Implementation of transportation modes in universitas indonesi campus based on fueled gas and electricity to reduce emission load

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Abstract The emission load at the University of Indonesia, with a population data of 44,113 people, consists of 85.11% of students and 14.89% of lecturers and employees of 30,864 tons CO₂/year, where the highest emissivity rate is generated by the electricity sector of 25,564 tons CO₂/year and public transportation 582,000 tons CO₂/year. The assessment was carried out on various indoor facilities for CO₂ emissions generated by the public transportation sector, namely gas procurement with CNG (Compressed Natural Gas) technology, hybrid electric-powered bus (PHEV), and electric tram (Transit Light Rail). Calculation is done with primary data base and secondary data with purpose. The calculation results of emission load for each mode of transportation in sequence namely; LRT of 0.000071 tCO₂e/year, PHEV of 0.00028 tCO₂e/year and CNG of 0.012958 tCO₂e/year. CO₂ emission load generated by a gas engine as a scenario 2 (PHEV) electricity feeder facility is 2.030995 tCO₂e/MWh.

1. Introduction

One of the functions of urban areas is as an educational center. Depok city has various levels of education. Educational activities also contribute to CO₂ emissions. In general, pollution caused by CO₂ emissions comes from two activities; nature (natural) and human (anthropogenic) such as CO₂ emissions originating from transportation, garbage and household electrical energy consumption. CO₂ emissions resulting from human concentration activities are relatively higher, thus disrupting the balance system in the air and ultimately damaging the environment and human welfare. Therefore, it is important to tackle CO₂ emissions in education areas.

The data obtained by the method of counting emission factor sampling from carbon emission for each region in University of Indonesia, with parameter of population data is 44.113 soul which consist of 85.11% student and 14.89% lecturer and employee is equal to 30.864,42 ton CO₂/year, where for the public transportation sector 582.29 tons CO₂/year (1.88%), motor 148.46 tons CO₂/year (0.45%), car 360.7 tons CO₂/year (1.17%) and electricity sector of 25,564.51 (82.83%) tons of CO₂/year, if projected at total carbon sink owned by University of Indonesia at 3034.2 ton CO₂/year, can only eliminate one-tenth of the carbon emissions produced [1].

The carbon emissions that are formed cause the greenhouse gas effect so that the global CO₂ content is increasing, at 406.17 ppm [2]. This causes the Ministry of Environment (KLH) in 2012 to target GHG emission reduction in Indonesia by 26% in 2020. The use of gas-based fuels for modes of transportation within the University of Indonesia campus has become one of the strategic projects or known as the Master Plan of the University of Indonesia 2020-2021, related to the procurement of SPBG (Gas Fuel Filling Station) and PLTMG (Gas Engine Power Plant) in campus, which is conceptualized to the CNG (Compressed Natural Gas) campus bus, with the utilization of gas pipeline network owned by PT. Jabar Energi.

With this Master Plan base of University of Indonesia, this study will be conducted Techno-Economy based study on three procurement schemes of campus transportation modes, which are gas station campus procurement with CNG (Compressed Natural Gas) technology, Electrically-powered campus bus (Plug in Hybrid Electrical Vehicle), and Light Rail Transit (LRT) electric tram to support University campus green campus program.
2. Theoretical Review

Natural gas is a gas-fueled fossil fuel and its main component is methane. In addition to methane, there are other contents in natural gas with small compositions including ethane, propane, butane, nonhydrocarbon gases, and other hydrocarbon liquids [3].

Commonly targeted by the natural gas market are housing and commercial users (use of natural gas for heating), industry (use of natural gas as a burner), transportation (use of natural gas as fuel) and power generation. The use of natural gas as a fuel commonly known is in the form of CNG [4].

The emission standard known today is the Euro standard. Although in fact this standard refers to the amount of exhaust gas limit from new vehicles sold in EU member countries. The regulated emissions are Nitrogen Oxides (NOx), Total Hydrocarbon (THC), Non-methane Hydrocarbon (NMHC), Carbon Monoxide (CO) and Particulate Matter (PM). The emissions generated by the BBG bus at this time at least meet the Euro IV emission standards (minimum) [5].

According to International Standard (ISO 8713: 2002) electric vehicles known in terms of Electric road vehicles in America developed into two types, including Zero Emission Vehicles (ZEV) and Low Emission Vehicles (LEV). Electric vehicles that are categorized into Zero Emission Vehicles are Batterai Vehicles (Battery Operate) and Fuel Cell Vehicles. While that is categorized into LEV is a vehicle that drive system combine between conventional engine with electric motor (Hybrid) [6].

Plug-in hybrid electric vehicles (PHEV) are hybrid electric vehicles that use rechargeable batteries, or other energy storage devices, which can be recharged by connecting the charging system to an external power source. PHEV has a difference with the plug-in model, this mode has an electric motor and internal combustion engine (ICE), and has a plug to connect to the power grid. Most of the application of PHEV technology is passenger vehicles but there is also a PHEV version of commercial vehicles [7].

Light Rail or Light Rail Transit is one of the Passenger Railway system that operates in urban areas whose construction is light and can run with other traffic or in special tracks. Travel speed is about 15 to 20 km / hour. When viewed in terms of efficiency when compared with the type of car minibus equivalent (MPV) [8].

Energy is one of the important sectors in the inventory of greenhouse gas (GHG) emissions. The types of GHG emitted by the energy sector are carbon dioxide, methane, and nitrous oxide. Based on the 2006 IPCC Guideline, GHG emission sources from the energy sector are classified into three main categories: fuel emissions, fugitive emissions in production and fuel supply, and emissions from carbon dioxide transport and injection to carbon dioxide storage activities in geological formations [9].

The Emission Factor is a representative value that links the quantity of a pollutant released to the atmosphere from an activity related to the source of the pollutant. These factors are usually expressed as the weight of pollutants divided by unit weight, volume, distance, or duration of activity emitting pollutants (eg, emitted particles per gram of fuel burned) [10].

The method of calculating emission level in land transportation mode can be done by using two types of emission factor method, ie EMEP / EEA and IPCC. Indonesia itself uses emission factors based on the IPCC to calculate its GHG emission levels [11]. The other modes are; Mobile Combustion, TIER 1 (Basic fuel), TIER 2 (Local emission factor), TIER 3 (Measurement), Speed Approach or Vehicle Kilometer Traveled (VKT) [12].

3. Research Method

Research conducted to obtain analysis of the problem formulation and problem objectives in this study was conducted based on systematic research procedures supported by primary and secondary data collection as well as to obtain the quality of the results close to real or actual on the University of Indonesia campus objects.

In preparatory procedures before the research is done, the researcher cooperates with related parties within the campus of University of Indonesia with the aim of obtaining data actualization. Data obtained in the form of mapping data, bus operational routes in the campus and data scenario masterplan University of Indonesia which is confidential in this study. Scenario masterplan that will serve as an object or feeder to obtain the actual data ie; the construction of PLTMG (Gas Engine Power Plant) within the campus of University of Indonesia and SPBG (Gas Filling Station), where the two masterplan scenarios have been identified feasibility in advance by the University of Indonesia
campus. The parties involved in the University of Indonesia campus segmentation namely Rectorate University of Indonesia (Directorate of Student Affairs); Directorate of Facilities Facility Maintenance (DPPF) University of Indonesia.

Then, after obtaining the secondary data, the researcher through the main or primary data retrieval as the basis of actual calculation at the time range of research conducted. Primary data taken are among others; data traffic counting on the day of test, distance between bus stops and the average speed of buses within the campus of University of Indonesia. The data is retrieved using equipment that is adjusted to the proper rules.

4. Results and Discussion

4.1. Calculation of Transportation Mode Unit in University of Indonesia Campus

In order to obtain the desired number of transportation units, a primary database is obtained from a direct survey of respondents and observe the conditions and operations in this case of University of Indonesia campus buses that are currently in operation.

To obtain primary data, direct survey and fluctuation survey of University of Indonesia civitas academica movement was conducted. Prior to the distribution of questionnaires an analysis of the number of samples and their distribution was determined for each faculty. The calculation of the minimum sample quantity using the calculation equation of the minimum sample size. Based on the calculation, the minimum sample size is 200 students. Furthermore, from the distribution of the minimum sample size, the sample distribution is divided into each clump of science as in Table 1 below.

| No | Faculty                              | Sample | Batch 2017 | Batch 2016 | Batch 2015 | Batch 2014 |
|----|--------------------------------------|--------|------------|------------|------------|------------|
| 1  | Rumpun Ilmu Kesehatan               | 62     | 11         | 16         | 21         | 14         |
| 2  | Rumpun Ilmu Sains dan Teknologi     | 85     | 21         | 24         | 24         | 16         |
| 3  | Rumpun Ilmu Sosial dan Humaniora    | 53     | 9          | 16         | 14         | 14         |
|    | Total                                | 200    | 75         | 41         | 56         | 59         |

The operational route of the campus bus is divided into two routes: red and blue, where the test results are 56.71% for the red route and 61.59% for the blue routes obtained with simple statistical calculations ie with distributive properties to see how large the mode of transportation on campus is required by University of Indonesia students.

Based on the calculation can be seen that the tendency of University of Indonesia students to the campus bus usage of 131 people from a total of 200 people for the red route, while for 134 people from a total of 200 people for the blue route.

Fluctuation survey results by taking the percentage of students to all civitas academica is 93% of the total volume of movement. Indicates fluctuations of movement not too far between periods, with peak movement volume in the period 07.30 - 08.30 WIB, 12.30 - 13.30 WIB, and 15.30 - 16.30 WIB.

4.2. Potential Users of Campus Bus

Based on Table 2, the potential demand is distributed into red routes and blue routes according to student composition activities on the route, namely the red route of 51.21% and the blue route of 48.79%. Then from the distribution result is taken the maximum value of the amount of demand potential to be used as the campus bus demand on the route, so it can be used as the calculation basis to get the number of transportation modes that will be operated on two operational routes namely red and blue.
Table 2. Request of Campus Bus Route Red and Blue Route

| Period       | Demand (Monday-Thursday) | Demand (Friday) |
|--------------|--------------------------|-----------------|
|              | Red Route (Peoples)      | Blue Route (Peoples) | Red Route (Peoples) | Blue Route (Peoples) |
| 06.30 - 07.30| 817                      | 845             | 817                 | 845                 |
| 07.31 - 08.30| 976                      | 1010            | 976                 | 1010                |
| 08.31 - 09.30| 634                      | 656             | 634                 | 656                 |
|              |                          |                 |                     |                     |
|              | Demand (Monday-Thursday) | Demand (Friday) |
|              | Red Route (Peoples)      | Blue Route (Peoples) | Red Route (Peoples) | Blue Route (Peoples) |
| 09.31 - 10.30| 654                      | 677             | 654                 | 677                 |
| 10.31 - 11.30| 558                      | 578             | 558                 | 578                 |
| 11.31 - 12.30| 828                      | 857             | 828                 | 857                 |
| 12.31 - 13.00| 690                      | 714             | 690                 | 714                 |
| 13.31 - 14.30| 681                      | 704             | 681                 | 704                 |
| 14.31 - 15.30| 724                      | 749             | 724                 | 749                 |
| 15.31 - 16.30| 839                      | 868             | 839                 | 868                 |

Based on Table 2 it can be seen that the demand of the user for the mode of transportation occurs in the morning and evening. For the calculation of demand on Monday-Friday and Friday seen from the red route is the highest at 07.31-08.30 WIB as well as for the blue route, for the afternoon occurred at 15.31-16.30 WIB.

4.3. Calculation of Time Between
The calculation of time between using the time equation between that has been applied to the research method with the assumption of seat bus capacity capacity 25-30 people, load factor 1 and the calculation period every one hour.
Figure 1. Headway Comparison of Campus Bus Existing On Red Routes and Blue Routes On Monday-Thursday

Based on Figure 1 the time between the headway of the mode of transportation within the University of Indonesia campus on Monday-Thursday the highest demand is at 10.31-11.30 WIB for the operation of red and blue routes.

Figure 2. Comparison of Existing Campus Bus Usage On Red Routes and Blue Routes On Friday

Based on Figure 2 the time between the headway of the modes of transportation within the campus of the University of Indonesia on Friday at the highest request level is at 11.31-12.30 WIB for the operation of red routes and blue routes.

4.4. Circulation Time Calculation

Circulation time calculation using the circulation time equation which has been applied to the research method, with 8.19 km red route length and 6.72 km of blue route (DPPF UI, 2017), the number of 19 shelters for the red route and 20 units for the blue route, stop time of each stop 30 seconds, speed of 20 km/h and the assumption of stop time at the main bus stop is 5 minutes. Based on the calculations performed, the circulation time for red route operation is 25.77 minutes (26 minutes) for one rite and the blue route is 22.15 minutes (22 minutes) for one rite.
4.5. Total Transportation Mode Needs

The number of campus transportation modes required by the calculation of the number of fleets or vehicles, with the value of vehicle availability factor is assumed 100%. The calculation is done by modeling the level of requirement for Monday-Thursday and Friday, this is distinguished by the fluctuating student movement level in both assumptions or modeling of the day.

![Figure 3. Transportation Mode Needs at University of Indonesia for Red & Blue Routes](image)

The needs of the transportation modes (units) to be implemented at the University of Indonesia are 30 units with details of each of 15 units serving the operational red routes and 15 units serving the operational blue routes, this is based on the highest demand for the rounded operational time (14, 97 ≈ 15) and the inter-stop waiting time is still long with University of Indonesia campus bus unit still operating in 2018 which is 27 units of outsourced campus bus (borrowing).

4.6. Test Scenario Calculation 1

In scenario 1 scenario, the value of Emission Factor (Fi) for CNG bus is 1.0346 kg / km (GHG Protocol, 2005), Fuel Consumption (Ki) 0.0560 kg / km (GHG Protocol, 2005) and test model the vehicle is the model bus CNG Scania L94UB [14] because this bus corresponds to the desired carrying capacity and corresponds to the dimensions in the category of Heavy Vehicle (Class-1) on the calculation of passenger unit before, for fuel consumption is also adjusted according to IPCC Guide 1996 and GHG Protocol 2005 on demographic and research conditions in Indonesia. The emission loads generated for CNG buses are as follows.

| Table 3. Results of Simulation of Technical Study Calculations on CNG Buses |
|---------------------------------------------------------------|
| **Type of Transport**                                         |
| Scania L94UB CNG                                            |
| **Type of Transport**                                        |
| Number of Vehicles [unit]                                    |
| 30                                                          |
| Type of Fuel                                                |
| Natural Gas                                                 |
| Emissions Factor CO₂ (GHG Protocol, 2005) [kg/km]            |
| 1,0346                                                      |
| Test Coefficient                                            |
Specific Fuel Consumption (GHG Protocol, 2005) 

\[ \text{[kg/km]} \quad 0.0560 \]

The Calculation Results

Emission Load CO\(_2\) 

\[ \text{[tCO}_2\text{e/tahun]} \quad 0.012958 \]

4.6.1. **Test Scenario Calculation 2**

Under scenario 2 the Emission Factor (Fi) value for the electric bus / PHEV is obtained \(0.0004244\) kgCO\(_2\) / Wh (Carbon Emissions-based Vehicle Scheme, 2017), for hybrid fuel consumption sharing scenario modeled 50:50 system for Blended Electric and Gasoline Mode [15] is also valued for the procurement and visibility of technology that has been fairly stable and has been produced by various markets Heavy Vehicle (HV) in this calculation using the SCANIA A30 Hybrid SCE-type electric bus. The emission load generated per unit of hybrid / PHEV electric buses is as follows.

| Table 4. Result of Simulation of Calculation of Technical Study on PHEV Bus |
| --- |
| **Type of Transport** | Scania Hybrid A30 PHEV |
| Test Coefficient | |
| Number of Vehicles [unit] | 30 |
| Type of Fuel | 50% Diesel |
| Emissions Factor CO\(_2\) (Carbon Emissions-based Vehicle Scheme, 2017) [kgCO/Wh] | 0.0004244 |
| Specific Fuel Consumption (IPCC Guide, 1996) [L/km & kWh/100 km] | 2.4 L/100 km & 10.6 kWh/100 km |
| The Calculation Results | |
| Emission Load CO\(_2\) [tCO\(_2\)e/tahun] | 0.000228 |

Gas emission load of gas engine type for procurement of PLTMG as gas-based gas feeder for operational of charging station in procurement of PHEV bus supporting facility unit also taken into account. The calculation assumption is based on a typical gas distribution by PT PGN (Persero). The result of emission load calculation for PTMG procurement obtained value of \(2.030995\) tCO\(_2\)e / MWh.

4.6.2. **Test Scenario Calculation 3**

Under scenario 3 the Emission Factor (Fi) value for the Electrical Tram is obtained \(0.0001472\) kgCO\(_2\) / Wh (FTH GHG Emission Estimator, 2017), then for specific fuel consumption used the calculation reference from Urban Transportation Canada (UTEC) [16] in MJ / 100 km and converted to kWh / 100 km to obtain comparison according to scenario 1 and 2. For vehicle test model selected vendor from Bombardier type of flexity outlook where this type is very suitable to be implemented for route not too far. The emission loads generated by Electric Tram are as follows.

| Table 5. Result of Simulation of Technical Study Calculation on Electric Tram / LRT |
| --- |
| **Type of Transport** | Bombardier LRT (Toronto LRT Car/Flexity Outlook) |
| Test Coefficient | |
| Number of Vehicles [unit] | 30 |
| Type of Fuel                      | Electric (Generator based) |
|----------------------------------|-----------------------------|
| Emission Factor CO₂              | 0.0001472                   |
| (Carbon Emissions-based Vehicle  |                             |
|     Scheme, 2017) [kgCO₂/Wh]     |                             |
| Specific Fuel Consumption        | 2.167                       |
| (UTEC, 2008) [kWh/km]            |                             |

The Calculation Results

| Emission Load CO₂               | 0.000071                     |
| [tCO₂e/tahun]                   |                             |

4.7. Comparison of Emission Load Existing Conditions Against Scenario Test

To review the problem, it can be compared to scenario 1, where in this scenario Diesel bus will be replaced by CNG (Compressed Natural Gas) bus procurement, the result of emission load calculation on campus environment of University of Indonesia can be seen in Figure 4.

![Figure 4](image)

**Figure 4.** Emissions Load In Scenario 1 (CNG Bus) On Campus Environment University of Indonesia

Then, after comparison of scenario 1 to the existing condition, comparison of scenario 2 is also done, where scenario 2 aims to reduce emission load by replacing diesel bus unit with Plug-in Hybrid Electrical Vehicle unit. The results of the calculation of the mixing of vehicle traffic within the campus of University of Indonesia can be seen in Figure 5.
Then, after the comparison of scenario 1 to the existing condition, scenario 2 to scenario 1 and the existing condition, comparison of scenario 3 is also done, where scenario 3 aims to reduce the emission load by replacing the diesel bus unit with the Electric Tram (Light Rail Transit). The results of the calculation of the mixing of vehicle traffic within the campus of University of Indonesia can be seen in Figure 6.

Figure 5. Emission Load In Scenario 2 (Electric Bus / PHEV) on University Campus Environment of Indonesia

Figure 6. Emissions Load In Scenario 2 (Electrical Tram) On Campus Environment University of Indonesia

5. Conclusion
1. The need of transportation modes (units) to be implemented at the University of Indonesia is 30 units with details of each 15 units serving the operational red routes and 15 units serving the operational blue routes
2. CO₂ emission load generated for diesel conditions (Current bus) is 16498 tCO₂e / year
3. The CO₂ emission load generated for scenario 1 (Compressed Natural Gas) is 0.012958 tCO₂e / year; The CO₂ emission load generated for scenario 2 (Plug-in Hybrid Electrical Vehicle) is 0.00028 tCO₂e / year; The CO₂ emission load generated for scenario 3 (Light Rapid Transit) is 0.000071 tCO₂e / year
4. CO₂ emission load generated by the gas engine based generator as a scenario 2 (PHEV) electricity feeder facility that is 2.030995 tCO₂e / MWh
Suggestion
1. Calculations of actual emission factors need to be done in order to compensate for the emission factor issued globally by the IPCC (Intergovernmental Panel on Climate Change), given the IPCC rarely reviews the demographics of Indonesia in particular (last done in 2006)
2. Calculation of the actual vehicle fuel consumption factor per km (kilo meter) needs to be consulted with the Transportation Agency of the Republic of Indonesia in order to obtain more actual and latest data

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