

Article

Life Cycle Assessment (LCA) Analysis Operational Vehicles Telecommunication Industry at PT. X in East Java Using OpenLCA Software and the ReCipe Midpoint H Method

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Abstract

The telecommunications industry heavily relies on operational vehicles to support network maintenance and customer service activities. This study aims to analyze the environmental impact resulting from the emissions of operational vehicles at PT. X, focusing on the East Java operational region. A Life Cycle Assessment (LCA) was conducted in accordance with ISO 14040, emphasizing the vehicle use phase. Primary data includes gasoline consumption and a total distance during the 2024 operational year. The analysis was performed using OpenLCA software with the Ecoinvent 3.3 database and the ReCipe Midpoint (H) method to quantify emissions and their associated environmental impacts. Results indicate that carbon dioxide (CO₂), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur dioxide (SO₂), and particulate matter (PM₁₀) are the primary contributors to environmental impact categories such as climate change, marine eutrophication, particulate matter formation, photochemical oxidant formation, and terrestrial acidification. The findings provide a quantitative basis for evaluating the environmental burden of operational fleets and highlight the importance of implementing efficient fleet management, eco-driving practices, and integrated emission reduction policies as part of corporate sustainability strategies.

Keywords: analyze environmental impact, LCA, OpenLCA, ReCipe Midpoint (H), vehicle emissions.

1. Introduction

Transportation serves as a fundamental component in supporting various socio-economic activities, including those in the telecommunications industry. Operational vehicles, which are utilized for tasks such as network maintenance, equipment distribution, and on-site customer services, play a strategic role in ensuring service continuity and performance [1]. The reliability and availability of these vehicles significantly influence the operational efficiency and quality of services delivered by the company.

Despite their functional importance, the use of fossil fuel-powered vehicles contributes to various environmental issues. Combustion of gasoline emits pollutants such as carbon dioxide (CO₂), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), sulfur dioxide (SO₂), and particulate matter (PM₁₀), all of which are recognized as contributors to environmental degradation [2]. These pollutants are associated with adverse effects including global warming, acid deposition, declining air quality, and increased human health risks. According to national emissions inventories, the transportation sector is

among the largest sources of greenhouse gas (GHG) emissions in Indonesia, with a consistent upward trend.

In light of these concerns, a comprehensive scientific approach is required to quantify and evaluate the environmental impacts associated with the operation of company vehicles. One of the most widely adopted methodologies for such assessments is the Life Cycle Assessment (LCA), a standardized approach for quantifying environmental impacts throughout the life cycle of a product or activity, from raw material extraction and production to distribution, use, and final disposal [3]. LCA facilitates the identification of critical emission hotspots and supports the development of data-driven strategies for emission reduction [4].

The utilization of transportation systems to support the operational activities of the telecommunications industry, particularly in a geographically vast and heterogeneous region such as East Java, has the potential to significantly increase the ecological footprint of corporate operations. The high frequency of vehicle mobilization and the presence of suboptimal routing patterns contribute to excessive fuel consumption, which in turn leads to elevated emission levels [5]. Prior research has indicated that fleet activities in service-based sectors are among the primary contributors to emissions, making them a critical focus for sustainability efforts. In this context, telecommunications companies are increasingly expected to implement operational strategies that align with national climate commitments and corporate sustainability goals encompassing Environmental, Social, and Governance (ESG) [6].

Recent technological innovations and evolving policy frameworks offer promising avenues for emission reduction [7]. The adoption of low-emission vehicles, the utilization of digital systems for route optimization, and the implementation of behavioral efficiency programs such as eco-driving training have proven effective in lowering energy consumption and minimizing environmental impacts [8]. Furthermore, the incorporation of Life Cycle Thinking into strategic decision-making enables organizations to assess environmental impacts not only from direct operations but also from upstream and downstream logistics activities. This comprehensive approach supports the transition

toward more sustainable fleet management while creating opportunities for economically feasible and environmentally beneficial decarbonization initiatives [9].

This study aims to analyze the environmental impacts resulting from the operation of gasoline-fueled vehicles used by a telecommunications company in East Java. The assessment is carried out using OpenLCA software with the Ecoinvent 3.3 database and the ReCiPe Midpoint (H) impact assessment method. The study emphasizes the use phase of the vehicle life cycle, identified as the most emission-intensive stage [10]. The results are expected to provide quantitative data on environmental burdens and support the development of sustainable fleet management policies, such as vehicle optimization, implementation of eco-driving practices, and integration into corporate sustainability strategies [11].

2. Material and Method

Goal and Scope Definition

This stage involves defining the functional unit and creating a conceptual map of the transportation process (operational vehicles), followed by the collection of data on fuel consumption, distance traveled, and emissions of carbon dioxide (CO₂), carbon monoxide (CO), nitrogen oxides, hydrocarbons (HC), nitrogen oxides (NO_x), sulfur dioxide (SO₂), and particulate matter (PM₁₀) in East Java for the year 2024.

Inventory Analysis

The collected data from both primary and secondary sources are then entered into Microsoft Excel to calculate the input and output data used in the transportation process (operational vehicles) at PT. X throughout the year 2024 in the East Java region.

Impact Assessment

Input data based on gasoline fuel consumption in the East Java region for 2024 is used to calculate the emissions generated using emission factors derived from [12] concerning Air Pollution Control in the Region. Emissions from the transportation process (operational vehicles) are then entered as outputs in the OpenLCA software, due to limitations in the database for including the inputs used. Subsequently, an automatic calculation of the environmental

impacts is performed using the characterization factors from the ReCiPe Midpoint (H) method in OpenLCA software.

Table 1. Emissions Factor

Polluter	CO (g/km)	HC (g/km)	NOx (g/km)	PM ₁₀ (g/km)	CO ₂ (g/kg BBM)	SO ₂ (g/km)
Motorecycle	14	5.9	0.29	0.24	3180	0.008
Gasoline Car	40	4	2	0.01	3180	0.026
Diesel Car	2.8	0.2	3.5	0.53	3172	0.44

Source: Peraturan Menteri Lingkungan Hidup No. 12/2010

Table 2. Characterization Emissions Factor ReCiPe Midpoint H

Dampak Lingkungan	Kontribusi Emisi	Faktor Karakterisasi
Climate Change	Karbon Dioksida (CO ₂)	1.000 kg CO ₂ -Eq/kg
Marine Eutrophication	Nitrogen Oksida (NO _x)	0.389 kg N-Eq/kg
Particulate Matter Formation	Nitrogen Oksida (NO _x)	0.220 kg PM ₁₀ -Eq/kg
	Sulfur Dioksida (SO ₂)	0.200 kg PM ₁₀ -Eq/kg
Photochemical Oxidant Formation	Nitrogen Oksida (NO _x)	1.000 kg NMVOC/kg
Terrestrial Acidification	Nitrogen Oksida (NO _x)	0.560 kg SO ₂ -Eq/kg
	Sulfur Dioksida (SO ₂)	1.000 kg SO ₂ -Eq/kg

Source: Characterization Factor Impact Analysis OpenLCA method ReCiPe Midpoint H

Tier 2 Method

For accurate estimation of emissions in the transportation sector, methodologies must consider variations in vehicle characteristics and usage patterns. The Tier 2 method, as recommended in the Intergovernmental Panel on Climate Change *Guidelines for National Greenhouse Gas Inventories*, utilizes more specific input data than Tier 1, such as vehicle type, fuel type, and actual fuel consumption or travel distance [13]. This enables more accurate GHG emission estimates and aligns with the requirements of LCA studies focusing on operational transportation systems [14].

Tier 2 method relies on more specific data compared to Tier 1 by taking into account factors

such as vehicle type, fuel type, and actual fuel consumption or distance traveled. This approach enables more accurate emission estimates, as it incorporates emission factors specific to each vehicle and fuel category [15].

This method employs national emission factors as stipulated in [12] concerning Regional Air Pollution Control. The emission load (E) is calculated using the following formula:

$$E = \text{Number of Vehicles} \times L \times FE \times 10^{-3}$$

E = Emission load (kilograms)

L = Total distance travelled (km)

FE = National Emission Factor (g/km/vehicle)

10⁻³ = Conversion factor from grams to kilograms

Table 3. Emissions Factor Petrol Car

Polluter	CO (g/km)	HC (g/km)	NOx (g/km)	PM ₁₀ (g/km)	CO ₂ (g/kg BBM)	SO ₂ (g/km)
Gasoline Car	40	4	2	0.01	3180	0.026

Source: Peraturan Menteri Lingkungan Hidup No. 12/2010

Interpretation

After obtaining the environmental impact values from the transportation process (operational vehicles) in East Java for the year 2024, further analysis was conducted to identify the emission types that contributed most significantly to environmental impacts. Additionally, the analysis determined which cities exhibited the highest environmental impacts for each impact indicator. Based on these findings, improvement recommendations were proposed to help minimize the environmental burden and reduce the contribution of major emission sources.

3. Results and Discussion

PT. X is a telecommunications company analyzed in this study to assess the environmental impacts arising from the operation of its fleet vehicles, with a case study focused on the East Java region. The analysis covers seven areas, including Area 3 (Head Office), Branch Surabaya, Branch Sidoarjo, Branch Malang, Branch Lamongan, Branch Madiun, and Branch Jember. Each of these locations provided application-based data for individual vehicles, presenting

monthly records of travel distance and gasoline fuel consumption.

Table 4. Distance and Fuel Consumption Data by Region

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	TOTAL
AREA 3	Distance (km)	30289	28332	30174	21217	36581	29852	37223	36173	28912	32451	38018	34783
	Total Fuel (kg)	1125	1015	1042	728	1311	1119	1387	1620	1268	1467	1599	1581
BRANCH SURABAYA	Distance (km)	18923	17688	18422	14488	20219	18578	18992	18428	18912	20141	17414	18887
	Total Fuel (kg)	2451	2026	1981	1420	2072	2297	2217	2446	2376	2654	2087	2002
BRANCH SIDOARJO	Distance (km)	21791	18917	21620	11868	26140	21126	28343	21814	19819	24173	25889	24958
	Total Fuel (kg)	2330	1974	2286	1285	2897	2343	3050	2168	2208	2891	2423	2750
BRANCH LAMONGAN	Distance (km)	17114	13680	19197	18198	19720	22187	22119	22045	19981	22427	20582	22197
	Total Fuel (kg)	2177	1686	2287	1986	2483	2847	4178	1987	1863	1891	1877	1938
BRANCH MADIUN	Distance (km)	18820	21284	21130	18178	29822	24623	28167	29114	23814	30619	35815	31328
	Total Fuel (kg)	3283	2835	2737	2984	4183	4580	4184	4173	3323	4306	4216	4159
BRANCH JEMBER	Distance (km)	18142	15483	20019	21028	28010	19118	27009	22006	19101	21982	22158	21793
	Total Fuel (kg)	1815	1802	1982	2007	2819	2133	2889	2420	2028	2644	2240	2483
BRANCH MALANG	Distance (km)	0	0	0	0	0	0	21824	17971	18886	20786	20280	88127
	Total Fuel (kg)	0	0	0	0	0	0	3096	2487	2809	3836	3868	19367

Source: Operational Vehicle Data of the Telecommunications Industry at PT. X in 2024

The data above presents the monthly travel distance and fuel consumption for each region within the East Java area throughout 2024 (January–November). The data were aggregated monthly for each region, covering fuel consumption (with a gasoline density of 0.75) and travel distance, based on a total of 86 operational vehicles in the East Java area in 2024.

3.1. Tier 2 Method

Formula Emissions Load (kilograms)

$$E = \text{Number of Vehicles} \times L \times FE \times 10^{-3}$$

1. Area 3 (Head Office)

$$E = 14 \times 347,833 \times FE \times 10^{-3}$$

Table 5. Emission Load Calculation Tier-2 Method in Area 3 (Head Office)

Polluter	CO (kg/k m)	HC (kg/k m)	NOx (kg/k m)	PM ₁₀ (kg/k m)	CO ₂ (kg/kg BBM)	SO ₂ (kg/k m)
Gasoline	19,47	1,947.	973.9	4.869	123,813.	12.66
Car	8.648	864	32		459	1

2. Branch Surabaya

$$E = 11 \times 194,887 \times FE \times 10^{-3}$$

Table 6. Emission Load Calculation Tier-2 Method in Branch Surabaya

Polluter	CO (kg/k m)	HC (kg/k m)	NOx (kg/k m)	PM ₁₀ (kg/k m)	CO ₂ (kg/kg BBM)	SO ₂ (kg/k m)
Gasoline	8,575.	857.5	428.7	2.143	68,267.7	5.573
Car	028	02	51		17	

3. Branch Sidoarjo

$$E = 9 \times 249,388 \times FE \times 10^{-3}$$

Table 7. Emission Load Calculation Tier-2 Method in Branch Sidoarjo

Polluter	CO (kg/k m)	HC (kg/k m)	NOx (kg/k m)	PM ₁₀ (kg/k m)	CO ₂ (kg/kg BBM)	SO ₂ (kg/k m)
Gasoline	8,977.	897.7	448.8	2.244	59,136.0	5.835
Car	968	96	98		75	

4. Branch Lamongan

$$E = 11 \times 221,607 \times FE \times 10^{-3}$$

Table 8. Emission Load Calculation Tier-2 Method in Branch Lamongan

Polluter	CO (kg/k m)	HC (kg/k m)	NOx (kg/k m)	PM ₁₀ (kg/k m)	CO ₂ (kg/kg BBM)	SO ₂ (kg/k m)
Gasoline	9,750.	975.0	487.5	2.437	94,000.0	6.337
Car	708	70	35		05	

5. Branch Madiun

$$E = 15 \times 312,028 \times FE \times 10^{-3}$$

Table 9. Emission Load Calculation Tier-2 Method in Branch Madiun

Polluter	CO (kg/k m)	HC (kg/k m)	NOx (kg/k m)	PM ₁₀ (kg/k m)	CO ₂ (kg/kg BBM)	SO ₂ (kg/k m)
Gasoline	18,72	1,872.	936.0	4.680	148,788.	12.16
Car	1.680	168	84		225	9

6. Branch Jember

$$E = 14 \times 238,761 \times FE \times 10^{-3}$$

Table 10. Emission Load Calculation Tier-2 Method in Branch Jember

Polluter	CO (kg/k m)	HC (kg/k m)	NOx (kg/k m)	PM ₁₀ (kg/k m)	CO ₂ (kg/kg BBM)	SO ₂ (kg/k m)
Gasoline	13,37	1,337.	668.5	3.342	83,418.2	8.690
Car	0.616	061	30		37	

7. Branch Malang

$$E = 12 \times 98,637 \times FE \times 10^{-3}$$

Table 11. Emission Load Calculation Tier-2 Method in Branch Malang

Polluter	CO (kg/k m)	HC (kg/k m)	NOx (kg/k m)	PM ₁₀ (kg/k m)	CO ₂ (kg/kg BBM)	SO ₂ (kg/k m)
Gasoline	4,734.	473.4	236.7	1.183	38,800.1	3.077
Car	576	57	28		34	

3.2. Life Cycle Assessment Analysis

Life Cycle Assessment (LCA) is an environmental assessment tool that serves as a

basis for informed decision-making regarding a production system. According to ISO 14040, the LCA consists of four key phases: goal and scope definition, life cycle inventory, life cycle impact assessment, and interpretation. The environmental impact assessment of the transportation process (operational vehicles) in the telecommunications industry at PT. X follows these stages:

Goal and Scope Definition

The goals of this study are:

1. To identify the environmental emission contributions from gasoline - fuelled operational vehicles over one year of operation.
2. To provide a foundation for decision-making related to carbon emission reduction and operational efficiency.

The scope of the study includes:

1. Product function: Operational transportation for PT. X in conducting technical and logistical activities.
2. System boundaries: Gate-to-Gate, including distribution (operational) processes and fuel consumption in vehicles.
3. Impact assessment method: ReCiPe Midpoint (H), using the Eco invent 3.3 database.

Life Cycle Inventory (LCI)

The inventory data input into OpenLCA for the East Java area includes:

1. Vehicle type: Gasoline-powered cars
2. Total fuel consumption: 206,613 liters
3. Total distance: 1,663,140 km
4. Emission data calculated using the Tier-2 method and aligned with the characterization factors for each impact category

Life Cycle Impact Assessment (LCIA)

The impact assessment was conducted using the ReCiPe Midpoint (H) method, which produces 18 impact categories. The five categories that were analyzed due to their significant impact are:

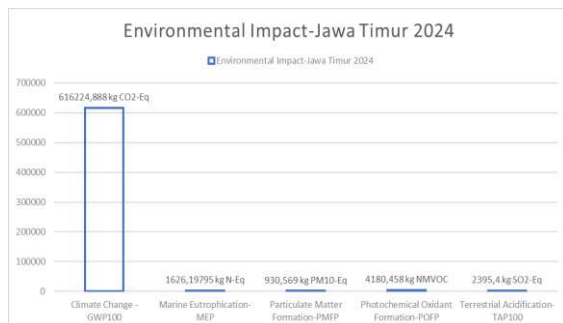


Fig 1: Result Environmental Impact Jawa Timur 2024

1. Climate Change:
Impact value: 616,224.888 kg CO₂-Eq
2. Marine Eutrophication:
Impact value: 1,626.19795 kg N-Eq
3. Particulate Matter Formation:
Impact value: 930.569 kg PM₁₀-Eq
4. Photochemical Oxidant Formation:
Impact value: 4,180.458 kg NMVOC
5. Terrestrial Acidification:
Impact value: 2,395.4 kg SO₂-Eq

1. Climate Change
Vehicle activities emit greenhouse gases such as carbon dioxide (CO₂). The accumulation of these gases in the atmosphere leads to global climate change, characterized by rising average global temperatures, sea level rise, and increased frequency of extreme weather events such as droughts and floods. These impacts pose serious risks to natural ecosystems, food security, and human livelihoods [16].

2. Marine Eutrophication
Nitrogen oxide (NO_x) emissions from vehicles can be deposited into water bodies via wet deposition. This leads to excessive nutrient enrichment in marine environments, triggering algal blooms. When the algae die and decompose, dissolved oxygen levels decline sharply, resulting in the formation of "dead zones" that threaten the survival of fish and other marine organisms. This phenomenon also disrupts marine food chains and degrades water quality for human use [17].

3. Particulate Matter Formation
Vehicles emit both primary particulates and precursor gases such as NO_x and SO₂, which contribute to the formation of secondary particulates (PM_{2.5} and PM₁₀) in the atmosphere. These fine particles can be inhaled deep into the human respiratory system, leading to severe health issues including asthma, chronic bronchitis, cardiovascular diseases, and even lung cancer. Moreover, particulate matter reduces air quality and visibility, particularly in urban areas [18].

4. Photochemical Oxidant Formation
Emissions of volatile organic compounds (VOCs) and NO_x from motor vehicles can react under sunlight to produce tropospheric ozone (ground-level ozone). This process leads to the formation of photochemical smog, which poses respiratory health risks and damages agricultural crops. Elevated ozone concentrations in urban areas further degrade the quality of life [19].

5. Terrestrial Acidification

Emissions of NO_x and SO₂ also contribute to soil acidification through the formation of acid rain. This lowers soil pH, damages soil structure, reduces agricultural productivity, and impairs forest growth. Moreover, acidified soils can release toxic heavy metals into groundwater, thereby threatening the quality of drinking water [20].

Interpretation

1. Climate Change

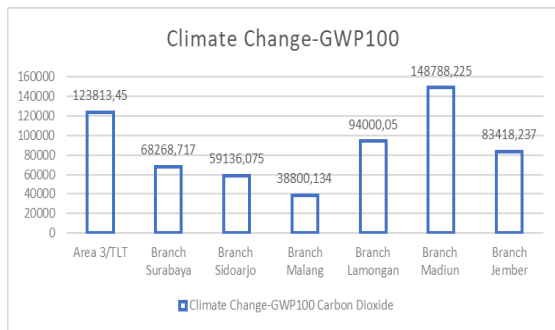


Fig 2: Result Chart Climate Change

In the Climate Change impact category, each region exhibits varying levels of contribution, which depend on the concentration of carbon dioxide (CO₂) emissions associated with fuel consumption and distance by operational vehicles. The emission values recorded are as follows: Area 3 with 123,813.45 kg CO₂-Eq, Branch Surabaya with 68,268.717 kg CO₂-Eq, Branch Sidoarjo with 59,136.075 kg CO₂-Eq, Branch Malang with 38,800.134 kg CO₂-Eq, Branch Lamongan with 94,000.05 kg CO₂-Eq, Branch Madiun with 148,788.225 kg CO₂-Eq, and Branch Jember with 83,418.237 kg CO₂-Eq.

2. Particulate Matter Formation

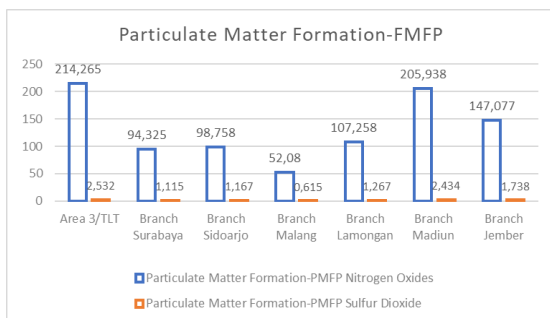


Fig 3: Result Chart Particulate Matter Formation

In the Particulate Matter Formation impact category, each region exhibits varying levels of

contribution, which depend on the concentration of nitrogen oxides (NO_x) and sulfur dioxide (SO₂) emissions associated with fuel consumption and distance by operational vehicles. The emission nitrogen oxides (NO_x) values recorded are as follows: Area 3 with 214.265 kg N-Eq, Branch Surabaya with 94.325 kg N-Eq, Branch Sidoarjo with 98.758 kg N-Eq, Branch Malang with 52.08 kg N-Eq, Branch Lamongan with 107.258 kg N-Eq, Branch Madiun with 205.938 kg N-Eq, and Branch Jember with 147.077 kg N-Eq. The emission sulfur dioxide (SO₂) values recorded are as follows: Area 3 with 2.532 kg SO₂-Eq, Branch Surabaya with 1.115 kg SO₂-Eq, Branch Sidoarjo with 1.167 kg SO₂-Eq, Branch Malang with 0.615 kg SO₂-Eq, Branch Lamongan with 1.267 kg SO₂-Eq, Branch Madiun with 2.434 kg SO₂-Eq, and Branch Jember with 1.738 kg SO₂-Eq.

3. Marine Eutrophication

In the Marine Eutrophication impact category, each region exhibits varying levels of contribution, which depend on the concentration of nitrogen oxides (NO_x) emissions associated with fuel consumption and distance by operational vehicles. The emission values recorded are as follows:

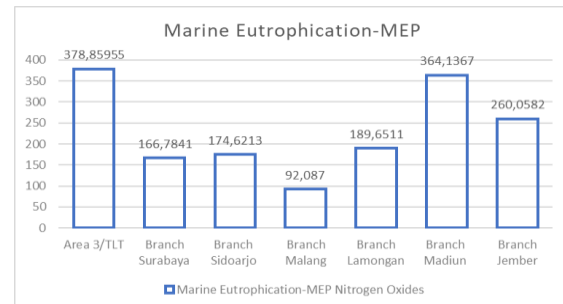


Fig 4: Result Chart Marine Eutrophication

Area 3 with 378.85955 kg N-Eq, Branch Surabaya with 166.7841 kg N-Eq, Branch Sidoarjo with 174.6213 kg N-Eq, Branch Malang with 92.087 kg N-Eq, Branch Lamongan with 189.6511 kg N-Eq, Branch Madiun with 364.1367 kg N-Eq, and Branch Jember with 260.0582 kg N-Eq

4. Photochemical Oxidant Formation

In the Photochemical Oxidant Formation impact category, each region exhibits varying levels of contribution, which depend on the concentration of nitrogen oxides (NO_x) emissions associated with fuel consumption and distance by

operational vehicles. The emission values recorded are as follows:

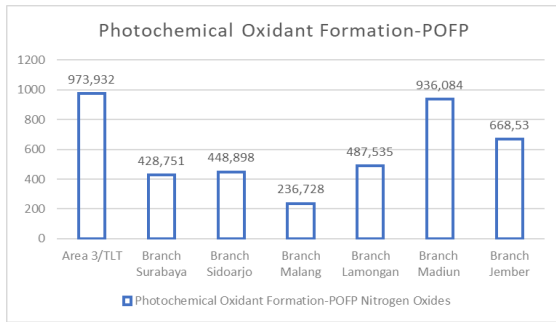


Fig 5: Result Chart Photochemical Oxidant

Area 3 with 973.932 kg N-Eq, Branch Surabaya with 428.751 kg N-Eq, Branch Sidoarjo with 448.898 kg N-Eq, Branch Malang with 236.728 kg N-Eq, Branch Lamongan with 487.535 kg N-Eq, Branch Madiun with 936.084 kg N-Eq, and Branch Jember with 668.530 kg N-Eq

5. Terrestrial Acidification

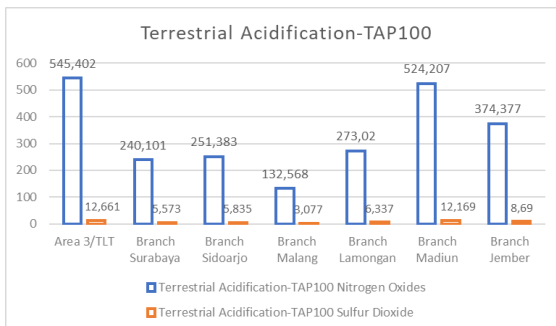


Fig 6: Result Chart Terrestrial Acidification

In the Terrestrial Acidification impact category, each region exhibits varying levels of contribution, which depend on the concentration of nitrogen oxides (NO_x) and sulfur dioxide (SO₂) emissions associated with fuel consumption and distance by operational vehicles. The emission nitrogen oxides (NO_x) values recorded are as follows: Area 3 with 545.402 kg N-Eq, Branch Surabaya with 240.101 kg N-Eq, Branch Sidoarjo with 251.383 kg N-Eq, Branch Malang with 132.568 kg N-Eq, Branch Lamongan with 273.02 kg N-Eq, Branch Madiun with 524.207 kg N-Eq, and Branch Jember with 374.377 kg N-Eq. The emission sulfur dioxide (SO₂) values recorded are as follows: Area 3 with 12.661 kg SO₂-Eq, Branch Surabaya with 5.573 kg SO₂-Eq, Branch Sidoarjo with 5.835 kg SO₂-Eq, Branch Malang with 3.077 kg SO₂-Eq, Branch Lamongan with 5.337 kg SO₂-Eq,

Eq, Branch Madiun with 12.169 kg SO₂-Eq, and Branch Jember with 8.69 kg SO₂-Eq.

4. Conclusions

Based on the results of the LCA study analyzing the transportation process (operational vehicles) of PT. X in 2024 in the East Java area. The total fuel (gasoline) consumption was 206,613 liters, with a travel distance of 1,663,140 km and a fleet of 86 vehicles. From this data, the environmental impact values obtained using OpenLCA with the ReCiPe Midpoint (H) method were: 616,224.888 kg CO₂-Eq Climate Change, 1,626.19795 kg N-Eq Marine Eutrophication, 930.569 kg PM₁₀-Eq Particulate Matter Formation, 4,180.458 kg NMVOC Photochemical Oxidant Formation, and 2,395.4 kg SO₂-Eq Terrestrial Acidification.

These findings emphasize the implementation of more sustainable transportation solutions, such as transitioning to low-emission or electric vehicles and optimizing travel routes. The adoption of environmental policies and effective fleet management practices can help reduce the environmental impacts associated with mobility in the telecommunications sector.

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