Environmental impact in the production of auto parts, a comparison between manufacturing processes from their power generation sources

Ciro Yoshiyasse
Robert Bosch

Juan Muzzi
Muzzicycles

André Ferreira
Robert Bosch

Francisco Del Moral Hernández
Fatec Campinas

ABSTRACT

This work aims to analyze the contribution of energy sources for extraction and transformation of raw material in the impact on emissions in the production of auto parts. Although it is recognized that the largest share of emissions originates from the burning of fuel, there is a share of emissions that can be reduced in process production, in addition to the fact that the choice of a relatively cleaner industrial chain directly impacts the general demand of industrial base that divides the production of other products whose share of emissions lies entirely in its manufacturing process, since they are interconnected, automotive production enables the production of non-automotive products and encourages their practices. The approach should use the concept of Embodied Energy, which represents the amount of energy incorporated into the process in obtaining the raw material and its transformation into a product, in addition to the CO2 emission data per material. In this way, it is intended to cross the data obtained to estimate the share related to energy consumption and to compare the carbon emissions of materials produced based on renewable sources already installed. Automotive and non-automotive components will be compared in order to provide an industrial base overview.

INTRODUCTION: INDICATORS

The choice of materials and industrial processes has been reduced to questions about producing locally or importing, this reflection suggests that we define what are the quantities that represent value for this analysis, in the present work, these indicators will focus on carbon emissions- here comprehensively referred to as CO2. To build a scenario where it is possible to compare different complex processes quickly, for decision-making at the beginning of the project, a comparison calculation feature was developed that indicates three quantities: 1) Embodied Energy – which represents the sum of energy needed to produce a certain amount of material, 2) Amount of water used in the processing of this same material, and finally 3) CO2 emissions.

This calculation resource, already presented in environmental forums of the automotive environment, has also been used in studies of environmental analysis of projects with relative success in relation to its proposal for rapid analysis of projects in which the LCA would not be viable due to the complexity and study time required. Basically, the idea is to compare products produced in different materials and processes through a graphical visualization of the amounts of energy involved in each project in the form of sphere graphs, where the sphere size is the implicit amount of energy and positioned on the axes described by used water and CO2.

The idea of the centrality of Energy incorporated in the described tool involves the understanding that, from the point of view of thermodynamics, the industry is a sum of efforts to transform matter with the use of energy that begins in mineral extraction or in cultivation, goes through phase of production of the raw material that will be transformed into subcomponents up to the final product.

In a second moment, the mass and the energy join the administration of the distances involved in the process and in the time in which the transformation occurs, so that we have the highest or lowest thermodynamic performance of the transformation. This efficiency, however, can be referred to in several ways, considering the complexity involved in the large number of convergent processes that make up the manufacture, nevertheless we can say that minimizing the scarce resources results in improving efficiency.

This search for minimizing the available resources under the strategic look of trends and scenarios represents in itself the practice of Ecodesign.

CONSIDERATIONS ON ECODESIGN [2]

Next, we will address four themes to study their implications in the hypothesis of comparison between automotive and non-automotive products in different strategies based on design decisions.: Choice of materials, decision by location, energy matrix and logistics decision on import or location. Finally, we will address the use of recycled materials as a result improvement measure.

Choice of materials: reduction of complexity and emissions - The reduction in mass, complexity or production time results in the choice of processes that result, in a certain way, in less entropy in the resulting system, the ideal project design defines the product's adhesion to the need, at the lowest environmental cost. This concept could not escape from thermodynamics inasmuch as the input data in question are physical quantities in transformation. One of the possible variables in this equation is the exchange of materials, which is also the one that involves major changes in the process chain resulting in good practices and product improvement. The exchange of metallic materials for polymeric ones is an example of this movement with a lot of impact that can be demonstrated here.

In the table below, it can be seen that the lower density of polymeric materials in relation to metallic and others results in proportional energy cost, as long as compared by volumetric unit (MJ / Liter) – because in general the substitutions of materials in components are carried out in this way. For example - when changing the material of a painted zinc alloy lock, for a polymer lock (POM) in the color of the car's interior finish, the volume of the original lock was maintained, but the weight reduction may have reached four times lighter.

Table 1. Embodied Energy / Volume [1]

MATERIAL	Density (Kg/dcm3)			Embodied Energy MJ / Kg			Embodied Energy MJ / dcm^3
	Min	Max	average	Min	Max	average	average
PP	0,89	0,92	0,91	76,00	84,00	80,00	72,40
ABS	1,01	1,21	1,11	95,00	104,00	99,50	110,45
PA	1,00	1,42	1,21	110,00	120,00	115,00	139,15
Acrylic	1,16	1,22	1,19	97,00	105,00	101,00	120,19
PC	1,14	1,21	1,18	120,00	130,00	125,00	146,88
POM	1,39	1,43	1,41	115,00	121,00	118,00	166,38
PVC	1,30	1,58	1,44	77,00	83,00	80,00	115,20
PU	1,12	1,24	1,18	110,00	118,00	114,00	134,52
Silicom	1,10	2,30	1,70	175,00	190,00	182,50	310,25
PBT, PET	1,19	1,81	1,50	89,00	95,00	92,00	138,00
Phenolic Resin	1,24	1,32	1,28	2,76	4,83	3,80	4,86
EVA	0,93	0,96	0,95	95,00	101,00	98,00	92,61
polychloroprene	1,23	1,25	1,24	115,00	124,00	119,50	148,18
SBS	0,94	0,95	0,95	105,00	111,00	108,00	102,06
Plastic Foan	0,03	0,10	0,07	150,00	190,00	170,00	11,05
fiber Glass composite	1,75	1,95	1,85	250,00	300,00	275,00	508,75
Carbon Fiber composite	1,55	1,60	1,58	600,00	800,00	700,00	1.102,50
Kévlar composite	1,37	1,40	1,39	400,00	500,00	450,00	623,25
Carbon Steel	7,80	7,90	7,85	57,00	72,00	64,50	506,33
Stainless steel	7,40	8,10	7,75	83,00	115,00	99,00	767,25
low carbon steel	7,80	7,90	7,85	60,00	83,00	71,50	561,28
Aluminum Alloys	2,50	2,95	2,73	235,00	335,00	285,00	776,63
Magnesium Alloys	1,73	1,95	1,84	300,00	500,00	400,00	736,00
Titanium alloys	4,36	4,84	4,60	750,00	1.250,00	1.000,00	4.600,00
Nickel-Chromium Alloys	7,65	9,30	8,48	40,00	690,00	365,00	3.093,38
Zinc die-Casting Alloys	5,50	7,20	6,35	50,00	145,00	97,50	619,13
Copper Alloys	8,93	8,94	8,94	100,00	130,00	115,00	1.027,53
Brass	8,50	7,80	8,15	100,00	120,00	110,00	896,50
Bronze	8,50	9,00	8,75	110,00	120,00	115,00	1.006,25
Ceramic	3,70	3,80	3,75	150,00	200,00	175,00	656,25
Glass	2,44	2,50	2,47	20,00	25,00	22,50	55,58

(*Average EE values converted from MJ / Kg to MJ / Liter)

From the development and use of polymers in automobiles it was possible to drastically reduce the three quantities simultaneously: 1) the replacement of metal parts reduces the amount of raw material in mass and in fuel needed to overcome the inertia of the extra weight, 2) The polymer, for example, Polyamide requires a reduced amount of energy per processed volume, the primary production of a dcm3 of Polyamide requires half the need to produce the same unit in Aluminum, 3) The injection time of a plastic component can represent much less than the casting processes, cold forging or stamping, which can be quite fast, but in general the metallic components are no longer competitive and may still require surface treatments rarely needed for polymers. Other advantages related to the reduction of time, mass and energy, considering that the molded complexity that polymers can offer in general and aggregate component functions resulting in reduction of assembled components, miniaturization, replacement of fasteners by forced assemblies and elimination of surface protection processes.

In the cited example it is possible to verify that the relationships between mass reduction, energy and time are related. If the posed problem involves comparing different processes and indicating which one has the best efficiency, we should compare the processes from the same quantity, in this case Energy, expressed in Kilojoules.

ENERGY MATRIX - In order to quantify the sum of converging efforts in three different quantities, we use the concept of Embodied Energy which by definition represents the amount of energy in Megajoules necessary to obtain a certain amount of material. Example: to produce one kilogram of primary aluminum, the amount of 285 MegaJoules is required, as well as for the transformation of this aluminum into a cast, laminated or machined part, the subsequent amounts of energy used for each process will be added.

In a similar way to consumption in the processing of different materials, the amount of gas emissions given off in each manufacturing process by material is also available in the literature on the study of materials, process and LCA. However, the particularity is in the volume of emissions - more specifically in the generation of energy, which is largely a choice resulting from local conditions in the country. In the table below, we can see that the power generation in clean matrices represents less than ten percent of the generation of oil-fired power.

Table 2. Generation Source [3]

Generation Source (g MJ)	
Hydroelectric	**23,95**
Diesel oil	**230,27**
Combined sources	**173,40**
Wind	**4,49**

Considering that the global energy matrix indicates the source of hydroelectric origin represents about 2% of total participation, considering that the national energy matrix is basically composed of the energy generated in hydroelectric plants, in addition to a considerable participation of Renewable energy – it is possible to affirm that local production is a special case of good environmental practices or at least circumstantial that demonstrate a very favorable scenario for cleaner production compared to practice in other countries less favored by water, sunshine and agricultural land. Factors that undoubtedly converge in the country in a generous and unique way.

LOGISTICS - The complexity of the distribution processes could be described as maximizing availability: concatenating location, material, time and distances in order to enable delivery and cost. The introduction of a fifth variable; the environmental factor can be classified as a circumstance of the legal / ethical scenario under study, but it can also be considered strategic specifically at a time when the structural basis for the transformation of logistical mobility as of commercialized products is undergoing rapid change. On the other hand, it is a concern that cargo transportation appears in a timid manner in the innovation scenario; merchant ships, airplanes, heavy trucks and even locomotives generally bring directly or indirectly the use of fossil fuel as a propellant for their cargo. It is possible to notice the impact on energy costs of these operations from the data that follows:

Table 3. Transporting and Emission [4]

Transport	**Grams CO2 emitted by trasnporting 1 ton of googds**	**Kg CO2 emitted by trasnporting 1 ton of googds**	
	1 Km	**200Km**	**20.000Km**
Air	560	0,112	11,2
Truck	47	0,0094	0,94
Rail diesel	21	0,0042	0,42
Rail eletric	18	0,0036	0,36
Ocean	8	0,0016	0,16

* values added in Kg of CO2 per Kg transported by displacement of 200 and 20,000 km.

According to the author, maritime transport has the lowest cost in emissions, on the other hand the distances traveled in trade between Chinese and Brazilian ports reach close to 20 thousand km, in this case each Kg handled contributes by an average of 0.16% in emitters in relation to the kilogram of weight transported. For comparative purposes, the maritime distance was compared to the air distance, it is a shorter distance - which would not make the total in emissions by air transport much more acceptable since the proportion is about 11.2 times the weight in emissions for the displacement stretch between China and Brazil.

Values were added to the table in an internal logistics hypothesis carried out over 200 km, possibly on trucks and trains. The values, although not negligible, are relatively small in relation to the choice for large displacements by sea or air.

The choice of transport can contribute with a significant portion of the energy costs of the production chain, since there are large consumption differences between transport alternatives, with the aggravation that the type of fuel in mobility is strongly based on the energy matrix of fossil origin. Other studies have already addressed emissions related to maritime transport and how the great distances practiced imply a considerable amount of emissions.

RECYCLING AND REUSE - Not all materials have a recyclability index compatible with reuse or a new function, particularly when this same function has similar properties and specifications. Most metals have good recyclability, while most polymers, although they can be recyclable, have in their economic viability frequent problems with dispersion, contamination and lack of labeling of post-use materials.

Perhaps for this reason, studying the expansion of polymer recycling rates beyond the rates of metals such as copper and aluminum is an urgent challenge, since improper disposal remains unsolved beyond what the legislation assumes at this time.

The advantage of recycling in terms of energy and resource savings is that recycled materials do not count twice the industrial effort of mining and initial or primary processing.

REUSE - Designing the product so that it is easier to dismantle and maintain is one of the conditions for extending the life of the product, the choice of iconic lines, or attributing subjective relationships to the design are strategies that make the products for various reasons cross the times, and with that they become successful solutions for environmentally friendly design - after all, there is implicit a stimulus in the saving of resources and in the valorization of the time of use of the product. However, the function of these products determines whether these strategies can be really efficient as a technologically outdated product can drain resources in its use, this is the case of automobiles and products that consume energy in general.

These two classes of products must then be analyzed separately, since the environmental impact must be at different times in the life cycle, in the case of objects that do not consume energy like a bicycle, the effort in natural resources is in their manufacture, while for a car or automotive component, the largest share of resource consumption is in energy consumption (fuel) over the life of the product. We will see ahead with the calculation examples that demonstrate this diversity between "energized and non-energized" products: an automotive auto part and a bicycle frame.

ENVIRONMENTAL CALCULATOR [5]

The calculation spreadsheet in question graphically presents the options proposed in three variables: Energy, CO2 and water consumption. From the considerations developed so far, we seek to answer the following questions:

Environmental gain in the use of recycled, remanufactured, local and imported products:

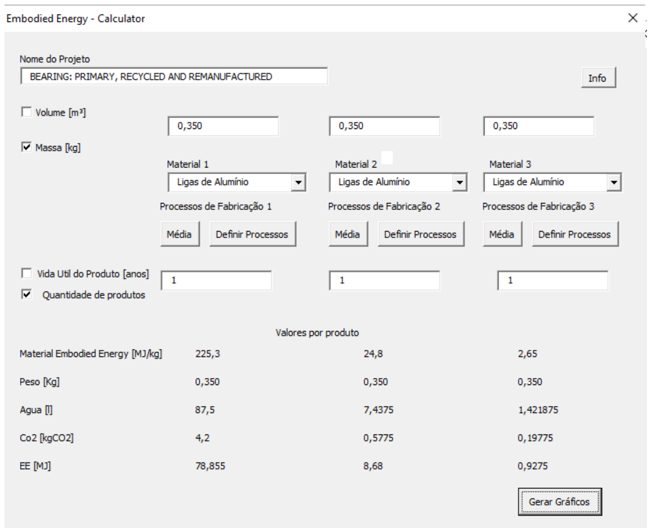
CASE 1: WIPER MOTOR BEARING – Compared with recycled material and remanufactured product.

Fig. 1. Wiper motor

Aluminum bearing weight: 350g

Material: aluminum alloy

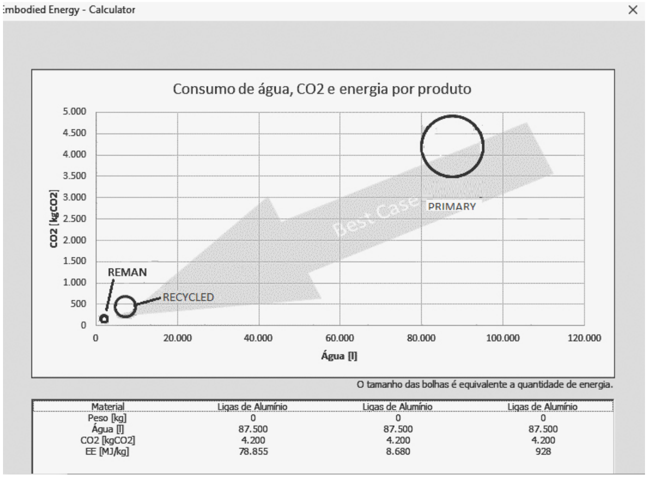
Fig. 2. Input data – Bearing



As the exception of the primary phase, water consumption and CO2 emissions data have been estimated, they represent a very small portion of the primary operation.

The design of the calculator aims to guide the project and its input data on the operations of the manufacturing chain has been simplified and limited to the database of information available in ASHBY [1] [2]

.Fig. 3. CO2 x Water x EE Chart - Bearing



The result of the simulation shows that the Remanufacturing or reconditioning of products drastically reduces the consumption of resources in general, largely due to production efforts and therefore, the consumption of resources in the primary production of metals in general involves the vast majority of the resources involved in the chain. The use of recycled material tends to produce the same effect for the same reason.

CASE 2: RECYCLED BICYCLE PP FRAME - Compared with aluminum or carbon steel frame.

Plastic frame - Weight: 4,5 Kg, Material: Recycled PP

Steel frame - Weight: 3.5 Kg, Material: carbon steel.

Aluminum frame - Weight: 2.5 Kg, Material: Aluminum alloy.

Fig. 4. Bicycle frame in recycled PP

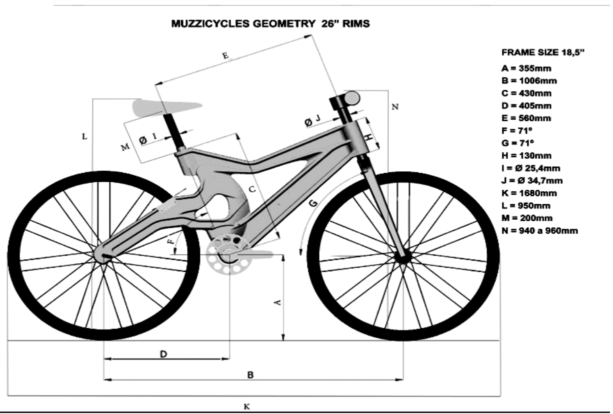


Fig. 5. Input data – Bike

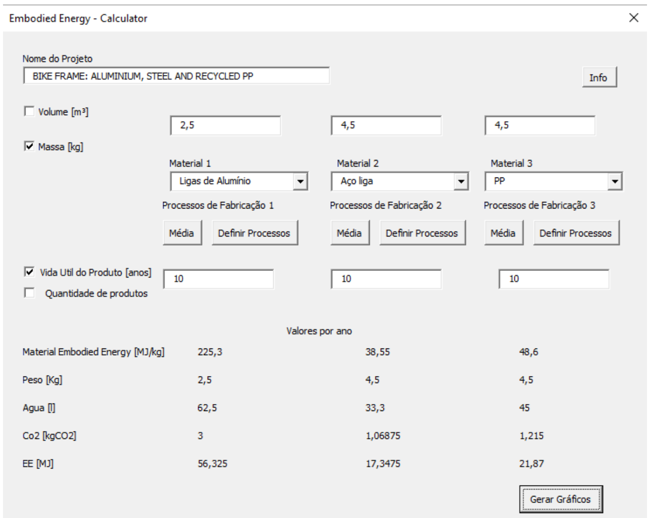
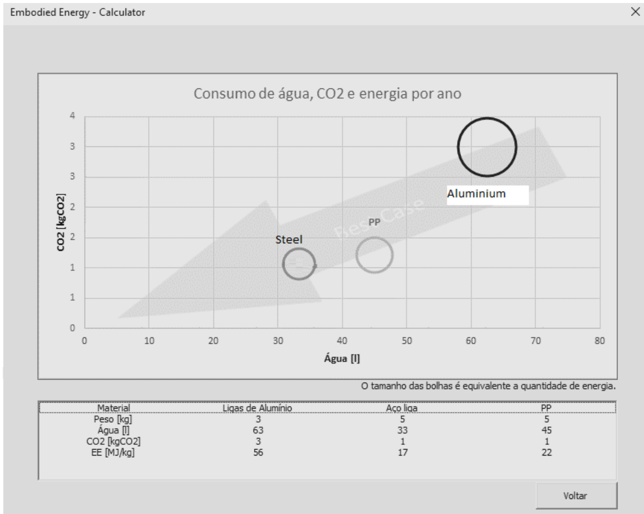


Fig. 6. CO2 x Water x EE Chart - Bicycle Frame



The result of the simulation is that the product made of recycled polymer has less emissions in its process, consumes little more in water and the energy cost is very close to that of aluminum. The fact that the steel option was the worst is mainly due to its low durability due to its estimated durability in half the time of the other frames.

Naturally the input data presupposes the customer experience, in the case of input data with durability or even the preference of choice of materials.

CONCLUSION

As demonstrated, the Brazilian energy matrix is unique due to the predominance of hydroelectric plants in a world scenario where this model represents 2% of the energy sources explored. In addition to these special conditions, which can be said to be unique in the supply of water, sunlight and soil, the use of ethanol as a fuel. In these conditions, it is possible to state that the LCA of products produced in the country should have much better results than if produced on the other side of the planet, whether due to the energy matrix, the emission produced in the chain and in particular in maritime transport. The latter imposes about 16% by mass of CO_2 emissions per kilogram, in the best scenario (maritime transport).

It must be said that the impacts of maintaining the national practices mentioned are not negligible: flooding of forests, the tragedies generated by irresponsible mining, the monoculture of sugarcane and the social impact that each of these actions presupposes. There is a need to respond responsibly and the response requirement must be maximum considering the value of unique resources in addition to the risk of the affected population.

REFERENCES

[1] ASHBY, Michael F. Materials and the Environment: Eco-Informed Material Choice. Oxford: Butterworth-Heinemann, 2009.

[2] ASHBY, Michael F.; JOHNSON, Kara. Materiais e design: arte e ciência da seleção de materiais no design de produto. Rio de Janeiro: Elsevier, 2011.

[3] MIRANDA, Mariana Maia de: Fator de emissão de gases de efeito estufa da geração de energia elétrica no Brasil: implicação da Avaliação de Ciclo de Vida. São Carlos: USP, 2012.

[4] GYNLEY, David S.: Transportation: shipping – Fundamentals of Materials for Energy and Environmental Sustainability. USA: Cambridge, 2012.

[5] YOSHIYASSE, Ciro S.: Desenvolvimento de motor elétrico baseado em indicadores Embodied Energy. São Paulo: SIMEA, 2010.