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POTENTIAL ASSESSMENT OF GREENHOUSE GAS REDUCTION IN PATTAYA HOTELS, THAILAND

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Abstract

Hotels in Thailand are one of the country's main economic growth sectors which inevitably result in increased sector energy use and cause a rise in GHG emissions. A study on the source of GHG emissions in the hotel sector can guide the suitable reduction measures. This paper reports the study results of the greenhouse gas (GHG) emissions and their reduction potential in 4- and 5-star hotels in Pattaya, Thailand. In the study, seven 4- and 5-star hotels participated in surveys to assess their GHG emissions from electricity use, stationary combustion, mobile combustion, refrigerant leak, wastewater, solid waste, and outsourced laundry. The data used in this study were based on the 2018 statistics. The average emission by the surveyed hotels was at 4,466.99

tCO₂e/year, equivalent to 107.88 kgCO₂e/m²-year, and 45.42 kgCO₂e/room-night. Electricity use was the major activity accounting for 77% of the total emissions. Hence, the GHG reduction plan was put forth to the energy efficiency improvement of energy-intensive machines. The findings from surveyed hotels were used as the basis to estimate the GHG emissions and potential reduction for 4- and 5-star hotels in the whole of Pattaya. By the proposed improvement scheme, the potential to reduce the GHG emission was 13,818.28 tCO₂e, for an equivalent reduction of 7.8% of the total GHG emissions. This study approach for GHG reduction can further be applied to other tourism hotels nationwide to support the country in achieving the national GHG emission reduction target and the sustainable tourism industry.

Keywords

Greenhouse Gas Emissions, Greenhouse Gas Reduction, Hotel Energy Efficiency, Electricity Use, 4- And 5-Star Hotels

1. Introduction

The hotel industry accounts for around 1% of all GHG emissions. Recognizing the importance of GHG emissions management, Thailand's Ministry of Energy published the 20-Year Energy Efficiency Development Plan (EEDP) that set a goal to reduce the country's energy intensity and to avoid CO₂ emissions. According to the EEDP, intensive implementation of various energy conservation measures could reduce 57% of the hotel sector energy consumption by 2030 compared to the business-as-usual case (Ministry of Energy, 2011). Understanding the impacts of and finding ways to reduce GHG emissions in hotels is essential in achieving the EEDP goal and securing the sustainability of Thailand's tourism industry.

In the literature, hotel GHG emissions have been assessed in various major cities, such as in Huang et al. (Huang et al., 2015), which reported that luxury hotels in Taiwan emitted 132 kgCO₂e/m² or 50 kgCO₂/room-night. The study found that electricity use was the primary emission source (Hu et al., 2015). Lai et al. (2012) carried out the comparative review of legislation and empirical GHG emissions from the hotel industry in Australia, the UK, and Hong Kong to develop a guideline for identifying GHG emissions sources and footprint analyses as well as developing GHG emission benchmarks for Hong Kong's hotel sector. In another study, Pieri et al. (2015) presented a method for reducing hotel CO₂ footprint by quantifying the index that could motivate the hotel implementation. They studied the energy use index (EUI) of Canada, USA, Singapore,

Hong Kong, Spain, and others to find ways to improve their hotels in reducing the carbon footprint. For Thailand, with its hot and humid climate, a survey of 63 hotels (Tangon et al., 2018) indicated that air conditioning contributed to 57% of total energy use, while lighting contributed the second most at 18%. In England, a study (Taylor et al., 2010) reported that both new and old hotels could reduce GHG emissions by 50% through improvements in building fabric, high-efficient heating, ventilation, air conditioning (HVAC) equipment, lighting, appliances, and renewable energy generation additions. Thus, prior studies have shown a strong correlation between energy consumption and GHG emissions.

Pattaya is one of the popular tourist destinations in Thailand. As the tourism industry has been heavily promoted to accelerate the province and country GDP growths, the Pattaya city's energy consumption has steadily increased by 5% in average during 2012-2018 (National Statistics Office (Chonburi province), 2019). The deliberated budget from the government of over 9 billion baht was allocated for "Greenovative Tourism City" under The Designated Areas for Sustainable Tourism Administration (DASTA) (Anuwat, 2012). To curb such increasing energy and the resulting GHG emission that would help achieving the EEDP's energy conservation target and the environmental sustainability, this paper conducted a field energy survey of the participated 4- and 5- star hotels where the energy consumption is intensive. The bottom-up analysis of the survey results was employed to identify the energy conservation options and to determine the potential GHG reduction. The proposed options in this study were considered applicable as they are commercialized technologies, and their implementations would not detrimentally affect the relaxation and satisfaction of hotel guests.

2. Materials and Methods

This study's content and methods focus on the famous tourist areas and the potential for energy use for one of Thailand's high tourism activities. The data collection and evaluation guidelines refer to the Greenhouse gas protocol and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

2.1. Study Area

Pattaya is a self-governing municipality in Chonburi province. In 2018, Chonburi province was the second highest in commercial energy consumption in the country. The energy source came from natural gas, petroleum products, and electricity at 673.32, 4,631.89, 1,062.43 ktoe/year,

respectively (Ministry of Energy, 2019). The economic expansion in the province was due to the business sector, including tourism. As seen in the world tourism report, Pattaya is a popular destination for Thai and foreign tourists and is recognized globally as a top 25 city destination by Euromonitor International (Geerts, 2017).

2.2. Data Collection

There were seven 4- and 5-star hotels participating in the field survey and energy auditing in this study. The collected hotel data were divided into standing data and annual data. The standing data were including the reporting year, hotel establishment year, utility space, and the number of guest rooms. The occupied room rate, energy consumption, refrigerant leak, water consumption, and food waste were the annual data. Greenhouse Gas Protocol, which established a comprehensive standardized framework applied to global data to measure and manage emissions for companies and organizations (WBCSD, 2004), was used as the data collection template.

2.3. GHG Emissions Assessment

The assessment classified the GHG emissions into four categories: energy use, refrigerant leak, wastewater treatment, and solid waste disposal. The emission calculation procedure was described as follows:

- The emissions from energy use were further sub-divided into (1) stationary combustion, (2) mobile combustion, (3) electricity consumption, and (4) outsourced laundry. In this study, the calculation of GHGs from stationary combustion and mobile combustion were according to Tier 1 methodology, for which the Intergovernmental Panel on Climate Change (IPCC) provided the emission factors and parameters (IPCC, 2008). The emission calculation from electricity consumption was from Tier 2 methodology, which used the country's emission factor of the grid electricity system. To estimate the GHG emissions from outsourced laundry, the LPG use was assumed the averaged value of LPG use per hotel room (LPG, kg/room) for the in-house laundry.
- Global warming potential over 100 years (GWP_{100}) was applied to calculate refrigerant leakage emissions from cooling systems (Forster et al., 2007).
- The cause of GHG emissions from wastewater is CH_4 and N_2O generated and emitted into the atmosphere (IPCC, 2008). Tier 1 calculation method was used for this emission type.

- The cause of GHG emissions from solid waste is CH₄ generated from waste degradation and emitted to atmosphere. The calculation method of waste disposal was dependent on the period of waste collection (IPCC, 2008).

Table 1 summarizes the calculation methods of the GHG emission.

Table 1: *The GHG Emission Calculation Methods used in this Study.*

Emissions type	Equation	Variable	Reference
Energy	$CO_2e = EC \times EF$	EC = The total of energy consumption, terajoule (TJ)/year EF = Emission factor of each type of energy	- EF for stationary combustion, UNFCCC, 2006 IPCC Volume 2, Chapter 2, Table 2.4 - EF for mobile combustion, UNFCCC, 2006 IPCC Volume 2, Chapter 3, Table 3.2.1 and 3.2.2 - EF for electricity consumption, EGAT, Thailand Grid Emissions Factor for GHG Reduction Project/Activity 2014-2017 - EF for outsourced laundry, following the EF for stationary combustion.
Refrigerant leak	$CO_2e = RL \times GWP_{100}$	RL = The total of refrigerant leakage, kg/year GWP ₁₀₀ = Global warming potential to the emissions of CO ₂ in a 100-year (tCO ₂ e)	- GWP ₁₀₀ , IPCC, Changes in Atmospheric Constituents and in Radiative Forcing. Chapter 2, Table 2.14
Wastewater treatment	$CO_2e = TOW \times Ef_j \times GWP_{100}[CH_4]$ $CO_2e = N_{EFFLUENT} \times EF_{EFFLUENT} \times 44/28 \times GWP_{100}[N_2O]$	TOW = Total organics in wastewater in inventory year, kg BOD/year EF _j = Emission factor, kg CH ₄ /kg BOD N _{EFFLUENT} = Nitrogen in the effluent discharged to aquatic environments, kg N/year EF _{EFFLUENT} = Emission factor for N ₂ O emissions	- UNFCCC, 2006 IPCC Volume 5, Chapter 6, Equation 6.1 - UNFCCC, 2006 IPCC Volume 5, Chapter 6, Equation 6.7 - Protein content in the wastewater, FAO, Food security and nutrition status in Thailand 2005-2011

		from discharged to wastewater, kg N ₂ O-N/kg N	
Solid waste disposal	$\text{CO}_2\text{e} = [\sum \text{CH}_4 \text{ generated}(x, T)] \times (1 - \text{OX}_T) \times \text{GWP}_{100}[\text{CH}_4]$	$T = \text{Inventory year}$ $x = \text{Waste category or type/material}$ $\text{OX}_T = \text{oxidation factor in year T, (fraction)}$	<ul style="list-style-type: none"> - UNFCCC, 2006 IPCC Volume 5, Chapter 3, Equation 3.1 - Waste composition, PCD, Community waste composition of municipalities nationwide: hotel sector

3. GHG Emissions from the Surveyed Hotels

The data analysis was carried out on 4- and 5-star hotels to estimate their GHG emissions. Seven hotels were participating in the survey. The data used for analysis consisted of General hotel information and greenhouse gas-producing activity data.

3.1. General Data

As shown in Table 2, the survey covered the old and new hotels. The oldest hotel was 47 years old, while the newest was just only two years old. The hotel size varied largely from 10,800 to 110,885 m² of utility space. The number of guest rooms varied, corresponding to the hotel size. Most of the surveyed hotels had above 50% occupancy rate, except for hotel D and F. Hotel D had more guest rooms than others, while the customers for Hotel F were mainly the group using function rooms service rather than guest rooms.

Table 2: *General Information of the Surveyed 4- and 5-Star Hotels.*

Participating hotels	Hotel A	Hotel B	Hotel C	Hotel D	Hotel E	Hotel F	Hotel G
Establishment year	2006	2004	2011	1973	1995	1995	2018
Utility space (m ²)	12,474	43,697	36,000	110,885	70,467	10,800	32,475
Number of rooms	249	594	252	1,020	723	51	257
Occupancy (room/year)	58,462	179,656	71,368	162,294	175,987	5,012	54,134
Occupancy rate	64%	83%	78%	44%	67%	27%	58%
Customer (person/year)	119,623	359,312	147,612	313,553	336,613	10,196	104,852

3.2. GHG Emissions by Source

All GHG sources in the participating hotels consist of electricity consumption, stationary combustion in buildings, mobile combustion from cars, refrigerant leakage in air-conditioning, outsourced laundry, solid waste from food, and wastewater. Table 3 presents the amount of GHG emissions of the surveyed hotels. The gray bar represents no emission from such activities. Some remarks could be drawn as follows:

- The electricity consumption was the primary emission source of the participating hotels that share up to 77% of the total emissions.
- The second largest source of emission was from the LPG used for cooking. This emission shared about 10% of the total hotel GHG emissions.
- The leakage of refrigerant from the air-conditioning system was about 4%. Most of the refrigerant used in hotels was R-22, R-134a, and R-404a. From interviews during the surveys, it was planned that chillers' replacement would gradually reduce the use of R-12 and R-22.
- The emission from outsourced laundry was comparable to that of the refrigerant leak. The emission amount was estimated using the LPG factor for laundry per hotel room (LPG, kg/room) by in-house laundry.
- Wastewater in hotels was primarily from bathing and flushing. Thus, the amount of tap water use in the study hotel was counted as wastewater. The GHG from wastewater depended on the type of wastewater treatment: centralized aerobic treatment plant (well controlled), anaerobic shallow lagoon, and anaerobic deep lagoon. All three treatments offered low GHG emissions.
- The participating hotels managed wastes by separating all plastic wastes for recycling, and food waste delivered to landfill by the Pattaya Municipality. GHG emissions from solid waste were then calculated from only food waste in the hotels.

Table 3: *GHG Emissions of the Surveyed Hotels (tCO_{2e}/year).*

GHGs sources		Hotel A	Hotel B	Hotel C	Hotel D	Hotel E	Hotel F	Hotel G
Stationary combustion	LPG	147.50	67.89	9.24	1,601.51	383.55	5.89	82.76
	Diesel		803.44					
	Fuel oil				206.35			
	Diesel	12.06	77.47		112.28	30.19	6.72	

Mobile combustion	Gasoline			11.86		1.69		
	LPG			13.26				
Electricity consumption		1,718.84	3,346.85	2,176.06	8,674.53	4,199.24	873.61	3,674.20
Refrigerant leak	R-22	10.86	199.10	72.40		99.55	108.60	9.05
	R-134A	8.58	37.18	14.30	80.08	14.30	28.60	7.15
	R-404A	23.53	50.98	78.43	78.43			19.61
	R-12	65.40					163.50	
	R-32	4.05						
Outsourced laundry	LPG			266.71			18.73	207.39
Solid waste		4.71	70.96	31.72	891.35	249.77	15.94	35.36
Wastewater		1.71	26.82	4.23	4.76	26.28	0.15	1.63
- Centralized, aerobic treatment plant		✓			✓		✓	✓
- Anaerobic shallow lagoon				✓				
- Anaerobic deep lagoon			✓			✓		
Total emissions		1,997.24	4,680.70	2,678.21	11,649.29	5,004.56	1,221.74	4,037.15

Figure 1 shows the proportion of the annual GHG emissions by the seven sources of the surveyed hotels. The highest proportion of the emissions was from electricity use at 77%, with stationary combustion for heat energy accounting for 10% of emissions, while the remaining sources contributed 13%.

The Average Proportion of GHG Emissions (%)

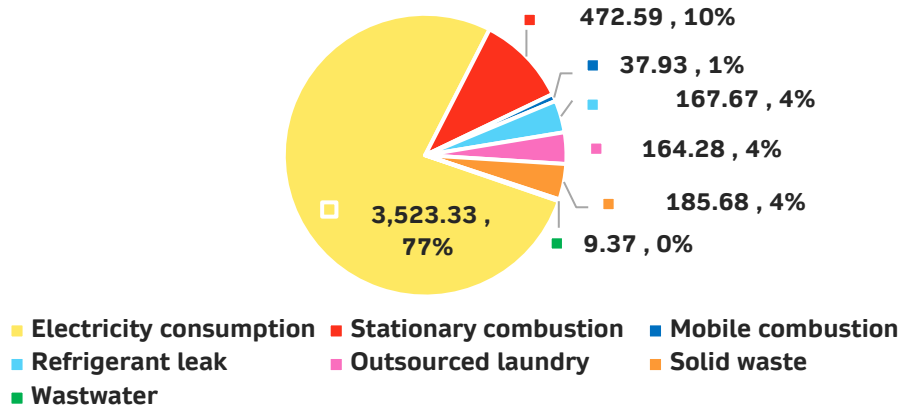


Figure 1: Proportion of the GHG emissions (%) of the participating hotels.

3.3. GHG Emissions by Hotel

This topic shows the amount of GHG emissions in each of the participating hotels. It also analyzes the proportion of GHG emissions per square meter and GHG emissions per occupancy of each hotel. Figure 2 shows the total GHG emissions from each participating hotel that ranged from 1,221.74 to 11,649.29 tCO₂e/year. The average emission value was 4,466.99 tCO₂e/year. The emission amount was also analyzed based on the floor area and of the occupied room-night. In Figure 3, the average GHG emissions per floor area was 107.88 kgCO₂e/m²-year; the standard deviation was 30.32 kgCO₂e/m²-year. A high standard deviation of emissions resulted from a variety of activities in the hotels. Also presented in Figure 3, the average GHG emissions per room-night mostly varied from 28.44-74.58 kgCO₂e/room-night. Hotel F is an exceptional case with an extremely high GHG emission of 243.76 kgCO₂e/room-night. It was noted that most of the guests at hotel F came for function room service and did not stay overnight at the hotel. The resulting low guest room occupancy rate was then the reason for such a high GHG emission per room. Therefore, hotel F was not taken into account in later analyses. The average GHG emissions would be 45.42 kgCO₂e/room-night excluding hotel F, and the standard deviation was 21.90 kgCO₂e/room-night. The study's result is close to the average GHG emissions per room in a study of hotels in Bangkok, which is 46.8 kgCO₂e/room-night and is ranged low based on the global carbon emissions intensity criteria from the Greenview study. Nevertheless, since it is at the higher end of the range, there is still room for improvement (Greenview, 2020).

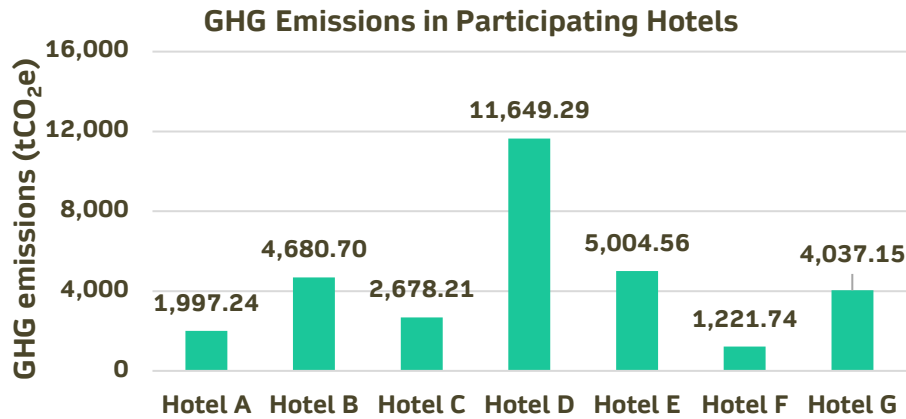


Figure 2: The total GHG Emissions in Participating Hotels

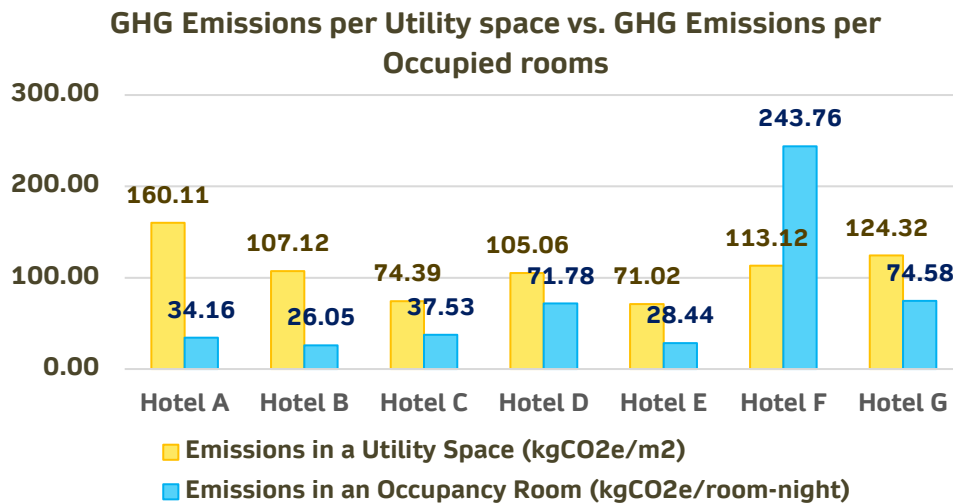


Figure 3: GHG Emissions Per Utility Space Vs. GHG Emissions Per Occupied Rooms.

3.4. GHG Reduction Potential

The survey indicated that electricity use was the primary emission source. This study focused on reducing the consumed energy by replacing the existing energy-intensive machines with better energy-efficiency ones; GHG reduction resulted from the energy reduction or savings after the machine replacement. The machine's actual performance was from the surveyed data, and the Department of Alternative Energy Development and Efficiency determined the range of energy-efficient in machines (DEDE, 2015). In this study, the machine improvement was limited to a chiller, lighting, water pump, and boiler.

- Chiller: Air-conditioning in Hotels B, E, and G was the chiller-based system. Hotel B and G just recently replaced their existing chillers. Thus, only Hotel E had the potential. The energy auditing of Hotel E reported the existing chiller performance at 0.85 kW/TR. Thus,

the replacement with the new chiller of 0.70 kW/TR could reduce the chiller energy consumption by 28%.

- **Lighting:** Replacing the fluorescent lamps with LED lamps could reduce energy use. Hotels A, B, and E still used fluorescent lights; the LED lamp replacement could reduce the hotels' lighting energy by 33%, 56%, and 41%, respectively.
- **Water pump:** There were three types of water pumps considered in energy improvement: chilled water pump, condenser water pump, and cold-water pump. Referring to the Department of Alternative Energy Development and Efficiency data, using an energy-efficient pump could save up to 10%.
- **Boiler:** Only hotels B and E used boilers. The boiler of more than 87% efficiency could replace the existing 75-80% boilers to save energy by at least 8%.

Figure 4 illustrates the reduced GHG emissions from the machine replacement measures. The percentage of GHG reduction varied from one hotel to another depending on the existing machines' performance. The GHGs reduction of Hotels A, B, and E was 10.22, 869.45, 214.39 tCO_{2e}/year, respectively.

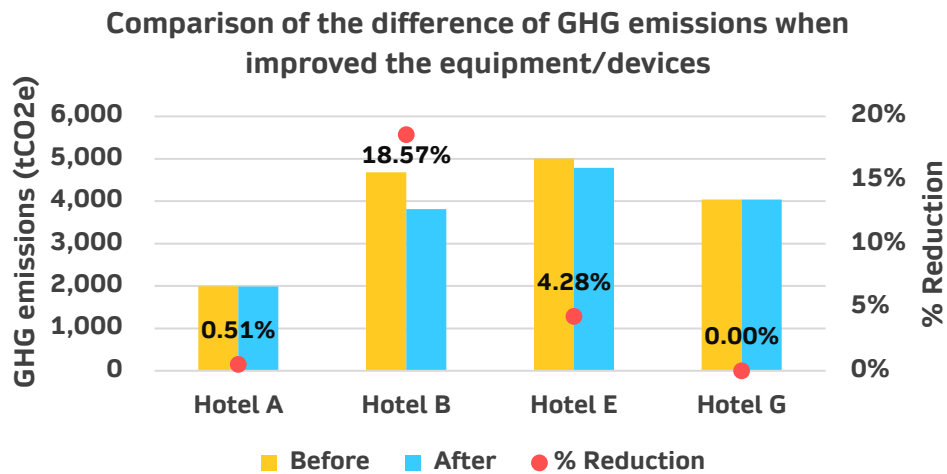


Figure 4: Comparison of GHG Emissions with Applied Energy Reduction Measures.

4. GHG Emissions of 4- and 5-Star Hotels in Pattaya

This section estimated the GHG emission from a total of 4- and 5-star hotels in Pattaya. Sixty-six hotels were postulated their emission characteristics identical to those of the surveyed hotels. As shown in Figure 5, annual electricity uses of the 4- and 5-star hotels in Pattaya was calculated in the first step by using the average energy use per room-night (kWh/room-night) and

the number of occupied room-night over the year (room-night/year). The average electricity use was 60.08 kWh/room-night after modified according to the interquartile range (IQR) method. The Ministry of Tourism and Sports (MOTS) public data reported that the 4- and 5-star hotels' occupancy rate was 4,005,997 rooms in the year 2018. Thus, the total electrical energy consumed could be calculated at 240,685,942 kWh. The GHG emissions from the electricity use were equal to 136,324.52 tCO₂e, according to Thailand's emission factor of power generation mix of 0.57 kgCO₂e/kWh. The GHG emissions from other sources were from applying the proportion of the emissions from the non-electricity use and the electricity use, which was 23/77 for this study. The annual total emissions from the 4- and 5-star hotels in Pattaya was thus 177,044.83 tCO₂e.

GHG emissions calculation pathway in 4 and 5-star Pattaya hotels

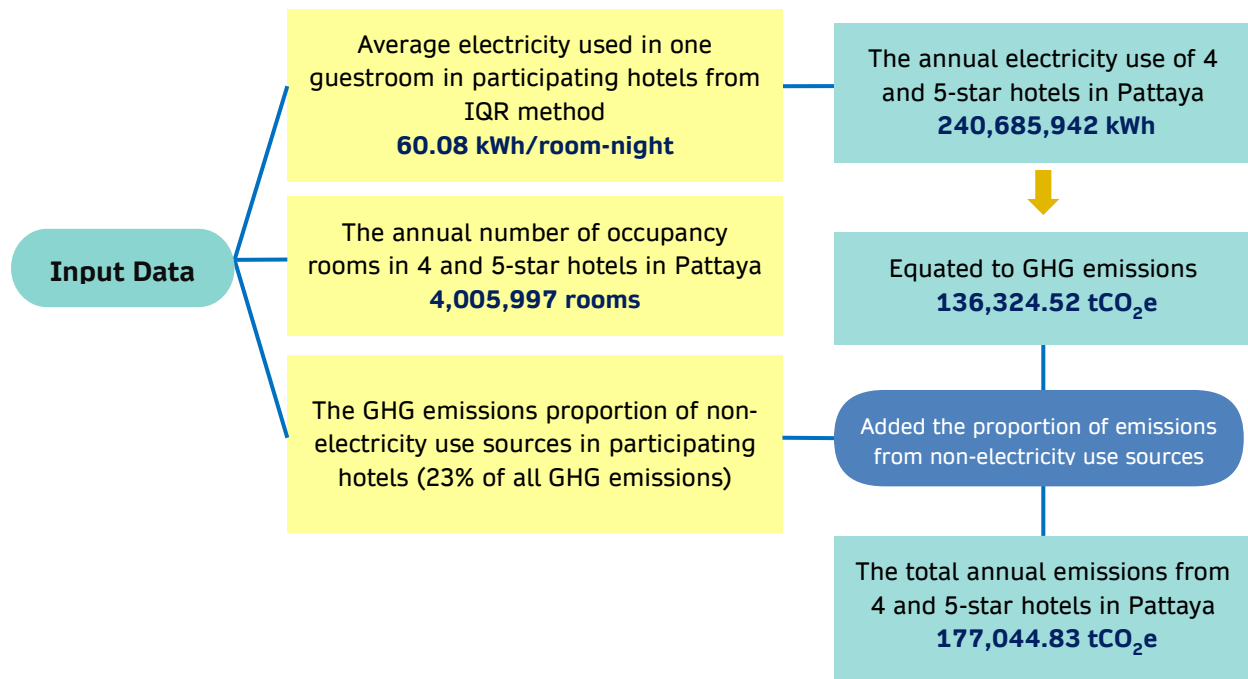


Figure 5: *GHG Emissions Calculation Procedure of 4 and 5-star Hotels in Pattaya.*

5. GHG Reduction Potentials of 4- and 5-Star Hotels in Pattaya

The study shows improving the efficiency of the energy-intensive machines operating in the hotels could reduce GHG emissions of the Pattaya 4- and 5-star hotels. Figure 6 depicts the calculation procedure of the emission reduction potentials. In this study, the energy efficiency measures were decided to implement to only the hotels older than 15 years, counted 19 hotels from the total, for an economical replacement of the machines due to its life-time end. Based on the

survey at participating hotels, improving the chiller, water pump, lighting lamps efficiency could technically reduce the hotel GHG emission from the electricity use by 17.15%, 1.9%, and 4%, respectively. The LPG boiler and diesel boiler efficiency improvement could reduce the hotel GHG emissions by 10.92% and 8.05%, respectively. The calculation shows that the chiller replacement offered the most significant emission reduction of 5.52% of total GHG emissions, followed by the lighting improvements at 1.29%. The calculation also shows that the Pattaya 4- and 5-star hotels' total emission reduction potential was at 13,818.28 tCO₂e, equivalent to 7.8% of the total GHG emissions.

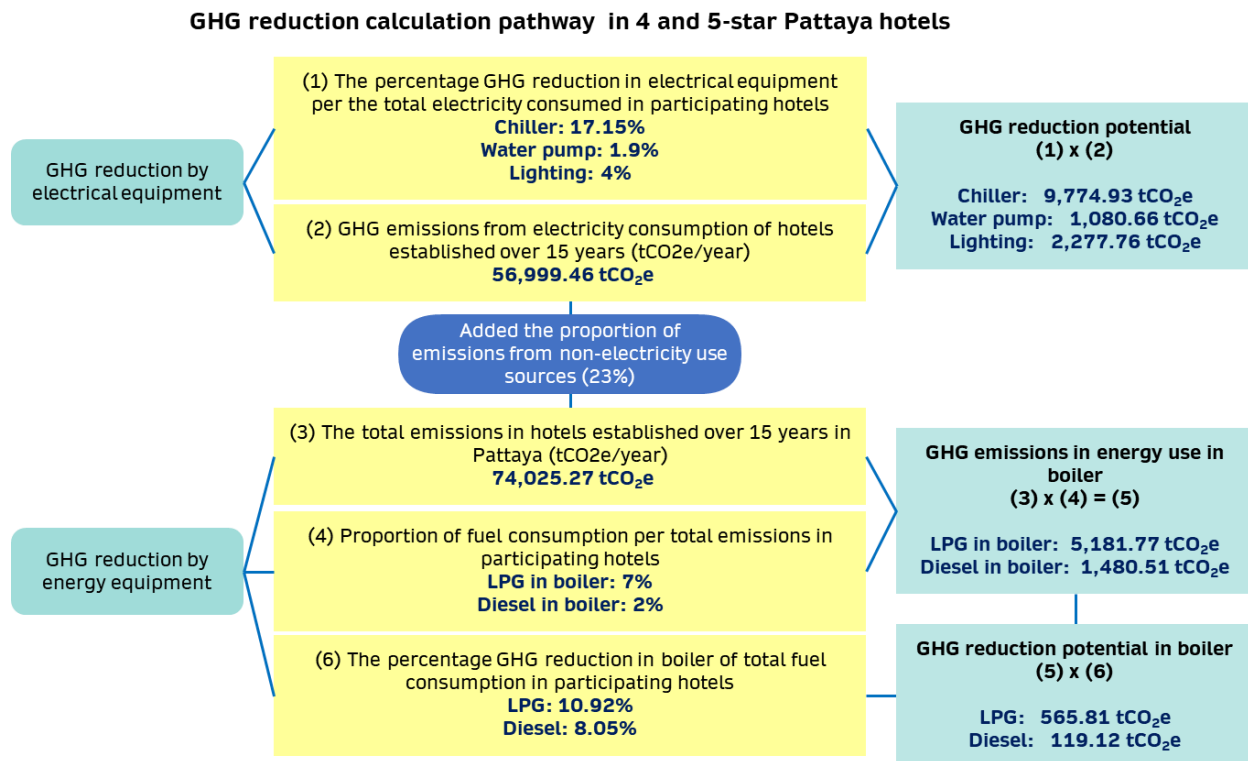


Figure 6: *GHG Reduction Calculation Procedure in 4- and 5-star Hotels in Pattaya.*

6. Conclusions

This study presents the GHG emissions and their reduction potential in seven participating 4- and 5-star hotels in Pattaya, Thailand. Seven hotel activities that caused emissions were electricity, stationary combustion, mobile combustion, refrigerant leak, wastewater, solid waste, and outsourced laundry. The average GHG emissions in utility space were 107.88 kgCO₂e/m²-year, and the average GHG emissions in the guestroom were 45.42 kgCO₂e/room-night. The

analysis revealed that the largest contributing source of GHG emissions of these hotels was electricity consumption that accounted for 77% of total emissions and the second largest of 10% emissions was from fuel consumption. Thus, the emissions reduction focused on improving the equipment's energy efficiency. Due to the restrictions on access to the data in some hotels, it was impossible to comprehensively analyze energy efficiency practices for reducing greenhouse gas emissions in all participating hotels. The results of the GHG reduction study thus were analyzed in only four out of seven hotels. The total GHG reduction potentials from energy efficiency improvements implemented in study hotels were estimated and extended to the 4- and 5-star hotels in Pattaya but only limited to the hotels established over 15 years for economic reasons. The total GHG reduction potentials for the 4- and 5-star hotels in the whole Pattaya was 13,818.28 tCO_{2e}, for an equivalent reduction of 7.8% of the total GHG emissions. Future research aims to find practical ways for hotels to contribute to reducing greenhouse gas emissions. One of the attractive schemes is to deploy the carbon market incentives to motivate owners and entrepreneurs. This mechanism will create the trading of carbon credit permission for companies and industries both emitting and reducing carbon dioxide, and finally the reduction of GHG emissions in the hotel sector.

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