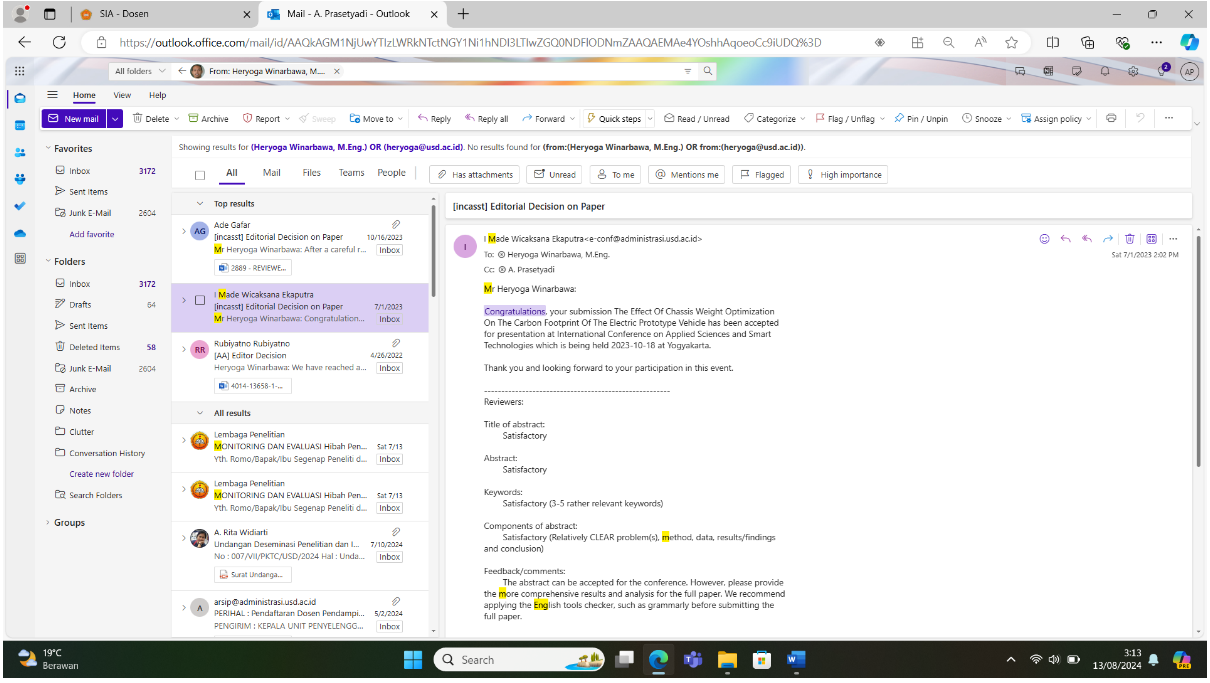
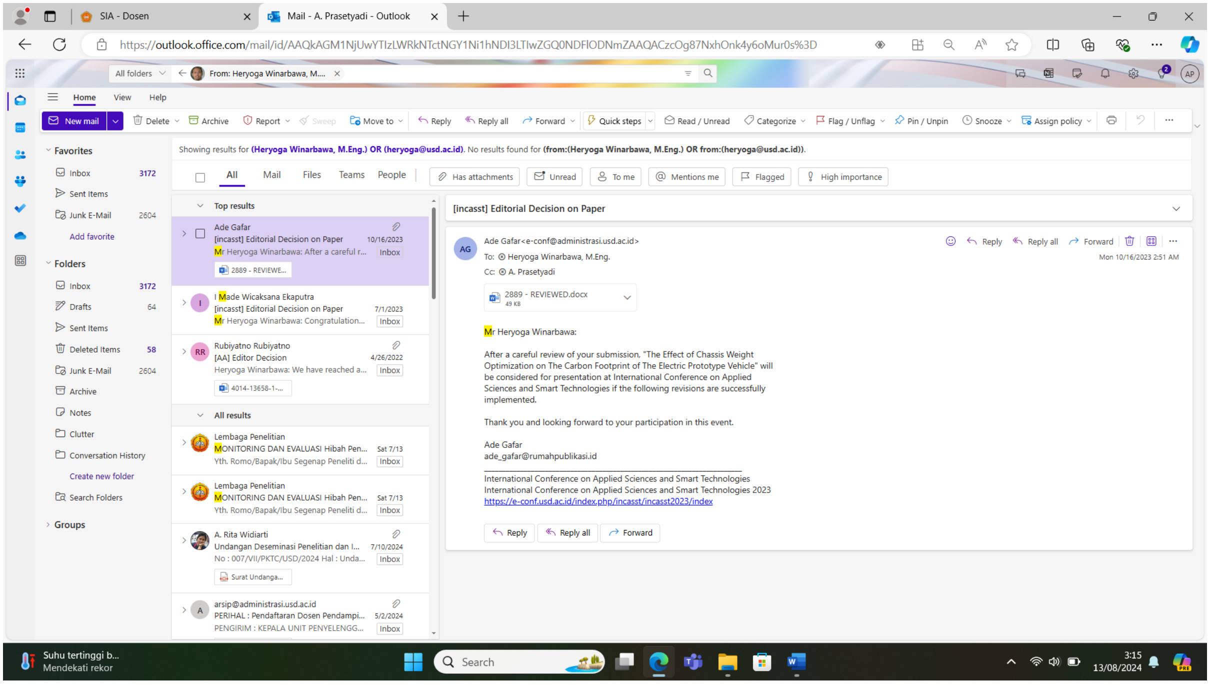
1. Notifikasi Penerimaan (1/7/2023)



2. Notifikasi Review (16/10/2023)



3. File Review (16/10/2023)

The Effect of Chassis Weight Optimization on The Carbon Footprint of The Electric Prototype Vehicle

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Abstract. Electrification of vehicles has become increasingly widespread lately. It aims to reduce carbon emissions globally. Another step, namely reducing vehicle weight, is expected to reduce energy consumption during the operation. A vehicle part that can be reduced in weight is the chassis. This research compares the carbon footprint between the stock chassis and the lightweight version. The lightweight chassis requires additional energy during its fabrication. Life cycle analysis (LCA) is conducted to calculate the carbon footprint of each chassis. Material loss and manufacturing time are the main differences in the footprint. Manufacturing strategy is important in order to minimize the emission of the process.

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1 Introduction

Electric vehicles are considered to be a solution for transportation fit into climate action. In dominated coal and hydropower electricity, the electricity vehicles can reduce emissions by 37% and 90%, respectively [1]. Such transportation modes have less carbon emission than internal combustion ones. The electric vehicles have higher direct efficiency than internal combustion vehicles. Electric motor is generally more efficient than diesel and petroleum engines. The electric vehicles reduce fuel transportation. The fuel for electricity just needs transportation from the source to the power plant. A green and clean grid is very positive to lower the emission. The battery capacity and electric intensity are also other factors of emission reducer. Specific travel requirement is important to make emission reduction real [2]. All of the aforementioned factors are external. The fewer moving parts number of the electric vehicles than internal combustion is the factor. However, it also has drawbacks due to battery requirements. The battery tends to be the heaviest part of the vehicles [3].

Lightweight is the key to the electric vehicle. Variation of the vehicle weight depends only on load of the vehicle during its travel. It is different from internal combustion vehicle that has fuel as another variable changing during its movement. The energy consumption of the electric vehicle depends on the unladen weight of the vehicle [3]. Heavier vehicle needs higher energy for every kilometre travel. Therefore, it is important to create the electric vehicle as light as possible. Among the parts, frame is unladen weight that contributes significantly to total weight of the vehicle.

Frame optimization is important for better electric vehicles. An excellent frame provides safety and performance. One of the criteria of a vehicle frame is its weight. The weight of the frame can affect significantly the vehicle's performance due to tractive force requirement. In addition to gradient, and aerodynamic, the rolling force is dominated by its weight [4]. Therefore, it is clear that the weight of the frame affects the emission operationally.

The emission of a vehicle depends on some factors in LCA. The factors include upstream, operational, and downstream cycles. A study of upstream factors was conducted by Yao, et al. [3]. Analysis of the fuel for all processes was also reported in China [1]. While the study of subsidies to meet the emission of China was the work of Zou et al. [2]. However, a detailed study of frame effect to emission was not available yet.

Aim to understand the effect of framework optimization for CO_2 emission of a prototype electric car. The work will be presented in 4 sections. The introduction starts the presentation to show state of the art of study. The methods show steps of data collection and frame model. Results and discussion become the third part. The final part is the conclusion showing some found of the work.

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2 Methods

Basic of LCA of energy and material used for the framework will be estimated for the carbon footprint. The data of the energy for production uses PLN report of 2022. The emission of the energy is calculated using energy mix of the PLN and energy need for the production of the frame. The energy for production consists of energy for material production and manufacturing production. The operational energy consumption is estimated in the form of the difference.

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2.1 Energy Mix Footprint

Indonesia Electricity Company (PLN) produced 273,761 GWh. The primary energy of the electricity consists of diesel fuel, coal, natural gas, geothermal, water, biomass, solar, and wind. The distribution of primary energy usage for electricity generating is presented in Table 1. The CO_2 emission equivalent for electricity generation was reported 663.5 gr/kWh [5].

Table 1. Electricity Generation according to energy type

Type of energy	Generated Electricity (GWh)	percentage
Oil Fuel	17,186	5.58
Coal	192,563	62.52
Natural Gas	68,315	22.18
Geothermal	6,899	2.24
Hydro	1,016	7.48

2.2 Chasis CO_2 Emission Footprint

Chasis CO_2 emission footprint consists of emission of metal production, manufacturing process, and metal destruction. The steel production emission was reported 1215.17 kg CO_2 equivalent/ton [6]. The aluminium CO2 equivalent emission was 7.15 ton/ton aluminium as the mean number [7]. In addition to steel production, the manufacturing consists cutting process, and welding process. The emission of chasis can be calculated using equation (1) as follow. The E_{CO2T}, E_{CO2P}, E_{CO2M},and E_{CO2D} are CO_2 equivalent emission of chasis, material production, manufacturing process, and demolishing, respectively. The manufacturing process is composed of cutting and welding. Therefore, the emission of the manufacturing process can find using equation (2) applying equation (3) and (4) for calculating the cutting and welding emission respectively. The demolishing of the metal, as it is recyclable, the number applies percentage of metal production using recycle material which is 10% [6]. The metal production and its scrapping can be calculated using equations (6) and (7) respectively.

$E_{CO2T} = E_{CO2P} + E_{CO2M} + E_{CO2D}$ (1)

$E_{CO2M} = E_{CO2cut} + E_{CO2weld}$ (2)

$E_{CO2cut} = Energy\ cutting\ (kWh) * 0.6635\ kg$ (3)

$E_{CO2weld} = Energy\ welding(kWh) * 0.6635\ kg$ (4)

$E_{CO2M} = Operationtime * E * 0.6635\ kg$ (5)

$E_{CO2P} = Mass\ material\ (kg) * 7.15\ kg$ (6)

$E_{CO2D} = Mass\ material\ (kg) * 0.715\ kg$ (7)

3 Results and Discussion

The complete chassis consists of 3 sections, the main chassis, front arm, and rear subframe. Each chassis section fabrication is then analyzed for its energy usage requirements. Energy consumption when fabricating each chassis is divided into 2 main parts. First, the preparation of each component for the welding process, such as cutting, drilling, and grinding, and the final step is the welding process itself. Then, the chassis is arranged in such a way as to form a vehicle that can operate. Energy consumption when the vehicle is operating is also then analyzed, which is then totaled by energy use during fabrication. The total energy used during chassis fabrication and when the vehicle is in operation is then converted into CO_2 equivalent.

3.1 Energy consumption for cutting, drilling, and grinding

The first step of fabricating a chassis is cutting the aluminum square tubing, round tubing, and sheet to the required as needed according to the design. For square and round tubing, a 1,7 kW miter saw is used to cut straight or at an angle. For aluminum sheets, the most effective way to cut is using a 3,3 kW laser cut machine. 0,9 kW machine is used for drilling operations. 0,67 kW angle grinder is used for grinding operations.

The general formula to calculate the energy consumption of each process as written in Equation (8)

$$E = P.t \quad (8)$$

Where E is energy consumption, P is the power of the machine used, and t is processing time.

The energy consumption for the first step in fabricating the chassis is then put together in the table.

Table 2. Energy consumption for cutting, drilling, and grinding

Chassis Section	**Energy Consumption (kWh)**	
	Chassis - Stock	**Chassis - Lightweight**
Main Chassis	0,0255	0,0596
Front Arm	0,0279	0,0645
Rear Sub-Frame	0,0818	0,0759
Total	0,1353	0,2000

3.2 Energy consumption for TIG welding

The final process for making a chassis is to combine each component that has been previously processed using a welding process. The TIG welding process is commonly used to weld aluminum. 6,1 kW TIG welding machine is used in this process.

The power and total energy consumption for TIG welding written in Equation (9) and (10), respectively

$$P = (V_{output} \cdot I_{output})/efficiency \quad (9)$$

$$E = P.t \quad (10)$$

Table 3. Energy consumption for TIG welding

Welding Process	Energy Consumption (kWh)	
	Chassis - Stock	**Chassis - Lightweight**
Main Chassis	1,433	0,373
Front Arm	0,442	0,317
Rear Sub-Frame	1,711	0,312
Total	3,586	1,002

3.3 Energy consumption while the vehicle is operating

Simulation of energy consumption (in Joule) when both vehicles are operating is then compared using Equation (4), and then converted to energy consumption (in Wh) using Equation (5). The difference between both vehicles is the mass of the vehicle, while the other specifications are the same. Vehicle specifications and energy usage results are shown in the table.

$$E_j = (\mu.m.g.Cos\Theta)+(m.g.Sin\Theta) +(0,25.C_d.A.\rho.(v_i^2+v_f^2).d)+(0,5.m.(v_i^2+v_f^2)) \quad (4)$$

$$E_{Wh} = E_j.0,000278 \quad (5)$$

Table 4. Chasis specification

Spesifications	Vehicle Chassis Type	
	Chassis - Stock	**Chassis - Lightweight**
Mass of vehicle, *m* (kg)	94,3	84,2
μ	0,004	
Gravitational acceleration, g (kg/m^2)	9,8	
Road elevation, Θ (°)	0	
Coefficient of drag of vehicle, C_d	0,15	
Frontal area of vehicle, *a* (m^2)	0,37	
Density of air, ρ	1,293	
Initial speed of vehicle, v_i (m/s)	8,5	
Final speed of vehicle, v_f (m/s)	0	
Diameter of vehicle's wheel, *d* (mm)	100	
Energy consumption, *E* (J)	3539,90	3174,64
Energy consumption, *E* (Wh)	0,98	0,88

3.4 The Emission

The CO_2 emission for both chassis from fabrication to demolishing can be shown in Table 5.

Table 5. Emission of the chasis life cycle

Cycle	Emission (kg)	
	Chasis Stock	Lightweight Chasis
Material Production	674.245	602,03
Manufacturing Process	2.469	0.798
Operation	130,046	116.776
Demolishing	67.424	60.203
Total Emission	874.185	779.806

Table 5 shows the emission of the chasis life cycle. It mentions that the material dominates the chasis emission. The second emission contributor is the operation assuming 200 hrs operation for the training and competition. Manufacturing is the least significant contributor of the emission. Therefore, optimization of the chasis has great impact of the emission.

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4 Conclusion

The lightweight chasis can reduce CO2 emission by 11% assuming 200 hrs operation. The stock chasis has 874.2 CO_2 emission, while the lightweight has 779.8 kg. The material is the main contributor of the emission. Therefore, optimization of the weight significantly reduces the emission.

References

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1. Gunakan template sesuai dengan ketentuan publisher.

2. Lakukan proofreading untuk meningkatkan kualitas kebahasaan.

3. Pastikan seluruh ilustrasi (tabel dan gambar) sudah berbahasa Inggris, serta dirujuk dalam teks.

4. Jumlah minimal referensi adalah 10, di mana 80% referensi adalah berupa artikel dari jurnal internasional berreputasi.

5. Pastikan jumlah antara referensi pada sitasi dan daftar pustaka sinkron. Untuk memudahkan, gunakan referencing manager.

6. Aspek-aspek yang terlalu lokal agar ditinjau dari sudut pandang global.

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