Carbon Footprint of Academic Activities: A Case Study in Diponegoro University

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Abstract. Carbon emissions are a significant cause of climate change. As an effort to reduce emissions in the university environment, carbon footprints at Diponegoro University (Undip) need to be calculated to find out how much campus activity contributes to the emissions produced and analyze scenarios that can be applied in minimizing them. The carbon footprint study at Undip was carried out in 3 scopes according to The Greenhouse Gas Protocol. Scope one covers clean water treatment activities. Scope two covers electricity usage activities, while scope three covers transportation, wastewater, and solid waste treatment activities in the campus environment. Carbon footprint emissions from the three scopes are calculated based on methods from the International Panel on Climate Change (IPCC). Emissions calculated are CO₂, CH₄, and N₂O expressed in TonCO₂-eq. The carbon footprint resulting from campus activities at Undip is 16,345.83 TonCO₂-eq. The first and second-largest carbon footprint contributors came from electricity and transportation activities with a total carbon footprint of 13,953.22 TonCO₂-eq and 1,449.99465 TonCO₂-eq, respectively. The emission reduction business strategies that can be carried out are through conservation and energy efficiency approaches as well as the use of Campus Buses and increasing the number of green space.

1. Introduction

Today the concept of sustainability is manifested in the form of Sustainable Development Goals (SDGs) [1]. The idea is based on economic, environmental and social dimensions [2]. In the world of higher education, the concept of sustainability on campus is known as the green campus [3]. One of the green campus assessments is the carbon footprint.

Carbon footprint is a calculation of the total CO₂ emissions directly or indirectly caused by an activity or accumulated through the product life cycle [4]. Carbon dioxide is one of the greenhouse gases (GHG) and the most significant contributing component to GHG, which is around 30%, followed by CH₄ and N₂O [5], [6]. The amount of GHG is denoted by carbon dioxide equivalent (CO₂-eq) or Global Warming Potential (GWP) which is a combination of a large GHG impact based on radiation power and the length of time GHG in the atmosphere [7].

Since its founding in 1957, Diponegoro University currently has 11 Faculties plus Vocational and Postgraduate Schools. Diponegoro University has a main campus in the Tembalang area and other colleges in the Peleburan and Jepara areas with a total area of 1352054 m². Every year, Diponegoro
University receives approximately 11,000 diploma, bachelor, master, and doctoral students [8]. With a significant, enough population, carbon footprints in Undip need to be calculated to find out how much the campus activity contributes to the emissions produced so that negative impacts on the environment can be minimized.

The carbon footprint study at Undip is carried out in 3 scopes according to The Greenhouse Gas Protocol (GHG Protocol), namely emissions from sources that are owned or controlled directly by the university, indirect emissions from electricity consumption, and other indirect emissions [9]. Carbon footprint emissions from the three scopes are calculated based on methods from the International Panel on Climate Change (IPCC) for the national greenhouse gas (GHG) inventory. Emissions calculated are carbon dioxide (CO$_2$), methane (CH$_4$), and nitrous oxide (N$_2$O) are included in long-lived greenhouse gases which are the main contributors to climate change [6]. The purpose of this study is to analyze how much carbon footprint from campus activities in Undip and scenarios that can be applied to minimize carbon footprint.

2. Methodology

2.1 Study Area

This research was conducted at the main campus of Diponegoro University, located in Tembalang, Semarang, Central Java. All campus activities that produce carbon emissions will be calculated to determine the carbon footprint value. All data were collected in each of the buildings and streets in Diponegoro University's main campus area which included 11 Faculties, Vocational Schools and institutions. All of those data were collected through observation, interviews, documentation, and from campus documents or archives and literature.

2.2 Assessment of Carbon Footprint

The carbon footprint of academic activities was assessed using three basic steps, by setting operational limits, collecting data, and finally calculating emissions using appropriate emission factors [10]. To help describe the sources of direct and indirect emissions, GHG emissions from various operations are categorized into three “scopes” (scope 1, scope 2, and scope 3). In this study, operation under scope 1 is the provision of clean water. Scope 2 covers GHG emissions from electricity use by Undip. While scope 3 is a consequence of activities on campus that occurs from sources that are not owned or controlled by the college [11]. Transportation, wastewater and solid waste treatment were included in scope 3 of this study. Two types of data were collected namely activity data and emissions factor (EFs). Activity data were collected from all activities within the defined boundaries for one year. Parameters and relevant sources of the activity data related to every operation are presented in Table 1.

| Scope | Activities          | Parameters of Activity Data                   | Source                      |
|-------|---------------------|------------------------------------------------|-----------------------------|
| 1     | Water supply        | Number of water pumps                          | Personal communication and observation |
|       |                     | Water pump power                               |                             |
|       |                     | Water pump capacity                            |                             |
|       |                     | The duration of use of the water pump           |                             |
|       |                     | Fuel consumption annually (l)                  |                             |
| 2     | Electricity usage   | Electricity consumption annually (kWh)         | Electricity bills           |
| 3     | Transportation      | Number of vehicles                             | Personal communication and observation |
|       |                     | Type of vehicles                               |                             |
The most relevant and appropriate EF is shown in Table 2 using assumptions taken for the conditions of Central Java, Indonesia, to increase research transparency. Whereas data processing and analysis are carried out using the calculation of emission factors that refer to the Intergovernmental Panel Guidelines on Climate Change (IPCC) for the 2006 National Greenhouse Gas Inventory which can be used for EF derivation for any activity anywhere in the world.

### Table 2. Emission factors for different activities

| Activities               | Parameters of Activity Data                  | Source                      |
|--------------------------|---------------------------------------------|-----------------------------|
| Waste disposal           | Amount of waste generation annually (kg/floor/day) | Sampling and personal communication |
| Wastewater treatment     | Wastewater treatment system                 | Personal communication and observation |

Calculation of each emission sources and activities were calculated in TonCO₂ eq/year or kgCO₂ eq/year [12]. After that, the total carbon footprint of Diponegoro University was calculated under three scopes as described in Table 3. Mapping was done using ArcGIS software by using three classification levels of significant carbon footprint estimates in the form of low, medium, and high.

### 3. Results and Discussion

#### 3.1 Total CFP of the organization

The results illustrate that overall carbon footprint (CFP) of this campus activities is 16,345.83 TonCO₂ eq/year as presented in Table 3. That was lower than the results show at UCLM that has total carbon footprint ranges between 23 and 36 kg CO₂ eq/year [13].

### Table 3. Calculated CFP of Diponegoro University under three scopes

| Scope       | Activities       | CFP TonCO₂ed/year | %   | Subtotal TonCO₂ed/year |
|-------------|------------------|-------------------|-----|------------------------|
| 1 (Direct)  | Water supply     | 77.62             | 0.5 | 77.62                  |
| 2 (Indirect)| Electricity usage| 13953.22          | 85.4| 13953.22               |
| 3 (Indirect)| Transportation   | 134.47            | 0.8 | 134.47                 |
|             | Waste disposal   | 1449.99           | 8.9 | 1449.99                |
|             | Wastewater treatment | 730.51     | 4.5 | 730.51                 |
| Total       |                  |                   |     | 16345.82               |

#### 3.2 Carbon Footprint Mapping

The results of the calculation of the total carbon footprint in table 3 are a combination of each value at each data collection point. Whereas in the field, each data collection point has a different value...
according to conditions that affect the area. Mapping is done using ArcGis which is a software based on graphic information systems (GIS) [14]. Through this software, we will know which regions produce high emissions, which contribute to the significant estimates of the carbon footprint of each sector. Mapping was done by classifying into three categories of levels, namely low, medium and high by distinguishing using colours, namely red for high emissions, yellow for medium emissions and green for low emissions. The following is a mapping of carbon footprints in academic activities throughout the Undip region.

3.2.1. CFP of the Clean Water Sector. The low classification carbon footprint ranges from 313.241 kgCO₂eq/year to 3,955.7979 kgCO₂eq/year. While the medium classification is the carbon footprints which has a value ranging from 3,956.7979 kgCO₂eq/year to 7,599.3539 kgCO₂eq/year, and those included in the high-level classification are those that have carbon footprint values ranging from 7,600.3539 kgCO₂eq/year to 11,240.9098 kgCO₂eq/year.

Areas included in the low carbon footprint level are the Psychology Faculty, the Faculty of Public Health (FKM), the SA-MWA Building, the Integrated Lab UPT, the Rector's Building, the ICT Building and the Prof. Soedarto building. Areas included in the medium carbon footprint are the Faculty of Law (FH), the Faculty of Cultural Sciences (FIB), the Faculty of Medicine (FK), the Faculty of Social and Political Sciences (FISIP), the Faculty of Fisheries and Marine Sciences (FPIK), the Faculty of Animal Husbandry and Agriculture (FPP), Faculty of Science and Mathematics (FSM), Faculty of Economics and Business (FEB), and Vocational Schools (SV) whereas the areas marked in red are areas that are included in the high carbon footprint level, namely the Faculty of Engineering (FT) and Diponegoro National Hospital (RSND), with a contribution of 26.46% of the total carbon footprint produced by the clean water sector. The high carbon footprint is influenced by the large population, clean water consumption, and electricity consumption related to the use of clean water [15].

3.2.2. CFP of the Transportation Sector. The low classification carbon footprint ranges from 35,326.19000 kgCO₂eq/year to 112,500.81754 kgCO₂eq/year. While the intermediate classification is the carbon footprint which has values ranging from 112,501 kgCO₂eq/year to 189,675.444509 kgCO₂eq/year and included in the high-level classification are those who have a carbon footprint ranging from 189,676 kgCO₂eq/year to 266,850.07264 kgCO₂eq/year.

The low carbon footprint level are shown the Civil Engineering front road, the road in front of the old FT Dean, the road behind FPIK, the road between Mechanical Engineering and FSM, the FSM Dean road, the road between FEB and FSM, the road at the Rear Gate, the road between SV and FH and the road ahead of FIB. The area included in the medium carbon footprint is the road in front of FPP and the road behind FEB. Whereas the red area is areas that are included in the high carbon footprint level, the Main Gate of Diponegoro University and the road in front of the Soedarto Building, contributing 34% of the total carbon footprint produced by the transportation sector. High and low forecasts of the carbon footprint resulting from transportation activities at Diponegoro University Tembalang are influenced by the amount of fuel consumption produced where the number of vehicles affects the amount of fuel consumption [16].

3.2.3. CFP of Wastewater Sector. The low classification carbon footprint ranges from 1,603.99 kgCO₂eq/year to 53,535.3 kgCO₂eq/year. While the intermediate classification is the carbon footprint which has values ranging from 53,536.3 kgCO₂eq/year to 105,468 kgCO₂eq/year, and included in the high level classification are those who have carbon footprints ranging from 106,468 kgCO₂eq/year to 157,399.93 kgCO₂eq/year.

Areas included in the low carbon footprint level are the Faculty of Psychology, FPP, FH, FKM, ICT Building, Rectorate Building, SA-MWA Building, Integrated Lab UPT, Soedarto building, and RSND. Areas included in the medium carbon footprint are FIB, FISIP, FEB, FSM, FK, FPIK, and SV. While the area marked in red is an area that is included in the high carbon footprint level, namely FT,
with a contribution of 21% of the total carbon footprint produced by the wastewater sector. The large population and the system of wastewater treatment in each region influence the high carbon footprint [17].

3.2.4. CFP of Solid Waste Sector. The low classification carbon footprint ranges from 1,277 tons of CO₂eq/year to 7,010 tons of CO₂eq/year. While the intermediate classification is the carbon footprint which has values ranging from 7,011 tons CO₂eq/year to 12,749 tons CO₂eq/year, and those included in the high-level classification are those who have a carbon footprint ranging from more than 12,750 tons CO₂eq/year.

Areas included in the low carbon footprint level are the Integrated Laboratory, SA-MWA, Rectorate, ICT, Faculty of Psychology, FKM, FPP, FH, FK, FISIP, and SV. Areas included in the medium carbon footprint are FIB, FPIK, FSM, FEB and Rusunawa whereas the red areas are areas that are included in the high carbon footprint level, namely FT and RSND with a contribution of 32.44% of the total carbon footprint produced by the waste sector. The large population in each region influence the high carbon footprint [18].

3.3 Recommendation of Reduction Carbon Footprint

Recommendation for reducing carbon footprint is carried out towards the most significant contributor's emission. The biggest contributor is electricity usage that can be reduced by proposing an energy conservation approach with a 10-20% reduction in energy consumption and an energy efficiency with a 30% reduction in energy consumption [19]. The second biggest contributor is transportation activities that can be reduce by means of the Bus facility which operates only around the Tembalang campus which can reduce 26% carbon footprint and 30% the number of vehicles that pass through and by optimizing the land as green space where the existing green space for absorption is greater than the carbon footprint produced at Diponegoro University in the transportation sector [20].

4. Conclusions

The carbon footprint resulting from campus activities in Undip in 2018 amounted to 16,345.83 TonCO₂eq. This total carbon footprint consists of a scope of one, two and three with percentages of 0.5%, 85.4%, and 14.1%. The first and second-largest carbon footprint contributors came from electricity and transportation activities with a total carbon footprint of 13,953.22 TonCO₂eq and 1,449.99465 TonCO₂eq, respectively. Based on the results of mapping in several sectors, one of the regions that have the highest level of carbon footprint is the area of engineering faculty.

Suggested solutions to reduce carbon footprints are carried out in 2 activities with the biggest carbon footprint producers, namely the use of electricity and the transportation of campus areas. The best recommendation for electricity use activities is to propose energy conservation whereas the scenario chosen for community transportation activities is by means of the Bus facility which operates only around the Tembalang campus and by optimizing the land as green space where the existing green space for absorption is greater than the carbon footprint produced at Diponegoro University in the transportation sector.

5. References

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