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Impacts of Green Tire Technology: Case Study of Environmental and Customer Perspectives

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Abstract: Contextualization: the scenario of natural resource degradation requires an urgent positioning of big companies. Government and social pressures are reflected in a company's responsibilities and products. Research Problem: Many of a company's required actions are focused on post-consumption, natural resource usage restrictions, and the search for alternatives to reduce the negative environmental effects. Justification: This work is concerned with improperly disposed tires, whose residues are difficult to eliminate in accordance with the National Environmental Council (CONAMA) legislation, and with the differentiation of green tires from low-cost and low-quality Chinese tires. Objectives: This research focused on the analysis of Michelin green tire technology in light of its efficiency and market views, comparing them to a common tire. Methodology: Using a case study, the cost, durability, market acceptance and associated usage benefits of both tires was studied. Results: Green tires increase fuel economy and cost slightly more than common tires. Regarding durability, the ordinary tires waste the equivalent of the value of two green tires in one life-cycle. But despite the benefits in fuel economy, reduced CO_2 emission and mileage, these benefits are usually not perceived by lay consumers. Conclusion: Green tires are a new trend, and the tests results proved that it is possible to reduce the environmental impact while maintaining or even improving comfort, safety, fuel economy and performance.

Keywords: Green Tires, Environment Impact, Sustainability

1. Introduction

1.1. Theme Presentation

The tire industry in Brazil is concentrated in large multinational companies, which are: Goodyear, Pirelli, Bridgestone/Firestone, Michelin and Continental. Together, the manufacturers have 12 plants in Brazil, mostly in the state of São Paulo [1].

The numbers of production and sales have been growing over the past few years. In 2005, they produced about 53 million tires, with a domestic sales volume of about 38 million units, including direct imports and exports of around 18 million units [2].

Sales are aimed at three different segments: the automakers (OEM), the aftermarket and the foreign market. Automakers account for 26% of sales, and the aftermarket, which is composed of tire dealers' shops, is responsible for 42%. Exports account for 32% of sales, aimed at about a hundred countries, especially the United States (USA), France, Argentina and Mexico. Exports are mostly inter-company operations [2].

With prospects of profitability in these three types of market, manufacturers had been making a series of investments in the country during the period 2004 to 2007. The investments totaled approximately R$ 3 billion, which resulted in an increase of 30% of installed capacity in the country. These investments were motivated by three factors: increased domestic demand, a favorable scenario for exports and a change of production of the world's tire industry in low

labor cost countries [3].

However, after planned investments in 2004 reached maturity, the country scenario was no longer favorable. The exchange rate frustrated the expectations of exports, and the growing share of remold and Chinese tires in the aftermarket intensified competition in the internal market. The importation of used tires, used as raw material for remolding tires, became the center of a controversy between the various actors in the industry [4].

Another widely discussed issue concerns the environmental impact of abandoned or improperly disposed tires, whose residues are difficult to eliminate. In order to solve this problem, the National Environmental Council (CONAMA) has created a resolution that has rules on the matter, forcing manufacturers to provide for environmentally adequate disposal of the waste tires [5].

In an attempt to differentiate their tires from Chinese tires and other low-cost and low-quality tires, the biggest manufacturers have stepped up investment in some technologies. At first, this would add even more costs to its products that were already at a price level higher than the new entrants, but it was the only way to differentiate their tires and not turn the product into commodities [6].

Due to this reason and the environmental preservation issue, a technology called Green Tires entered the scene. These tires provide greater durability, and greater fuel economy, as a primary benefit, through its low rolling resistance coefficient [7].

1.2. Objective

The aim of this work is to present Green Tire technology, which is increasingly widespread due to the social and environmental pressures that have affected the tire industry, and the advantages and disadvantages of this new product.

In order to draw conclusions about the efficiency and market acceptation of this new technology, a comparison between a green tire and a common tire is proposed to analyze on a financial optical if the highest price during tire acquisition worth after product usage.

1.3. Justification

The advancement of this type of product and the high technology employed aroused interest in understanding what stage the big companies of this segment are at, with respect to the current trend of sustainability [8].

Tires are created for every market share and consumer profile. A customer who opts for a conventional or performance-oriented tire wants better braking and grip performance. At the other extreme, a customer of a compact car is more focused on the economy and durability of the tire. There are still those concerned with environmental issues, and this public is the focus of this dissertation, as well as the real advantages and disadvantages in the purchase of this type of product.

1.4. Methodology

The methodology used for the qualitative research will be the case study approach, aiming to objectively and directly present a comparison of the costs involved during the acquisition of tires with different technology, taking into account their initial costs, durability and associated benefits during their use.

2. Theoretical Foundation

2.1. World Tire Market

The tire market experienced strong growth in the last three decades. The gross sales of the industries in the sector more than tripled over that time, starting from a level of about US $35 billion in 1985 to US $110 billion in 2015 [9]. During this period, the tire industry went through a process of concentration amongst the ten largest companies, subjecting them to mergers and acquisitions, which resulted in five groups (Table 1).

Table 1. *Enterprise mergers and acquisitions processes.*

1981	2005
Goodyear Dunlop	Goodyear
Firestone Bridgestone	Bridgestone
Michelon BF Goodrich Uniroyal	Michelin
Pirelli Armstrong	Pirelli
Continental General	Continental

Source: Michelin (2009).

Table 2. *2016 Tire manufacturers ranking.*

			2016	
Rank	**Brand**	**Euro**	**Share Tyres**	
1. (1.)	BRIDGESTONE	27,042.3	22,412.5	82,9%
2. (2.)	MICHELIN	20,907.0	20,488.9	98%
3. (3.)	GOODYEAR	14,380.0	14,380.0	100%
4. (4.)	Continental	40,549.5	10,717.4	26,4%
5. (5.)	PIRELLI	6,058.4	6,056.2	100%
6. (7.)	SUMITOMO	6,131.1	5,254.6	85,7%
7. (6.)	HANKOOK	5,216.8	5,216.8	100%
8. (8.)	YOKOHAMA	4,831.4	3,857.7	79,8%
9. (9.)	MAXXIS	3,436.7	3,436.7	100%
10. (11.)	COOPER TIRES	2,774.8	2,774.8	100%

Source: adapted from Tyrepress (2017).

Over the past decade, Bridgestone and Michelin have alternated in sales leadership in the sector, while Goodyear ranks third in the market share. Together, the three largest companies held more than 50% of the world market. Table 2

illustrates the industry ranking [10].

2.2. Brazil's Tire Market

The Brazilian industry had a starting point with the implementation of the General National Transportation Plan in 1934. In 1936, the Brazilian Society of Rubber Artifacts was inaugurated. Also known as Tires Brazil, in its first year of operation it produced 29,000 tires [11].

The first companies to install plants in Brazil were Goodyear, Firestone and Pirelli, around 1940. Michelin started local production only in early 1990. With the opening of Continental's plant in 2006, the five largest world producers began to manufacture in Brazil. The country is the seventh largest producer of tires for cars and the fifth of tires for buses and trucks [1].

It is worth mentioning that the factories invest, on average, US $12 million annually in innovation, R $8.4 million in internal R & D. Among the innovations, we can mention green tires, tire labeling, the use of new raw materials (such as rice husk to produce silica) and the test fields specially designed for the different Brazilian land. Among the products specially designed for the country, we have as examples the specific tires for tractors and trucks that are used in sugar cane cultivation and special tires for small passenger cars [1].

The country's manufacturers strictly fulfill the environmental commitment and legal obligation to collect waste tires responsibly, according to the annual targets set by IBAMA. Reciclanip, an entity maintained by the industry. has an annual cost of US$ 40 million associated with the 834 collection sites in 26 states and the Federal District which ensure the proper disposal of waste [12].

Not all importers comply with this legal obligation. IBAMA annually publishes the Tires Report, which has consolidated information provided by manufacturers and importers on intended volumes of waste tires. It is apparent that from 2009 to 2013, an environmental liability of approximately 150,000 tons of waste tires accumulated, which were the responsibility of importers who have not fulfilled the obligation [12].

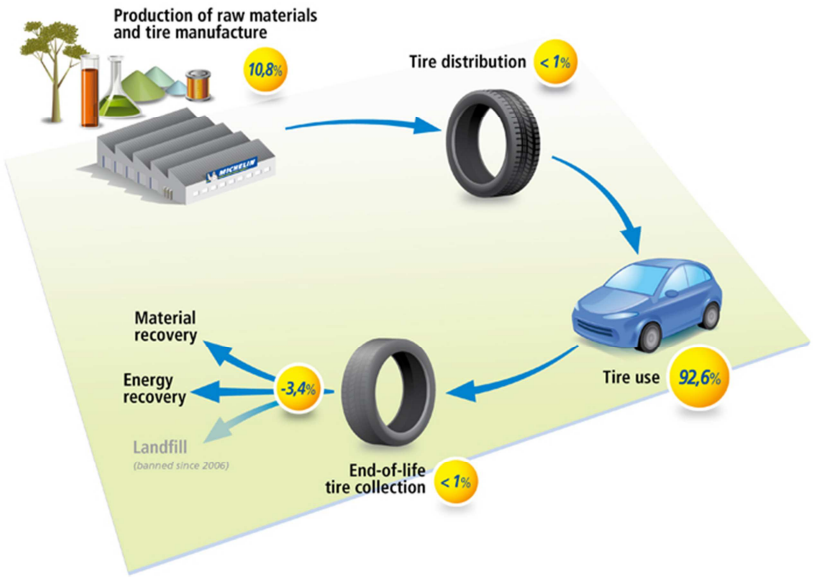
2.3. Tire Environment Impact

According to Wills [13], we can cite the following as automotive emissions that impact the environment:

1. Emissions of particles through the exhaust of the vehicle;
2. Fuel evaporative emission (emitted into the atmosphere through evaporation of fuel hydrocarbons);
3. Crankcase gas emissions (combustion byproducts that pass through the engine piston rings and lubricant vapors);
4. Dust emissions from tire wear, brake and clutch;
5. Re-suspension of soil dust particles and
6. Evaporative emissions of fuel in the fuel transfer operations (associated with the storage and refueling).

All these emissions are responsible for acid rain, cloud urban pollution, greenhouse gases (GHG), global warming and other environmental problems.

The presence of vehicle tire emissions in the atmosphere is due to the burning of fuel in the engine to overcome the rolling resistance [14]. Figure 1 illustrates clearly what life cycle assessments of tires clearly show, that it is during its use that the impact of a tire on the environment is at its greatest: 92.6% for a car tire [3].



Source: Adapted from Michelin (2009)

Figure 1. *Contribution of different tire stages to its impact on the environment.*

The tire becomes an unusable product after wear of the tread, because the worn tire puts the safety of vehicle occupants at risk in wet road conditions. Discarding tires generates disorder and their environmental impact can be quite high.

According to Lagarinhos [15], tire wear is influenced by

several factors, such as tire design, composition of the tread, enhancing tissue, soil conditions, the driver and the severity of usage.

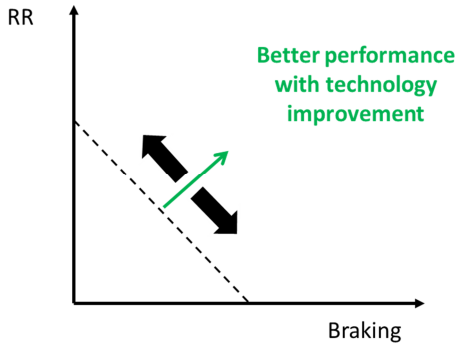
2.4. Green Tires

One of the ways to reduce the environmental impact of a vehicle is to reduce its pollutant emissions into the atmosphere, i.e., reduce your fuel consumption. One of the most effective ways to achieve this is by reducing the rolling resistance force that is linked directly to the type of tire of the vehicle [16].

Three factors should be considered for reducing rolling resistance: a decrease in the tire weight, a change in its structure and a change in its compounds. The challenge for companies is to balance the three fronts, because there is no point in creating an extremely light tire if it has short durability [17].

The green tire concept originated in 1983 by the manufacturer Pirelli and has evolved since then, making use of new technologies and new raw materials [18].

Figure 2 below shows the challenge of the tire industry; because hysteresis improves rolling resistance, this reduces the vehicle braking capability [19]. The role of new technologies is to improve the tire performance as a whole.

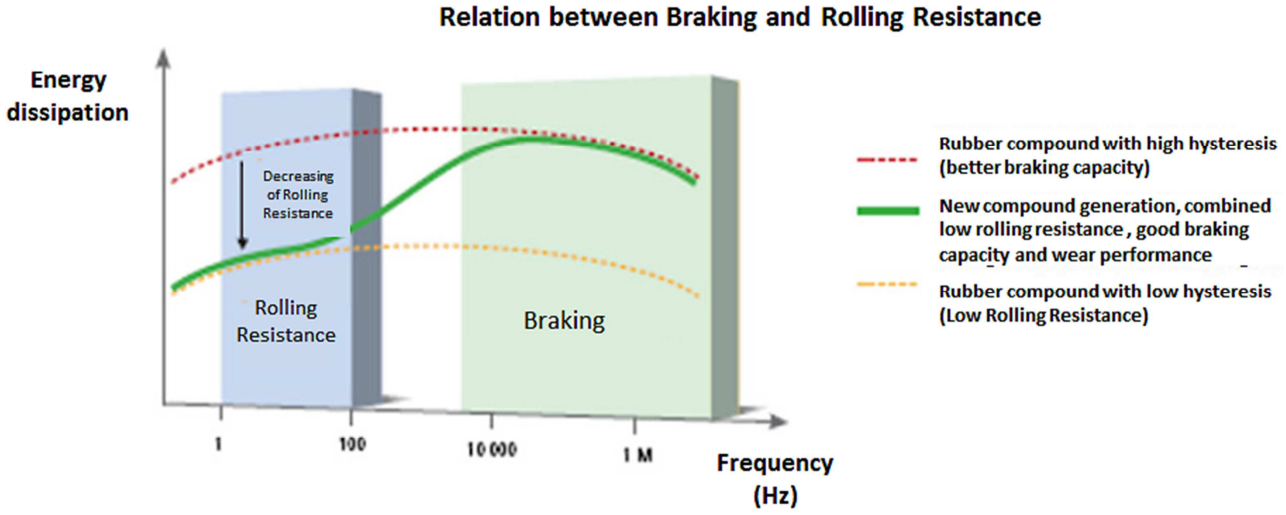


Source: Adapted from Michelin (2009)

Figure 2. *Graph showing relationship between rolling resistance and braking of the vehicle.*

The substance responsible for hysteresis and lower rolling resistance (RR), and which achieves the best performances, is silica.

With the addition of silica, it was possible to develop rubber compounds which exhibit low hysteresis at low frequencies (the portion related to the rolling resistance) and high hysteresis at high frequencies (related to braking) [20], as shown in Figure 3.



Source: Adapted from Michelin (2009)

Figure 3. *Difference between highly hysteretic compound with little hysteresis and silica.*

In combination with the silica, it is important to use one or more rubbers which have a glass transition point at appropriate temperatures, because the hysteresis of the compound is low at normal operating temperatures [21].

With this change in the composition of tires, it was possible to reduce the rolling resistance by 20-30%, while other characteristics were maintained or even improved [22]. To further the reductions in rolling resistance values and thus create ever more ecological tires which maintain safety, pneumatic industries should follow three precepts [23]:

1. Improve tire architecture, reducing efforts, strengths and unnecessary distortions, through which there is energy loss;
2. To reduce the hysteresis losses at frequencies involving rolling resistance (results achieved using silica and binding of chemical elements forming a compound that, unlike the rubber compound with carbon black, have no long polymer chains. This entails a very hysteretic material in the high frequencies, improving friction, and low hysteresis at low frequencies, improving the RR);
3. Reducing the weight of the rubber compound used in the tire through a new design or new materials, that is, designing tires which are lighter, thinner.

3. Case Study

A fact widely discussed regarding green tires is their higher price. By using different raw materials, the cost of a green tire can often be higher than the usual tires, but studies prove that this value is returned to the customer, thanks to fuel economy [24].

According to a study by the National Academies of Science, a 10% decrease in rolling resistance can result in a savings of 1 to 2% of fuel. As some green tires that are on the market today reach a 20% decrease in rolling resistance, the customer can save up to 4% in fuel consumption [1].

This case study aims to compare all the costs and benefits that a driver would have, using a common tire and using a tire with green tire technology.

Two brands of tires were chosen with great relevance to the Brazilian market: Michelin and Pirelli.

Michelin's recognition of product quality and investment in technology are the reasons the brand was chosen to represent the tire with green tire technology.

Pirelli, the leader in the Brazilian market, has a more popular appeal for the vast majority of its products. The fact that it does not have such a strong investment in technology means that its cost of manufacturing is lower, which ends up being reflected in the final price of the product [25].

Unfortunately, due to the maturity of the national market, the price aspect is decisive for the choice of product, leaving performances related to product safety and durability in the background [26].

The size of the tires chosen for this study is 205/55 R16. This dimension equips a circulating fleet of 1,940,000 vehicles in the national territory, resulting in the parking of 7.760.000 tires in soil [27, 28]. Table 3 shows the list of the main vehicles of the Brazilian fleet that are equipped with this dimension of tires.

Table 3. *Brazilian fleet equipped with 205/55R16.*

Brazilian main fleet equipped with 205/55 R16		
HONDA CIVIC	KIA SOUL	CITROEN C4
TOYOTA COROLLA	FIAT STILO	VOLKSWAGEN BEETLE
VOLKSWAGEN GOLF	FIAT BRAVO	NISSAN SENTRA II
CHEVROLET VECTRA	CHEVROLET ZAFIRA	FIAT LINEA
CHEVROLET ASTRA	FORD FOCUS	PEUGEOT 308
VOLKSWAGEN JETTA	RENAULT MEGANE	FORD FOCUS II
RENAULT SANDERO STEPWAY	VOLKSWAGEN GOLF VII	JAC J6
PEUGEOT 307	PEUGEOT 408	VOLKSWAGEN BORA
NISSAN SENTRA	CHEVROLET SONIC	AUDI A3 SEDAN

Both of the tires chosen for this test have a rather compelling business appeal, and this coupled with the maturity of a price-oriented market, means that the lay consumer is left without many alternatives for a smarter choice.

For this comparative study we will use some Brazil vehicle averages, such as the annual mileage, average fuel consumption, average vehicle weight, average fuel price and average vehicle autonomy with a single tank of gasoline. Table 4 shows the averages considered for the study.

Table 4. *Assumptions.*

Background & assumptions		
Vehicle consumption	10	1 / 100 km
KMs traveled per year	15,000	Km/year
Vehicle weight	900	kg
Fuel prices	1.16	€/liter
Vehicle range	500	km

After these premises, we needed to differentiate the tires in the performance that characterizes the "green tires" technology: the Rolling Resistance (RR).

The following values were identified for the two brands participating in the study:

a) Pirelli Phantom: F on RR → 12,0 Kg per Ton

b) Michelin Primacy 3: C on RR → 7,8 Kg per Ton

Table 5 expresses the gain in Kg / Ton between the two tire brands studied and the price difference between them. For the moment, we will consider that the 2 tires have the same durability, even though we know that green tires have longer durability than normal tires.

Table 5. *RR coefficients.*

	Normal tires	**Green tires**	**Gain**
Rolling Resistance Coefficient	12 Kg/T	7.8 Kg/T	4.2 Kg/T
Longevity	50,000 Km	50,000 Km	0 Km
Longevity per year	3.3 years	3.3 years	0 year
Purchase price for a tire	70 €	86 €	-64€/4 tires

Table 6 shows the economy generated by green tires through gasoline consumption. The difference between the

green tire and the normal tire is 2.9% per year. This percentage may seem small, but it means a difference of 147 liters throughout the life of the vehicle's tires. In order to have an idea of the impact of this on the national market, this economy is multiplied by the data of the tire park only from the size of the aforementioned study.

Table 6. *Fuel saved.*

	Normal tires	Green tires	Gain
Cost of four tires	5.60€/1,000Km	6.88€/1,000 km	-1.28€/1,000km
Vehicle consumption (1/100)	10 L/100	9.706L/100	0.294 L/100
Fuel expense	116€/1,000km	112.59€/1,000Km	3.41€/1,000Km
Vehicle Annual consuption	1,500L/year	1,455.9 L/year	44.1 L/year

Comparing the 2 previous tables, where one shows the extra initial cost of buying a green tire and the other shows the fuel economy that this tire provides, we have table 7.

Table 7. *Gains on fuel and KM.*

	Normal tires	Green tires	Gain
Annual fuel cost	1,740 €/year	1,688.84 €/year	51.16 €/year
Annual tire cost	84 €/year	50,000 Km	-19.20€/year
Annual fuel and tire cost	1,824 €/year	3.3 years	31.96 €/year
Free km			441 Km/year

In spite of an annual investment of 19.20 € to buy 4 green tires, in that same year (that is the basis of the study) the vehicle owner saves 31.96 € in fuel due to the low coefficient of rolling resistance of these tires. This saved amount, following these same premises of consumption, allows the driver to drive an additional 441 km per year.

Extrapolating these calculations to the whole tire life cycle, estimated to be 3.3 years according to assumptions used in the calculation, the driver would have a savings of €107, or could drive another 1,470 km.

Another point raised can be the durability of the product. Thanks to new raw materials, a green tire can last longer, which would offset the cost a bit more compared to other tires. As green tires reduce hysteresis, it also reduces heat generation, thereby causing its degradation to slow down, because heat accelerates the chemical reactions that promote the aging of rubber compounds.

These calculations were quite conservative, especially since we did not consider green tire wear. Using all the previous premises (and taking into account that a green tire has a 14% longer life than the normal tire, corresponding to 57,000 km), at the end of the life of the 4 tires the fuel economy provides for the purchase of 2 new green tires. Table 8 shows this calculation.

Table 8. *Fuel and wear gains.*

	Normal tires	Green tires	Gain	Gains on whole life of the Green tires
Rolling Resistance Coefficient	12 Kg/T	7.8 Kg/T	4.2 Kg/T	
Longevity	50,000 Km	57,000 Km	7,000 Km	7,000 Km
Longevity per year	3.3 years	3.8 years	0.5 year	
Purchase price for a tire	70 €	86 €	-64€/4 tires	
Cost of four tires	5.60€/ 1,000Km	6.04€/1,000 km	-0.44€/ 1,000km	
Vehicle consumption (1/100)	10 L/100	9.706 L/100	0.294 L/100	
Fuel expense	116€/ 1,000km	112.59€/ 1,000Km	3.41€/ 1,000Km	
Vehicle Annual consuption	1,500L/year	1,455.9 L/year	44.1 L/year	167.58 liters
Annual fuel cost	1,740 €/year	1,688.84 €/year	51.16 €/year	194 €
Annual tire cost	84 €/year	90.53 €/year	-6.53€/year	-25 €
Annual fuel and tire cost	1,824 €/year	1,779.37 €/year	44.63 €/year	170 €
Free km			441 Km/year	1,676 Km

4. Theme Discussion and Results

The technology of green tires has been gaining prominence in the national market, supported mainly by three factors.

The first of these factors is the product cost, combined with the performance gain. The development cost of the green technology for tire manufacturers has decreased over the years that the product is on the market, making the tire with this technology more affordable and with a cost close to "common" tires. The initial disbursement cost is still a decisive factor for the purchase of tires in the national market, even though it is clear that the green products have a longer durability, which provides a lower cost.

Associated with the factor of cost is the main benefit of the green tire, which is the fuel economy. Although little valued by consumers, as the case study shows, this benefit may be much higher than the lay consumer perceives. An example of this is the last simulation of the case study that shows that at the end of the life of 4 green tires, the savings on the same vehicle would be equivalent to the cost of 2 more green tires.

Usually the average driver does not know how to measure

mileage or fuel economy, other than fleet or professional users, who need to closely monitor all the costs of their activities for their business. Proof of this is the higher percentage of lower quality tires in the passenger car market compared to the percentage of these tires in the light truck and truck market. The other issue that has been supporting the growth of green tires is the environmental impact of these products compared to the common tire. This environmental impact can be ciphered economically through fuel economy, the focus of this study, but also through the amount of CO_2 emitted into the atmosphere and the amount of trees needed to absorb that amount of CO_2.

Extrapolating these calculations, we can predict this impact by comparing the liters of air taken from the atmosphere per year and the equivalence in days of oxygen necessary for man, as shown in table 9.

Table 9. *Environmental impact.*

	Normal tires	**Green tires**	**Gain**
Vehicle range	500 km	515 km	15 km
Average CO_2 emited in g/km over tire's life	250g CO_2/Km	242.65g CO_2/Km	7.35g CO_2/Km
CO_2 emited by the vehicle in tons per year on average over tire's life	3.750 T/year	3.640 T/year	0.110 T/year
Equivalent to the Carbon caught annualy	150 trees	145.6 trees	4.4 trees
Liters of air taken from the atmosphere each year	13,899,000 liters/year	13,490,369 liters/year	408,631 liters/year
Equivalence of oxygen necessary for a man respiration	927 days	899 days	27 days

With consumers becoming increasingly sensitive to evident environmental concerns, this type of analysis can be a decisive factor in the purchase of green tires.

5. Conclusion

5.1. Reviews and Comments

This work noted the growing concern over the environment and fuel economy, which make green tires a current trend.

It was found that each manufacturer chooses to approach the green segment in a different way, either with a decrease in tire weight, a new design on the tread, the use of new raw materials or a combination thereof in order to achieve the ideal results and always improve the final product characteristics. Regardless of approach, each of the major companies has green products, making it even clearer that this is a growing and promising market.

Looking at the products available today and the results obtained in the various tests, this paper proves that it is possible to reduce environmental impacts while maintaining or even improving other tire characteristics, such as comfort and safety. Even if the tire presents a higher price, this cost can be returned through fuel savings over the life of the tire.

Many innovations have been presented in the tire market, yielding increasingly promising results for the environment, such as the innovative materials presented in this paper.

Legislation can increasingly help to promote these new technologies which balance the environmental impacts, safety, economy and comfort by analyzing and exposing all aspects to the consumer.

It was observed that a possible way to boost both automakers and tire manufacturers is to increase the dissemination of energy efficiency results, making membership in government labeling programs mandatory for manufacturers. In this way, the end product is the reality seen in the market.

5.2. Future Works

The maturity of the national market means that environmental impact is a strong decision criterion for choosing products. Based on the studies of this work, the potential environmental gain that the green tires provide in relation to the number of trees and CO_2 emission saved due to this technology, could be a very interesting line of study for future work.

References

[1] TYREPRESS. Leading tire manufactures. Available at: https://www.tyrepress.com/leading-tyre-manufacturers. Acess in: 23 mai. 2018.

[2] EUROPEAN TYRE & RUBBER MANUFACTURERS´ASSOCIATION. TYRE LABELLING. Available at: http://www.etrma.org/tyres/tyreHlabelling. Access in: 26 oct. 2018.

[3] MICHELIN. Tyre and Environmental Evolutionary Scenario. São Paulo, 2009.

[4] INFOPNEUS. Tire's history. Available at: http://www.infopneus.com.br/historia-dopneu/. Access in: 08 ago. 2018.

[5] KNEPPER, G. W. Akron City at the Summit. Akron: Comtinental Heritage Press, 1981. P. 197, 200, 201.

[6] GOODYEAR. New Goodyear Innovation Could Make Tire Pumps Obsolete. 2011. Available at: http://www.goodyear.com/cfmx/web/corporate/media/news/story.cfm?a_id=559/ Access in: 12 ago. 2018.

[7] WALTER, Joseph D. Innovation in the tire industry. The University of Akron College of Engineering, 2007.

[8] NABOLEIA. When appeared the first tire in the world. Available at: http://naboleia.com.br/saiba-quando-surgiu-o-primeiro-pneu-do-mundo/. Access in: 24 may. 2019.

[9] ALLEN, H. The house of Goodyear: fifty years of men and industry. Cronology of rubber. Cleveland: Goodyear Tire & Rubber Company, 1949. 687p.

[10] CONTINENTAL. Reinfengrundlagen Pkw. [S.I.]: GmbH, 2009. 30p.

[11] COSTA, Argemiro. Vehicle Dynamics – Tires: History – Introduction. Pós Graduação – Escola de Engenharia Mauá, São Caetano do Sul, 2011.

[12] IBAMA. Consulting the emission levels of Brazilian new vehicles. Available at: http://servicos.ibama.gov.br/ctf/publico/selmarcamodelorvep.php. Access in: 10 oct. 2018.

[13] WILLS, William. Increasing energy efficiency in light vehicles and its implications for greenhouse gas emissions: Brazilian scenarios between 2000 and 2030. 2008. 149 f. Dissertação Pós Graduação Universidade Federal do Rio de Janeiro, Rio de Janeiro, 2008.

[14] NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES. Tires and Passenger Vehicle Fuel Economy: Informing Consumers, Improving Performance. Washington, 2006. 152 p.

[15] LAGARINHOS, Carlos. Tire recycling: analysis of the impact of environmental legislation through reverse logistics. 2011. 293 f. Tese Doutorado USP, São Paulo, 2011.

[16] RUFFO a, Gustavo Henrique. The green tire: Industry invests more and more to reduce consumption and avoid problems with the disposal of tires. Available at: http://quatrorodas.abril.com.br/autoservico/reportagens/pneuHverdeH479152.shtml. Access in: 22 set. 2018.

[17] RUFFO b, Gustavo Henrique. Tire history: from wooden wheel to hi-tech airless tire. Available at: http://quatrorodas.abril.com.br/autoservico/reportagens/historiaHpneuH476615.hml. Access in: 22 set. 2018.

[18] PIRELLI. Green Performance. Available at: http://www.pirelli.com/tyre/br/pt/car/genericContent/greenperformance. Access in: 10 oct. 2018.

[19] PADOVAN, Joe. Tire Rolling Resistance. University of Akron, Akron, 2012.

[20] POTTINGER, Marion. Rolling Resistance, Tire/ Pavement interaction Noise and Tire Created Ride Problems. Akron, 2012. 93 p.

[21] HOLTSCHULZE, Dr. Jens. Requirements for Tires of Modern Vehicles in the 21st Century. In: TIRE TECHNOLOGY EXPO, 2011, Cologne.

[22] TONACHEL, Luke. Tire Efficiency: How Your Car Can Cruise on Less Gas. Available at: http://www.hsw.uol.com.br/framed.htm?parent=pneusHbaixoHconsumoHcombustivel.htm&url=http://switchboard.nrdc.org/blogs/ltonachel/tireefficiencyowyourcarc.html. Access in: 20 set. 2017.

[23] INMETRO. Consumer Information: Tags. Available at: http://www.inmetro.gov.br/consumidor/etiquetas.asp. Access in: 04 set. 2018.

[24] RUFFO, Gustavo Henrique. Truths about the world of tires. Available at: http://quatrorodas.abril.com.br/autoservico/reportagens/historiaHpneuH476615.shtml. Access in: 22 set. 2018.

[25] PIRELLI. Cinturato Family. Available at: http://www.pirelli.com/tyre/br/pt/car/genericContent/cinturato. Access in: 10 oct. 2018.

[26] PIRELLI. Scorpion Verde All Season. Available at: http://www.pirelli.com/tyre/br/pt/suv/sheet/scorpionverdeall_season.html. Access in: 20 set. 2018.

[27] PIRELLI. Cinturato P1. Available at: http://www.pirelli.com/tyre/br/pt/car/sheet/cinturatop1.html. Access in: 20 sep. 2018.

[28] PIRELLI. Cinturato P7. Available at: http://www.pirelli.com/tyre/br/pt/car/sheet/cinturatop7.html. Access in: 20 dez. 2018.