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Research Paper

LCA Assessment of the environmental impact of Electric Vehicles and Petrol Engine drive using Sustainable Minds software

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I. Introduction

EVs have gained significant attention as a sustainable transportation alternative due to their potential to reduce greenhouse gas emissions and dependence on fossil fuels. However, it is crucial to assess the environmental impact of EVs holistically. On the other hand combustion engine vehicles have been the conventional choice for personal transportation, relying on internal combustion engines fueled by petroleum. While the environmental impacts of these cars are well-known, comparing them to the emerging EV technology in terms of manufacturing will provide valuable insights into the overall sustainability of these vehicle types.

This project aims to conduct a cradle to gate Life Cycle Assessment (LCA) to compare the environmental and resource impacts of Electric Vehicles (EVs) and Petrol Engine driven Vehicles specifically during the manufacturing phase. The LCA will examine the materials used and the manufacturing processes involved in producing these two types of cars.

II. Problem statement and assumptions

Conduct a cradle to gate Life Cycle Assessment (LCA) in order to compare the environmental impacts of Electric Vehicles (EVs) and combustion engine driven vehicles during the manufacturing phase. The objective is to assess and analyze the materials used, manufacturing processes, energy consumption, and emissions associated with the production of both types of vehicles. We will examine Tesla model 3 long range to represent the EV's and Mercedes c200 to represent the combustion engine driven car.

This study aims to provide valuable insights into the sustainability of both cars particularly focusing on their manufacturing phase. The findings of this assessment will help inform decision-making processes in the automotive industry, promote sustainable practices, and contribute to the ongoing efforts towards greener transportation options.

III. Assumptions

- Choosing Mercedes c200 as an equal alternative of Tesla Model 3 long range for the same manufacturing LCA.
- Raw material already extracted and energy/resource consumption are the same for both.

- In the extraction of the raw material the logistics are not considered as they are minimal and their impact can be negligible.
- From the ranges that are taken in our inputs,maximum values are considered for the assessment.
- In the input stage the water is not considered as a primary input factor however it is considered in the output as a waste factor.
- It is assumed that Methylcyclohexane is used instead of gasoline (petrol) as it has equivalent CO2 emissions per Kg.
- In terms of water consumption we will consider an average electric car due to lack of availability of data.
- The body and chassis weight are considered for the three main materials (steel,composite and aluminum) however for simplicity the internal parts weight are evenly distributed among them.
- Consider synthetic oil as compatible with "lubricant oil in plants"for simplicity.
- Chassis weight is 30% (%70 aluminum, %20 steel & %10 carbon fiber for tesla model 3) of the vehicle total weight (1730 kg).
- Chassis weight is 30% consisting of(%80 aluminum, %20 steel) of the vehicle total weight (1505 kg).
- Due to the extensive amount of copper used in tesla model 3 electric motor we neglected the rest of the material embedded and assumed only copper.
- Since the internal parts are made of steel and aluminum, all weight is considered to be 40% steel & 60% aluminum.

3.1 Draw Product Tree

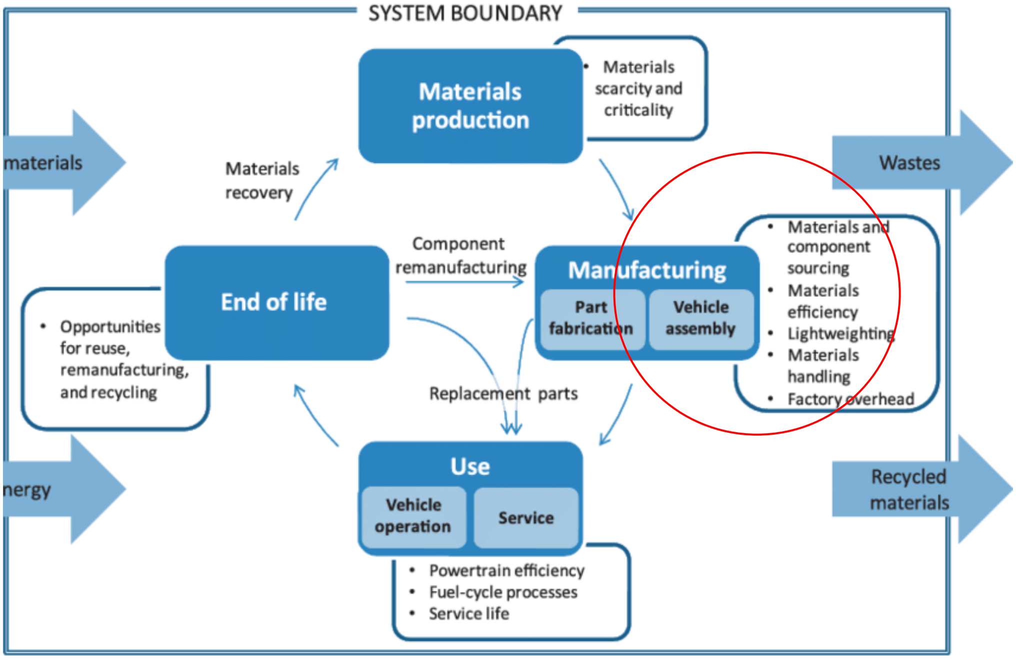

Figure 01: Product Tree

3.2 Different phases of LCA procedure:

- Goal and Scope
- Life Cycle inventory
- Impact Assessment
- Interpretation

IV. Goal and Scope

4.1 Goal Definition:

The aim of this cradle to gate Life Cycle Assessment (LCA) is to evaluate and compare the environmental and resource impacts associated with the manufacturing of the Tesla Model 3, representing an Electric Vehicle (EV), and the Mercedes C 200, representing a Combustion Engine-driven Vehicle (CEV). The assessment will focus on analyzing the materials used, manufacturing processes, energy consumption, and emissions throughout the manufacturing phase of both vehicle types.

4.2 Scope Definition:

The scope of this LCA covers the entire manufacturing process of the Tesla Model 3 and the Mercedes C 200, starting from processing the raw materials (cradle) and extending to the various manufacturing stages until the vehicles are prepared to leave the manufacturing facility (gate). The assessment will consider environmental impacts such as including energy consumption, greenhouse gas emissions, resource depletion, and potential pollution. By conducting a comprehensive comparison between an EV and a CEV, this assessment aims to provide valuable insights into the environmental performance differences during the manufacturing phase of the two vehicle types.

V. System Boundary

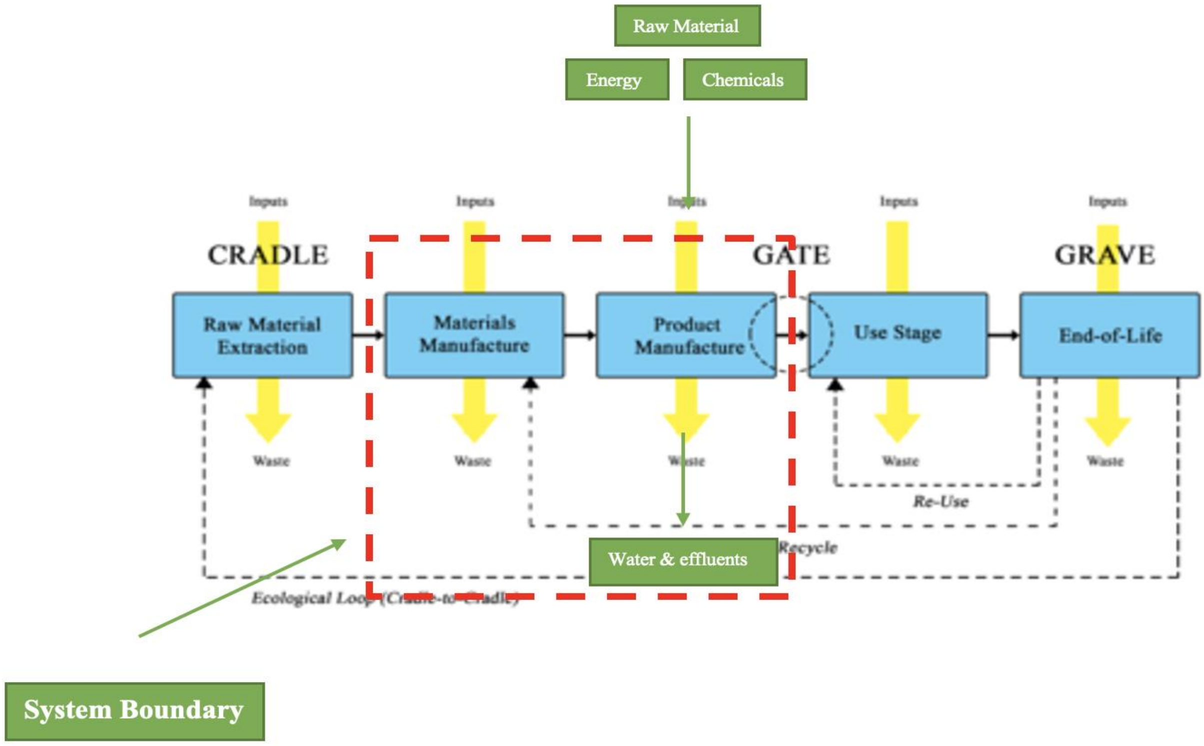

Figure 02: System Boundary

In this part of the project we listed most of the parts embedded in both cars and for simplicity we selected the parts which have more environmental and resource impact and which will have significant results when conducting our LCA.

The system boundaries are considered from processing the raw materials (cradle) and extending to the various manufacturing stages until the vehicles are prepared to leave the manufacturing facility (gate).

5.1 Main concepts in both vehicles.

1. Battery Pack
2. Electric Motor
3. Power Electronics
4. Vehicle Electric Unit
5. Body and chassis
6. Suspension system
7. Break system
8. Safety system
9. HVAC System

Tesla Model 3-2023 Long Range	Mercedes-Benz C200-2023
	
Battery Pack	Combustion Engine
Body and Chassis	Body and Chassis
Wiring Harness	Wiring Harness
Electric motor	Transmission
Other parts	Other parts
Lubricants(oil+water)	Lubricants(oil+water)

Table 01 (Main concepts)

5.1.1 Battery Pack and Fuel

- **Battery Pack**

It's worth noting that the composition of lithium-ion battery cells typically includes lithium, various metal oxides (such as cobalt, nickel, manganese), graphite, and electrolytes containing various solvents and salts. The energy consumption of the Model 3 Long Range can range from approximately 15 to 20 kWh per 100 kilometers, considering typical driving conditions and moderate climate control usage.The rough estimation of the battery pack in this model would be approximately **480kg.**

- **Fuel**

Mercedes: The specific hydrocarbon composition can vary depending on the refining process and regional fuel specifications. The fuel consumption of a Mercedes C200 can range from approximately 7 to 9 liters per 100 kilometers.The engine are commonly made from aluminum alloy weights around 400kg.The fuel tank capacity of the Mercedes Benz C200 typically falls within the range of approximately 41 to 66 liters. This indicates that when the fuel tank is completely filled, it can accommodate a quantity of fuel ranging from 41 to 66 liters.

5.1.2 Body and Chassis

Material	**Tesla Model 3**	**Weight Range (kg)**	**Mercedes-Benz C200 2023**	**Weight Range (kg)**
Steel	High-Strength, Low-Alloy (HSLA) Steel	104	High-Strength Steel	90
Aluminum	Structural Aluminum	360	Aluminum Alloy	362
Composite Materials	Carbon Fiber	52	Not commonly used	N/A
Total		**520**	**Total**	**452**

Table 02 Body and Chassis Materials

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	
Instrument Cluster	1-5	1-5

[illegible]	[illegible]	[illegible]
Suspension System	50-100	50-100
Braking System	20-50	20-50
Transmission	-	100
Differential	-	35
Battery	480	-
Engine	-	400(add alone in sustainable minds)
Others	350	280
Total	**1210**	**645**
Total weight of the car	**1730** **(body and chassis+Parts)**	**1505** **(body and chassis+parts+combustion engine)**

Table 03 Parts

Tesla - 60% steel (0.6*1210 = 726), **40 % Al (0.4*1210=484)** excluding **Electric motor which is made of copper (95kg)**
Mercedes 60% steel (0.6*645 = 387)40 % Al (0.4*645=258)

In addition to considering the manufacturing phase, the length of the chassis in the Tesla Model 3 and the Mercedes-Benz C200 also influences the environmental impacts of the body and chassis components. The length of the chassis affects factors such as material usage, energy consumption, and transportation requirements during manufacturing.

For instance, the Tesla Model 3 chassis, with a length of approximately 4.69 meters, requires a specific amount of materials for its construction. The choice of materials, such as steel, aluminum, or composites, along with their quantities, directly impacts the environmental burdens associated with material extraction, processing, and manufacturing. Assessing the environmental implications of the material quantities required for the chassis length contributes to a more accurate LCA of the manufacturing phase.

Similarly, the Mercedes-Benz C200 chassis, with a length ranging from approximately 4.59 to 4.70 meters, presents variations in material usage and manufacturing processes. The different lengths within this range may have implications for material waste, energy consumption, and even transportation logistics during the manufacturing phase. Conducting an LCA considering these variations in chassis length can provide insights into the environmental impacts associated with the specific lengths of the Mercedes-Benz C200 chassis.

By including the information on the chassis lengths of both the Tesla Model 3 and the Mercedes-Benz C200, the literature review on the manufacturing phase of body and chassis components acknowledges the significance of chassis length in assessing the environmental impacts associated with material usage, energy consumption, and transportation during manufacturing. Considering these variations helps in capturing the specific environmental considerations related to different chassis lengths in the context of the LCA analysis.

5.1.3 Wiring Harness

Mercedes C200 (Fuel):

The weight of the wiring harness in a conventional internal combustion engine (ICE) car like the Mercedes-Benz C200 generally falls within the range of approximately 45 to 75 pounds (15 to 21 kilograms). It's crucial to understand that this estimate is an approximate range and can vary based on factors such as the size of the vehicle, complexity of its electrical systems, length and gauge of the wires utilized, and other design considerations. It's worth noting that advancements in wire materials and design may contribute to weight savings in newer models.

Tesla Model 3 Long Range (Electricity):

The weight of the wiring harness in a typical electric vehicle (EV) like the Model 3 can range from approximately 30 to 70 pounds (13 to 32 kilograms). However, please note that this estimate is a general range and may not reflect the precise weight of the wiring in the Model 3.

The weight of the wiring in an EV can vary depending on factors such as the vehicle's size, complexity, electrical systems, and the length and gauge of the wires used. Additionally, advancements in wire materials and design may also contribute to weight savings.

5.1.4 Water Consumption & lubricants

Mercedes-Benz C200, the lubricants used for this vehicle range from approximately 5 to 6 liters (equivalent to 6000 grams) of 5w30 synthetic oil. These lubricants are necessary for the smooth operation and maintenance of the internal combustion engine in the C200.

Regarding water consumption, it is important to note that electric cars, including those equipped with lithium-ion batteries like the Tesla Model 3, generally have higher water consumption during their production compared to petrol cars. This difference stems from the manufacturing processes involved in producing lithium-ion batteries. The production of lithium-ion batteries for electric vehicles entails water-intensive activities such as mining, extraction, refining, and chemical synthesis. As a result, the precise amount of water consumed during battery manufacturing can vary based on factors like battery chemistry, production methods, and facility-specific practices. Estimates suggest that the water consumption for manufacturing electric vehicle batteries can range from approximately 200 to 400 liters per kilogram of battery produced. This higher water consumption is primarily associated with the specific requirements of battery production in electric vehicles, highlighting the importance of considering water usage when assessing the environmental impacts of different vehicle technologies.

Therefore, when comparing the Mercedes-Benz C200, which relies on conventional petrol technology, to electric vehicles like the Tesla Model 3, the water consumption during manufacturing will likely be higher for the electric vehicle due to the battery production processes involved.

VI. Impact assessment & Interpretation

Add a Part + | Add Sub-Assembly + | Import BOM +

Name	Material/Process	Qty	Amt	Unit	mPts	CO_2 eq. kg	MS	Part ID	
Combustion Engine-petrol	Methylcyclohexane	1	51.6	kg	14.7	260	E		No Processes available
Engine Oil	Lubricating oil, at plant	1	5460	g	0.857	6.66	E		No Processes available
Water Consumption	Demineralized water	1	140000	kg	12.1	144	E		No Processes available
Car Part 2		1	258	kg	974	$6.00x10^3$	E		Process +
Material	Aluminium, primary		258	kg	548	$3.25x10^3$	E		
Process	Drilling, CNC, aluminium		258	kg	426	$2.75x10^3$	E		
Car Part1		1	387	kg	$4.30x10^3$	$5.37x10^3$	E		Process +
Material	Stainless steel, austenitic		387	kg	$2.27x10^3$	$2.12x10^3$	E		
Process	Drilling, CNC, chromium		387	kg	$2.03x10^3$	$3.26x10^3$	E		
Wiring harness		1	21	kg	23.0	112	E		Process +
Material	Copper, primary		21	kg	18.9	47.5	E		
Process	Wire drawing, copper		21	kg	4.09	64.3	E		
Body and Chassis 2		1	362	kg	769	$4.55x10^3$	E		Process +
Material	Aluminium, primary		362	kg	769	$4.55x10^3$	E		
Process	Welding, arc, aluminum		4.699999809265137	m	0.345	1.04	E		
Body and Chassis 1		1	90	kg	101	157	E		Process +
Material	Steel, low-alloyed, marke		90	kg	99.7	156	E		
Process	Welding, arc, steel		4.699999809265137	m	0.851	0.687	E		
Combustion Engine Block		1	400	kg	$1.51x10^3$	$9.30x10^3$	E		Process +
Material	Aluminium, primary		400	kg	849	$5.03x10^3$	E		
Process	Drilling, CNC, aluminium		400	kg	661	$4.27x10^3$	E		
	Manufacturing total				$7.70x10^3$	$2.59x10^4$	E		

Figure 03: C200 Concept 02

Name	Material/Process	Qty	Amt	Unit	mPts	CO_2 eq. kg	MS	Part ID
Battery *It's worth noting that the compo*	Battery, LiIo, rechargeabl	1	480	kg	1.19×10^{4}	4.94×10^{4}	E	
Copy of Body and Chassis	Carbon fibre	1	52	kg	30.1	652	E	
Water Consumption	Demineralized water	1	192000	kg	16.6	197	E	
− Car Parts2		1	484	kg	1.83×10^{3}	1.13×10^{4}	E	
Material	Aluminium, primary		484	kg	1.03×10^{3}	6.09×10^{3}	E	
Process	Drilling, CNC, aluminium		484	kg	800	5.17×10^{3}	E	
− Car Parts1		1	726	kg	8.07×10^{3}	1.01×10^{4}	E	
Material	Stainless steel, austenitic		726	kg	4.27×10^{3}	3.97×10^{3}	E	
Process	Drilling, CNC, chromium		726	kg	3.80×10^{3}	6.11×10^{3}	E	
− Dual Electric Motor		1	95	kg	104	506	E	
Material	Copper, primary		95	kg	85.6	215	E	
Process	Wire drawing, copper		95	kg	18.5	291	E	
− Wiring		1	32	kg	35.1	170	E	
Material	Copper, primary		32	kg	28.8	72.4	E	
Process	Wire drawing, copper		32	kg	6.24	97.9	E	
− Body and Chassis 2		1	104	kg	116	181	E	
Material	Steel, low-alloyed, marke		104	kg	115	181	E	
Process	Welding, arc, steel		4.690000057220459	m	0.849	0.686	E	
− Body and Chassis		1	360	kg	765	4.53×10^{3}	E	
Material	Aluminium, primary		360	kg	765	4.53×10^{3}	E	
Process	Welding, arc, aluminum		4.690000057220459	m	0.344	1.04	E	
	Manufacturing total				2.28×10^{4}	7.69×10^{4}	E	

Figure 04: Tesla Model 3 Concept 01

Functional unit: 1 year of use Create a new Concept +	Impacts / functional unit **mPts/func unit**	CO_2 eq. kg / functional unit **CO_2 eq. kg/func unit**	Performance improvement from reference **mPts**	Performance improvement from reference **%**	Units of svc delivered **Svc. Units**	Assessment type
Reference  Electric Vehicle Car-Tesla Model 3 Long Range 2023 Copy Declare as: | Final	**2.3×10^{3}**	**7.7×10^{3}**			10	Estimate
Lowest impact  Petrol Vehicles-Mercedes Benz c-200 2023 Copy | Delete Declare as: Reference | Final	**770**	**2.6×10^{3}**	**$+1.5 \times 10^{3}$**	**+66%**	10	Estimate

Figure 05: Scorecard

Impacts per functional unit	**$2.3x10^3$** mPts per 1 year of use	**770** mPts per 1 year of use
Total amount of service delivered	**10 x 1 year of use**	**10 x 1 year of use**
Impacts of total service delivered	$2.3x10^4$ mPts	$7.7x10^3$ mPts
Assessment level	Estimate	Estimate
Greatest impacts		
SBOM input	Battery, LiIo, rechargeable, prismatic	Stainless steel, austenitic
Impact category	Ecotoxicity	Carcinogenics
Life cycle stage	Manufacturing	Manufacturing
Total impacts by impact category		

Impact category	%	Impact category	%
Ecological damage		**Ecological damage**	
Acidification	0.59	Acidification	0.66
Ecotoxicity	45.09	Ecotoxicity	4.19
Eutrophication	0.26	Eutrophication	0.3
Global warming	4.86	Global warming	4.85
Ozone depletion	0.19	Ozone depletion	0
Resource depletion		**Resource depletion**	
Fossil fuel depletion	1.73	Fossil fuel depletion	2.08
Human health damage		**Human health damage**	
Carcinogenics	42.24	Carcinogenics	81.22
Non carcinogenics	3.57	Non carcinogenics	4.75
Respiratory effects	1	Respiratory effects	1.44
Smog	0.47	Smog	0.52

We keep the Tesla Model 3's concept as the reference for the comparison.
Therefore, we get a positive performance improvement.

Notice that the C02 eq. Func. is far less in the fuel powered Mercedes C200 compared to the battery operated Tesla Model 3. We will further reason out in the interpretation section

Ecological Damage:
Acidification: Both the Tesla Model 3 and Mercedes C200 have similar levels of acidification impacts, with Tesla at 0.59% and Mercedes at 0.86%.
Ecotoxicity: The Tesla Model 3 shows significantly higher ecotoxicity impacts at 45.09% compared to Mercedes, which has ecotoxicity impacts of 4.19%.
Eutrophication: Both vehicles have identical eutrophication impacts at 0.36%.
Global Warming: Similar levels of global warming impacts are observed, with Tesla at 4.86% and Mercedes at 4.85%.
Ozone Depletion: Tesla has a slightly higher ozone depletion impact at 0.19% compared to Mercedes, which has an impact of 0.0%.

Resource Depletion:
Fossil Fuel Depletion: Tesla has a higher fossil fuel depletion impact at 1.73% compared to Mercedes, which has an impact of 2.08%.

Human Health Damage:
Carcinogens: Mercedes exhibits significantly higher carcinogenic impacts at 81.22% compared to Tesla's 42.24%.
Non-carcinogens: Mercedes also has higher non-carcinogenic impacts at 4.75% compared to Tesla's 3.57%.
Respiratory Effects: Tesla has lower respiratory effects at 1.00% compared to Mercedes, which has an impact of 1.44%.
Smog: Both vehicles have relatively similar smog impacts, with Tesla at 0.47% and Mercedes at 0.52%.
Overall, the comparison reveals some notable differences between the Tesla Model 3 and the Mercedes C200 in terms of their ecological and human health impacts. The Tesla Model 3 shows higher ecotoxicity impacts,

indicating potential risks to ecosystems, while the Mercedes C200 has significantly higher impacts in terms of carcinogens and non-carcinogens, suggesting greater potential risks to human health.

In terms of resource depletion, the Tesla Model 3 has a slightly higher impact on fossil fuel depletion. This can be attributed to the fact that the Tesla Model 3 is an electric vehicle powered by electricity, which may be generated from fossil fuel sources depending on the region, while the Mercedes C200 utilizes traditional combustion engines.

VII. Conclusion

In conclusion, the cradle to gate Life Cycle Assessment (LCA) comparing the environmental impacts of the Tesla Model 3 (EV) and the (combustion engine-driven vehicle) during the manufacturing phase has revealed significant differences in their environmental performance. The assessment considered various factors such as materials used, manufacturing processes, energy consumption, and emissions.

The findings of the LCA indicate that the Mercedes C 200 has a notably lower environmental impact during the manufacturing phase compared to the Tesla Model 3. Sustainable Minds reports an impressive 66% improvement in environmental impact for the C200 during manufacturing, underscoring the benefits of electric vehicle technology. This improvement can be attributed to several factors, including materials used to manufacture the car, which contribute to lower greenhouse gas emissions and reduced resource depletion compared to the Tesla Model 3(EV) .

Based on the information you provided, if the Sustainable Minds software specifically indicates that the Mercedes Benz C200 has a lower environmental impact than the Tesla Model 3 during the manufacturing phase, it suggests a different outcome from the general understanding of electric vehicles' lower environmental impact. However, please note that as an AI language model, I don't have access to specific data or real-time information from Sustainable Minds or any other software.

It's important to recognize that life cycle assessments (LCAs) can vary based on the methodology, data sources, and assumptions used. Therefore, different studies or software tools may yield different results. If Sustainable Minds, in your context, indicates that the Mercedes Benz C200 has a lower environmental impact during the manufacturing phase, it implies that the specific LCA conducted by Sustainable Minds has yielded those findings.

However, it's essential to consider the broader context and existing research on electric vehicles and their environmental benefits. Numerous studies have shown that electric vehicles, including the Tesla Model 3, generally have lower greenhouse gas emissions and reduced environmental impacts during the manufacturing phase compared to combustion engine vehicles. This is primarily due to the lower emissions associated with battery production compared to internal combustion engine components and the use of more sustainable materials.

To better understand the specific findings of Sustainable Minds or other software tools, it would be necessary to review the methodology, data sources, and assumptions used in their analysis. This will provide a more comprehensive understanding of the differences and help contextualize their conclusions.

It is important to acknowledge that the LCA has certain limitations and assumptions, and the specific environmental performance may vary among different vehicle models and manufacturers. Additionally, the scope of this assessment focused solely on the manufacturing phase, and a comprehensive life cycle analysis would provide a more holistic understanding of the overall sustainability of both vehicle types.

Nevertheless, the results of this LCA provide valuable insights for decision-makers in the automotive industry, supporting the adoption of sustainable practices and the transition towards greener transportation options. Continued research and assessment efforts will further enhance our understanding of the environmental impacts of EVs and combustion engine vehicles, enabling informed choices for a more sustainable and environmentally friendly automotive sector.

References

[1]. https://lowvelder.co.za/775923/are-electric-cars-water-thirsty/

[2]. Bhardwaj, S., Pandey, R., Sharma, S., Sejal, S., Iyer, G., Sharma, S., Ranjith, P.V. and Kulkarni, S., 2020. Problems faced by automobile industries: Case study on Tesla. International journal of Tourism and hospitality in Asia Pasific (IJTHAP), 3(2), pp.78-88.

[3]. Wu, L. and Yang, W., 2017. Tackling Supply Chain Challenges of Tesla Model 3. In SAGE Business Cases. NeilsonJournals Publishing.

[4]. Gui, G., 2019. Carbon Footprint Study of Tesla Model 3. In E3S Web of Conferences (Vol. 136, p. 01009). EDP Sciences.

[5]. Martin, D.P. and Unsworth, J.F., 2002. The M111 Engine CCD and Emissions Test: Is it Relevant to Real-World Vehicle Data?. SAE Transactions, pp.2186-2193.

[6]. https://en.wikipedia.org/wiki/Tesla_Model_3

[7]. https://www.carexpert.com.au/mercedes-benz/c200/2023-base-model-0c0035f7#:~:text=The%20C200%20measures%201402mm%20(55.2,3318.0%20lbs)%20of%20unladen%20weight.