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CIÊNCIAS EXATAS E DA TERRA

Study of anthropogenic emissions in the life cycle of Body in White manufactured in new generation steels

Estudo de emissões antropogênicas no ciclo de vida de Carroceria Veicular fabricada em aços de nova geração

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ABSTRACT

The objective of this article is to evaluate the life cycle of vehicles with a B-Body developed in new-generation steels (New BIW), compared to currently used steels (Current BIW), aiming to reduce vehicle mass and anthropogenic emissions. The method was based on the estimation of anthropogenic emissions through simulation in the GREET2.7 Module, where the life cycle of vehicles with a Body developed in new-generation steels (New BIW), which have greater mechanical strength, was compared to BIW in currently used steels (Current BIW), which have lower mechanical strength, aiming to reduce vehicle mass and its respective emissions. As a result, a 2.65% reduction in vehicle mass was obtained, which resulted in a reduction of 0.11 tons of greenhouse gases. Just as, in the comparison of simulated emissions, between the current BIW and the new one, there is a reduction in total GHG emissions of 2.8% during the life cycle of the materials, of 3.6% during the life cycle of the Body of vehicles (BIW, interior, exterior and windows), 2.04% over the complete life cycle of vehicles and 0.78 ℓ/100 km of consumption. The conclusions show that the mass reduction of vehicles developed in new generation steels (New BIW) provides a significant change with regard to anthropogenic emissions, mainly in the vehicle use phase, due to the reduction in the burning of fossil fuels and the study provides an important decision-maker regarding the mitigation of global warming, as it is essential to recognize that motor vehicles are significant air polluters.

Keywords: Body in White; Life cycle analysis; Anthropogenic emissions; New generation steels; Simulation; Consumption.

RESUMO

O objetivo deste artigo é avaliar o ciclo de vida de veículos com carroceria veicular desenvolvida em aços de nova geração (Novo BIW), em comparação com os aços atualmente utilizados (BIW Atual), visando a redução da massa do veículo e das emissões antropogênicas. O método foi baseado na estimativa de emissões

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antropogênicas por meio de simulação no Módulo GREET2.7, onde o ciclo de vida de veículos com Carroceria desenvolvida em aços de nova geração (Novo BIW), que possuem maior resistência mecânica, foi comparado com o BIW em aços atualmente utilizados (BIW Atual), que possuem menor resistência mecânica, com o intuito de reduzir a massa do veículo e suas respectivas emissões. Como resultado, obteve-se uma redução de 2,65% na massa do veículo, resultando em uma diminuição de 0,11 toneladas de gases de efeito estufa. Da mesma forma, na comparação das emissões simuladas entre o BIW Atual e o Novo, observa-se uma redução nas emissões totais de GEE de 2,8% durante o ciclo de vida dos materiais, de 3,6% durante o ciclo de vida da Carroceria de veículos (BIW, interior, exterior e vidros), 2,04% ao longo do ciclo de vida completo dos veículos e 0,78 ℓ/100 km de consumo. As conclusões mostram que a redução de massa de veículos desenvolvidos em aços de nova geração (Novo BIW) proporciona uma mudança significativa em relação às emissões antropogênicas, principalmente na fase de uso do veículo, devido à redução na queima de combustíveis fósseis. O estudo fornece informações importantes para tomadores de decisão no que diz respeito à mitigação do aquecimento global, uma vez que é essencial reconhecer que os veículos automotores são poluentes significativos do ar.

Palavras-chave: *Carroceria veicular; Análise de Ciclo de Vida; Emissões Antropogênicas; Aços de Nova Geração; Simulação; Consumo.*

1. INTRODUCTION

The transportation sector is a significant contributor to greenhouse gas (GHG) emissions, accounting for approximately one-quarter of global emissions. The automotive industry, in particular, has a significant impact on the environment, not only during the use phase but also in the manufacturing and end-of-life stages of a vehicle's lifecycle. One of the key factors influencing a vehicle's environmental impact is its weight, particularly the weight of its Body-in-White (BIW) structure. The BIW structure is the backbone of a vehicle, providing structural support and crash protection. However, the weight of the BIW structure can significantly impact a vehicle's fuel efficiency and GHG emissions. Therefore, there is a growing interest in developing lightweight BIW structures and using low-carbon materials to reduce the environmental impact of vehicles.

One approach is to use stronger materials, such as dual-phase steels, in the fabrication of the BIW structure. These materials are typically more expensive than carbon steel, but they can help to reduce the weight of the vehicle and lower its overall GHG emissions.

Similarly, the manufacturing processes used to assemble a BIW structure can have a significant impact on GHG emissions. Implementing more efficient production processes, using renewable energy sources, or reducing the amount of scrap material generated during production can all help to reduce emissions associated with BIW manufacturing.

Finally, designing vehicles with a lighter overall weight can also help to reduce GHG emissions associated with the vehicle's use phase. This can be accomplished through a variety of methods, such as using lighter weight components, optimizing the vehicle's aerodynamics, or reducing the overall size of the vehicle.

While there may be a general relationship between the mass of a BIW structure and its GHG emissions, a variety of factors, including the specific materials and manufacturing processes used, can also have a significant impact on emissions. To reduce the environmental impact of BIW

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production, automakers must consider the entire life cycle of the materials and processes used, and strive to implement more sustainable and efficient practices throughout the manufacturing process.

This paper aims to evaluate the life cycle of vehicles with Body in White developed in new generation steels (New BIW), in comparison to the current steels used (Current BIW), in order to reduce the mass of the vehicle and anthropogenic emissions.

2. METHODS

The methodology of this study was based on the estimation of anthropogenic emissions through simulation in Module GREET2.7, where the life cycle of vehicles with BIW developed in new generation steels (New BIW) was compared with BIW in steels currently used (Current BIW), in order to reduce the mass of the vehicle and its respective emission. The vehicle lifecycle module (GREET2.7) was developed by Argonne National Laboratory, with the model of greenhouse gases, regulated emissions and energy use in transport. This module was used in this study in order to evaluate the emission associated with the recovery and production of materials, manufacture of vehicle components, vehicle assembly and vehicle disposal/recycling. With regard to vehicle assembly, Argonne's analysis used data from an energy use survey of US assembly plants that contained welding, painting, and body assembly operations. The research collected three years of data from 35 factories, with the participation of the American affiliates of GM, Ford, Honda, Toyota and Subaru (Boyd, 2005).

Emissions were analyzed using the following parameters: ICEV vehicle (Conventional Material - vehicle with an internal combustion engine), conventional material and passenger car 1.

Initially, the total masses of the current vehicle (1083 kg) and the new one (1055 kg) were transformed into pounds and then replaced in the "Car" worksheet in item 9 - "Vehicle Time Series Data and in the sub-item "Current vehicle weight sans battery and fluids (lbs)." From this, the automatic calculation operation of the GREET 2.7 equations was carried out in order to obtain an estimate of the anthropogenic emission of the current vehicle.

The results of the anthropogenic emission estimate were obtained from the Vehi_Comp_Sum and Vehi_Sum spreadsheets.

In the Vehi_Comp_Sum worksheet, which refers to the Summary of Energy Consumption and Emissions for Vehicle Components, the results were obtained through items 2 (Summary of Energy Consumption and Emissions for Vehicle Materials: per-vehicle lifetime) and 3 (Summary of Energy Consumption and Emissions by Vehicle Component: per-vehicle lifetime). For both items, the gases in Table 1 were analyzed.

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Table 1 – Gases analyzed in GREET2.7.

Total emissions: (grams per vehicle life)	**Urban emissions: (grams per vehicle life)**
VOC	VOC
CO	CO
NO_x	NO_x
PM_{10}	PM_{10}
$PM_{2.5}$	$PM_{2.5}$
SO_x	SO_x
BC	BC
OC	OC
CH_4	
N_2O	
CO_2	
CO_2 (VOC, CO, CO_2)	
GHG	

Source: Prepared by the author.

The difference between the items in the worksheet is the way in which the results are obtained. While item 2 is related to the material, item 3 is related to emissions per vehicle component. In this case, only emissions related to the body of the vehicle (BIW, interior, exterior and glass) were verified.

For the Vehi_Sum spreadsheet, which refers to the Energy Use and Emissions of Vehicle Cycle, the following items were used: 1 - Summary of Energy Consumption and Emissions: mmBtu or grams per-vehicle lifetime and 2 - Summary of Energy Consumption and Emissions of Vehicle Cycles: Btu or grams per mile.

For items 1 and 2, the following data on energy consumption and gas emissions were analyzed:

Power consumption (mmBtu):

- Total energy; Fossil fuels; Coal; Natural gas; Petroleum; Water consumption;

Gas Emissions (grams/vehicle life and grams/mile):

- CO_2: Total; CO_2 (VOC, CO, CO_2): Total; CH_4: Total; N_2O: Total; GHG: Total; VOC: Total; CO: Total; NO_x: Total; PM_{10}: Total; $PM_{2.5}$: Total; SO_x: Total; BC: Total; OC: Total; VOC: Urban; CO: Urban; NO_x: Urban; PM_{10}: Urban; $PM_{2.5}$: Urban; SO_x: Urban; BC: Urban; OC: Urban.

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The difference between the items resides in the fact that item 2 has its value obtained from item 1 divided by the useful life of the vehicle of 173,151 miles. The useful life value, used by GREET2.7, comes from the estimated sales of American vehicles between the years 1991 to 2015, obtained from VISION (GREET 2.7, 2017).

Among gas emissions, it is noteworthy that pollutants are separated into total and urban emissions, where total emissions are emissions that occur everywhere, while urban emissions are a subset of total emissions that occur in urban areas. In GREET, urban areas are metropolitan areas with a population greater than 125,000, as defined by the US Bureau of the Census. The separation of pollutant emission criteria is a step towards providing some information about potential human exposure to pollutant emission (Brinkman et al., 2005).

The second analysis followed the same procedure, but involved the vehicle with a mass reduction (new) and a reduction in the percentage of steel present in the vehicle, from 65.3% to 64.1%, as shown in Table 2.

The reduction of the percentage of steel present in the vehicle was obtained by reducing the BIW mass by 28 kg (Current 157 kg - New 129 kg) referring to the reduction in the thickness of the steel plates in the new BIW.

Thus, in the Car spreadsheet, in item 7 (Material Composition for Each Passenger Car Component, % by wt) the change in percentage was performed to the obtained value of 64.1% and, thus, the emissions data referring to this analysis, were obtained automatically.

Table 2 – Percentage of steel used for body simulation of current and new vehicles.

Material	Current	New	Variation
Steel	65.3%	64.1%	-1.9%
Wrought Aluminum	3.1%	3.1%	0.0%
Cast Aluminum	0.2%	0.2%	0.0%
Copper/Brass	1.9%	1.9%	0.0%
Zinc	0.0%	0.0%	0.0%
Magnesium	0.0%	0.0%	0.0%
Glass Fiber-Reinforced Plastic	0.8%	0.8%	0.0%
Glass	4.4%	4.4%	0.0%
Carbon Fiber-Reinforced Plastic	0.0%	0.0%	0.0%
Average Plastic	21.7%	21.7%	0.0%
Rubber	1.8%	1.8%	0.0%
Others	0.9%	2.1%	+1.2%

Source: Prepared by the autor.

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3. RESULTS

Table 3 and figures 1 and 2 shows the results regarding emissions in the life cycle of materials for current and new vehicles, obtained in GREET2.7, resulting in emission reductions between 2.5 and 3.4%, respectively.

Emissions during the life cycle of the current and new vehicle Body (BIW, interior, exterior and glass) are presented in table 4 and in figures 3 and 4, where reductions in emissions between 2.9 and 4 can be observed, 3%.

Table 5 and figures 5 and 6 shows the emissions during the complete life cycle of the current and new vehicles, where reductions of up to 3.2% in gas emissions and a carbon footprint of 5.60 tons can be observed in the vehicle's life cycle for the current one and 5.49 tons for the new one.

Table 3 – Results referring to emissions in the life cycle of materials for current and new vehicles.

	Gases	Current (grams/vehicle life cycle)	New (grams/vehicle life cycle)	Reduction (%)
Total Emissions	VOC	2,828.50	2,750.38	2.8
	CO	14,144.93	13,665.24	3.4
	NO_x	4,051.28	3,938.46	2.8
	PM_{10}	1,519.79	1,472.37	3.1
	$PM_{2.5}$	793.70	769.34	3.1
	SO_x	10,690.91	10,357.94	3.1
	BC	19.64	19.14	2.5
	OC	47.41	46.12	2.7
	CH_4	8,840.90	8,595.95	2.8
	N_2O	108.44	105.58	2.6
	CO_2	3,534,175	3,433,596	2.8
	CO_2 (VOC, CO, CO_2)	3,565,218	3,463,642	2.8
	GHG	3,896,381	3,785,697	2.8
Urban Emissions	VOC	33.60	32.77	2.5
	CO	156.27	151.98	2.7
	NO_x	293.30	285.11	2.8
	PM_{10}	28.40	27.60	2.8
	$PM_{2.5}$	23.55	22.89	2.8
	SO_x	249.69	242.55	2.9
	BC	1.24	1.21	2.7
	OC	5.26	5.11	2.8

Source: Prepared by the author.

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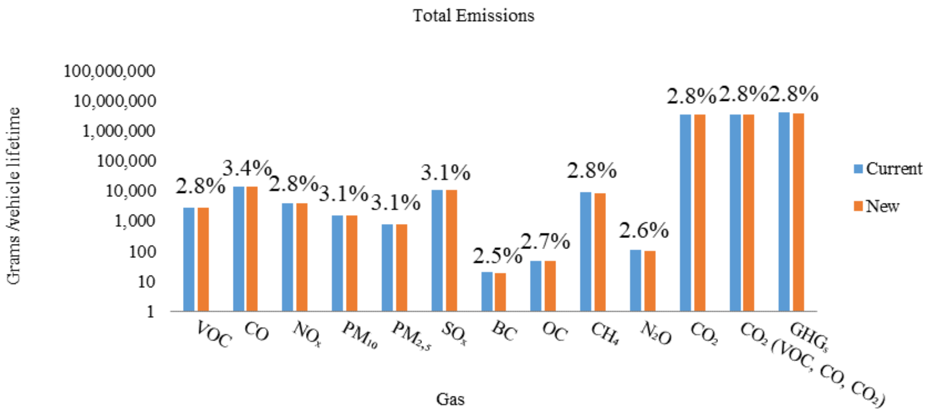
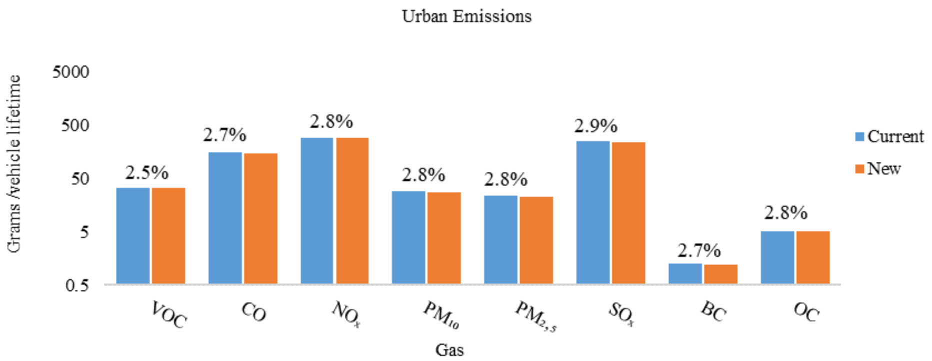
Figure 1 – Variation of total emissions in the material life cycle of current and new vehicles.



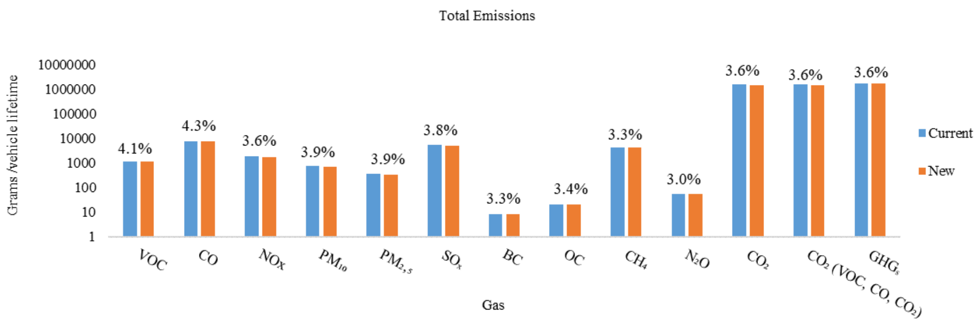
Source: Prepared by the author.

Figure 2 – Variation of urban emissions in the material life cycle of current and new vehicles.



Source: Prepared by the author.

Figure 3 – Variation of total emissions in the life cycle of the current and new vehicles Body (BIW, interior, exterior and windows).



Source: Prepared by the author.

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Table 4 – Results referring to emissions in the vehicle body's life cycle (BIW, interior, exterior and glass) current and new.

	Gases	**Current Emissions (grams/body lifecycle)**	**New Emissions (grams/body lifecycle)**	**Reduction (%)**
Total Emissions	VOC	1,182.91	1,134.20	4.1
	CO	7,629.50	7,302.19	4.3
	NO_x	1,825.48	1,760.49	3.6
	PM_{10}	742.98	713.70	3.9
	$PM_{2.5}$	358.64	344.50	3.9
	SO_x	5,255.48	5,054.33	3.8
	BC	8.39	8.10	3.3
	OC	21.04	20.32	3.4
	CH_4	4,430.62	4,285.09	3.3
	N_2O	54.55	52.93	3.0
	CO_2	1,559,996	1,503,227	3.6
	CO_2 (VOC, CO, CO_2)	1,575,672	1,518,237	3.6
	GHG	1,731,345	1,668,896	3.6
Urban Emissions	VOC	16.23	15.76	2.9
	CO	69.73	67.47	3.2
	NO_x	127.49	123.27	3.3
	PM_{10}	12.06	11.65	3.3
	$PM_{2.5}$	10.05	9.71	3.3
	SO_x	102.54	99.06	3.4
	BC	0.53	0.51	3.2
	OC	2.31	2.23	3.4

Source: Prepared by the author.

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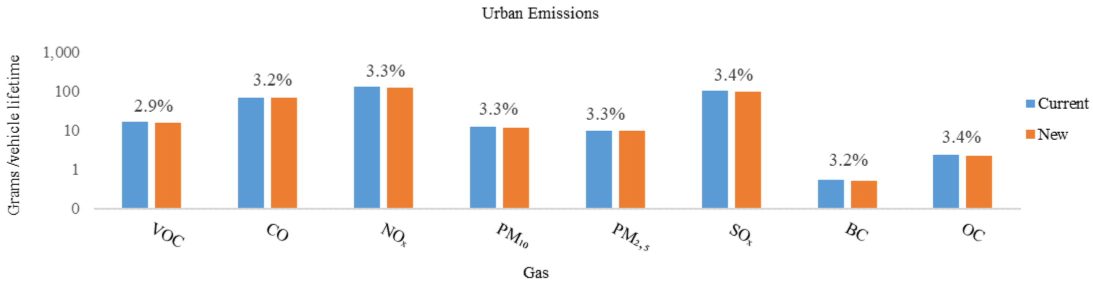
Figure 4 – Variation of urban emissions in the life cycle of the current and new vehicles Body (BIW, interior, exterior and windows).



Source: Prepared by the author.

Table 5 – Results referring to emissions in the complete life cycle of current and new vehicles.

		Current		New		
	Gases	**Grams per vehicle lifetime**	**Grams per mile**	**Grams per vehicle lifetime**	**Grams per mile**	**Difference (%)**
Total Emissions	VOC	32,050.93	0.185	31,972.37	0.1847	0.24
	CO	14,993.32	0.087	14,512.06	0.0838	3.21
	NO_x	5,757.30	0.033	5,641.63	0.0326	2.00
	PM_{10}	1,842.34	0.011	1,794.50	0.0104	2.59
	$PM_{2.5}$	972.53	0.006	947.93	0.0055	2.52
	SO_x	13,002.79	0.075	12,667.29	0.0732	2.58
	BC	30.618	0.00018	30.10	0.0002	1.67
	OC	71,148	0.0004	69.80	0.0004	1.89
	CH_4	12,545.43	0.072	12,292.61	0.0710	2.01
	N_2O	145.31	0.001	142.37	0.0008	2.02
	CO_2	5,031,209	29	4,926,922	28.45	2.07
	CO_2 (VOC, CO, CO_2)	5,154,662	30	5,049,374	29.16	2.04
	GHG	5,606,284	32	5,491,634	31.71	2.04
Urban Emissions	VOC	19,229.05	0.111	19,228.19	0.11	0.004
	CO	289.54	0.002	284.90	0.001	1.60
	NO_x	748.72	0.004	739.79	0.004	1.19
	PM_{10}	99.71	0.001	98.82	0.0006	0.88
	$PM_{2.5}$	67.00	0.00039	66.27	0.0004	1.09
	SO_x	1,026.06	0.006	1,018.14	0.0059	0.77
	BC	4.14	0.000024	4.10	0.0000	0.89
	OC	9.97	0.00006	9.80	0.0001	1.67

Source: Prepared by the author.

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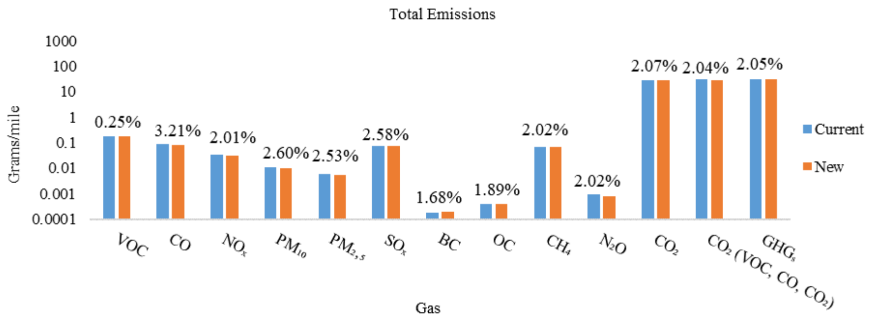
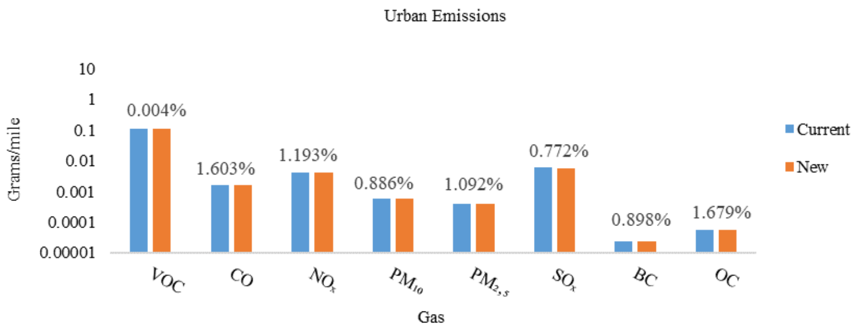
Figure 5– Variation of total emissions in the complete life cycle of current and new vehicles (BIW, interior, exterior and windows).



Source: Prepared by the author.

Figure 6– Variation of urban emissions in the complete life cycle of current and new vehicles (BIW, interior, exterior and windows).



Source: Prepared by the author.

Total energy, fossil fuels (coal, natural gas and oil) and water consumption in the new BIW showed reductions of up to 2.8% when compared to the current one (table 6 and figure 7).

Table 6 – Results referring to the consumption of energy, fossil fuels and water in the complete life cycle of current and new vehicles.

	Current		**New**		
Gases	**Grams per vehicle lifetime**	**Grams per mile**	**Grams per vehicle lifetime**	**Grams per mile**	**Reduction (%)**
Total energy	81.53	470.88	79.94	461.69	1.9
Fossil fuels	73.41	424	72.01	415.92	1.9
Coal	21.37	123	20.76	119.94	2.8
Natural gas	36.04	208	35.41	204.52	1.8
Petroleum	15.99	92	15.83	91.45	1.0
Water consumption	7,408	0.043	7,227	0.041	2.4

Source: Prepared by the author.

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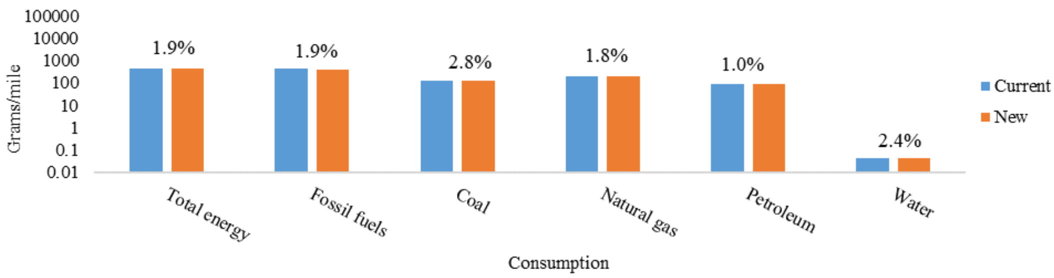
Figure 7– Total energy consumption, fossil fuels, coal, natural gas, oil and water in the complete life cycle of current and new vehicles (BIW, interior, exterior and windows).



Source: Prepared by the author.

4. DISCUSION

In this study, both the emissions in the life cycle of the materials, as well as those of the Body (BIW, interior, exterior and glass) and complete vehicles of the new BIW show reductions when compared to the current BIW, either in total emissions or in emissions urban.

The evaluation of the results obtained in the context of this study showed the presence of anthropogenic emissions totaling 5.60 tons over the life cycle of the vehicle, considering the current state of Body-in-White (BIW) for total emissions, that is, those that occur anywhere. However, when performing a direct comparison with the results derived from the use of the new BIW, a global decrease in anthropogenic emissions to 5.49 tons was found. This reduction represents approximately 2%, equivalent to 0.11 tons of anthropogenic emissions, during the vehicle's life cycle. Likewise, urban emissions tend to reduce emissions when comparing the current with the new, but have a smaller representation when compared to total emissions (table 5).

When comparing these findings with the research conducted by Refiadi et al. (2019), there is a remarkable similarity in the results. In fact, in that study, the author found that a reduction of 12.6% in the mass of the vehicle enabled a reduction of up to 3.6 tons of carbon dioxide (CO_2).

In line with these findings, the results of this study converge with the studies by Du et al. (2010), who demonstrated that a 17.7% reduction in vehicle weight contributed to a decrease of 9.5 liters per-100 km traveled (equivalent to 3.54 g/mile of CO_2). Extrapolating these numbers to a lifecycle of 173,151 miles results in a savings of 0.61 tons of CO_2. The present study, when reporting a 2.65% reduction in vehicle mass, resulted in a decrease of 0.11 tons of greenhouse gases (GHG).

Additionally, it is worth mentioning the study conducted by Tomazi (2021), which recorded a significant reduction of 480 kg in vehicle mass. This weight reduction resulted in a marked decrease of 28.64 grams per mile in carbon dioxide (CO_2) emissions, equivalent to approximately a 30% reduction in weight for a 10% decrease in emissions. In the scenario of this case study, there is a decrease of 2.65% in vehicle mass (equivalent to 28 kg) and an estimated reduction of about 0.29 grams per mile in emissions. Therefore, it is valid to state that both studies presented congruent results, taking into account the respective investigated values.

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Isenstadt et al. (2016) concluded in their studies that a reduction of about 10% in vehicle mass results in an approximate decrease of 5% in gasoline consumption. In a similar context, Helms et al. (2006) observed a 100 kg reduction in vehicle weight, resulting in a decrease in gasoline consumption of about 0.35 ℓ/100 km.

When analyzing the impact of weight reduction on fossil fuel consumption (Table 6) in the present study, a reduction of 0.78 ℓ/100 km was observed from the reduction of 28 kg. In other words, in this study the percentage reduction per kilogram is in line with expectations.

With regard to the analysis of fuel economy, the study conducted by Sun et al. (2019) evaluated the weight reduction of the BIW from 430 kg to 344 kg, i.e., a reduction of 86 kg, which resulted in a fuel economy of 653.3 liters over the entire life cycle (200,000 km) of the vehicle.

Similar studies, such as those by Simplay et al. (2016), Brooker et al. (2013) and Cheah (2010) present correlated data, indicating that a decrease of up to 25% in weight results in 10% fuel savings. Contributing to this perspective, research carried out by different authors, including Fontaras et al. (2017), Pervaiz et al. (2016), Mayyas et al. (2012) and Kulkarni et al. (2018), also highlight the relationship between the variation in vehicle mass and the consequent decrease in CO_2 emissions. These studies suggest that weight loss between 50 kg and 200 kg can generate a reduction in CO_2 emissions of around 6.5 g/km to 12 g/km, considering different conditions and operating cycles.

Therefore, based on the results of this study and evidence previously found in related research, it can be concluded that vehicle weight reduction plays a significant role in mitigating anthropogenic emissions.

5. CONCLUSION

This study performed a comparative analysis of anthropogenic emissions over the life cycle of body-in-white vehicles with different masses, allowing the identification of important trends and environmental benefits.

- A 2.65% reduction in vehicle mass resulted in a reduction of 0.11 tons of greenhouse gases;
- Comparing the simulated emissions in GREET 2.7 between the current and new BIW, there was a reduction in total GHG emissions of 2.8% over the life cycle of the materials, 3.6% over the life cycle of the body (BIW, interior, exterior, and windows), and 2.04% over the entire life cycle of the vehicle;
- Vehicle fuel consumption was reduced by 0.78 ℓ/100 km as a result of the 28 kg mass reduction;
- The weight reduction of vehicles developed with new-generation steels (New BIW) provides a significant reduction in anthropogenic emissions, particularly during the vehicle's in-use phase, due to the reduction in fossil fuel combustion.

In practical terms, these findings reinforce the relevance of weight reduction strategies as an effective way for the automotive sector to meet international decarbonization targets and energy efficiency regulations. The adoption of high-strength steels allows manufacturers to balance

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structural integrity, passenger safety, and emissions performance without drastically redesigning vehicle architectures. Furthermore, this approach can support industrial competitiveness by aligning product development with environmental policies and market trends toward sustainable mobility.

However, it is important to note that limitations of the method include the use of the GREET 2.7 simulation model, which is parameterized based on pre-existing manufacturing data. Therefore, the results may not fully reflect regional variations in energy matrices, vehicle use patterns, or material recycling processes in other contexts. Furthermore, the analysis focused on CO_2-equivalent emissions and did not include a comprehensive assessment of the economic or social impacts associated with the transition to advanced materials.

Despite these limitations, the study provides a solid foundation for future research and decision-making in the automotive sector, demonstrating that reducing vehicle mass through new-generation steels is a viable and measurable strategy for mitigating greenhouse gas emissions and promoting more sustainable mobility.

6. REFERENCES

BOYD, G. A. *et al*. Development of a Performance-based Industrial Energy Efficiency Indicator for Automobile Assembly Plants. **USA: Argonne National Laboratory**, 2005. (ANL/DIS-05-3).

BRINKMAN, N.; WANG, M.; WEBER, T.; DARLINGTON, T. Well-to-Wheels Analysis of Advanced Fuel/Vehicle Systems - A North American Study of Energy Use, **Greenhouse Gas Emissions, and Criteria Pollutant Emissions**, 2005.

BROOKER, A. D. *et al*. Lightweighting Impacts on Fuel Economy, Cost, and Component Losses. In: SAE WORLD CONGRESS AND EXHIBITION, 2013, Usa. Conference. [SL]: **Anais Sae Internacional**, 2013. p. 1-10..

CHEAH, L. W. **Cars on a diet: the material and energy impacts of passenger vehicle weight reduction in the US**. 2010. Thesis. Massachusetts Institute of Technology, Massachusetts, 2010.

DU, JD *et al*. Potential for reducing GHG emissions and energy consumption from implementing the aluminum intensive vehicle fleet in China. **Elsevier BV**,v. 35, n. 12, p. 4671-4678,2010.Disponivel em: http://dx.doi.org/10.1016/j.energy.2010.09.037 . Acesso em: 24 out.2023.

FONTARAS, G. *et al*. Fuel consumption and CO 2 emissions from passenger cars in Europe – Laboratory versus real-world emissions. Progress In Energy and Combustion Science. **Elsevier BV**, v. 60, p. 97-131, 2017.Disponivel em: http://dx.doi.org/10.1016/j.pecs.2016.12.004 . Acesso em: 24 out.2023.

GREET 2.7, COPYRIGHT 2017, US Department of Energy laboratory managed by UChicago Argonne, LLC. ANL/ESD/06-5 **Development and Applications of GREET 2.7 — The Transportation Vehicle-Cycle Model** [BURNHAM, A. et al. Development and Applications of GREET 2.7: the transportation vehicle-cycle model. USA: Argonne National Laboratory, 2006. 124 p. (ANL/ESD/06-5).]

DOI: http://dx.doi.org/10.15536/thema.V24.2025.3565
ISSN: 2177-2894 (online)

HELMS, H.; LAMBRECHT, U. The potential contribution of light-weighting to reduce transport energy consumption. **Int. J. Life Cycle Assess**, v. 12, n. 1, p. 58-64, 2007.

ISENSTADT, A. *et al*. Lightweighting technology development and trends in US passenger vehicles. **International Council on Clean Transportation working paper,** v. 25, n. 25, 2016.

KULKARNI, S. *et al*. Evaluation of vehicle lightweighting to reduce greenhouse gas emissions with focus on magnesium substitution. **Journal Of Engineering: Design and Technology**, Aaa, v. 12, n. 6, p. 869-888, 2018.

MAYYAS, A.T.; QATTAWI, A.; MAYYAS, A. R.; OMAR, M. A. Life cycle assessment-based selection for a sustainable lightweight body-in-white design. **Energy** v.39, p.412-425,2012.

PERVAIZ, M.; PANTHAPULAKKAL, S.; KC, B.; SAIN, M.; TJONG, J. Emerging Trends in Automotive Lightweighting through Novel Composite Materials. Materials Sciences and Applications. **Scientific Research Publishing,** v. 07, n. 1, p. 26-38, 2016.Disponível em**:** http://dx.doi.org/10.4236/msa.2016.71004 .Acesso em: 24 out.2023.

REFIADI, G. *et al*. Trends in Lightweight Automotive Materials for Improving Fuel Efficiency and Reducing Carbon Emissions. Automotive Experiences. **Universitas Muhammadiyah Magelang**, v. 2, n. 3, p. 78-90, 26 Oct. 2019. Disponpivel em http://dx.doi.org/10.31603/ae.v2i3.2984. Acesso em:24 out.2023.

SIMPLAY, S. *et al*. Architecting Next Generation Lightweight Vehicles. **USA: Tata Technologies**, 2016,14 p.

SUN, X.; MENG, F.; LIU, J.; M. CKECHNIE, J.; YANG, J. Life cycle energy use and greenhouse gas emission of lightweight vehicle and A body-in-white design. **Journal of Cleaner Production** v.220, p. 1 – 8, 2019.

TOMAZI, B. A. *et al*. PERFORMANCE ANALYSIS OF A VEHICLE DUE TO INCREASE IN MASS. 2021. 61 f. Monografia (Graduation) - Mechanical Engineering Course, Exact Sciences and Technology Center, University of Caxias do Sul, Caxias do Sul, 2021.

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