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Using Emergy to Assess the Business Plan of a Small Auto-parts Manufacturer in Brazil

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Abstract

The initiative of evaluating products using the supply chain standpoint to help reducing the environmental and socioeconomic impact connected with manufacturing has been recently acknowledged. Yet, there are no studies making an allowance for the various types of small businesses that operate in the sphere of influence of large supply chains to fill gaps or serve consumers with particular needs. These little companies that, in general, have no control over the decisions made along the supply chain have to reconcile their production processes with the decisions taken by the leading companies. This work evaluates a case of induced product change, and its cost regarding the use of environmental resources and energy of a small company working in the Brazilian automotive aftermarket. This approach also looks into an underexplored aspect in the use of emergy accounting in which the studied system is at the end of the production chain, and confirms the thought that actions in the central supply chain may have advantageous effects that can go beyond what was expected by the decision maker. The simulation performed for the period 2014-2025, according to the company's commerce plan, shows that the earlier the products change is completed, the greater would be the profit, the greater the resources and energy savings, and, consequently, the greater eco-efficiency of the business.

1. Introduction

With the globalization of the automotive sector, the challenges and the difficulties in the manufacturing industry are focused on the needs of planning the large-scale production, but also in maintaining quality and competitive prices, while defining sustainability policies, based on the concern about the increasingly intense scarcity of natural resources. Recently, the significance of adopting holistic strategies, in which the use of energy and resources throughout the product value chain is examined, has been recognized by the authorities and companies. Under this perspective, several methods are adopted to assess the entire supply chain in order to diminish the environmental impact related to the provision of products and services. In Brazil, within the sphere of influence of large supply chains, a number of small businesses emerge to fill gaps or serve custom-

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ers with individual needs. These small businesses do not have influence on the decisions taken by the chain's leading companies, but, are affected, positive or not, both in their profits and their individual environmental impact.

Emergy synthesis assimilates the production of raw materials by nature and their use by man, quantifying all the investment required in comparable physical units, which can then be converted into monetary values. Several authors have used this method for assessing industrial systems and their impact. Bakshi (2000) introduced the use of emergy analysis to evaluate the waste treatment in industrial systems. The author proposed a way of assessing the impact of emissions by separating the emergy flows that contribute to the product from those required to treat emissions or employed in the effluent treatment. Yang et al. (2002) proposed two new indices based on the idea suggested by Bakshi (2000). According to these authors, the greater the emergy investment for waste disposal, the more severe are the effects of the waste on the environment. Following the same idea, Mu et al. (2011) calculated emergy indices for the evaluation of a generic system incorporating industrial waste management, and concluded that traditional emergy indices should be adjusted for analysis involving waste management. Hau and Bakshi (2003) discussed the main features and critical aspects in using emergy to evaluate the relationship between industry and environment and proposed the use of cumulative exergy concepts to complement emergy results. The study points to the close link between the emergy requirement and the cumulative ecological exergy highlighting that the most critical difficulties found are common to all holistic approaches and, regularly, the result of misunderstandings derived from the lack of communication between various disciplines.

Ulgiati et al. (2010) analyzed and compared power generation systems, alternative and biofuels, and waste management strategies in order to show the importance of a multiple point of view to the proper assessment of the environmental performance and resource utilization of a system. Various energy resources conversion systems and selected materials were compared in an integrated framework called Sustainability Multiscale Multimethod Assessment (SUMMA). These authors argue that only an analysis based on several complementary approaches can highlight the inevitable trade-offs that reside in alternative scenarios, and allow a more accurate selection of an option, optimizing the commitment (trade-off) among the existing economical, technological and environmental conditions.

Dealing the impact of emissions on ecosystems and human health, Ulgiati and Brown (2002) suggested a quantitative method for assessing the environmental services effectively needed to absorb or dilute emissions at different scales of time and space. The authors illustrated the method by accounting for the environmental services required to absorb or dilute gaseous waste from electric power generation systems. In 2004, Ukidwe and Bakshi translated the impact of emissions on human health, obtained by the combination of emergy requirement and the cumulative ecological exergy, with the help of the Disability Adjusted Life Years (DALY) indicator. However, Lingmei et al. (2005), using as example the assessment of coal gasification for power generation, emphasized that emergy indices are practical to assess comprehensively systems with multiple products and its sustainability.

In regard to the use of resources to obtain goods or services, the sustainable use of resources in the Sassuolo district in the Province of Modena was analyzed by Bastianoni et al. (2001), who showed that the district has a considerable consumption of non-renewable primary resources. Wang et al. (2005) used in the emergy synthesis for evaluating an eco-industrial park based on a power generation plant. Considering the movement of material and the use of energy cascade, these authors proposed a new indicator of sustainability to an industrial ecosystem that considers the emergy yield and the environmental burden. In the calculations of these new indicators all the gains due to the interconnections between the various companies in the eco-industrial park are represented by additional electrical energy or renewable resources use and are discounted from the total emergy requirements. Cao and Feng (2007) evaluated industrial processes from two categories: inseparable and semi-independent products. These authors concluded that, when multiproduct systems areanalyzed, a distinction between inseparable and semi-independent products must be done. For inseparable products the emergy for each product would be equal to that of the entire system. If the product belongs to a semi-independent multi-product system, unnecessary entries (such as information, materials, energy, work equipment) would be discounted.

Emergy synthesis has been also used to improve the performance of industrial systems. Giannetti et al. (2005) evaluated a reverse logistics network for steel recycling. The data obtained were used to assess and compare environmental costs of the system, and the benefits were evaluated from both the perspective of the distributor and steel plant. The results were used to propose improvements in the efficiency and effectiveness of all components of the reverse logistics network. Xue et al. (2006) suggested an input and output model operating at different spatial scales for steel making processes operating in parallel within a manufacturing. These authors concluded that the combination of environmental analysis and input/output models is useful for understanding the relationship between the environmental impact and the manufacturing processes inputs, and provides valuable clues on how to manage manufacture in order to achieve zero emissions. In 2008, Giannetti et al. assessed the cleaner production practices adopted by a medium-sized manufacturer of semi-jewels in Brazil, in order to reduce pollution and waste generation. The cost-effectiveness of the selected practices and additional benefits were discussed through the use of local and global indicators, and, it was found that the environmental benefits at a global level are greater than those perceived locally.

Geng et al. (2010) evaluated the economic and ecological interface highlighting the internal relations among different subsystems and components. The evaluation provided valuable insights into the environmental performance and sustainability of an industrial park and to assist in the preparation of environmental policies. Advantages and limitations were identified and discussed. According to the authors, the emergy synthesis is an important supplement to the tools that are available for industrial parks and administrators managers. Similar conclusions were drawn by Almeida et al. (2010) who identified throughout an emergy assessment some opportunities for internal wastewater treatment and rainwater catchment in four bus-washing Sao Paulo, Brazil. A case of product change was analyzed by Almeida et al. (2013), who evaluated the options to reduce or eliminate lead from soft solders and their replacement by lead-free alloys, with and without the use of reverse logistics for waste recovery. With the use of emergy synthesis, Life Cycle Assessment, and the DALY indicator, these authors showed that more resources are used to produce a ton of lead-free solder than to produce one ton of tin-lead alloy. The evaluation air emissions during the production weld showed that the benefits of lead-free alloy are limited to manufacturing and assembly steps. The tin-lead solder was identified as the best option in terms of efficient use of resources and with regard to emissions into the atmosphere when the whole supply chain is considered.

This study uses emergy synthesis to assess a small company operating in the Brazilian automotive aftermarket, which produces carburetion and electronic fuel injection gaskets. Currently, the company fabricates electronic injection gaskets for new vehicles spare parts and carburetion gaskets to meet the need of old cars, which still circulate on the national territory. According to the company's business plan, the carburetion gaskets will be manufactured till 2025. The substitution of one product for another, in this case, implies change of manufacturing design and material. The use of emergy accounting in the JP Juntas aims to assist the management of non-renewable natural resources that the industry uses to manufacture its products, allowing the choice of the best strategy for productivity and competitiveness. The effect of product change is evaluated with respect to the efficient use of resources, productivity, environmental burden and overall productivity.

2 Method

2.1 Emergy synthesis

The emergy can be understood as the memory of energy or total energy embodied in a product or service. Emergy is the amount of energy required, directly or indirectly, to obtain a product in a given process, expressed in seJ (solar energy joule). The use of a single unit, in which different types of energy are converted, allows to add all the energy contributions used to obtain a particular product or service (Odum, 1996).

The term transformity expresses the amount of solar energy used, directly or indirectly, in obtaining a joule of a product or service (seJ / J). The transformity can be used for the conversion of energy and the emergy of a product, but is also an indicator of the emergy concentration (Odum, 1996). As one can express the amount of energy using quantities (weight, volume, etc.) the term Emergy Value Unit (UEV), which also includes the transformity, is used to facilitate the understanding.

The total emergy required to obtain a product or service vary according to the raw material used, the type of energy used for production, and with quantity and quality of labor. The total emergy can be calculated by equation 1.

$$E_m = \Sigma_i Tr_i \times E_i \tag{1}$$

where E_m is the emergy, Tr_i Tr_i the transformity (or UEV) of the i flow and E_i Ei the energy contained in the inflow relative to a product or service i.

For a given product, the value of the UEV is part of a range of values that depend on the production process, the region in which it was made, the origin of the raw material, the level of the employed workforce and the necessary investments. This range of values generally purviews from a lowest UEV, below which it is not possible to obtain the product, and a maximum UEV above which the acquisition of the resource is not feasible. Products with lower UEVs are simpler, and processes with smaller UEVs are more efficient. Values of the transformities are mostly taken from the literature and are relative to the 15.83 x 10^{24} seJ/year baseline (Odum and Odum, 2000).

The emergy inflows are divided into three classes: renewable (R), non-renewable (N) and the feedback from the economy (F). Renewable resources (R) are extracted from the local environment and have temporal and spatial renewal capacity faster than their consumption. R flows include solar, wind, rain, tides, the gravitational energy, geothermal, etc. Ulgiati and Brown (1998) defined these flows as (i) limited flows (is not possible to increase the flow rate in the system); (ii) free (they are usually available at no charge) and (iii) available locally. The non-renewable resources (N) are also local, but their consumption is faster than the ability at which the environment performs their renewal. Within this category there are resources such as natural gas, minerals, and oil. According Ulgiati and Brown (1998), the N flows are characterized by: (i) limited stocks; (ii) not always free, and (iii) locally available. Finally, the feedback from the economy (F) is linked to goods and services or non-renewable resources that come from outside the limits of the system under study. The feedback flows are: (i) limited stocks (in the same way as non-renewable flows); (ii) never free; (iii) not available locally (Ulgiati and Brown, 1998).

To quantify services associated with the F flow, the prices of each input were recorded and converted into emergy units. The link between emergy supply and economic performance was made using the ratio of total emergy used to the Gross Domestic Product (seJ/currency unit) accordingly to the recommendations found in Ulgiati and Brown (2014). The price of each input was multiplied by the emergy money ratio (EMR) of Brazil (Giannetti et al., 2013) since the company does not use inputs imported from abroad. The value of the EMR was used both to convert the emergy values in currency and to convert input prices to emergy. The sources used to obtain the input's prices are listed in Appendix A.

2.2 Description of the studied system and data collection

The JP Juntas started its activities within the automotive aftermarket in 1992. Figure 1 shows leading gasket models used for replacement in old engines and the substitute for vehicles with electronic injection.

The production system of JP Juntas, as in most industries in this segment, operates accordingly to the energy diagram shown in Figure 2. The components that complement the kits assembled by the company are purchased from suppliers already registered.

The diagram shown in Figure 2 outlines the components that contribute to the production process both in the manufacture of carburetor and electronic fuel injection gaskets. The infrastructure has all the necessary elements needed for production, such as machinery and equipment and stored raw materials. The main raw material is cut with the use of molds according to of each vehicle model (national or imported), and when an order is placed, an employee separates the components (auxiliary materials) and sends it to the assembly sector. The kit is complemented with other purchased components, packed (in a plastic bag or blister) and sent to the client. Both kits may be assembled by a manual or a semi-automatic process. In the manual process, the kits are assembled one by one, checked, packaged and shipped to customers. In the semi-automatic process, a conveyor belt is used to help employees to assemble the kits. Packaging is automatic, and kits are dispatched to the client.

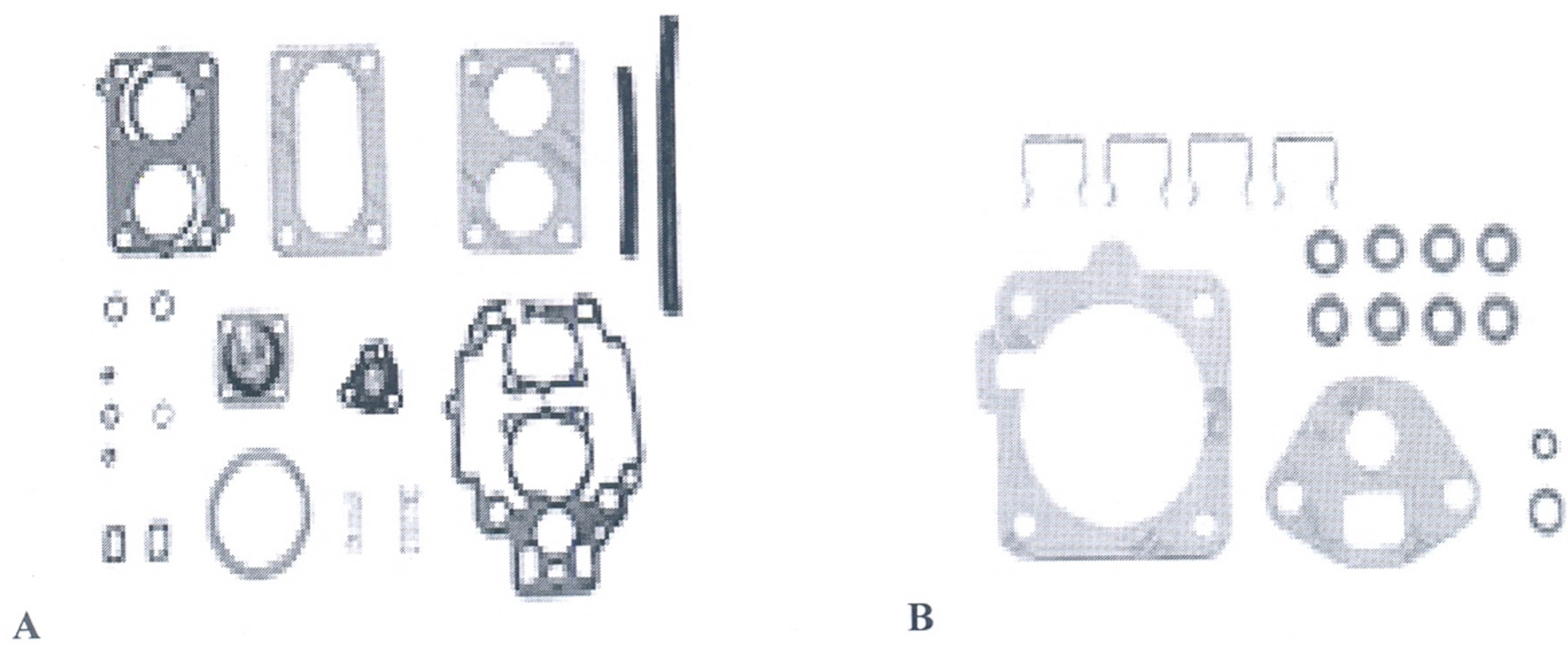

Fig. 1 Carburetor (A) and electronic injection (B) kits produced by the company.

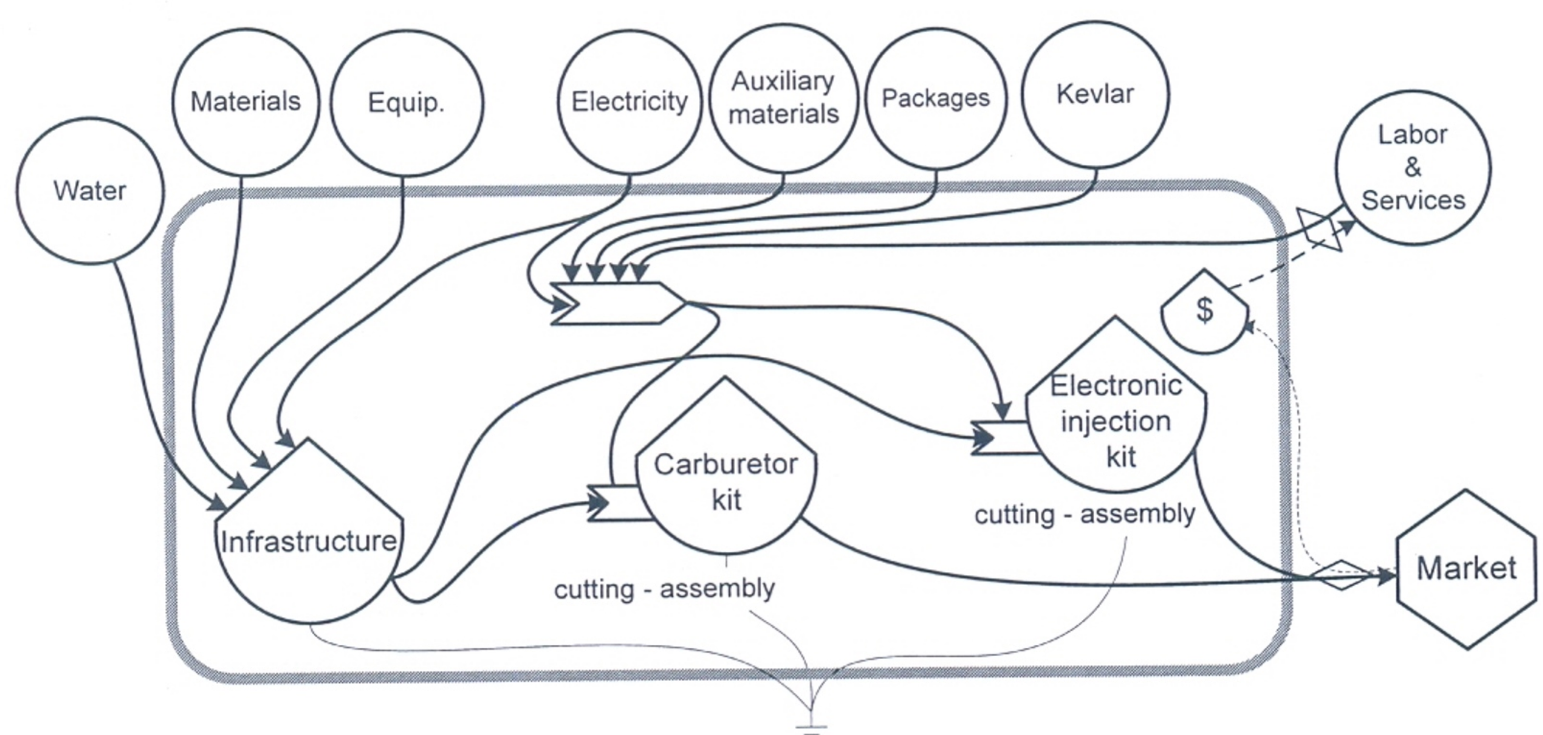

Fig. 2 Energy diagram of JP Juntas.

3 Results and Discussion

The emergy accounting was performed with and without services in order to evaluate the technological process and its dependence on labor and services performed outside the boundaries of the company.

3.1 Emergy accounting of the JP Juntas without services

Table 1 shows the environmental accounting of the company in 2013. The emergy invested annually in the company's infrastructure is represented by the cost of the building, facilities, offices and machinery, and account for only 7% of the total annual cost. In the year of 2013, equal amounts of both types of gaskets were produced. The production of the carburetor kit corresponds to 67.4% of the total of emergy and, as expected, the greatest contribution to total emergy is associated with the use of Kevlar materials, followed by the cellulose paper utilized in the carburetor kit .

Table 1 Emergy environmental accounting of JP Juntas in 2013.

		Quant.	Unit	UEV/ (seJ/un.)*	Emergy/ (seJ/year)	% (seJ/ seJ)
	Facility					
1	Concrete	2.62×10^{7}	g	1.23×10^{9}	3.22×10^{16}	2.4
2	Steel	7.85×10^{5}	g	5.31×10^{9}	4.17×10^{15}	0.3
3	Wood	5.32×10^{5}	g	4.04×10^{8}	2.15×10^{14}	<0.1
	Office					
4	Plastic	1.86×10^{4}	g	3.80×10^{8}	7.07×10^{12}	<0.1
5	Copper	4.54×10^{3}	g	6.80×10^{10}	3.09×10^{14}	<0.1
6	Steel	1.64×10^{6}	g	5.31×10^{9}	8.71×10^{15}	0.6
7	Glass	2.00×10^{3}	g	8.40×10^{8}	1.68×10^{12}	<0.1
	Production Plant					
8	Plastic	3.76×10^{5}	g	3.80×10^{8}	1.43×10^{14}	<0.1
9	Steel	8.92×10^{6}	g	5.31×10^{9}	4.74×10^{16}	3.5
	Emergy of infrastructure				**9.30×10^{16}**	**7**
	Carburetor kit production					
10	Water	8.48×10^{7}	g	6.64×10^{5}	5.63×10^{13}	<0.1
11	Electricity	2.30×10^{11}	J	1.28×10^{5}	2.94×10^{16}	2.2
12	Labor**	6.20×10^{9}	J	1.15×10^{7}	7.13×10^{16}	5.2
13	Lubricants	8.65×10^{9}	J	5.91×10^{4}	5.11×10^{14}	<0.1
14	Rubber(*O-rings*)	9.60×10^{4}	g	2.10×10^{4}	2.02×10^{9}	<0.1
15	Copper (diaphragms and coils)	8.64×10^{5}	g	6.80×10^{10}	5.88×10^{16}	4.3
16	Zinc (diaphragms and coils)	1.30×10^{6}	g	6.80×10^{10}	8.81×10^{16}	6.5
17	Rubber tubes	1.68×10^{6}	g	2.10×10^{4}	3.53×10^{10}	<0.1
18	Cellulose paper	2.78×10^{7}	g	3.90×10^{9}	1.09×10^{17}	8.0
19	Red Kevlar	1.34×10^{6}	g	1.25×10^{10}	1.68×10^{16}	1.2
20	Green Kevlar	3.76×10^{7}	g	1.25×10^{10}	4.70×10^{17}	34.6
21	Paper	4.80×10^{5}	g	3.90×10^{9}	1.87×10^{15}	0.1
22	Cardboard	1.58 x 106	g	3.90×10^{9}	6.18×10^{15}	0.5
23	Labels	2.40×10^{5}	g	3.90×10^{9}	9.36×10^{14}	0.1
24	Blister	5.04×10^{3}	g	3.80×10^{8}	1.92×10^{12}	<0.1
25	Plastic bags	2.38×10^{5}	g	3.80×10^{8}	9.03×10^{13}	<0.1
	Carburetor kit				**9.16×10^{17}**	**67.4**
	Electronic injection kit production					
26	Water	8.48×10^{7}	g	6.64×10^{5}	5.63×10^{13}	<0.1
27	Electricity	9.84×10^{10}	J	1.28×10^{5}	1.26×10^{16}	0.9
28	Labor**	6.20×10^{9}	J	1.15×10^{7}	7.13×10^{16}	5.2
29	Lubricants	8.65×10^{9}	J	5.91×10^{4}	5.11×10^{14}	<0.1
30	Rubber(*O-rings*)	1.34×10^{6}	g	2.10×10^{4}	2.82×10^{10}	<0.1
31	Green Kevlar	2.42×10^{7}	g	1.25×10^{10}	3.02×10^{17}	22.3
32	Paper	4.80×10^{5}	g	3.90×10^{9}	1.87×10^{15}	0.1
33	Cardboard	1.58×10^{6}	g	3.90×10^{9}	6.18×10^{15}	0.5
34	Labels	2.40×10^{5}	g	3.90×10^{9}	9.36×10^{14}	0.1
35	Blister	9.60×10^{4}	g	3.80×10^{8}	3.65×10^{13}	<0.1
36	Plastic bags	1.80×10^{5}	g	3.80×10^{8}	6.84×10^{13}	<0.1
	Electronic injection kit				**4.43×10^{17}**	**32.6**

* Values of the UEVs are taken from the literature and are relative to the 15.83×10^{24} seJ/year baseline (Odum and Odum,2000).
** Direct labor is accounted for by average emergy of the State of São Paulo per inhabitant (Demétrio, 2011).

The total emergy of the company in 2013 considers all the resources and energy needed for the production of 480,000 kits for carburetor engines and fuel injection (Table 2). The UEVs, which reflect the use of energy and resources per unit of product, show that to produce a carburetor kit approximately twice emergy is needed (Table 2), which is untoward both for the environment and for the company. As the carburetor kit is sold on average for $2.00 and the electronic injection kit for $3.50, the ratio of the emergy used and the revenues of the company (seJ/US$) shows that less emergy is used to generate one US dollar in the production of electronic injection kits.

Table 2 Summary of environmental/economic accounting of JP Juntas in 2013.

	Carburetor kit	Electronic injection kit	Company
Total emergy / 10^{17}(seJ/year)	9.16	4.89	14.5
UEV / 10^{12} (seJ/kit)	3.82	1.85	3.2
*EmPrice** (Em$/year)	538,824	287,647	852,941
Emergy/Revenue / 10^{12} (seJ/US$)	1.53	0.58	1.01
Revenue (US$/year)	600,000	840,000	1,440,000

* The EmPrice of the kits was calculated as the quotient of the emergy by the money generated by sales of each product.

The last column of Table 2 (Company) shows the overall performance of the company. As expected, the UEV = 3.2 x 10^{12} seJ / kit) has an intermediate value between the UEVs of each type of joint and shows the potential gain, if the company had decided completely to stop the production of carburetor kits in 2013. The same reasoning can be applied to EmPrice values - the quotient of the emergy of the company and its revenues. Similarly, the emergy/revenue ratio of the company, which can be translated as the emergy required to generate one unit of income, would have a reduction of approximately 62% with the total change of product.

An additional benefit due to the product change can be associated with a reduction in the amount of solid waste produced due to the design of each gasket. In 2013, for the production of the carburetors kits there was a material waste equivalent to 4.04 x 10^{17} seJ, which corresponds to approximately 44% of the total emergy. The greatest amount of material lost through these processes is due to the production of the component made of cellulosic paper. As for the production of electronic injection kit, the green Kevlar waste corresponds to 28% of total emergy. In total, the product change would result in a 31% reduction in the amount of solid waste produced. Although a change in the product design is not a decision within the reach of the small business, this kind of information may provide a useful feedback that could help the chain leaders to reduce the production of solid waste of the total supply chain.

3.2 Accounting for the services required by JP Juntas

The emergy accounting discriminates the work (activity directly applied to a process, recorded in Table 1 as labor) and services (activities in the larger scale economy that indirectly contribute to a process). The direct labor is accounted for by the hours of work and worker quality (not qualified, trained, educated, etc.) using UEVs based on the level of training and education (seJ/person hour). This calculation of the emergy of workforce carries the memory of fuels, materials, food, minerals necessary direct and indirectly to support the workers' lives. The inclusion of services in emergy accounting adds valuable information on the structure, infrastructure and socio-economic development of the place where a process occurs and how it affects the performance and cost of the process under investigation.

Services, as defined by the methodology, refers to the indirect work employed outside the system to produce the necessary resources (F) for the manufacture of the product of interest. Since the two methods (emergy synthesis and conventional economic pricing) count the inputs used by the company differently, values were found in Em$ and dollar are different for each input. It is worth to emphasize that the emergy evaluation records all inputs, in the same way, adding renewable resources, non-renewable and from the economy, and the sum of these quantities is divided by the Brazilian EMR to obtain the Em$ values shown in Table A2, Appendix A. The prices of each input correspond to the real expenses incurred by the company in the acquisition of raw materials, and serving as support for the operation of business (administrative salaries, phones, etc.). These prices are, in part, increased or decreased by the customer's buying decisions, especially in markets with a large number of competitors, where companies seek to expand profit margins to the maximum (SEBRAE, 2010). Figures 3 and 4 show the difference between the Em$ calculated from the emergy table for each input and the prices paid to suppliers.

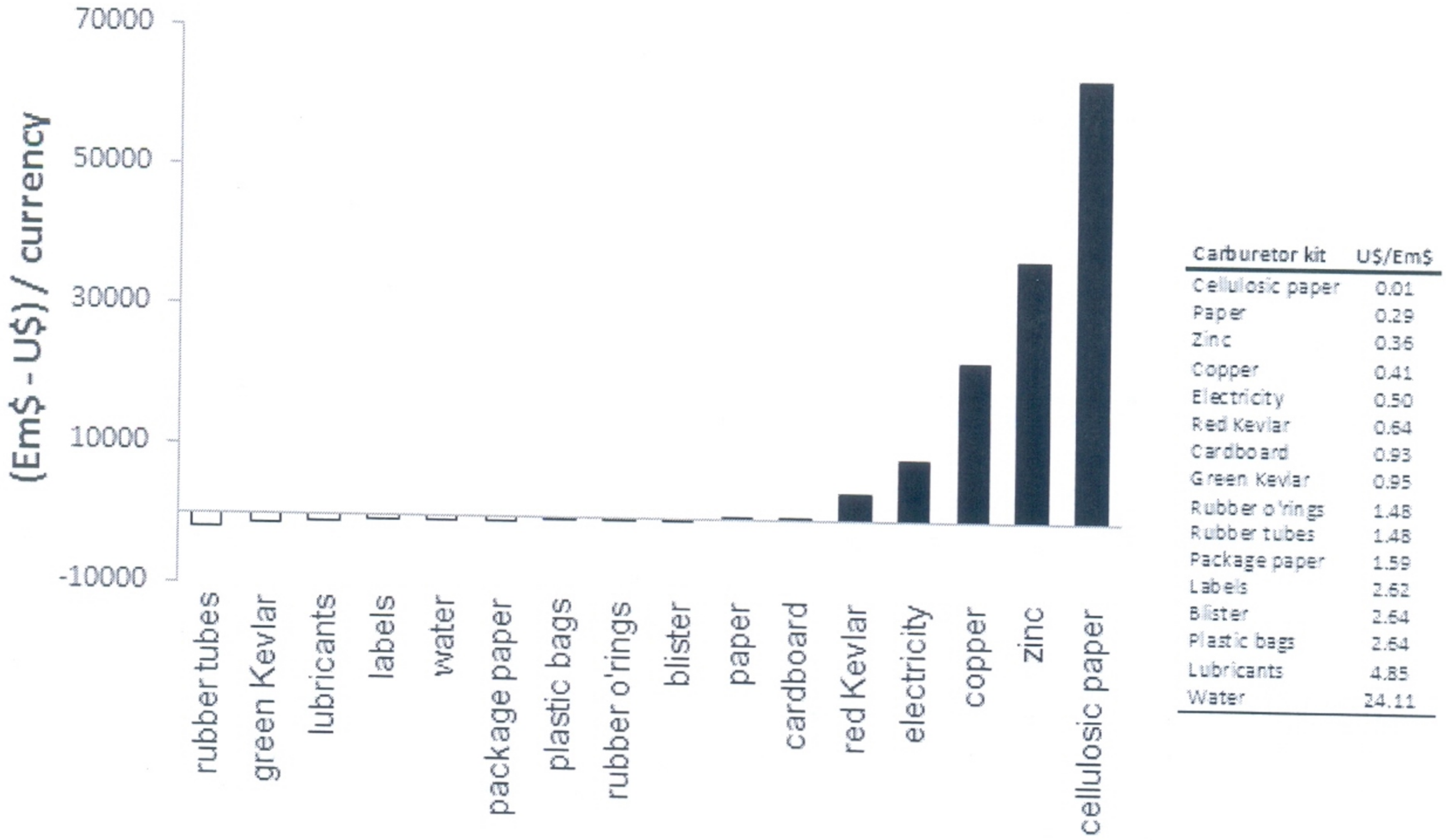

Fig. 3 The difference between the values in Em$ and prices in the manufacture of carburetor kits. The ratio U$/Em$ shows if the company has advantage (U$/Em$ < 1) or disadvantage (U$/Em$ > 1) in buying each input in relation to the value of the emergy/currency equivalent. The sources used to obtain the input prices are listed in Appendix A.

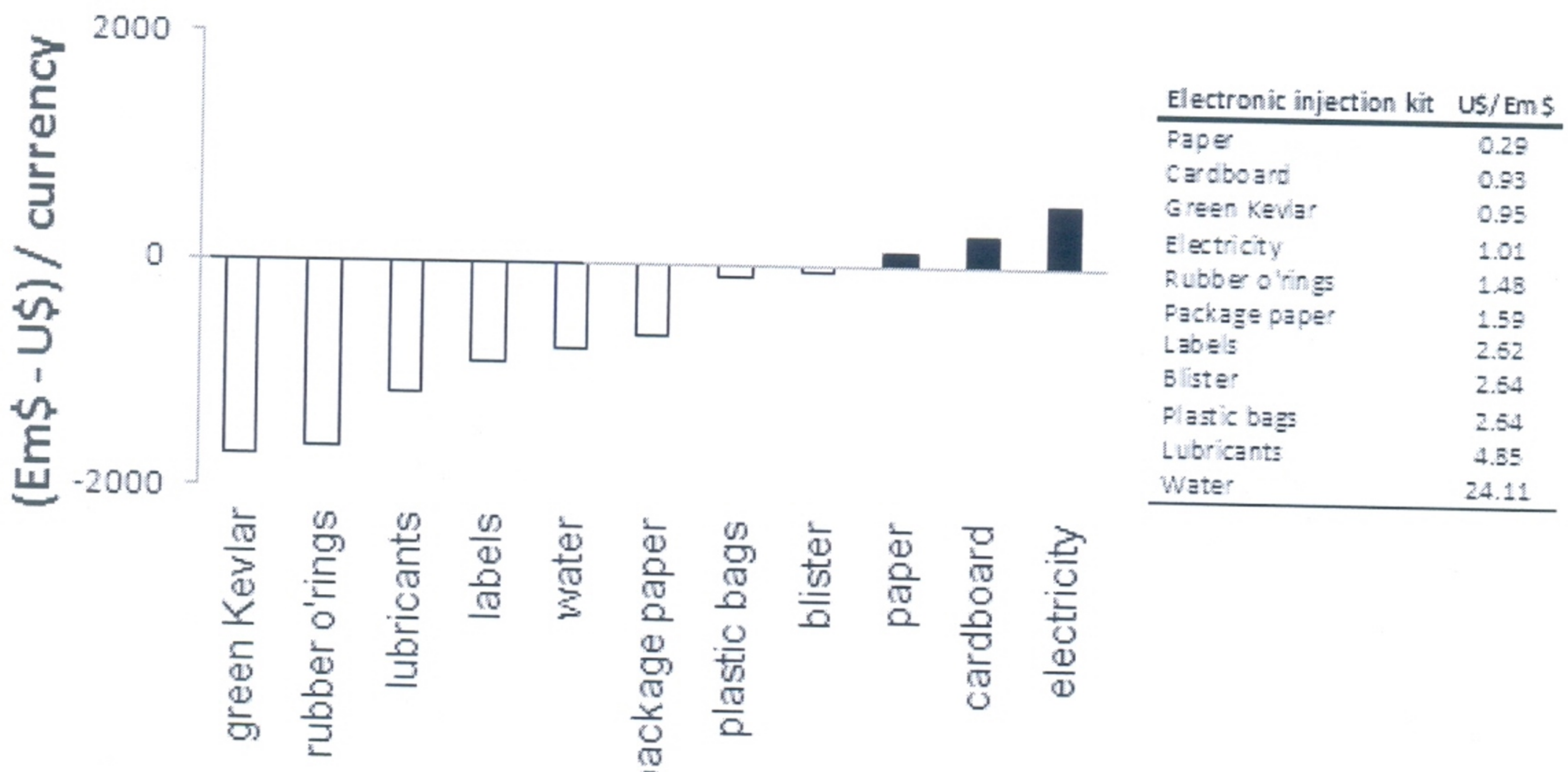

Fig. 4 The difference between the values in Em$ and Dollar in the manufacture of electronic injection kits. The ratio U$/Em$ shows if the company has advantage (U$/Em$ < 1) or disadvantage (U$/Em$ > 1) in buying each input in relation to the value of the emergy/currency equivalent. The sources used to obtain the input prices are listed in Appendix A.

When the Em$ is greater than the value in dollars, the company is receiving more emergy than the amount paid in cash to suppliers. When the difference (Em$ - U$) is negative, the price paid for the input is greater than the value indicated by the emergy/currency equivalent. Assuming that the emergy synthesis can estimate the actual cost of an input, also including the contributions of nature, it is observed that the company pays more for some products (e.g. green Kevlar, rubber and water) and less for others (metals and electricity, for example) than indicated by the Em$ calculated.

The overall result is shown in Table 3. The company receives more emergy than it pays in cash for their input to maintain its infrastructure and to produce the carburetor kits. However, the production of electronic injection kits shows a slight disadvantage. The final balance of the company shows that it receives 42% more emergy than it pays for maintenance inputs, and 56% to make the carburetor kits. In producing the electronic injection kits, the company ceases to consume metals and cellulosic paper, which results in a U$/Em$ ratio around 1.0 configuring a fairer condition with respect to the value of inputs taken from the environment.

Even including services, the ratio of the emergy used and the revenues of the company (seJ/US$) shows that less emergy is used to generate one US dollar in the production of electronic injection kits. The overall performance of the company, with and intermediate UEV = 4.3 x 10^{12} seJ/kit, points to a potential gain in efficiency in regard to the complete substitution of carburetor kits. However, the emergy/revenue ratio increases from 1.01 (Table 2) to 1.43, due to the exchange of raw materials purchased with advantage (eg. metals) for inputs coming from the economy (services).

Table 4 shows the contribution of services to total emergy of company. Services cause a 30% increase in the company total emergy and, consequently in the UEVs kits. This result shows that the production of electronic injection kits depends more on the external services than that of the carburetor kits.

Table 3 Summary of the emergy/currency equivalent and expenses expressed in dollars of JP Juntas in 2013. The ratio U$/Em$ shows if the company has advantage (U$/Em$ < 1) or disadvantage (U$/Em$ > 1) in buying each input in relation to the value of the emergy/currency equivalent. The sources used to obtain the input prices are listed in Appendix A.

	Em$	**U$**	**U$/Em$**
Infrastructure	52,133	29,994	0 .58
Carburetor kit production	225,024	97,090	0 .43
Electronic injection kit production	118,945	122,677	1 .03
Total JP Juntas	396,102	249,761	0 .63

Table 4 Summary of environmental accounting in emerging from JP Juntas in 2013, with and without services.

	Without services		With services		
	Emergy 10^{17} (seJ/year)	UEV 10^{12} (seJ/kit)	Emergy 10^{17} (seJ/year)	UEV 10^{12} (seJ/kit)	% Services (seJ/seJ)
Total JP Juntas	14.5	3.0	20.6	4.3	30
Carburetor kit production	9.2	3.8	12.0	5.0	24
Electronic injection kit production	4.4	1.9	7.7	3.2	42

* The complete table with the calculation of services is available in Appendix A.

Table 5 Emprices products of JP Juntas and EMR company, considering the services in the year 2013.

	Carburetor kit	**Electronic injection kit**	**Company**
EmPrice* (Em$/year)	707,059	450,588	1,211,176
Emergy/Revenue / 10^{12} (seJ/U$)	2.00	0.91	1.43
Revenue (U$/year)	600,000	840,000	1,440,000

* The EmPrice is the quotient of emerging for dollars from the sale of the product (Campbell and Tilley, 2014).

** The dollar emerged regarding the company (EMR) is also calculated by the ratio between the total emerged and the company's revenue.

3.3 Evaluating the business plan of the company

The company planned to gradually reduce the production of carburetor kits by 2025, based on decrease of 10% of the current fleet of the domestic market foreseen by the National Association of the sector (SINDIPEÇAS, 2012). The impact of this managerial decision was evaluated through a simulation that took into account:

- the reduction in the number of carburetor kits is offset by the increase of electronic injection kits;
- the reduction in energy use due to the small number of cutting operations in the production of electronic fuel injection kits;
- a decrease of the workforce in 2020, estimated according to the number and type of produced kits;
- the price of the kits was kept constant.

Table 6 shows the results of environmental accounting of the company until 2025. It is clear that, with increasing percentage of electronic injection kits, the total emergy of the company decreases along with the use of energy and materials to produce a unit of output (UEVs). The EmPrice, which reflects the costs in emergy into currency, would also decrease by 35% while the company's revenue would increase 24%.

Figure 5 shows that the emergy of the company's products may decrease by 31% by 2025. A 17% reduction in emergy costs for maintenance is also expected, as well as in the use of auxiliary materials and labor. Packaging material may significantly decrease by more than 80% while the revenue the company increases could increase by 24%.

Table 6 Summary of environmental accounting in emerging from JP Juntas in the period 2014-2025

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
% Emergy of electronic injection kits	37	41	45	50	54	60	64	70	77	84	92	100
Total emergy x 10^{18} (seJ/year)	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.8
UEV x 10^{12} (seJ/kit)	2.7	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2.0	1.9	1.9	1.8
EmPrice x 10^6 (Em$/year)	0.8	0.8	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.5
Revenue x 10^6 (U$/year)	1.35	1.38	1.41	1.44	1.47	1.5	1.53	1.56	1.59	1.62	1.65	1.68

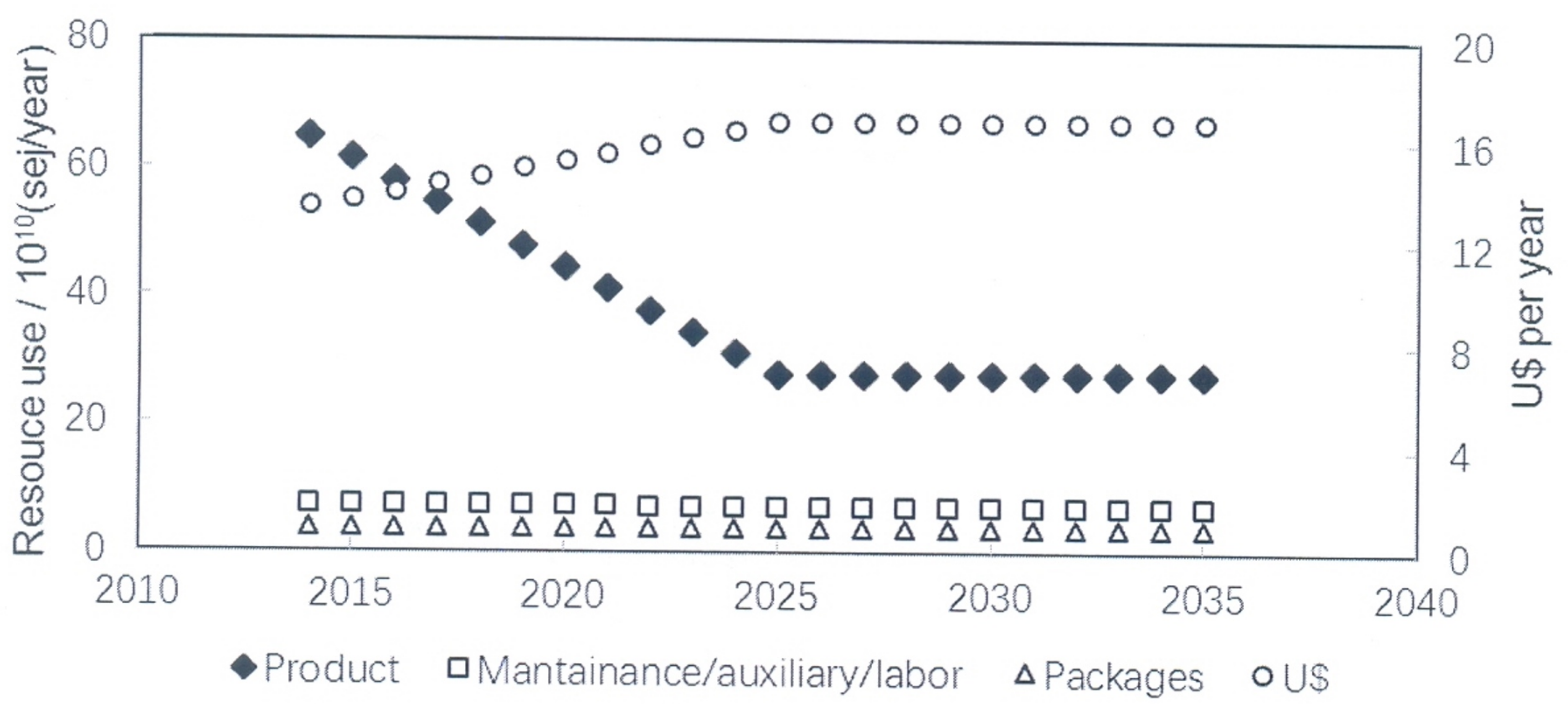

Fig. 5 Forecast for the use of emerging products, maintenance, auxiliary materials, labor and packaging between 2014 and 2035. Simulation was extended to 2035 to show the position of the company in the following ten years after the complete product change.

With regard to the emergy costs converted to monetary values, the results shown in Figure 6 clearly show that the product change will benefit not only the company, reducing environmental costs by 35%, but that the overall productivity will increase 55% due to less use of raw materials, auxiliaries, packaging, and energy.

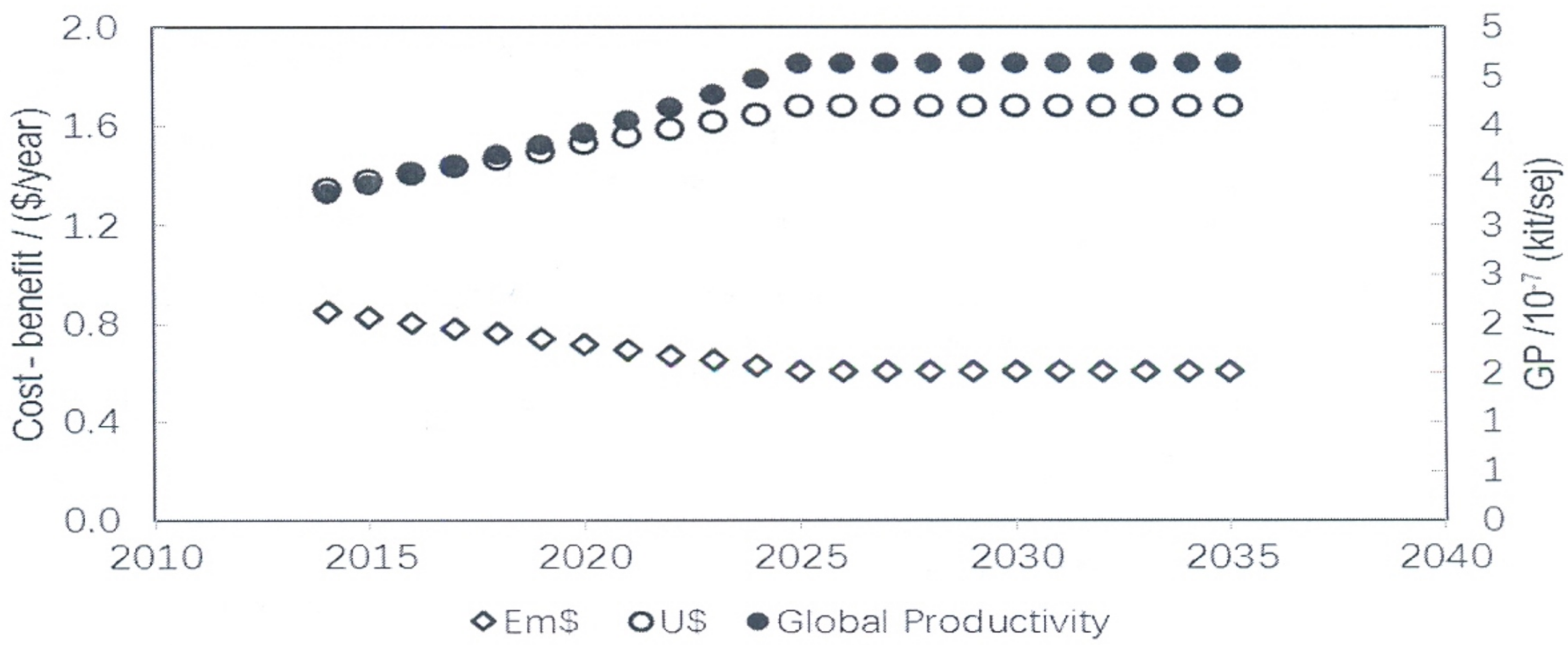

Fig. 6 Cost / benefit and overall productivity of JP Juntas in the period 2014-2035. Simulation was extended to 2035 to show the position of the company in the following ten years after the complete product change.

Gains due to an increase in overall productivity are not limited to the company and business managers, but extend to the environment, since part of the energy and resources saved can be used for other purposes. The relationship emergy/revenue, which may decrease by 48% till 2025, shows that the change of product makes a most eco-efficient company, which profits more with less use of resources and energy.

4. Conclusions

With the intention of investigating possibilities for the development of eco-efficient products, this work presents an approach to help decision makers of small companies, through the use of emergy synthesis. The usefulness of this tool was exemplified with a case study of the production of carburetion and electronic injection gaskets. Made according to the company's business plan, simulation results for the period 2014-2025 show that the earlier the exchange of products, the greater the eco-efficiency of the company.

The evaluation of a small company in the Brazilian automotive aftermarket confirms the idea that actions along the supply chain can help reduce the environmental load associated with the manufacture of products in and out of the main supply chain. The results show that the technological change occurred in the central supply chain may have beneficial effects on small business that exist and survive around the main chain but without participating in it directly. the separation of "without service" and "with service" make clear the influence that workforce imposes to the system carrying the memory of fuels, materials, food, minerals necessary direct and indirectly to support the workers' lives. The inclusion of services in emergy accounting adds valuable information on the structure, infrastructure and socio-economic development of the place where a process occurs and how it affects the performance and cost of the process under investigation.

In addition to the useful results for the management and future business plans of the company, this work, which employs underexplored aspects of emergy synthesis, shows that this methodology is a valuable tool for evaluating systems at the end of the production chain. Although it is not possible to calculate traditional indicators since the contribution of renewable resources is not evident, but only included in the UEVs of the inflows, the relationship between the resources used and the price charged, and the dependence on services occurring outside company boundaries provide valuable information for short and long-term decision making.

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Appendix A Detailed calculations of the inputs shown in Table 1

Table A1 Prices of the inputs used in JP Juntas.

	Prices/un.	Data source
Blister	R$1.98/kg	23 http://www.rededoplastico.com.br/cotacoes-de-materias-primas-do-plastico/
Cardboard	R$145/85 m x 400g/m^2	http://www.quickpack.com.br/default.asp?p=produto&a=detalhe&c=11&pId=409
Cellulosic paper	R$11.70/m^2	JP Juntas
Construction	R$436/m^2	Sindicato da Indústria da Construção Civil do Estado de São Paulo http://www.sindusconsp.com.br/downloads/estprod/economia/2014/04_boletimEconomi

		co_abril2014.pdf
Copper	U$6.56/kg	http://galeazi.com.br/cotacoes/
Electricity	R$273.05/MWh	http://www.aneel.gov.br/area.cfm?idArea=493
Green Kevlar	R$15.70/m^2	JP Juntas
Lamps	R$14.90/lamp	http://www.giamar.com.br/lampada-mista-250w-e27-ge-pr-1169-97542.htm
Lubricant	R$2.70/kg	http://www.lojaderolamentos.com.br/lubrificantes/graxas.html?SID=kca0m8b4fp3ibq3hol4nicem44&mode=list&limit=5
Package paper	R$58.21/8kg	http://www.quickpack.com.br/default.asp?p=produto&a=categoria&c=10&s=97
Paper	R$12/500pages	http://www.solostocks.com.br/venda-produtos/papel-a4-500-folhas_b
Plastic	R$6.10/kg	http://www.rededoplastico.com.br/cotacoes-de-materias-primas-do-plastico/
Plastic bags	R$1.98/kg	24 http://www.rededoplastico.com.br/cotacoes-de-materias-primas-do-plastico/
Red Kevlar	R$3.30/m^2	JP Juntas
Rubber	R$3.35/m	http://www.fg.com.br/mangueira-borracha-multipurpose-300lbs-1-2-preta-prod-5709.html?utm_source=google-cpc&utm_medium=google-cpc&utm_campaign=google-cpc&midia=google-cpc&gclid=CIDswuLp274CFavm7AodQhsARA
Steel	R$ 5.2/kg	http://www.superbid.net/leilao/oferta.htm?offer_id=664751&auction_id=23349&pager.offset=13
Water	R$66.56 /month	http://site.sabesp.com.br/uploads/file/clientes_servicos/comunicado_07_2013.pdf
Zinc	U$14.3/kg	http://galeazi.com.br/cotacoes/

Table A2 Services contributing to JP Juntas, calculated using the Brazilian EMR (Giannetti et al., 2013).

	Emergy/ (seJ/year)	U$/year	Services / (seJ/year)
Facility			
Concrete	3.22 x 10^{16}		
Steel	4.17 x 10^{15}	2878	4.89 x 10^{15}
Wood	2.15 x 10^{14}		
Office			
Plastic	1.19 x 10^{13}	57	9.64 x 10^{13}
Copper	3.09 x 10^{14}	30	5.06 x 10^{13}
Steel	8.71 x 10^{15}	4264	7.25 x 10^{15}
Glass	1.68 x 10^{12}	745	1.27 x 10^{15}
Production Plant			
Plastic	2.40 x 10^{14}	1147	1.95 x 10^{15}
Steel	4.26 x 10^{16}	20873	3.55 x 10^{16}
Subtotal	**1.56 x 10^{17}**	**62908**	**1.07 x 10^{17}**
Carburetor kit production			
Water	5.63 x 10^{13}	799	1.36 x 10^{15}
Electricity	2.94 x 10^{16}	8707	1.48 x 10^{16}
Paper	2.65 x 10^{14}	45	7.65 x 10^{13}
Rubber (o'rings)	4.13 x 10^{14}	360	6.12 x 10^{14}
Package paper	1.87 x 10^{15}	1746	2.97 x 10^{15}
Cardboard	6.18 x 10^{15}	3378	5.74 x 10^{15}
Copper (diaphragms)	6.53 x 10^{16}	15898	2.70 x 10^{16}
Zinc (diaphragms)	9.79 x 10^{16}	20592	3.50 x 10^{16}
Rubber tubes	7.22 x 10^{15}	6300	1.07 x 10^{16}
Copper (coils)	6.53 x 10^{15}	1590	2.70 x 10^{15}
Zinc (coils)	9.79 x 10^{15}	2059	3.50 x 10^{15}
Lubricants	5.11 x 10^{14}	1460	2.48 x 10^{15}

Labels	9.36×10^{14}	1440	2.45×10^{15}
Blister	3.22×10^{12}	5	8.48×10^{12}
Plastic bags	1.52×10^{14}	235	4.00×10^{14}
Cellulose paper	1.09×10^{17}	710	1.21×10^{15}
Red Kevlar	1.68×10^{16}	6288	1.07×10^{16}
Green Kevlar	4.70×10^{16}	29127	4.95×10^{16}
Electronic injection kit production			
Water	5.63×10^{13}	799	1.36×10^{15}
Electricity	1.26×10^{17}	74634	1.27×10^{17}
Paper	2.65×10^{14}	45	7.65×10^{13}
Rubber(*o'rings*)	5.78×10^{15}	5040	8.57×10^{15}
Package paper	1.87×10^{15}	1746	2.97×10^{15}
Cardboard	6.18×10^{15}	3378	5.74×10^{15}
Lubricants	5.11×10^{14}	1460	2.48×10^{15}
Labels	9.36×10^{14}	1440	2.45×10^{15}
Blister	6.12×10^{13}	95	1.62×10^{14}
Plastic bags	1.15×10^{14}	178	3.03×10^{14}
Green Kevlar	6.05×10^{16}	33862	5.76×10^{16}