Electricity and Water Supply Consumption and Greenhouse Gas Emission at the Office of the Faculty of Science and Technology, Suan Sunandha Rajabhat University

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Abstract: This work was a data collection of electricity and water supply consumption of the Dean's Office of the Faculty of Science and Technology, Suan Sunandha Rajabhat University, Thailand. The greenhouse gas emissions from electricity and water supply consumptions were calculated using the up-to-date emission factor from the Thailand Greenhouse Gas Management Organization (TGO) database. In average, the office consumes 1.045 m^3/d and 87.9 kWh/d of water and electricity, respectively. This is equal to 68.5 Liter per person (11.25 L/m^2) and 4.1 kWh per person (0.6788 kWh /m^2) for the daily water supply and electricity consumptions, respectively. The total daily greenhouse gas emission from both electricity and water supply consumption is 59.01 kg-CO_2 eq. which is mainly came from the electricity consumption (≈ 98%). The average emission based on people and area are 2.566 kg-CO_2 eq per person and 0.422 kg-CO_2/m^2, respectively.

Keywords: Resources management, Electricity, Water supply, Greenhouse gases emission

Introduction

Nowadays, global warming is a major problem in the world. This problem is even more intense due to the increase in resources consumption like electricity and water. These consumptions require a lot of natural resources and this results in a higher amount of greenhouse gases (GHGs) emissions. Therefore, it is necessary to collect the data from resources consumption and calculate the emission of greenhouse gases, for proper management of resources. The data can be used as a tool for the decision making process of the resources management and as a database to compare the emissions before and after management.

There were researches conducted to study the resources consumption and calculate the emission of GHGs. Aroonsrimorakot et al. (2013) collected the data and calculated the GHGs emission from the activities of Faculty of Environment and Resource Studies in Mahidol University, Salaya campus in the year 2010. The collected data include the consumption of water supply, electricity, paper usage , diesel , gasohol, chemicals and also the generating of solid waste and wastewater treatment. The results showed that the faculty generated 1,091.85 $MTCO_2e$ (Metric Ton Carbondioxide Equivalent). The major GHGs emission came from the electricity consumption as it accounted to 80% of the total GHGs emisison. Another research by Chalfoun (2014) studied the management of the saving energy from 9 buildings of the University of Arizona. The research focused on the result after the improvement of inefficient windows, installation of external insulation, shading of critical building elements, energy-saving light fixtures, and envelope solar reflectance in summer. The results showed that before starting project all buildings with total area of 1,081,512 ft² consumed an annual average 70.2 KBtu/ft² (221.59 kWh/m^2) at the cost of $2,186,264 per year. After the improvement, the energy consumption was decreased with the average of 61.42 KBtu/ft² (193.76 kWh/m^2) annually. The decrease was calculated by 12.5% and the reduction of 2915 metric tons of CO_2 equivalent emission. Another research by Aroonsrimorakot (2015) collected the data of resources consumption from several offices that attended the green office program from the period of June 2014 to October 2014 based on the capital average and area average. The results from the research were then used to compare the results of this work.

The faculty of science and technology, Suan Sunandha Rajabhat University is divided into 4 divisions namely: Office of the Dean, Department of Science, Department of Applied Science, and Science Center. The dean's office contains 23 employees (16 officers and 7 administrative staff) with the total area of 140 m^2. The office has attended the Green Office program since 2014 and received the silver medal for the year 2014. The office is continuously improving its green office management by collecting the data of resources consumption like electricity and water supply. The collected data have been used in the study of estimating the GHGs emissions from office. The purpose of this research is to collect and to analyze the data as a decision tool for the improvement of the office's management of resources consumption and GHGs emissions which is a part of Green Office program. The objectives of this work were to calculate the total amount of electricity and water supply consumption and estimate the emission of greenhouse gases as a result of these consumption. The comparison between the data for the year 2014 and 2015 was analyzed using statistics.

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Material and Methods

The data of electricity and water supply consumption were manually collected from the period of 29th August 2014 to 30th March 2015. The date of 29th August 2014 (11:00 AM , GMT +7) was set as a reference time and the next time of data collection were subtracted by the data of the reference time. The dates and time which the datum was collected would be converted to Julian Date (JD) to find the difference of the data between the time of collection. The JD were used to normalize the data to the exactly required time before the statistical comparison.

The reference time (29th August 2014, 11:00 AM GMT +7) was converted to the JD of 2456898.654. At that time, the meter of the water supply and electricity showed the value of 21.038 m^3 and 1369 unit of electricity (kWatt-hour or kWh), respectively. The following week from the reference time, the data were collected at 5th September 2014 (11:15 AM, GMT +7) and this was converted to the JD of 2456905.664. At this time, the meter showed 32.804 m^3 and 2081 kWh for the water supply and electricity, respectively. The difference in the time was 2456905.664 – 2456898.654 = 7.010 day and that week consumed 32.804 – 21.038 = 11.766 m^3 (for the water) and 2081 – 1369 = 712 kWh (for the electricity) and these actual data were plotted in the Figure 1. The data were normalized to the exact 7.000 day in each week for the analysis part (Figure 2) and the first week gave 11.749 m^3 (for the water) and 710.942 kWh (for the electricity).

The average consumptions rate (per day) were investigated and compared with the data with the existing literature. The GHGs emissions from the consumption of electricity and water supply were calculated by multiplying the consumption with the emission factor from the Thailand Greenhouse gas management Organization (TGO)'s database. The emission factors are 0.6093 kg-CO2 eq / kWh and 0.7043 kg-CO2 eq / m^3 for the consumption of electricity and water supply, respectively (TGO, 2014).

The data from the date 29th Aug to 28th Nov 2014 was selected as the representation of data in 2014 (semester 1/2014) which contains 13 weeks. The date 5th Jan to 30th Mar 2015 was selected as the representation of data in 2015 (semester 2/2014) which contains 12 weeks. The data in December was not included in this analysis due to the end of semester. During semester break, the resources consumption is less than normal period.

The descriptive and inferential statistics of the data were analyzed using SPSS version 20 to compare the weekly data from 2014 - 2015. The following statistical hypothesis were used for calculating both resources consumption and GHGs emisison.

$$H_o : \mu_{2014} = \mu_{2015}$$
$$H_1 : \mu_{2014} \neq \mu_{2015}$$

Results and Discussion

Analysis of cumulative resources consumption

The results of cumulative consumption of water supply and electricity are shown in Figure 1

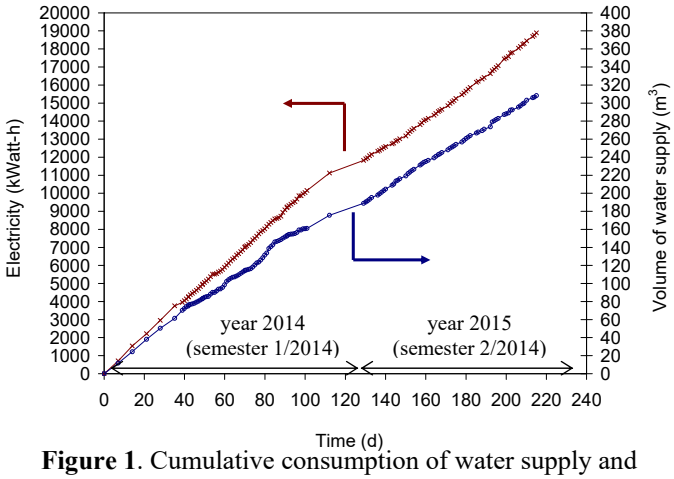

Figure 1. Cumulative consumption of water supply and electricity

Figure 1 shows that within 213 days of data collection, the water and electric consumption of the Dean's office is 306.6051 m^3 and 18,768.3 kWh, respectively. The mean resource usage of water consumption was calculated as 1.045 m^3 per day. On the other hand, the mean resource usage of electricity was 87.9 kWh per day.

The results in Figure 1 are summarized in Table 1

Table 1. Mean usage of water supply and electricity consumption

Parameter	Water supply	Electricity
average's mean usage	1.575 m^3/d	95.0 kWh/d
maximum of average's mean usage	1.816 m^3/d	109.7 kWh/d
minimum of average's mean usage	1.425 m^3/d	86.6 kWh/d

It can be inferred from the table that the dean's office daily consumes water supply and electricity about 68.5 Liter per person (1.575 × 1000 ÷ 23 = 68.5 L ca^{-1} d^{-1}) and 4.1 kWh per person (95.0 ÷ 23 = 4.1 kWh ca^{-1} d^{-1}) respectively. In the total area point of view, the office daily consume around 11.25 Liter per square meter (1.575 × 1000 ÷ 140 = 11.25 L m^{-2} d^{-1}) and 0.6788 kWh per square meter (95.0 ÷ 140 = 0.6788 kWh m^{-2} d^{-1}) for the water supply and electricity, respectively. The result suggests that the resources' consumption of the office of the dean is quite lower than the average consumption in several other offices based on people average however it is quite higher than the average consumption in several other offices based on area average. The comparison of the resources consumption in other several offices are summarized in Table 2.

Analysis of weekly resources consumption

The data from the Figure 1 was used to calculate the weekly consumption of the resources. The results of such calculations are shown as Figure 2.

Table 2. The average daily resources consumption

The office of / Source	Water supply ($L\ ca^{-1}\ d^{-1}$)	Water supply ($L\ m^{-2}\ d^{-1}$)	Electricity ($kWh\ ca^{-1}\ d^{-1}$)	Electricity ($kWh\ m^{-2}\ d^{-1}$)	Reference [1]
Bangchak Petroleum Public Co.,Ltd.	197.69	17.24	4.05	0.354	Aroonsrimorakot, 2015
Bank for Agriculture and Agricultural Cooperatives, Bang Khen Headquarters	110.53	3.77	10.40	0.355	Aroonsrimorakot, 2015
Denso (Thailand) Co., Ltd.	68.45	54.44	0.83	0.658	Aroonsrimorakot, 2015
Denso (Thailand) Co., Ltd., Wellgrow Plant	14.11	2.46	10.43	1.839	Aroonsrimorakot, 2015
Department of Environmental Quality Promotion	92.62	1.52	7.38	0.121	Aroonsrimorakot, 2015
Electricity Generating Authority of Thailand (EGAT)	99.97	5.03	6.63	0.335	Aroonsrimorakot, 2015
Electricity Generating Public Co., Ltd.	222.80	2.61	24.65	0.283	Aroonsrimorakot, 2015
Fuji Xerox (Thailand) Co., Ltd.	No data	No data	6.52	0.744	Aroonsrimorakot, 2015
Honda Automobile (Thailand) Co.,Ltd	105.73	19.89	4.48	0.843	Aroonsrimorakot, 2015
Honda Automobiles - Training Center	208.16	75.43	22.88	8.282	Aroonsrimorakot, 2015
Koh Kha Sub District Municipality	57.07	2.46	2.98	0.131	Aroonsrimorakot, 2015
Mae Fah Luang Foundation	8.54	3.12	0.88	0.326	Aroonsrimorakot, 2015
Mueang Phon Town Municipality	36.97	2.67	0.18	0.013	Aroonsrimorakot, 2015
Office of the dean, Faculty of Science & Tech., SSRU [2]	68.50 (*7/18*) [3]	11.25 (*12/16*)	4.1 (*8/20*)	0.679 (*15/19*)	This work
PEA [4] at Ban Bang Mun Nak District, Phichit Province	145.35	0.66	5.81	0.027	Aroonsrimorakot, 2015
PEA at Buriram Province	69.91	0.48	3.02	0.022	Aroonsrimorakot, 2015
Si Sa Ket Town Municipality	149.84	No data	8.86	No data	Aroonsrimorakot, 2015
Thai Onono Public Co.,Ltd.	94.89	No data	4.28	No data	Aroonsrimorakot, 2015
Toyota Motor Thailand Co.,Ltd. (Ban Pho Plant)	8.79	0.14	1.90	0.030	Aroonsrimorakot, 2015
University of Arizona (focus only 9 buildings) before the implementation of energy saving program	–	–	No data	0.607	Chalfoun, 2014
University of Arizona (focus only 9 buildings) after the implementation of energy saving program	–	–	No data	0.531	Chalfoun, 2014
Water usage of 13 rural communities of northeast Thailand	10 – 90	No data	–	–	Frankel and Shouvanavirakul, 1973
Electricity consumption of Thailand in 2012	–	–	6.53	No data	EPPO [5] , 2013

[1] The data of the resources consumption from Aroonsrimorakot (2015) were collected from the period of June 2014 to October 2014.
[2] Suan Sunandha Rajabhat University
[3] The number in the blanket is the rank of resource consumption saver compared to the offices or the data sources used in the prioritization
e.g. *1/18* mean the office has the lowest resource consumption compared to the other 18 data sources in the same column that used in the prioritization
e.g. *18/18* mean the office has the highest resource consumption compared to the other 18 data sources in the same column that used in the prioritization
[4] Provincial Electricity Authority
[5] The Energy Policy and Planning Office of Thailand

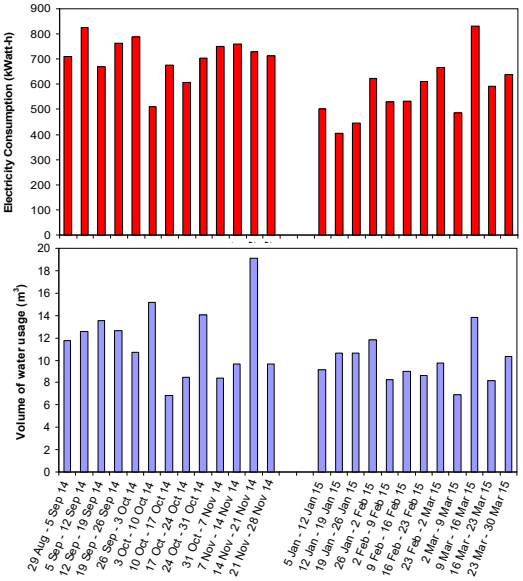

Figure 2. Weekly consumption of water supply and electricity

The inferential statistics were used to analyze the data in Figure 2 using SPSS version 20 and display in Tables 3 and 4

Table 3. Statistical data of weekly water supply consumption

Parameter		All data	Data of 2014	Data of 2015
Number of week		25	13	12
Average (m^3/week)		10.7836	11.7404	9.7474
SD (m^3/week)		2.8391	3.3054	1.84798
minimum (m^3)		6.8597	6.8597	6.9110
maximum (m^3)		19.1310	19.1310	13.8020
C.I. of 95% (t-Dist) in m^3	lower	9.6117	9.9257	8.8024
	upper	11.9556	13.5620	10.7864

According to Shapiro-Wilk's test of normality, the distribution of two data groups (year 2014 & 2015) in water supply consumption is within the normal curves of normality. It has a confidential interval of 95%. This is because the observed significances are 0.787 and 0.771 for years 2014 and 2015, respectively, which are greater than 0.05. The findings imply that t-test can be used for the testing of hypothesis. The Levene's test was conducted before the analysis of t-test to elucidate the equity of variances. It was found that the groups of data have the same variances (for the C.I. of 95%) with significances of 0.090 which is higher than the reference value (0.05). The two-tailed analysis of t-test was then conducted and found a significance of 0.079 which exceed the reference value (0.05). This inferred that null hypothesis (H_o) is accepted. This could be interpreted that there is no difference between the average of weekly water supply consumption in year 2014 and 2015 ($\mu_{\text{water consumption, 2015}} = \mu_{\text{water consumption, 2014}}$).

Table 4. Statistical data of weekly electricity consumption

Parameter		All data	Data of 2014	Data of 2015
Number of week		25	13	12
Average (kWh/week)		642.6	708.0	571.7
SD (kWh/week)		119.0	81.1	114.8
minimum (kWh)		405.6	511.6	405.6
maximum (kWh)		832.6	824.2	832.6
C.I. of 95% (t-Dist) in kWh	lower	593.4	661.7	510. 6
	upper	691.7	745.6	639.1

It could be implied from the Shapiro-Wilk's test of normality for the electricity consumption that the distribution of the both groups of data (years 2014 and 2015) are within the normal curves with the confidential interval of 95%. This is due to the significances are 0.294 and 0.652 for years 2014 and 2015, respectively, which are greater than 0.05. This finding implies that t-test could be used for the testing of hypothesis. The Levene's test was conducted before the analysis of t-test to elucidate the equity of variances. It was found that both groups of data have the same variances (for the C.I. of 95%) with significances of 0.220 which is higher than the reference value (0.05). The two-tailed analysis of t-test was then performed and found a significance of 0.002 which is lower than the reference value (0.05). This infers that alternative hypothesis (H_1) is accepted which could be interpreted that there is a difference between the average of weekly water supply consumption in year 2014 and 2015. According to the Table 4, it can be noticed that the lower bound of μ_{2014} (661.7 kWh) is higher than the upper bound of μ_{2015} (639.1 kWh). This means that electricity consumption of year 2015 is lower than that of year 2015 ($\mu_{\text{electricity consumption, 2015}} < \mu_{\text{electricity consumption, 2014}}$). The calculated reduction was about 19.25%. The possible reason that affects the decrease of electricity consumption might be due to the campaign of the faculty about the green office program in which the saving electricity consumption was included.

Calculation of Greenhouse Gases emissions

The cumulative of GHGs emissions from the consumption of electricity and water supply were displayed in Figure 3.

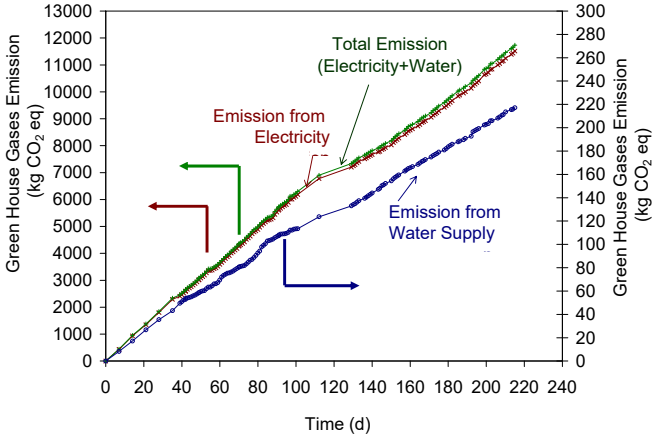

Figure 3. Cumulative Greenhouse gases emissions

During the days of data collection, Figure 3 shows that the Office of The Dean emitted an equivalent greenhouse gases of 217.2 kg-CO_2 eq (kilogram of carbon dioxide equivalent) from water supply consumption and 11,514.5 kg-CO_2 eq from electricity consumption. The total emission from both consumptions is 11,731.7 kg-CO_2 eq. Majority of emission came from the electricity consumption which is about 98.1% whilst the water consumption shared the minority emission of 1.9%. This finding was consistent with the previous study of Aroonsrimorakot and co-worker in 2013 that states the GHGs emission mainly came from the electrical consumption.

The mean of the emissions for each day were determined using the slope of the curves. There are 136 data for each type of emissions in the Figure 1 which were used for determination of the slope. This leads to the mean emissions per day for each type of emissions. The results are summarized in Table 5.

Table 5. Mean of the greenhouse gases emissions in kg-CO_2 eq per day

Parameter	Water supply	Electricity	Total
average's mean emission	1.109 (1.9%)	57.90 (98.1%)	59.01 (100%)
minimum of average's mean emission	1.003	52.74	53.75
maximum of average's mean emission	1.279	66.82	68.04

It could be inferred from the table that each person in the office consume an average of 2.566 kg-CO_2 eq per day and on the basis of area average the office consume 0.422 kg-CO_2 eq per square meter per day.

The comparison of the GHGs emission in several offices is summarized in Table 6. The values of the GHGs average emission in the table were calculated by multiplying the resources consumption rate in Table 2 with the specific emission factor of each resources consumption of TGO (2014) displayed in the section of Material and Methods. The results of the comparison between GHGs emitters gave the same pattern as those of the comparison between resources consumers. When compared to several other offices, the Office of the Dean's GHG emission based on people average is quite low. On the other hand, its GHG emission based on area average is quite high. It is interesting to note that the ranks of GHGs emission saver of the dean's office are the same. However, there are exceptions in the column of area based GHGs emission from the electricity consumption . The rank is lower than that of area based electricity consumption. The possible reason for this is the different emission factors which were applied to the offices in Thai and to the building in the university of Arizona.

Analysis of weekly Greenhouse Gases emissions

The data from the Figure 3 were selected to calculate the weekly consumption of the resources in the same manner as the section of weekly resources' consumption analysis and the results were displayed as Figure 4

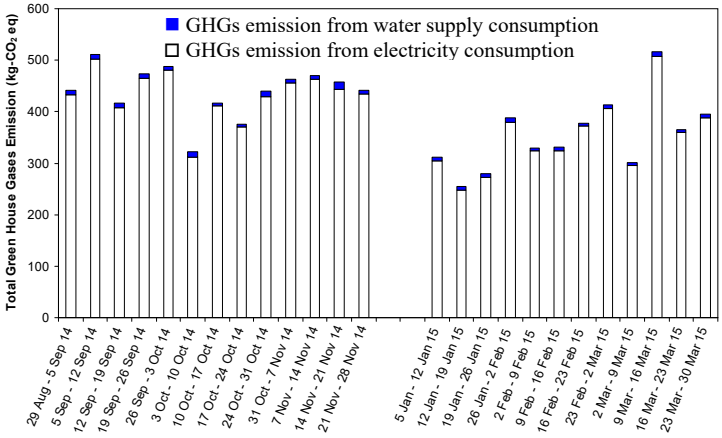

Figure 4. Weekly emissions of greenhouse Gases

The whole stacks represent the total emission while the clear and dark parts of the stacks represent the emission from electricity and water supply consumption, respectively. It could be observed from the figure that the minority emission came from the water supply consumption with the minimum of 1.16% and a maximum of 3.31% and an average of 1.94%.

The analysis of inferential statistics was achieved by the same manner of the previous section. It is interesting to note that the results of the emissions from electricity and water supply consumptions is the same as the previous section in which the emission from the water consumption had an equity between the emission of 2014 and 2015 ($\mu_{\text{water's GHGs 2015}} = \mu_{\text{water's GHGs 2014}}$). The emission from the electrical consumption of 2015 is greater than that of 2014 ($\mu_{\text{electricity's GHGs 2015}} < \mu_{\text{electricity's GHGs 2014}}$). This is because the GHGs emission data were generated from multiplying the emission factor to the data of resources consumption which was no effect in the results of hypotheses testing.

The total emission as a result of the combination effect of electricity and water supply consumptions was analyzed. The statistical data were shown in the Table 7.

Table 7. Statistical data of weekly total greenhouse gases emission

Parameter		All data	Data of 2014	Data of 2015
Number of week		25	13	12
Average (kg-CO_2 eq /week)		369.5	439.6	355.2
SD (kg-CO_2 eq /week)		127.6	49.27	70.66
minimum (kg-CO_2 eq)		254.6	322.4	254.6
maximum (kg-CO_2 eq)		517.0	511.0	517.0
C.I. of 95% (t-Dist) in kg-CO_2 eq	lower	368.9	411.4	316.9
	upper	429.3	463.9	399.9

Table 6. The greenhouse gases emission of each resource consumption

The office of / Source	Water supply ($kg\text{-}CO_2$ eq ca^{-1} d^{-1})	Water supply ($kg\text{-}CO_2$ eq m^{-2} d^{-1})	Electricity ($kg\text{-}CO_2$ eq ca^{-1} d^{-1})	Electricity ($kg\text{-}CO_2$ eq m^{-2} d^{-1})	Reference [1]
Bangchak Petroleum Public Co.,Ltd.	0.139	0.0121	2.47	0.216	Aroonsrimorakot, 2015
Bank for Agriculture and Agricultural Cooperatives, Bang Khen Headquarters	0.078	0.0027	6.34	0.216	Aroonsrimorakot, 2015
Denso (Thailand) Co., Ltd.	0.048	0.0383	0.50	0.401	Aroonsrimorakot, 2015
Denso (Thailand) Co., Ltd., Wellgrow Plant	0.010	0.0017	6.36	1.120	Aroonsrimorakot, 2015
Department of Environmental Quality Promotion	0.065	0.0011	4.50	0.074	Aroonsrimorakot, 2015
Electricity Generating Authority of Thailand (EGAT)	0.070	0.0035	4.04	0.204	Aroonsrimorakot, 2015
Electricity Generating Public Co., Ltd.	0.157	0.0018	15.02	0.173	Aroonsrimorakot, 2015
Fuji Xerox (Thailand) Co., Ltd.	No data	No data	3.98	0.453	Aroonsrimorakot, 2015
Honda Automobile (Thailand) Co.,Ltd	0.074	0.0140	2.73	0.514	Aroonsrimorakot, 2015
Honda Automobiles - Training Center	0.147	0.0531	13.94	5.046	Aroonsrimorakot, 2015
Koh Kha Sub District Municipality	0.040	0.0017	1.82	0.080	Aroonsrimorakot, 2015
Mae Fah Luang Foundation	0.060	0.0022	0.54	0.198	Aroonsrimorakot, 2015
Mueang Phon Town Municipality	0.026	0.0019	0.11	0.008	Aroonsrimorakot, 2015
Office of the dean, Faculty of Science & Tech., SSRU [2]	0.0482 (*7/18*) [3]	0.0079(*12/16*)	2.50 (*8/20*)	0.414 (*13/19*)	This work
PEA[4] at Ban Bang Mun Nak District, Phichit Province	0.102	0.0005	3.54	0.016	Aroonsrimorakot, 2015
PEA at Buriram Province	0.049	0.0003	1.84	0.013	Aroonsrimorakot, 2015
Si Sa Ket Town Municipality	0.106	No data	5.40	No data	Aroonsrimorakot, 2015
Thai Onono Public Co.,Ltd.	0.067	No data	2.61	No data	Aroonsrimorakot, 2015
Toyota Motor Thailand Co.,Ltd. (Ban Pho Plant)	0.006	0.0001	1.16	0.018	Aroonsrimorakot, 2015
University of Arizona (focus only 9 buildings) before the implementation of energy saving program	–	–	No data	0.633 [5]	Chalfoun, 2014
University of Arizona (focus only 9 buildings) after the implementation of energy saving program	–	–	No data	0.554 [5]	Chalfoun, 2014
Electricity consumption of Thailand in 2012	–	–	3.98	No data	EPPO [6] , 2013

[1] The data of GHGs emissions from Aroonsrimorakot (2015) were not taken directly from that work but they were calculated by multiplying the emission factor from TGO (which are 0.7043 kg-CO_2 eq / m^3 for water supply and 0.6093 kg-CO_2 eq / kWh for electricity) (TGO, 2014) with the resources consumptions data in the literature of Aroonsrimorakot (2015).

[2] Suan Sunandha Rajabhat University

[3] The number in the blanket is the rank of GHGs emissions saver compared to the offices or the data sources used in the prioritization
e.g. *1/18* mean the office has the lowest GHGs emissions compared to the other 18 data sources in the same column that used in the prioritization
e.g. *18/18* mean the office has the highest GHGs emissions compared to the other 18 data sources in the same column that used in the prioritization

[4] Provincial Electricity Authority

[5] These values were calculated based on the emission factor stated in the literature of Chalfoun (2014) (which is 1.043262451 kgCO_2eq / kWh)

[6] The Energy Policy and Planning Office of Thailand

The data in the table were analyzed by inferential statistics by the same manner as the section of weekly resources' consumption analysis

The results suggest that the two groups of the data (2014 and 2015) have a normal distribution which can be further used for t-test analysis. The testing of variances indicates that the two groups of data have the same variance. The testing hypotheses using t-test inferred a difference between the average of weekly water supply consumption in year 2014 and 2015. This means that, the total GHGs emission of 2015 is lesser than that of 2014 ($\mu_{\text{total GHGs 2015}} < \mu_{\text{total GHGs 2014}}$).

This is because the electricity consumption plays a major role in the GHGs emission (approx. 98%), thus reducing electricity consumption resulted in the significant decrease of total GHGs emission.

Conclusions

In this study the resources consumption (electricity and water supply) and their GHGs emission were evaluated. Both descriptive and inferential statistics showed that the all data of resources consumption have a normal distribution and same variance. The water consumption has not been changed in 2014 and 2015. On the other hand, the results of the study showed that electrical consumption had decreased significantly in 2015 compared to the year 2014 and this resulted in the decreasing of total GHGs in 2015. The findings of this study can be as a reference for sustainable management of resources in other organizations, e.g. green office project.

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