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The carbon footprint of Trisakti University's campus in Jakarta, Indonesia

J Iskandar¹, N Rahma¹, D Rosnarti¹ and A B Purnomo^{1, 2,3}

¹ Dept. of Architecture, Faculty of Civil Engineering and Planning, Trisakti University, Jln. Kyai Tapa No.1, West Jakarta, 11440, Indonesia.

² Trisakti University Research Institute, Trisakti University, Jln. Kyai Tapa No. 1, West Jakarta, 11440, Indonesia

³Corresponding author

Abstract. Minimizing greenhouse gas (GHG) emission has become a priority in campus around the world. For example Trisakti University in Jakarta, Indonesia, is currently developing green campus. In developing a green campus, the identification of the existing problem becomes necessary. One aspect of that problem is of GHG emission. Carbon Footprint (CFP) is an indicator of how much GHG emission produced in a campus.. We use six sources of emission to estimate CFP of a campus, i.e., fuel usages (Scope-1), electricity, air conditioning (Scope-2), commuting, wastes, food and other materials (Scope-3). From the data collected at Campus A of Trisakti University in 2018, the total CFP in the campus is 999,571.60kgCO₂eq/month. From the total CFP, 84.47% (844,325.52 kgCO₂eq/month) derives from Scope-3 consisting mainly of CFP produced from commuting process (53.38 %). With the development of Jakarta Mass Rapid Transit (MRT) Phase-2, we expected the students and the staff, as well as the faculties of Trisakti University will change their mode of transportation from using a private vehicle to using MRT and will eventually decrease the CFP of Scope-3 from 84.47% to 76.97%. Whereas, we propose a five-year plan for Scope-1 and Scope-2 in terms of reducing CFP into 26.22% from the total of CFP at Campus A of Trisakti University in 2018.

1. Introduction

Many institution considered building as one of the largest producers of Greenhouse Gas (GHG). United Nation Climate Changes Conferences stated that 70% of the earth comprises of the urban environment, which produces 40-50% of GHG emission (UN Environment, 2017). In 2010, carbon from buildings is the third of the total emission (Lucon et al., 2014). The US Green Building Council (2007), indicated that in the USA buildings produced 39% of the total carbon emission. As a comparison, the number two producer of carbon is the transportation sector (34%), while in Indonesia, there is very few information regarding the portion of GHG emission from buildings. However, Asia Carbon Indonesia (2018) released that the carbon emission produced by buildings in Indonesia is only 18.40%; it is smaller than the carbon emission by building in the USA. This carbon emission in Indonesia is almost the same as the emission caused by transportation.

Just recently (2018) the architects and its allied profession in America had formally become more concern towards the emission reduction (AIA President, 2018) and nationally, architect also begin to incorporate the concept of reducing emission on the planning and designing. In 2015, at the national level, the Ministry of Public Works and Housing of the Republic of Indonesia introduced Law No. 21, 2015, which imposed green building concept to all new buildings constructed in Indonesia. Even



though the history of sustainable architecture had begun in the 20th century, carbon neutral architecture had just emerged in 2006 (Attia, 2018). In 2012, the Provincial Government of Jakarta introduced the Law No. 38, 2012 which regulates the application of green building in the Special Capital Province of Indonesia.

The above explanation provides a positive trend on the needs for more sustainable architecture in the world and Indonesia. According to Attia (2018), the trend is now moving from a carbon-neutral building design to a more adaptable architecture that can adapt itself on how it manages its carbon emission. In the wake of the transformation concept of sustainable architecture, Trisakti University in Jakarta, beginning with its Campus A, has been trying to reduce its carbon emission. The university has set its effort by defining its problem area and set the year 2018 as its foundation year. Therefore, the aim of our paper is to present the research result on the estimation of carbon emission or carbon footprint (CFP) at Campus A of Trisakti University in 2018.

2. Methods

To estimate the CFP at Campus A of Trisakti University, we initially need to identify the source of carbon emission, in this case, the emission of carbon equivalent to Greenhouse Gas (GHG). According to the Colgate Office of Sustainability (Dickinson, 2016), there are three types of a source regarding carbon emission, which we classify into Scope-1 until Scope-3. Scope-1 includes all of the GHG emission that is under the control of the university, i.e., the energy directly used or produced by the campus. Scope-2 is the GHG emission from energy used under the management of the university, but bought from an outside provider, in this case, consumption of electricity for air conditioning (AC). Scope-3 consists of GHG emission from the energy consumption that is not under the control of the university, includes GHG emission produced from the activities of students and staffs, faculties, water consumption, and waste production.

The data of GHG emission from Scope-1 are the monthly fuel-typed consumption recorded by the Transportation Department of Trisakti University. The Scope-1 data consist of monthly consumption records of fuel types for the operation of official cars. If the average of type i fuel used in a year is F_i (liter/month), and the CO₂ equivalent Fuel i Conversion Factor is Cf_i , then the emission in terms of kgCO₂eq/month or the CPF of fuel in Scope-1 is,

$$\text{FuelCFP} = \frac{\left(\sum_{i=0}^{i=n} (F_i Cf_i) \right)}{12} \text{ kgCO}_2 \text{ eq / month} \quad (1)$$

Where n is the number of fuel types used by the campus cars, and for Campus A, Trisakti University $n=2$, $i=1$ is for petroleum, and $i=2$ is for diesel fuel.

The data of the consumption of electricity on the campus is also recorded monthly into the university database. If the campus used electricity from the grid each month is E_i (kWh/month), and its conversion factor to kgCO₂eq/month is Ce , then the Electricity CFP is calculated with the equation below.

$$\text{ElectricityC} = \frac{\left(\sum_{j=1}^{j=m} E_j Ce \right)}{12} \text{ kgCO}_2 \text{ eq / month} \quad (2)$$

Trisakti University recorded the data on air conditioning as the horsepower (HP) of each AC machine. There was no information or data about the time-span of each AC machine. Therefore, we could only transform the total horsepower of AC machine into kgCO₂eq/month emission using the equation below.

$$\text{AcC} = \frac{\left(\sum_{k=1}^{k=K} P_k C_{ac} \right)}{12} \text{ kgCO}_2 \text{ eq / month} \quad (3)$$

Cac is the conversion factor of AC horsepower to equivalent carbon dioxide produced each month by the AC and K is 12, which is the number of months within a year.

The data on waste is the information about monthly garbage disposal that is recorded by the campus administration. The unit of the data is the tonnage of garbage being sent every month to the municipal garbage by the campus management. The CFP of waste can be calculated based on the equation below.

$$\text{WasteCFP} = \frac{\left(\sum_{r=1}^{r=K} G_r C_g \right)}{12} \text{kgCO}_2 \text{eq / month} \quad (4)$$

G_r is the tonnage of waste produced every month by the campus, C_g is the conversion factor. The data for the estimation of emission from the consumption of water is also collected every month by the campus administration, which we calculate by using the equation below.

$$\text{WaterCFP} = \frac{\left(\sum_{r=1}^{r=K} W_r C_w \right)}{12} \text{kgCO}_2 \text{eq / month} \quad (5)$$

W_r is the sum of water consumed in the campus in liter/month and C_w is the conversion factor for water consumption.

We differentiate data for the calculation of CFP of Scope-3 is into three categories: first, the emission generated by students on campus, followed by faculties, and third is by the activities of university staffs. We analyze all the categories into emission from commuting, consumption of food and drinks, and also from other consumable products such as papers and plastics.

We use questionnaires survey to gather the data for the estimation of Scope-3 type emission. The respondents comprised of 200 students, 100 faculties, and 100 staffs. Each respondent is a random sample from the existing campus population. The questionnaire contains five questions. The first question is about the daily commuting distance (km) and mode of commuting of the respondents to and from the campus. The second question is about distance (km) and means of inter-city travels of the respondents each month to do official tasks of the university. The third question asks the quantity and types of foods (kg) and drinks (liter) consumed by the respondents daily when they are on campus. The fourth question asks the respondents about the paper and plastic goods that are necessary to do their tasks such as writing papers and making models monthly. We convert the papers, and plastics into kilogram from its average unit mass (kg/m^3) and estimated volume (m^3).

Based on the survey conducted in 2018 at Campus A of Trisakti University, we calculate the CFP of Scope-3 by using the following equation.

$$\text{Scope3CFP} = \frac{\left(\sum_{r=1}^{r=K} \frac{\sum_{q=1}^{q=N_{\text{resp}}} \sum_{c=1}^{c=N_{\text{quest}}} S_{r,q,c} C_{s_{qc}}}{N_{\text{resp}}} \right)}{12} \text{kgCO}_2 \text{eq / month.} \quad (6)$$

$S_{r,c}$ is the answer to the question about consumption type c in r month (with each respective unit explained above). C_{s_c} is the conversion factor of consumption type c . For example, $c=1$ is the distance (km) of commuting by the respondent using bicycle daily. N_{resp} is the number of respondents. For students, $N_{\text{resp}}=200$, for faculty $N_{\text{resp}}=100$ and for staffs $N_{\text{resp}}=100$. N_{quest} is the number of questions in the questionnaire. In this study, $N_{\text{quest}}=5$.

3. Result and Discussion

The result of the study shows the total CFP at Campus A of Trisakti University is 999,571.60kgCO₂eq/month. Figure 1 shows the portion of CFP of Scope-3 is 84.47%, Scope-2 is

15.18%, and Scope-1 is 0.35%. As the dominant scope, the portion of CFP of Scope-3 (Figure 2) consists of CFP from students (59.98%), faculties (11.41%), Staffs (9.54%), water consumption (1.67%), and waste production (1.86%). Each of the CFP portions of Scope-3 is larger than the total CFP of Scope-1(0.35%).

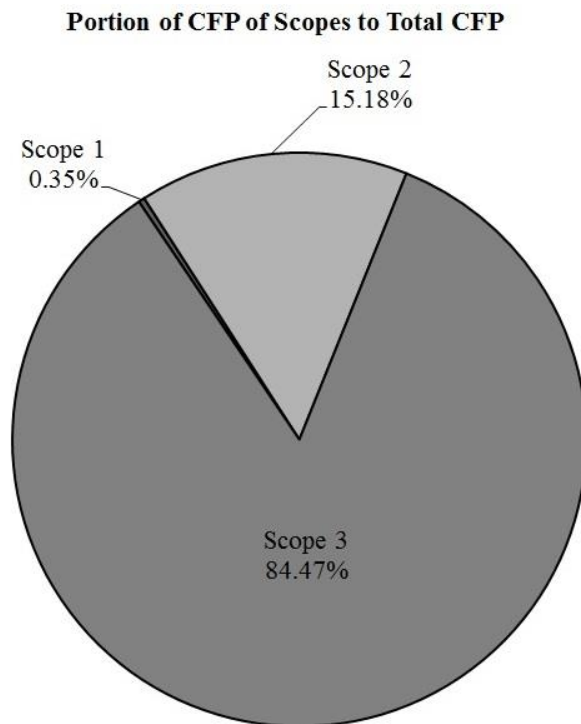


Figure 1. The portion of CFP scopes.

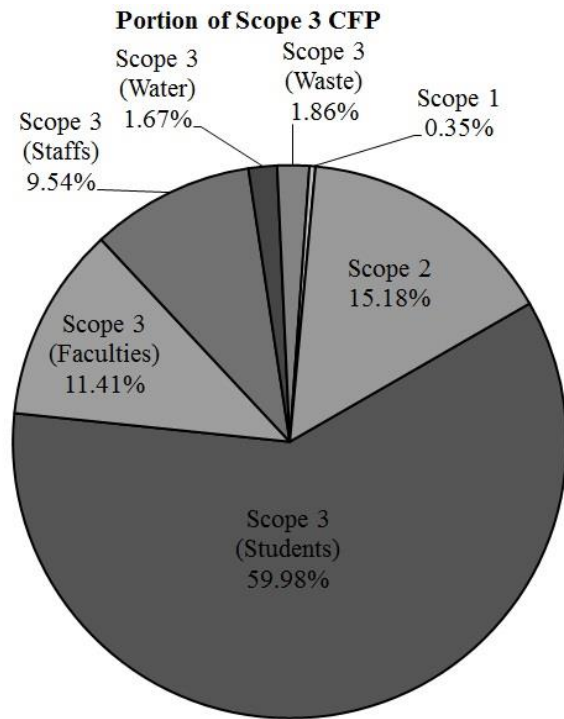


Figure 2. The portion of Scope-3 CFP.

Figure 3 represents the most dominant CFP of Scope-3 or by any other scopes which are the CFP from the commuting activities of the students (37.53%), followed by students' food consumption (19.84%). Figure 4 shows that the portion of CFP comes from the commuting of faculties (7.66%). The faculties commuting CFP is almost the same as the CFP of the staffs (9.50%). In terms of the staffs CFP (Figure 5), the most dominant portion is from commuting (8.19%), which is larger than the CFP of the faculties commuting (7.76%).

Scope-2 (Figure 6) consists of CFP from the consumption of electricity (12.56%) and the use of air conditioning (2.63%). The portion of CFP from the consumption of electricity is bigger than that of the CFP of the staffs commuting (8.19%) and faculties commuting (7.76%).

Scope-3 is the largest portion of CFP in Campus A of Trisakti University. Scope-3 becomes problematic since it is not within the control of the university. However, since portion of Scope-3 is large, compares to other scope, the best way is to cut CFP in this scope. For instance, a cut of CFP of 20% from Scope-3 is more than a 100% cut of CFP from Scope-2.

The largest portion of CFP in Scope-3 comes from students (59.98%). Since students are not the employee of the university, cutting-off CFP becomes a more difficult problem at Campus A of Trisakti University. The biggest portion derives from students' commuting activities (37.53%), which is mainly because Trisakti University is located relatively in the center of Jakarta metropolitan city, while the students and staffs mostly live on the periphery of Jakarta. Trisakti University, with its Campus A in Grogol, Jakarta, is a commuting university, where most of the campus community live far from the campus and have to commute every day to go to work or study. Public transportation is a big problem in Jakarta, according to Sumardjito and Sutomo (2012), its growth within the interval of 2001 to 2011 was stagnant. Therefore, cutting-off CFP for the university is challenging. The choices

are between cutting-off the CFP from the students commuting and forcing them to use public transportation or to use private cars.

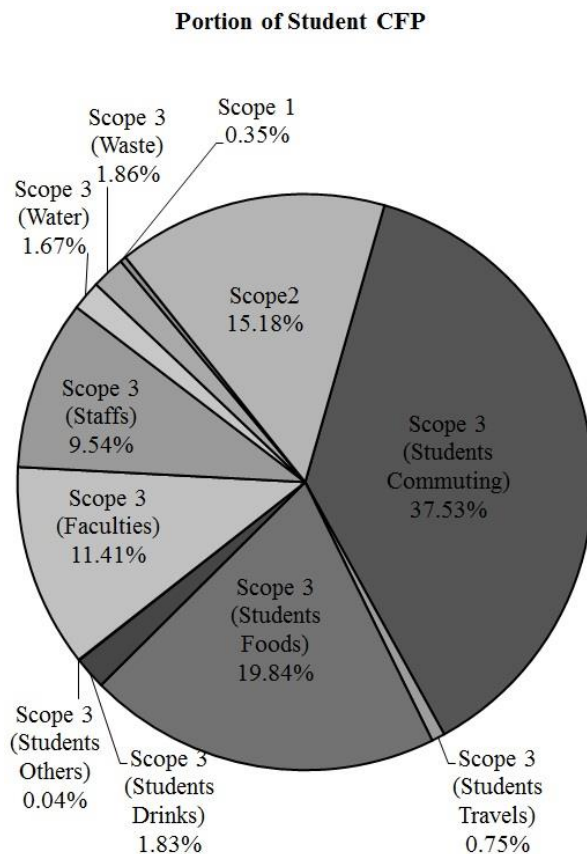


Figure 3. The portion of student CFP.

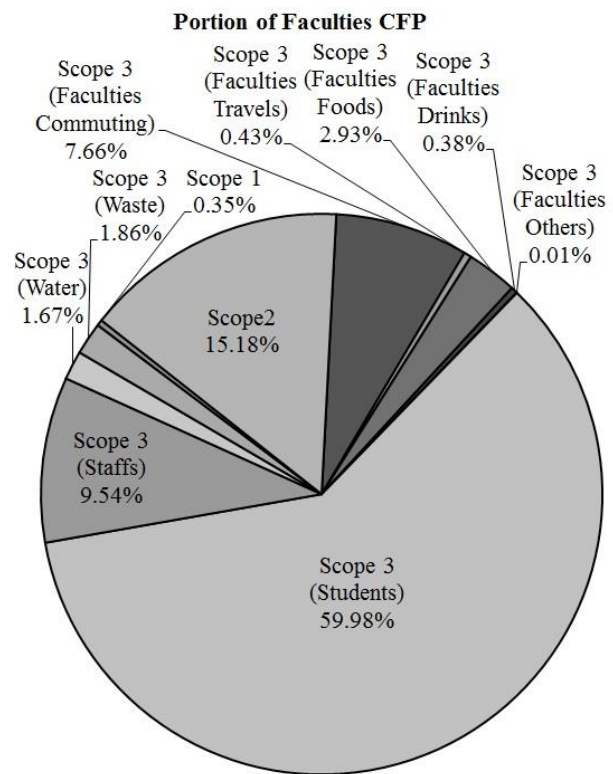


Figure 4. The portion of faculties CFP.

CFP of Scope-2 is more than that of Scope-1. Therefore, the second target in cutting-off CFP is to cut CFP from Scope-2. The consumption of electricity is the biggest cause of Scope-2 CFP. Therefore, to decrease electricity consumption is an important step in trying to cut CFP. Since AC also uses electricity, cutting-off the heat load that has to be handled by AC is also important effort if we want to lower the overall CFP of the campus.

CFP of Scope-1 of Campus A at Trisakti University is relatively very small compared to other scopes (it is only 0.35% of the overall CFP) because Trisakti University does not have its in-house energy generation. The existing electric generators are small generators for emergency. Scope-1 includes the emission calculated from fuel for university executive's official cars, such fuel is part of Scope-2.

In this paper, we propose several ways to cut CFP at Campus A of Trisakti University within five years from 2018 as the foundation year. In line with the nature of CFP at Campus A of Trisakti University explained above, we propose two means of cutting-off CFP for the campus. First, we propose of cutting-off CFP of Scope-1 and Scope-2 portion of electricity consumption by changing the lighting with more efficient Compact Fluorescent or LED type lighting fixture in all buildings in the campus. According to Racz (2012), the change from the conventional lighting fixture to Compact Fluorescent or LED can reduce the electrical consumption from 24% to 74%.

Further, cutting-off CFP from the use of electricity for AC is by applying window film to all glass-opening on buildings at Campus A of Trisakti University. The application of window film can reduce the heat gains that are usually operated by AC system to about 35% (Jahromi et al., 2017) and up to 61.82% (3 M Sun Control, 2019). The university Building Management Office estimated that the

application of window film to all buildings at Campus A of Trisakti University will be completed within the academic year of 2020-2021.

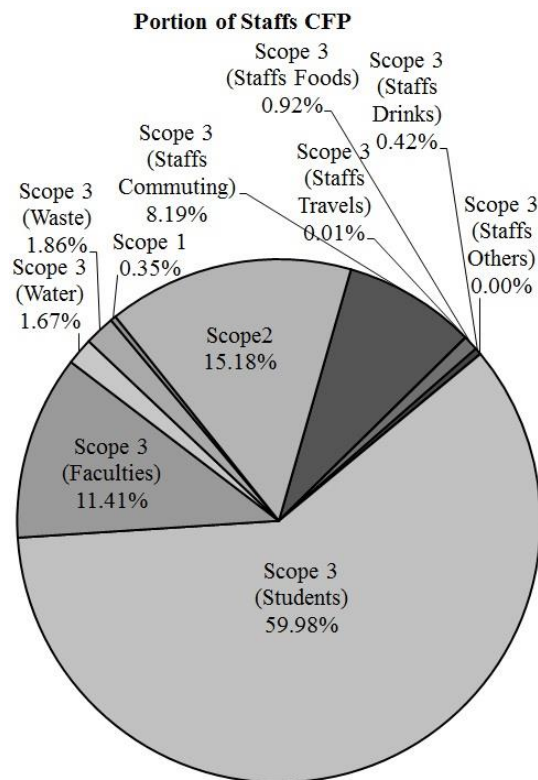


Figure 5. The portion of staffs CFP.

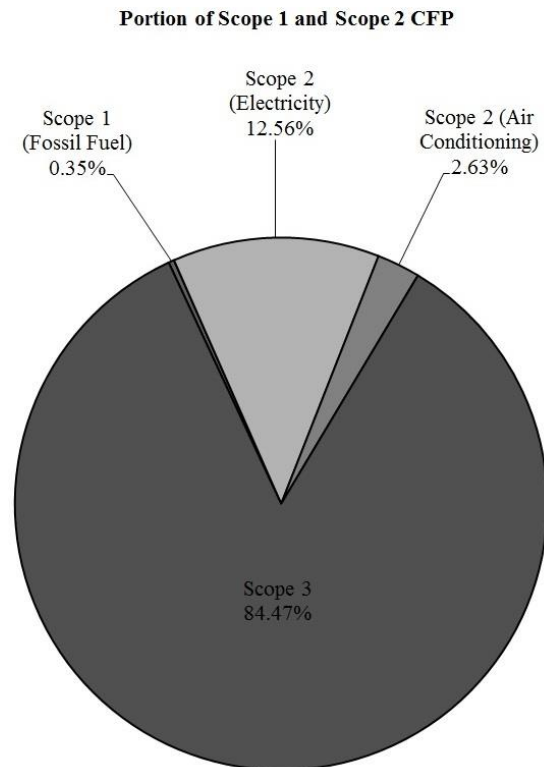


Figure 6. The portion of Scope-1 and Scope-2 CFP.

To cut the consumption of electricity from the Grid, Trisakti University can use its rooftops in generating solar energy (Dutta et al., 2018). Campus A of Trisakti University has approximately 1.8 hectares of rooftops, which are potential for producing sustainable electricity that can cut the total of CFP. By using the Annual Solar Energy Calculator of the Photovoltaic-Software.com (2019), the rooftops of the campus have the potential to produce 295133kWh/month. The electricity from the solar panels on the rooftops is enough to fulfill all the needs of the university. However, establishing facilities for the production of solar energy for Trisakti University is expensive; therefore, it should be considered as a long-term investment. For that reason, within five year we propose for Campus A of Trisakti University only to develop 10% of its total potential of solar energy.

In case of the cutting of water consumption at Campus A of Trisakti University, it is recommended to optimize the use of rainwater and grey-water produced in the campus. There are 1.8 hectares of roofs that can be used to harvest rainwater in the campus of University of Trisakti. The present treatment of rainwater as part of grey-water system at Campus A of Trisakti University is to discharge directly it to the city sewers. To cut consumption of water of the CFP, Trisakti University has to build facilities for processing and storing rainwater and grey-water. We estimate it will need three years to develop rainwater and grey-water system in Campus A. As Zavala et al., (2016) highlighted, the development of grey-water system can decrease the CFP produced from the consumption of water in the campus to up to 48%.

There are two steps to reduce CFP from waste production in Campus A of Trisakti University. First is by sorting and recycling waste. However, sorting waste needs time since the students, faculties, and staffs' habits should change first. Trisakti University is an urban university with a limited area for developing waste recycling facility. If Trisakti University agrees to begin the immediate changing habits in terms of waste sorting, in 3 years, as a second step, the university can send its waste to a waste bank. According to Revani et al. (2016) with the help of waste banks, after five years, the CFP

of Campus A of Trisakti University can be reduced to about 20.11% out of the overall waste production.

Scope-3 does fall not under the management of Trisakti University. We can only indirectly propose to cut CFP within five years. First, to re-implement the university's policy that prohibits junior student from using a private car to campus. The policy used to be implemented, but due to the unreliability of public transportation in Jakarta, the university management deemed that such rule cannot be applied. To our estimation, every year, at least there are 20% junior students from all of the student bodies that are active at Campus A of Trisakti University (Trisakti Annual Report 2018). If the policy can be re-implemented and shifted the students' transportation preference to the newly operational Mass Rapid Transit (MRT), at least the cutting-off CFP due to students commuting will reach to about 20% within two years after 2018.

At present, car parking in Campus A of Trisakti University is free. We propose Trisakti University to begin charging car parking in the campus. In the past, there was a discussion about the idea of charging parking, but due to the unreliability of public transportation in Jakarta, the management of Trisakti University was afraid that the policy of charging parking might affect the number of prospective students enrolling to the university. In other words, the location of the campus, coupled with the unreliability of public transportation enforced the management of Trisakti University to employ free parking for its campus community. However, with the recent favorable development of public transportation in Jakarta, especially the development of MRT that will pass Campus A of Trisakti University, we suggest the university to implement the policy of charging parking. According to the experience of several cities in the world (Cachia, 2016; Hayashi et al., 1998), the operation of MRT can cut the number of private transportation use for commuting into half (50%). If we can replicate such experience in Jakarta, the CFP from commuting will decrease 50% within five years periods.

As an urban university with restricted land, Campus A of Trisakti University has significant vegetation in the form of trees. Secondary data from the office of Open-space Management of the university, at least there are 1005 mature trees on the campus. The average age of the trees is about 15.6 years, with the diameter of average breast height stem is 30.2 cm. To cut the CFP of the campus, it is recommended to increase planting trees for five years, meaning 100 new trees per year. By using allometric functions of Kettering (Hairiah and Rahayu, 2007), we estimate that the carbon sequestered by a tree with the above average age and stem diameter is 5344.83 kgCO₂eq/tree/5 year. It means that within five years, by planting trees, we can cut the CFP of Campus A of Trisakti University to about 0.11% out of the total CFP. The cut is quite small, but it out-weighted other benefits such as the production of oxygen and the provision of sun-shade to the open space as the typical weather in the tropical country.

Table 1 comprises the resume of the above discussion on how to cut the CFP at Campus A of Trisakti University within five years. In sum, it can be said that with 5-year planning, we can decrease the CFP at Campus A of Trisakti University to about 26.22%, which is relatively the same as the target slated by the government to keep up with the CFP cut set by the international community for Indonesia (Kuramochi et al., 2015).

4. Conclusion

From the study explained above, we conclude, that the total CFP at Campus A of Trisakti University in Jakarta, Indonesia is 999,571.60kgCO₂eq/month. The largest portion of the overall CFP is Scope-3 which comes from the students, followed by the faculties, and the staffs. The largest part the CFP of students derives from their commuting CFP.

The second dominant portion of CFP at Campus A of Trisakti University is of Scope-2, which is 15.18% out of the total CFP of the campus. CFP of Scope-2 consists of two similar portions of the CFP. The first portion of Scope-2 is the CFP of electricity consumption and the second is of AC. Since Campus A of Trisakti University does not have any significant energy generator, the portion of CFP of Scope-1 is quite small, which is 0.35%.

To reduce the CFP at Campus A of Trisakti University, we introduce six actions. The actions will reduce the CFP of the campus to about 26.22% within five years period. By then, Campus A of Trisakti University will already contribute to the GHG reduction set for Indonesia by the international community.

Table 1. Plan to reduce CFP of Campus A of Trisakti University within 5 years.

Carbon Plan	Type of CFP to be cut	Cut (%)	Literature	Base year CFP (kgCO ₂ eq/Month)	Carbon cut (kgCO ₂ eq/Month)
Change lighting fixture (Compact Fluorescent or LED)	CFP from electricity consumption	49.00	Racz (2012)	125512.48	61501.12
Use window film to reduce heat gain and reduce AC	Utilization of AC	61.82	3 M Sun Control (2019)	26270.62	16240.50
Install rooftop photo-voltaic	Electricity consumption	20.00	Dutta et al., 2018	61501.12	59026.60
Develop rainwater and grey-water harvesting systems	Water consumption	48.00	Zavala et al., 2016	16649.72	7991.87
Recycle waste at a waste bank	Waste production	20.11	Revani et al., 2016	18629.25	3746.34
Reduce commuting with the help of MRT	Student commuting	20.00	Annual report of Trisakti University, 2018	375089.59	75017.92
Charge parking	Student commuting	50.00	Cachia, 2016; Hayashi et al., 1998	75017.92	37508.96
Plant 100 trees every year	Total CFP	0.11	Hairiah and Rahayu, 2007	999571.60	1099.53
				Total cut on CFP	232619.53
				The portion of CFP cut (%)	26.22

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