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Article

Greenhouse Gas (GHG) Assessment and Its Mitigation Measurements by Stakeholders' Perception towards Low Carbon University

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Abstract: This study aimed to assess greenhouse gas (GHG) emissions at Rajamangala University of Technology Thanyaburi (RMUTT) and to propose strategies for transitioning towards a low-carbon university. The assessment combined three established scopes of GHG emissions, with data collected through 400 questionnaires distributed to students and staff to assess their awareness of low-carbon development and the possibility of implementing GHG reduction policies. Results indicated that Scope 2 emissions, primarily from electricity consumption, account for the largest share at approximately 7,527.05 tCO_2eq/year, followed by Scope 3 emissions at 2,577.92 tCO_2eq/year and Scope 1 emissions at 256.35 tCO_2eq/year, totaling 10,361.32 tCO_2eq/year. The average GHG emissions per person were estimated at 0.38–0.56 tCO_2eq/year. Using the rate-based target method, a 10% reduction in GHG emissions by 2030, in association with Thailand's carbon neutrality goals, is projected to reduce total emissions to 3,612.18 tCO_2eq/year. Currently, carbon storage is expected to increase from 953.56 tCO_2eq/year to 1,929.70 tCO_2eq/year over a 10-year period, with 2032 as the target. Tree planting is identified as a cost-effective strategy for CO_2 removal; however, it should be complemented by additional mitigation measures informed by stakeholders' perspectives on low-carbon university development. Achieving RMUTT's transformation into a low-carbon institution requires technological advancements and policy reforms that foster sustainable practices and active stakeholder engagement. This study highlighted the importance of assessing and reporting GHG emissions as an essential step for institutions aiming to become sustainable organizations.

Keywords: greenhouse gas; carbon footprint organization; carbon storage; low carbon university; perception

1. Introduction

Greenhouse gas (GHG) emissions from human activities such as using energy at home, driving, and managing waste—have increased rapidly, becoming a major cause of climate change and global warming (Ozawa-Meida et al., 2013). Climate change now affects almost every country, making it essential to prioritize this issue and adopt sustainable development practices. Moving toward a 'low-carbon economy and society' is a practical and environmentally friendly solution (TGO, 2018). The target is to lower carbon dioxide (CO_2) emissions by at least 300,000 tons by 2050, addressing climate change across all sectors, including education. Many educational institutions are putting more emphasis on environmental issues to reduce their ecological impact. According to Valls-Val and Bovea (2021), universities play a key role in promoting sustainable development by taking steps to measure their carbon footprint (CF), which helps assess their sustainability in terms of greenhouse gas (GHG) emissions. Organizations can evaluate their GHG emissions and removals using the Carbon Footprint of Organization (CFO) method from an organization's activities (TGO, 2018). This tool is useful for tracking activities that affect the environment (Robinson et al., 2018) and for providing baseline data to guide future on-campus efforts to reduce emissions (Letete et al., 2011). However, there are no standardized methods for conducting GHG inventories and calculating emissions specific to educational institutions (Santovito and Abiko, 2018). In Thailand, the use of CFO assessments to measure GHG emissions has been gradually explored from an educational perspective, with increasing attention given to how educational institutions can contribute to climate change mitigation through more precise carbon footprint assessments. Poolprathin (2012) conducted a study on the carbon footprint (CF) of the Department of Chemical Engineering at Kasetsart University, following Thailand's standards and CFO assessment guidelines, such as the Greenhouse Gas Protocol (2004), ISO 14064 Part 1 (2006), and ISO/DTR 14069 (2011). The study divided GHG emissions into three categories, showing that in the 2010 academic year, the department's total carbon footprint was 826.13 tCO_2eq/year. Building on this, Puttipiriyangkul (2016) conducted further assessments of the carbon footprint and proposed strategies to reduce GHG emissions, with a focus on carbon storage through tree planting. Based on the 2016 baseline, emissions for the years 2017 to 2020 were projected to decrease in order to improveme air conditioning systems and the expansion of perennial tree planting to absorb more carbon. Similarly, Chakhamrun and Yothanan (2016) assessed GHG emissions from the student dormitories at Ubon Ratchathani University. Their findings resulted in the creation of a set of practical plans to implement several sustainability initiatives, including energy conservation projects, waste separation and waste bank programs, and water-saving measures. A study conducted at Nakhon Si Thammarat Rajabhat University explored the reduction of GHGs through green spaces as carbon sinks by quantifying carbon storage using allometric equations. This method involved multiplying biomass values by a conversion factor of 0.5 across four plots, each measuring 50 m × 300 m (Markphan et al., 2018). Similarly, Sudha and Hirun (2019) assessed GHG emissions across four areas: energy and electricity, fuel and transportation, waste disposal, and other factors, including fuel and electricity consumption by employees and staff at Chaiyaphum Rajabhat University. Their recommendations for reducing GHGs emphasized controlling electricity consumption from air conditioners and managing motorcycle transportation. In another study, Jantakat et al. (2022) evaluated the sustainability of green spaces at Rajamangala University of Technology Isan (RMUTI) using Geographic Information System (GIS) data. This analysis considered tree characteristics, such as the crown canopy (greater than 5 sq. m.), height (greater than 5 m.), and diameter at breast height (DBH) at 1.30 m (greater than 30 cm) within each green area. The importance of sustainable universities in addressing environmental impact is widely acknowledged in international frameworks (Valls-Val and Bovea, 2021). For example, the UI Green Metric World University Ranking on Sustainability has become an important tool for evaluating sustainability efforts in universities across Thailand (Green Metric, 2010). Rajamangala University of Technology Thanyaburi (RMUTT) is one of the institutions that has developed a strategy to become a green university, with a focus on energy management and reducing environmental pollution since 2015 (Building and Ground Division of RMUTT, 2018). The university consists of 12 faculties and serves around 27,000 students and staff. As a large educational institution, RMUTT carries out a range of activities that contribute significantly to greenhouse gas (GHG) emissions, particularly through electricity consumption, waste generation, and the use of office supplies (Building and Ground Division of RMUTT, 2018). At present, RMUTT does not have a clear and comprehensive record and evidence of greenhouse gas (GHG) emissions from its various activities, nor is there a well-structured approach to implementing strategies to reduce these emissions. These gaps present significant challenges for the university in its efforts to transition towards becoming a low-carbon institution. Therefore, the main objectives of this study were: (1) to assess GHG emissions within the institution by evaluating emissions from different activities, following the Carbon Footprint of Organization (CFO) guidelines, and (2) to examine how the perspectives of students and staff can help inform strategies for reducing GHG emissions. By gaining a clear understanding of the current GHG emissions from institutional activities, universities can use this data to develop effective management and policy frameworks. The findings of this study aimed to help RMUTT reduce its GHG emissions through improved resource management, while also supporting the university's dedication to social responsibility. Additionally, this research aimed to develop a set of best practices that can guide other educational institutions in the country in their efforts towards creating a low-carbon society.

2. Methods

2.1 Study Area Profile

RMUTT is located in Khlong Hok Subdistrict of Khlong Luang District and Rangsit Subdistrict of Thanyaburi District, Pathum Thani Province. The total area is approximately 1.14 sq. km. According to GIS-based land use classification, the largest land use category is miscellaneous land, covering 0.45 sq. km. (39.65 percent) of the university's area. This is followed by green areas at 0.25 sq. km. (21.58 percent), water sources at 0.15 sq. km. (12.71 percent), buildings and structures at 0.19 sq. km. (16.73 percent), and roads at 0.10 sq. km. (9.32 percent) (Figure 1).

(**a**) RMUTT source: www.rmutt.ac.th | (**b**) Land Use Classification

Figure 1. RMUTT characteristic and its land use classification.

2.2 Data Collection and Analysis

(1) GHG Emission Assessment

RMUTT's GHG emissions can be categorized into three scopes based on the GHG Protocol for evaluation (World Resource Institute, 2022). Scope 1 represents direct emissions, while Scope 2 refers to indirect emissions from energy use (energy indirect emissions). Lastly, Scope 3 includes all other indirect emissions resulting from the university's activities.

Table 1. Determining of GHG emissions scope of RMUTT.

Scope	Resources Used	Pollution Produced	Sources of Greenhouse Gas Emissions	Notes *	EF Sources
Scope 1 is the direct release of GHGs (direct emissions)	fuel from burning	CO_2	Various vehicles, including lawn mowers, generators	/	IPCC
	wastewater treatment	CH_4	Wastewater treatment plant	X	IPCC
	using manure as fertilizer to nourish trees	N_2O	Tree maintenance work within the university	/	IPCC
	food waste and organic waste	CH4	The university cafeteria	X *	IPCC
	refrigerants	HFCs	Air conditioning and refrigeration equipment	X *	IPCC
Scope 2 is the release of GHGs (indirect emissions) from energy use. This includes the GHGs emitted from the electricity of various buildings within the university.	electricity	GHGs	Building connection areas, walkways (1)	/	TGO
Scope 3 is the release of GHGs (indirect emissions) beyond Scopes 1 and 2. These	fuel production process	GHGs	Oil refinery	/	TGO

Scope	Resources Used	Pollution Produced	Sources of Greenhouse Gas Emissions	Notes *	EF Sources
emissions result from the organization's use activities, but the organization does not have control over the source of the emissions.	tap water production process	GHGs	Provincial Waterworks Authority	X *	TGO
	the production process of clear plastic bottles (drinking water)	GHGs	A water bottle factory	X *	TGO
	cooking gas process	CO_2 and GHGs	food shop in the university cafeteria	X *	IPCC and TGO
	chemicals for washing	GHGs	Chemical production plant	X *	IPCC

⁄ means within the considered area. X means not within the considered boundary. * This is not included in the calculation because RMUTT has contracted an external company to manage this responsibility, and no internal data is recorded. The university has also hired external services for air conditioning system maintenance following environmental regulations. As a result, chemicals that contribute to fugitive emissions are excluded from the calculations in this section.

The amount of resource use and energy in each area in Table 1 can be calculated below equation (1):

$$\text{GHGs emission} = \text{Activity Data} \times \text{Emission Factor} \quad (1)$$

where, GHGs emission = amount of GHG released from the use of resources and energy from various activities that occur within the organization (tCO_2eq/year)

Activity data = activity data that causes the release of greenhouse gases (unit/year)

Emission factor = constant value used to convert activity data into quantity values for greenhouse gas emissions (tCO_2eq/unit)

The results of the GHG assessment also include an evaluation of data quality and uncertainties to assess the reliability of the organization's data collection process.

(2) Investigate of Students and Staff' Perception towards GHGs strategy of RMUTT

The population for this study comprised 24,519 individuals from RMUTT, including 22,398 students and 2,121 staff members. The sample size was set at 400, slightly above the 394 required for a 95% confidence level (Yamane, T., 1967). A random sampling method was employed to distribute the questionnaire across 10 faculties and staff offices. Individuals who were conveniently available and willing to participate were selected to complete the online questionnaire until the target sample size of 400 was reached. The questions demonstrated a total correlation discrimination power ranging from .53 to .95, meeting the selection criteria of a positive correlation coefficient of .32 or higher (Aiken et al., 2003). The questionnaire's reliability, assessed using Cronbach's alpha, ranged from .794 to .912, exceeding the acceptable threshold of .80. The questionnaire was designed to explore two main categories: (1) personal characteristics and (2) behavioral understanding within the context of a low-carbon society, aimed at informing RMUTT's strategy to become a low-carbon institution. No personally identifiable information, such as names, social security numbers, emails, or addresses, was collected. To ensure anonymity, respondents were informed on the cover page that all data collected would remain anonymous and invisible to individuals. Data collection was securely handled according to the university's policy for research projects. A 5-point Likert scale was used to assess responses in each section of the questionnaire.

2.3. The Study Framework

The research framework for this study was as follows: (1) a review of related research on GHG assessments in the educational sector, (2) a physical and environmental survey to assess GHG emissions for data analysis, (3) an analysis of the Carbon Footprint of Organization (CFO), and (4) a questionnaire survey of students and staff to develop strategies for reducing GHG emissions, as illustrated in Figure 2.

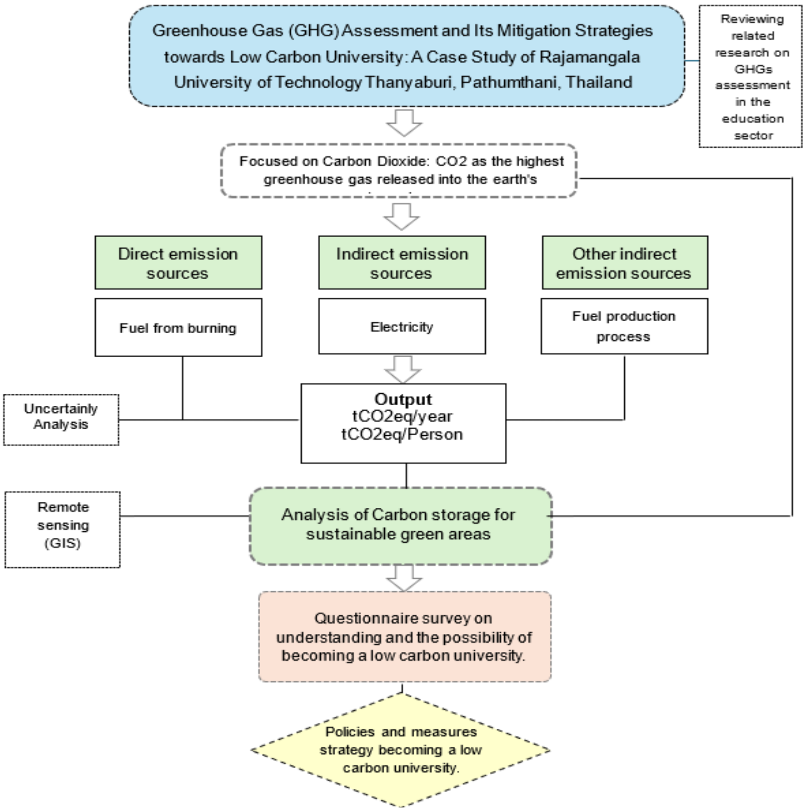


Figure 2. GHGs assessment framework of RMUTT.

3. Results and Discussions

3.1. GHGs Assessment of RMUTT

Table 2 illustrates the GHG emissions at RMUTT, showing that Scope 2 accounted for the largest proportion, with 7,527.05 tCO_2eq/year, representing 72.64 percent of the total emissions. This was followed by Scope 3, which contributed 2,577.92 tCO_2eq/year, or 24.88 percent, and Scope 1, which made up 256.35 tCO_2eq/year, or 2.48 percent.

Table 2. GHGs analysis of RMUTT.

Scope	Resources Used		tCO_2eq/y	tCO_2eq/y	Percentage
Scope 1 is the direct release of GHGs (direct emissions)	fuel from burning	stationary combustion	64.97	**256.35**	**2.48**
		mobile combustion	188.58		
	wastewater treatment process		0.00		
	using manure as fertilizer to nourish trees		2.79		
Scope 2 is the release of GHGs (indirect emissions) from energy use.	electricity		7,527.05	**7,527.05**	**72.64**
Scope 3 is the release of GHGs (indirect emissions) beyond Scopes 1 and 2. These emissions result from the organization's use activities	fuel production process		2,577.92	**2,577.92**	**24.88**
	Total			**10,361.32**	**100.00**

Based on a total of 10,361.32 tCO_2eq/year in GHG emissions, the individual carbon footprint was calculated by dividing the total emissions by the 26,750 students, faculty, and staff at RMUTT during the 2022 academic year (Office of Academic Promotion and Registration and Personnel Management Division, 2021). This calculation resulted in an average carbon footprint of 0.38 tCO_2eq per person. When comparing RMUTT's emissions to those of other universities, the differences were minimal, as shown in Table 3. Although RMUTT's individual carbon footprint was slightly lower, Scope 2 remained the largest contributor, consistent with trends seen at other public institutions, where electricity consumption was the primary source of emissions. For example, Suranaree University of Technology (SUT) reported total GHG emissions of 13,319 tCO_2eq/year, with electricity consumption representing 8.81 tCO_2eq/year (Puttipiriyangkul, 2016). Similarly, Eastern Asia University's GHG emissions totaled 5,553.17 tCO_2eq/year, mostly from electricity use, resulting in an individual carbon footprint of 1.61 tCO_2eq (Maimun et al., 2018). Chaiyaphum Rajabhat University (CPRU) reported electricity-related emissions of 1,825.46 tCO_2eq/year, which made up 52.62 percent of its total emissions, yielding an individual carbon footprint of 0.569 tCO_2eq (Sudha & Hirun, 2019). At Khon Kaen University (KU), Scope 2 emissions amounted to 1,151 tCO_2eq/year, accounting for 55 percent of total emissions (Pruangpreechasak et al., 2020). Similarly, the University of Phayao (UPH) in 2022 recorded 6,173.33 tCO_2eq/year from electricity use, which contributed 53.15 percent of its total emissions, resulting in an individual carbon footprint of 0.52 tCO_2eq.

These comparisons showed that, like other universities, RMUTT's GHG emissions were significantly influenced by electricity consumption. The proportion of Scope 2 emissions at RMUTT aligns with those observed at other institutions, focusing on the importance of electricity consumption as a key area for GHG reduction in universities.

Table 3. Comparison of the GHG emissions from RMUTT and other universities.

Scope	Resources Used	SUT 2016	EAU 2018	CPRU 2019	KKU 2020	UPH 2022	RMUTT 2023
Scope 1	Fuel from burning	3,592.38	1,125.77	1,030.46	303.00	3243.00	256.35
Scope 2	Electricity	8,809.63	4,383.47	1,825.46	1,151.00	6,173.33	7,527.05
Scope 3	Fuel production process	917.61	43.93	613.22	651.00	2197.00	2577.92
Total GHG emissions (tCO_2eq/year)		13,319.62	5,553.17	3,469.14	2,105.00	11,614.00	10,361.32
GHG emissions/person (tCO_2eq)		*** 1.38**	**** 1.61**	***** 0.56**	****** 0.30**	******* 0.52**	**0.38**

* The population was 18,411 (Puttipiriyangkul, 2016), ** the population was 3,454 (Maimun et al, 2018), *** the population was 1,942 (Sudha & Hirun, 2019), **** the population was 7,000, the Faculty of Public Health, Khon Kaen University, has prepared the carbon footprint organization for 2020 (Pruangpreechasak et al, 2020), ***** the population of University of Phayao includes students, academic personnel, and support personnel involved in university activities, totaling 22,310 people (University of Phayao, 2022).

As a result, GHG emissions values may be different depending on the data used for calculations. Scope 3 emissions were influenced by the resources utilized and the availability of relevant information. The study excluded tap water usage at RMUTT and waste collection activities, as these services are provided by the Rama IX Water Reservoir under the Royal Initiative Project and the Thanyaburi Subdistrict Municipality, respectively. Additionally, the analysis did not include the use of office supplies due to insufficient data on material purchases from various departments. In terms of uncertainty evaluation process of preparing the GHGs inventory, the level of data quality was assessed as shown in Table 4. The reason is that data collection by the organization is not continuous and mostly relies on recording fees and receipts only. However, for electricity usage, meters and automatic tracking systems were installed, providing valuable quality data. The university should use this information to be improved for the next assessment to ensure a good quality database.

Table 4. Uncertainly Analysis of GHGs Assessment.

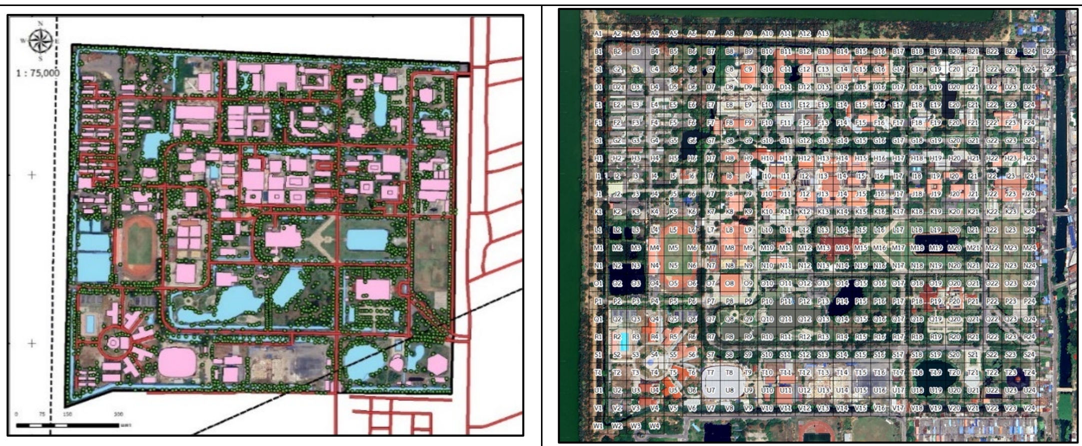
Scope	Resources Used		Score of Data Collection *	EF Score **	Result	Quality Level ***
Scope 1	Fuel from burning	Stationary combustion	3	2	6	1
		Mobile combustion	3	2	6	1
	Wastewater treatment process		-	-	-	-
	Using manure as fertilizer to nourish trees		3	2	6	1
Scope 2	Electricity		4	2	8	2
Scope 3	Fuel production process		1	2	2	1

Source: researcher, 2023. * Collect data by installing automation systems = 6 Points, collect data by meter and receipt = 4 Points, collect data by estimation = 1 Points. ** Emission Factor, EF: Quality measurement = 4, EF: Producer = 3, EF: International = 1. *** Quality Level, Level 1 = 1–6 is very high uncertainty and low quality of data, Level 2 = 7–12 is high uncertainty and moderate quality of data, Level 3 = 13–18 is low uncertainty and good quality of data, Level 4 = 19–24 is low uncertainty and best quality of data (TGO, 2018).

3.2. GHGs Sequestration for Mitigation Impacts of Carbon Dioxide (CO_2)

3.2.1 GHGs Sequestration of existing trees in RMUTT

Forests play an important role in reducing atmospheric greenhouse gas (GHG) concentrations by storing substantial amounts of carbon (C) and sequestering CO_2 in their biomass as they grow. This natural ability has driven extensive tree-planting initiatives aimed at offsetting emissions from fossil fuels (Jin et al., 2023). CO_2 uptake occurs in forests, biomass plantations, and restored degraded mine lands. To assess carbon storage at RMUTT, an extensive survey was conducted across the entire campus, dividing the area into 523 subplots, each measuring 50 m × 50 m. Geographic Information Systems (GIS) were used to analyze the distribution of existing trees, revealing that the majority of buildings are concentrated on the northern side of the campus. The analysis showed that approximately 4,015 trees are distributed across the university, as depicted in Figure 3.



(**a**) Trees distribution in campus

(**b**) The 523 sub plots with 50 m. × 50 m. to calculate carbon storage in RMUTT

Figure 3. Carbon Sequestration by using GIS Application.

The calculation of carbon storage within the RMUTT assumes a linear relationship between the amount of carbon sequestered by trees and time. The increasing carbon storage is defined as an annual increase of 9.5 kg. of carbon dioxide/tree/year (TGO, 2018). This method, known as the stock-based approach, provides an estimate of the carbon currently stored by trees in the study area (Puttipiriyangkul, 2016; Tsutsumi et al., 1983). Calculating the carbon storage using the T-VER-TOOL-01-01 Version 01 for Carbon Sequestration Calculation by Thailand Greenhouse Gas Management Organization (TGO, 2018). The amount of carbon storage of trees in the area can be estimated from Equation (2) below:

$$CTT = T \times t \times MAI \times 10^{-3} \quad (2)$$

where CTT = Carbon storage amount of trees in the project area (tCO_2eq)

T = Number of trees in the entire project area (trees)

t = Year of follow-up (year)

MAI = Rate of increasing carbon storage of trees. (9.5 $kgCO_2$/plant/year)

The results showed that the amount of carbon stored by trees on campus in 2022 was 953.56 tCO_2eq/year. The variation in carbon storage among trees in each plot ranged from 0.00 to 5.93 tCO_2eq/year, with a standard deviation of 1.18 (Figure 4).

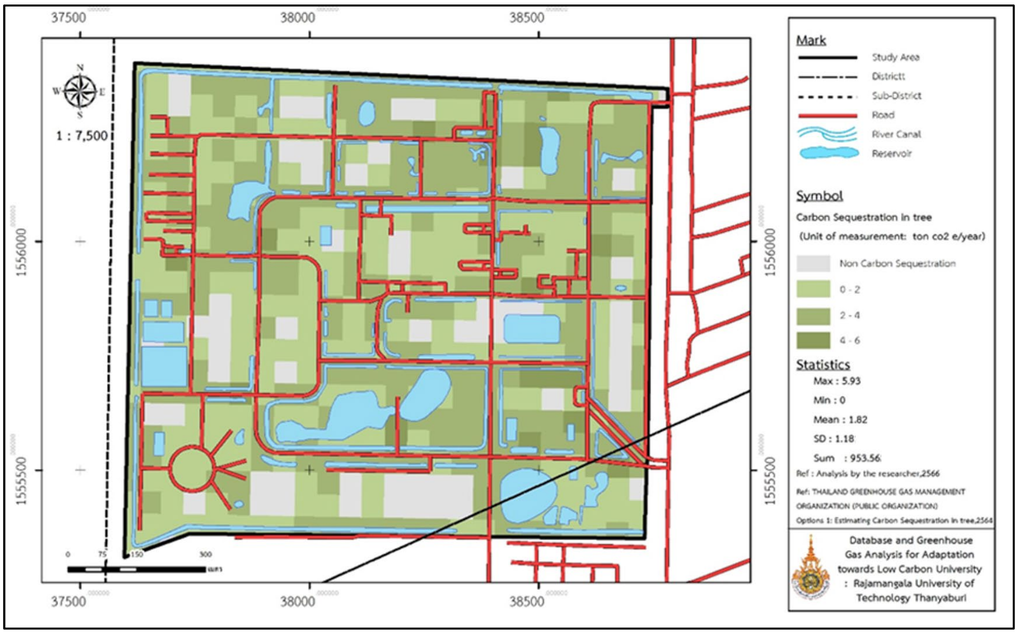


Figure 4. Carbon storage of trees within 523 plots in 2022.

Given the total GHG emissions of 10,361.32 tCO_2eq/year, it indicated that the carbon storage of trees in 2022 could absorb only 9.20 percent of total emissions. Therefore, an urgent and concrete plan to increase green space, particularly with perennial trees, is necessary, as trees need at least 10 years to reach their full potential for carbon dioxide absorption (TGO, 2018). Currently, large green areas with mature trees cover less than 30 percent of the university's area. According to the policy action plan on sustainable urban green space management, educational institutions should have at least 30 percent green coverage with large trees (Office of Natural Resources and Environmental Policy and Planning, 2019). To achieve this goal, the university needs to plant an additional 10,275 trees, which means adding approximately 6,260 more trees than those currently in place.

3.2.2. Forecasting GHGs and Carbon Storage

Based on the GHG calculation process in Section 3.1, the reduction of GHG emissions can be projected using the baseline year of 2022. RMUTT has established a framework to reduce energy consumption and fuel use by 10 percent annually, with the goal of achieving carbon neutrality by 2030, in line with Thailand's national policy. To support this goal, a 10-year GHG reduction plan has been set in place. The projection shows that GHG emissions, starting from the base year of 2022 at 10,361.32 tCO_2eq/year, will decrease by 3,612.77 tCO_2eq/year in 2032 (Figure 5).

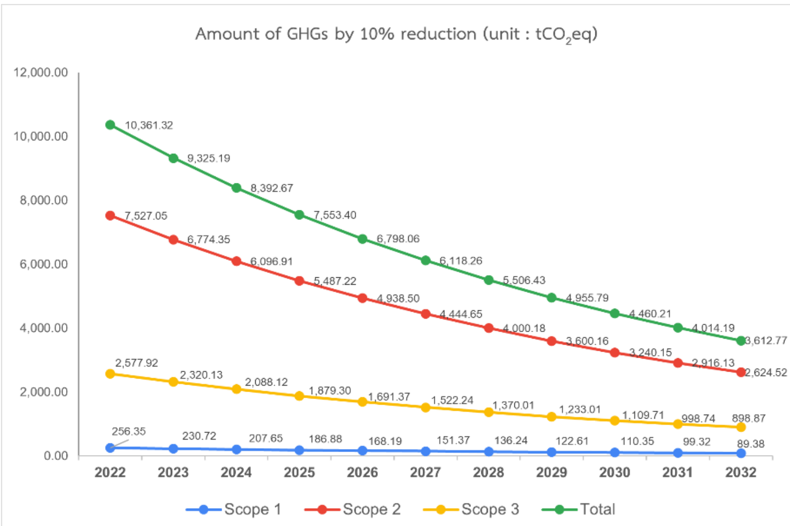


Figure 5. Amount of GHG emissions by 10% reduction of 10 Year (unit: tCO_2eq).

To calculate the carbon storage needed in the university area to meet the sustainable green space standard of 30 percent over the next 10 years (Equation (2)), it is assumed that fast-growing perennial trees will be planted over this period, with regular trimming and maintenance. The carbon storage capacity of the existing large tree group (comprising 4,015 trees with an average age of 25 years) is estimated to be 1,144.27 tCO_2eq/year in 5 years and 1,334.98 tCO_2eq/year in 10 years. In addition, the newly planted group of 6,260 trees is expected to sequester approximately 594.71 tCO_2eq/year by the 10th year. When comparing these figures to the projected total GHG emissions from RMUTT activities for 2022, 2027, and 2032, the corresponding reabsorption rates would be 9.20 percent, 18.70 percent, and 53.41 percent, respectively.

Table 5. Forecasting Carbon Storage Potential in RMUTT.

No	Group	No. of Tree	Age (Year)	Age (Year)		Carbon storage (tCO_2eq/Year)		
				5	10	Existing 2022	Five-Year 2027	Ten-Year 2032
1	Existing tree	4,015	25	30	35	953.56	1,144.27	1,334.98
2	Planting a new tree *	6,260	-	-	10 *	-	-	594.71
	Total	**10,275**				**953.56**	**1,144.27**	**1,929.70**
	Amount of GHG by 10% reduction 2022-2032 (10year)					10,361.32	6,118.25	3612.77
	Percentage of Carbon storage					9.20	18.70	53.41

* Calculate carbon storage per tree at 10 Year as fast-growing species from, Thailand Voluntary Emission Reduction Program T-VER-TOOL-01-01 Version 01.

However, in this study, it was assumed that the trees would be planted over a 10-year period with high carbon storage potential, as outlined in Table 5. To gain more precise estimates of carbon storage as the trees mature, it is expected that carbon absorption will gradually decrease. Conducting measurements every two years would provide more accurate forecasts and valuable insights, allowing for adjustments in long-term replanting strategies (TGO, 2018). To effectively manage tree mortality and ensure ongoing carbon sequestration, it is standard practice to include a "mortality buffer" by planting an additional 10–20% of the required trees (Domke et al., 2020). This approach helps compensate for natural mortality rates, ensuring that long-term carbon storage targets are met even if some trees fail to survive or reach maturity. For example, if 6,260 trees are needed to meet the sequestration target, a 10% buffer would raise the planting goal to 6,886 trees. Additionally, replacing dead or decaying trees is crucial for maintaining overall carbon storage. While decomposing trees release carbon dioxide, replanting offsets these emissions and preserves the forest's ability to meet its intended carbon storage capacity. The university's volunteer reforestation project has been consistently implemented to support environmental conservation efforts on campus (Building and Ground Division of RMUTT, 2018). This initiative has played a key role in engaging students, staff, and external collaborators in tree planting and maintenance activities. Partnerships with organizations such as the Royal Forest Department, which provide free, high-quality seedlings, help significantly reduce costs. Furthermore, the university utilizes its in-house resources, such as producing organic fertilizers and receiving soil preparation support from the Faculty of Agricultural Technology at RMUTT, to further minimize expenses. This collaborative approach not only supports sustainable green area conservation but also enhances carbon absorption, helping the university achieve its carbon storage targets.

3.3 Measurement Strategies for Reducing GHGs

To understand the measurement and policies aimed at reducing greenhouse gas (GHG) emissions at RMUTT, it is essential to engage people within the organization, as they play an important role in promoting sustainable development within their educational community through a participatory approach. The results of a questionnaire survey showed that out of 400 respondents, most (240 respondents, or 60%) were female, 150 (37.5%) were male, and 10 (2.5%) were unspecified. Of these respondents, 365 (91.25%) were students, while 35 (8.75%) were staff members. Regarding the age distribution of respondents, 231 (57.75%) were under 20 years old, followed by those aged 21–25 (31.5%). Only 0.75% of respondents were aged 46 or older. In terms of educational background, 385 respondents (96.25%) held a bachelor's degree, and 15 (3.75%) held a master's degree, as shown in Table 6.

Table 6. Respondent's survey information.

Personal Information		No. Respondents	Percentage
Gender	Male	150	37.50
	Female	240	60.00
	Unspecified	10	2.50
Status	Students	365	91.25
	Staff	35	8.75
Age	Less than 20 year	231	57.75
	21–25	126	31.50
	26–30	10	2.50
	31–35	11	2.75
	36–40	13	3.25
	41–45	6	1.50
	>46 up	3	0.75
Education Background	Bachelor's degree	385	96.25
	Master's degree	15	3.75

In surveying respondents' opinions on participation in activities to support a low-carbon university, the overall score was 3.87 out of 5.0 on a Likert scale, indicating an "agree" level. For participation activities, most respondents agreed on three key approaches: receiving information on low-carbon initiatives and GHG emissions as communicated by the university (3.88), participating in the setup and planning of low-carbon programs and activities aimed at reducing GHG emissions (3.88), and engaging in action-oriented activities at both faculty and university levels (3.88). Additionally, respondents agreed on taking part in decision-making and evaluation processes for projects, activities, and operations at the faculty and university levels (3.88). Participating in the initial process by providing comments and suggestions on activities, projects, and operations had an average score of 3.86, as shown in Table 7. These findings are in line with a study by Araújo (2023) on developing sustainable university campuses, including the Agrarian School of Ponte de Lima (ESA IPVC) in Northern Portugal. The study emphasized that, in transforming a campus into a sustainable community, it is essential to raise awareness and encourage participation among users, including teaching staff, students, employees, and visitors. Awareness-raising actions through social networks can provide opportunities to receive feedback from stakeholders, fostering a stronger sense of integration and participation. This approach helps university members become active agents of change in their attitudes and behaviors, voluntarily contributing to the success of both current and future initiatives.

Table 7. Respondents' Opinion on Participation towards Low Carbon University.

Items	Level of Agreement							
	Strongly agreed (5)	**Agreed (4)**	**Neither agreed nor disagreed (3)**	**Disagreed (2)**	**Strongly disagreed (1)**	**Mean $\bar{x}$**	**S.D.**	**Indication Level ***
1. Receiving information on low-carbon initiatives and GHG emissions as communicated by the university	129	120	131	14	6	**3.88**	**67**	**High**
	32.25	30.00	32.75	3.50	1.50	Percentage		
2. Participating in the initial process by providing comments and suggestions on activities, projects, and operations	135	117	118	20	10	**3.86**	**71**	**High**
	33.75	29.25	29.25	5.00	2.50	Percentage		
3. Participating in the setup and planning of low-carbon programs and activities aimed at reducing GHG emissions	134	144	133	9	10	**3.88**	**63**	**High**
	33.5	28.5	33.25	2.25	2.50	Percentage		
4. Engaging in action-oriented activities at both the faculty and university levels	125	136	113	18	8	**3.88**	**61**	**High**
	31.25	34.00	28.25	4.50	2.00	Percentage		
5. Taking part in decision-making and evaluation processes for projects,	133	124	118	15	10	**3.88**	**72**	**High**
	33.25	31.00	29.50	3.75	2.50	Percentage		

activities, and operations at the faculty and university levels	
Overall score	**3.87**

* Indication level: 1.00–1.80 = Very Low, 1.81–2.60 = Low, 2.61–3.40 = Moderate, 3.41–4.20 = High, 4.21–5.00 = Very high

Since 2015, RMUTT has implemented a strategy to become a green university and transition towards a low-carbon society by focusing on energy management and environmental pollution reduction (Building and Ground Division of RMUTT, 2023). The university's goal aligns with Thailand's policy to achieve carbon neutrality by 2050 and net-zero GHG emissions by 2065. The strategy is structured around four key areas: (1) Sustainability in the use of energy, resources, and clean technology; (2) Advancement towards a green policy; (3) Behavioral change towards sustainability; and (4) Supporting society and communities in low-carbon development. To assess the effectiveness of these strategies, a survey was conducted to gather respondents' opinions on each area. The results, as shown in Table 8, reveal that the mean scores for agreement across all four strategic frameworks were high. Among them, the strategy focused on behavioral change towards sustainability received the highest score of 3.78, followed by the growth towards a green policy at 3.72, the management plan for promoting low-carbon community development at 3.72, and sustainability in energy, resource, and clean technology use at 3.69. A closer look at specific measures revealed the highest scores in selecting environmentally friendly products (3.82), creating green spaces with perennial trees to absorb CO_2 (3.77), promoting collaboration with students and communities through activities like recycling and organic gardening (3.75), and organizing a master plan for energy and resource use to reduce carbon emissions (3.73). Particularly, students' behavioral tendencies and their willingness to engage in university activities have shown to be crucial in reducing overall carbon emissions, especially through energy-saving behaviors (Xiwang et al., 2015).

Table 8. Respondents' Opinions Survey on RMUTT's Four-Strategy Framework.

Strategy Plan Framework	Measurements	Respondent's Agree Level Score ($\bar{x}$) *
Sustainability in the use of energy, resources, and clean technology	Organizing a master plan for energy and resource use to reduce carbon emission	**3.73**
	Land use control and control of green buildings	3.70
	Creation of an energy database system for energy management	3.70
	Using alternative energy that does not create carbon (Zero-carbon Energy System), such as solar energy (Solar PV development	3.68
	Improving and designing green buildings and structures	3.65
		3.69
Growth towards a green policy	Arranging green space/landscape with perennial trees to absorb carbon dioxide	**3.77**
	Creating a green path (Green Cover Way) connecting within the university	3.76
	Sustainable waste management within the university towards "RMUTT Zero Waste" to be a model university for waste management	3.76
	Water conservation: Organizing a wastewater treatment system and new water processes. Promote sustainable environmental and water management.	3.74

Strategy Plan Framework	Measurements	Respondent's Agree Level Score ($\bar{x}$) *
	Preparation of the carbon footprint organization at Faculty-Level	3.60
		3.72
Behavioral change towards sustainability	Selecting environmentally friendly goods and products	**3.82**
	Reducing paper and water resources by implementing the 3R rule: reduce (Reduce), reuse (Reuse), and recycle (Recycle) efficiently	3.80
	Saving electricity by establishing rules and regulations for the use of various electrical equipment	3.79
	Modifying transportation to emit lower carbon emissions (Low Carbon Transportation)	3.78
	Prohibit the use of plastic and foam boxes in faculty/university areas	3.78
	Choose food that reduces greenhouse gas emissions and reduce the consumption of meat	3.73
		3.78
Management plan for promoting and supporting society and community towards low carbon	Activities to promote green research on safety and the risks of increasing greenhouse gases.	3.74
	Basic subject activities on the importance of natural resources and environmental limitations.	3.74
	Promoting cooperation with students and communities through activities such as recycling banks and organic vegetable plots within and around the university.	**3.75**
	Activities to transfer knowledge and research studies that are environmentally friendly to agencies/communities.	3.73
	Project activities for short clip contests or news exchanges to change behaviour and create awareness among students and staff through online media channels.	3.67
		3.72

* Indication level: 1.00–1.80 = Very Low, 1.81–2.60 = Low, 2.61–3.40 = Moderate, 3.41–4.20 = High, 4.21–5.00 = Very high.

To implement the four strategies, RMUTT has launched several environmental programs under the Green Campus project, aimed at balancing carbon emissions within these strategic frameworks. For example, the strategy of Sustainability in the Use of Energy, Resources, and Clean Technology includes an electric motorcycle initiative, developed in collaboration with a company specializing in smart energy management. This program reduces oil consumption, as well as dust and noise pollution, while also providing greater convenience for students. For successful execution, the programs outlined in the four strategies (as shown in Table 7) require approval from the university senate. However, before implementation can proceed, these programs must first be formally endorsed by the senate. This policy marks the beginning of RMUTT's Green Campus initiative and is a significant step toward achieving its

Carbon Neutrality goals.

4. Conclusion

To address climate change and develop effective strategies to reduce its environmental impact, RMUTT has assessed its total greenhouse gas (GHG) emissions. The total emissions across all three scopes were 10,361.32 tCO_2eq/year, or 0.38 tCO_2eq/year per person. Among these, Scope 2 emissions, which primarily result from electricity production for various university buildings, were the highest. As a result, energy management has become a critical focus in RMUTT's energy efficiency and conservation plan. By 2030, the university aims to reduce emissions from 10,361.32 tCO_2eq/year to 3,612.77 tCO_2eq/year. Using the T-VER-TOOL-FOR/AGR-01 method to calculate carbon storage in existing sustainable green spaces, RMUTT has found that increasing tree planting could significantly reduce CO_2 levels at a low cost. Aligning with the policy goal of maintaining 30% sustainable green space, as outlined in the 2007 Sustainable Urban Green Area Management Plan (ONEP), the university could achieve the following reductions in emissions: 9.20% in 2022, 18.70% in 2027, and 53.41% in 2032, capturing annual emissions of 10.36 tCO_2eq, 6.11 tCO_2eq, and 3.61 tCO_2eq, respectively. Expanding green spaces should therefore be prioritized, as they offer greater potential for carbon dioxide absorption. However, forests interact with their environments in complex and multifaceted ways, and this must be considered when assessing the impact and value of tree-planting initiatives. This research focuses on baseline carbon dioxide sequestration. To evaluate the increase in carbon sequestration capacity from this baseline, continuous monitoring and assessment are essential. The carbon sequestration ability of trees varies with their growth rate and eventually declines. Once trees reach full maturity, they should be harvested for timber use in various industries, and new trees should be replanted in the same area. This rotational planting practice ensures a continuous increase in carbon dioxide absorption during the growth phase of the new generation of trees. Future research should comprehensively examine tree planting initiatives, focusing on critical aspects such as tree growth dynamics, biomass formation, carbon dioxide absorption across different age classes, and economic value assessments. These studies would provide a robust framework for optimizing reforestation efforts and their contribution to carbon mitigation strategies. This strategy must also work in tandem with other mitigation efforts. Survey responses have shown a high level of participation in activities aimed at reducing GHG emissions. RMUTT should promote involvement across four key areas: (1) sustainable energy, resource use, and clean technology, (2) advancing green policy, (3) behavioral shifts toward sustainability, and (4) supporting society and communities in low-carbon development. This study will support both technological and organizational behavioral changes, encouraging environmentally friendly policies and advancing RMUTT's mission to become a low-carbon university by exploring sustainable solutions and engaging all stakeholders.

Conflict of Interest Statement

The authors have no competing interests to declare.

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