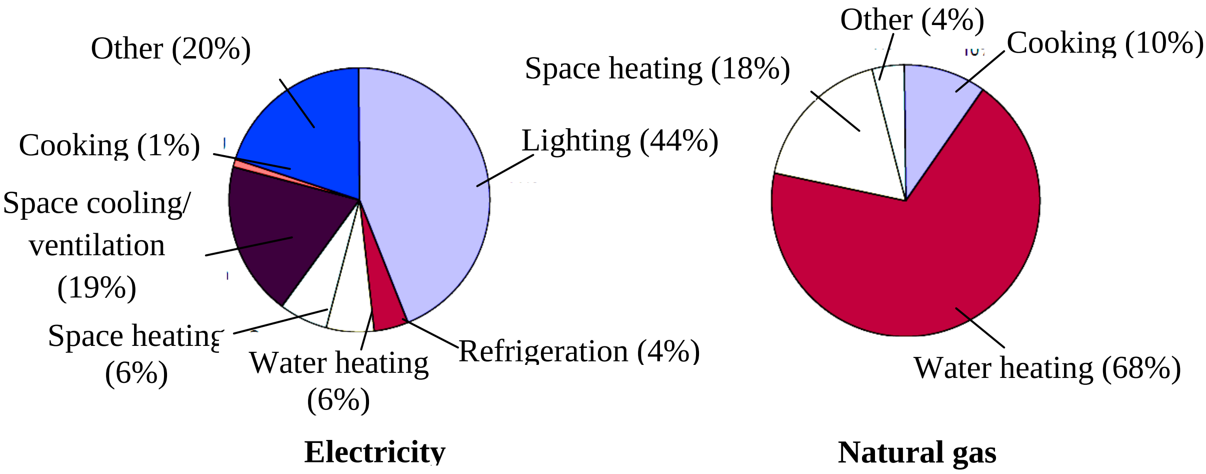

Figure 2.6 A break-down of general energy use in American hotels (Eisenberg *et al*., 1998)

Deutsche Gesellschaft für Internationale Zusammenarbeit: GIZ (2010) study GHG emissions in tourism from 125 hotels in the Koh Chang designated area, Thailand and found that hotel use electricity for variable activities, as shown in Fig. 2.10. Cooling is the main end-use of electricity consumption, room cooling was 45 % and refrigerators' cooling was 6% (Fig. 2.7).

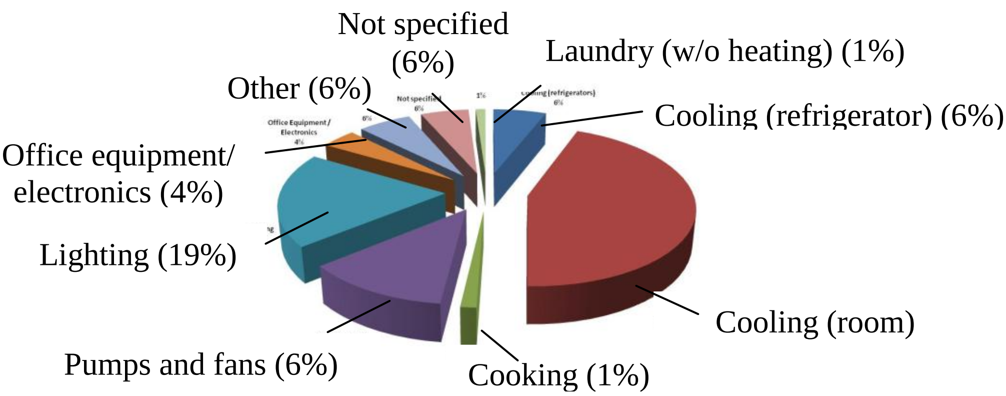

Figure 2.7 Electricity consumption of the average hotel in the Koh Chang designated area, Thailand (Adelphi Consult, 2009)

The relative importance of the different energy end-uses is described as follows (Hotel Energy Solutions, 2011a). Space conditioning (heating/cooling, ventilation and air-conditioning) is the largest single end-user of energy in hotels, accounting for approximately half of the total consumption – it is thus widely accepted that outdoor weather conditions and floor areas are among the main factors affecting energy use in hotels. The indoor temperature levels also greatly influence the quantity of energy consumed in a building.

Domestic hot water is commonly the second largest user, accounting for up to 15 per cent of the total energy demand. Lighting can fluctuate between a range of 12-18 per cent and up to 40 per cent of a hotel's total energy consumption, depending on the category of the establishment. Services, such as catering and laundry, also account for a considerable share of energy consumption, particularly considering that they are commonly the least energy-efficient. Sports and health facilities are typically high energy consumers. Broadly similar results have been reported by studies of Greek hotels: 72-75 per cent of the total energy consumption is used for space conditioning (heating and air conditioning) and for hot water production, 8-9 per cent is used for lighting, 15 per cent is used for catering. No specific data have been found in the literature on the specific energy consumption breakdown of SME hotels.

In some studies, energy use was separated by hotel departments. For example, there are 80 Jordan hotels in which the engineering and housekeeping departments had the highest averaged percentages for consuming this type of energy (20.43% and 20.32%, respectively) (Ali *et al*., 2008). Although some other facilities including lighting hotels' main building and outside areas, air conditioning consume more electricity if put together and were compared to these two departments (Fig. 2.8). Besides, the Energy Conservation Center (2009) reported that banquet service department (hall, meeting rooms and ballroom), food and drink service department (bars, restaurants, Karaoke, etc.), bathhouse and sauna, esthetic salon, athletic and swimming pool have large energy intensity.

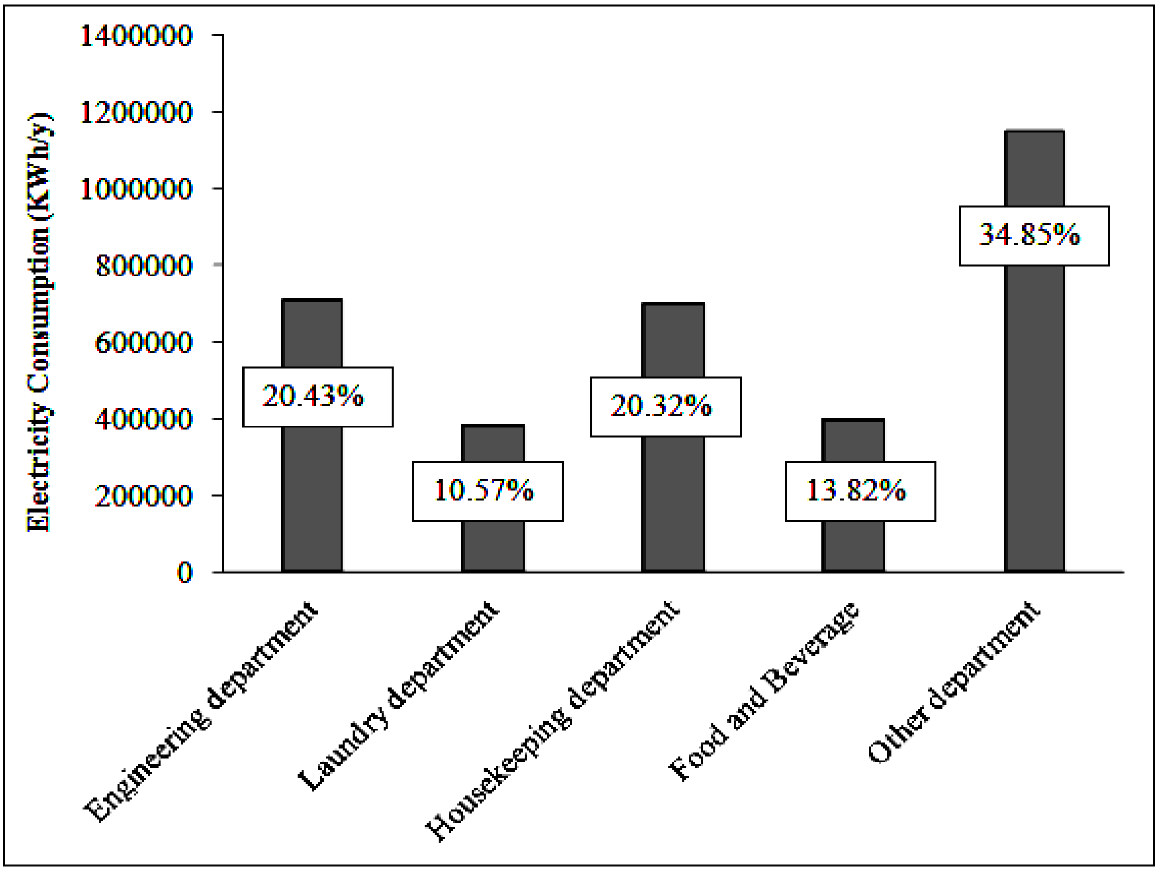

Figure 2.8 The averaged percentage breakdown of the total electricity used in all classified hotels per department (Ali *et al*., 2008)

2.1.4 Energy used intensity (EUI)

Performance comparison is much easier using energy intensities that are calculated by dividing the total energy consumption by a normalizing factor. Normalization factors can be a physical characteristic of the hotel (such as floor area, number of guestrooms) or a measure of hotel throughput (such as number of guests or the number of occupied rooms) (Commonwealth of Australia, 2002). The units commonly used to express energy consumption include is Watt- hours (Wh) and Joules (J) (electricity and total energy, SI system), British Thermal Units (Btu), and thermos (energy based on fuels, i.e. natural gas, IP system) (Stipanuk, 2003 a and b). Energy consumption is divided by normalization factors to produce a performance indicator that can be used to compare different hotels. Generally, energy use intensity (EUI) is shown as follow (Bohdanowicz and Martinac, 2007):

$$EUI = \frac{\text{Total energy consumed}}{\text{Normalizing factor}}$$

Hence, energy use intensity was chosen as the comparison of hotel electricity consumption, which can then be used as the basis for comparing the energy performance of different hotels. Normalized factor was chosen as the primary normalization variable to construct EUI. Electricity consumption was normalized in accordance with the units of normalized factor (Hotel Energy Solutions, 2011a).

2.2 General information of hotels in Thailand

2.2.1 Definition of hotel

A hotel is a residential premise open to the public for rental with more than 4 rooms on all floors in aggregate whether in a single building or in several buildings, and with a total service capacity of 20 guests, operating as a business which provides an additional source of income for the owners (Thailand Hotel Act B.E 2547).

The key features of the Ministerial Regulation, the Building Control Act B.E. 2522 and the Hotel Act B.E 2547, are as follows:

1. The Ministerial Regulation specifies the criteria and conditions relating to location, size, safety, sanitation and facilities of a hotel.

2. The definition of a hotel excludes any residential premises open to the public for rental with no more than 4 rooms on all floors in aggregate whether in a single building or in several buildings, and with a total service capacity of 20 guests, operating as a small business which provides an additional source of income for the owners. The owners of such premises are also required to report to the Hotel Registrar.

3. The building of a hotel must comply with the Building Control Act and its amendments. Additionally, a permit to use the building as a hotel or a building certificate inspection is required for any building located in the area under the enforcement of the Building Control Act. As for any building located outside of the area under the enforcement of the Building Control Act, a building inspection certificate and a Hotel Registrar duly approved building system are required.

2.2.2 Vocabulary in hotels

1) Occupancy rate or Occupancy: the number of guestrooms occupied during a period as compared with the number of guestrooms available during that period (Commonwealth of Australia, 2002) Occupancy rate was from derived variable calculated by dividing stay unit nights occupied by stay unit nights available. For example, if a hotel had 60 of its 100 rooms occupied every night in June, it would have 60 x 31 = 1,860 stay unit nights occupied, and its occupancy rate would be 60 percent (Statistic New Zealand, 2012).

2) Guest night or visitor-night: equivalent to one guest spending one night at an establishment. For example, a motel with 15 guests spending two nights would report provision of 30 guest nights of accommodation (Statistic New Zealand, 2012).

3) Room-night: one hotel room occupied for one night; a statistical unit of occupancy (Travel Industry Dictionary, 2013). Number of rooms blocked or occupied multiplied by number of nights each room is reserved or occupied (TermWiKi, 2013).

2.2.3 The number of hotels in Thailand

During the year 2003 – 2011, the Statistical Forecasting Bureau in Thailand reported that the number of tourists has been increasing continuously (Fig. 2.9). The annual number of tourists increased from approximately 10 million to 20 million, equivalent to the increasing rate of 1.1 million tourists per year (Department of Thailand Tourism, 2012).

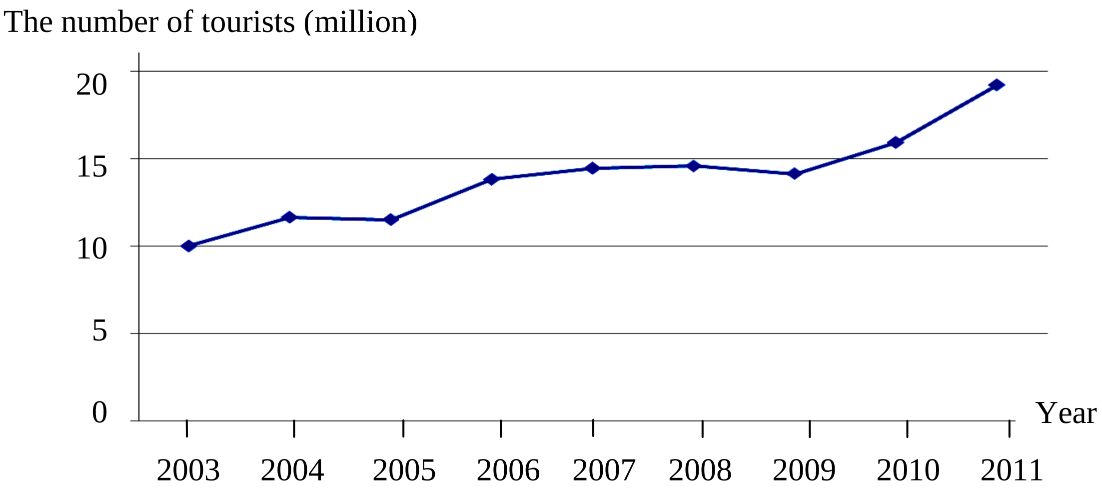

Figure 2.9 The number of tourists in Thailand during the year 2003 – 2011

Together with the growing number of hotels in Thailand during the year 2002 – 2006, the number of hotels increased from approximately 6.2 thousands hotels (335,421 rooms) to 7.5 thousands hotels (370,827 rooms) equivalent to the increasing rate of 258 hotels (7,081.2 rooms) per year (Tourism Authority of Thailand, 2007) as shown in Fig. 2.10.

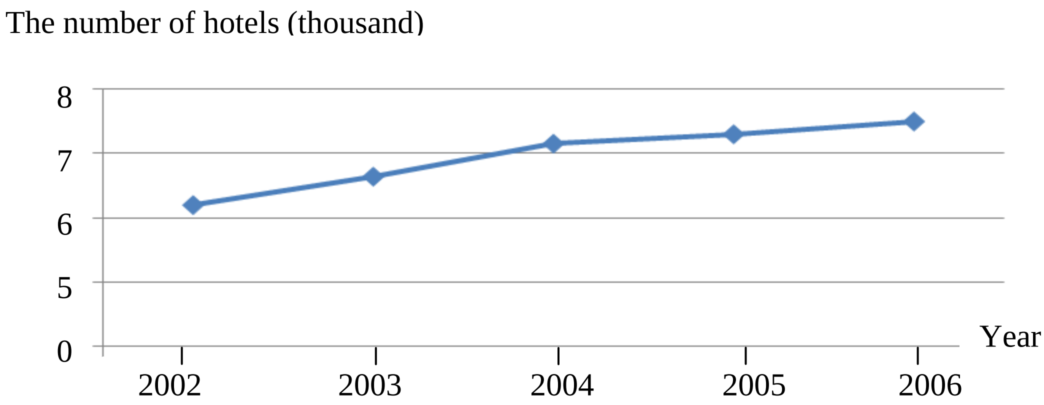

Figure 2.10 The number of hotels in Thailand during the year 2002 – 2006

In 2011, the total hotels in Thailand were 5,538 hotels (Department of Business Development, 2011). The majority of hotels were in Bangkok (31%). The percentage of hotel that classified by region were shown in Fig. 2.11. There are 187 hotels recorded in the list of the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand.

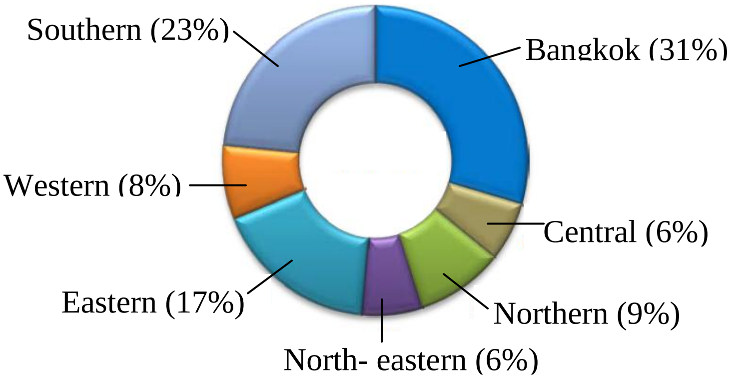

Figure 2.11 The percentage of hotels classified by region in 2011 (Department of Business Development, 2011)

2.2.4 Type of hotels in Thailand

Unlike many other countries, Thailand has no formal government classification of hotels. According to the European Commission (1994), by taking into account the facilities at hotels, it is possible to classify them according to size, class or category, number of rooms, whether they are business or holiday hotels, according to location - in a tourist area or a city, etc., or the type of services provided - restaurant, swimming pool, meeting rooms, sauna, etc. Clearly, there is a huge variety of types of hotel, but hotels are generally classified by number of rooms and category, being divided into small hotels (those with less than 50 rooms), medium (50-150) and large (150 or more). According category the average square meters per room are 22 m^2 for one and two star hotels, 32 m^2 for three star hotels and 42 m^2 for four star and luxury hotels.

1) Star rating classification

At present, The Thai Hotels Association has a total of 813 Members (Thai Hotels Association, 2012). The rest of the hotels are not be the members of Thai Hotels Association. The “Thailand Hotel Standard” is the hotel classification of Thai Hotels Association. The hotel standard is divided into 5 levels and arranged in ascending order with one star denoting the lowest standard and five stars denoting the highest standard. The major factors taken into consideration in the assessment and certification of an individual hotel and resort property are (1) physical aspects, such as location and surroundings, (2) construction aspects i.e. the physical structure of the hotel, systems in place, security system, etc., (3) facilities for hotel guests taking into consideration guests who are resident at the hotel (in-house guests) as well as guests who frequent the hotel and use the services provided. For example, the quantity of the facilities, décor, equipment, etc, (4) quality of service and the ability to maintain quality includes such criteria as personality, the quality of services, cleanliness, hygiene, etc. and (5) the maintenance of the hotel and the abovementioned facilities. The checklist for hotel star rating is shown in Table 2.1. The standard scores for star rating of hotels to be qualified a shown in Table 2.2. There are 9 two-star, 55 three-star, 99 four-star and 68 five-star hotels (Thai Hotels Association, 2012). The rest are not classified by the Thai Hotels Association.

Table 2.1 The checklist for hotel star rating

Sections	**Items**	**The number of indicators**	**Weighting of each indicator**	**Total score**	**Percentage (%)**
1	Location, physical structure of the hotel and parking	39	3	117	5.37
2	Reception hall, , public toilets, elevator and Thoroughfare within the building	81	3	243	11.19
3	Standard room (Corridors, balconies and bathrooms)	167	4	668	30.76
4	Suite room and executive floor	22	2	44	2.03
5	Restaurants, coffee shops, bars and kitchens	124	2.5	310	14.27
6	Facilities for hotel : pool	110	2	220	10.13
7	Business service : meeting rooms and business centers	76	1.5	114	5.25
8	Staffs and service	79	3	237	10.91
9	Security system	36	3	108	4.97

Table 2.1 The checklist for hotel star rating (Cont')

Sections	Items	The number of indicators	Weighting of each indicator	Total score	Percentage (%)
10	Resources and surroundings	28	2.5	70	3.22
11	Human rights and labor law	18	1.5	27	1.24
12	Other characteristics	14	1	14	0.64
Total		794	29	2172	100

Table 2.2 The standard scores for hotel star rating

Star rating	The number of indicators	Weighting of each indicator	Total scores	Percentage of requirements (%)	Requirement scores
1-star	140	3	3,126	95	More than 2,969.70
2-star	158	3	3,336	95	More than 3,169.20
3-star	229	3	4,221	95	More than 4,009.95
4-star	393	3	6,138	95	More than 5,831.10
5-tar	438	3	6,516	95	More than 6,190.20

2) Green leaf certificate

Green Leaf Certificate is the hotel classification of the Green Leaf Foundation. The Green Leaf Certificate is divided into 5 levels and arranged in ascending order with one green leaf denoting the lowest environmental standard and five green leaf denoting the environmental highest standard, the most practiced hotel in environmental management (The Green Leaf Foundation, 2012). A self environmental audit in operational process of hotel which divides into 18 sections (Table 2.3). Scores will be calculated from questionnaires and results of audit which will be compared to the Standard score derived from 20 reference hotels. The standard scores for Green leaf certificate to be qualified a shown in Table 2.4.

Table 2.3 The checklist for Green Leaf Certificate

Sections	Items	The number of indicators
1	Policy	14
2	Personal development and training	32
3	Environmental committees	14
4	Standards of environmental practice	21
5	Waste management	19
6	Efficiently use of energy	45
7	Efficiently use of water	25
8	Restaurants and kitchens	31
9	Laundry	14
10	Purchasing	15
11	In-door Air quality, Air Pollution and Noise Pollution	26
12	Quality of Water	17
13	Spa and massage	14
14	Facilities and outdoor activities	39
15	Security system	12
16	Impact on eco-system	11
17	Cooperation with community and local organizations	10
18	Culture promotion	8

Table 2.4 The standard scores for Green Leaf Certificate

Leaf certificate	Percentage of requirements (%)
1-green leaf	Less than 52
2-green leaf	From 52-56.8
3-green leaf	From 56.90-61.7
4-green leaf	From 61.8-66.5
5-green leaf	More than 66.5

3) American hotel classifications

Types of American hotel classifications are as follows (The Waiters' Digest, 2009):

3.1 Commercial hotels are hotels catering mainly to business clients and usually offering room service, coffee-shop, dining room, cocktail lounge, laundry and valet service as well as access to computers and fax services,

3.2 Airport hotels are hotels located near airports and are conveniently located to provide any level of service from just a clean room, to room service. They provide bus or limousine services to the air lines,

3.3 Conference Centers are hotels designed to specifically provide meeting spaces for groups. They provide all services and equipment necessary to handle conventions.

3.4 Economy hotels are hotels providing a limited service. They are known for clean rooms at low prices meeting just the basic needs of travelers,

3.5 Suite or all-suite hotels are hotels offering spacious layouts and design. Business people like the setting, which provides spaces to work and entertainment separate from the bedroom,

3.6 Residential hotels are hotels offering for long term accommodations,

3.7 Casino hotels are hotels supporting the gambling operations. They offer top name entertainment and excellent restaurants,

3.8 Resort hotels are hotels located at the ocean or in mountains away from inner cities. They may offer any form of entertainment to keep their guests happy and busy.

4) Thailand's Hotel Act B.E 2547 classifications

Types of Thailand's hotels are classified by The Hotel Act B.E 2547 are as follows:

4.1 Type 1 are hotels providing accommodation only, the number of rooms does not exceed 50. The size of each room is not less than 8 square meters,

4.2 Type 2 are hotels providing accommodation and catering or restaurant services. The size of each room is not less than 8 square meters,

4.3 Type 3 are hotels providing accommodation, catering or restaurant services. The size of each room is not less than 14 square meters, and which has either conference rooms or entertainment venues which under the Place of Service Act B.E. 2509 could be a place for dancing, bars and night clubs, spa,

4.4 Type are hotels providing accommodation, catering or restaurant services, conference rooms and entertainment venues. The size of each room is not less than 14 square meters.

For Type 3 and 4 hotels, no entertainment venues are allowed unless these hotels operate more than 80 rooms. However this restriction will be waived if the hotels are located in entertainment areas or if the entertainment venues are operated by a hotel which serves food, alcohol or entertainment only, and has opening hours after 12 p.m.

2.2.5 Energy consumption of hotels in Thailand

In 2002-2010, the energy consumption by buildings in Thailand increased from 3,480 to 4,940 ktoe or 1.4 time in 7 years. Fig. 2.12 shows the main types of energy are electricity, 79 and 82%. Electricity consumption increased while LPG consumption in building was decreased (Ministry of Energy, 2011).

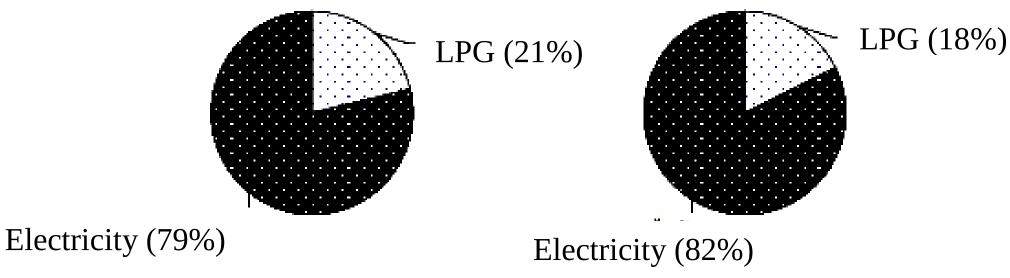

Figure 2.12 Energy consumption of buildings in 2002 and 2010 (Ministry of Energy, 2011)

The electricity consumption by buildings in Thailand in 2002 was 14,100 GWh. It was 33% of the total electricity consumption in Thailand, 19,100 GWh, in 2007. The large-sized business buildings in Thailand are separated into 8 types: office, mall, hyper mart, condominium, hotel, hospital and school. The data from The Provincial Electricity Authority of Thailand and The Metropolitan Electricity Authority of Thailand presented that electricity consumption of Thailand came from medium size building (40%). Office (7,139 GWh or 37%), mall (2,351 GWh or 12%), hyper mart (2,351 GWh or12%) and hotel (2,339 GWh or 12%) are the highest electricity consumer in the building. Additionally, they are the highest LPG consumer in building also which 31 ktoe (12%), 72 ktoe (28%), 91 ktoe (36%) and 32 ktoe (13%) of total LPG consumption in the building. The electricity consumption of Thailand's hotels in 2002-2007 is shown in Fig. 2-13. Due to hotels being the one of highest electricity and LPG consumers among buildings, saving energy in these sectors is highly efficient.

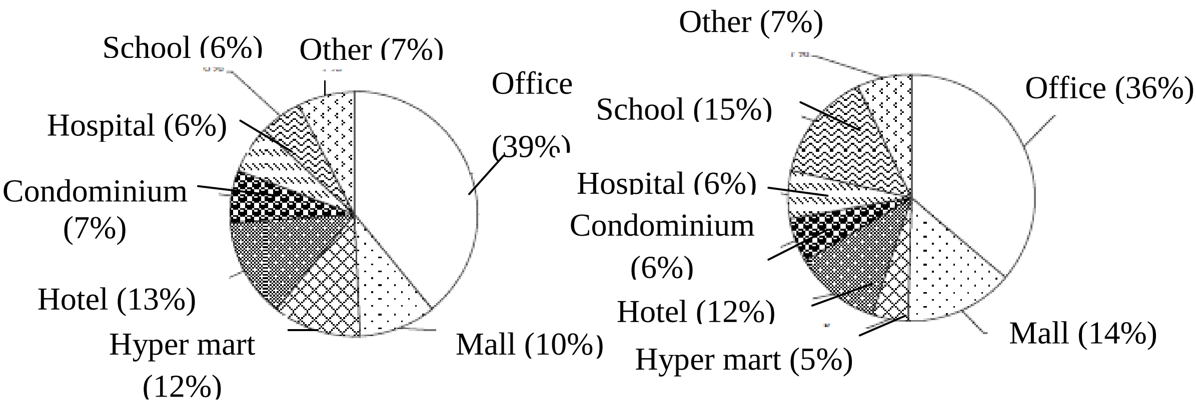

Figure 2.13 Electricity consumption separated by type of building in 2002 and 2007 (Ministry of Energy, 2011)

During the last decade, Thailand's average annual energy demand increased by about 4.3%. Electricity generation has produced the largest proportion of carbon dioxide emissions in Thailand (Wibulswas, 2004). The Ministry of Energy (2011) studied energy efficiency in 2030 and found that the highest electricity efficiency were large size business buildings (2,335 ktoe or 37% of total electricity saving.) The high electricity efficiency building is office, school, mall, hyper mart and hotel which are 7,033 GWh (26%), 6,797 GWh (25%), 4,094 GWh (15 %) and 4,169 GWh (15%).

2.3 Factors influencing electricity consumption

2.3.1 The physical and operational parameters

Hotel Energy Solutions (2011a) stated that hotel energy consumption is influenced by physical and operational parameters.

1) The physical parameters common to most buildings, include size, structure and design of the building (prevailing architectural / construction practices), geographical and climatic location, the age of the facility, the type of energy and water systems installed, the way these systems are operated and maintained, types and amounts of energy and water resources available locally, as well as energy-use regulations and cost.

2) Operational parameters that influence energy use in hotels include operating schedules for the different functional facilities in the hotel building, the number of facilities (restaurants, kitchens, in-house laundries, swimming pools and sports canters, business centers, etc.), services offered, fluctuation in occupancy levels, variations in customer preference relevant to indoor comfort, on-site energy conservation practices, as well as culture and awareness of resource consumption among personnel and guests. Some of these factors, such as the level of environmental awareness of users, may be difficult to quantify or evaluate as they are mostly qualitative in character (Despretz, 2001).

2.3.2 The internal and external factors

Warnken and Bradley (2002) stated that the factors affecting energy consumption were internal and external factors.

1) Factors internal to tourist accommodation

Internal factors that may influence environmental performance include year of building construction; accommodation star rating; occupancy levels; total floor area; number of guest rooms; services and facilities provided; and temperature control systems.

2) Factors external to tourist accommodation

Climatic variables are external factors that are likely to influence the environmental performance of tourist accommodation enterprises, because the use of air conditioning dominates total energy consumption and the operation of air conditioning is related to climate. Other external factors that may influence energy consumption include government policy, legislation and regulations at federal, state and local levels.

From an architectural and systems' perspective a hotel can be seen as a combination of three zones, all serving distinctly different purposes (IMPIVA, 1994; Ransley and Ingram, 2000; Bohdanowicz *et al*., 2001; Lawson, 2001):

1) The guestroom areas (bedrooms, bathrooms / showers, toilets) – individual spaces, often with extensive glazing, asynchronous utilization and varying energy loads, as well as highly user-specific patterns of water use;

2) The public areas (reception hall, lobby, bars, restaurants, meeting rooms, swimming pool, sauna, etc.) – spaces with a high rate of heat exchange with the outdoor environment (high thermal losses) and high internal loads (occupants, appliances / equipment, and lighting). Advanced heating, ventilation and air-conditioning (HVAC) systems installed in these enclosures must be able to respond quickly to fluctuating numbers of occupants and diverse thermal comfort requirements, some of the areas are additionally equipped with high energy- and water-intensive installations;

3) The service areas (kitchens, office, storage rooms, laundry, staff facilities, machine rooms and other technical sections) – energy- and water- intensive areas typically requiring advanced handling (ventilation, cooling, heating). In addition, service spaces typically need to be isolated from public and service areas, e.g. to prevent the transport of odors.

2.3.3 Investigation of factors affecting electricity consumption in hotels

1) Correlation

Generally, the correlation is one of the most common and most useful statistics. A correlation is a single number that describes the degree of relationship between two variables (Trochim, 2006). Correlation is computed into what is known as the correlation coefficient. The correlation coefficient is calculated as (Statistics how to, 2012):

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

where r is correlation coefficient,

x is a independent variable,

y is a dependent variable.

The correlation coefficient will vary from -1 to +1. A result of -1 means that there is a perfect negative correlation between the two values, while a result of 1 means that there is a perfect positive correlation between the two variables. A result of 0 means that there is no linear relationship between the two variables (Statistics how to, 2012).

The correlation is significant (2-tailed) at the 0.05 level if it is less than or equal to 0.05. It indicates that this independent variable is a significant factor affecting total electricity consumption in the hotel at a significant level of 95%.

2) Linear regression

Significant variations in facility types within the hotel sector make it difficult to provide a general model explaining the energy consumption of individual facilities that could be universally applicable to all types of hotels. Nevertheless, a number of attempts have been made to develop such models. The models vary in applicability, the number of factors/variables included, data collection and verification procedures, as well as modeling methodology used (Hotel Energy Solutions, 2011a).

Generally, a linear regression model is used to describe the total energy consumption of a hotel. The analysis of actual energy use and data on hotel facilities is then made using this regression model, and is used to identify the most significant variables that influence energy use. Although many variables may have some influence on total hotel energy use, in practice only a few variables are generally considered depending on data availability (Hotel Energy Solutions, 2011a).

Linear regression is often used to determine how many specific factors or sectors, influence the dependent factor. It is also used to model the impact that each of these variables has on the dependent variable. The model creates a relationship in the form of a straight line (linear) that best approximates all the individual data points (Investopedia, 2012). The general regression model found in any basic statistics test can be written as (Ding, 2006):

$$y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_n + \varepsilon_i$$

where β_0 is intercept,

β_k is the regression slope or coefficient for a given independent variable *k*,

ε_i is error term for individual *i*.

This equation has one key feature. It assumes that all individuals are drawn from a single population with common population parameters. However, when a sample consists of various groups of individuals, such as star rating and the age of a hotel, or different intervention groups, regression analysis can be performed to examine whether the effects of independent variables on a dependent variable differ across groups, either in terms of intercepts or slope.

Additionally, methods for modeling hotel energy consumption are performed by stepwise linear regression procedure. The independent variables were identified using a stepwise procedure. Depending on the hotel amenity group, a regression model may include two or all of these independent variables. In other words, only the statistically significant variables ($X_1,\ldots,X_n$) are left in the regression model, while the others are discarded (Xuchao *et al.,* (2010).

Although models for determining the factors that influence hotel energy consumption are based on a limited number of variables, they are able to account for major effects in energy consumption variations in the samples of hotels as indicated by high coefficients of correlation (Hotel Energy Solutions, 2011a).

3) Process of transforming inputs into outputs

Anderson *et al.* (1997) used a flowchart to illustrate the process of transforming model inputs to outputs, which can be adapted to explain the differentiation of two types of inputs (factors) in energy benchmarking (Fig. 2.14). The output, which is hotel energy performance in this case, is influenced by both controllable and uncontrollable inputs.

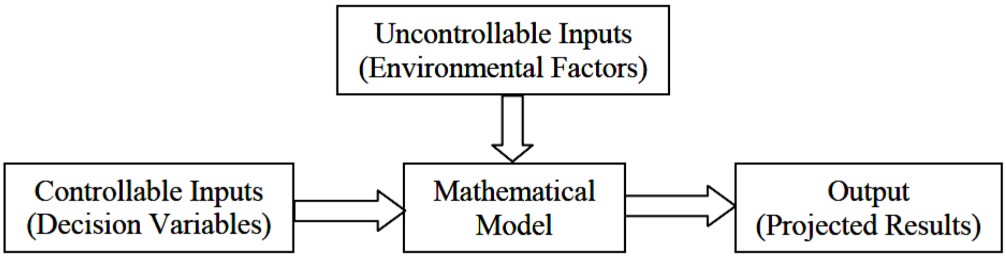

Figure 2.14 Process of transforming inputs into outputs (Anderson *et al.*, 1997)

The uncontrollable inputs are not readily amenable to energy management practices or system efficiency improvements. Hotel location and star rating, building age, local climate, allocation of floor area, level of business activity, to name a few, all belong to this category. In other words, there is nothing or very little a hotel manager can do to these factors in order to make energy performance improvements.

On the other hand, the controllable inputs are at the discretion of the hotel manager, and certain decisions can be made related to these factors to achieve better energy performance, for example, carrying out energy retrofit, and choosing more efficient equipment among alternatives. In comparing energy performance of hotels, the uncontrollable inputs should be normalized if found to have significant influence, but the controllable inputs should be left out for the hotel manager to make improvements upon.

2.4 GHG emissions from hotels

2.4.1 Source and GHG emissions

CP/RAC (2012) states that global emissions from tourism in 2005 was 4.95 % of total emissions as indicated in Table 2.5. The emission from accommodation (hotels) was 21% of total tourism emissions.

Table 2.5 Global emissions from tourism in 2005 and contributions by subsector (CP/RAC, 2012)

Action	CO_2 (Mt)
Air transport	517
Other transport modes	468
Accommodation (hotels)	274
Tourist activities	45
Total emission on tourism	1.307
Total emission of the planet	26,400

Additionally, studying CO_2eq emissions of hotels in the Koh Chang clustered area showed that hotels and home stays are emitting 58%, restaurants 27%, commercial boat traffic is responsible for 10% and other operators (tour guides, shops etc.) for around 5% of the GHG emissions from tourism (Adelphi consult, 2009). Fig 2.15 showed that the largest part of the hotel emissions was electricity and fuel consumption (31%), followed by emission from transport (25%) and waste playing a rather minor role (2%).

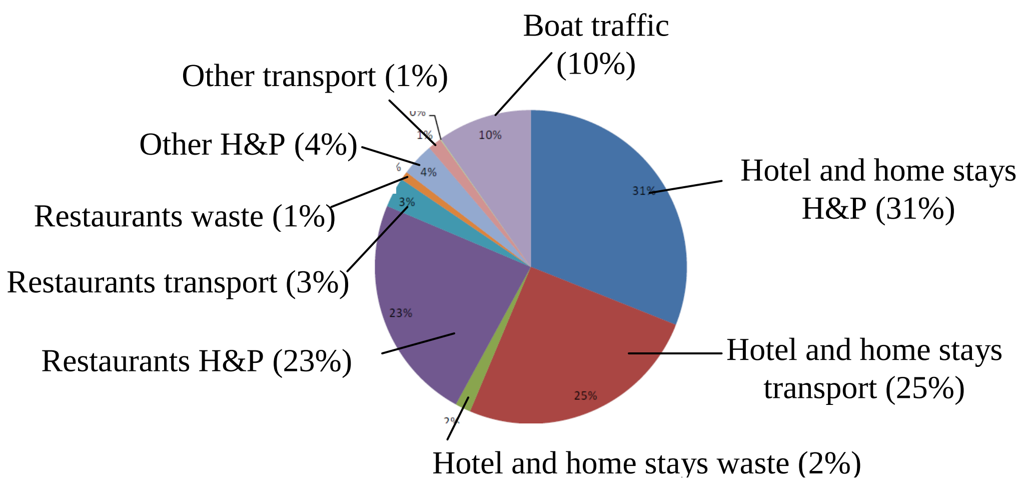

Figure 2.15 The percentage of emissions from tourism separated by the tourism facilities and sources (Henzler *et al*., 2010)

Globally, the building sector was responsible for more electricity consumption than any other sector, 42% to a significant extent, and implicates the electricity sector at large (Baumert *et al.*, 2005). Not surprisingly, more than 40 percent of all electricity was consumed in hotel buildings. Electricity emits the largest GHG. In Thailand, GHG emission by energy sector was 159.39 TgCO_2eq or 69.6% of total GHG emission of in 2000. In 2004, GHG emission increased 27.9% of total emission or 6.4% per year (ONEP, 2010). With respect to GHG composition, CO_2 forms the largest proportion of almost 70%, while the electricity generation sector was the largest source of CO_2 emissions (Nairam, 2009).

To give more examples, the Commonwealth of Australia (2002) reported that electricity is the most common form of energy used by the 50 hotels, 66%. Although electricity makes up 66% of total energy use, it contributes over 90% of total greenhouse gas emissions due to its high greenhouse intensity.

In Thailand, the average CO_2eq emissions of hotels in the Koh Chang clustered area is shown in Table 2.6. The average CO_2eq emissions per month of electricity and fuel consumption is the most (50.90%), followed by emissions from transport (46.15%) and waste (2.95%). The average CO_2eq emissions per month/room of electricity and fuel consumption was the most (45.19%), followed by emissions from transport (52.42%) and waste (2.39%).

Table 2.6 The average CO_2eq emissions of hotels (Adelphi Consult, 2009)

CO_2eq emissions	**Location**			
	Koh Chang	**Koh Kood**	**Koh Mak**	**Total**
(ton per month)				
Electricity and fuel consumption	840.9	141.7	126.8	1,109.4
Transport	633.6	193.8	178.5	1,005.9
Waste	50.1	9.7	4.6	64.4
(kg per month/ room)				
Electricity and fuel consumption	240	201	197	638
Transport	184	278	278	748
Waste	14.48	13.17	6.15	33.8

2.4.2 Calculation of GHG emission

The greenhouse emissions were calculated from the national average intensities, and of course, individual hotels would be subject to local intensities that would vary with the method of generation of electricity in that location. Generally, in terms of calculating GHG emissions produced by electricity consumption, used The IPCC Energy – Approach Tier 1.

The Tier 1 method is fuel-based, since emissions from all sources of combustion can be estimated on the basis of the quantities of fuel combusted (usually from national energy statistics) and average emission factors. Tier 1 emission factors are available for all relevant direct greenhouse gases.

The quality of these emission factors differs between gases. For CO2, emission factors mainly depend upon the carbon content of the fuel. Combustion conditions (combustion efficiency, carbon retained in slag and ashes, etc.) are relatively unimportant. Therefore, CO_2 emissions can be estimated fairly accurately based on the total amount of fuels combusted and the averaged carbon content of the fuels.

However, emission factors for methane and nitrous oxide depend on the combustion technology and operating conditions and vary significantly, both between individual combustion installations and over time. Due to this variability, the use of averaged emission factors for these gases, which must account for a large variability in technological conditions, will introduce relatively large uncertainties.

According to the 1996 Guidelines and IPCC Good Practice Guidance, the most common simple methodological approach is to combine information on the extent to which a human activity takes place (called activity data or AD) with coefficients which quantify the emissions or removals per unit activity. These are called emission factors (EF). The basic equation is as follows (IPCC, 2006):

Emissions = Activity data (AD) X Emission factor (EF)

2.5 Mitigation option of GHG emissions from energy consumption in hotels

2.5.1 The benefits and main sources of energy saving

Various studies have estimated that hotels have the potential to save at least 10 - 15 per cent of the energy they consume, depending on the age and size of the hotel, as well as type of equipment installed and the maintenance and operating procedures in use. An assessment of potential energy conservation in southern European hotels revealed that there is a potential for 25 - 30 per cent energy savings, especially in hotels with high annual energy consumption. European studies have estimated savings of 15 - 20 per cent for heating, 5 - 30 per cent for cooling, 40 - 70 per cent for hot water and 7 - 60 per cent for lighting (Hotel Energy Solutions, 2011b).

Most data is available from surveys carried out by Bohdanowicz in hotels in Sweden and Poland, in chain and affiliated hotels (average size: 133 rooms), and in independent hotels (average size: 57 rooms). Reported in two separate papers, the total number of hotels sampled in these surveys is 610. The results show that around 80 percent of the hotels that responded reported taking some energy conservation measures. Almost as high a proportion also reported that they had undertaken measures for water conservation and responsible waste management. Data for Sweden and Poland (Fig. 2.16), showed that the energy conservation and efficiency measures comprise energy efficient lighting (just over 70 percent of hotels), energy efficient equipment (between 40 – 60 percent of hotels), and providing leaflets to encourage guests to save energy (between 20 – 40 percent of hotels) (Hotel Energy Solutions, 2011b).

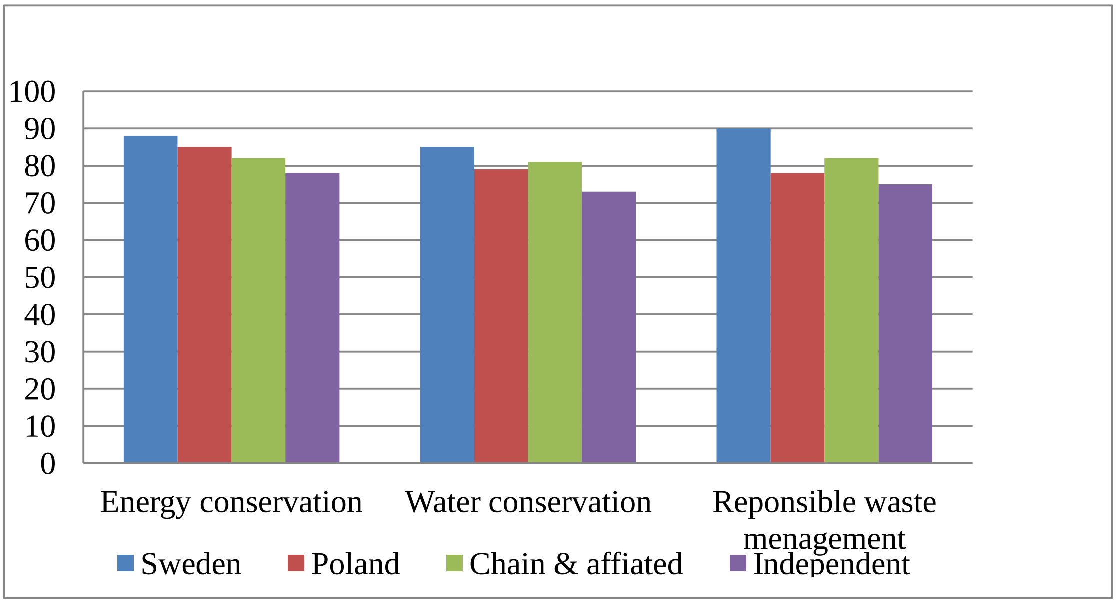

Figure 2.16 Energy conservation and efficiency measures undertaken by hotels (Bohdanowicz, 2006)

For other example, the hotels, one older and the other newer, were chosen to represent the most common UK hotel types. The effects were studied of interventions expected to be available in 2030, including fabric improvements, HVAC changes, lighting and appliance improvements and renewable energy generation. The main finding was that it is technically feasible to reduce emissions by 50% without compromising guest comfort (Taylor *et al.*, 2009). The proportions of remaining emissions after all interventions have been applied to the two hotels are shown in Fig. 2.17. Electricity is responsible for around half of the remaining emissions.

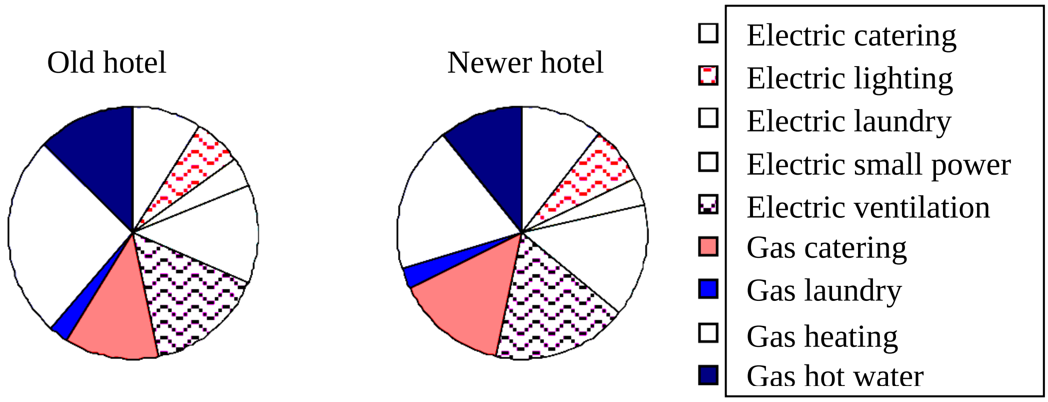

Figure 2.17 Contributions to remaining emissions (Taylor *et al.*, 2009).

In Thailand, the Ministry of Energy (2011) pointed out that energy consumption in Thai business buildings will increased 3.7 times more than during 1990-2010. The proportions of remaining emissions in 2030 were studied and found that energy saving can reduce 6 millions tones of CO_2 emissions per year and 27,420 GWh of electricity consumption. It also saves 20,000 million Bath per year.

2.5.2 The difficulties of sustainable tourism

Hotel Energy Solutions (2011b) referred the study of Hobson and Essex in 2001 that the main difficulties were a lack of interest, lack of time and energy amongst hotel managers, the costs involved, and lack of information and support for implementation of the suitable measures (Fig. 2.18).

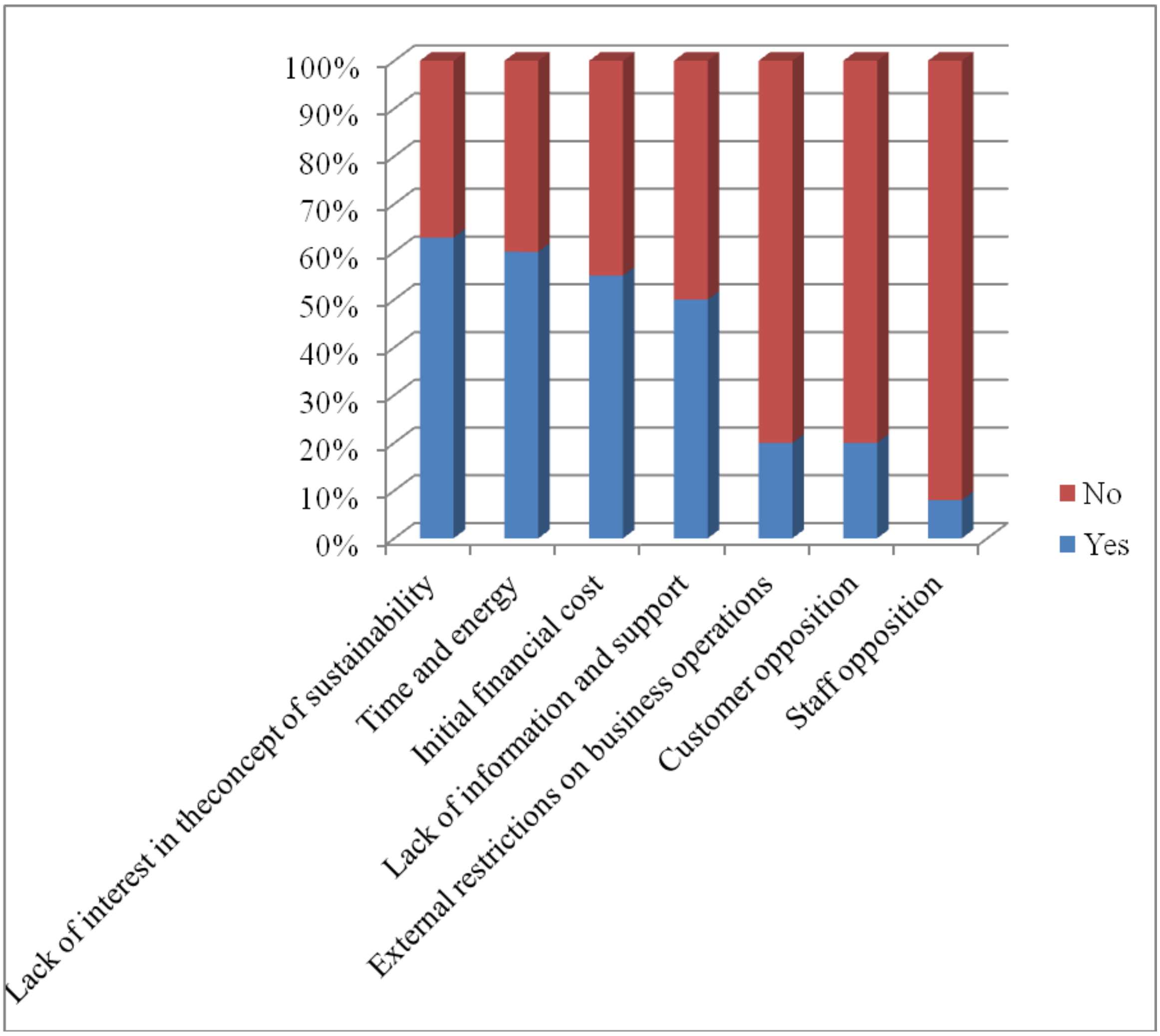

Figure 2.18 Difficulties of sustainable tourism (Perceptions of 64 hotels in Plymouth, UK) (Hotel Energy Solutions, 2011b)

2.5.3 Standard classification of energy consumption in hotels

Due to the huge variations that exist regarding types of establishment, number of rooms, category, geographical location, fuel and energy sources used, etc., it is difficult to arrive at a standard classification of energy consumption in hotels (European Commission, 1994). However, it is possible to establish a typical model indicating the main areas of energy consumption in a hotel (Table 2.7).

Table 2.7 Typical parameters regarding energy consumption in different types of hotels (European Commission, 1994)

Efficiency rating	**Good**	**Fair**	**Poor**	**V. Poor**
A) large hotels (more than 150 rooms) with air conditioning, laundry & indoor swimming pool				
Electricity (kWh/m^2 year)	<165	165-200	200-250	>250
Fuel (kWh/m^2 year)	<200	200-240	240-300	>300
Total (kWh/m^2 year)	<365	365-440	440-550	>550
Water (kWh/m^2 year)	<220	230-280	280-320	>320
B) Medium-sized hotels (50-150 rooms) without laundry, with heating & air conditioning in some areas				
Electricity (kWh/m^2 year)	<70	70-90	90-120	>120
Fuel (kWh/m^2 year)	<190	190-230	230-260	>260
Total (kWh/m^2 year)	<260	260-320	320-380	>380
Water (kWh/m^2 year)	<160	160-185	185-220	>220
C) Small hotels (4-50 rooms) without laundry, with heating & air conditioning in some areas				
Electricity (kWh/m^2 year)	<60	60-80	80-100	>100
Fuel (kWh/m^2 year)	<180	180-210	210-240	>240
Total (kWh/m^2 year)	<240	240-290	290-340	>340
Water (kWh/m^2 year)	<120	120-140	140-160	>160

2.5.4 Mitigation option of emission from energy saving

Mitigation can be described as an anthropogenic (man-made) intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001). Generally, mitigating climate change could be implemented by elimination, reduction, substitution and offsetting of GHG emissions (Simpson *et al.*, 2008) (Fig. 2.19).

Elimination means avoiding useless production of GHGs. These measures have the best proportion of cost to benefit; savings can be felt immediately.

Reduction could usually be achieved by replacing devices and/or optimizing given structures. This mitigation approach is very effective and could be integrated in the daily business with low effort.

Substitution measures are usually implicating cost intensive investments. Also, the reduction potential is very high.

Offset is the method with the lowest cost-benefit proportion and hard to move into practice at this scale.

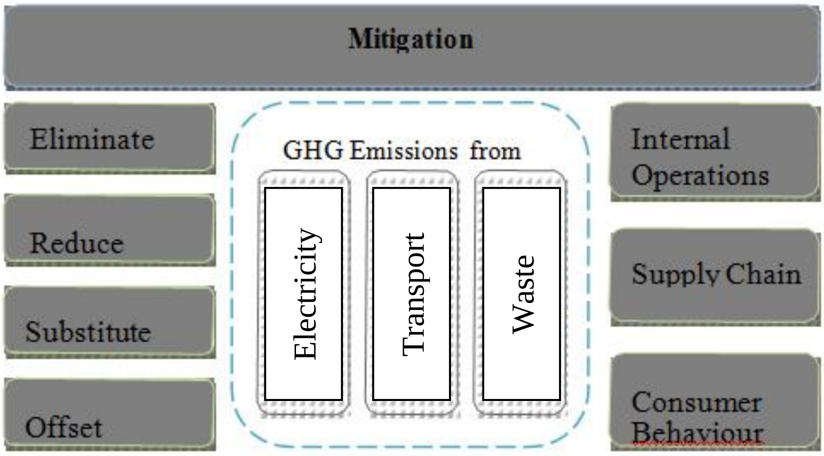

Figure 2.19 Mitigating climate change (Henzler *et al*., 2010)

1) Energy saving in hotel zones

The space of a hotel can be divided into three clearly-defined areas according to purpose. For the energy saving point of view, the three zones must be considered separately, as each has different requirements. Comfort levels required in each zone vary, and correct design will take this into account, limiting energy demand for heating, lighting and cooling (European Commission, 1994).

1.1) In the guest room area, the orientation of the building is an important factor regarding the need to install solar protection and the existence of energy saving opportunities. Levels of insulation and the ventilation system employed will depend on the degree of exposure to wind and noise, and will be closely linked to heating or air conditioning demand.

1.2) Hotel restaurants and meeting rooms are spacious areas designed to hold large numbers of people. Such facilities also require a degree of discretion and intimacy. In order to rationalise energy consumption, units should be thermally independent.

1.3) Services, offices, store rooms, staff facilities and technical sections are located in the less luxurious areas of the hotel. With the exception of staff bedrooms, which require natural light, these facilities are located in basements or isolated sections between the guest room area and general service areas.

2) Energy saving in hotel departments

CP/RAC (2012) suggested the proposal of mitigation alternatives of GHG emissions from electricity consumption in the hotel sector as shown in Table 2.8.

Table 2.8 The proposal of mitigation alternatives of GHG emissions from electricity consumption in the hotel sector

Hotel departments	**Mitigation**
Kitchens	- Use of energy efficient equipment, and replacement of old equipments for new and efficient ones. - Let new dishwashers dry with the door opened. - Keep electrical appliances' doors closed. - Do not let frost in the refrigerator. - Turn equipment off when not in use. - Cover cooking pots. - Good ventilation of the electrical and gas appliances. - Do not use water or heat to defrost the electrical appliances and food.
Heating, ventilation and air conditioning systems	- Improve the building external thermal insulation. - Use of steam pumps. - Implement regulation and control systems. - Identification and reparation of air escapes in windows and doors. - Ensure that furniture does not obstruct the air inlets. - Periodic maintenance of the installation. - Keep the air conditioning at a temperature between 25 °C and 26 °C in summer, and 20°C and 21 °C in winter.

Table 2.8 The proposal of mitigation alternatives of GHG emissions from electricity consumption in the hotel sector (Cont')

Hotel departments	**Mitigation**
Lighting	- More rational use of energy. - Use of low energy light bulbs. - Use of compact fluorescents - Implementation of a regulation and control system of lighting: - Timed on-off. - Installation of presence detectors. - Photocell installation. - Switches located, shutting off phases of the hotel that are not in use. - Card activation system in rooms. - Good design in the different hotel areas: - Take advantage of sunlight. - Well located switches. - Well located luminaries. - Avoid an excessive outdoor lighting in gardens, facades, car parks and road accesses.
Boilers	- Use of low temperature or condensation boilers. - Installation of solar photovoltaic panels to heat the domestic hot water up. - Isolation of pipes and canals. - Temperature Control Systems. - Periodic maintenance of the installation. - Periodic tests of the boilers atmosphere emissions.
Laundries	- Use of energy efficient equipments, and replacement of old equipments for new and efficient ones. - Reduce the wash temperature. - Turn equipment off when not in use. - Use the washing machines with full load. - Keep the filters clean.
Leisure Facilities	- Installation of presence detectors to switch-off the lights when nobody is there. - Turn equipment off when not in use. - Establish an adequate lighting in every case. - Establish an adequate temperature in every case. - Cover swimming pools to avoid temperature losses during the night.

3) Energy saving in energy end-use

3.1) Heating

As the different areas in a hotel, particularly guest rooms, meeting rooms, etc., have variable, and not simultaneous, periods of occupation, the time during which they are in use is the most important factor as regards energy consumption.

Autonomous temperature control systems should be used to enable the temperature in a room to be lowered when it is not occupied, keeping it at standby level so that it can be quickly restored to the normal level. The use of such control systems can produce energy savings of 20-30% (European Commission, 1994).

Table 2.9 Temperature recommended for hotel areas and rooms (European Commission, 1994)

Type of acclimatization	State of space	Recommended temp.
Normal heating	Occupied	20°C +/- 2°C
Standby heating	Unoccupied for certain periods	16-18°C
Minimal heating	Unoccupied in winter	12-14°C
Cooling	Lounges & guest rooms	5°C lower than external temp. in hot regions. 23°C in winter

3.2) Air conditioning and ventilation

The cooling power of a system is in direct relation to the temperature of the cold water in the cooling circuit. In order to maximise energy savings, this temperature should be regulated to the highest point within it operating range. Each degree by which the temperature of the cold water rises gives energy savings of 5-10%, whilst each degree by which ambient temperature rises increases energy consumption around 6 to 8% (European Commission, 1994).

The heat extracted by cooling equipment could be used by heat exchangers to produce hot water for consumption in the hotel, providing significant energy savings. Ventilation systems are used to maintain optimal air quality in the different areas. Poor ventilation can greatly reduce comfort levels, but excessive ventilation wastes energy.

Control of air conditioning when spaces are unoccupied can give energy savings of around 30% (European Commission, 1994).

3.3 Domestic hot water (DHW)

The following measures enable great energy savings in the production of DHW without affecting comfort levels (European Commission, 1994):

- Minimisation of DHW leaks through correct maintenance of pipes and taps in showers, baths and hand basins.
- Insulation of piping and storage tanks.
- Installation of programmed taps in toilets and services in general service areas.
- Installation of low consumption systems in showers and baths without reducing quality of supply.
- Installation of hot water consumption meters in order to monitor performance of services.

3.4 Lighting

Lighting levels necessary for each zone are established in the lighting regulations of each particular country. These levels should be reached by using the most suitable lamps for each case (Table 2.10). There are some measures which can be adopted for energy savings in lighting (European Commission, 1994):

- Installation of more efficient lamps
- Change to HF electronic ballasts with fluorescent lamps
- Installation of more efficient luminaries
- Optimal use of day lighting
- Regular maintenance and cleaning of lamps
- Use of localised lighting instead of general lighting
- Installation of automatic lighting controls

Table 2.10 Recommended luminance values for each area (European Commission, 1994)

Area	**Luminance in flux**
Entrance & Hall	200-400
Reception	400-600
Stairs & corridors	100-300

Table 2.10 Recommended luminance values for each area (European Commission, 1994) (Cont')

Area	**Luminance in flux**
Dining rooms & lounges	200-400
Rooms: general lighting	200-300
Local	500-700
Bathrooms: general lighting	200-300
Local	500-700
Kitchens: general lighting	200-400
Local	500-700
Garage: stores & annexes	200-300
Machine room (general lighting)	200-300
Offices	500-900

4) Energy savings by EMS of ISO 14001

Chan (2009) identified and generalized the environmental measures, environmental management systems (EMS) of ISO 14001, undertaken by studied hotels and to evaluate the performance of these environmental measures. Three case studies were carried out to identify the green measures undertaken in ISO 14001-certified hotels. A total of 113 measures were identified, nearly half of which concern energy conservation. Results of multiple regression showed that R^2 for different utilities varied. The explanatory power of equation was strong for electricity consumption, moderate for fuel gas consumption, and weak for both gas and water consumption.

As shown in Figure 2.20 and Table 2.11, core electricity reduction practices were adopted by these three hotels. Contrary to many claims that environmental works entailed high investment, only four measures were identified as higher capital investment namely, solar control window film, sensors of air-conditioning system, key tag controlled switches and energy-saving light bulbs. It is believed that the purchase of these technologies may effectively reduce energy use in hotels.

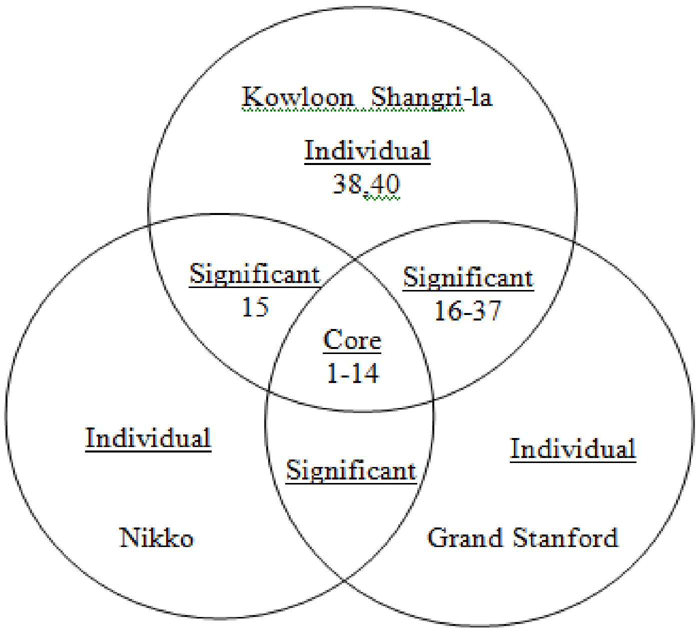

Figure 2.20 Taxonomy of electricity reduction practices (Chan, 2009)

Table 2.11 Taxonomy of electricity reduction practices (Chan, 2009)

Core	Significant	Individual
1. Fine tuning of controllers of air conditioning 2. Key tag room control 3. Solar control film 4. Energy saving light bulbs 5. Additional light switches 6. Cleaning light fittings 7. Energy saving policy 8. Main entrance door is normally closed 9. Washing machine at full load 10. Preventive maintenance programme	15. Drapes and blinds of unoccupied room are closed 16. Minimize the opening of Lifts are energy efficient freezers 17. Light bulbs and light tubes reduction 18. Internal Venetian blinds 19. Automatic setting of temperature when room is vacant 20. Checks accuracy of built-in instruments 21. Chilled water supply temperature not too low	38.Close guest floor during low occupancy to save energy 39.A boiler should be operated at percentage load of over 30% 40. Escalator will automatically stop and all driving power will be cut off if no passengers use it for a predetennined period and then remains in a standby state

Table 2.11 Taxonomy of electricity reduction practices (Chan, 2009) (Cont')

Core	Significant	Individual
11. Record all operating parameter 12. Energy saving stickers 13. Turns off ventilation and lights when not in use 14. Illumination level is not higher than necessary	22. Installed computerized energy monitor system in the chiller plant room 23. Each landing call will only be answered by one lift 24. Follow flow rate specified 25. Fine tune of pneumatic control for all AHUs and PAUs 26. ESO (energy saving operations) function in lifts 27. Examined the cooling distribution carefully 28. Installed natural cooling distribution equipment 29. Installed frequency inverter for sea-water pump 30. Lifts are energy efficient 31. Lamps and ventilation system in car park controlled by timer switch 32. Checked indoor parameters(temperatures and humidity) to ensure no over cool	

Table 2.11 Taxonomy of electricity reduction practices (Chan, 2009) (Cont')

Core	Significant	Individual
	33.Replaced the fluorescent light ballast with electronic type 34.Sea water pumps are designed for at least two chillers 35. Stop all associated water pumps when chiller is shut off 36. Strict control of maximum electrical current limit on the chiller units 37.Temperature and fan speed settings for room thermostats are correctly adjusted	

Table 2.11 shows the assessment methods pertaining to the electricity consumption before and after certification had originated from respective hotels. The averaging based on per occupied room, multiple regression and normalized performance indicator (NPI) are the methods generally adopted by hotel practitioners, scholars and building professionals, respectively. The average usage of electricity based on per occupied room was on the increase instead of declining after the adoption of the identified measures. This was mainly due to the use of the lower explanatory power variable – occupied room. In the two investigating periods, the occupancy of these three studied hotels had about 10 per cent spread in average. The lower occupancy in the post-certification period pushed up the electricity usage per occupied room. On the other hand, multiple regression results with average R^2 over 0.9 shows positive electricity saving ranging from 314,252kWh to 2,405,635kWh in average per year for Nikko and Shangri-la. For the Grand Stanford, the reverse trend of electricity savings

was due to the replacement of fuel oil fired boiler by electric heat pumps, which consumed a substantial amount of electricity in post certification period. This change in the type of energy used directly affected the predictability of the regression equation, which was built on the data using diesel oil-fired boiler (i.e. a situation without electric heat pump). The third method, NPI, appears to be relatively suitable for these three cases and shows a moderate reduction (5-25kWh in average) of electricity usage on per square meter basis.

5) Energy savings in Koh Chang clustered area, Thailand

Henzler *et al*. (2010) stated that most of the mitigation measures led to a short- to mid-term reduction of costs and emissions in 125 hotels of the Koh Chang clustered area, Thailand due to the reduction of energy use, improvement of energy efficiency and increasing use of renewable energies. The largest reduction potential lies within the electricity use of hotels and restaurants, which is responsible for about 54 % of the total emissions. With acceptable effort 20-40 % of these could be avoided within a foreseeable period if energy saving aspects are included in the planning and purchasing process as well as operations.

Table 2.11 Assessment of performance of energy-saving measures (Chan, 2009)

Electricity	**Regression (kWh)**		**Per occupied room basis (kWh)**			**Normalized performance indicator (kWh per m^2)**	
	Before certification	**Post-certification**	**Variance**	**Before certification**	**Post-certification**	**Before certification**	**Post-certification**
Nikko	19,245,482.00	18,931,230.00	314,252.00	63.60	69.76	290.91	281.43
Shangri-la	43,923,095.00	41,517,460.00	2,405,635.00	107.19	129.18	390.43	364.19
G Stanford	21,524,408.10	22,931,330.00	-1,406,921.90	64.06	70.54	254.19	248.55
Equation							
Monthly electricity consumption = 278,268 +19,003AVTemp + 4.6Guest	where R^2 = 0:923 (Nikko)						
Monthly electricity consumption = 1,304,171 + 1,609CDD + 19.6OCC	where R^2 = 0:915 (Shangri-la)						
Monthly electricity consumption = 463,008 + 781CDD + 6Cover	where R^2 = 0:948 (Grand Stanford)						
Gas	**Regression (MJ)**		**Per occupied room basis (MJ)**			**Gas usage per food cover basis (MJ per cover)**	
	Before certification	**Post-certification**	**Variance**	**Before certification**	**Post-certification**	**Before certification**	**Post-certification**
Nikko	12,836,305.00	12,639,264.00	197,041.32	44.62	46.54	7.86	9.37
Shangri-la	20,730,816.00	24,132,096.00	-3,401,280.00	54.21	75.11	15.19	18.76
G Stanford	194,995.14	248,921.00	-53,925.86	0.80	0.77	0.26[c]	0.31
Equation							
Monthly gas consumption = 489,401.4 + 2,345.7AVTemp + 1.8Cover	where R^2 = 0:384 (Nikko)						
Monthly gas consumption = 665,581.5 2 9,252AVTemp + 7.8Cover	where R^2 = 0:596 (Shangri-la)						
Monthly gas consumption = 1,625.7 + 0.24Cover	where R^2 = 0:748 (Grand Stanford)						

Table 2.11 Assessment of performance of energy-saving measures (Chan, 2009) (Cont')

Diesel oil	Regression (litres)			Per occupied room basis (litres)		Normalized performance indicator (litres per m^2)	
	Before certification	**Post-certification**	**Variance**	**Before certification**	**Post-certification**	**Before certification**	**Post-certification**
Nikko	2,054,142.00	944,200.00	1,109,942.00	4.33	3.53	19.79	14.04
Shangri-la	2,138,831.00	2,011,500.00	127,331.50	5.64	6.26	20.55	17.64
G Stanford	766,961.11	1,316,492.00	-549,530.89	5.37	4.05	21.3	14.27
Equation							
Monthly diesel oil consumption = 92,203.1 - 1,413.7AVTemp + 0.48Cover	where R^2 = 0:608 (Nikko)						
Monthly diesel oil consumption =127,217.4 - 2,617.3AVTemp + 1.8OCC	where R^2 = 0:779 (Shangri-la)						
Monthly diesel oil consumption = 43,313.1 - 1,184.3AVTemp + 0.5Cover	where R^2 = 0:742 (Grand Stanford)						

CHAPTER 3
METHODOLOGY

The survey strategy was chosen because the objective was to have a comprehensive understanding of the whole population, rather than that of a particular hotel building. Summary of research process and technical specifications of the study are shown in Table 3.1 and Fig. 3.1.

Table 3.1 Technical specifications of the study

Items	Technical specifications
Methodological procedure	- Survey by fax, post and e-mail, using self administered questionnaire - Visits and interviews either by telephone or face-to-face conversations
Universe/ Geographic scope	187 hotels recorded in the Royal Decree on Designated Buildings list, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand in 2011.
Data treatment	Computer, using statistical package SPSS
Data analysis	Correlation and linear regression

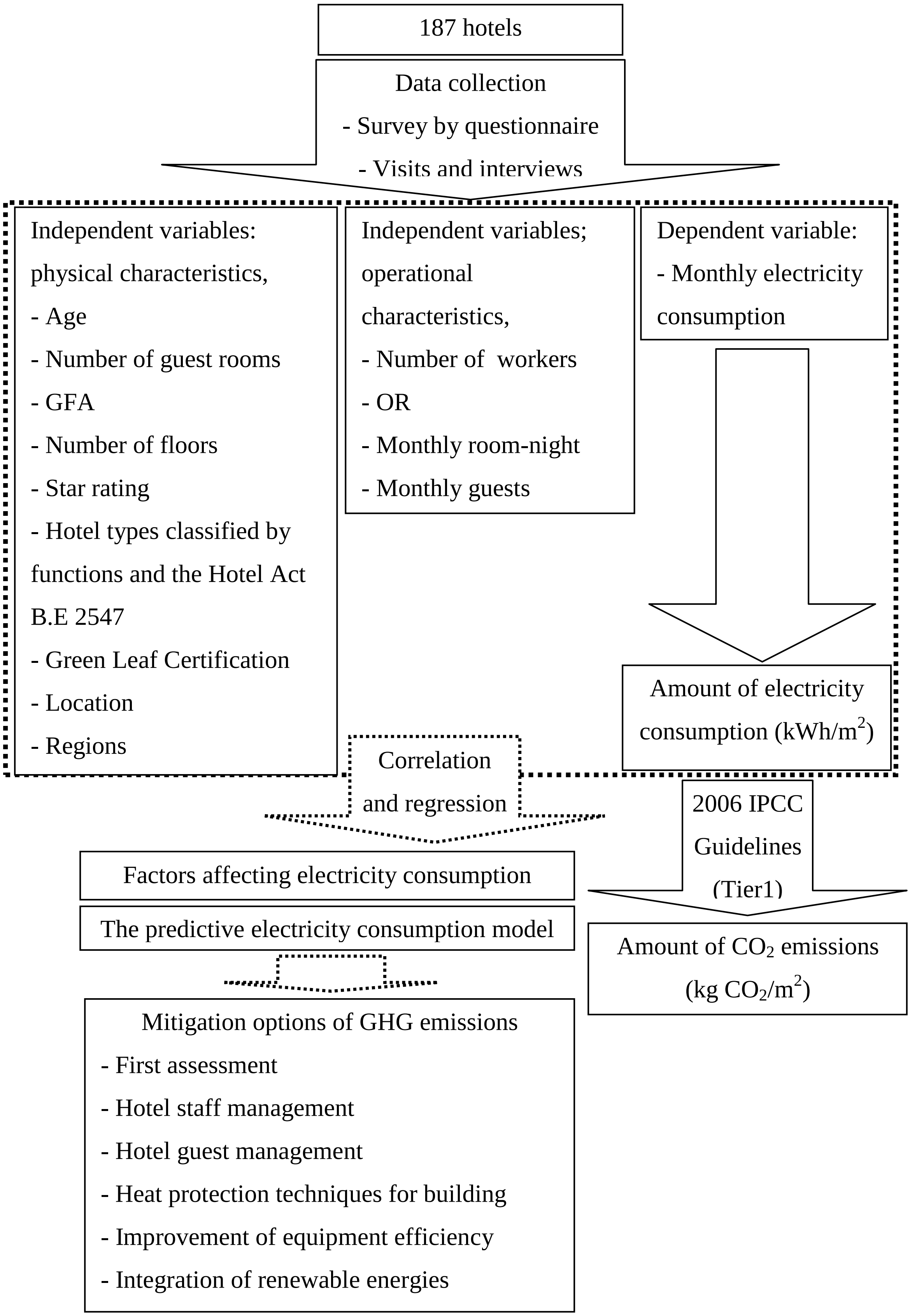

Figure 3.1 Summary of research process

3.1 Sampling

The names of hotels and their electricity consumption, as well as the 187 hotels in Thailand that was conducted with 187 hotels recorded in the list of the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand in 2011. The group of hotel contains high energy consumption hotels that consume commercial energy including electricity and steam as from January 1, to December 31 of the past year in total volume of 20 million megajoules or more of electricity energy equivalent. They were believed to have the largest potential in making energy savings.

According to Yamane (1967), the sample size needs to be adjusted as follows:

$$n = \frac{N}{1 + Ne^2}$$

where	n	is	sample size
	N	is	population size
	e	is	value from the standard normal distribution table, at the required confidence level (e.g. 90 per cent)

For this study, the population size was 187 and if 90 per cent level of confidence was required

$$n = \frac{187}{1 + 187(0.1)^2} = 65.16$$

3.2 Data collection

Although the 187 hotels recorded in the list of the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand constitute less than half of the hotel population (187 out of 7.5 thousands hotels).

3.2.1 Questionnaire

1) Questionnaire for information of hotels

The survey of sampled hotels was conducted with a carefully designed questionnaire. With the exception of the energy use data of hotels, the factors affecting the electricity consumption of those sampled hotels were retrieved from questionnaires complemented by site visits and interviews with hotel engineering personel. The data needed for this research work was determined through reviewing past studies of similar objectives. It was acknowledged that a very long questionnaire with many details was likely to deter some hotels from participating in the survey. On the other hand, a very short one will inevitably fail to collect the necessary data. Therefore, the principle was to keep it succinct but still able to grasp the essentials. Ultimately, the questionnaire was finalized as a result of careful evaluation of these factors as shown in Table 3.2. It consisted of two sections: hotel's general information and energy consumption (see Appendix A).

Table 3.2 Details of hotels required for this study

Section	Studying parameters	Relevant Unit
General information	Age	Years
	Number of guest rooms	Rooms
	GFA	m^2
	Number of floors	Floors
	Star rating	- Unclassified by the Thai Hotels Association - Classified by the Thai Hotels Association (1-star, 2-star, 3-star, 4-star or 5-star)
	Types of the hotels classified by function	- Resort hotel - Conference hotel - Commercial hotel - Residential hotel

Table 3.2 Details of hotels required for this study (Cont')

Section	Studying parameters	Relevant Unit
	Types of the hotels classified by the Hotel Act B.E 2547	- Type 1 - Type 2 - Type 3 - Type 4
	Green Leaf Certification	- Uncertified by the Green Leaf Foundation - Certificated by the Green Leaf Foundation
	Locations	- Rural or remote - Urban
	Regions	- Central region - Northern region - Southern region - Eastern region - Western region - Bangkok region - North-eastern region
	Number of workers	Workers
	OR	%
	Monthly room-nights	Room-nights
	Monthly guests	Guests
Energy consumption	Energy sources and Monthly energy consumption	- Electricity (kWh) - LPG (kg/liter) - Diesel (liter) - Other such as fuel oil (liter)

The first section contains general information and factors that may affect energy use in buildings. Some were physical characteristics, such as hotel name, age, type of the hotel classified by function and location, while others were operational characteristics, e.g. number of workers, OR, monthly guests and room-nights. The section of energy consumption, the sampled hotels were asked to provide monthly energy data, separating different energy sources such as electricity, LPG and diesel.

When it comes to questionnaire dissemination, there were many ways to choose, among which post and fax are often deemed as more formal means than the others. The questionnaire was first sent to all hotels by post. A letter addressed to the hotel's engineering manager was enclosed along with it, which helped to explain the purpose and the objectives of the survey. Two weeks after the first correspondence, a follow-up email was sent with a soft copy of the questionnaire. It was to facilitate their filling-out of the form, and also to remind them to make response. Furthermore, personal contacts in the industry were also used as a channel to reach more hotels.

2) Questionnaire for proposal of mitigation option

The most significant variables affecting electricity consumption intensity (ECI) were firstly proposed and planned for mitigation options for the reduction of GHG emissions by hotel electricity consumption. Generally, GHG mitigation plans for hotel's electricity consumption should be considered in a basis of GHG emission reduction potential of technology, the specific hotel conditions and technical feasibility.

The hotel factors affecting ECI and the predictive model were submitted to the professors of energy management in hotels for discussing and proposing mitigation for the reduction of GHG emissions from electricity consumption of hotels in Thailand. At least 3 professors of hotel engineers, energy managers and/or energy academics were visited and interviewed. The interviewing was either by telephone or face-to-face conversation.

Based on the hotel factors affecting ECI and the predictive model, the questionnaire was designed to cover various aspects pertaining to the hotel's electricity performance. It consisted of six sections: make a first assessment, involve hotel staff, involve hotel guests, protect the building from the extreme temperature, improve equipment efficiency and integration of renewable energies (Appendix B). Each section contains hotel electricity reduction mitigation as shown in Table 3.3. Each mitigation contains five indicators that is divided into 3 weighting levels as shown in Table 3.4.

Table 3.3 Details of mitigation options

Items	Mitigation
First assessment	- Establishment of management standards
	- Making a clearly defined energy use policy and an action plan
	- Energy conservation targets and investment budget setting
	- Establishment of energy management organization and employee education
	- Measurements and recording of monthly usage (electricity, gas, oil, and water) and graphs showing differences of energy intensity ($MJ/m^2/year$) from previous month of year
	- Grasp status of implementation of energy conservation
Hotel staff management	- Information to staff (management standards, energy use policy and an action plan, energy conservation targets**,** energy management organization and employee education and status of implementation of energy conservation**)**
	- Warning labels and equipment maintenance for staff and engineering staff (e.g. turn equipment off when not in use)
	- Staff education and training of energy conservation
	- Establishing a well-defined operation and maintenance program for engineering staff
	- Review of operating hours
Hotel guest management	- Information to guests (management standards, energy use policy and an action plan, energy conservation targets**,** energy management organization and employee education and status of implementation of energy conservation**)**
	- Providing leaflets to encourage guests to save energy
	- Making a encourage guests to save energy policy (discount and memento)
	- Customer feedback

Table 3.3 Details of mitigation options (Cont')

Items	Mitigation
Heat protection techniques for building	- Blocking of solar radiation on the windows (e.g. double glazing, shading curtains and light-shielding films)
	- Blocking of solar radiation on the roof (e.g. heat reflection coating, insulation and shading of roof)
	- Fresh ventilated air and ventilation control
	- Blocking of solar radiation on the building (e.g. insulation of walls)
	- Prevention of air infiltration at doors and windows (tightening the property shell, with added or better insulation, eliminating leaks, replacing windows)
	- Building waterproofing
	- Automatic control of cooling and limiting room temperature (e.g. installing motion sensors in public areas and occupancy sensors in guestrooms)
Improvement of equipment efficiency	- Use of indirect evaporative coolers instead of compression refrigeration systems
	- Use of alternative cooling technologies (e.g. ground cooling with ground-air heat exchangers, use night ventilation techniques)
	- Maintain the place around the condensing units for air-conditioning and chillers
	- Effective operation of total heat exchanger (e.g. cooling water quality control)
	- Installation of (manual or automatic) inverter device to ventilation fans
	- Automatic control of electricity in guest rooms
	- Water heater and hot water pipe insulation
	- Reduce internal loads by using of high efficiency lighting systems (e.g. installing energy efficient lighting and dimmers, installing LED (light emitting diode) exit signs, replacing the magnetic ballasts with electronic ballasts, using T5 lamps for lighting, use super metal halide fluorescent lamps)
	- Using natural day lighting whenever possible

Table 3.3 Details of mitigation options (Cont')

Items	Mitigation
Improvement of equipment efficiency	- Cleaning of lighting fixtures
	- Control of steam pressure and blow-down
Integration of renewable energies	- Solar photovoltaic integrated in buildings
	- Solar water heating

Table 3.4 Indicator weighting

Weighting of each indicator	**Indicators**				
	Energy conservation effect	**Opportunity for success**	**Cost/ Budget**	**Payback period**	**Time for action**
3	Large	Large	Low	< 2 years	Present
2	Medium	Medium	Medium	2-5 years	In 5 years
1	Small	Small	High	> 5 years	In 10 years

3.2.2 Visits and interviews

An important step in conducting a survey was to check for data integrity. In the current study, this step was taken through site visits and interviews with the hotel engineering personnel, mostly directors of the engineering department. Therefore, the ambiguities in the returned questionnaires were able to be clarified. A large percentage of the surveyed hotels were visited and their engineers interviewed either by telephone or face-to-face conversation.

3.3 Data analysis

3.3.1 Hotel characteristics

The data was collected from the reports and websites of the relevant organizations, questionnaire, visits and interviews during September 2012 to February 2013. The data was analyzed by the commercial statistical software SPSS version 16.0.

The physical and operational characteristics were presented in statistics such as maximum, minimum, average, standard deviation and percentage.

3.3.2 ECI of hotel

Due to the difference in energy used between hotels generally determined by the hotel size, hotel activities, hotel energy management and so on, the electricity consumption of each hotel was different. Therefore, ECI was chosen as the criterion to comparison hotel electricity consumption, which can then be used as the basis for comparing energy performance of different hotels.

The factors, which were significant (2-tailed) at the 0.05, were run for the regression analysis. A correlation analysis was performed to examine the relationship between these factors: age, number of guest rooms, GFA and the number of floors, star rating, types of hotel that were classified by hotel functions and the Hotel Act B.E 2547, Green Leaf Certification, locations, region, number of workers, OR, the monthly average guests, room-nights and electricity consumption of the hotel in kWh (Fig. 3.2). The most significant factors were chosen as the primary normalization factor to construct ECI. Then ECI unit depends on normalized factor unit. For examples, they were in kWh/m^2, kWh/guest room and kWh/room-night.

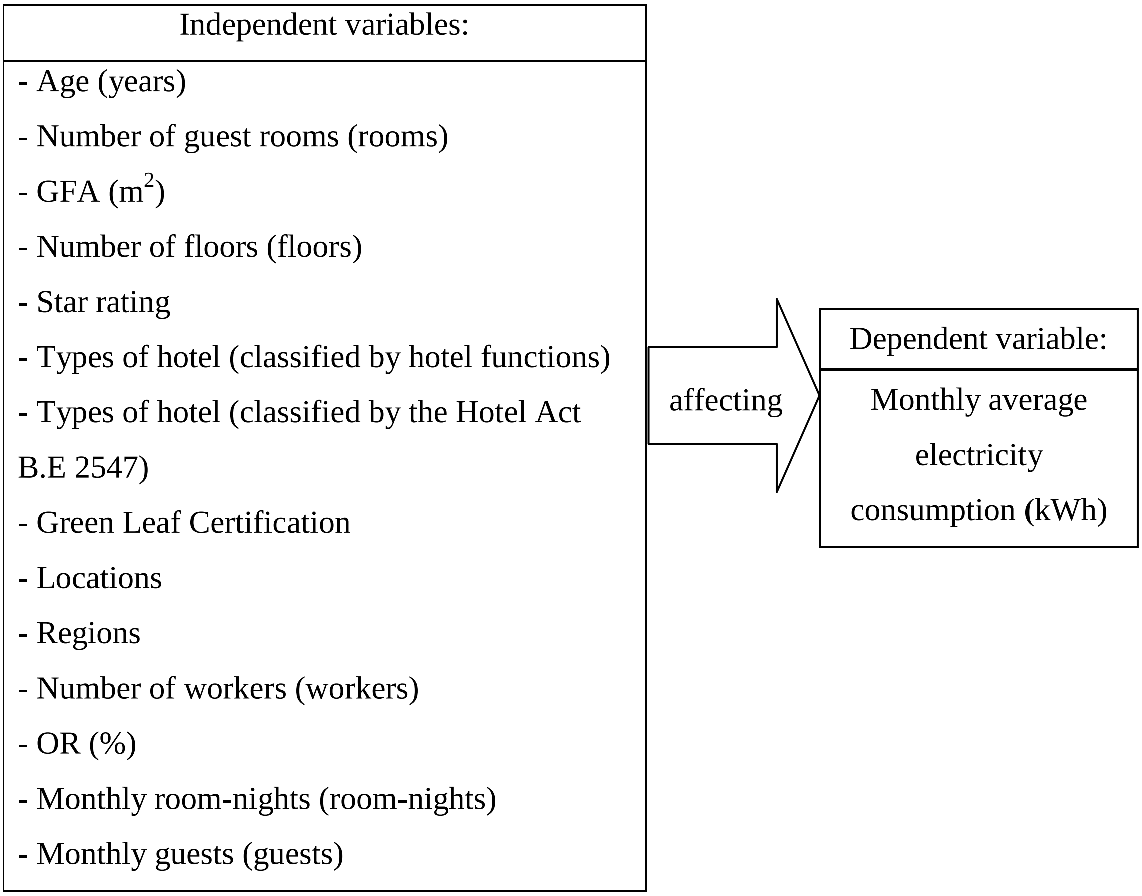

Figure 3.2 Relation between independent variables and electricity consumption

3.3.3 GHG calculations

In terms of calculating GHG emissions produced by electricity consumption, used The IPCC Energy – Approach Tier 1 when activity data is amount of electricity consumption (kWh) and emission factors of TGO is 0.5477 tCO_2/MWh (Thailand Greenhouse gas Management Organization: TGO, 2012). In this study, GHG emissions were only calculated from CO_2. The CO_2 emissions indicators (CEI) unit depends on normalized factor units. For examples, they were in kg CO_2/m^2, kg CO_2/guest room and kg CO_2/room-night.

3.3.4 Factors affecting electricity consumption and the predictive model of electricity consumption

Hotel factors affecting electricity consumption were investigated from secondary energy drive, the previous factor had an influence on ECI. Therefore, a regression analysis has been performed to examine the influences of these factors on the ECI in kWh/m^2, kWh/guest room and kWh/room-night.

The predictive model was determined based on a stepwise linear regression procedure with ECI as the dependent variable and the previous factors as potential independent variables.

3.3.5 Proposal of mitigation option

The data was collected from the questionnaire, visits and interviews were presented in statistics such as averages, and percentages.

CHAPTER 4
RESULTS

4.1 Sampled hotels

The questionnaires of the hotel's information were sent to 187 hotels recorded in the list of the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand. As a result, complete data sets were received from 63 hotels. This was about 33.69 per cent of the 187 hotels recorded in the list. When compared to the sample size determined in the sampling process, it was a bit short if 90 per cent confidence level was required, 65 hotels.

In many studies of a similar nature and with similar objectives, no sampling process or response rate was reported, probably because the sampling had been done out of convenience rather than systematically. For the others, their response rates were basically comparable to that of the current study. Priyadarsini *et al.* (2009) collected complete energy consumption data from 29 (out of 102) Singapore hotels, hence having a response rate of 28 per cent. Shiming and Burnett (2002) reported a study of energy use in 16 quality hotels, which were 20% of the total hotels in Hong Kong and a detailed analysis of energy use in only one of the 16 hotels. The other studies include 3 from 67 Mauritius hotels (4.48 % of the total hotels) (Mohee and Bhurtun, 2012), 80 from 222 Jordan hotels (36.4 3% of the total hotels) (Ali *et al*., 2008), 51 from over 3,700 Australia hotels (1.38% of the total hotels) (Commonwealth of Australia, 2002) and 25 from 116 Fiji accommodations (213.43% of the total hotels) (Becken, 2005).

4.2 Hotel characteristics

4.2.1 Hotel building physical characteristics

The physical characteristics were the hotels' ages, number of guest rooms, number of floors, GFA, star rating, Green Leaf Certification, locations, regions, hotel types classified by hotel functions and the Thailand Hotel Act B.E 2547. The ages of sampled hotels range from 1 to 45 years and the average of age was 20 years. The number of guest rooms ranged from 31 to 4,100 rooms and the average of guest rooms was 378 rooms. The number of floors ranged from 1 to 61 floors and the average of floors was 14 floors. The gross floor areas (GFA) were between 6,160 and 408,457 m^2. The average of GFA was 39,667.54 m^2. Characteristics of 63 Thailand's sampled hotels in 2011 were shown in Appendix C. Minimum, maximum and average of characteristics, hotel ages, number of guest rooms, number of floors and GFA, of 63 Thailand's sampled hotels in 2011 a shown in Table 4.1.

Table 4.1 Minimum, maximum and average of characteristics of 63 Thailand's sampled hotels in 2011

Hotel characteristics	**Min**	**Max**	**Mean**	**Std. Deviation**
Age (years)	1	45	20.35	9.29
Number of guest rooms (rooms)	31	4,100	378.02	515.69
GFA (m^2)	6,160.00	408,457.00	39,667.57	53,614.68
Number of floors (floors)	1	61	13.71	11.68
Number of workers (workers)	35	1,300	325.83	241.32
Occupancy rates (OR) (%)	23.10	82.47	57.33	16.14
Monthly average room-nights (room-night)	237.17	42,814.75	6,139.43	5,878.27
Monthly average number of guests (guests)	359.17	85,629.50	11,575.91	11,160.88

The star ratings of 63 Thailand sampled hotels were classified into 4 types: hotels that were not classified by the Thai Hotels Association, 3-star, 4-star and 5-star hotels. The majority was the unclassified hotels (28 hotels) (Table 4.2 and Fig. 4.1).

Table 4.2 Some characteristics of 63 Thai sample hotels in 2011

Hotel characteristics	Number of hotels	Percentage
Star rating		
Unclassified	28	45
3-star	4	6
4-star	17	27
5-star	14	22
Main function		
Resort hotel	17	27
Conference hotel	16	25
Commercial hotel	28	45
Residential hotel	2	3
The Hotel Act B.E 2547		
Type 3	31	49
Type 4	32	51
Green Leaf Certification		
Uncertified	28	44
Certificated	35	56
location		
Rural	25	40
Urban	38	60
Regions		
Central	2	3
Northern	8	25
Southern	16	13
Eastern	6	10
Western	2	3
Bangkok	24	38
North-eastern	5	8

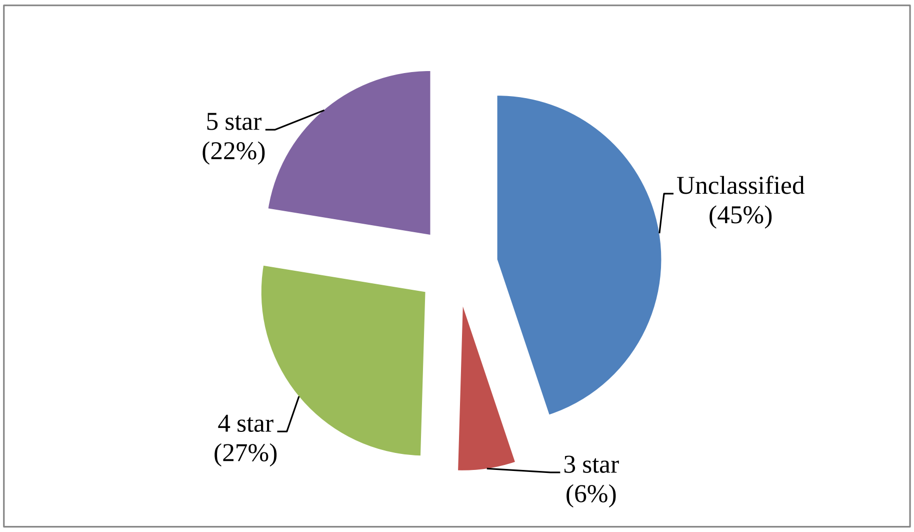

Figure 4.1 Star rating of sampled hotels

The 63 sampled hotels were classified by hotel functions, comprised of resort hotel, conference hotel, commercial hotel and residential hotel. The majority of hotels were of the commercial type (26 hotels) (Table 4.2 and Fig. 4.2).

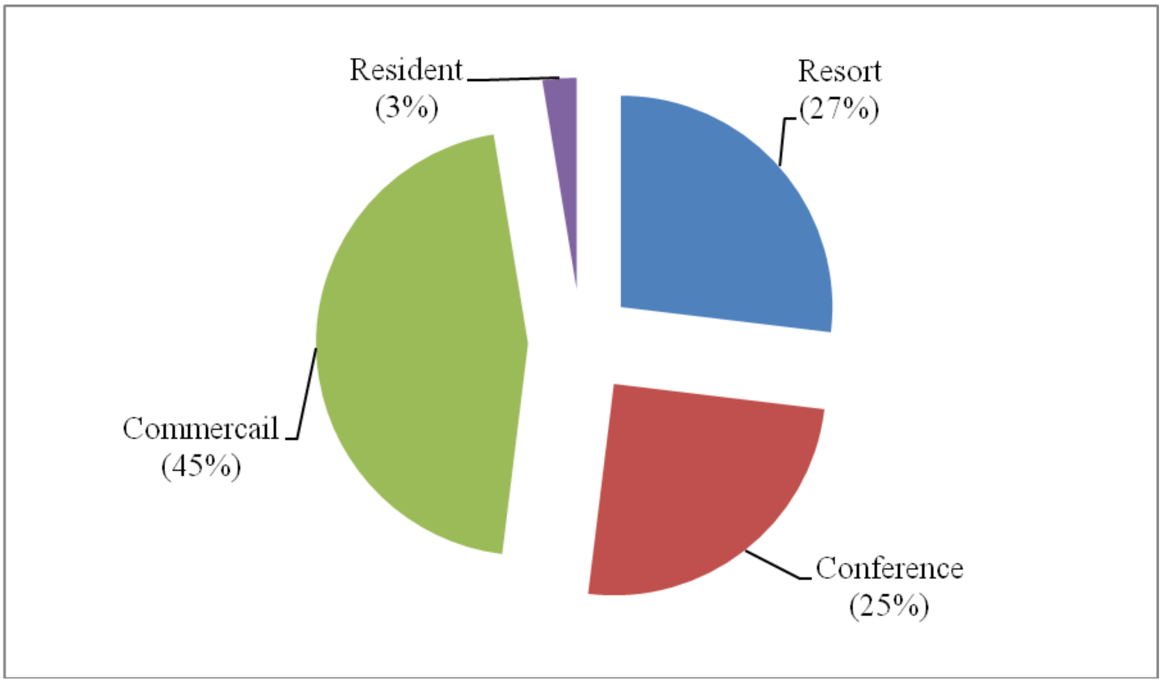

Figure 4.2 Types of sampled hotels classified by hotel functions

The Hotel Act B.E 2547 classifies hotels into 4 types. Type 1: hotels providing accommodation only. Type 2: hotels providing accommodation and catering or restaurant services. Type 3: hotels providing accommodation, catering or restaurant services, conference rooms or entertainment venues. Type 4: hotels providing accommodation, catering or restaurant services, conference rooms and entertainment venues. The 63 sampled hotels classified by the Hotel Act B.E 2547 were separated into 2 types: Type 3 and Type 4 hotels. The 32 sampled hotels were of Type 4 (Table 4.2 and Fig. 4.3).

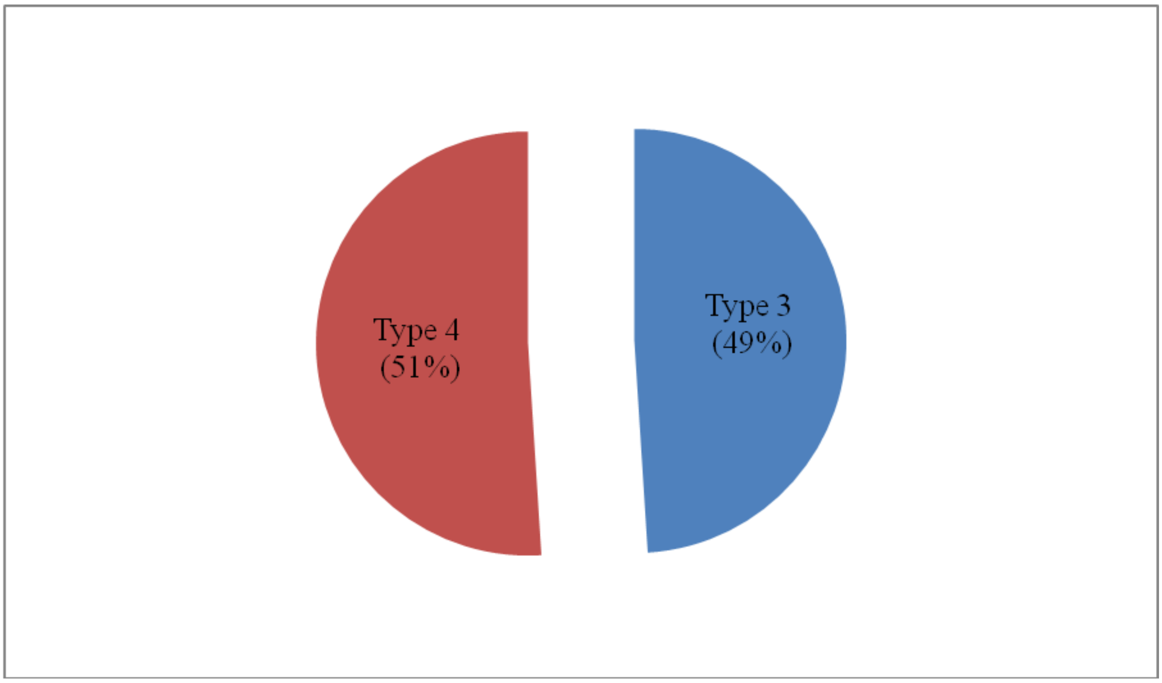

Figure 4.3 Types of sampled hotels classified by the Hotel Act B.E 2547

When classified by Green Leaf Certification, the majority was certificated by the Green Leaf Foundation (35 hotels). The rest was 44% uncertified, 28 hotels (Table 4.2 and Fig. 4.4).

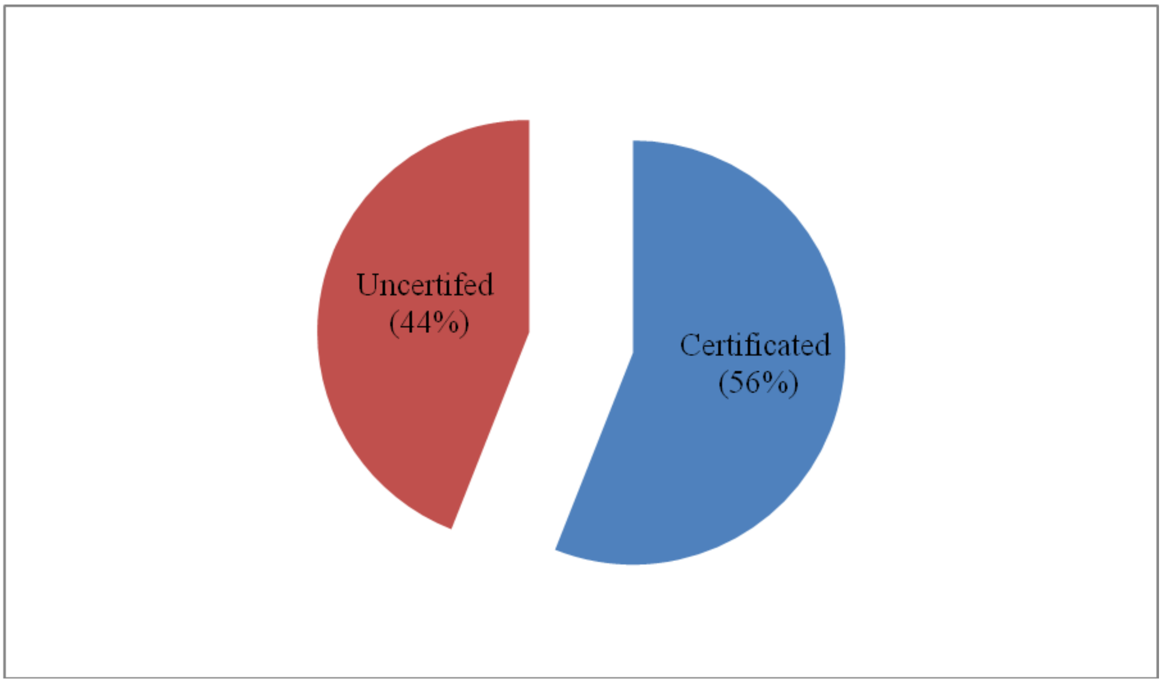

Figure 4.4 Green Leaf certification of sampled hotels

The 63 sampled hotels were classified by regions, which were Central, Northern, Southern, Eastern, Western, Bangkok and North-eastern. The majority of the hotels are located in Bangkok (24 hotels) (Table 4.2 and Fig. 4.5). When classified by location, rural and urban, the majority hotels located in urban areas (38 hotels) (Table 4.2 and Fig. 4.6).

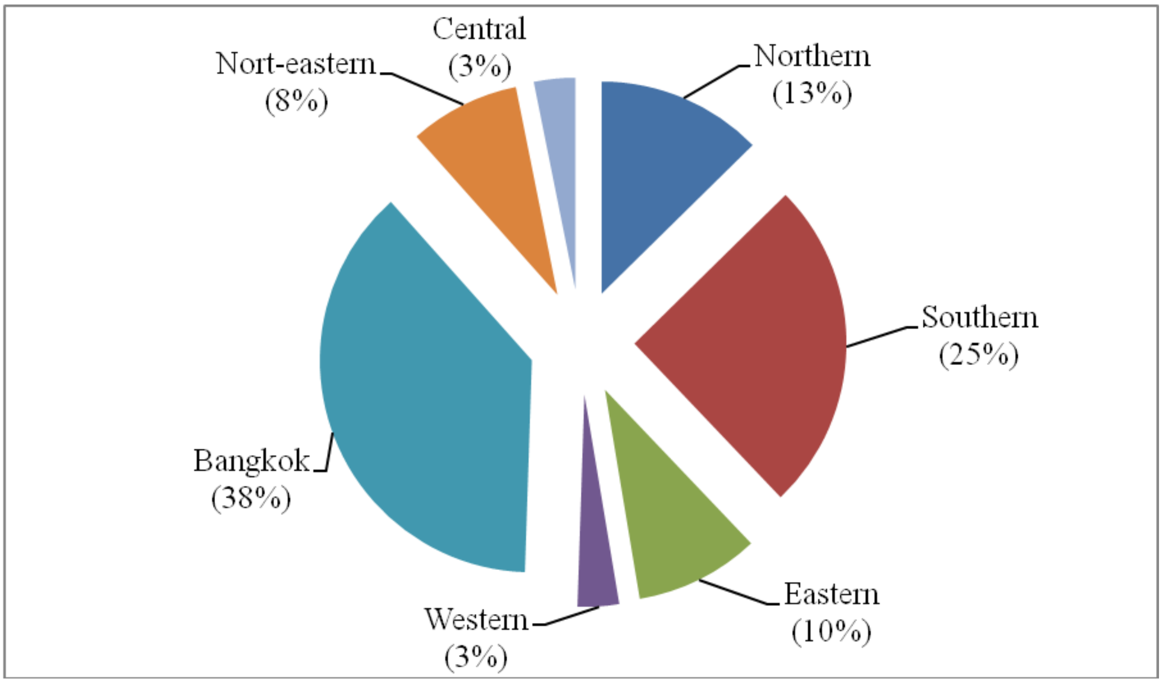

Figure 4.5 Regions of sampled hotels

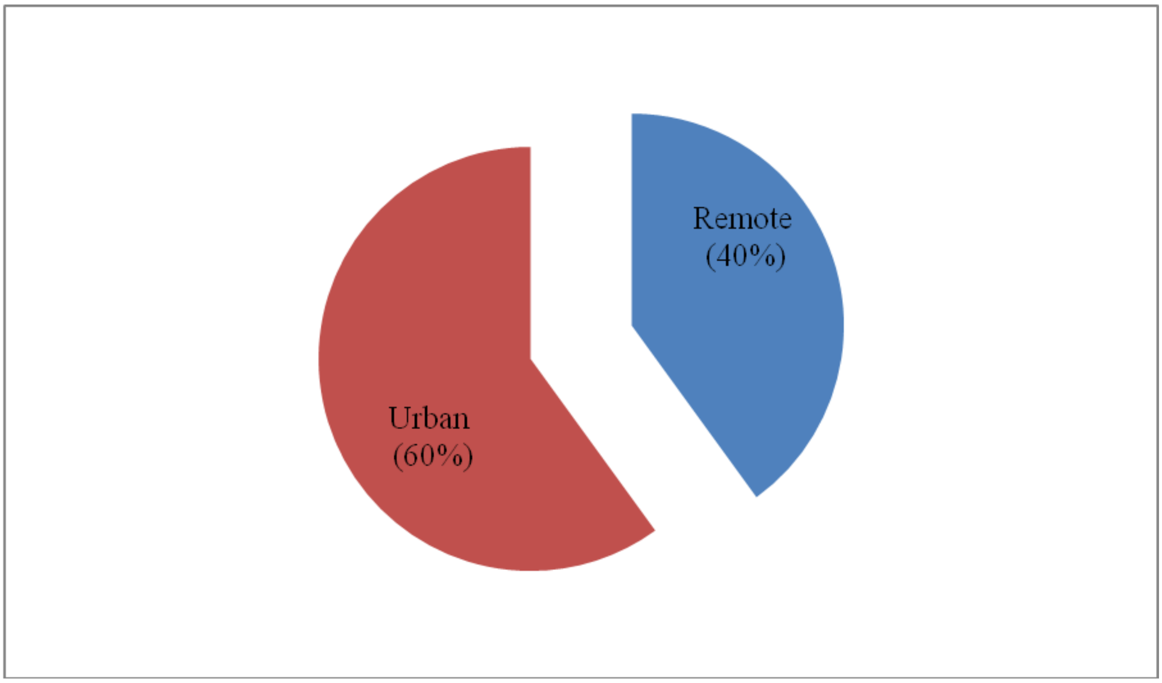

Figure 4.6 Locations of sampled hotels

4.2.2 Hotel operational characteristics

The hotel operational characteristics were the number of workers, OR, monthly guests and monthly room-nights. The number of the hotel's workers ranged from 35 to 1,300 workers with the average of 326 workers. The hotel's OR were in the range of

23.10 to 82.47% with the average of 57.33%. The number of monthly room-night ranged from 237 to 42,815 room-nights with the average of 6,139 room-night. The monthly number of guests ranged from 359 to 85,630 guests with the average of 11,576 guests. Characteristics of 63 Thailand sampled hotels in 2011 a shown in Appendix B. Minimum, maximum and average workers, OR, monthly guest numbers and monthly room-nights of 63 Thailand sampled hotels in 2011 a shown in Table 4.1.

This indicates that the majority of the sampled hotels in Thailand were large commercial hotels providing accommodation, catering or restaurant services, conference rooms and entertainment venues.

4.3 Hotel electricity consumption and electricity consumption intensity (ECI)

4.3.1 Hotel electricity consumption

Table 4.3 and Appendix C present the energy sources and energy used in the 63 Thai sampled hotels in 2011. The energy sources of the sampled hotels in Thailand a electricity and fossil fuel (LPG, diesel and fuel oil). Electricity was the primary energy source, which was used to power HVAC, lighting, vertical transportation, and almost all equipment. Like electricity, LPG was also consumed in all the sampled hotels, mainly for cooking, but there was not recorded in 7 hotels. Diesel and fuel oil were used in the hotels for one or all of the following purposes: hot water and steam production, standby electricity generation. The later incurs very little consumption, as diesel is only consumed in regular (monthly, or even quarterly) test-runs of the emergency generator to ensure it works when in need. Diesel was consumed in 61 hotels, but there was not recorded in 10 hotels while fuel oil was used in 22 hotels. On the other hand, the 63 hotels report on electricity consumption while 56, 51, and 22 hotels could report on LPG, diesel, and fuel oil consumption.

Table 4.3 Energy used of sampled hotels in 2011

Energy use (MJ/month)		No. of sampled hotel	Sum	Min	Max	Mean	Std. Deviation
Electricity		63	209,146,195.18	215,400.00	20,943,168.00	3,319,780.88	3,629,265.66
Fossil fuel	LPG	56	51,296,874.73	12,306.35	13,627,763.17	916,015.62	2,127,920.33
	Diesel	51	3,645,124.68	54.63	1,361,514.09	71,473.03	223,849.97
	Fuel oil	22	25,636,803.85	4,953.60	6,656,400.00	1,165,309.27	1,459,806.69

Table 4.3 presents the monthly average electricity consumption of the 63 hotels ranked from 215,400.00 to 20,943,168.00 with an average of 3,319,780.88 MJ. The monthly average LPG consumption of the 56 hotels ranked from 12,306.35 to 13,627,763.17 with the average of 916,015.62 MJ. The monthly average diesel consumption of the 51 hotels ranked from 54.63 to 1,361,514.09 with the average of 71,473.03 MJ. The monthly average fuel oil consumption of the 56 hotels ranked from 4,953.60 to 6,656,400.00 with an average of 1,165,309.27 MJ.

Table 4.4 Energy used by 32 Thailand sampled hotels consuming electricity, LPG, and diesel in 2011

Energy use (MJ/month)		**Sum**	**Min**	**Max**	**Mean**	**Std. Deviation**
Electricity		106,520,723.67	438,084.00	11,808,900.00	3,328,772.61	3,170,501.15
Fossil fuel	LPG	36,750,030.77	14,064.40	13,627,763.17	1,148,438.46	2,605,204.97
	Diesel	1,845,181.13	54.63	748,431.00	57,661.91	152,587.21
Monthly Fossil fuel		38,595,211.90	15,157.00	13,774,144.26	1,206,100.37	2,619,885.37
Monthly energy used		145,115,935.57	476,338.80	23,620,764.66	4,534,872.99	5,149,821.75

Table 4.5 Energy used by19 Thailand sampled hotels consuming electricity, LPG, diesel, and fuel oil in 2011

Energy use (MJ/month)		**Sum**	**Min**	**Max**	**Mean**	**Std. Deviation**
Electricity		85,188,650.39	411,174.00	20,943,168.00	4,483,613.18	4,855,387.03
Fossil fuel	LPG	8,163,368.77	12,306.35	2,778,547.80	429,650.99	599,987.74
	Diesel	1,799,943.55	342.35	1,361,514.09	94,733.87	313,341.11
	Fuel oil	23,741,434.92	4,953.60	6,656,400.00	1,249,549.21	1,547,737.15
Monthly Fossil fuel		33,704,747.24	189,355.77	7,124,251.02	1,773,934.07	1,612,755.59
Monthly energy used		118,893,397.63	899,994.72	28,067,419.02	6,257,547.24	6,265,312.59

According to the received data, the majority of the hotels consume electricity, LPG and diesel (Hotel A), accounting for 63% of the total hotels. Second comes the hotels that consume electricity, LPG, diesel and fuel oil (Hotel B), accounted for 33%. The rests are the hotels that consume only electricity and LPG (Hotel C) and electricity, LPG and fuel oil (Hotel D). The percentage of energy sources from the hotel showed in Fig. 4.7.

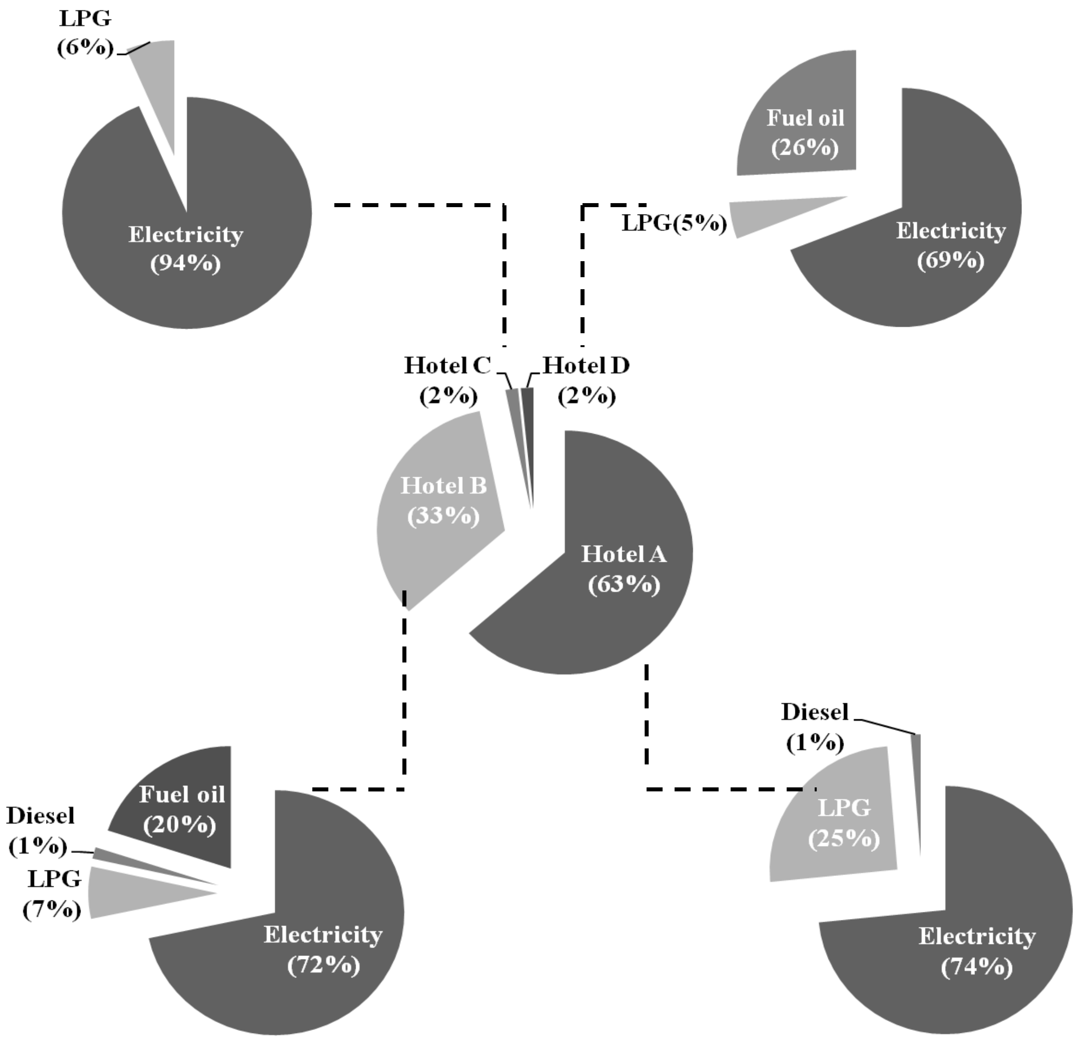

Figure 4.7 The percentage of energy sources

40 out of the 63 hotels (Hotel A) used electricity, LPG, and diesel, but there was completely recorded in 32 hotels. Monthly average energy used of 32 hotels were 4,534,872.99 MJ (Table 4.4). Monthly average energy used of 21 hotels (Hotel B) that consumed electricity, LPG, diesel and fuel oil but there was completely recorded in 19

hotels were 6,257,547.24 MJ (Table 4.5). Monthly average energy used of a hotel that consumed electricity and LPG (Hotel C) was 3,006,416.14 MJ. Monthly average energy used of a hotel that consumed electricity, LPG and fuel oil (Hotel D) was 229,866.24 MJ. The percentage of energy sources from the hotel are shown in Fig. 4.7.

It was observed that electricity is the main energy source consumed by hotels in Thailand, ranging from 69% to 94%. Electricity, the primary energy source, is used to power Heating, Ventilation and Air-conditioning (HVAC), lighting, escalators, elevators, and other electric equipments. Like electricity, LPG is also consumed in all sampled hotels, mainly for cooking. Diesel and fuel oil are used in the hotels for the following purposes: hot water and steam production, and standby electricity generation. The latter incurs very little consumption, as diesel is only consumed in regular (monthly, or even quarterly) test-runs of the emergency generator to ensure it works when in need. Similar to the electricity consumption in worldwide hotels, the percentages of electricity consumption compared to the total energy consumption were the highest shares, as shown in Table 4.6.

Table 4.6 Energy sources and shares of electricity consumption in hotels worldwide

Studies	**Energy sources**							**Shares of electricity (%)**
	electricity	**Natural gas**	**LPG**	**Diesel**	**Fuel oil**	**Wood**	**Coal**	
Singapore (Priyadarsini *et al.*, 2009)	✓	✓						91
	✓	✓		✓				77
Hong Kong (Shiming and Burnett, 2002)	✓	✓		✓				73
Mauritius (Mohee and Bhurtun, 2012)	✓	✓		✓				65.67
New Zealand (Becken, 2000)	✓	✓	✓		✓	✓	✓	73.41

Table 4.6 Energy sources and shares of electricity consumption in hotels worldwide (Cont')

Studies	Energy sources							Shares of electricity (%)
	electricity	Natural gas	LPG	Diesel	Fuel oil	Wood	Coal	
Greece (Xydis *et al*, 2009)	✓			✓				68.33
Saudi Arabia (Alamoudi, 2009)	✓			✓	✓			89[a]
	✓			✓	✓			75[b]
	✓			✓	✓			76[c]
	✓			✓	✓			66[d]
Australia (Commonwealth of Australia, 2002)	✓	✓	✓	✓				66

Note: a is 5-star rating
b is 4-star rating
c is 3-star rating
d is 2-star rating

Interestingly, the share of electricity consumption in Saudi Arabia's hotels were affected by the star rating of the hotels. The higher star-rating hotels had larger electricity shares than the lower star-rating hotels. In contrast to the Saudi Arabia's hotels, the shares of electricity consumption in Thailand's hotels decreased as the star rating increased. This is because the higher star-rating hotels mostly provide banquet with international cuisine, fitness, sauna and spa which consume additional LPG and fuel oil for cooking and heating hot water. Even though, the share of electricity in the higher star-rating hotels decreased, their annual electricity consumption in MJ per square GFA increased. The four and five-star hotels consumed electricity more than 100 $MJ/m^2/year$. It is incredible that the annual electricity consumption of five-star hotels was approximately three times higher than that of three-star hotels. Accordingly, the energy conservation should be focused on the hotels that have higher star-rating.

Despite the fact that the higher star-rating hotels need to provide luxury and best services to their customers, the hotels should take more consideration on energy conservation as well

4.3.2 Hotel energy end-use of electricity consumption

Only 34 of the 63 hotels were able to provide a reasonably detailed breakdown of energy end-use. Fig. 4.8 presents the major electricity consumption of the 34 Thailand hotels was air conditioning (56.46%), followed by lighting (17.93%), lift and escalators (8.96%), water heating (8.53%) and fan and pumps (7.95%)

Electricity was the primary energy source used to power HVAC in tropical climate hotels. The tropical hotels need high electricity for satisfying guests. Thailand is in a tropical climate. Likely, Hong Kong's climate is subtropical and monsoonal with cool dry winters and hot wet summers (Wikipedia, 2013a). Both of them need electricity for cooling also.

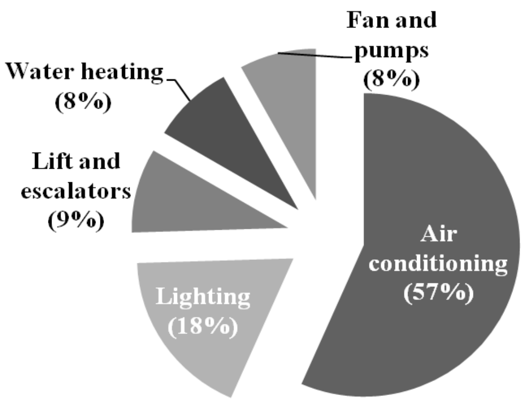

Figure 4.8 The percentage of energy end-use in 34 Thailand hotels

Hotel energy end-use in Thailand is similar to the averaged percentage breakdown of the total electricity use in the 16 Hong Kong hotels. Air conditioning (45%) consumed the most electricity, followed by miscellaneous (31%), lighting (17%), and lift and escalators (7%) (Shiming and Burnett, 2002). Besides, energy end-use from air conditioning of Cairns Hilton hotel in Australia was also the most electricity consumption (37.4%) (Commonwealth of Australia, 2002). Cooling is the main end-use of electricity consumption from 125 hotels in the Koh Chang designated area, Thailand, rooms’ cooling was 45 % and refrigerators’ cooling was 6% (Adelphi consult, 2009).

4.3.3 ECI of hotel

Due to the differences in electricity consumption between hotels generally determined by the hotel size, hotel activities, hotel energy management and so on, the electricity consumption of each hotel was different. Therefore, energy used intensity was chosen as the criterion for comparing hotel electricity consumption.

Correlation analyses were conducted to correlate hotel electricity consumption with the primary determinants (Appendix D). Tables 4.7 - 4.9 show that the number of guest rooms, GFA, number of floors, workers, Monthly average room-night, and number of guests correlate to electricity consumption and total energy use. Table 4.7 showed that the number of guest rooms, floors and workers, the monthly average number of guests and room-nights and GFA were significant at the 0.01 level; a correlations, Bangkok (dummy variable, 1 for hotels located in Bangkok, and 0 for hotels located in other regions) was significant at the 0.05 level, while the others were insignificant.

Table 4.7 Pearson correlation between monthly electricity consumption of 63 hotels and 30 independent variables

Variables	Pearson Correlation
Number of guest rooms	.743**
GFA	.818**
Number of floors	.520**
Bangkok	.269*
Number of workers	.804**
Monthly average room-night	.771**
Monthly average number of guests	.770**

Note: * Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4.8 Pearson correlations between energy uses of 32 hotels consuming electricity, LPG, and diesel and 30 independent variables

Variables	**Pearson Correlation**	
	Electricity consumption (MJ)	**Energy use (MJ)**
Age	.503**	.473**
Number of guest rooms	.556**	.696**
GFA	.756**	.719**
Number of floors	.473**	.546**
5-star	.350*	.434*
Number of workers	.708**	.787**
Monthly average room-night	.604**	.641**
Monthly average number of guests	.679**	.728**

Note: * Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4.9 Pearson correlations between energy uses of 19 hotels consuming electricity, LPG, diesel, and fuel oil and 30 independent variables

Variables	**Pearson Correlation**	
	Electricity consumption (MJ)	**Energy use (MJ)**
Number of guest rooms	.883**	.909**
GFA	.891**	.911**
Number of floors	.544*	.473*
4-star	.608**	.613**
Bangkok	.470*	-
Number of workers	.906**	.939**
Monthly average room-night	.889**	.920**
Monthly average number of guests	.885**	.910**

Note: * Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

GFA had the best correlation with the hotel monthly average electricity consumption, followed by the number of workers, the monthly average room-night, monthly average number of guests, number of guest rooms, number of floors and hotels located in Bangkok. Regression analyses were conducted to correlate hotel electricity consumption with the primary determinants. The plot of relation between hotel monthly average electricity consumption and GFA are shown in Fig. 4.9. The plots of electricity consumption against other capacity indicators were very similar. However, that the regression models and R^2s were different. Hence, they were not presented here.

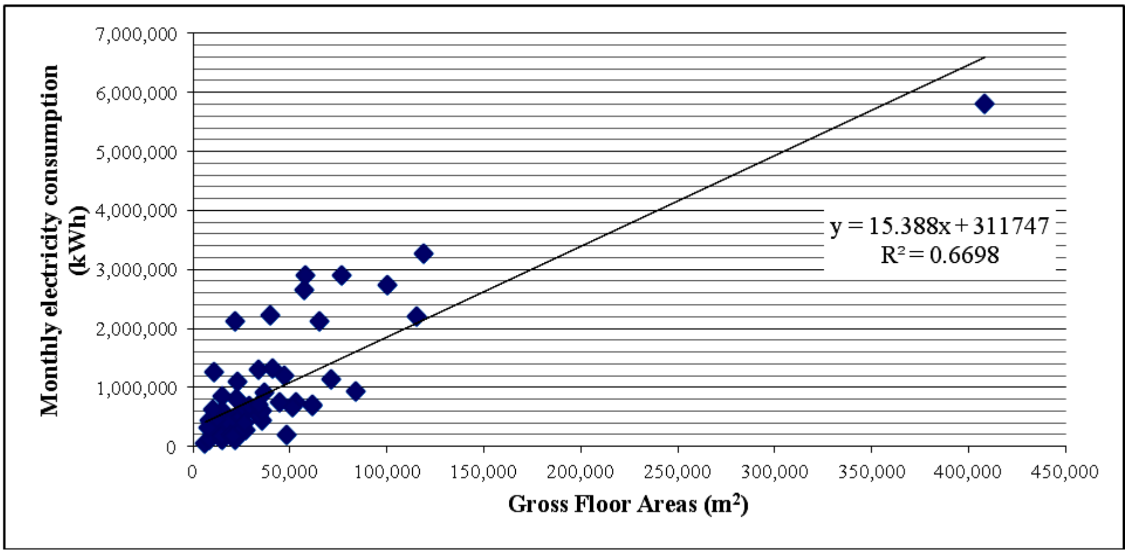

Figure 4.9 Monthly average electricity consumption (kWh) vs. GFA (m^2)

In the literatures, Thai hotels' factors affecting electricity consumption were similar to those in Singapore, Australia Japan, Hong Kong, USA and Europe. The factor affecting energy use in Singapore, Australia Japan and Europe hotels was GFA (Priyadarsini *et al.*, 2009, Commonwealth of Australia, 2002, Bohdanowicz and Martinac, 2007 and The Energy Conservation Center, 2009). The relationship between energy consumption of 51 Australia hotels in 2000 and hotel floor area is not particularly strong for accommodation hotels and resorts but the relationship is much stronger for business hotels (Commonwealth of Australia, 2002). In 29 Singapore hotels, hotel floor area correlated with total energy (R^2 = 0.90) and electricity (R^2 = 0.86). The number of workers and guest rooms correlated with electricity (R^2 = 0.81 and 0.72) in 29 Singapore hotels (Priyadarsini *et al.*, 2009). The number of room-nights affecting energy use in hotels of Singapore, Europe, Trang Province in Thailand and San Francisco, California in USA (Priyadarsini *et al.*, 2009, Bohdanowicz and Martinac, 2007, Treerattanapan, 2011 and Kammerud *et al*., 2012). In Hong Kong hotels, the number of guests was found to be a factor affecting energy use in hotels (Shiming and Burnett, 2002).

Although the number of workers and guests had good correlation with hotel electricity consumption, they were controllable inputs that should not be normalized if it were found to have a significant influence. Hence, the number of workers and guest were not chosen as the primary normalization variable. Not surprisingly, GFA, a uncontrollable input, had very good correlation with the hotel electricity use. Traditionally, floor area is the primary normalization variable for comparing building energy use. In additionally, the number of guest rooms and room-nights can often be used as an alternative in the hotel industry. Therefore, GFA, number of guest rooms and number of room-nights were chosen as the primary normalization variables to construct ECI, which can then be used as the basis for comparing energy performance of different hotels.

Table 4.10 ECI of 63 Thailand sampled hotels monthly in 2011

ECI	Min	Max	Mean	Std. Deviation
Electricity consumption in kWh/m^2	4.23	116.72	26.82	20.27
Electricity consumption in kWh/guest room	356.32	20,058.39	2,934.20	3,220.24
Electricity consumption in kWh/room-night	23.59	2,621.79	191.03	332.38

Table 4.10 and Appendix E show the energy used intensity from electricity consumption of 63 Thai sampled hotels in 2011**.** The energy used intensity from electricity consumption ranged from 4.23 to 116.72 kWh/m^2/month, 356.32 to 20,058.39 kWh/guest room/month and 23.59 to 2,621.79 kWh/room-night/month with the average of 26.82 kWh/m^2/month, 2,934.20 kWh/guest room/month and 191.03 kWh/room-night/month.

In a later study, the Commonwealth of Australia (2002) presented a monthly average electricity consumption of 18.24 kWh/m^2/month in 51 Australia hotels in 2000. Bohdanowicz and Martinac (2007) investigated the monthly average electricity consumption of 73 Hilton hotels and 111 Scandic hotels in Europe. The hotels monthly average electricity consumption was found to be 14.97 and 11.47 kWh/m^2/month, respectively. In study of the Hong Kong hotels, Shiming and Burnett (2002) reported 22.23 kWh/m^2/month. The monthly average electricity consumption of 29 Singapore hotels was 35.58 kWh/m^2/month. Some literature reported that monthly average electricity consumption of a small hotel in Trang Province, Thailand was 3.41 kWh/m^2/month (Treerattanapan, 2011).

As discussed previously, electricity is the primary energy source used to power HVAC the in tropical climate hotels. The Mediterranean and temperate climate hotels need lower electricity consumption than in the hotels located in tropical. Thailand and Singapore are in a tropical climate. Likely, Hong Kong's climate is subtropical and monsoonal with cool dry winters and hot wet summers (Wikipedia, 2013a). Electricity consumption per m^2 of Thailand hotels was similar to Singapore and Hong Kong hotels. Australia belong to the temperate zone while the climate of Europe is of a temperate, continental nature, with a maritime climate prevailing on the western coasts and a Mediterranean climate in the south (Wikipedia, 2013b and Wikipedia, 2013c). Not surprisingly, the monthly average electricity consumption in Thailand hotels was higher than Australia and European hotels. Due to a small hotel in Trang, Thailand has only 2,288 m^2, 30 air-condition rooms and 38 electricity fan rooms, its monthly average electricity consumption was lower than 63 hotels lit in the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand..

4.4 GHG emissions from electricity consumption in hotels

Based on the energy use data, in terms of calculating GHG emissions produced by energy use by using the IPCC Energy – Approach Tier 1. The activity data in this study was amount of electricity, LPG, diesel and fuel oil consumption. Emission factor of TGO, 0.5477 (tCO_2/MWh) was used for emissions produced by electricity calculation (TGO, 2012). Conversion factors of LPG, diesel and fuel oil were 0.23

kgCO_2/kWh or 1.65 kgCO_2/liter, 2.68kgCO_2/liter and 3.00 kgCO_2/liter, respectively (Thomas *et al.*, 2000).

The CO_2 emissions of energy use from 63 sampled hotels were estimated (Table 4.11 and Appendix E). The monthly average CO_2 emissions from electricity consumption of the 63 hotels ranked from 32,770.72 to 3,186,270.31 with the average of 505,067.77 kgCO_2. The monthly average CO_2 emission from LPG consumption of the 56 hotels ranked from 789.55 to 874,330.00 with the average of 58,769.73 kgCO_2. The monthly average CO_2 emission from diesel consumption of the 51 hotels ranked from 4.02 to 100,188.30 with the average of 5,259.41 kgCO_2. The monthly average CO_2 emission from fuel oil consumption of the 56 hotels ranked from 360.00 to 483,750.00 with the average of 86,051.99 kgCO_2.

Table 4.11 CO_2 emissions from energy use of sampled hotels in 2011

Energy use (kgCO_2/month)		**No. of sampled hotel**	**Sum**	**Min**	**Max**	**Mean**	**Std. Deviation**
Electricity		63	31,819,269.81	32,770.72	3,186,270.31	505,067.77	552,152.45
Fossil fuel	LPG	56	3,291,104.80	789.55	874,330.00	58,769.73	136,523.11
	Diesel	51	268,229.96	4.02	100,188.30	5,259.41	16,472.21
	Fuel oil	22	1,893,143.87	360.00	483,750.00	86,051.99	106,026.32

Table 4.12 CO_2 emissions of 32 Thailand sampled hotels consumed electricity, LPG, and diesel in 2011

Energy use ($kgCO_2$/month)		Sum	Min	Max	Mean	Std. Deviation
Electricity		16,205,944.57	66,649.61	1,796,592.93	506,435.77	482,356.52
Fossil fuel	LPG	2,357,808.42	902.34	874,330.00	73,681.51	167,144.73
	Diesel	135,779.40	4.02	55,074.00	4,243.11	11,228.27
Monthly Fossil fuel		2,493,587.82	982.74	885,101.59	77,924.62	168,272.56
Monthly energy used		18,699,532.39	70,291.19	2,383,155.48	584,360.39	595,504.17

Table 4.13 CO_2 emissions of 19 Thailand sampled hotels consumed electricity, LPG, diesel, and fuel oil in 2011

Energy use ($kgCO_2$/month)		Sum	Min	Max	Mean	Std. Deviation
Electricity		12,960,506.63	62,555.56	3,186,270.31	682,131.93	738,693.19
Fossil fuel	LPG	523,745.38	789.55	178,266.06	27,565.55	38,494.01
	Diesel	132,450.55	25.19	100,188.30	6,971.08	23,057.50
	Fuel oil	1,752,326.36	360.00	483,750.00	92,227.70	112,332.70
Monthly Fossil fuel		2,408,522.30	13,737.12	513,793.85	126,764.33	115,518.21
Monthly energy used		15,369,028.93	97,177.97	3,700,064.16	808,896.26	836,684.91

Monthly average CO_2 emissions of the 32 hotels (Hotel A) that consumed electricity, LPG, and diesel ranked from 70,291.19 to 2,383,155.48 with the average of 584,360.39 $kgCO_2$ as shown in Table 4.10. Monthly average CO_2 emissions of the 19 hotels (Hotel B) that consumed electricity, LPG, diesel and fuel oil ranked from 97,177.97 to 3,700,064.16 with the average of 808,896.26 $kgCO_2$ as shown in Table 4.11. Monthly average CO_2 emissions of a hotel (Hotel C) that consumed electricity and LPG was 33,698.85 $kgCO_2$. Monthly average CO_2 emissions of a hotel (Hotel D) that consumed electricity, LPG and fuel oil was 382,640.95 $kgCO_2$. The percentage of CO_2 emissions from the hotel showed in Fig. 4.10.

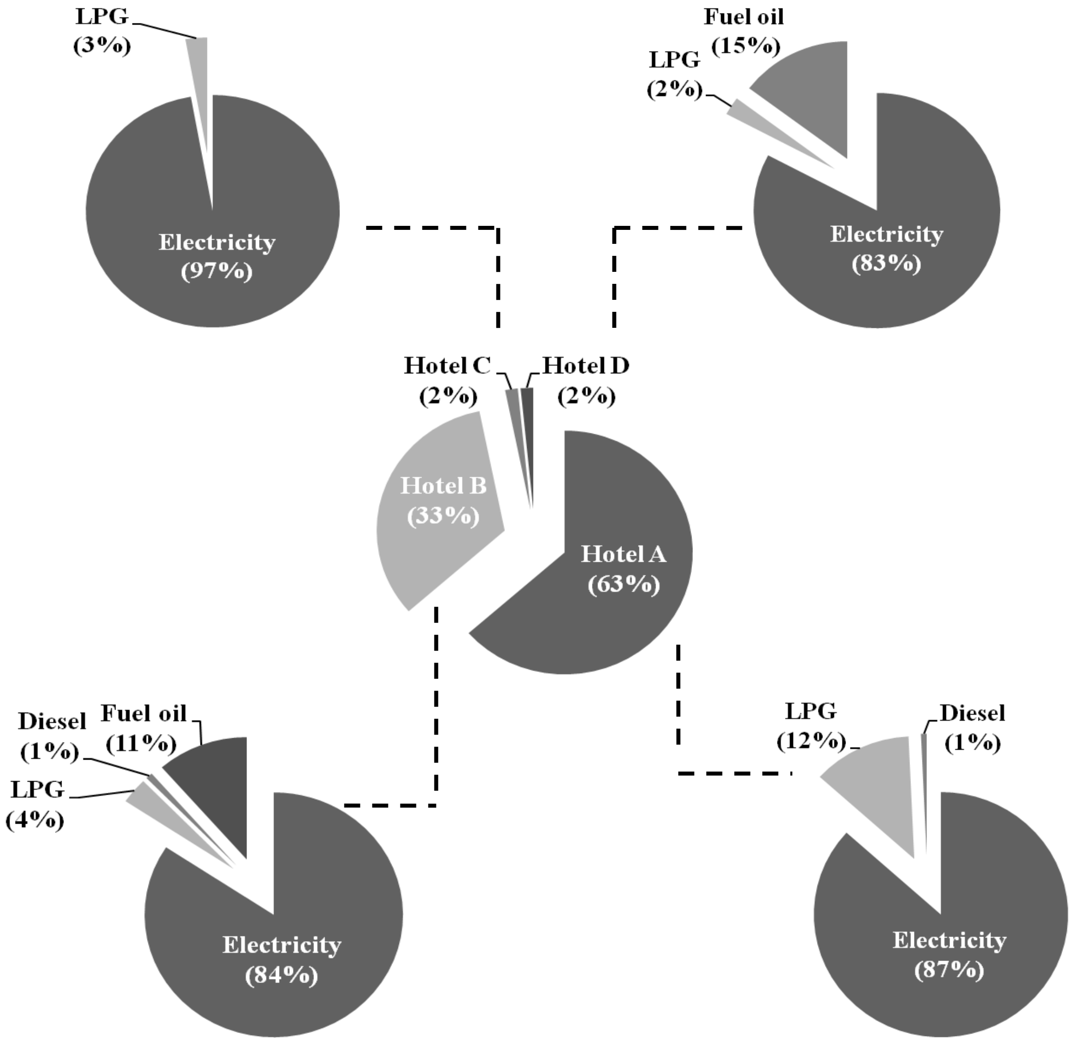

Figure 4.10 The percentages of emission sources

Fig. 4.10 shows that electricity was the main emission source in Thailand hotels, 83% and 97%. Apparently, electricity was the main emission source in worldwide hotels. Not surprisingly, many studies pointed that hotel electricity consumption was a major source of hotel emission. For example, GHG emission from electricity consumption of hotels in Singapore, Australia and Taiwan accounted for 93.64%, 91% and 79.14%, respectively (Priyadarsini *et al.*, 2009, Commonwealth of Australia, 2002 and Huang *et al*, 2010). As discussed previously, the amount of CO_2 emissions depended on energy source, emission factors and amount of energy use.

While floor area normalization (GFA, treated floor area, and so on) is a convention in building energy studies, for the hotel industry, the number of guest rooms and room-nights can often be used as an alternative. Then, the CO_2 emissions indicators (CEI) were calculated by dividing the total emissions with the selected normalizing denominators: GFA, number of guest rooms and room-night. The CEI from electricity consumption of Thailand hotels ranged from 2.32 to 63.93 $kgCO_2/m^2$, 195.15 to 10,985.98 $kgCO_2$/guest room and 12.92 to 1,435.95 $kgCO_2$/room-night with the average of 14.69 $kgCO_2/m^2$, 1,607.06 $kgCO_2$/guest room and 104.63 $kgCO_2$/room-night (as shown in Table 4.12 and Appendix D). Xuchao *et al.* (2010) reported that the CEI from electricity consumption of 29 Singapore sampled hotels in 1993 was 20.46 $kgCO_2/m^2$. The CEI from the electricity consumption of Singapore hotels was higher than in Thailand.

Table 4.14 The average CEI from electricity consumption of 63 Thailand sampled hotels monthly in 2011

CEI	Min	Max	Mean	Std. Deviation
Emission from electricity consumption in $kgCO_2/m^2$	2.32	63.93	14.69	11.10
Emission from electricity consumption in $kgCO_2$/guest room	195.15	10,985.98	1,607.06	1,763.73
Emission from electricity consumption in $kgCO_2$/room-night	12.92	1,435.95	104.63	182.04

Apparently, the amount of CO_2 emissions depended on energy source, emission factors and amount of energy use. For example, in Singapore hotels (Xuchao *et al*., 2010), the emission factors of electricity is 0.575kgCO_2/kWh. The monthly average electricity consumption of 63 Thailand hotels (26.82 kWh/m^2/month) and emission factors of electricity of Thailand (0.5477 kgCO_2/kWh) were lower than the monthly average electricity consumption of 29 Singapore hotels (35.58 kWh/m^2/month) and emission factors of electricity of Singapore (0.575 kgCO_2/kWh). Therefore, the CEI from electricity consumption in Thailand (14.69 kgCO_2/m^2) was lower than in Singapore (20.46 kgCO_2/m^2).

4.5 Factors affecting electricity consumption of hotels

4.5.1 Primary energy drivers

The analysis in the last section showed that GFA had the best correlation with the hotel monthly average electricity consumption, followed by the number of workers, the monthly average room-night, monthly average number of guests, number of guest rooms, number of floors and hotels located in Bangkok.

Regression analyses were conducted to correlate hotel electricity consumption with the primary determinants. The R^2s between monthly electricity consumption and GFA, the number of workers, the monthly average room-night, monthly average number of guests and number of guest rooms were 0.6698, 0.6465, 0.5943, 0.5935 and 0.5520, respectively. The R^2 of 0.6698 indicated that GFA could explain 66.98 per cent of the variation of electricity use in the hotels. The R^2 of 0.6465, 0.5943, 0.5935 and 0.5520 indicated that the number of workers, the monthly average room-night, monthly average number of guests and number of guest rooms can explain 64.65, 59.43, 59.35 and 55.20 per cent of the variation of electricity use in the hotels. The plots of electricity consumption against GFA, number of workers, monthly average room-night, monthly average number of guests and number of guest rooms were shown Fig.4.9 and Fig.4.11, 4.13 to 4.15.

Due to the fact that the sampled hotels in Thailand are large commercial and high-class hotels that providing accommodation, catering or restaurant services, conference rooms and entertainment venues, they need large floor areas to support their services. Not surprisingly, GFA will be increase when the number of guest rooms increase. The relation between GFA and the number of guest rooms are shown in Fig. 4.12.

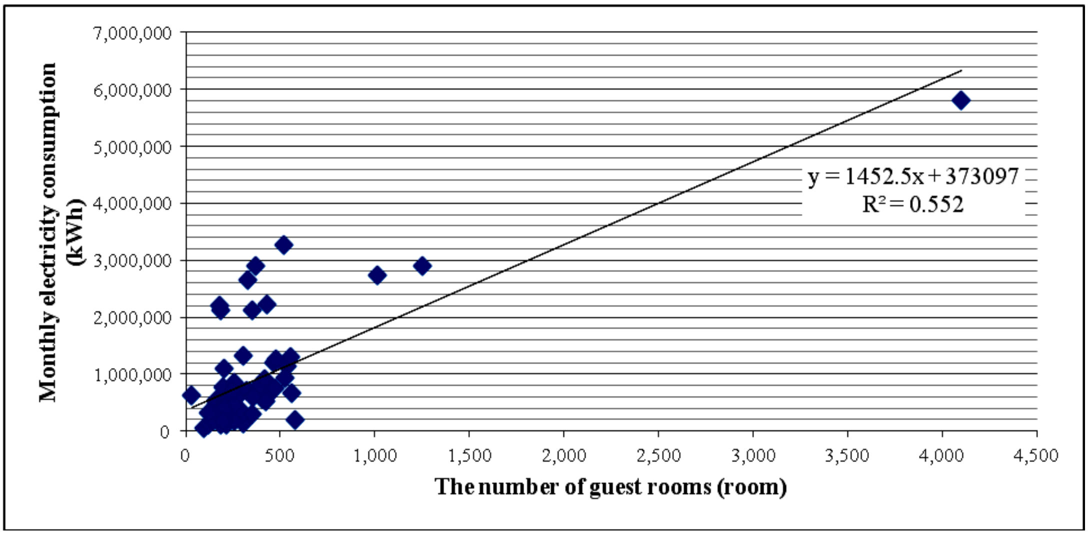

Figure 4.11 Monthly average electricity consumption (kWh) vs. the number of guest rooms (room)

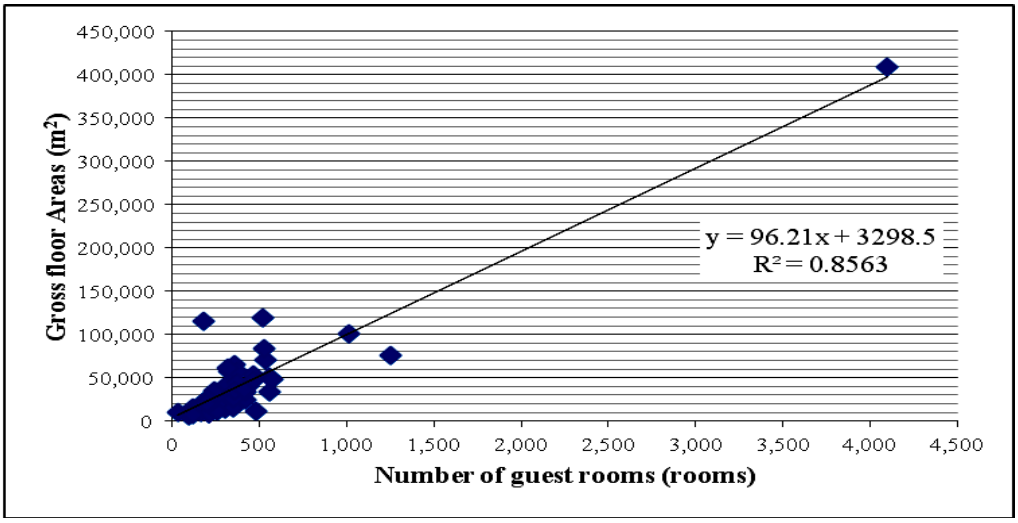

Figure 4.12 GFA (m^2) vs. the number of guest rooms (rooms)

In tropical hotels, interviews with hotel engineers in Singapore (Priyadarsini *et al.*, 2009) revealed that air-conditioning was usually kept on in guest rooms even when they were not occupied (but set-point temperature is a bit higher). This is especially the case in high-class hotels, in which thermal discomfort and bad IAQ are much less tolerable. Therefore air-conditioning in guest rooms may have caused the insensitivity of electricity consumption. On the other hand, the more GFA and guest rooms were large, the more high electricity was consumed.

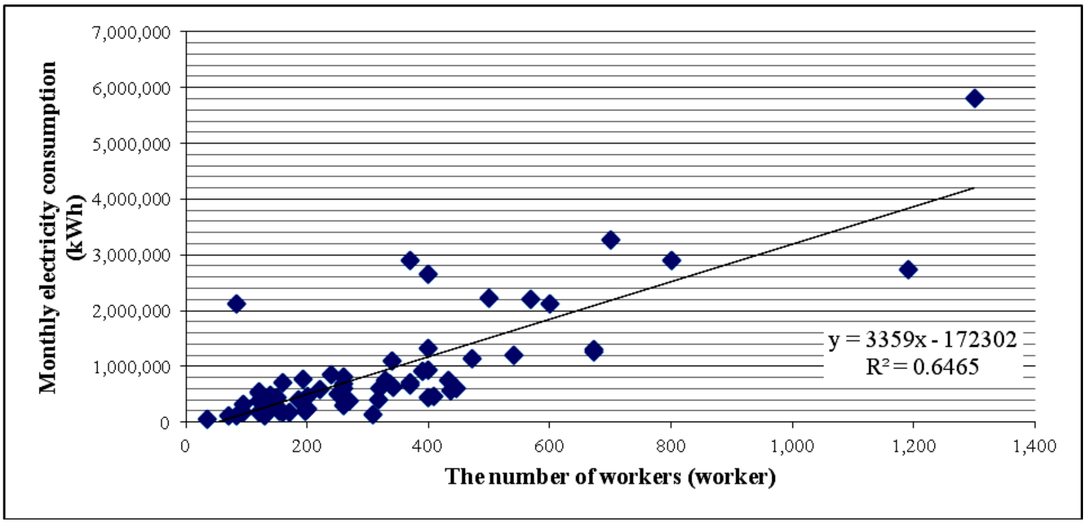

Figure 4.13 Monthly average electricity consumption (kWh)
vs. the number of workers (worker)

Hotels usually have multiple work shifts in a day. The number of workers was an indicator of a building's capacity and occupancy, but in hotel buildings, it was also related to service quality and the level of business activities. As one can expect, with the increase of worker numbers, the monthly average electricity consumption of a hotel also increased. Superficially, it was because hotel workers added energy demands to the hotels, since they were also energy users. A more important but less obvious reason was that worker numbers actually reflect a hotel's level of business activities. If a hotel has more patronage (not only hotel room guests, but also customers to restaurants, shops etc.) and provides more services than its peers do, it will inevitably incur more energy consumption. In addition, worker numbers are often quoted as an indicator of hotel service quality in hospitality management. Hence, it is an indication of both the quantity and quality of the services a hotel provides.

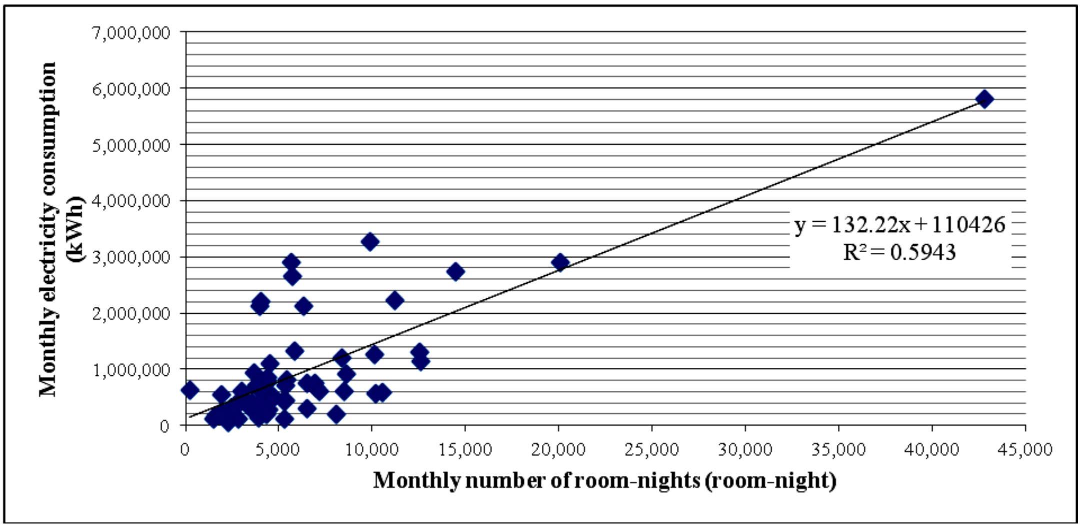

Figure 4.14 Monthly average electricity consumption (kWh) vs. monthly number of room-nights (room-night)

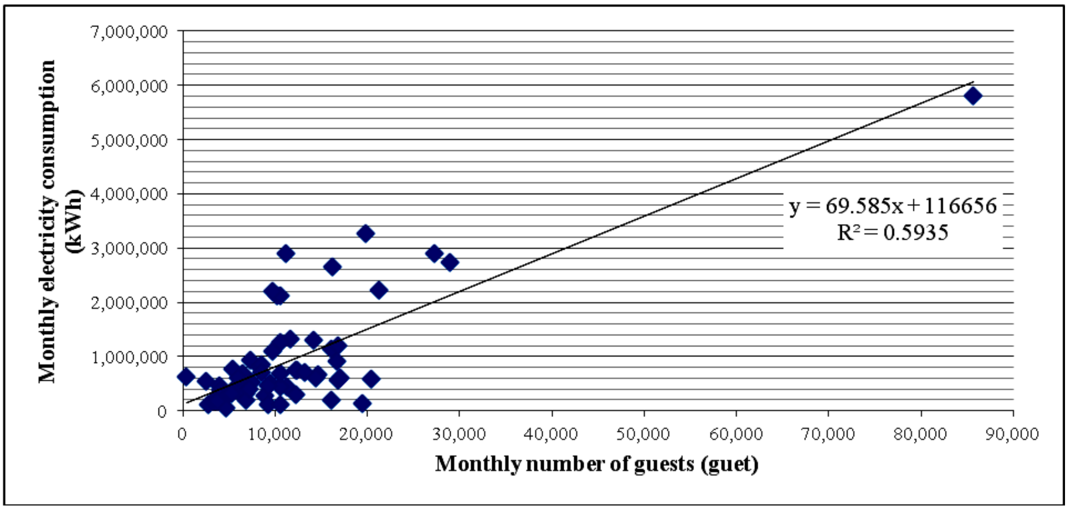

Figure 4.15 Monthly average electricity consumption (kWh) vs. monthly number of guests (guest)

Though walk-in guests, such as patrons of the restaurants, are usually not counted, OR is relatively a good indicator of the population in a hotel (Xuchao *et al.*, 2010). Then the number of guests, room-nights and OR could be the one of operational factors. The relation between energy consumption and the number of guests in Thailand sampled hotels like relation in Hong Kong (Deng and Burnett, 2002) and a 5-star Cyprus hotels (Papamarcou *et al.*, 2001). A study conducted in Hong Kong postulated a regression model that correlates a hotel's monthly total electricity consumption with two independent variables: outdoor air temperature and number of guests. The high R^2 of 0.93 indicates a strong correlation. In addition, by comparing the standardized coefficients of the two independent variables, conclusion was made that outdoor air temperature is about four times more significant than number of guests in affecting the total electricity use in that hotel. The relationship was between monthly electricity use and the number of guests in a 5-star Cypriot hotel. The postulated regression model had a high R^2 of 0.95, indicating its excellent goodness of fit. In this study, monthly electricity consumption was plotted against monthly average guest numbers for the sampled hotels in Thailand. Only a few of these trend curves were statistically significant, and their R^2s were much lower than that of the Cypriot hotel.

There are a few reasons that could probably account for this lack of fit. Firstly, the exponential relationship found in the Cypriot hotel was rather a special case, which could not be generalized to other hotels. Secondly, unlike some vacation hotels, occupancy

rate in the surveyed hotels does not vary a lot throughout the year, which makes the predictor variable being kept in a very small range. Draper and Smith (1981) pointed out that these small ranges frequently cause the corresponding regress coefficients to be found “non-significant”, although empirical experience tells the correlation should be a significant one. Thirdly, nonstop provision of air-conditioning in guest rooms has caused the insensitivity of electricity consumption.

Due to the number of guests and room-nights being in high relation as shown in Fig. 4.16, the reason for discussing how the number of room-nights affect electricity consumption in hotels was the same. However, in the case of the hotel’s dry run, where the hotels conduct a test of a new operation without guests, OR or room-nights, the hotel monthly electricity consumption will be rank from 110,426 to 116,656 kWh. The values, 110,426 and 116,656, were the intercept β_o of the linear regression model, as shown in Figs 4.14 and 4.15. The monthly electricity consumption from hotel’s dry run depend on hotel’s physical and operational characteristics such as GFA, star rating , types of hotel, the number of workers, number of years after the last major retrofit, building management system used, presence of laundry facilities and so on.

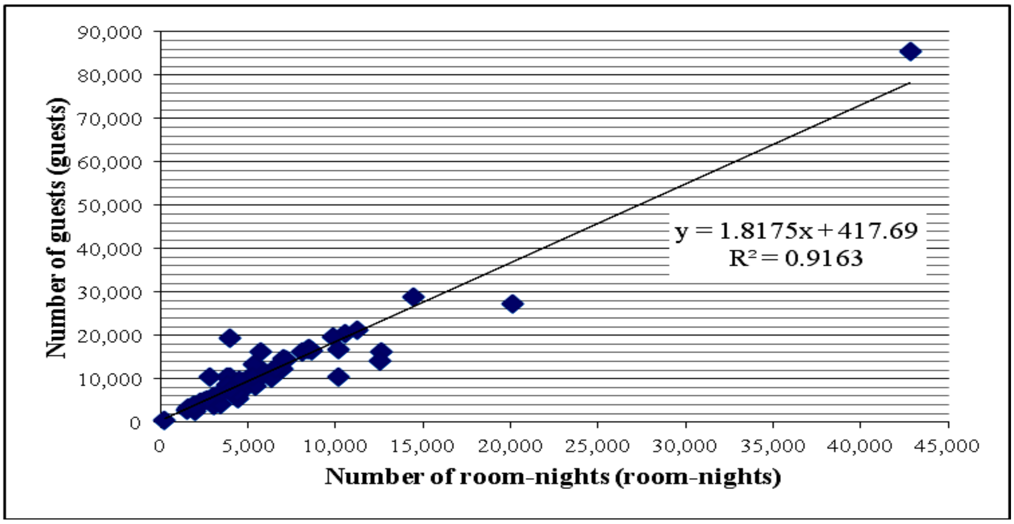

Figure 4.16 Number of guest (guests) vs. the number of room-nights (room-nights)

4.5.2 Secondary energy drivers

As GFA was an uncontrollable input and had the best correlation with the hotel monthly average electricity consumption, the analysis of secondary energy drivers, it was selected as the primary normalization variable to keep consistent with previous research work. Additionally, floor area is the primary normalization variable for comparing building energy use. Therefore, GFA was chosen as the primary normalization variable to construct ECI, which can then be used as the basis for comparing energy performance of different hotels.

In view of the literature, the number of guest rooms and room-nights can often be used as an alternative. Therefore, they were chosen as the primary normalization variable to construct the monthly average electricity consumption in kWh/guest room and kWh/room-night) again. Pearson correlations between electricity consumption in kWh/guest room and kWh/room-night and 30 independent variables as potential secondary drivers were calculated.

Table 4.15 shows that worker density (number of workers per 1,000 m^2 of GFA) had correlations with monthly electricity consumption in kWh/m^2. It was significant at the 0.01 level. OR had correlations with monthly electricity consumption in kWh/room-night which was significant at the 0.05 level. In contrast, the others were insignificant. The R^2s of two factors were 0.3782 and 0.0640, respectively. The R^2s indicates that worker density can explain 37.82 per cent of the variation of electricity use in kWh/m^2, while OR can explain 6.40 per cent of the variation of electricity use in kWh/room-night. Table 4.15 – 4.17 pointed that worker density was the most factor affecting electricity consumption of hotels in Thailand. This because it correlated the ECI of 63, 32, and 19 hotels.

Table 4.15 Pearson correlations between ECI in kWh per m^2, kWh per guest room and kWh per room-night and 30 independent variables

Variables	**Pearson correlation**		
	kWh/m^2	**kWh/guest room**	**kWh/room-night**
Worker density	.615**	-	-
OR	-	-	-.253*

Note: - is insignificant variable.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4.16 Pearson correlations between ECI of 32 hotels consumed electricity, LPG, and diesel and 30 independent variables

Variables	**Pearson Correlation**					
	Electricity consumption			**Energy use**		
	MJ/m^2	**MJ/ guestroom**	**MJ/ room-night**	**MJ/m^2**	**MJ/ guestroom**	**MJ/ room-night**
Number of workers	-	-	-	.370*	-	-
Worker density	.638**	-	-	.587**	-	-
OR	-	-	-	-	-	-.370*
Monthly average room-night	-	-	-	.353*	-	-

Note: * Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4.17 Pearson correlations between ECI of 19 hotels consumed electricity, LPG, diesel, and fuel oil and 30 independent variables

Variables	**Pearson Correlation**					
	Electricity consumption			**Energy use**		
	MJ/m^2	**MJ/ guestroom**	**MJ/ room-night**	**MJ/m^2**	**MJ/ guestroom**	**MJ/ room-night**
5-star	-	.531*	-	-	-	.512*
Green leaf certificated	-	.486*	-	-	-	-
Resort	-	-	-	.572*	-	-
Number of workers	-	-	-	-	-	-
Worker density	-	-	-	.709**	-	-
OR	-	-	-	.510*	-	-

Note: * Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

4.5.3 Determining predictive model

The predictive model was determined based on a stepwise linear regression procedure performed by the statistical software package SPSS, with hotel the monthly average electricity consumption (kWh, kWh/m^2, kWh/guest room and kWh/room-night) as the dependent variable and the previously discussed factors, 24 independent variables, as potential independent variables. The predictive model and the R^2 showed in Tables 4.18 – 4.20. Tables 4.18 – 4.20 show that number of workers was the factor affecting electricity consumption the most in the predictive model of Thailand. Apparently, number of worker entered the regression model with high R^2, more than 0.6.

Table 4.18 The predictive model and the R^2 of 63 Thailand sampled hotels electricity consumption

The monthly average electricity consumption	**The predictive model**	R^2
kWh	Log(the predicted monthly average electricity consumption) = 2.190 + (0.705) Log(workers) + (0.424) Log(GFA) (4.861)* (3.197)*	0.649
kWh/ m^2	Log(The predicted monthly average electricity consumption per m^2) = 0.806 + (0.560) Log (worker density) – (0.277) (the 3-star hotel) (4.406)* (2.164)*	0.309
	Log(The predicted monthly average electricity consumption per m^2)[a] = 0.529 + (0.560) Log (worker density)	
	Log(The predicted monthly average electricity consumption per m^2)[b] = 0.806 + (0.560) Log (worker density)	
kWh/guest room	Log(the predicted monthly average electricity consumption per guest room) = 4.832 + (0.723) Log (workers) – (7.615) Log (guest rooms) (5.313)* (4.273)* + (0.498) Log (GFA) + (6.472) Log (room-nights) – (6.074) Log (ORR) (3.458)* (3.655)* (3.371)*	0.614

Table 4.18 The predictive model and the R^2 of 63 Thailand sampled hotels electricity consumption (Cont')

The monthly average electricity consumption	The predictive model	R^2
kWh/room-night	Log(the predicted monthly average electricity consumption per room-night) = 4.832 + (0.723) Log (workers) + (5.472) Log (room-nights) (5.313)* (3.09)* + (0.498) Log (GFA) – (6.615) Log (guest rooms) – (6.074) Log (ORR) (3.458)* (3.712)* (3.371)*	0.622

Note: a is the 3-star hotel (dummy value = 1)

b is the 4 and 5-star hotel (dummy value = 0)

* is t-statistic value

Table 4.19 The predictive model and the R^2 of 32 sampled hotels consumed electricity, LPG, and diesel

Energy use		The predictive model	R^2
The monthly average electricity consumption	MJ	Log(the predicted monthly average electricity consumption) = 3.476 + (0.666) Log(workers) + (0.466) Log(GFA) + (6.97) Log (OR) (3.684)* (2.773)* (2.279)*	0.675
	MJ/m^2	Log(The predicted monthly average electricity consumption per m^2) = 3.539 + (0.511) Log (worker density) – (1.066) (the 3-star hotel) hotel) (3.430)* (2.736)* – (0.502) (the conference (2.252)*	0.508
	MJ/ guest room	Log(the predicted monthly average electricity consumption per guest room) = 3.653 + (0.788) Log (workers) – (1.945) Log (guest rooms) + (0.587) Log (GFA) (4.066)* (4.382)* (3.033)* + (0.741) Log (room-nights) (2.300)*	0.626
	MJ/ room-night	Log(the predicted monthly average electricity consumption per room-night) = 7.967 - (0.800) Log (room-nights) + (0.868) Log (workers) + (0.470) (the conference hotel) (5.278)* (5.115)* (2.252)*	0.586

Note: * is t-statistic value

Table 4.19 The predictive model and the R^2 of 32 sampled hotels consumed electricity, LPG, and diesel (Cont')

Energy use		The predictive model	R^2
The monthly average total energy use	MJ	Log(the predicted monthly average total energy use) = 6.208 + (0.624) Log(workers) + (0.5254) Log(GFA) – (0.979) (the 3-star hotel) (3.242)* (3.063)* (2.265)*	0.708
	MJ/m^2	Log(The predicted monthly average total energy use per m^2) = 3.627 + (0.527) Log (worker density) – (1.074) (the 3-star hotel) (3.267)* (2.564)*	0.430
	MJ/ guest room	Log(the predicted monthly average total energy use per guest room) = 3.653 + (0.788) Log (workers) – (1.945) Log (guest rooms) (4.066)* (4.3823)* + (0.587) Log(GFA) + (0.741) Log (room-nights) (3.033)* (2.300)*	0.626
	MJ/ room-night	Log(the predicted monthly average total energy use per room-night) = 5.738 + (0.769) Log (workers) - (0.890) Log (room-nights) (4.003)* (5.834)* + (0.442) (the commercial hotel) + (0.3758) Log (GFA) (2.156)* (2.071)*	0.659

Note: * is t-statistic value

Table 4.20 The predictive model and the R^2 of 19 sampled hotels consumed electricity, LPG, diesel, and fuel oil and 30 independent variable

Energy use		**The predictive model**	$\mathbf{R^2}$
The monthly average electricity consumption	MJ	Log(the predicted monthly average electricity consumption) = 8.493 + (1.110) Log(workers) (6.541)*	0.716
	MJ/m^2	Log(The predicted monthly average electricity consumption per m^2) = 2.694 + (0.775) Log (worker density) (3.250)*	0.383
	MJ/ guest room	Log(the predicted monthly average electricity consumption per guest room) = 8.783 + (0.742) (the 5-star hotel) (2.436)*	0.259
	MJ/ room-night	Log(the predicted monthly average electricity consumption per room-night) = 5.829 + (0.754) (the green hotel) - (1.184) (the 3-star hotel) (3.145)* (2.208)*	0.434

Table 4.20 The predictive model and the R^2 of 19 sampled hotels consumed electricity, LPG, diesel, and fuel oil and 30 independent variable (Cont')

Energy use		**The predictive model**	$\mathbf{R^2}$
The monthly average total energy use	MJ	Log(the predicted monthly average total energy use) = 8.493 + (1.110) Log(workers) (6.541)*	0.716
	MJ/m^2	Log(The predicted monthly average total energy use per m^2) = 2.876 + (0.879) Log (worker density) (4.521)*	0.546
	MJ/ guest room	Log(the predicted monthly average total energy use per guest room) = 9.212 + (0.788) (the 5-star hotel) (2.340)*	0.244
	MJ/ room-night	Log(the predicted monthly average total energy use per room-night) = 6.423 + (0.538) (the 5-star hotel) (2.111)*	0.208

Note: * is t-statistic value

1) The monthly average electricity consumption (kWh)

For the monthly average electricity consumption (kWh), two of them were selected by the stepwise procedure to enter the regression model: the number of workers and GFA (Table 4.9). The model, with an R^2 of 0.649, can be expressed as follows:

$$Log(Y) = 2.190 + (0.705)\ Log(X_1) + (0.424)\ (LogX_2) \qquad eq(1)$$

$$\qquad (4.861)^* \qquad (3.197)^*$$

where Y is the predicted monthly average electricity consumption (kWh),

X_1 is the number of workers (worker),

X_2 is GFA (m^2).

* is t-statistic value

The regression residuals, which were the differences between what was actually observed and what was predicted by the regression equation, could be considered as "observed errors" if the model was correct. In performing regression analysis, certain assumptions about these errors were made. The usual assumptions were that the errors were independent. It had zero mean, no multicollinearity, a constant variance (as showed in Appendix E), and followed a normal distribution (K-S test = 0.200).

The regression equation indicated that the number of workers and GFA were the factors affecting the monthly average electricity consumption (kWh) at significant level of 95%. The worker density and GFA could explain 64.9 per cent of the variations in the hotel monthly average electricity consumption (kWh). The monthly average electricity consumption would increase 0.705 and 0.424 per cent when worker and floor area increase one per cent, respectively.

The predictive model between the monthly average electricity consumption (kWh) and 24 independent variables of 63 Thailand hotels was different from the predictive model of 16 Hong Kong hotels and a small hotel in Trang Province, but was similar to the predictive model of 111 European hotels. The Hong Kong hotels predictive model presented that outdoor air temperature and the number of guests were affecting the hotel monthly electricity consumption (Shiming and Burnett, 2002). The factors affecting the hotel energy consumption of the small hotel in Trang Province were types of guest room, electricity fan rooms and air-condition rooms. The European hotels predictive model presented that hotel floor area, number of room-night and food covers sold affected to energy use (Bohdanowicz and Martinac, 2007). The value of R^2 of Thailand predictive model was 0.649, while Singapore was 0.751.

The difference might come from the differences in input factors, energy sources, the number and types of sample hotels, and so on. For an example, the difference between the predictive model of 63 hotels and the predictive model of the small hotel in Trang Province, Thailand. The small hotel in Trang Province had 38 electricity fan rooms and 30 air-condition rooms and 2,288 m^2. The hotel energy consumption was from electricity and LPG. Together with, the study analyzed the energy consumption in lighting and air-conditioning systems. Not surprisingly, the factors affecting the hotel energy consumption of the small hotel in Trang Province were types of guest room, electricity fan rooms and air-conditioned rooms.

2) The monthly average electricity consumption (kWh/m^2)

For the monthly average electricity consumption (kWh/m^2), two of them were selected by the stepwise procedure to enter the regression model: worker density (the number worker per 1,000 m^2) and the 3-star hotel. The model, with an R^2 of 0.309, can be expressed as follows:

$$\mathrm{Log}(Y) = 0.806 + \underset{(4.406)^*}{(0.560)\ \mathrm{Log}(X_1)} - \underset{(2.164)^*}{(0.277)\ (X_2)} \qquad \text{eq(2)}$$

where Y is the predicted monthly average electricity consumption (kWh/m^2),

X_1 is worker density,

X_2 is the 3-star hotel.

* is t-statistic value

Rating stars affect the model constant. In case of the 3-star hotel, the predictive final model was shown in eq(3). For other types of hotels, the predictive final model was shown in eq(4). The predictive model and the R^2 were shown in Table 4.9.

$$\text{Log}(Y) = 0.529 + (0.560)\ \text{Log}\ (X_1) \qquad \text{eq(3)}$$

$$\text{Log}(Y) = 0.806 + (0.560)\ \text{Log}\ (X_1) \qquad \text{eq(4)}$$

Due to it having zero mean, no multicollinearity, a constant variance (as shown in Appendix E), and following a normal distribution (K-S test = 0.200), the model was correct.

The regression equation indicated that worker density and the 3-star hotel were the factors affecting the monthly average electricity consumption (kWh/m^2) at significant level of 95%. The worker density and the 3-star hotel could explain 30.9 per cent of the variations in hotel the monthly average electricity consumption (kWh/m^2). The monthly average electricity consumption would increase 0.560 per cent when worker density increased one per cent.

The predictive model between the monthly average electricity consumption (kWh/m^2) and 24 independent variables of 63 Thailand hotels and the predictive model of 29 Singapore hotels were the same. Worker density and the 3 star hotels affected the hotel monthly electricity consumption (kWh/m^2). The value of R^2 of Thailand predictive model was 0.309, while Singapore was 0.73.

3) The monthly average electricity consumption (kWh/ guest room)

For the monthly average electricity consumption (kWh/guest room), the number workers and guest rooms were selected by the stepwise procedure to enter the regression model. The model, with an R^2 of 0.614, can be expressed as follows:

$$\text{Log}(Y) = 4.832 + \underset{(5.313)^*}{(0.723)\ \text{Log}\ (X_1)} - \underset{(4.273)^*}{(7.615)\ \text{Log}\ (X_2)} + \underset{(3.458)^*}{(0.498)\ \text{Log}\ (X_3)}$$

$$+ \underset{(3.655)^*}{(6.472)\ \text{Log}\ (X_4)} - \underset{(3.371)^*}{(6.074)\ \text{Log}\ (X_5)} \qquad \text{eq(5)}$$

where Y is the predicted monthly average electricity consumption (kWh/guest room),

X_1 is the number workers (worker),

X_2 is the number of guest rooms (room).

X_3 is GFA (m^2)

X_4	is	the number of room-nights (room-night)
X_5	is	OR (%)
*	is	t-statistic value

Due to it having zero mean, no multicollinearity, a constant variance (as shown in Appendix E), and following a normal distribution (K-S test = 0.200), the model was correct.

The regression equation indicated that the number of workers, guest rooms, room-nights, GFA and OR were the factors affecting the monthly average electricity consumption (kWh/guest room) at significant level of 95%. They could explain 61.4 per cent of the variations in the hotel monthly average electricity consumption (kWh/guest room). The monthly average electricity consumption would increase 0.723, 0.498 and 6.472 per cent when the number workers, GFA and the number of room-nights increased one per cent, respectively. But when the number of guest room and OR increased one percent, the monthly average electricity consumption would decrease 7.615 and 6.074 per cent, respectively.

4) The monthly average electricity consumption (kWh/room-night)

For the monthly average electricity consumption (kWh/room-night), the number of workers, room-nights and floors were selected by the stepwise procedure to enter the regression model. The model, with an R^2 of 0.622, can be expressed as follows:

$$\text{Log}(Y) = 4.832 + \underset{(5.313)^*}{(0.723)\,\text{Log}(X_1)} + \underset{(3.09)^*}{(5.472)\,\text{Log}(X_2)} + \underset{(3.458)^*}{(0.498)\,\text{Log}(X_3)}$$

$$- \underset{(3.712)^*}{(6.615)\,\text{Log}(X_4)} - \underset{(3.371)^*}{(6.074)\,\text{Log}(X_5)} \qquad \text{eq(6)}$$

where	Y	is	the predicted monthly average electricity consumption (kWh/room-night),
	X_1	is	the number workers (worker),
	X_2	is	the number of room-nights (room-night),
	X_3	is	GFA (m^2)
	X_4	is	the number of guest rooms (room),

X_5 is OR (%).

* is t-statistic value

Due to it having zero mean, no multicollinearity, a constant variance (as shown in Appendix E), and following a normal distribution (K-S test = 0.200), the model was correct.

The regression equation indicated that the number of workers, room-nights, guest rooms, GFA and OR were the factors affecting the monthly average electricity consumption (kWh/room-night) in the hotels at a significant level of 95%. They can explain 62.2 per cent of the variations in the hotel monthly average electricity consumption per room-night. The monthly average electricity consumption would increase 0.723, 5.472 and 0.498 per cent when the number workers, the number of room-nights and GFA increased one per cent, respectively. But when the number of guest room and OR increased one percent, the monthly average electricity consumption would decrease 6.615 and 6.074 per cent, respectively.

As a result, there are many factors contributing to their high electricity consumption, some of which are related to hotel designs (such as the number of guest rooms and GFA) and operations (such as star rating, the number of room-nights, workers, worker density and ORR). The number of workers and GFA affected the electricity consumption in kWh, kWh/guest room and kWh/room-night. Apparently, worker density (the number of workers per 1,000 m^2) affecting the electricity consumption in kWh/m^2 also.

4) Factors affecting electricity consumption of case studies

The Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by star rating, functions, the Hotel Act B.E 2547 and Green Leaf Certification a shown in Appendixes F to I and Tables 4.10 to 4.13, respectively. The predictive model and the R^2 of hotels that separated by star rating, functions, the Hotel Act B.E 2547 and Green Leaf Certification were shown in Tables 4.14 to 4.17, respectively.

Table 4.10 shows that GFA was the high significant at the 0.01 level. It well correlated with electricity consumption in kWh of the 3, 4 and 5 star hotels. Table 2.13 shows that GFA and number of workers were the high significant at the 0.01 level. They well correlated with electricity consumption in kWh of the resort, conference and commercial hotels. Table 4.12 shows that GFA and number of workers were the high significant at the 0.01 level. They well correlated with electricity consumption in kWh of the type 3 and 4 hotels. Table 4.13 shows that GFA, the number of guest rooms, workers, room-nights and guests were the high significant at the 0.01 level. They well correlated with electricity consumption in kWh of the Green Leaf certification and uncertified Green Leaf hotels. Apparently, GFA were high correlated with electricity consumption in kWh of the star rating (3, 4 and 5-star hotels), hotel functions (resort, conference and commercial hotels), the Hotel Act B.E 2547 (type-3 and type-4 hotels) and Green Leaf Certification (certified and uncertified Green Leaf hotels), followed by the number of worker, monthly average guest, the number of guest room, monthly average room-night and number of floor, respectively. As a result, it was similar variables (GFA, the number of workers, the monthly average room-night, monthly average number of guests, number of guest rooms and number of floors) affecting electricity consumption in kWh of total 63 sampled hotels.

Table 4.21 Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by star ratings

Variables	**Pearson Correlation**							
	4 hotels (three-star)			**17 hotels (four-star)**		**14 hotels (five-star)**		
	(kWh)	**(kWh/m^2)**	**(kWh/ room-night)**	**(kWh)**	**(kWh/m^2)**	**(kWh)**	**(kWh/ guest room)**	**(kWh/ room-night)**
Number of guest rooms	.999**	.980*	-	.945**	-	.616*	-	-
GFA	.996**	.956*	-	.924**	-	.820**	-	-
Number of floors	.965*	-	-	.791**	-	.599*	.616*	.690**
Green Leaf Certification	-	-	-	-.536*	-	-	-	-
Uncertified green Leaf	-	-	-	.536*	-	-	-	-
Northern region	-	-	-	-	-.510*	-	-	-
Number of workers	-	-	-	.976**	-	.630*	-	-
OR	-	-	-.997**	-	-	-	-	-
Monthly average room-night	-	-	-	.972**	-	.693**	-	-
Monthly average of guests	-	-	-	.953**	-	.746**	-	-

Note: - is insignificant variable.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4.22 Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by functions

Variables	Pearson Correlation									
	17 hotels (resort)				16 hotels (conference hotel)				28 hotels (commercial hotel)	
	(kWh)	(kWh/m^2)	(kWh/ guest room)	(kWh/ room-night)	(kWh)	(kWh/m^2)	(kWh/ guest room)	(kWh/ room-night)	(kWh)	(kWh/ room-night)
Number of guest rooms	-	-	-	-	.945**	-	-	-	.499**	-
GFA	.775**	-	.838**	.830**	.927**	-	-	-	.687**	.436*
Number of floors	-	-	-	-	.851**	-	-	-	.502**	.386*
5-star hotel	-	-	-	-	-	-	-	-	.462*	.425*
Southern region	-	-	-	-	-	-	.608*	.568*	-	-
Number of workers	.741**	-	-	-	.922**	-	-	-	.636**	-
Worker density	-	.881**	-	-	-	.626**	.772**	.789**	-	-
Monthly average room-night	-	-	-	-	.962**	-	-	-	.463*	-
Monthly average of guests	-	-	-	-	.928**	-	-	-	.599**	-

Note: - is insignificant variable.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4.23 Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by the Hotel Act B.E 2547

Variables	**Pearson Correlation**				
	31 hotels (type 3)			**32 hotels (type 4)**	
	(kWh)	**(kWh/m^2)**	**(kWh/room-night)**	**(kWh)**	**(kWh/m^2)**
Number of guest rooms	.575**	-	-	.810**	-
GFA	.680**	-	-	.887**	-
Number of floors	.644**	-	-	.517**	-
5-star hotel	.398*	-	-	-	-
Number of workers	.718**	.491**	-	.835**	-
Worker density (number of workers per 1,000 m^2 of GFA)	-	.788**	-	-	-
OR	-	-	-.391*	-	.416*
Monthly average room-night	.558**	-	-	.844**	-
Monthly average of guests	.485**	-	-	.861**	-

Note: - is insignificant variable.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 4.24 Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by Green Leaf Certification

Variables	Pearson Correlation						
	35 hotels (green leaf certification)				28 hotels (uncertified green leaf)		
	(kWh)	(kWh/m^2)	(kWh/ guest room)	(kWh/ room-night)	(kWh)	(kWh/ guest room)	(kWh/ room-night)
Number of guest rooms	.605**	-	-	-	.849**	-	-
GFA	.812**	-	.705**	.690**	.870**	-	-
Number of floors	.421*	-	-	-	.677**	-	-
Unclassified star	-	-	.345*	-	-.560**	-	-
4-star hotel	-	-	-	-	.493**	-	-
Bangkok	.387*	-	-	-	-	-	-
Number of workers	.827**	.523**	.513**	.431**	.792**	-	-
Worker density	-	.796**	-	-	-	.444*	.561**
OR	.371*	.405*	.451**	-	-	-	-.468*
Monthly average room-night	.687**	.451**	-	-	.831**	-	-
Monthly average of guests	.741**	-	-	-	.827**	-	-

Note: - is insignificant variable.

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

The predictive model and the R^2 of hotels (Table 4.14 to 4.17) show that star rating (3, 4 and 5- star hotels), hotel function (conference and commercial hotels), type-4 hotels that separated by the Hotel Act B.E 2547 and certified Green Leaf hotels affecting monthly electricity consumption. The R^2 between monthly electricity consumption and star rating were 0.998, 0.768 and 0.999, respectively. The R^2s of conference, commercial, type-4 and certified Green Leaf hotels were 0.998, 0.998, 0.999 and 0.999, respectively. It indicated that 3, 4, 5- star hotels, conference and commercial hotels, type-4 hotels and certified Green Leaf hotels can explain 76.8 – 99.9 per cent of the variations in the monthly average electricity consumption.

Table 4.14 shows that OR affects the monthly average electricity consumption in the predictive model of 3, 4 and 5-star hotels, while GFA affects the monthly average electricity consumption in the predictive model of resort, conference and commercial hotels, GFA, number of guest rooms, workers and guests affecting the monthly average electricity consumption in the predictive model of type 3 and 4 hotels. The number of workers affects the monthly average electricity consumption in the predictive model of Green Leaf certification and uncertified Green Leaf hotels at significant level of 95%.

As a result, hotel staff (the number of workers and worker density) and guests (the number of guests and OR) were the important factors affecting the electricity consumption in kWh, kWh/m^2, kWh/guestroom and kWh/room-night. As discussed previously, either the study of total 63 hotels or case studies, it is believed that workers or hotel staff was the largest factor which was affecting the hotel electricity consumption. Although behaviors and knowledge of worker related the hotel electricity consumption, there are some other contributors such as the energy conservation policy of hotel. For these factors, energy savings can often be realized by incorporating energy efficient technologies or making changes to hotel operations. However, there are some other contributors, usually related to guest behaviors and knowledge, which cannot be easily altered by the hotel management for the sake of reducing energy use.

Table 4.25 The predictive model and the R^2 of hotels separating by star rating

The monthly average electricity consumption	**The 3 star hotel**		**The 4 star hotel**		**The 5 star hotel**	
	The predictive model	**R^2**	**The predictive model**	**R^2**	**The predictive model**	**R^2**
kWh	Log(A) = 3.235 + (0.891) Log(guestroom) (29.979)*	0.998	Log(A) = 2.297 + (0.944) Log (roomnight) (7.055)*	0.768	Log(A) = (1.487) Log(guest) (101.378)*	0.999
kWh/ m^2	Log(B) = 0.474 + (0.333) Log (guestroom) (-)* – (0.013) (the resident hotel) - (0.063) Log (GFA) (-)* (-)*	1.000	Log(B) = (0.752) Log (ORR) + (0.164) (BKK) (24.785)* (2.145)*	0.989	-	-
	Log(B) = 0.461 + (0.333) Log (guestroom) - (0.063) Log (GFA)[a]		Log(B) = 0.164 + (0.752) Log (ORR)[c]			
	Log(B) = 0.474 + (0.333) Log (guestroom) - (0.063) Log (GFA)[b]		Log(B) = (0.752) Log (ORR)[d]			
kWh/guest room	-	-	Log(C) = 1.913 – (0.803) Log (ORR) (2.286)*	0.258	Log(C) = (41.817) (ORR) + (80.411) (floor) (3.786)* (3.188)*	0.860
kWh/room-night	Log(D) = 3.523 – (1.011) Log (ORR) (7.153)*	0.962	-	-	Log(D) = 1.898 + (0.352) Log (floor) (2.741)*	0.385

Note: Log(A) is Log(the predicted monthly average electricity consumption)

Log(B) is Log(The predicted monthly average electricity consumption per m^2)

Log(C) is Log(the predicted monthly average electricity consumption per guest room)

Log(D) is Log(the predicted monthly average electricity consumption per room-night)

a is the resident hotel

b is the other hotel

c is hotel located in BKK

d is hotel located in other region

* is t-statistic value

(-)* is no t-statistic value

Table 4.26 The predictive model and the R^2 of hotels separating by function

The monthly average electricity consumption	The resort hotel: The predictive model	The resort hotel: R^2	The conference hotel: The predictive model	The conference hotel: R^2	The commercial hotel: The predictive model	The commercial hotel: R^2
kWh	Log(A) = 3.146 + (1.060) Log(worker) (4.549)*	0.580	Log(A) = (1.148) Log (GFA) + (0.633) Log (worker density) (28.056)* (3.226)*	0.998	Log(A) = (0.803) Log (GFA) + (0.608) Log (room night) (3.958)* (2.470)*	0.998
kWh/ m^2	Log(B) = (1.115) Log (workerdensity) + (0.220) (type4 hotel) (15.002)* (2.169)*	0.982	Log(B) = (0.434) Log (ORR) + (0.574) Log (worker density) (3.329)* (2.511)*	0.963	-	-
	Log(B) = (1.335) Log (worker density) [a]					
	Log(B) = (1.115) Log (worker density) [b]					
kWh/guest room	Log(C) = 3.717 - (0.474) Log(floor) (2.679)*	0.324	Log(C) = 3.093 + (0.646) (southern) (2.972)*	0.387	Log(C) = (0.512) Log (GFA) + (0.625) Log (ORR) (4.636)* (2.230)*	0.994
			Log(C) = 3.739[c]			
			Log(C) = 3.093[d]			
kWh/room-night	Log(D) = 2.368 - (0.399) Log(floor) (2.233)*	0.294	Log(D) = (0.799) Log(worker) + (0.747) (southern) (18.103)* (3.004)*	0.971	Log(D) = (0.480) Log (GFA) (41.929)*	0.985
			Log(D) = 0.747 + (0.799) Log(worker) [c]			
			Log(D) = (0.799) Log(worker) [d]			

Note: Log(A) is Log(the predicted monthly average electricity consumption)
Log(B) is Log(The predicted monthly average electricity consumption per m^2)
Log(C) is Log(the predicted monthly average electricity consumption per guest room)
Log(D) is Log(the predicted monthly average electricity consumption per room-night)

Table 4.27 The predictive model and the R^2 of hotels separating by the Hotel Act B.E 2547

The monthly average electricity consumption	**The type 3 hotel**		**The type 4 hotel**	
	The predictive model	R^2	**The predictive model**	R^2
kWh	Log(A) = 3.077 + (0.987) Log(worker) (5.787)* + (0.296) Log (floor) (2.225)*	0.609	Log(A) = (0.994) Log (guest) + (0.689) Log (GFA) (5.750)* (4.622)* - (0.503) Log (guestroom) (2.155)*	0.999
kWh/ m^2	Log(B) = 0.632 + (0.712) Log(workerdensity) (4.113)*	0.368	Log(B) = (0.771) Log (ORR) (34.51)*	0.975
kWh/guest room	Log(C) = 4.073 + (0.808) Log(worker) (4.747)* – (0.703) Log (guest) +(0.359) (the 5 star hotel) (5.147)* (2.689)*	0.628	Log(C) = (0.948) Log (ORR) + (0.742) Log (GFA) (5.313)* (4.897)* - (0.661) Log (guestroom) (3.010)*	0.996
	Log(C) = 4.432 + (0.808) Log(worker) – (0.703) Log (guest) [a]			
	Log(C) = 4.073 + (0.808) Log(worker) – (0.703) Log (guest) [b]			
kWh/room-night	Log(D) = 3.753 - (1.028) Log (guest) (7.802)* + (0.839) Log (worker) + (0.303) Log (floor) (5.475)* (2. 452)* + (0.271) (the 5 star hotel) Log(D) (2.234)*	0.752	Log(D) = (0.849) Log (GFA) - (0.685) Log (guestroom) (7.341)* (3.303)*	0.991
	Log(C) = 4.024 - (1.028) Log (guest) + (0.839) Log (worker) + (0.303) Log (floor) [a]			
	Log(D) = 3.753 - (1.028) Log (guest) + (0.839) Log (worker) + (0.303) Log (floor) [b]			

Note: Log(A) is Log(the predicted monthly average electricity consumption)

Log(B) is Log(The predicted monthly average electricity consumption per m^2)

Log(C) is Log(the predicted monthly average electricity consumption per guest room)

Log(D) is Log(the predicted monthly average electricity consumption per room-night)

a is the 5 star hotel

b is the other hotel

* is t-statistic value

Table 4.28 The predictive model and the R^2 of hotels separating by Green Leaf Certification

The monthly average electricity consumption	The Green Leaf Certification hotel: The predictive model	The Green Leaf Certification hotel: R^2	The Green Leaf uncertified hotel: The predictive model	The Green Leaf uncertified hotel: R^2
kWh	Log(A) = (0.533) Log (room night) + (0.597) Log (GFA) + (0.489) Log (worker) (3.112)* (5.298)* (2.492)*	0.999	Log(A) = 3.392 + (0.975) Log (worker) + (0.509) (north eastern) (6.442)* (2.409)*	0.639
			Log(A) = 3. 901 + (0.975) Log (worker) [a]	
			Log(A) = 3.392 + (0.975) Log (worker) [b]	
kWh/ m^2	Log(B) = (0.364) Log (worker) + (0.465) Log (worker density) (5.837)* (3.080)*	0.981	Log(B) = 0.745 + (0.606) Log (worker density per m^2) (2.792)*	0.231
kWh/guest room	Log(C) = (0.555) Log (GFA) + (0.726) Log (ORR) - (0.650) Log (guestroom) + (0.501) Log(worker) (4.582)* (2.997)* (3.213)* (2.657)*	0.997	Log(C) = 4.647 - (0.948) Log (guest) + (0.638) Log (worker) + (0.689) (northeastern) (5.46)* (4.365)* (3.919)* – (0.249)(conference) + (0.290) (5 star) (2.55)* (2.221)*	0.712
			Log(C) = 5.377 - (0.948) Log (guest) + (0.638) Log (worker) [c]	
			Log(C) = 5.087 - (0.948) Log (guest) + (0.638) Log (worker) [d]	
			Log(C) = 5.626 - (0.948) Log (guest) + (0.638) Log (worker) [e]	
			Log(C) = 5.336 - (0.948) Log (guest) + (0.638) Log (worker) [f]	
			Log(C) = 4.688 - (0.948) Log (guest) + (0.638) Log (worker) [g]	
			Log(C) = 4.398 - (0.948) Log (guest) + (0.638) Log (worker) [h]	
			Log(C) = 4.937 - (0.948) Log (guest) + (0.638) Log (worker) [i]	
kWh/room-night	Log(D) = (0.600) Log (GFA) - (0.602) Log (guestroom) + (0.388) Log (worker) (5.572)* (2.997)* (2.284)*	0.993	Log(D) = 3.553 - (0.869) Log (guest) + (0.790) Log (worker) + (0.639) (northeastern) + (0.301) (5 star) (5.996)* (5.044)* (3.333)* (2.108)*	0.993
			Log(D) = 7.202 - (0.948) Log (guest) + (0.638) Log (worker) [k]	
			Log(D) = 4.192 - (0.948) Log (guest) + (0.638) Log (worker) [l]	
			Log(D) = 6.563 - (0.948) Log (guest) + (0.638) Log (worker) [m]	
			Log(D) = 3.553 - (0.948) Log (guest) + (0.638) Log (worker) [n]	

Note:
- a is the hotel located in north-eastern region
- b is the hotel located in other region
- c is the 5 star and conference hotel that located in north-eastern region
- d is the conference hotel that located in north-eastern region
- e is the 5 star hotel that located in north-eastern region
- f is the other hotel that located in north-eastern region
- g is the 5 star and conference hotel that located in other region
- h is the conference hotel that located in other region
- i is the 5 star hotel that located in other region
- j is the other hotel that located in other region
- k is the 5 star hotel that located in north-eastern region
- l is the other hotel that located in north-eastern region
- m is the 5 star hotel that located in other region
- n is the other hotel that located in other region
- * is t-statistic value

4.6 Mitigation for reducing emissions from hotel electricity consumption

As discussed previously, the major electricity consumption of the 34 Thailand hotels was air conditioning (56.46%), followed by lighting (17.93%), lift and escalators (8.96%), water heating (8.53%), and fan and pumps (7.95%). The electricity was the main energy source in Thailand hotels, accounting for 69% and 74% of energy uses in 14 and 63 hotels, respectively. As a result, electricity was the main GHG emission source in Thailand hotels, ranging from 83% - 97%.

There are lots of factors contributing to their high electricity consumption and GHG emissions, some of which are related to hotel designs (such as the number of guest rooms and GFA) and operations (such as star rating, the number of room-nights, workers, worker density and ORR). However, hotel staff (the number of workers and worker density) and guests (the number of guests and OR) were important factors affecting the electricity consumption in kWh, kWh/m^2, kWh/guestroom and kWh/room-night. According to the results, workers or hotel staff was the ,most significant factor which was affecting the hotel electricity consumption. Besides, energy conservation policy of hotel, building extreme temperature protection, equipment improvement and integration of renewable energies were important measures for energy conservation in hotels (Hotel Energy Solution, 2011b).

In this study, the six mitigation measures for the reduction of GHG emissions from the electricity consumption of hotels in Thailand were designed, such as first assessment, hotel staff management, hotel guest management, heat protection techniques for building, improvement of equipment efficiency and integration of renewable energies. The details of each measure a shown in Appendix B. The impacts (high, medium and low) of each measures on energy conservation, opportunity for success, investment/operation cost, payback period and readiness for action were evaluated by 11 experts (hotel engineers, energy managers and/or energy academics). At least 3 experts were visited and interviewed. The interviewing was either by telephone or face-to-face conversation. The 6 from 11 professors who proposed mitigation for the reduction of GHG emission from electricity consumption of hotels a presented in Table 4.29.

Table 4.29 Names, positions and organizations of the experts

Name-Surname	Position	Organization
Mr. Jumphol Keartisuwan	Director-Engineering	W Bangkok Hotel
Mr. Pattanapong Pajareeyanont	Director-Engineering	Pullman Bangkok G
Mr. Mongkol Kaesema	Energy Audit Specialist	The Energy Conservation Center of Thailand
Mr. Veera Teemuangsong	Manager of Engineering	Kosa Hotel Khonkaen
Mr. Treepop Paojeen	Director-Engineering	Moevenpick Resort & Spa Karon Beach Phuket
Mr. Sumeth Junsuthonpoj	Social and Environment Coordinator	Soneva Kiri Resort Koh Kood

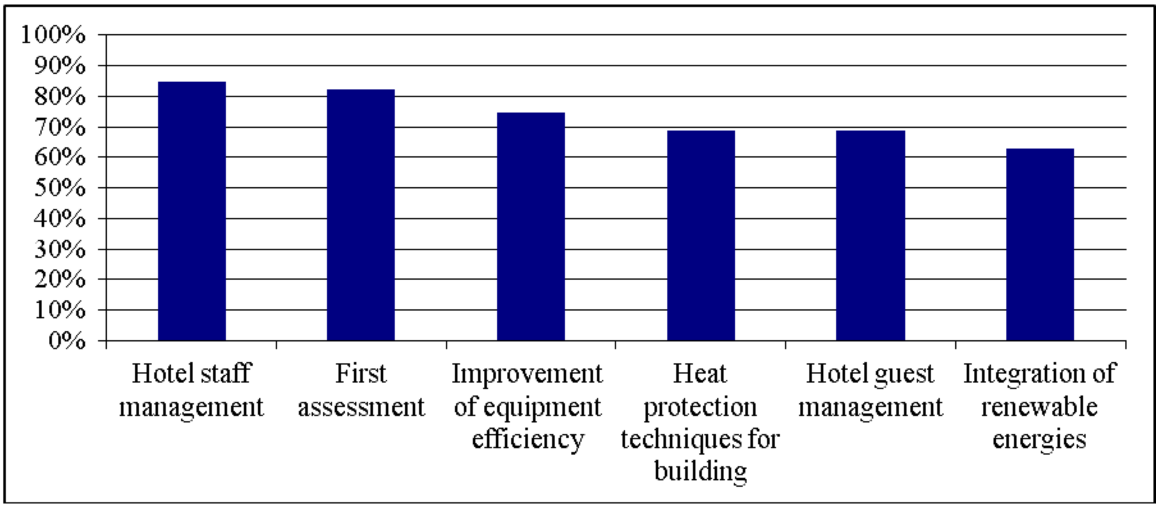

Figure 4.17 Total impact of each GHG mitigation

The impacts of each GHG mitigation a shown in (Figure 4.17). The hotel staff management (84.97%), was the most appropriated mitigation, followed by first assessment (82.32%), improvement of equipment efficiency (74.66%), heat protection techniques for building (68.83%), hotel guest management (68.79%), and integration of renewable energies (62.73%), respectively. That is because hotel staff management had the significant impacts in energy consumption of hotel as discussed previously. As shown in appendix B, hotel staff management had the result on energy conservation effect (80.61%) and opportunity for success (76.97%). Additionally, the hotel staff management were in the high cost (90.30%), had payback period in less than 2 years (80.61%), and the measure can implement in the present year (96.36%). The impacts of each GHG mitigation measure on energy conservation effect, opportunity for success, cost or budget, payback period, and time for action a shown in Fig. 4.18 – 4.21.

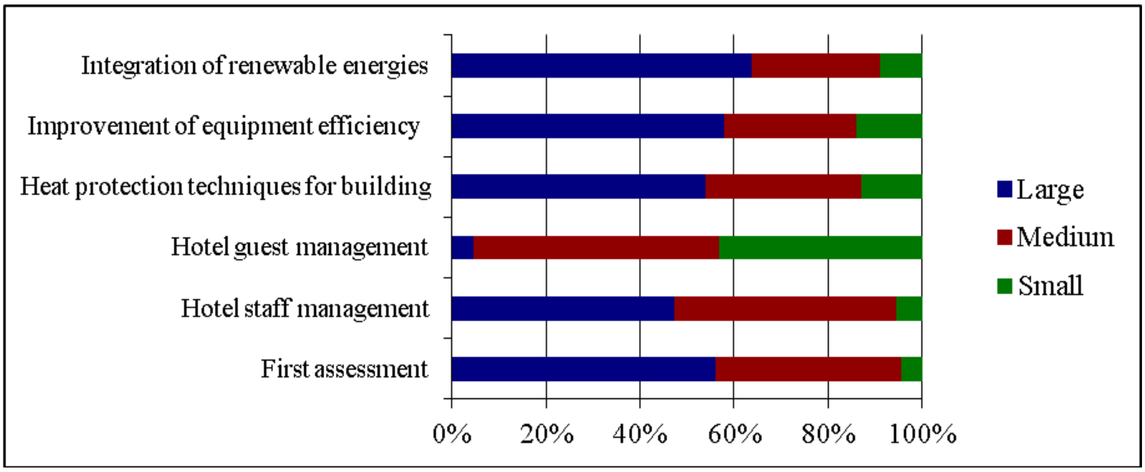

Figure 4.18 Analysis of energy conservation in hotels with various GHG mitigation options.

The impact of each measure on energy conservation a presented in Fig. 4.18. The graph indicated that integration of renewable energies, improvement of equipment efficiency, first assessment, and heat protection techniques for building had the largest effect on energy conservation in hotels, while the hotel staff management and hotel guest management had a medium effect. This is because integration of renewable energies, improvement of equipment efficiency, first assessment, and heat protection techniques for building are the measures related directly to energy management.

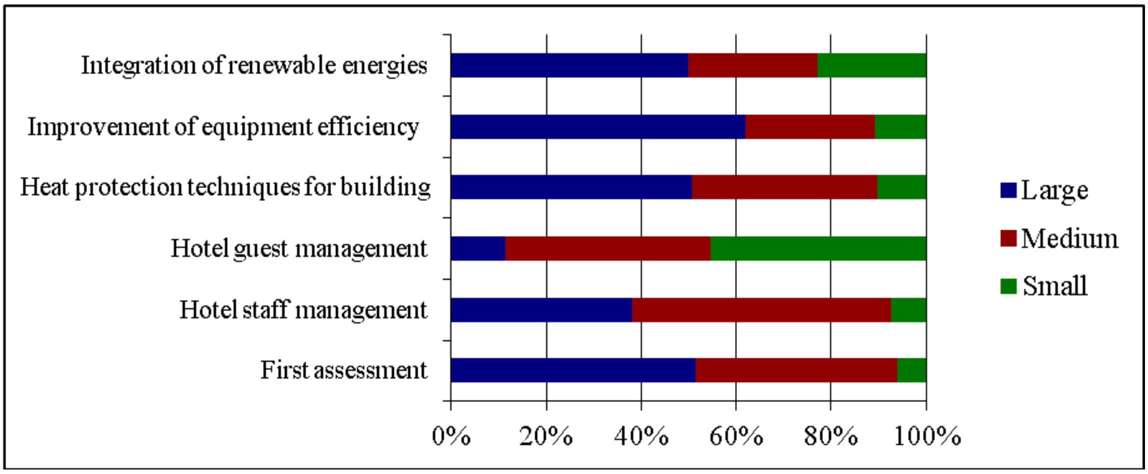

Figure 4.19 Analysis of opportunity for success with various GHG mitigation options.

Fig. 4.19 shows that the improvement of equipment efficiency, first assessment, heat protection techniques for building, and integration of renewable energies had the largest level of opportunity for success, while the hotel staff management and hotel guests management had the medium and the small levels of opportunity for success, respectively.

As discussed previously, the improvement of equipment efficiency, first assessment, heat protection techniques for building, integration of renewable energies, and hotel staff management were controllable indicators that could be conducted by hotels themselves. While the hotel guest management was the uncontrollable indicators, resulting in high uncertainty on opportunity for success.

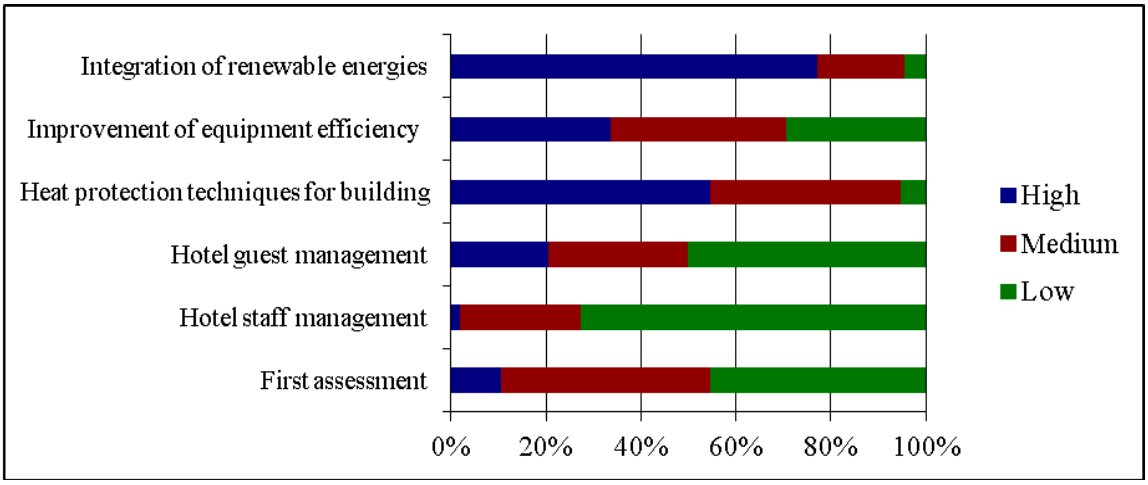

Figure 4.20 Analysis of cost or budget with various GHG mitigation options.

Fig. 4.20 showed that the integration of renewable energies, and heat protection techniques for buildings had the high investment costs. The improvement of equipment efficiency and hotel guest management had the medium costs, while hotel staff management, and first assessment had the low costs. In comparison to hotel staff management and first assessment, the integration of renewable energies and heat protection techniques for building require more advance technology and equipment. As a result, these measures require high investment costs.

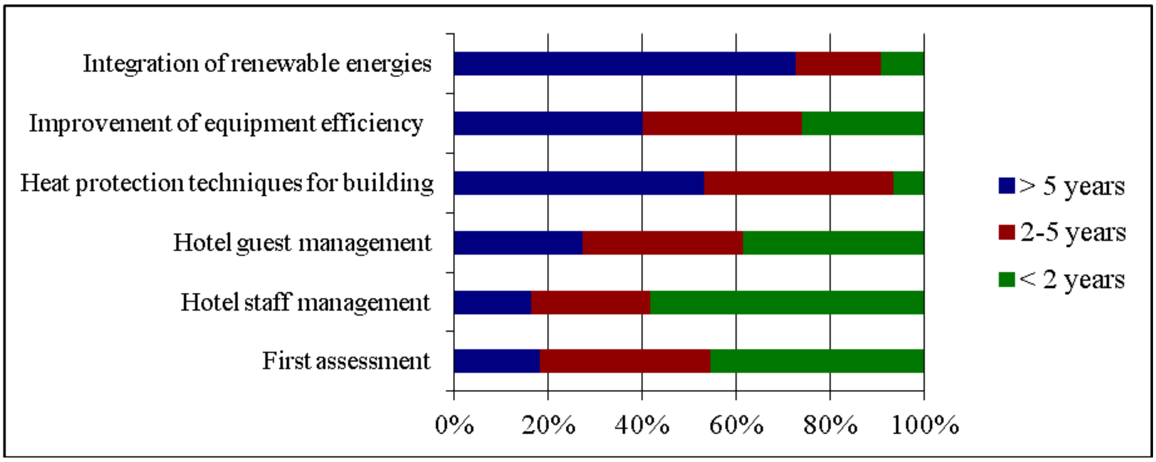

Figure 4.21 Analysis of payback period with various GHG mitigation options

Fig. 4.21 shows that the hotel staff management, first assessment, and hotel guest management were mitigation measures had payback periods of less than 2 years, while the integration of renewable energies, heat protection techniques for building, and improvement of equipment efficiency had payback periods of more than 5 years. This is due to the impacts of investment costs as discussed previously.

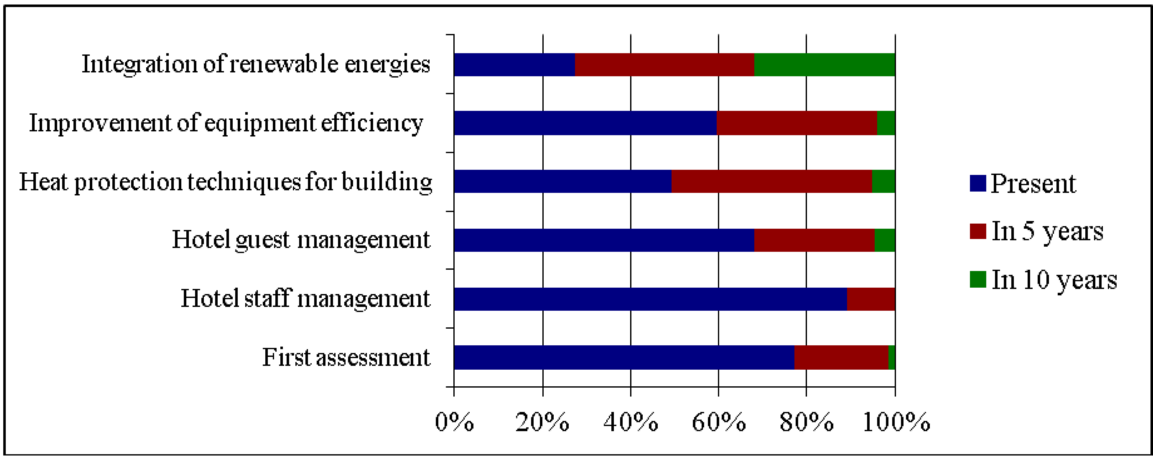

Figure 4.22 Analysis of time for action with various GHG mitigation options

Fig. 4.22 shows that hotel staff management, first assessment, hotel guest management, improvement of equipment efficiency, and heat protection techniques for building were mitigations that could be implemented immediately. While the integration of renewable energies were mitigations that could be implemented in 5 years. Although the integration of renewable energies had the largest effect on energy conservation and opportunity for success in hotels, the investment costs were high and the payback period was more than 5 years. For this reason, the integration of renewable energies was a measure that could be operated within 5 years.

CHAPTER 5
CONCLUSIONS

5.1 Conclusions

All the data in this study was collected in the year 2011. The sampled hotels were conducted from 187 hotels recorded in the list of the Royal Decree on Designated Buildings, B.E. 2538 of the Energy Conservation Promotion Act, B.E. 2535, Thailand. The complete data sets were received from 63 hotels, about 33.69 per cent.

The majority of the sampled hotels in Thailand were large type 4 commercial hotels with unclassified star rating and certificated by the Green Leaf Foundation. They were in Bangkok and located in urban areas. The average of hotel age, guest rooms, floors and the gross floor areas were 20 years 378 rooms, 14 floors and 39,667.54 m^2, respectively. The average of hotel workers, OR, monthly guests and monthly room-nights were 326 workers, 57.33%, 6,139 room-nights and 11,576 guests, respectively.

The main energy sources were electricity, LPG, diesel, and fuel oil. Electricity was the main energy source consumed by hotels in Thailand, ranging from 69% to 94%. The major electricity consumption of the 34 Thailand hotels was air conditioning (56.46%). The ECI was 26.82 kWh/m^2/month, 2,934.20 kWh/guest room/month and 191.03 kWh/room-night/month.

Hotel electricity consumption was converted to GHG emissions by Tier 1 of the 2006 IPCC Guidelines. The monthly average CO_2 emission of electricity, LPG, diesel, and fuel oil consumption were 505,067.77, 58,769.73, 5,259.41, and 86,051.99 $kgCO_2$, respectively. The electricity was the main CO_2 emission in hotels of Thailand which ranges from 83% to 97%. The CEI was 14.69 $kgCO_2/m^2$, 1,607.06 $kgCO_2$/guest room and 104.63 $kgCO_2$/room-night.

The worker density had correlations with the monthly electricity consumption and the total energy use, while the number of worker entered the electricity consumption and total energy use model with high R^2, more than 0.6. This indicats that the number of workers was the factor most affecting electricity consumption of hotels in Thailand.

Together with the hotel factors influencing electricity consumption and the predictive model, the mitigation for the reduction of GHG emissions from electricity consumption of hotels in Thailand was proposed. With summary of mitigation, the hotel staff management was the most appropriated mitigation. This is because hotel staff management had the result on energy conservation effect and opportunity for success. Additionally, the hotel staff management were in the high cost had payback period in less than 2 years, and the measure can implement in the present year.

5.2 Recommendation for future studies

5.2.1 According to the results, hotel staff management was the most significant factor affecting electricity consumption of hotels in Thailand. Thus, the details of the measure should be investigated further.

5.2.2 It was interesting that the Green leaf certificate did not show a significant correlation with electricity consumption as expected. Among all indicators, the indicators regarding to energy conservation are found to be only 12%. Therefore, it is possible that hotels with Green leaf certificate might have low scores in energy conservation section but have high scores in other aspects. In order to increase awareness and promote energy conservation in hotel industry, the criteria of Green leaf certification should be paid more attention in quantitative indicators that strongly affect energy consumption or given more weighting on those indicators.

5.2.3 Future research may focus on increasing the sample size, collection of data from some lower-class hotels, comparison of designs, operations and other aspects of hotels in different countries, and so on. Also, in order to capture quantitative contributions of each relevant variable effecting to electricity consumption in the hotel business, decomposition analysis methods should be employed in future studies.

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Appendix A: Questionnaire

STUDY OF VARIABLES AFFECTING ELECTRICITY CONSUMPTION AND GREENHOUSE GAS EMISSION OF HOTELS IN THAILAND

Directions: Please fill your information in space and do the symbol ✔ into ☐

Part 1: Hotel general information in 2011

1. Name of hotel ……………………………………….……………………….…….
2. Age of building …………………….…………………………..……………... years
3. Number of stories of hotel / Number of floors……………………................... floors
4. Number of guest rooms …………………………………………………… rooms
5. Worker number…………………….……………………………………...workers
6. Gross floor area (GFA)………………………………………….………….. m^2
7. Hotel facilities

Hotel facilities	Number (rooms)	Area (m^2)
Dining facilities		
Convention		
Laundry		
Swimming pool		
Retail shops		
Office		
Guest room		
Other:		

8. Location

☐ Rural/Remote ☐ Urban

9. Type of hotel (classified by main function of hotel)

☐ Resort hotel: hotels are the planned destination of guests, usually vacationers. This is because resorts are located at the ocean or in the mountains away from inner cities. Resort hotels may offer any form of entertainment to keep their guest happy and busy

☐ Conference hotel: hotels are designed to specifically provide meeting space for groups, they provide all services and equipment necessary to handle conventions

☐ Commercial hotel: hotels are mainly to business clients and offer room service, coffee-shop, dining room, cocktail lounge, laundry and valet service, computers and fax-services

☐ Residential hotel: hotels offer long term accommodations

10. Electricity consumption into end-uses

End-uses	**Percentage of Electricity consumption (%)**
Air-condition	
Lighting	
Lifts and escalators	
Water heating	
Other:	

11. Hotel operation in 2011

Month	Monthly guest number (guests)	Monthly room-night (room-nights)	Monthly occupancy rate (%)
January			
February			
March			
April			
May			
June			
July			
August			
September			
October			
November			
December			
Total			

Part 2: Hotel energy consumption in 2011

Month	Electricity consumption (kWh)	Flue consumption			Others	
		Diesel (Liter)	LPG (kg)	Fuel oil (Liter)		
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						
Total						

For more details, please contact

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Appendix B: Mitigation for the reduction of GHG emissions from electricity consumption of hotels

Directions: Please do the symbol ✔ into ☐ and fill your estimation in space

Items	Mitigation	Energy conservation effect			Opportunity for success			Cost/ Budget			Payback period			Time for action			Percentage
		Large (3)	Medium (2)	Small (1)	Large (3)	Medium (2)	Small (1)	High (1)	Medium (2)	Low (3)	> 5 years (1)	2-5 years (2)	< 2 years (3)	Present (3)	In 5 years (2)	In 10 years (1)	
First assessment	- Establishment of management standards	7 (63.64)	4 (36.37)	0 (0.00)	5 (45.46)	6 (54.55)	0 (0.00)	3 (27.28)	5 (45.46)	3 (27.28)	3 (27.28)	5 (45.46)	3 (27.28)	8 (72.73)	3 (27.28)	0 (0.00)	**78.79**
	- Making a clearly defined energy use policy and an action plan	7 (63.64)	4 (36.37)	0 (0.00)	6 (54.55)	5 (45.46)	0 (0.00)	2 (18.19)	5 (45.46)	4 (36.37)	2 (18.19)	5 (45.46)	4 (36.37)	8 (72.73)	3 (27.28)	0 (0.00)	**81.82**
	- Energy conservation targets and investment budget setting	5 (45.46)	6 (54.55)	0 (0.00)	6 (54.55)	4 (36.37)	1 (9.09)	2 (18.19)	5 (45.46)	4 (36.37)	3 (27.28)	3 (27.28)	5 (45.46)	8 (72.73)	3 (27.28)	0 (0.00)	**80.00**
	- Establishment of energy management organization and employee education	7 (63.64)	3 (27.28)	1 (9.09)	5 (45.46)	4 (36.37)	2 (18.19)	0 (0.00)	6 (54.55)	5 (45.46)	1 (9.09)	6 (54.55)	4 (36.37)	10 (90.91)	1 (9.09)	0 (0.00)	**83.03**
First assessment	- Measurements and recording of monthly usage (electricity, gas, oil, and water) and graphs showing differences of energy intensity ($MJ/m^2/year$) from previous month of year	6 (54.55)	5 (45.46)	0 (0.00)	6 (54.55)	5 (45.46)	0 (0.00)	0 (0.00)	4 (36.37)	7 (63.64)	1 (9.09)	3 (27.28)	7 (63.64)	8 (72.73)	2 (18.19)	1 (9.09)	**86.06**
	- Grasp status of implementation of energy conservation	5 (45.46)	4 (36.37)	2 (18.19)	6 (54.55)	4 (36.37)	1 (9.09)	0 (0.00)	4 (36.37)	7 (63.64)	2 (18.19)	2 (18.19)	7 (63.64)	9 (81.82)	2 (18.19)	0 (0.00)	**84.24**
	SUM	**37 (56.06)**	**26 (39.39)**	**3 (4.55)**	**34 (51.52)**	**28 (42.42)**	**4 (6.06)**	**7 (10.61)**	**29 (43.94)**	**30 (45.45)**	**12 (18.18)**	**24 (36.36)**	**30 (45.45)**	**51 (77.27)**	**14 (21.21)**	**1 (1.52)**	**82.32**
	Percentage	**83.84**			**81.82**			**78.28**			**75.76**			**91.92**			
Hotel staff management	- Information to staff (management standards, energy use policy and an action plan, energy conservation targets, energy management organization and employee education and status of implementation of energy conservation)	5 (45.46)	5 (45.46)	1 (9.09)	4 (36.37)	5 (45.46)	2 (18.19)	0 (0.00)	3 (27.28)	8 (72.73)	2 (18.19)	2 (18.19)	7 (63.64)	10 (90.91)	1 (9.09)	0 (0.00)	**84.24**
	- Warning labels and equipment maintenance for staff and engineering staff (e.g. turn equipment off when not in use)	6 (54.55)	5 (45.46)	0 (0.00)	5 (45.46)	6 (54.55)	0 (0.00)	0 (0.00)	3 (27.28)	8 (72.73)	1 (9.09)	3 (27.28)	7 (63.64)	10 (90.91)	1 (9.09)	0 (0.00)	**87.88**
	- Staff education and training of energy conservation	5 (45.46)	5 (45.46)	1 (9.09)	3 (27.28)	7 (63.64)	1 (9.09)	0 (0.00)	3 (27.28)	8 (72.73)	1 (9.09)	4 (36.37)	6 (54.55)	10 (90.91)	1 (9.09)	0 (0.00)	**84.24**
	- Establishing a well-defined operation and maintenance program for engineering staff	7 (63.64)	4 (36.37)	0 (0.00)	6 (54.55)	5 (45.46)	0 (0.00)	1 (9.09)	2 (18.19)	8 (72.73)	3 (27.28)	2 (18.19)	6 (54.55)	11 (100.00)	0 (0.00)	0 (0.00)	**87.27**
	- Review of operating hours	3 (27.28)	7 (63.64)	1 (9.09)	3 (27.28)	7 (63.64)	1 (9.09)	0 (0.00)	3 (27.28)	8 (72.73)	2 (18.19)	3 (27.28)	6 (54.55)	8 (72.73)	3 (27.28)	0 (0.00)	**81.21**
	SUM	**26 (47.27)**	**26 (47.27)**	**3 (5.45)**	**21 (38.18)**	**30 (54.55)**	**4 (7.27)**	**1 (1.82)**	**14 (25.45)**	**40 (72.73)**	**9 (16.36)**	**14 (25.45)**	**32 (58.18)**	**49 (89.09)**	**6 (10.91)**	**0 (0.00)**	**84.97**
	Percentage	**80.61**			**76.97**			**90.30**			**80.61**			**96.36**			

Appendix B: Mitigation for the reduction of GHG emissions from electricity consumption of hotels (Cont')

Items	Mitigation	Energy conservation effect			Opportunity for success			Cost/ Budget			Payback period			Time for action			Percentage
		Large (3)	Medium (2)	Small (1)	Large (3)	Medium (2)	Small (1)	High (1)	Medium (2)	Low (3)	> 5 years (1)	2-5 years (2)	< 2 years (3)	Present (3)	In 5 years (2)	In 10 years (1)	
Hotel guest management	- Information to guests (management standards, energy use policy and an action plan, energy conservation targets, energy management organization and employee education and status of implementation of energy conservation)	1 (9.09)	5 (45.46)	5 (45.46)	0 (0.00)	6 (54.55)	5 (45.46)	0 (0.00)	4 (36.37)	7 (63.64)	2 (18.19)	5 (45.46)	4 (36.37)	9 (81.82)	2 (18.19)	0 (0.00)	**72.12**
	- Providing leaflets to encourage guests to save energy	0 (0.00)	5 (45.46)	6 (54.55)	1 (9.09)	3 (27.28)	7 (63.64)	2 (18.19)	6 (54.55)	3 (27.28)	2 (18.19)	5 (45.46)	4 (36.37)	8 (72.73)	3 (27.28)	0 (0.00)	**66.06**
	- Making a encourage guests to save energy policy (discount and memento)	1 (9.09)	6 (54.55)	4 (36.37)	3 (27.28)	4 (36.37)	4 (36.37)	5 (45.46)	2 (18.19)	4 (36.37)	5 (45.46)	3 (27.28)	3 (27.28)	6 (54.55)	4 (36.37)	1 (9.09)	**65.45**
	- Customer feedback	0 (0.00)	7 (63.64)	4 (36.37)	1 (9.09)	6 (54.55)	4 (36.37)	2 (18.19)	1 (9.09)	8 (72.73)	3 (27.28)	2 (18.19)	6 (54.55)	7 (63.64)	3 (27.28)	1 (9.09)	**71.52**
	SUM	**2 (4.55)**	**23 (52.27)**	**19 (43.18)**	**5 (11.36)**	**19 (43.18)**	**20 (45.45)**	**9 (20.45)**	**13 (29.55)**	**22 (50.00)**	**12 (27.27)**	**15 (34.09)**	**17 (38.64)**	**30 (68.18)**	**12 (27.27)**	**2 (4.55)**	**68.79**
	Percentage	**53.79**			**55.30**			**76.52**			**70.45**			**87.88**			
Heat protection techniques for building	- Blocking of solar radiation on the windows (e.g. double glazing, shading curtains and light-shielding films)	8 (72.73)	2 (18.19)	1 (9.09)	8 (72.73)	2 (18.19)	1 (9.09)	9 (81.82)	2 (18.19)	0 (0.00)	8 (72.73)	3 (27.28)	0 (0.00)	6 (54.55)	4 (36.37)	1 (9.09)	**67.88**
	- Blocking of solar radiation on the roof (e.g. heat reflection coating, insulation and shading of roof)	5 (45.46)	4 (36.37)	2 (18.19)	5 (45.46)	4 (36.37)	2 (18.19)	9 (81.82)	2 (18.19)	0 (0.00)	8 (72.73)	3 (27.28)	0 (0.00)	3 (27.28)	7 (63.64)	1 (9.09)	**61.21**
	- Fresh ventilated air and ventilation control	4 (36.37)	5 (45.46)	2 (18.19)	3 (27.28)	7 (63.64)	1 (9.09)	4 (36.37)	7 (63.64)	0 (0.00)	3 (27.28)	8 (72.73)	0 (0.00)	3 (27.28)	7 (63.64)	1 (9.09)	**66.06**
	- Blocking of solar radiation on the building (e.g. insulation of walls)	6 (54.55)	4 (36.37)	1 (9.09)	3 (27.28)	6 (54.55)	2 (18.19)	8 (72.73)	3 (27.28)	0 (0.00)	8 (72.73)	3 (27.28)	0 (0.00)	2 (18.19)	8 (72.73)	1 (9.09)	**61.21**
	- Prevention of air infiltration at doors and windows (tightening the property shell, with added or better insulation, eliminating leaks, replacing windows)	6 (54.55)	4 (36.37)	1 (9.09)	6 (54.55)	5 (45.46)	0 (0.00)	1 (9.09)	8 (72.73)	2 (18.19)	2 (18.19)	6 (54.55)	3 (27.28)	9 (81.82)	2 (18.19)	0 (0.00)	**81.21**
	- Building waterproofing	5 (45.46)	4 (36.37)	2 (18.19)	7 (63.64)	3 (27.28)	1 (9.09)	3 (27.28)	6 (54.55)	2 (18.19)	3 (27.28)	6 (54.55)	2 (18.19)	8 (72.73)	3 (27.28)	0 (0.00)	**75.76**
	- Automatic control of cooling and limiting room temperature (e.g. installing motion sensors in public areas and occupancy sensors in guestrooms)	8 (72.73)	2 (18.19)	1 (9.09)	7 (63.64)	3 (27.28)	1 (9.09)	8 (72.73)	3 (27.28)	0 (0.00)	9 (81.82)	2 (18.19)	0 (0.00)	7 (63.64)	4 (36.37)	0 (0.00)	**68.48**
	SUM	**42 (54.55)**	**25 (32.46)**	**10 (12.99)**	**39 (50.65)**	**30 (38.96)**	**8 (10.39)**	**42 (54.55)**	**31 (40.26)**	**4 (5.19)**	**41 (53.25)**	**31 (40.26)**	**5 (6.49)**	**38 (49.35)**	**35 (45.45)**	**4 (5.19)**	**68.83**
	Percentage	**81.39**			**80.09**			**50.22**			**51.08**			**81.39**			

Appendix B: Mitigation for the reduction of GHG emissions from electricity consumption of hotels (Cont')

Items	Mitigation	**Energy conservation effect**			**Opportunity for success**			**Cost/ Budget**			**Payback period**			**Time for action**			**Percentage**
		Large (3)	Medium (2)	Small (1)	Large (3)	Medium (2)	Small (1)	High (1)	Medium (2)	Low (3)	> 5 years (1)	2-5 years (2)	< 2 years (3)	Present (3)	In 5 years (2)	In 10 years (1)	
Improvement of equipment efficiency	- Use of indirect evaporative coolers instead of compression refrigeration systems	8 (72.73)	2 (18.19)	1 (9.09)	7 (63.64)	3 (27.28)	1 (9.09)	8 (72.73)	3 (27.28)	0 (0.00)	7 (63.64)	4 (36.37)	0 (0.00)	2 (18.19)	6 (54.55)	3 (27.28)	**64.85**
	- Use of alternative cooling technologies (e.g. ground cooling with ground-air heat exchangers, use night ventilation techniques)	6 (54.55)	1 (9.09)	4 (36.37)	5 (45.46)	3 (27.28)	3 (27.28)	8 (72.73)	3 (27.28)	0 (0.00)	9 (81.82)	1 (9.09)	1 (9.09)	2 (18.19)	7 (63.64)	2 (18.19)	**59.39**
	- Maintain the place around the condensing units for air-conditioning and chillers	6 (54.55)	4 (36.37)	1 (9.09)	8 (72.73)	3 (27.28)	0 (0.00)	2 (18.19)	1 (9.09)	8 (72.73)	3 (27.28)	1 (9.09)	7 (63.64)	10 (90.91)	1 (9.09)	0 (0.00)	**86.67**
	- Effective operation of total heat exchanger (e.g. cooling water quality control)	7 (63.64)	4 (36.37)	0 (0.00)	9 (81.82)	2 (18.19)	0 (0.00)	2 (18.19)	5 (45.46)	4 (36.37)	3 (27.28)	3 (27.28)	5 (45.46)	11 (100.00)	0 (0.00)	0 (0.00)	**85.45**
	- Installation of (manual or automatic) inverter device to ventilation fans	4 (36.37)	5 (45.46)	2 (18.19)	5 (45.46)	4 (36.37)	2 (18.19)	3 (27.28)	6 (54.55)	2 (18.19)	3 (27.28)	6 (54.55)	2 (18.19)	4 (36.37)	7 (63.64)	0 (0.00)	**70.91**
	- Automatic control of electricity in guest rooms	7 (63.64)	3 (27.28)	1 (9.09)	8 (72.73)	2 (18.19)	1 (9.09)	7 (63.64)	4 (36.37)	0 (0.00)	6 (54.55)	5 (45.46)	0 (0.00)	3 (27.28)	8 (72.73)	0 (0.00)	**68.48**
	- Water heater and hot water pipe insulation	8 (72.73)	3 (27.28)	0 (0.00)	7 (63.64)	4 (36.37)	0 (0.00)	3 (27.28)	8 (72.73)	0 (0.00)	3 (27.28)	8 (72.73)	0 (0.00)	4 (36.37)	7 (63.64)	0 (0.00)	**74.55**
	- Reduce internal loads by using of high efficiency lighting systems (e.g. installing energy efficient lighting and dimmers, installing LED (light emitting diode) exit signs, replacing the magnetic ballasts with electronic ballasts, using T5 lamps for lighting, use super metal halide fluorescent lamps)	8 (72.73)	2 (18.19)	1 (9.09)	9 (81.82)	2 (18.19)	0 (0.00)	5 (45.46)	6 (54.55)	0 (0.00)	4 (36.37)	6 (54.55)	1 (9.09)	7 (63.64)	4 (36.37)	0 (0.00)	**75.76**
	- Using natural day lighting whenever possible	7 (63.64)	1 (9.09)	3 (27.28)	5 (45.46)	3 (27.28)	3 (27.28)	1 (9.09)	3 (27.28)	7 (63.64)	3 (27.28)	2 (18.19)	4 (36.37)	8 (72.73)	3 (27.28)	0 (0.00)	**76.97**
	- Cleaning of lighting fixtures	4 (36.37)	5 (45.46)	2 (18.19)	7 (63.64)	3 (27.28)	1 (9.09)	1 (9.09)	0 (0.00)	10 (90.91)	3 (27.28)	1 (9.09)	6 (54.55)	11 (100.00)	0 (0.00)	0 (0.00)	**84.24**
	- Control of steam pressure and blow-down	5 (45.46)	4 (36.37)	2 (18.19)	5 (45.46)	4 (36.37)	2 (18.19)	0 (0.00)	5 (45.46)	4 (36.37)	2 (18.19)	2 (18.19)	4 (36.37)	10 (90.91)	1 (9.09)	0 (0.00)	**73.94**
	SUM	**70 (57.85)**	**34 (28.10)**	**17 (14.05)**	**75 (61.98)**	**33 (27.27)**	**13 (10.74)**	**40 (33.06)**	**44 (36.36)**	**35 (28.93)**	**46 (38.02)**	**39 (32.23)**	**30 (24.79)**	**72 (59.50)**	**44 (36.36)**	**5 (4.13)**	**74.66**
	Percentage	**81.27**			**83.75**			**64.19**			**58.95**			**85.12**			

Appendix B: Mitigation for the reduction of GHG emissions from electricity consumption of hotels (Cont')

Items	Mitigation	Energy conservation effect			Opportunity for success			Cost/ Budget			Payback period			Time for action			Percentage
		Large (3)	Medium (2)	Small (1)	Large (3)	Medium (2)	Small (1)	High (1)	Medium (2)	Low (3)	> 5 years (1)	2-5 years (2)	< 2 years (3)	Present (3)	In 5 years (2)	In 10 years (1)	
Integration of renewable energies	- Solar photovoltaic integrated in buildings	6 (54.55)	4 (36.37)	1 (9.09)	4 (36.37)	4 (36.37)	3 (27.28)	8 (72.73)	3 (27.28)	0 (0.00)	9 (81.82)	2 (18.19)	0 (00.00)	4 (36.37)	2 (18.19)	5 (45.45)	**59.39**
	- Solar water heating	8 (72.73)	2 (18.19)	1 (9.09)	7 (63.64)	2 (18.19)	2 (18.19)	9 (81.82)	1 (9.09)	1 (9.09)	7 (63.64)	2 (18.19)	2 (18.19)	2 (18.19)	7 (63.64)	2 (18.19)	**66.06**
	SUM	**14 (63.64)**	**6 (27.27)**	**2 (9.09)**	**11 (50.00)**	**6 (27.27)**	**5 (22.73)**	**17 (77.27)**	**4 (18.18)**	**1 (4.55)**	**16 (72.73)**	**4 (18.18)**	**2 (9.09)**	**6 (27.27)**	**9 (40.91)**	**7 (31.82)**	**62.73**
	Percentage	**84.85**			**75.76**			**42.42**			**45.45**			**65.15**			

Note: ( ) is in the percentage

Large of energy conservation effect is mitigation that reduces more than 80 percent of total electricity consumption reduction
Medium of energy conservation effect is mitigation that reduces 50-80 percent of total electricity consumption reduction
Small of energy conservation effect is mitigation that reduces less than 50 percent of total electricity consumption reduction

Large of opportunity for success is mitigation has success in reduction more than 80 percent of total opportunity for success
Medium of opportunity for success is mitigation has success in reduction 50-80 percent of total opportunity for success
Small of opportunity for success is mitigation has success in reduction less than 50 percent of total opportunity for success

High of cost is mitigation that pays more than 80 percent of total cost of investment
Medium of cost is mitigation that pays 50-80 percent of total cost of investment
Low of cost is mitigation that pays less than 50 percent of total cost of investment

Appendix C: Hotel characteristics, and energy use of 63 Thailand sampled hotels monthly in 2011

Hotel No	Characteristics														Energy use									
	Age (years)	Number of guest rooms (rooms)	Gross floor areas (m^2)	Number of floors (floors)	Star rating[a] (stars)	Function[b]	Types[c]	Green Leaf Certification[d]	Locations[e]	Regions[f]	Number of workers (workers)	Monthly average occupancy rates (%)	Monthly average room-nights (room-night)	Monthly average number of guests (guests)	Electricity (MJ)	Electricity (kWh)	Fossil fuel						Monthly fossil fuel (MJ)	Monthly energy (MJ)
																	LPG (MJ)	LPG (kg)	Diesel (MJ)	Diesel (liter)	Fuel oil (MJ)	Fuel oil (liter)		
1	22	165	10,486.00	7	4	3	3	1	1	6	200	38.49	1,923.17	3,846.33	856,500.00	237,916.67	241,706.76	4,812.00	54.63	1.50	No	No	241,761.39	1,098,261.39
2	28	340	61,264.00	5	5	3	4	1	1	6	337	40.44	4,162.33	6,424.33	2,502,000.00	695,000.00	N.A.	N.A.	N.A.	N.A.	No	No	N.A.	N.A.
3	19	407	34,257.00	27	0	3	3	0	1	6	437	81.79	10,179.50	16,759.67	2,050,800.00	569,666.67	12,306.35	245.00	2,428.12	66.67	990,720.00	24,000.00	1,005,454.47	3,056,254.47
4	23	96	6,160.00	9	0	3	4	0	1	6	35	78.25	2,282.80	4,656.67	215,400.00	59,833.33	14,466.24	288.00	No	No	No	No	14,466.24	229,866.24
5	20	469	53,210.00	43	5	3	4	1	1	6	432	45.67	6,484.58	12,276.00	2,739,600.00	761,000.00	246,930.68	4,916.00	342.35	9.40	1,320,960.00	32,000.00	1,568,233.03	4,307,833.03
6	20	1,251	76,370.95	37	4	2	3	1	1	6	800	53.03	20,074.83	27,227.58	10,437,300.00	2,899,250.00	822,028.60	16,365.29	8,261.27	226.83	2,799,004.16	67,805.33	3,629,294.03	14,066,594.03
7	15	211	17,846.60	6	4	3	3	1	1	6	200	47.22	3,020.83	3,953.67	1,655,100.00	459,750.00	583,660.04	11,619.75	1,165.44	32.00	No	No	584,825.48	2,239,925.48
8	5	199	12,988.00	11	0	2	3	0	1	6	120	71.25	4,314.50	5,908.33	1,360,800.00	378,000.00	270,840.16	5,392.00	758.60	20.83	No	No	271,598.76	1,632,398.76
9	30	423	24,646.00	5	4	3	4	1	1	6	221	82.47	10,567.50	20,379.17	2,081,700.00	578,250.00	149,099.21	2,968.33	No	No	775,616.93	18,789.17	924,716.14	3,006,416.14
10	45	538	71,076.60	14	0	3	3	0	1	6	472	76.95	12,577.58	16,131.33	4,101,600.00	1,139,333.33	66,705.44	1,328.00	N.A.	N.A.	1,113,560.00	28,000.00	N.A.	N.A.
11	18	160	16,404.45	16	4	2	3	1	1	6	120	40.14	1,945.17	2,546.75	1,993,200.00	553,666.67	142,649.18	2,839.92	652.65	17.92	381,800.00	10,000.00	525,101.83	2,518,301.83
12	16	160	16,618.00	19	0	3	3	0	1	6	140	66.40	3,028.58	6,057.17	1,759,203.00	488,667.50	855,919.20	17,040.00	1,805.83	49.58	No	No	857,725.03	2,616,928.03
13	27	525	84,060.90	16	0	3	3	0	1	6	400	23.10	3,681.33	7,362.67	3,369,000.00	935,833.33	1,329,688.56	26,472.00	455.25	12.50	No	No	1,330,143.81	4,699,143.81
14	15	198	23,405.80	6	4	3	3	1	0	6	193	73.53	4,415.67	5,347.17	2,795,100.00	776,416.67	293,385.06	5,840.83	2,185.20	60.00	No	No	295,570.26	3,090,670.26
15	15	188	21,018.61	15	3	4	3	1	1	6	95	32.97	1,869.42	3,737.83	666,420.00	185,116.67	21,762.15	433.25	3,642.00	100.00	No	No	25,404.15	691,824.15
16	25	304	14,175.00	9	0	2	3	0	1	6	308	50.18	3,928.50	19,450.00	496,500.00	137,916.67	5,767,437.90	114,820.58	N.A.	N.A.	No	No	N.A.	N.A.
17	14	296	27,251.00	25	3	4	3	1	1	3	131	49.93	4,472.25	8,840.42	989,273.40	274,798.17	48,220.80	960.00	1,608.55	44.17	139,526.42	3,508.33	189,355.77	1,178,629.17
18	17	285	16,700.00	16	0	3	4	1	0	6	270	39.90	3,458.83	4,070.92	1,357,200.00	377,000.00	193,707.81	3,856.42	9,105.00	250.00	710,784.33	18,616.67	913,597.14	2,270,797.14
19	15	327	57,376.00	61	5	3	3	1	1	6	400	57.51	5,723.00	16,222.75	9,548,242.20	2,652,289.50	432,028.23	8,601.00	7,284.00	200.00	4,953.60	120.00	444,265.83	9,992,508.03
20	27	354	65,359.84	9	0	3	3	1	1	6	600	60.96	6,355.83	10,242.92	7,624,200.00	2,117,833.33	2,778,547.80	55,316.50	2,913.60	80.00	85,836.92	2,158.33	2,867,298.32	10,491,498.32
21	22	431	39,770.00	22	4	3	4	1	1	6	500	71.92	11,239.58	21,285.58	7,987,800.00	2,218,833.33	1,501,374.70	29,890.00	2,428.00	66.67	No	No	1,503,802.70	9,491,602.70
22	41	517	118,900.40	23	5	3	4	1	1	6	700	62.94	9,879.08	19,758.17	11,808,900.00	3,280,250.00	1,364,703.68	27,169.10	4,916.70	135.00	No	No	1,369,620.38	13,178,520.38
23	13	370	57,711.90	40	5	3	3	0	1	6	370	50.58	5,686.75	11,138.92	10,449,000.00	2,902,500.00	6,879,580.33	136,961.58	5,827.20	160.00	No	No	6,885,407.53	17,334,407.53
24	3	213	8,714.00	7	0	2	3	0	1	6	70	82.08	5,316.50	9,203.00	451,500.00	125,416.67	24,110.40	480.00	728.40	20.00	No	No	24,838.80	476,338.80
25	18	202	24,616.00	9	0	3	4	1	1	1	250	76.77	4,714.58	9,429.17	1,810,872.00	503,020.00	978,668.76	19,483.75	748,431.00	20,550.00	No	No	1,727,099.76	3,537,971.76
26	19	119	15,290.00	5	3	1	3	1	0	1	130	42.44	1,528.25	2,808.67	438,084.00	121,690.00	86,332.81	1,718.75	728.40	20.00	No	No	87,061.21	525,145.21
27	24	4,100	408,457.00	42	4	2	4	0	0	6	1,300	34.50	42,814.75	85,629.50	20,943,168.00	5,817,546.67	464,937.42	9,256.17	2,913.60	80.00	6,656,400.00	161,250.00	7,124,251.02	28,067,419.02
28	21	220	13,786.00	12	4	3	3	1	1	4	135	51.10	3,411.80	6,840.00	1,137,488.40	315,969.00	235,478.24	4,688.00	2,701.15	74.17	No	No	238,179.39	1,375,667.79
29	39	1,012	100,383.00	19	5	2	4	0	0	4	1,191	47.09	14,441.50	28,883.00	9,846,620.40	2,735,172.33	13,627,763.17	271,307.25	146,381.09	4,019.25	No	No	13,774,144.26	23,620,764.66
30	29	260	22,454.00	11	4	1	3	1	0	4	260	68.71	5,412.42	8,293.25	2,909,686.83	808,246.34	2,279,035.56	45,372.00	1,456.80	40.00	No	No	2,280,492.36	5,190,179.19
31	39	184	21,694.57	3	0	3	3	0	1	4	84	51.38	2,817.67	10,511.83	411,174.00	114,215.00	108,375.24	2,157.58	22,616.82	621.00	357,828.66	8,668.33	488,820.72	899,994.72
32	22	464	46,850.00	8	5	1	4	1	0	4	540	59.58	8,396.50	16,793.00	4,295,715.30	1,193,254.25	326,203.71	6,494.20	9,809.88	269.35	2,992,800.00	72,500.00	3,328,813.59	7,624,528.89
33	1	555	33,600.00	20	0	3	4	0	1	4	673	73.71	12,558.83	14,178.25	4,723,908.00	1,312,196.67	1,598,590.68	31,825.42	1,456.80	40.00	No	No	1,600,047.48	6,323,955.48
34	29	560	51,080.00	6	0	2	4	0	0	5	370	41.01	6,989.50	14,610.42	2,405,380.35	668,161.21	265,610.38	5,287.88	910.50	25.00	899,897.12	22,627.54	1,166,418.00	3,571,798.35
35	21	304	40,877.40	7	5	1	4	0	0	5	399	63.14	5,839.08	11,678.17	4,801,056.00	1,333,626.67	328,194.45	6,533.83	3,896.94	107.00	1,124,057.51	27,758.67	1,456,148.90	6,257,204.90
36	25	240	35,708.00	3	5	1	3	1	0	3	400	73.28	5,340.80	11,304.75	1,598,816.40	444,115.67	N.A.	N.A.	N.A.	N.A.	No	No	N.A.	N.A.
37	25	420	34,056.50	12	4	2	3	1	1	2	120	36.62	4,636.83	7,395.25	1,895,580.00	526,550.00	N.A.	N.A.	N.A.	N.A.	No	No	N.A.	N.A.
38	20	576	48,536.00	10	0	2	3	0	0	2	154	45.95	8,065.67	16,131.33	738,855.00	205,237.50	66,253.37	1,319.00	2,913.60	80.00	No	No	69,166.97	808,021.97
39	21	375	44,797.00	17	0	3	4	0	1	2	328	60.68	6,909.58	12,375.25	2,723,454.00	756,515.00	210,162.32	4,184.00	2,901.46	79.67	1,244,007.20	30,135.83	1,457,070.98	4,180,524.98
40	6	130	14,328.10	10	5	3	3	0	1	2	130	63.18	2,496.00	4,992.00	1,163,611.20	323,225.33	49,413.76	983.75	2,081.59	57.16	No	No	51,495.35	1,215,106.55
41	21	256	14,806.40	3	0	3	3	0	1	2	240	54.60	4,376.50	8,536.08	3,071,160.00	853,100.00	188,383.89	3,750.43	128,077.00	3,516.67	No	No	316,460.89	3,387,620.89
42	22	271	26,945.40	10	5	1	4	1	0	2	260	36.59	3,017.92	6,035.83	2,180,592.00	605,720.00	588,293.76	11,712.00	613.07	16.83	No	No	588,906.83	2,769,498.83
43	36	258	19,929.00	5	4	2	4	1	1	2	160	24.61	1,924.42	3,263.50	665,002.80	184,723.00	N.A.	N.A.	N.A.	N.A.	No	No	N.A.	N.A.
44	18	186	17,860.00	9	4	3	4	1	1	7	185	62.35	3,525.67	7,051.33	1,468,065.00	407,795.83	139,840.32	2,784.00	439,613.68	12,070.67	No	No	579,454.00	2,047,519.00
45	40	184	21,694.50	3	0	3	4	0	1	7	84	66.40	3,978.08	10,511.83	7,674,900.00	2,131,916.67	14,064.40	280.00	1,092.60	30.00	No	No	15,157.00	7,690,057.00
46	18	320	61,480.47	19	0	2	4	0	1	7	370	55.07	5,351.00	13,252.00	2,566,175.70	712,826.58	473,509.84	9,426.83	2,428.00	66.67	1,542,726.53	40,406.67	2,018,664.37	4,584,840.07
47	17	140	14,596.86	9	5	2	4	1	1	7	170	38.10	1,613.50	3,328.08	607,590.00	168,775.00	100,321.86	1,997.25	168,290.62	4,620.83	No	No	268,612.48	876,202.48
48	11	210	8,548.96	4	0	1	4	0	0	3	150	82.29	5,255.92	10,511.83	1,606,132.20	446,147.83	108,374.99	2,157.58	1,361,514.09	37,383.69	547,036.35	13,966.83	2,016,925.43	3,623,057.63
49	26	350	15,100.00	23	0	1	4	0	0	3	320	67.61	7,182.60	14,365.19	2,180,214.00	605,615.00	100,861.84	2,008.00	34,887.45	957.92	No	No	135,749.29	2,315,963.29
50	17	178	115,501.00	1	0	1	4	1	0	3	568	74.81	4,046.17	9,775.33	7,968,449.40	2,213,458.17	371,057.38	7,387.17	64,311.65	1,765.83	No	No	435,369.03	8,403,818.43
51	24	254	11,850.60	3	5	1	4	1	0	3	408	59.99	4,623.75	9,247.50	1,677,132.00	465,870.00	141,403.73	2,815.13	4,079.04	112.00	No	No	145,482.77	1,822,614.77
52	23	350	25,267.00	25	4	1	3	1	0	3	260	61.75	6,538.17	12,296.50	1,079,559.00	299,877.50	N.A.	N.A.	N.A.	N.A.	No	No	N.A.	N.A.
53	16	251	29,019.00	20	4	2	4	1	1	3	260	49.82	3,798.92	10,511.83	2,517,861.00	699,405.83	1,613,726.65	32,126.75	1,232.21	33.83	No	No	1,614,958.86	4,132,819.86
54	5	358	35,335.00	7	0	1	4	0	0	3	446	78.08	8,494.25	16,988.50	2,186,545.86	607,373.85	337,909.77	6,727.25	19,243.96	528.39	1,249,247.98	31,777.92	1,606,401.71	3,792,947.57
55	19	31	10,385.50	3	0	2	3	0	0	3	341	25.33	237.17	359.17	2,238,516.00	621,810.00	412,522.25	8,212.67	9,014.16	247.51	No	No	421,536.41	2,660,052.41
56	27	479	10,860.00	3	0	1	3	1	0	3	672	69.68	10,131.00	10,511.83	4,563,183.24	1,267,550.90	333,591.54	6,641.28	6,755.91	185.50	No	No	340,347.45	4,903,530.69
57	11	414	36,658.36	4	0	1	4	0	0	3	390	68.73	8,638.25	16,630.67	3,317,757.00	921,599.17	365,071.64	7,268.00	54,630.00	1,500.00	No	No	419,701.64	3,737,458.64
58	5	121	8,000.00	4	4	1	4	0	0	3	95	72.24	2,655.58	5,311.17	1,126,855.20	313,015.33	92,624.12	1,844.00	2,466.06	67.71	No	No	95,090.18	1,221,945.38
59	16	203	22,918.00	4	5	1	4	1	0	3	340	73.08	4,497.67	9,763.92	3,937,620.00	1,093,783.33	472,153.63	9,399.83	281,608.55	7,732.25	508,432.00	12,316.67	1,262,194.18	5,199,814.18
60	21	243	33,833.00	22	0	2	3	1	0	3	160	51.47	3,796.75	8,527.17	2,572,413.38	714,559.27	391,517.57	7,794.50	59,504.21	1,633.83	185,416.14	4,491.67	636,437.92	3,208,851.30
61	12	208	19,467.10	7	0	1	4	0	0	3	196	69.15	4,323.08	6,858.00	688,807.80	191,335.50	385,766.40	7,680.00	N.A.	N.A.	6,192.00	150.00	N.A.	N.A.
62	5	203	26,484.09	24	4	3	3	1	1	2	317	72.38	3,958.83	7,249.58	1,436,100.00	398,916.67	N.A.	N.A.	N.A.	N.A.	No	No	N.A.	N.A.
63	18	199	20,232.00	10	3	3	4	1	1	7	120	30.70	1,857.33	3,714.00	675,755.12	187,709.76	N.A.	N.A.	N.A.	N.A.	No	No	N.A.	N.A.
Sum (per month)		23,815.00	2,499,056.86								20,527.00		386,784.40	729,282.03	209,146,195.18	58,096,165.33	50,461,600.07	1,004,610.79	3,454,836.72	94,860.98	22,549,506.92	556,258.79	76,465,943.70	285,612,138.88
Min	1.00	31.00	6,160.00	1.00							35.00	23.10	237.17	359.17	215,400.00	59,833.33	12,306.35	245.00	54.63	1.50	4,953.60	120.00	0.00	229,866.24
Max	45.00	4,100.00	408,457.00	61.00							1,300.00	82.47	42,814.75	85,629.50	20,943,168.00	5,817,546.67	13,627,763.17	271,307.25	1,361,514.09	37,383.69	6,656,400.00	161,250.00	13,774,144.25	28,067,419.02
Mean	20.35	378.02	39,667.57	13.71							325.83	57.33	6,139.43	11,575.91	3,319,780.88	922,161.35	800,977.78	15,946.20	54,838.68	1,505.73	357,928.68	8,829.50	1,213,745.14	4,533,526.01
Std. Deviation	9.29	515.69	53,614.68	11.68							241.32	16.14	5,878.27	11,160.88	3,629,265.67	1,008,129.35	2,029,963.44	40,413.37	202,725.44	5,566.32	1,009,849.83	24,582.58	2,214,831.47	5,247,621.27
Sum (per year)													*4,641,413*	*8,751,384*	*2,509,754,342.16*	*697,153,984*	*605,539,200.84*	*12,055,329.00*	*41,458,040.64*	*1,138,332.00*	*270,594,083.04*	*6,675,105.00*	*917,591,324.40*	*3,427,345,666.56*

Note : a
0: hotel that unclassified by the Thai Hotels Association
3: 3-star hotel
4: 4-star hotel
5: 5-star hotel

b
1: resort hotel
2: conference hotel
3: commercial hotel
4: residential hotel

c
3: hotels providing accommodation, catering or restaurant services, and which has either conference rooms or entertainment venues
4: hotels providing accommodation, catering or restaurant services, conference rooms and entertainment venues

d
0: hotel that uncertified by the Green Leaf Foundation
1: hotel is certificated by the Green Leaf Foundation

e
0: rural or remote
1: urban
N.A. is not available

f
1: Central region
2: Northern region
3: Southern region
4: Eastern region
5: Western region
6: Bangkok
7: North-eastern region

Appendix D: Hotel CO_2 emissions of 63 Thailand sampled hotels monthly in 2011

Hotel No	CO_2 emissions					
	Electricity ($kgCO_2$)	Fossil fuel ($kgCO_2$)			Monthly fossil fuel	Monthly energy ($kgCO_2$)
		LPG	Diesel	Fuel oil		
1	130,306.96	15,507.42	4.02	No	15,511.44	145,818.40
2	380,651.50	N.A.	N.A.	No	N.A.	N.A.
3	312,006.43	789.55	178.68	72,000.00	72,968.23	384,974.66
4	32,770.72	928.13	No	No	928.13	33,698.85
5	416,799.70	15,842.58	25.19	96,000.00	111,867.77	528,667.47
6	1,587,919.23	52,739.71	607.91	203,416.00	256,763.62	1,844,682.85
7	251,805.08	37,446.46	85.76	No	37,532.22	289,337.30
8	207,030.60	17,376.56	55.82	No	17,432.38	224,462.98
9	316,707.53	9,565.91	No	56,367.51	65,933.42	382,640.95
10	624,012.87	4,279.69	N.A.	84,000.00	N.A.	N.A.
11	303,243.23	9,152.09	48.03	30,000.00	39,200.11	342,443.34
12	267,643.19	54,914.06	132.88	No	55,046.94	322,690.13
13	512,555.92	85,310.16	33.50	No	85,343.66	597,899.58
14	425,243.41	18,823.00	160.80	No	18,983.80	444,227.21
15	101,388.40	1,396.22	268.00	No	1,664.22	103,052.62
16	75,536.96	370,027.27	N.A.	No	N.A.	N.A.
17	150,506.96	3,093.75	118.37	10,525.00	13,737.12	164,244.08
18	206,482.90	12,427.91	670.00	55,850.00	68,947.91	275,430.81
19	1,452,658.96	27,718.07	536.00	360.00	28,614.07	1,481,273.03
20	1,159,937.32	178,266.06	214.40	6,475.00	184,955.46	1,344,892.78
21	1,215,255.02	96,325.20	178.67	No	96,503.87	1,311,758.89
22	1,796,592.93	87,556.66	361.80	No	87,918.46	1,884,511.39
23	1,589,699.25	441,380.10	428.80	No	441,808.90	2,031,508.15
24	68,690.71	1,546.88	53.60	No	1,600.48	70,291.19
25	275,504.05	62,789.43	55,074.00	No	117,863.43	393,367.48
26	66,649.61	5,538.94	53.60	No	5,592.54	72,242.15
27	3,186,270.31	29,829.45	214.40	483,750.00	513,793.85	3,700,064.16
28	173,056.22	15,107.81	198.77	No	15,306.58	188,362.80
29	1,498,053.89	874,330.00	10,771.59	No	885,101.59	2,383,155.48
30	442,676.52	146,218.36	107.20	No	146,325.56	589,002.08
31	62,555.56	6,953.14	1,664.28	26,004.99	34,622.41	97,177.97
32	653,545.35	20,928.58	721.87	217,500.00	239,150.45	892,695.80
33	718,690.11	102,562.38	107.20	No	102,669.58	821,359.69
34	365,951.89	17,041.03	67.00	67,882.61	84,990.64	450,942.53
35	730,427.33	21,056.30	286.76	83,276.00	104,619.06	835,046.39
36	243,242.15	N.A.	N.A.	No	N.A.	N.A.
37	288,391.44	N.A.	N.A.	No	N.A.	N.A.
38	112,408.58	4,250.68	214.40	No	4,465.08	116,873.66
39	414,343.27	13,483.59	213.51	90,407.50	104,104.60	518,447.87
40	177,030.52	3,170.29	153.18	No	3,323.47	180,353.99
41	467,242.87	12,086.33	9,424.67	No	21,511.00	488,753.87
42	331,752.84	37,743.75	45.11	No	37,788.86	369,541.70

Appendix D: Hotel CO_2 emissions of 63 Thailand sampled hotels monthly in 2011 (Cont')

Hotel No	CO_2 emissions					
	Electricity ($kgCO_2$)	Fossil fuel ($kgCO_2$)			Monthly fossil fuel	Monthly energy ($kgCO_2$)
		LPG	Diesel	Fuel oil		
43	101,172.79	N.A.	N.A.	No	N.A.	N.A.
44	223,349.78	8,971.88	32,349.39	No	41,321.27	264,671.05
45	1,167,650.76	902.34	80.40	No	982.74	1,168,633.50
46	390,415.12	30,379.44	178.67	121,220.00	151,778.11	542,193.23
47	92,438.07	6,436.45	12,383.82	No	18,820.27	111,258.34
48	244,355.17	6,953.12	100,188.30	41,900.50	149,041.92	393,397.09
49	331,695.34	6,471.09	2,567.23	No	9,038.32	340,733.66
50	1,212,311.04	23,806.30	4,732.43	No	28,538.73	1,240,849.77
51	255,157.00	9,072.18	300.16	No	9,372.34	264,529.34
52	164,242.91	N.A.	N.A.	No	N.A.	N.A.
53	383,064.57	103,533.47	90.67	No	103,624.14	486,688.71
54	332,658.66	21,679.61	1,416.09	95,333.75	118,429.45	451,088.11
55	340,565.34	26,466.60	663.32	No	27,129.92	367,695.26
56	694,237.63	21,402.57	497.14	No	21,899.71	716,137.34
57	504,759.86	23,422.27	4,020.00	No	27,442.27	532,202.13
58	171,438.50	5,942.58	181.47	No	6,124.05	177,562.55
59	599,065.13	30,292.43	20,722.43	36,950.00	87,964.86	687,029.99
60	391,364.11	25,118.98	4,378.67	13,475.01	42,972.66	434,336.77
61	104,794.45	24,750.00	N.A.	450.00	N.A.	N.A.
62	218,486.66	N.A.	N.A.	No	N.A.	N.A.
63	102,808.63	N.A.	N.A.	No	N.A.	N.A.
Sum (per month)	31,819,269.75	3,237,515.25	254,227.41	1,668,776.36	5,160,519.02	36,979,788.77
Min	32,770.72	789.55	4.02	360.00	0.00	33,698.84
Max	3,186,270.31	874,330.00	100,188.30	483,750.00	885,101.59	3,700,064.16
Mean	505,067.77	51,389.13	4,035.36	26,488.51	81,913.00	586,980.77
Std. Deviation	552,152.45	130,238.39	14,917.74	73,747.75	145,957.86	651,080.34
Sum (per year)	*381,831,237.00*	*38,850,183.00*	*3,050,728.92*	*20,025,316.32*	*61,926,228.24*	*443,757,465.24*

Appendix E: Pearson correlation between monthly electricity consumption (kWh) and 30 independent variables

Variables	kWh	kWh/m^2	kWh/guest room	kWh/room-night
Age	.246	.061	.066	.034
Number of guest rooms	**.743****	-.058	-.114	-.086
Gross floor area	**.818****	-.132	.063	.011
Number of floors	**.520****	-.047	.011	-.027
Unclassified	-.148	.108	.100	.102
3-star hotel	-.190	-.230	-.160	-.083
4-star hotel	.065	-.022	-.131	-.104
5-star hotel	.219	.030	.114	.039
Resort hotel	-.098	.177	-.003	-.086
Conference hotel	.087	-.168	-.016	.156
Commercial hotel	.055	.044	.056	-.038
Residential hotel	-.125	-.156	-.112	-.061
Type3 hotel	-.150	.008	.014	.108
Type4 hotel	.150	-.008	-.014	-.108
Green Leaf Certification	-.051	-.034	-.036	-.092
Uncertified	.051	.034	.036	.092
Remote location	.058	.130	.103	.120
Urban location	-.058	-.130	-.103	-.120
Central region	-.110	-.114	-.067	-.054
Northern region	-.168	-.121	-.136	-.081
Southern region	-.130	.212	.183	.183
Eastern region	.051	-.013	-.081	-.070
Western region	.014	-.036	-.008	-.016
Bangkok	.269*	-.077	-.031	-.045
North-eastern region	-.059	.057	.064	.006
Number of workers	**.804****	.153	.144	.081

Appendix E: Pearson correlation between monthly electricity consumption (kWh) and 30 independent variables (Cont')

Variables	kWh	kWh/m^2	kWh/guest room	kWh/room-night
Worker density (number of workers per 1,000 m^2 of GFA)	-.096	**.615****	.142	.236
Occupancy rates	-.019	.239	-.009	-.253*
Monthly average room-night	**.771****	.049	-.102	-.130
Monthly average of guests	**.770****	-.025	-.080	-.117

Note: * Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Appendix F: ECI, and CEI from electricity of 63 sampled Thai hotels in 2011

Hotel No	Monthly electricity (kWh)	Energy used intensity (EUI) of electricity			Monthly CO_2 emissions from electricity ($kgCO_2$)	CO_2 emissions indicators (CEI) from electricity		
		(kWh/m^2)	(kWh/room)	(kWh/room-night)		($kgCO_2/m^2$)	($kgCO_2$/room)	($kgCO_2$/room-night)
1	237,916.67	22.69	1,441.92	123.71	145,818.40	12.43	789.74	67.76
2	695,000.00	11.34	2,044.12	166.97	380,651.50	6.21	1,119.56	91.45
3	569,666.67	16.63	1,399.67	55.96	312,006.43	9.11	766.60	30.65
4	59,833.33	9.71	623.26	26.21	33,698.84	5.32	341.36	14.36
5	761,000.00	14.30	1,622.60	117.36	416,799.70	7.83	888.70	64.28
6	2,899,250.00	37.96	2,317.55	144.42	1,844,682.85	20.79	1,269.32	79.10
7	459,750.00	25.76	2,178.91	152.19	289,337.29	14.11	1,193.39	83.36
8	378,000.00	29.10	1,899.50	87.61	224,462.98	15.94	1,040.35	47.98
9	578,250.00	23.46	1,367.02	54.72	316,707.53	12.85	748.72	29.97
10	1,139,333.33	16.03	2,117.72	90.58	712,292.55	8.78	1,159.88	49.61
11	553,666.67	33.75	3,460.42	284.64	333,243.23	18.49	1,895.27	155.90
12	488,667.50	29.41	3,054.17	161.35	322,690.14	16.11	1,672.77	88.37
13	935,833.33	11.13	1,782.54	254.21	597,899.57	6.10	976.30	139.23
14	776,416.67	33.17	3,921.30	175.83	444,227.21	18.17	2,147.69	96.30
15	185,116.67	8.81	984.66	99.02	102,784.61	4.82	539.30	54.24
16	137,916.67	9.73	453.67	35.11	445,564.23	5.33	248.48	19.23
17	274,798.17	10.08	928.37	61.45	161,150.32	5.52	508.47	33.65
18	377,000.00	22.57	1,322.81	109.00	274,760.81	12.36	724.50	59.70
19	2,652,289.50	46.23	8,110.98	463.44	1,481,273.03	25.32	4,442.38	253.83
20	2,117,833.33	32.40	5,982.58	333.21	1,344,892.78	17.75	3,276.66	182.50
21	2,218,833.33	55.79	5,148.11	197.41	1,311,758.88	30.56	2,819.62	108.12
22	3,280,250.00	27.59	6,344.78	332.04	1,884,511.38	15.11	3,475.03	181.86
23	2,902,500.00	50.29	7,844.59	510.40	2,031,079.35	27.55	4,296.48	279.54
24	125,416.67	14.39	588.81	23.59	70,291.18	7.88	322.49	12.92
25	503,020.00	20.43	2,490.20	106.69	393,367.48	11.19	1,363.88	58.44
26	121,690.00	7.96	1,022.61	79.63	66,703.21	4.36	560.08	43.61
27	5,817,546.67	14.24	1,418.91	135.88	[illegible],700,064.16	7.80	777.14	74.42
28	315,969.00	22.92	1,436.22	92.61	188,362.80	12.55	786.62	50.72

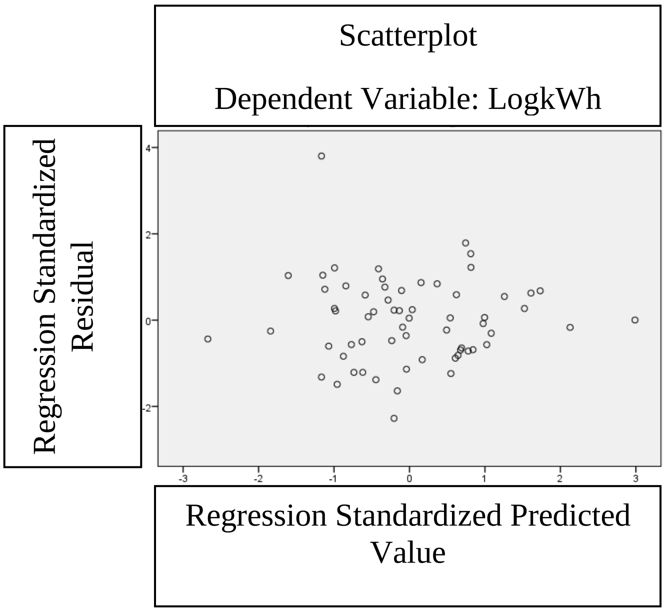
Appendix F: ECI, and CEI from electricity of 63 sampled Thai hotels in 2011 (Cont')

Hotel No	Monthly electricity (kWh)	Energy used intensity (EUI) of electricity			Monthly CO_2 emissions from electricity ($kgCO_2$)	CO_2 emissions indicators (CEI) from electricity		
		(kWh/m^2)	(kWh/room)	(kWh/room-night)		($kgCO_2/m^2$)	($kgCO_2$/room)	($kgCO_2$/room-night)
29	2,735,172.33	27.25	2,702.74	189.40	2,383,155.48	14.92	1,480.29	103.73
30	808,246.34	36.00	3,108.64	149.33	589,002.08	19.71	1,702.60	81.79
31	114,215.00	5.26	620.73	40.54	97,177.96	2.88	339.98	22.20
32	1,193,254.25	25.47	2,571.67	142.11	892,695.80	13.95	1,408.50	77.84
33	1,312,196.67	39.05	2,364.32	104.48	821,359.69	21.39	1,294.94	57.23
34	668,161.21	13.08	1,193.15	95.59	450,942.53	7.16	653.49	52.36
35	1,333,626.67	32.63	4,386.93	228.40	835,046.38	17.87	2,402.72	125.09
36	444,115.67	12.44	1,850.48	83.16	243,242.15	6.81	1,013.51	45.54
37	526,550.00	15.46	1,253.69	113.56	288,391.44	8.47	686.65	62.20
38	205,237.50	4.23	356.32	25.45	116,873.66	2.32	195.15	13.94
39	756,515.00	16.89	2,017.37	109.49	518,447.87	9.25	1,104.92	59.97
40	323,225.33	22.56	2,486.35	129.50	177,183.69	12.36	1,361.77	70.93
41	853,100.00	57.62	3,332.42	194.93	488,753.87	31.56	1,825.17	106.76
42	605,720.00	22.48	2,235.13	200.71	369,541.71	12.31	1,224.18	109.93
43	184,723.00	9.27	715.98	95.99	101,172.79	5.08	392.14	52.57
44	407,795.83	22.83	2,192.45	115.66	264,671.04	12.51	1,200.81	63.35
45	2,131,916.67	98.27	11,586.50	535.92	1,168,633.50	53.82	6,345.93	293.52
46	712,826.58	11.59	2,227.58	133.21	542,193.23	6.35	1,220.05	72.96
47	168,775.00	11.56	1,205.54	104.60	92,438.07	6.33	660.27	57.29
48	446,147.83	52.19	2,124.51	84.88	393,397.09	28.58	1,163.60	46.49
49	605,615.00	40.11	1,730.33	84.32	340,733.65	21.97	947.70	46.18
50	2,213,458.17	19.16	12,435.16	547.05	1,240,849.77	10.50	6,810.74	299.62
51	465,870.00	39.31	1,834.13	100.76	264,529.34	21.53	1,004.56	55.18
52	299,877.50	11.87	856.79	45.87	164,242.91	6.50	469.27	25.12
53	699,405.83	24.10	2,786.48	184.11	486,688.72	13.20	1,526.15	100.84
54	607,373.85	17.19	1,696.57	71.50	451,088.11	9.41	929.21	39.16
55	621,810.00	59.87	20,058.39	2,621.79	367,695.25	32.79	10,985.98	1,435.95

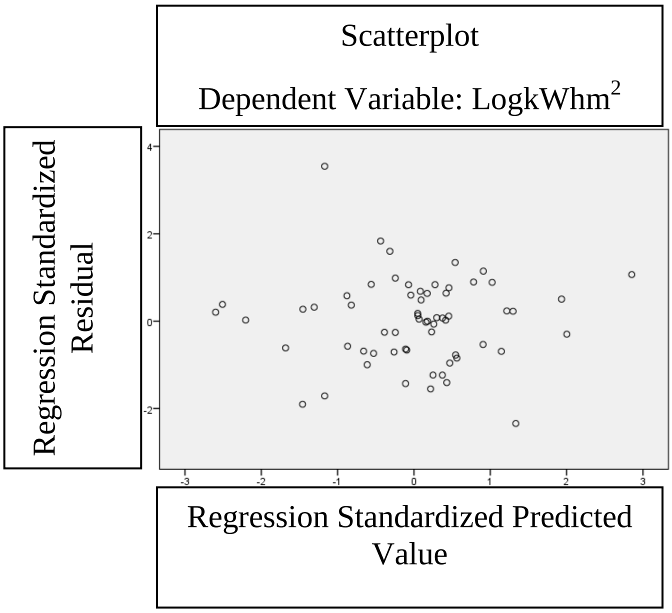
Appendix F: ECI, and CEI from electricity of 63 sampled Thai hotels in 2011 (Cont')

Hotel No	Monthly electricity (kWh)	Energy used intensity (EUI) of electricity			Monthly CO_2 emissions from electricity ($kgCO_2$)	CO_2 emissions indicators (CEI) from electricity		
		(kWh/m^2)	(kWh/room)	(kWh/room-night)		($kgCO_2/m^2$)	($kgCO_2$/room)	($kgCO_2$/room-night)
56	1,267,550.90	116.72	2,646.24	125.12	716,137.33	63.93	1,449.35	68.53
57	921,599.17	25.14	2,226.08	106.69	532,202.13	13.77	1,219.23	58.43
58	313,015.33	39.13	2,586.90	117.87	177,562.54	21.43	1,416.85	64.56
59	1,093,783.33	47.73	5,388.10	243.19	687,029.99	26.14	2,951.06	133.19
60	714,559.27	21.12	2,940.57	188.20	434,336.78	11.57	1,610.55	103.08
61	191,335.50	9.83	919.88	44.26	129,994.45	5.38	503.82	24.24
62	398,916.67	15.06	1,965.11	100.77	218,486.66	8.25	1,076.29	55.19
63	187,709.76	9.28	943.27	101.06	102,808.63	5.08	516.63	55.35
Sum	58,096,165.33	1,689.64	184,854.50	12,034.70	36,979,788.77	925.42	101,244.81	6,591.40
Min	59,833.33	4.23	356.32	23.59	33,698.84	2.32	195.15	12.92
Max	5,817,546.67	116.72	20,058.39	2,621.79	3,700,064.16	63.93	10,985.98	1,435.95
Mean	922,161.35	26.82	2,934.20	191.03	586,980.77	14.69	1,607.06	104.63
Std. Deviation	1,008,129.35	20.27	3,220.24	332.38	651,080.34	11.10	1,763.73	182.04

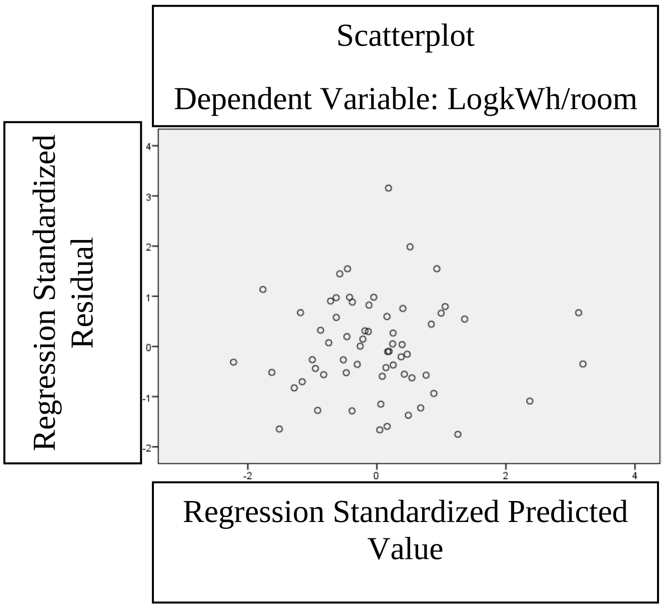
Appendix G : Scatter plot of regression standardized residual and regression standardized predicted values



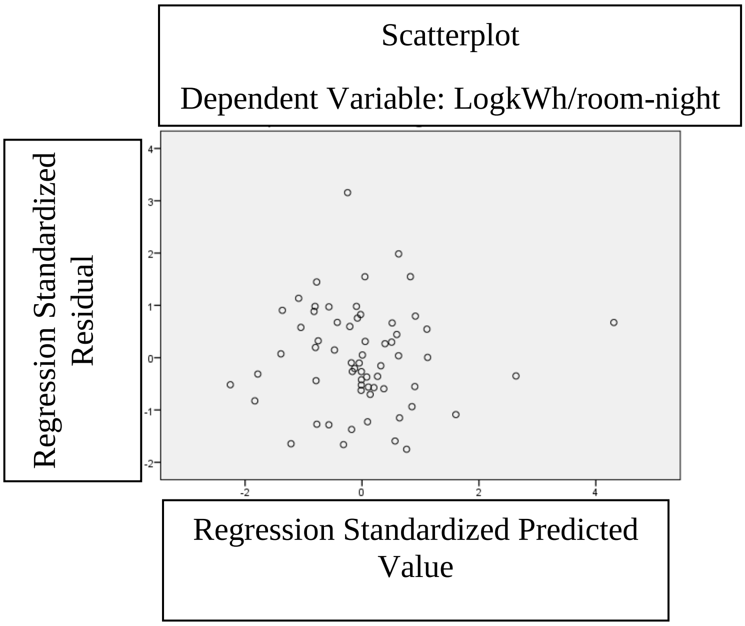
Scatter plot of regression standardized residual and regression standardized predicted value between electricity consumption (kWh) and 24 independent variables



Scatter plot of regression standardized residual and regression standardized predicted value between electricity consumption (kWh/m^2) and 24 independent variables



Scatter plot of regression standardized residual and regression standardized predicted value between electricity consumption (kWh/guest room) and 24 independent variables



Scatter plot of regression standardized residual and regression standardized predicted value between electricity consumption (kWh/room-night) and 24 independent variables

Appendix H: Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by star rating

Variables	Pearson Correlation											
	4 three-star hotels				17 four-star hotels				14 five-star hotels			
	(kWh)	(kWh/m²)	(kWh/guest room)	(kWh/room-night)	(kWh)	(kWh/m²)	(kWh/guest room)	(kWh/room-night)	(kWh)	(kWh/m²)	(kWh/guest room)	(kWh/room-night)
Age	-.844	-.726	.571	.365	.122	-.238	-.321	-.219	.407	-.240	-.099	-.097
Number of guest rooms	**.999****	.980*	-.904	-.495	**.945****	-.184	-.178	-.010	.616*	.008	.062	.123
Gross floor area	**.996****	.956*	-.862	-.470	**.924****	-.207	-.152	.020	**.820****	.024	.393	.418
Number of floors	.965*	.879	-.743	-.547	**.791****	-.025	.008	.104	.599*	.358	.616*	**.690****
Resort hotel	-.749	-.806	.829	-.203	-.185	.116	-.025	-.254	-.396	.136	-.217	-.328
Conference hotel	-	-	-	-	.400	-.230	-.164	.342	.047	-.265	-.297	-.216
Commercial hotel	-.049	.186	-.415	.565	-.241	.132	.176	-.134	.363	.051	.427	.481
Residential hotel	.691	.537	-.359	-.314	-	-	-	-	-	-	-	-
Type3 hotel	.049	-.186	.415	-.565	-.260	-.064	-.053	.085	.150	.238	.404	.401
Type4 hotel	-.049	.186	-.415	.565	.260	.064	.053	-.085	-.150	-.238	-.404	-.401
Green Leaf Certification	-	-	-	-	-.536*	-.019	.078	.050	-.298	-.253	-.205	-.242
Uncertified green Leaf	-	-	-	-	.536*	.019	-.078	-.050	.298	.253	.205	.242
Remote location	-.749	-.806	.829	-.203	.267	.044	.076	-.111	-.199	.128	-.272	-.354
Urban location	.749	.806	-.829	.203	-.267	-.044	-.076	.111	.199	-.128	.272	.354
Central region	-.749	-.806	.829	-.203	-	-	-	-	-	-	-	-
Northern region	-	-	-	-	-.220	-.510*	-.380	-.261	-.340	-.169	-.225	-.159
Southern region	.874	.788	-.648	-.855	-.197	-.042	-.068	-.156	-.333	.208	-.135	-.295
Eastern region	-	-	-	-	-.123	.106	.009	-.089	.247	-.049	-.175	-.157
Western region	-	-	-	-	-	-	-	-	.000	.099	.094	.029
Bangkok	-.076	-.167	.234	.492	.451	.386	.342	.416	.519	.114	.515	.596*
North-eastern region	-.049	.186	-.415	.565	-.112	-.070	-.011	-.085	-.310	-.346	-.293	-.238
Number of workers	.121	.143	-.140	-.708	**.976****	.018	.001	.055	.630*	.083	.099	.097
Worker density (number of workers per 1,000 m² of GFA)	-.772	-.750	.697	-.071	-.395	.319	.157	-.077	-.350	.231	-.326	-.398
Occupancy rates	.442	.298	-.124	**-.997****	-.183	.465	.432	-.167	.086	.377	.300	.038
Monthly average room-night	.924	.848	-.717	-.789	**.972****	-.043	-.082	-.024	**.693****	.120	.190	.170
Monthly average of guests	.940	.868	-.741	-.763	**.953****	-.098	-.105	-.040	**.746****	.223	.305	.269

Note: - is insignificant variable. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Appendix I: Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by functions

Variables	Pearson Correlation											
	17 Resort hotels				16 Conference hotel				28 Commercial hotel			
	(kWh)	(kWh/m^2)	(kWh/guest room)	(kWh/room-night)	(kWh)	(kWh/m^2)	(kWh/guest room)	(kWh/room-night)	(kWh)	(kWh/m^2)	(kWh/guest room)	(kWh/room-night)
Age	.156	.232	-.024	.042	.273	-.148	-.056	-.033	.228	.053	.184	.147
Number of guest rooms	.265	.369	-.218	-.212	.945**	-.114	-.166	-.154	.499**	-.008	.091	.140
Gross floor area	.775**	-.323	.838**	.830**	.927**	-.129	-.129	-.120	.687**	-.044	.333	.436*
Number of floors	-.294	-.193	-.354	-.333	.851**	.075	-.205	-.254	.502**	.082	.314	.386*
Unclassified star	.215	.249	.152	.055	-.426	-.048	.191	.201	-.116	.052	-.057	-.095
3-star hotel	-.310	-.249	-.180	-.140	-	-	-	-	-.173	-.186	-.163	-.109
4-star hotel	-.258	-.069	-.129	-.161	.373	.081	-.146	-.152	-.221	-.003	-.166	-.237
5-star hotel	.136	-.079	.035	.141	.098	-.045	-.074	-.082	.462*	.025	.326	.425*
Type3 hotel	-.216	.113	-.251	-.267	-.299	.334	.213	.210	-.038	-.037	.019	.119
Type4 hotel	.216	-.113	.251	.267	.299	-.334	-.213	-.210	.038	.037	-.019	-.119
Green Leaf Certification	.210	.060	.216	.282	-.151	.055	-.146	-.173	.018	-.147	-.045	-.048
Uncertified green Leaf	-.210	-.060	-.216	-.282	.151	-.055	.146	.173	-.018	.147	.045	.048
Remote location	-	-	-	-	.381	.128	.329	.336	-.127	.001	-.055	-.071
Urban location	-	-	-	-	-.381	-.128	-.329	-.336	.127	-.001	.055	.071
Central region	-.310	-.249	-.180	-.140	-	-	-	-	-.104	-.074	-.048	-.101
Northern region	-.075	-.103	-.065	.122	-.250	-.401	-.219	-.158	-.185	.005	-.108	-.131
Southern region	-.065	.202	.062	-.087	-.129	.492	.608*	.568*	-	-	-	-
Eastern region	.170	-.028	-.011	.004	.292	.117	-.008	-.038	-.157	-.097	-.223	-.252
Western region	.278	.000	.139	.182	-.071	-.151	-.094	-.078	-	-	-	-
Bangkok					.306	.122	-.198	-.204	.290	-.092	.086	.171
North-eastern region	-	-	-	-	-.162	-.262	-.094	-.099	-.029	.282	.238	.190
Number of workers	.741**	.396	.424	.407	.922**	.142	.016	.001	.636**	.057	.231	.246
Worker density (number of workers per 1,000 m^2 of GFA)	.079	.881**	-.171	-.197	-.181	.626**	.772**	.789**	-.195	.090	-.256	-.302
Occupancy rates	.225	.256	.258	.069	-.166	-.130	-.367	-.407	.098	.188	.125	-.150
Monthly average room-night	.296	.437	-.140	-.206	.962**	-.075	-.193	-.190	.463*	.143	.137	.006
Monthly average of guests	.308	.032	-.017	-.084	.928**	-.168	-.212	-.202	.599**	.244	.320	.193

Note: - is insignificant variable. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Appendix J: Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by the Hotel Act B.E 2547

Variables	Pearson Correlation							
	31 type 3 hotels				32 type 4 hotels			
	(kWh)	(kWh/m²)	(kWh/guest room)	(kWh/room-night)	(kWh)	(kWh/m²)	(kWh/guest room)	(kWh/room-night)
Age	.077	.001	-.066	-.037	.347	.130	.232	.348
Number of guest rooms	**.575****	.094	-.194	-.218	**.810****	-.129	-.118	-.039
Gross floor area	**.680****	-.110	.042	-.055	**.887****	-.177	.099	.187
Number of floors	**.644****	.025	.130	-.030	**.517****	-.156	-.188	-.118
Unclassified star	-.091	.135	.098	.151	-.190	.077	.105	-.012
3-star hotel	-.240	-.268	-.180	-.107	-.138	-.173	-.130	-.084
4-star hotel	-.037	-.048	-.149	-.136	.179	.009	-.112	-.122
5-star hotel	.398*	.103	.221	.059	.095	-.026	.036	.154
Resort hotel	-.101	.199	-.131	-.127	-.160	.180	.131	.056
Conference hotel	-.069	-.056	.127	.232	.229	-.316	-.224	-.098
Commercial hotel	.226	.007	.053	-.076	-.036	.088	.059	.028
Residential hotel	-.181	-.209	-.146	-.085	-	-	-	-
Green Leaf Certification	.101	.073	-.130	-.185	-.139	-.161	.082	.145
Uncertified green Leaf	-.101	-.073	.130	.185	.139	.161	-.082	-.145
Remote location	-.151	.195	.194	.228	.134	.073	.013	.004
Urban location	.151	-.195	-.194	-.228	-.134	-.073	-.013	-.004
Central region	-.151	-.158	-.098	-.060	-.088	-.062	-.027	-.076
Northern region	-.172	-.080	-.133	-.111	-.155	-.186	-.147	-.056
Southern region	-.103	.260	.256	.318	-.184	.176	.121	.015
Eastern region	-.149	-.083	-.113	-.096	.189	.070	-.041	-.029
Western region	-	-	-	-	-.016	-.054	-.009	.014
Bangkok	.350	-.042	-.003	-.092	.327	-.137	-.086	-.066
North-eastern region	-	-	-	-	-.130	.096	.118	.155
Number of workers	**.718****	**.491****	.239	.141	**.835****	-.081	.094	.161
Worker density (number of workers per 1,000 m² of GFA)	.048	**.788****	.298	.321	-.279	.279	-.223	-.306
Occupancy rates	.046	.089	-.261	-.391*	-.088	.416*	.309	.080
Monthly average room-night	**.558****	.193	-.177	-.242	**.844****	-.031	-.067	-.034
Monthly average of guests	**.485****	-.035	-.226	-.290	**.861****	-.023	-.024	.017

Note: - is insignificant variable. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Appendix K: Pearson correlation between monthly electricity consumption and 30 independent variables of hotels separated by Green Leaf Certification

Variables	Pearson Correlation							
	35 Green Leaf Certification hotels				28 uncertified Green Leaf			
	(kWh)	(kWh/m^2)	(kWh/guest room)	(kWh/room-night)	(kWh)	(kWh/m^2)	(kWh/guest room)	(kWh/room-night)
Age	.266	.126	.001	.009	.247	.026	.099	.050
Number of guest rooms	**.605****	.285	.016	.000	**.849****	-.186	-.156	-.109
Gross floor area	**.812****	-.040	**.705****	**.690****	**.870****	-.198	-.109	-.069
Number of floors	.421*	.013	.140	.225	**.677****	-.130	-.102	-.117
Unclassified star	.176	.292	.345*	.297	**-.560****	-.086	-.066	.007
3-star hotel	-.295	-.316	-.281	-.259	-	-	-	-
4-star hotel	-.124	-.009	-.201	-.227	**.493****	-.012	-.074	-.057
5-star hotel	.197	-.012	.130	.183	.294	.110	.132	.034
Resort hotel	-.019	.250	.150	.045	-.171	.092	-.120	-.145
Conference hotel	-.034	-.110	-.154	-.021	.169	-.238	.064	.212
Commercial hotel	.134	-.039	.078	.064	-.010	.145	.045	-.074
Residential hotel	-.191	-.211	-.194	-.189	-	-	-	-
Type3 hotel	-.050	.113	-.109	-.070	-.240	-.112	.111	.196
Type4 hotel	.050	-.113	.109	.070	.240	.112	-.111	-.196
Remote location	-.072	.228	.133	.032	.167	.013	.084	.167
Urban location	.072	-.228	-.133	-.032	-.167	-.013	-.084	-.167
Central region	-.167	-.151	-.111	-.160	-	-	-	-
Northern region	-.193	-.196	-.194	-.119	-.154	-.044	-.104	-.094
Southern region	-.033	.223	.170	.062	-.221	.200	.205	.269
Eastern region	-.038	.030	-.059	-.101	.120	-.062	-.102	-.082
Western region	-	-	-	-	.005	-.063	-.019	-.037
Bangkok	.387*	.087	.162	.246	.176	-.270	-.177	-.136
North-eastern region	-.229	-.183	-.178	-.160	.105	.365	.268	.064
Number of workers	**.827****	**.523****	**.513****	**.431****	**.792****	-.118	-.033	.018
Worker density (number of workers per 1,000 m^2 of GFA)	-.004	**.796****	-.092	-.168	-.229	.345	.444*	**.561****
Occupancy rates	.371*	.405*	**.451****	.205	-.362	.053	-.344	-.468*
Monthly average room-night	**.687****	**.451****	.165	.058	**.831****	-.181	-.209	-.183
Monthly average of guests	**.741****	.319	.310	.196	**.827****	-.199	-.209	-.180

Note: - is insignificant variable. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).