Carbon Footprint Reduction from Energy-Saving Measure and Green Area of Suranaree University of Technology, Thailand

Sudjit Karuchit, Wichayanee Puttipiriyangkul, and Tanyarut Karuchit

***Abstract*—This paper presents the carbon footprint estimation of Suranaree University of Technology (SUT). It also describes the carbon footprint reduction from the implementation of the energy-saving measure and the capturing of CO_2 by trees in the green area within the campus. For the academic year 2016, the total emission from sources and the total sinks of greenhouse gases (GHGs) were 13,318.64 tCO_2eq and 5,281.65 tCO_2eq, respectively, and the net carbon footprint was 8,036.99 tCO_2eq. Electricity usage accounted for 66% of the total emission. Other notable emitters were refrigerant leakage and waste disposal. The energy-saving measure – using energy-efficient air conditioners – can reduce the emission at considerably high costs, 33,332 baht/tCO_2eq. These air conditioners also use a higher GWP-value refrigerant, type R-410a. The green area played a very important role as the only sink of GHGs in the university. It captured approximately 40% of the total emission value. From the 4-year projection scenario, the net carbon footprint of the university has a downward trend, decreasing at an average rate of 1,005.46 tCO_2eq per year.**

***Index Terms*—Carbon footprint, energy-saving, green area, greenhouse gases.**

I. Introduction

Climate change caused by anthropogenic emission of greenhouse gases (GHGs) is undeniably an imminent threat to the health and welfare of the world's population. To reduce the country's GHGs emissions, Thailand Greenhouse Gas Management Organization (TGO) was established to be the center for collaboration among the 3 stakeholders: governmental agencies, private sector, and international organizations. TGO's responsibility includes promoting the estimation of GHGs emissions in the country and providing management guidelines to effectively reduce GHGs emissions. One of the guidelines, Guidelines for Estimating Carbon Footprint of Organizations, can be adopted by industrial organizations, local administrative offices, or academic institutes [1]. Consequently, the first carbon footprint estimation of Suranaree University of Technology (SUT) was carried out in 2016 using this guideline [2]. The results were among other universities which have reported their studies in the literature [3]–[8].

The first autonomous university in Thailand, SUT is in Nakhon Ratchasima province in the north-eastern part of the country. It has approximately 20,000 students, lecturers, and staffs combined, and the campus area of 6,911 rais. Early results of the study of GHGs emission of SUT was presented in a related paper [9]. The goals of this paper are to 1) presents the carbon footprint estimation from the sources and sinks of GHGs in Suranaree University of Technology, Thailand; and 2) analyze the carbon footprint reduction as a result of the energy-saving measure implement by the university and the carbon dioxide captured by the green area within the university.

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II. Methodology

A. Defining Boundaries

The methodology in this study followed the Guidelines for Estimating Carbon Footprint of Organizations by TGO. The first step was the identification of the organization boundary – the sources of GHGs emission and storage to be included in the analysis. The organization boundary for this study consisted of the internal units under the operational control of the university: the university council, the office of the president, institutions, centers, enterprise units, and other units. There were also units which were defined based on area: residential areas, green area, water supply system, wastewater treatment system, and waste disposal system.

The other boundary which had to be defined was the operational boundary. It involves defining sources and sinks of the GHGs related to the university operation to be included in the analysis. The operational boundary for GHGs sources in this study consisted of 3 groups, or "Scopes". Scope 1, direct emission, consisted of power generation, LPG usage, vehicle fuel combustion, refrigerant, fire extinguisher, fertilizer and detergent usage, and manure from animal farms. Scope 2 was the indirect emission from electricity. Scope 3, indirect emission from other sources, consisted of traveling by personnel, water supply, use of office and toilet papers, waste disposal, and tenant usage of fuel, electricity, and water. The operational boundary for GHGs sinks in this study consisted of only 1 group – the capture of CO_2 by trees in the green area of the university.

B. Data Collection

Pertinent information of the university's activities in the academic year 2016 was gathered for each activity defined in the operational boundary. For the sources of GHGs, primary data collected included surveying, personnel interviews, questionnaires, and data extraction from operational records.

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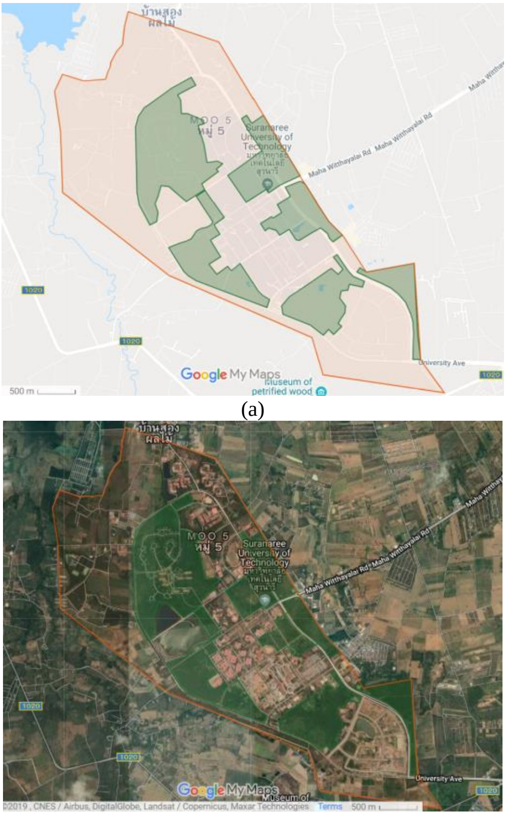
Secondary data collected included electricity bills, equipment and supplies records, receipts, disbursement records, and operational records.

For the sink of GHGs, the trees in the green area were sampled for their numbers, types, heights, and diameters. Within the 6,911 rais (1 rai = 1,600 square meters) of the university area, approximately 1,793 rais (26%) were the green area defined in this study. It was divided into 6 sub-areas, as shown in Fig. 1. For each sub-area, two 20 × 20 square meters sampling areas were randomly located. Within each sampling area, two 4 × 4 square meters data collection areas were then randomly located. Trees in each of these areas that were higher than 1.30 meters and had diameters greater than 4.5 centimeters were measured for their heights and diameters at breast height (1.30 meters).



(a)

(b)

Fig. 1. The green area in the university, divided into 6 sub-areas: (a) basic area map and (b) satellite image map.

C. Calculation of GHGs Emission from Sources

The amount of GHGs emission from the university sources was calculated from the activity data and corresponding emission factors using (1) and (2):

$$E_A = A \times EF \quad (1)$$

$$E_T = (D/F) \times EF \quad (2)$$

where E_A and E_T are the GHGs emission from activity and trip, respectively; A is the activity data, D is the distance traveled, F is the fuel consumption rate, and EF is the emission factor. The unit of GHGs emission is ton CO_2 equivalent (tCO_2eq). The GHGs emission factor used in the calculation of each activity is based on recommendations by TGO [1].

D. Calculation of GHGs Reduction from Sinks

Calculation of GHGs reduction from sinks involved the estimation of carbon dioxide captured by trees in the university's green area. First, the carbon storage in trees can be calculated from the total above-ground biomass (W_T) using the allometric equations [10]. W_T is the sum of stem wood biomass (W_S), branch biomass (W_B) and leaf biomass (W_L). These biomass values are related to the tree heights (H) and diameters at breath height (DBH). For trees of general type, the calculation of W_S, W_B, W_L, and W_T of each tree follows (3) to (6) [11].

$$W_S = 0.0396\,(D^2H)^{0.933} \quad (3)$$

$$W_B = 0.00349\,(D^2H)^{1.030} \quad (4)$$

$$W_L = (28/(W_S + W_B + 0.025))^{-1} \quad (5)$$

$$W_T = W_S + W_B + W_L \quad (6)$$

The units of D and H used in the equations are centimeters and meters, respectively. The units of biomass values are kilograms. The amount of carbon in the trees can then be calculated by multiplying W_T with 0.47, the conversion factor representing the proportion of carbon in the total biomass [10]. Finally, the carbon dioxide storage can be computed from the carbon storage multiplied by the molecular weight of carbon dioxide per carbon mass (44/12) to obtain the unit to the mass of carbon dioxide equivalent.

The CO_2 captured annually by trees, or the mean annual increment (MAI), can be estimated from the difference of carbon dioxide storage between the base year (C_0) and the nth year (C_n), as shown in (7).

$$MAI = (C_n - C_0)/n \quad (7)$$

III. Results and Discussion

A. Carbon Footprint Estimation

Table I shows the calculation results of CO_2 captured by trees in the green area of the university. The above-ground biomass, carbon storage, and CO_2 storage in the academic year 2016 were 15.5 tC/rai, 7.14 tC/rai, and 25.03 tCO_2/rai, respectively. The total CO_2 storage in the green area was 44,882 tCO_2. The CO_2 captured in the year 2016, 5,282 tCO_2, was calculated from the MAI equation, using the year 2015 as the base year and n = 1.

Table II shows the summary results of the GHGs sources and sinks calculation. For the GHGs sources, the direct emission (Scope 1), electricity (Scope 2), and indirect emission (Scope 3) were equal to 2,807.92, 8,808.63 and 1,634.22 tCO_2eq, or 21%, 66% and 12%, respectively. It was unmistakable that Scope 2 – electricity usage – dominated the overall emission. Furthermore, it should be noted that refrigerant leakage and waste disposal were the second and third largest contributors, respectively. Both were in Scope 1. The total emission from GHGs sources was 13,318.64 tCO_2eq. For the GHGs sink, on the other hand, the total CO_2 captured in the year 2016 by the green area was equal to

5,281.65 tCO_2eq. The net value of Suranaree University of Technology's carbon footprint was calculated from the total GHGs emission (source) minus the total GHGs reduction (sink), which was equal to 8,036.99 tCO_2eq.

TABLE I: CO_2 STORAGE AND CAPTURE BY THE GREEN AREA IN SUT

Area	Biomass Above Ground (tC/Rai)	Carbon Storage (tC/Rai)	CO_2 Storage (tCO_2)				CO_2 Capture in 2016 (tCO_2)	
			Year 2016		Year 2015			
			Per Rai	All	Per Rai	All	Per Rai	All
Green Area	15.15	7.14	25.03	44,882	22.09	39,601	2.95	5,282

TABLE II: SUMMARY RESULTS OF THE GHGS CALCULATION AND THE NET VALUE OF CARBON FOOTPRINT

Category	Group	Activities	GHGs Emission/Capture (tCO_2eq)	% Within Group	% Between Group
Source	Direct Emission	Power generator	3.39	0.09	0.03
		LPG usage	35.05	0.98	0.26
		Vehicle fuel combustion	305.97	8.52	2.30
		Equipment fuel combustion	56.18	1.56	0.42
		Refrigerant	2,095.18	58.32	15.73
		Fire extinguisher	0.13	0.00	0.00
		Fertilizer and detergent usage	59.92	1.67	0.45
		Waste disposal	716.60	19.95	5.38
		Manure from animal farms	319.98	8.91	2.40
		Total	3,592.40	100.00	26.97
	Electricity	Electricity usage	8,808.63	100.00	66.14
		Total	8,808.63	100.00	66.14
	Indirect Emission	Traveling of personnel	55.15	6.01	0.41
		Water supply	484.63	52.81	3.64
		Use of office/toilet paper	38.73	4.22	0.29
		Fuel used by tenant	71.71	7.81	0.54
		Electricity used by tenant	263.46	28.71	1.98
		Water supply used of tenant	3.93	0.43	0.03
		Total	917.61	100.00	6.89
		Total Source	13,318.64		
Sink	CO_2 capture	CO_2 captured by green area	5,281.65	100.00	100.00
		Total	5,281.65	100.00	100.00
		Total Sink	5,281.65		
		Net Carbon Footprint (Source - Sink)	8,036.99		

B. *Carbon Footprint Reduction Analysis*

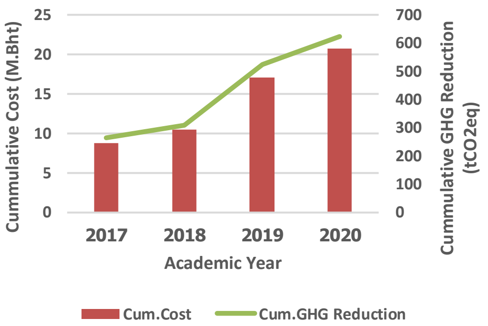
Analysis of carbon footprint reduction focused on the major source and sink of GHGs of the university. The electricity usage was the most important source, accounting for over 66% of the university's carbon footprint. On the other hand, the green area had a very important role as the only sink of GHGs in the university. It captured 5,281.65 tCO_2eq, which was approximately 40% of the total source emission value. This section explores the university's carbon footprint reduction scenarios that involve an energy-saving measure and the annual CO_2 capture by green area.

As an energy-saving measure, the university's Division of Building and Ground (DBG) have plans for replacing the existing, old air conditioners in selected buildings every year. The new air conditioners are the ones with a higher energy efficiency ratio (EER). They also have the variable refrigerant flow (VRF) systems, which can adjust the amount of refrigerant flow according to the working load and the number of units served. Both features make the new air conditioners more energy-efficient, which leads to energy saving and thus the GHGs emission reduction.

Fig. 2 shows the analysis of the measure with regards to the GHGs reduction, based on the DBG plan during the academic year 2017 – 2020. The cumulative cost is estimated to be 20.76 million baht (Fig. 2 (a)). The amount of GHGs reduced via this measure will be 622.07 tCO_2eq in 2020. The annual costs of GHGs reduction vary slightly, with the average value equals to 33,332 baht/tCO_2eq (Fig. 2 (b)).

The new air conditioners, however, have an undesirable aspect regarding their refrigerant – type R-410a. When compared with the refrigerant used in the existing air conditioners, type R-22, the new chemical has a higher Global Warming Potential (GWP) value. As a result, the annual emission from refrigerant leakage increased, as shown in Fig. 3 (a). The additional GHGs emission from refrigerant change will be 34.29 tCO_2eq in 2020 (Fig. 3 (b)).

As for the GHGs reduction through CO_2 storage by trees in the green area, the amount stored in 2015 and 2016 were 39,601 tCO_2 and 44,882 tCO_2, respectively. The increase of CO_2 storage from 2015 was considered the CO_2 captured in 2016. That amount was 5,282 tCO_2, which was equal to 13.34% of the CO_2 storage in 2015.



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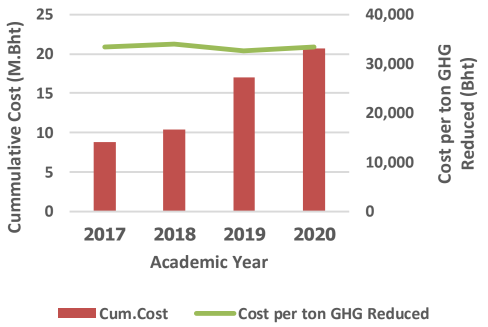
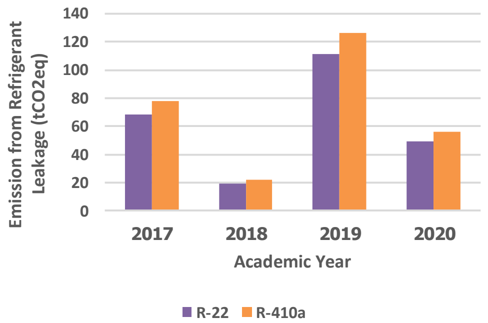
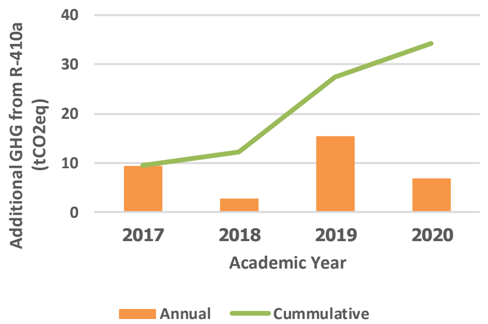


(b)

Fig. 2. Analysis of energy-saving measure by changing air conditioners: (a) cumulative cost and cumulative GHG reduction and (b) cumulative cost and cost per ton GHG reduced.



(a)



(b)

Fig. 3. Emission from refrigerant leakage: (a) comparing R-22 and R-410a usage and (b) additional GHGs emission from the use of R-410a.

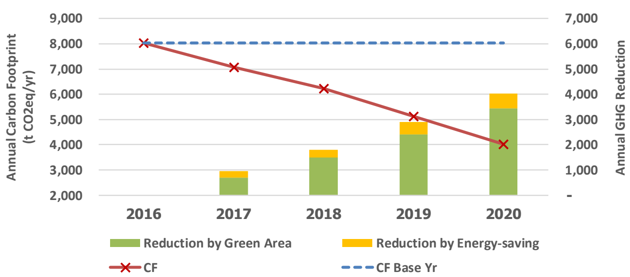


Fig. 4. Projection of carbon footprint of Suranaree University of Technology during the academic year 2017 – 2020.

Fig. 4 shows the projection of the carbon footprint of Suranaree University of Technology during the academic year 2017 – 2020. The assumptions were that all emissions were constant, and the only changes were the annual reduction of GHGs from the energy-saving measure and the green area CO_2 capture. The annual reduction by green area was calculated based on the assumption that the CO_2 captured each year equals to 13.34% of the CO_2 storage of the earlier year. This assumption means the existing green area is preserved and the trees are allowed to grow naturally without significant biomass loss from branch cutting or trimming. From the projection, the annual carbon footprint of the university has a downward trend, decreases from 8,036.99 tCO_2eq in 2016 (base year) to 4,015.16 tCO_2eq in 2020. The average annual reduction rate over the 4 years is 1,005.46 tCO_2eq per year. It is apparent that the more significant reduction comes from the green area. The energy-saving measure accounted for only 15% - 27% of the total reduction annually.

IV. Conclusion

For the academic year 2016, the estimated university's carbon footprint was 8,036.99 tCO_2eq. The most significant emission came from electricity usage, 66%. The green area captured nearly 40% of the total emission. The energy-saving measure of installing new, more energy-efficient air conditioners can reduce the GHGs emission but has substantial costs and an undesirable usage of higher GWP-value refrigerant. The capture of CO_2 by the green area contributed more significantly. From the 4-year projection scenario, the average GHGs reduction rate is 1,005.46 tCO_2eq per year. The findings and the approach of this work are valuable parts of the foundation for carbon footprint analysis and reduction of the university.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

W. Puttipiriyangkul and S. Karuchit conducted the research and analyzed the data; S. Karuchit and T. Karuchit analyzed the carbon footprint reduction options and wrote the paper. All authors had approved the final version.

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