PROMOB-e

Impacts of electric bicycles and kick-scooters sharing systems:

Identification of socio-environmental aspects

Product prepared by:
PROMOB-e
German Cooperation for Sustainable Development
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Impacts of electric bicycles and kick-scooters sharing systems:

Identification of socio-environmental aspects

Prepared by:
NOVí

Authors:
Caroline Marques Leal Jorge Santos
Lucas Lara de Paula Leite Novaes
Luiz Eduardo Rocha Corrêa Rielli (Organizer)

STUDY 2 of 3

Brasília, April of 2019

PROCEEDINGS

Product prepared by:
PROMOB-e
German Cooperation for Sustainable Development
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Prepared by:
NOVí SOLUCOES SOCIOAMBIENTAIS LTDA

Authors:
Caroline Marques Leal Jorge Santos
Lucas Lara de Paula Leite Novaes
Luiz Eduardo Rocha Corrêa Rielli (Org.)

This document was prepared within the scope of the Project DKTI Project - Efficient Propulsion Systems - PROMOB-e (PN 15.2127.7-001.00), the result of a bilateral articulation between the governments of Brazil and Germany. The project "Assessment of environmental, social and economic impacts and opportunities of electric bicycles and kick-scooters batteries used in sharing systems in the Brazilian market" directly involves the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, the executing agency for the German Cooperation for Sustainable Development, as well as other institutional partners. GIZ and its partners would like to thank Tembici's support in the development of the activities.

Coordination:
Jens Giersdorf (GIZ)
Fernando Fontes, Assessor Técnico (GIZ)
Luiz Eduardo Rocha Corrêa Rielli, Diretor-Executivo (NOVí)

Brasília, April of 2019.

NOVi
cooperação
alemã
DEUTSCHE ZUSAMMENARBEIT

Por meio da:
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
MINISTÉRIO DA
ECONOMIA
PÁTRIA AMADA
BRASIL
GOVERNO FEDERAL

CONTENT

This report presents a preliminary identification of the environmental and social impacts of electric bicycles and kick-scooters sharing systems in the Brazilian market. It explores the environmental and social impacts of vehicle components, mainly related to batteries. In this way, it can be used as a repository of information and analysis and can support policy makers and agents involved in the implementation of urban micro-mobility products and services.

The execution of this report was possible with the support of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, executing agency for the German Cooperation for Sustainable Development, as well as institutional partners, such as the Ministry of Economy of Brazil. In addition, we would like to thank the operator Tembici, who supported the project, and professionals from the electric mobility market interviewed, listed in the Appendix.

LIST OF FIGURES

LIST OF GRAPHS

LIST OF TABLES

LIST OF CHARTS

LIST OF CONTENTS

1. INTRODUCTION

Any human action or economic activity has environmental and social impacts. The challenge of sustainability is to seek a balance between different aspects, making these effects tangible and measurable.

Considering the urban micro-mobility sector, knowing the negative effects of a particular product or service can facilitate decision making. It is not about causing paralysis or restricting the implementation of new models or technologies. The provision of technically correct and accessible information in terms of understanding allows everyone involved to choose travel options consciously. Users, customers and parts of the system will be able to choose between alternatives that consider costs, travel time, convenience and the socio-environmental impacts generated. Operators will never get a better assessment of risks and potential negative consequences generated by their businesses. Lastly, regulators and public policy makers will distribute the responsibilities, avoiding market failures and assessing the real impacts of their actions. Thus, the assessment of the socio-environmental impacts of urban micro-mobility systems should facilitate decisions that consider technical aspects, concerns and expectations of those involved, in a perspective of long-term dynamic balance.

This orientation is supported by a sense of responsibility (lato sensu) and by a life cycle approach, through which the needs of using resources and energy are compared for the production of items that will be used in a specific function and discarded in some future time. In this sense, the Life Cycle Assessment (LCA) method is used as a tool to demonstrate the effects in a concrete and objective way, examining all the links in the value chain. In legal terms, it is foreseen in the National Solid Waste Policy (art. 7, XIII).

According to the report "Impacts of electric bicycles and kick-scooters sharing systems: challenge characterization"[1] the electric bicycles and kick-scooters sharing market is in rapid expansion. The dynamics of the market, of strong competition and benefits to the pioneers, have induced operators to offer services before even identifying, measuring and assessing the risks associated with environmental and social impacts. In addition to market conditions, gains in scale and reduced battery costs will further drive the adoption of vehicles as an option for urban micro-mobility.

However, while new solutions and technologies can bring real benefits to cities and people's lives, they can also generate direct and indirect negative socio-environmental impacts hitherto unnoticed. Thus, what is sought to be avoided is the so-called problem shifting, or the transfer of problems along the value chain. When considering electric bicycles and kick-scooters, a new scale of availability requires comprehension of direct, indirect and induced impacts along the life cycle of its components and materials. In particular, it is necessary to understand the use and post-use aspects of batteries as hazardous waste.

Considering the scope of this study, electric bicycles and kick-scooters in sharing systems are positioned as a clean, accessible, and dynamic means of transport. These attributes are fundamentally relative, comparing the new equipment and the way of use to the traditional and predominant individual use of combustion engine cars. In fact, when comparing the energy efficiency between combustion engine cars and electric bicycles and kick-scooters, the benefits of new light vehicles are evident, considering the same function. It is enough to say that for the transport of an average individual weighing 63 kilos, an average car uses a mass of more than one ton, while an electric kick-scooter does the same with 12.5 kilos. That is, in simple terms, the energy used in automobiles is

---

[1] RIELLI, L. SANTOS, C., CHAPMAN, S., NOVAES, L. (2019). Impacts of electric bicycles and kick-scooters sharing systems: challenge characterization. GIZ. Brasilia, 2019.

converted to move its own weight and is also dissipated in the form of heat, vibrations and noise. In electric kick-scooters, energy is used fundamentally to move the driver[2].

This study identifies socio-environmental aspects, impacts and damage factors resulting from the use of bicycles and electric kick-scooters and compares them with the use of combustion engine cars. To this end, it makes use of the recent literature available on LCA in light electric mobility vehicles (Appendix 6.2), not having the objective of carrying out the impact inventory, with the generation of primary data. In this sense, it offers a preliminary framework, indicating relevant aspects for further deepening. However, the insights generated can guide those involved in the rapid implementation of new sharing systems.

The report is divided into four parts. Chapter 2 presents the definitions and method of Life Cycle Assessment. Then, Chapter 3 indicates socio-environmental aspects and impacts of electric bicycles and kick-scooters from studies available in the literature. The next step introduces the topic of legal liability for damages. Finally, the conclusion presents the activities to be developed in subsequent research.

---

2. Bird (2018), ParisflieswithBird. Available at:(www.bird.co/wp-content/uploads/2018/12/Paris-flies-with-Bird.pdf?utm_campaign=%F0%9F%8F%A2%20%F0%9F%9A%99%20%F0%9F%A4%96%20The%20Physical%20World%20Tech%20Newsletter%20&utm_medium=email&utm_source=Revue%20newsletter), "(...) electric kick-scooters use energy to move the driver, unlike cars in which 1.5% of the energy is effectively used for displacement. The rest is lost in the form of heat and noise". The same passage quotes the book Autonomy: the quest to build the driverless car - and how it will reshape our world, de Lawrence Burns and Christopher Shulgan " (...) less than 30% of the energy from the gas put in the car is used to move on the roads. (...) only 5% of the gasoline energy is translated into movement to move the user, which totals only 1.5% of the fuel's total energy".

2. LIFE CYCLE ASSESSMENT

2.1. ORIGINS

Life Cycle Assessment is an environmental management technique that analyzes in a quantified way all interactions of a given product or service with the environment and its consequent associated impacts, throughout all links in a value chain.

Its origin is inserted in the context of growth of environmental concerns verified mainly from the middle of the 20th century, as a reflection of the accentuated rhythm of the increase in population, production and consumption, on the one hand, and the scarcity and environmental degradation on the other.

The oil crisis, starting in the 1960s, highlighted the dependence on fossil fuels and the need to seek diversification of the global energy matrix from alternative, less polluting energy sources. In this context, in 1965 the first study recognized as LCA emerges, carried out by the beverage industry in the United States, whose scope was to analyze between glass, aluminum and plastic materials what would cause lower emissions and use less resources in the manufacturing process of soft drink packaging[3].

As a result of advances in the institutionalization of the environment on the international agenda, the LCA gained space as a tool capable of making impacts visible and measurable by mapping the entire flow of inputs and outputs in the production process, enabling the understanding of local and global impacts thus, to guide public and private sector initiatives.

From the 1980s onwards, the global focus turned to topics associated with climate, especially the ozone layer and the greenhouse effect, making the scope of the LCA, initially limited to the calculation of energy, incorporate the variables of emissions of pollutants related to air and water. As a result, this new and more robust methodology it became known by other designations, such as eco-profile or cradle-to-grave analysis. However, the multiplicity of aspects and forms of measurement demanded the standardization of processes, so that identical objects of analysis would not present different results. In this sense, at the end of the 90s, the International Organization for Standardization (ISO) launched ISO 14040 Environmental Management - Life Cycle Assessment– Principles and Structure. Since then, the standard has undergone a series of revisions over time, culminating in ISO 14044: 2006, with the requirements and guidelines for carrying out an LCA study. In Brazil, with support from the Brazilian National Standards Organization (ABNT), in 2009 the version of the specific standard for LCA, NBR ISO 14044 (corrected version 2014) was launched.

2.2. CONCEPTS

The series of ISO 14000 standards is focused on environmental management and standardization of practices, with ISO 14040[4] being a reference for the LCA methodology. It establishes, in summary, a common nomenclature on the definition of principles and procedures to be adopted, describing the expected content from data collection to publication of results, with special focus on the clarity in the methodology of each phase and the extension of the study. As a result, a LCA study is divided into 4 phases: i) definition of the objective and scope of the analysis; ii) data collection and inventory analysis. iii) impact assessment and iv) interpretation of information.

The first stage consists of (i) precise delimitation of the object and scope of the study, which will influence the analyzed variables. It is also known as the stage for defining analysis boundaries, in terms of reaching the value chain, time and assessed organizations. Thereafter, during the inventory (ii), the entire product flow is surveyed regarding the use of natural resources, energy, pollutant emissions to water, air and soil and other data, considering the impacts outlined in the first phase. All results must be weighted by the functional unit. Then,

---

3. Available at: < http://acv.ibict.br/acv/historico-da-acv/>. Accessed 3/20/2019.
4. ISO 14040:2006. ISO - International Organization for Standardization. Available at: www.iso.org/standard . Accessed 2/14/2019.

(iii) the data collected are objectively classified and characterized, to be subsequently measured critically in relation to the entire cycle. The results are condensed in the interpretation (iv), which, instead of being a tight phase, dialogues with all the others, in addition to subsidizing possible direct actions, such as changes in design or use of the product itself. Finally, it is recommended to submit the results to a sensitivity analysis, isolating critical variables, indicating the need for further analysis in a certain aspect or the collection of more reliable data.

From these stages, the methodology allows mapping the critical points of the production process, optimizing the systems in the short term, reducing their environmental impacts, as well as enabling the realization of a long-term strategic planning. On the other hand, LCAs can raise criticism regarding the cost and reliability of their data based on inappropriate premises. Despite them, LCA is a very widespread methodology and, even today, considered the most reliable to assess the life cycle of products.

3. SOCIO-ENVIRONMENTAL ASPECTS AND IMPACTS

3.1. DEFINITIONS

As indicated in the previous chapter, the impact assessment of electric bicycles and kick-scooters sharing systems in the Brazilian market using the LCA methodology should start with the determination of objectives, scope of analysis and assumptions. This document introduces the concepts and elements provided for in the stage (i) of LCA, guiding data collection and inventory formation to be carried out in a later study.

The general objective of the LCA, therefore, is to contribute to the conscious assessment during the choice of modal for short distance travel in the urban environment, offering information on the socio-environmental impacts generated throughout the life cycle of the vehicle used. Thus, it should contribute to avoid the occurrence of the problem shifting, supporting decision makers with technical information. As a specific objective, it aims to compare the socio-environmental impacts of conventional bicycles, electric bicycles and kick-scooters with the impacts generated by combustion engine cars.

The function to be analyzed, therefore, will be the displacement of people over short distances in the Brazilian urban environment, and the unit of comparison: kilometers traveled. Thus, modes that meet the expectation of offering displacement on a certain short distance route at a given speed will be compared. To do so, one must define the premises regarding geographical boundaries, such as, for example, a neighborhood, city or region, as well as the temporal boundaries and the period of analysis. It is clear that LCA studies are based on specific cases, from which insights are extracted for general assessments.

3.2. CHARACTERIZATION OF VEHICLES

Electric bicycles in urban mobility systems weigh between 21 and 25 kilos, with approximately 25% of that weight corresponding to electrical systems and components. The set consists of the motor, battery, control module, cables and sensors. Most of the dough originates from components made of aluminum alloys (30%), followed by steel alloys (10%). Other parts and components are made of plastics and compounds such as rubbers and foams[5]. In electrical parts, copper is the main material with economic value, predominantly used in the engine and in the battery. The engine, in turn, can represent approximately 18% of the mass of the equipment. Appendixes 6.3 and 6.4 contain detailed tables of the participation of urban electric bicycle components.

At the time of publication of this document, public studies with data on components and materials for electric kick-scooters are not available. For this reason, a common equipment in the Brazilian market, the Segway-Ninebot ES2, was used as a parameter. According to the information provided by the manufacturer, it has a total weight of 12.5 kg. From data obtained in the spare parts market[6], it is considered 1.35 kg for the battery (10%), 1 kg for the tires (8%) and 4.5 kg for the engine (36%). The rest of the weight is made up of aluminum alloys and plastics (PVC, polyurethane, among others) (46%).

For illustrative purposes, Table 1 presents characteristics of vehicles used in urban mobility systems. Kick-scooters stand out for their autonomy and energy efficiency, but there are still uncertainties regarding maintenance needs during their service life.

When considering the environmental aspects of different types of vehicles with the new electrical alternatives, batteries are often considered critical elements. To a large extent, the focus of attention occurs due to the fact that it is a component with a short service life, of high added value, being subject to environmental conditions (for example: weather conditions) and use (for example: vandalism) and having a poorly structured after-use management system in several markets, which leads to uncertainties regarding possible environmental damage and their respective responsibilities (Chart 1).

---

[5] Frischknecht R. (2010) LCI modelling approaches applied on recycling of materials in view of environmental sustainability, risk perception and eco-efficiency. ESU Services.

[6] Alibaba (2018). Search for spare parts at www.alibaba.com. Accessed on 26 March 2019.

Table 1 | VEHICLE COMPARISON AT THE STAGE OF USE

	Bicycle	Electric bicycle	Electric kick-scooter
Weight (Kg)	17	24	12,5
Service life (km)	15.000	15.000	25.000
Electric energy (kWh)	-	0,01/km	0,8455[7]/load 0,03/km
Need for maintenance / replacement in service life	Plastic components: 50% Steel components: 5% Tires: 3 pairs	Plastic components: 50% Steel components: 5% Tires: 3 pairs Lithium batteries: 2.7 batteries	Not available

Note: Prepared by NOVí. Bicycles and electric bikes data adapted from Duce (2001). Electric kick-scooter data indicated from interviews with operators and using the Segway Ninebot ES2 model as a reference. Does not consider conditions of use in sharing systems.

Chart 1 | LITHIUM-ION BATTERIES

Lithium is a light, non-toxic and non-scarce metal. The main active mines are in the Andes, Tibet and Australia[8]. In Brazil, production is in the state of Minas Gerais, with prospecting in the Northeast states[9]. The refining of the mineral extracted from nature occurs close to mining, transforming the lithium ore (amblygonite, spodumene, petalite and lepidolite) into lithium carbonate (Li2CO3). This processed mineral is mainly destined for Asia, in manufactures in China, South Korea and Taiwan.

Considering the different chemical compositions, batteries that contain cobalt (lithium-nickel-manganese-cobalt oxide; lithium-cobalt oxide; lithium-cobalt-aluminum oxide) have a higher energy density, being used in electric vehicles[10]. Despite being known for lithium, the material is in less than 1% of the cell, having a greater participation in the electrolyte, such as lithium salt.

Despite the low toxicity, lithium-ion batteries are a concern for health and safety, due to the risk of causing burns and fires due to overheating and explosion. This occurs due to dysfunctions such as overload, exposure to high temperatures and physical impacts, which can cause rapid thermal leaks[11].

The work of Manhart et al (2018)[12] and EnBausa.de (2014)[13] deepens the risks associated with the health and safety of workers and users regarding lithium batteries.

The low economic attractiveness of the components has hampered the viability of waste management and recycling systems for lithium-ion batteries. The presence of nickel, copper and cobalt directly influences the economic viability of materials recovery and recycling systems. According to a recent study by GIZ (2018)[14], the recycling process is carried out in plants in Belgium (Umicore), the United States (Retriev Texchnology), Canada (American Manganese) and Germany (Accurec and Redux Recycling).

For other markets, the current context requires transportation to an environmentally appropriate destination (for example: licensed landfill or recycling). However, logistical costs, international trade barriers to the transport of hazardous waste and the risks of explosion associated with transport have hampered the process. The valuation of components, due to the growing demand and structuring of the market[15], and new methods of transport should facilitate the process of recycling batteries[16].

---

7. Segway. Available at: www.segway.com/products/consumer-lifestyle/es2-kickscooter.

8. Garcia, I. (2018). Recursos e Reservas de Lítio (Nacional e Internacional). Departamento Nacional de Produção Mineral, Brasil. Available at: www.cetem.gov.br/images/eventos/2018/iii-litio-brasil/apresentacoes/recursos-reservas-litio-dnpm.pdf. Accessed 3/21/2019.

9. Valor (2018). Lítio o "petróleo do futuro", começa a ser explorado no Brasil. Available at: https://www.valor.com.br/empresas/6042267/litio-o-petroleodo-futuro-comeca-ser-explorado-no-brasil. Accessed 4/8/2019.

10. GIZ, (2018). End-of-Life Management of Batteries in the Off-Grid Solar Sector. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany. Available at: < https://www.giz.de/de/downloads/giz2018-en-waste-solar-guide.pdf>. Accessed 3/21/2019.

11. Manhart, A. Hilbert, I. Magalini, F. (2018). End-of-Life Management of Batteries in the Off-Grid Solar Sector. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany. Available at: <https://www.giz.de/de/downloads/giz2018-en-waste-solar-guide.pdf>. Accessed on 26 March 2019.

12. Manhart, A. Hilbert, I. Magalini, F. (2018). Report on the fact finding mission on management and recycling of end-of-life batteries used in solar home systems in Muanmar. Freiburg & Yagon In, Manhart, A. Hilbert, I. Magalini, F. (2018). End-of-Life Management of Batteries in the Off-Grid Solar Sector. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany. Available at: <https://www.giz.de/de/downloads/giz2018-en-waste-solar-guide.pdf>. Accessed 3/26/2019.

13. EnBausa.de (2014). Brandgefahr auch bei Lithium-Eisenphosphat-Batterien. Available at: < https://www.enbausa.de/solarenergie/aktuelles/artikel/brandgefahr-auch-bei-lithium-eisenphosphat-batterien-3269.html>. Accessed on 15 Jan 2018. In. Manhart, A. Hilbert, I. Magalini, F. (2018). End-of- Life Management of Batteries in the Off-Grid Solar Sector. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany. Available at: < https://www.giz.de/de/downloads/giz2018-en-waste-solar-guide.pdf>. Accessed 3/21/2019.

14. Idem item 11.

15. Idem item 2.

16. Idem item 10.

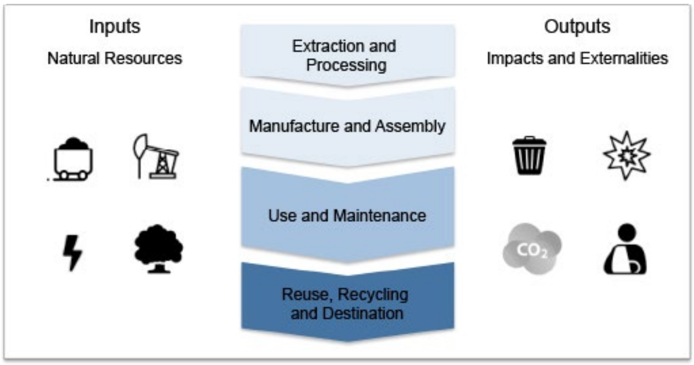
3.3. IDENTIFICATION OF SOCIO-ENVIRONMENTAL ASPECTS

When resuming and expanding the bibliographic review (Appendix 6.2), it is observed that the studies available on electric bicycles are relatively recent, dating from 2009. No LCA studies have been identified for electric kick-scooters. Additionally, there are assessments of electric bicycles in relation to automobiles in European and United States markets, with a strong concern in the aspect of local pollution. Analysis of existing studies indicates that, so far, shared electric mobility services, their equipment and processes have not been put under scrutiny. Thus, it is considered that the analysis of equipment in different modes would be the first stage of identification.

The emphasis on specific socio-environmental impact or damage at a given stage in the production chain can induce hasty assessments. The focus on reducing emissions (smoke with soot, for example) during use disregards any impacts during the production process or the disposal of its components. LCA is recommended, precisely, to identify and measure the various impacts, to relativize them and to balance them along the entire chain.

In an eventual later study, the inventory of socio-environmental aspects of electric bicycles and kick-scooters should consider their direct and indirect impacts. To a large extent, the scope of the assessment of these effects will depend on their relevance, access to data and technical feasibility. Figure 1 illustrates the value chain to be considered.

Figure 1 | STAGES OF THE VALUE CHAIN



Note: Prepared by NOVí. Credits: Iconfinder[17].

After defining the variables that will be considered, the inventory phase identifies the flow of inputs and outputs of materials and energy used in the service life of bicycles and electric kick-scooters. For indicative purposes, the following study presents secondary data obtained from a review of the reference literature (Appendix 6.2).

The use of electric vehicles is associated with a clean and low impact means of transport. This understanding and positioning takes as a starting point the use of energy sources during the use stage. However, as stated, the life cycle assessment makes it possible to raise potential additional impacts. In a recent study of electric bicycle LCA in Italy (Petrillo et al, 2018), 15 socio-environmental aspects were preliminarily raised, as shown in Table 2.

Table 2 | POTENTIAL SOCIO-ENVIRONMENTAL ASPECTS IN ELECTRIC BICYCLES

Damage factor	Impact category
Human health	Carcinogenic
	Non-carcinogenic
	Organic compounds
	Inorganic compounds
	Ionization radiation
	Ozone layer depletion
Ecosystem balance	Aquatic ecotoxicity
	Terrestrial ecotoxicity
	Terrestrial acidification
	Land occupation
	Aquatic acidification
	Eutrophication
Climate change	Global warming
Degradation of natural resources	Extraction of mineral resources
	Non-renewable resources

Note: Prepared by NOVí. Adapted from Petrillo et al (2018). Grouping adopted by the reference study.

Following the LCA methodology, the next step is to identify the potential impacts at each stage of the value chain. For simplification purposes, pre-use, use and post-use will be assessed.

3.3.1. STAGE OF PRE-USE

During pre-use, the flow of materials and energy is considered from the extraction of natural resources to the manufacture and transportation of equipment. In both electric bicycles and kick-scooters, the main materials used in the components are aluminum, copper and steel, in addition to the lithium battery. These materials are energy-intensive and traded on the global market, being influenced by the electrical matrix and the type of transport modal used to calculate environmental impacts. As an example, the greenhouse gas emissions factor of the Brazilian electricity grid is 0.5882 tCO2/kWh (2017) while in China, the emission factor varies

---

[17] Free icons. Available at: www.iconfinder.com/search/?q=co2&price=free

between 0.811 and 1.042 tCO2/kWh (2015), according to the region of the country[18], since electricity generation comes from coal-fired power plants. In relation to transport, another example is the distance from Taiwan to the port of Santos, which corresponds to 19,800 kilometers, more than four times the distance from the Brazilian bicycle production hub in the Manaus Free Trade Zone[19].

In the stage of manufacture and assembly of urban electric bicycles, the activities related to the structure of the bicycles are those with the greatest impact. The predominant use of aluminum alloys has an impact on the use of natural resources, especially electricity. In relation to the energy storage system, the extraction of lithium (Annex 6.5) and production of energy storage cells requires a large amount of electrical energy[20] for drying components in a controlled environment at low temperature and humidity (Appendix 6.5), also contributing for pressure on natural resources and increased greenhouse gas emissions, which cause global warming. Finally, electronic components are associated with intense use of energy and fugitive emissions of CFCs, which cause impacts on the ozone layer.

Table 3 | **SUMMARY OF IMPACTS DURING PRE-USE**

Aspect	Impact category	Processes
Environmental	Extraction of mineral resources	Extraction of lithium, iron, bauxite and copper ores
		Use of water in mineral processing
		Extraction of oil and derivatives as a petrochemical input
	Use of non-renewable energy sources	Mineral processing using electricity and thermal energy from fossil fuels
		Drying of lithium cells using electricity
		Welding of metal alloys during the manufacture of metal components
		Local transport of materials and international transport of materials, components and finished products
	Land occupation	Open-pit mining or in underground galleries, affecting the landscape and local ecosystem balance
		Storage of mining waste in dams
	Aquatic and terrestrial ecotoxicity	Storage of mineral processing effluents
	Global warming	Extraction and processing of mineral resources of intense energy use
		Fugitive emissions during industrial physical-chemical processes (for example: lithium sulfation and decryption)
		Use of fossil fuels in local and international transport
Social	Ozone layer depletion	Fugitive emissions from CFCs during production of electronic components
	Organic compounds	Exposure of workers to fugitive emissions in assembly processes for electronic components and batteries (for example: resins, chemical solutions and solders)
	Safety of workers	Accidents during mining activities (examples such as explosions, landslides, being run over and crushed)
		Exposure to toxic gases in underground mining
		Accidents during high temperature industrial processes (burns and explosions)

Note: Prepared by NOVí. Qualitative and non-exhaustive assessment.

---

[18] Institute for Global Environmental Strategies (2019). List of Grid Emission Factors version 10.4. Available at: https://pub.iges.or.jp/pub/iges-list-grid-emission-factors. Accessed on 5 April 2019.

[19] ANTAQ - Agência Nacional de Transportes Aquaviários. (2008). Distância entre os principais portos brasileiros. Available at: <http://web.antaq.gov.br/Portal/Anuarios/Portuario2008/pdf >. Accessed on 5 April 2019.

[20] Yuan, C. Deng, Y. Yang, F. (2017) Manufacturing energy analysis of lithium ion battery pack for electric vehicles. CIRP Annals – Manufacturing Technology. 66: 53-56.

Table 4 | SUMMARY OF IMPACTS DURING USE

Aspect	Impact category	Processes
Environmental	Use of non-renewable energy sources	Transport of components and equipment during assembly and implementation of sharing systems
		Equipment collection and return logistics, using fossil fuels
		Battery charging with electricity (impact of the non-renewable portion of the Brazilian grid)
	Land occupation	Use of public and private spaces. Impacting urban planning.
	Global warming	Use of fossil fuels in equipment logistics
Social	Safety of workers	Falls and collisions during travel
		Burns, contamination and explosions during battery handling
	Users and third parties' security	Falls and collisions of users during commuting
		Road obstructions, resulting in accidents with third parties. Potential severity due to low helmet use.

Note: Prepared by NOVí. Qualitative and non-exhaustive assessment.

3.3.2. STAGE OF USE

Although relevant, battery charging is not a single source of impacts. This activity has effects on the use of electricity and, consequently, contributes to climate change. When considering the processes of the sharing systems, battery charging and maintenance of equipment are highlighted in the face of the impacts caused by the daily collection and return of vehicles, often using combustion engine vehicles (cars, vans and trucks) on long distance itineraries that contribute to the occurrence of environmental and social impacts such as congestion, excessive noise and emission of air pollution. Additionally, the high rates of vandalism and the intense and severe conditions of use reduce the service life of the equipment, requiring periodic replacements.

Despite the importance of this variable for the results of the life cycle assessment, there are no official data on vandalism and rate of replacement of assets by operators of sharing systems. According to electric kick-scooter operators in the Brazilian market, some vehicles would not be able to operate in less than three months, as they are not designed for the conditions of the Brazilian market.

3.3.3. STAGE OF POST-USE

Finally, post-use is highly dependent on waste management conditions in local markets. During interviews with sharing system operators in the Brazilian market, there was an indication of reuse of components in their own activities or those of third parties. The lack of a local market for spare parts encourages the reuse of parts and, according to one of the operators interviewed, the need for parts "cannibalizes" vehicles that could return to operation. Unused parts are intended for recyclers and landfills, according to the economic attractiveness of the materials.

Regarding lithium batteries, there is no remanufacturing in the Brazilian market, being destined to the origin, in reverse logistics to suppliers of vehicles located in Asian markets. Thus, for the analysis of socio-environmental impacts, the reuse and recycling of materials will have significant relevance in the results.

Table 5 | **SUMMARY OF IMPACTS DURING POST-USE**

Aspect	Impact category	Processes
Environmental	Use of non-renewable energy sources	Transport of materials, components and useless equipment for recycling and final destination
	Land occupation	Storage of useless components and equipment
	Aquatic and terrestrial ecotoxicity	Storage, transportation and disposal of components and vehicles
	Global warming	Use of fossil fuels in reverse logistics or equipment recycling
Social	Safety of workers	Burns, contamination and explosions during battery handling
		Accidents during recycling activities (examples such as being run over, collapsing, falling and crushing)

Note: Prepared by NOVí. Qualitative and non-exhaustive assessment.

3.4. CLASSIFICATION AND ASSESSMENT

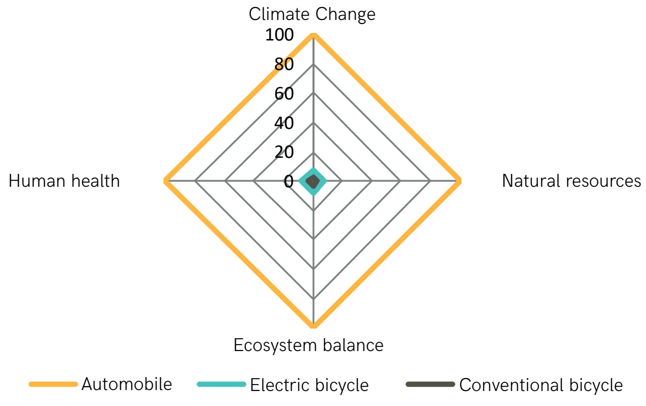
Following the LCA method, once the inventory has been carried out, it is possible to compare the impacts generated by transport alternatives in the same function. The present study does not have data from the specific case in the Brazilian mobility market, however, after browsing the available literature and interacting with the sharing system operators, initial analyzes can be obtained.

Firstly, it is evident that bicycles and kick-scooters, conventional and electric, have less impact in all aspects, when compared to a combustion engine car[21]. Likewise, when considering only the new modes, the impacts in absolute terms of electric bicycles and kick-scooters are greater when compared to those of conventional bicycles and kick-scooters because of the additional components of the electric propulsion system.

Using the literature, it was possible to compile an illustrative and comparative summary from the socio-environmental damage factors identified previously (Table 2) of the main alternatives for urban micro-mobility (Graph 1). The end of each aspect represents the reference mode in the analysis, with the greatest damage, with the results of the other modes being presented in a relative manner.

Taking Duce's LCA study (2011), carried out in the Swiss market, it is possible to indicate that the relative difference in socio-environmental impacts of electric bicycles for combustion engine cars is of the order of 8% and that of conventional bicycles for combustion cars is 3 % (Graphic 1). For comparative purposes with the Brazilian market, it is worth highlighting the special difference of automotive fuels used in Switzerland, predominantly gasoline and diesel[22].

Graph 1 | **SOCIO-ENVIRONMENTAL DAMAGES OF MOBILITY VEHICLES**



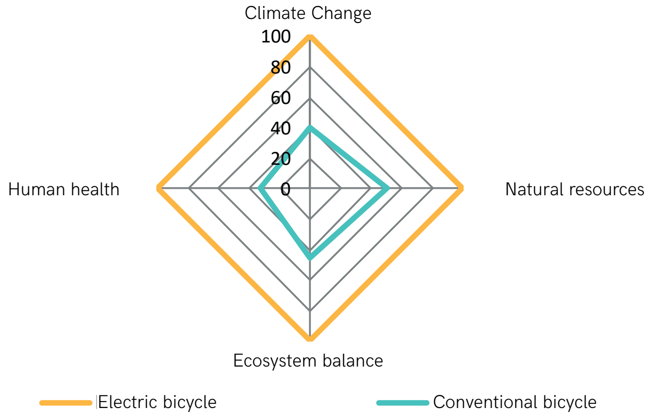
Note: Prepared by NOVí. Illustrative graphic from Duce (2011).

---

[21] Weber, N. Rocha, B. Schneider, P. Daemme, L. Penteado, R. (2018). Energy and Emission Impacts of Liquid Fueled Engines Compared to Electric Motors for Small Size Motorcycles Based on the Brazilian Scenario. Journal: El Sevier.

[22] European Union (2018). Passenger cars in the EU: statistics explained. Eurostat. Available at: https://ec.europa.eu/eurostat/statistics-explained/pdfscache/25886.pdf. Accessed 4/30/2019.

Graph 2 | SOCIO-ENVIRONMENTAL DAMAGES OF LIGHT MOBILITY VEHICLES



Note: Prepared by NOVí. Illustrative graphic from Duce (2011).

In the second illustration, the impacts of automobiles were disregarded, comparing only the alternative modes with each other. In this context, electric bicycles become relatively the mobility vehicle with the greatest socio-environmental damage (Graph 2). The differences occur due to socio-environmental aspects and damages during the value chain, as identified in section 3.3. In particular, the difference in damage to human health is linked to the industrial processes of the components of the electrical system.

Although LCA is a technique for measuring environmental aspects[23], social aspects are equally relevant during the stages of the value chain, deserving attention. From the analysis of the literature and interviews with operators, the concern to demonstrate the positive effects on job creation and the increase in local income is evident, as well as to mitigate the safety aspects of the user, especially their behavior in traffic. In the markets where shared electric kick-scooters have been implemented, there have been public debates about the occurrence of accidents with users and third parties (Chart 2).

Chart 2 | OCCURRENCE OF ACCIDENTS

A recent and pioneering study conducted by Trivedi et al (2019) analyzed the occurrence of accidents associated with the use of electric kick-scooters in two emergency health units in Santa Monica, California, in the United States. During the period from September 2017 to August 2018, 249 patients had injuries caused using electric kick-scooters, compared to 195 for bicycles and 181 for pedestrians. The following characteristics of the case study are relevant to the impact assessment and subsequent recommendations:

- 95% of those attended were kick-scooter users and 5% non-users. The 21 non-users consisted of pedestrians hit or who collided with parked kick-scooters. Special concern has been raised in relation to people with reduced mobility such as wheelchair users and the blind.
- 10% were under 18 years old, which is prohibited by local laws. Less than 5% wore a helmet, a mandatory safety item locally.
- 80% of accidents were due to falls, 11% from collisions with parked kick-scooters, 9% were hit by other moving vehicles.
- 94% were minor injuries. However, the 6% hospitalized had severe injuries due to impacts on the chest and head.

Regarding severity, the same issue was observed during interviews with sharing system operators in Brazil, who acknowledged the existence of minor incidents and accidents, but revealed that they were unaware of serious occurrences in the Brazilian market or notifications and demands of judicial and indemnity nature.

---

[23] ISO 14040:2006 covers life cycle assessment (LCA) studies and life cycle inventory (LCI) studies. It does not describe the LCA technique in detail, nor does it specify methodologies for the individual phases of the LCA. Year 2006. ISO - International Organization for Standardization. Available at: https://www.iso.org/standard/37456.html. Accessed 2/14/2019.

3.5. ANALYSIS

The main aspect responsible for the environmental impacts of electric alternatives for urban micro-mobility is the composition of the energy matrix. This aspect was observed in the pre-use stage, during the processing of lithium, the manufacture of batteries and, mainly, the production of aluminum and copper components. In a survey by Yale University, Ellingsen et al (2013)[24] indicate the potential to reduce the total impact of electric vehicles by 60% if the production of lithium cells occurs with clean electricity in relation to atmospheric emissions.

As a result of the concentration of the batteries and bicycle components production in Asian markets, international transport starts to contribute to the increase in impacts. Thus, the pre-use stage has the highest occurrence of impacts for the indicated categories.

The same issue is observed during the use stage, due to electricity charges. It is evident, therefore, that the predominantly renewable nature of the Brazilian electrical matrix (in the order of 80%[25]) contributes to the lowest impact when compared to other markets.

Considering the post-use, the reuse of components in alternative and subsequent uses (second life) and the recovery of materials contribute significantly to the reduction of impacts. Thus, the fundamental conclusion is that a good environmental management system for traceability and guarantee of origin of equipment, collection and recycling of batteries would significantly compensate for adverse effects in previous stages of the value chain[26].

The eventual irregular destination of the batteries can cause little known damage. The battery components can be classified as emerging contaminants, which started to be manufactured or which have only recently become a concern. They are, in any case, potentially toxic substances and whose effects and interactions in the environment are little known, remaining, as a rule, outside the legal framework.

The unpredictability of the amount of substances coming from the batteries of electric bicycles and kick-scooters in post-use due to the difficulty in dimensioning the market, and their interaction with the environment, especially the possibility of soil and water contamination, bring great uncertainties, the which reinforce the need for an in-depth technical assessment.

Another fundamental element to mitigate the occurrence of impacts refers to the design of batteries and their post-use process. The impacts of the batteries could be reduced by optimizing their service life, coinciding with those of the vehicle they supply[27].

Finally, the service life of vehicles in sharing systems is a critical factor for analyzing the sustainability of the new modes. Ending the "disposable" profile, as mentioned by one of the interviewed operators, should significantly change the results of the analysis. It is evident that it is necessary to expand the operating time of electric kick-scooters, for example, with the development of more robust equipment and eventual adjustments to the operation model.

---

24. Ellingsen, L. Majeau-Bettez, G. Singh, B. Srivastava, A. Valøen, L. Strømman, A. (2013). Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack. Journal of Industrial Ecology, Vol 18, Número 1.

25. Balanço Energético Nacional (2018). Empresa de Pesquisa Energética, Ministério de Minas e Energia. República Federativa do Brasil. Brasília, 2018. Available at: www.epe.gov.br

26. Matheys, J. Timmermans, J. Autenboer, W. Mierlo, J. Maggetto, G. Meyer, S. Groof, A. Hecq, W. Bossche, P. (2009). Comparison of the Environmental impact of 5 Electric Vehicle Battery technologies using LCA. International Conference on Life Cycle Engineering. Available at: <https://www.researchgate.net/publication/234162894_Comparison_of_the_Environmental_impact_of_5_Electric_Vehicle_Battery_technologies_using_LCA>. Accessed 2/14/2019.

27. Idem item 26.

4. CIVIL AND ENVIRONMENTAL RESPONSIBILITY IN POST-USE

In Brazil, LCA gained space through the efforts of the private sector to conform to the standard established by ISO 14000.

This transformation process was supported by the new status given to the environment in the Federal Constitution of 1988 and consolidated by the National Solid Waste Policy (PNRS) in 2010. In effect, Law 12.305, of August 2, 2010[28] made the concept of the product life cycle normative as "a series of stages that involve product development, obtaining raw materials and inputs, the production process, consumption and the final disposition "(art. 3, IV) making the implementation of the LCA, as stated, one of the objectives of the referred national policy (art. 7, XIII). In this way, PNRS strongly established the shared responsibility for the life cycle of products covering absolutely all the entities in the chain.

Among the means of implementing this comprehensive responsibility, reverse logistics makes it possible to return the waste to the productive sector after consumption, for reuse or environmentally appropriate destination. The PNRS foresaw three ways for its implementation (art. 33, § 1): regulation, sectoral agreements or terms of commitment. At the federal level, sectoral agreements have been chosen as the preferred instrument due to the arrangement in which the government and other agents in the chain individualize their responsibilities according to a contractual arrangement. Currently, we have the following normative outlook regarding reverse logistics systems (Table 6).

Table 6 | REVERSE LOGISTICS SYSTEMS

Prior to the PNRS	
Useless tires	Resolution CONAMA No. 416/09
Pesticide packaging	Law No. 7802/89; Law 9974/00; Decree No. 0474/02; Resolution CONAMA 465/14
Used or contaminated lubricating oil	Resolution Conama No. 362/05
Cells and batteries	Resolution Conama No. 401/08, Normative Instruction IBAMA No. 8/12
After the PNRS	
Plastic packaging of lubricating oils	Sectoral agreement published on 2/7/2013
Fluorescent lamps of sodium and mercury vapor and mixed light	Sectoral agreement published on 3/12/2015
General packaging	Sectoral agreement published on 11/27/2015
Steel packaging	Term of commitment published on 12/27/2018
Electric and electronic products and its components	Unified proposal received on January 2014 under negotiation. Next public consultation stage
Medicines	Next stage of analysis of the contributions received in the public consultation carried out and preparation of the final draft of the Decree

Note: Prepared by NOVí. Assessment in March 2019.

---

[28] BRASIL. Lei n. 12.305, de 02 de agosto de 2010. Institui a Política Nacional de Resíduos Sólidos; altera a Lei n. 9.605, de 12 de fevereiro de 1998; e dá outras providências. Available at: < http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2010/Lei/L12305.htm>. Accessed 3/20/2019.

In the case under analysis of bicycles and electric kick-scooters, the post-use of batteries is an important challenge, since there is no specific regulation. Currently, traditional cells and batteries (lead-acid, nickel-cadmium and mercury oxide) share the same regime established before the PNRS that regulates their destination and environmentally appropriate management. In the case of lithium batteries, the legislation only requires the implementation of selective collection programs.

However, the fact that there is no regulation, sectoral agreement or term of commitment for lithium batteries does not remove the responsibility of those who participate in its chain. Indeed, in the current Brazilian regulatory framework, the civil and environmental liability of those who exercise activities capable of causing damage to the environment is sufficiently supported, regardless of fault (art. 14, § 1 of the National Environmental Policy and art. 927, sole paragraph, of the Civil Code).

In other words, although there is currently no specific regime that establishes the reverse logistics and the management and destination of lithium batteries discarded in the Brazilian market, all those who participated, directly or indirectly, in the generation of this waste can be held responsible for possible environmental damage. that they will cause.

4.1. COMPARATIVE: SECTORAL AGREEMENT ON LAMPS

It is possible to establish a comparison between the treatment given to fluorescent, sodium and mercury vapor and mixed light lamps, and the case of lithium batteries as both are fundamentally imported products. For this reason, it is worth analyzing how the attributions of each entity were distributed in that sectoral agreement signed in November 2014.

Thus, in the first place, there is an obligation for household waste generators to separate the discarded lamps from other waste and send them to specific points of delivery or through occasional collections. Similarly, non-household generators must sort and store the lamps using containers and / or consolidation points made available or specified.

The indication is made by a non-profit management entity, created specifically to implement and operate the system. This is currently the role of the Brazilian Association for the Management of Reverse Logistics for Lighting Products - Reciclus. Reciclus receives resources from importers whose contribution is defined in proportion to the respective number of lamps offered to the market.

Importers must give an environmentally appropriate destination to all discarded lamps. To this end, they must coordinate with the management entity, the distribution and marketing networks, technical assistance and public authorities to create the necessary structure to enable the flow of delivery of reverse logistics. Distributors and dealers, in turn, are primarily responsible for the first stage of the process, that is, the reception and packaging of the lamps received by the household generator until their removal by the management entity.

In addition, the management entity may choose to hire a specialized company for the decontamination or recycling of the lamps. Once the impossibility of recycling is verified, the tailings are sent to sanitary landfills suitable for final destination, in the case of those that use technical processes duly approved by the competent public bodies for control.

Finally, all parties must act on the communication plan, whose scope is to bring effectiveness to reverse logistics. In the specific case of lamps, the sectoral agreement gave priority attention to retailers of lighting and construction products, industries, lighting and construction professionals in general and the final consumer.

Above all, the sectoral agreement on lamps a consensus among the entire chain (private sector, government, other entities and civil society) and brought more legal certainty through the individualization of roles in reverse logistics and the establishment of procedures and goals. Whether by sectoral agreement or other instrument, before or after the PNRS, no arrangement related to post-use proved trivial. For this reason, it is not appropriate to postpone discussions about the future scenario for electric bicycle and kick-scooters batteries.

5. CONCLUSIONS

The rapid introduction of new technologies and electric mobility vehicles has become a disruptive force in individual transport over short distances. It is a market in rapid expansion and transformation, with business models undergoing experimentation. Strong competition has led to the start of new product and service activities even before identifying, assessing and measuring risks associated with social and environmental impacts.

While the novelty brings opportunities and benefits to society, it raises concerns about planning, impacts on the environment and people. In this sense, it is necessary to understand the process in a broad way and to compare them between displacement alternatives, identifying potential for improvement, whether in pre-use, in use and in post-use, with the proper destination of equipment and components. The legal and public policy framework must also be considered, with clear responsibilities and implications.

This study identifies the main aspects, impacts and factors of socio-environmental damage. In the social context, the safety of users and third parties has been the main concern of those involved in sharing systems, and there are also precautions to be taken regarding the health of workers in the production and handling of components, especially lithium batteries.

In the environmental aspect, electric bicycles and kick-scooters can be considered clean transport modes, considering the energy efficiency and the low local impact in terms of atmospheric emissions during their use. However, the analysis shows the relevance of the composition of the electrical matrix used in the origin of the components and during the charging of the equipment. This factor can bring significantly different results regarding the "environmental footprint" of the solutions. Additionally, energy-intensive components such as aluminum, copper and steel can be replaced by new materials and the service life of critical components, such as batteries, harmonized with that of other components. Finally, well-structured post-use processes, considering the reuse and recycling of battery components and materials significantly reduce the negative environmental effects of vehicles.

As anticipated, the present study found clear limitations in the literature used. Among the main ones is the low level of transparency of life cycle inventories; the lack of consistent, complete and verifiable databases; the lack of studies on electric kick-scooters; and the lack of a specific case study for the Brazilian reality of electric bicycles and kick-scooters. Add to these already known restrictions the experimental character and the little historical implementation of the sharing solutions, making it difficult to access consistent and public data.

Although enlightening, this study is limited by the scope of analysis and research conditions previously determined. The lack of background and available data represents barriers for public policy makers and agents involved in the Brazilian micro-mobility market to correctly map socio-environmental challenges. In this sense, it is necessary to deepen the impact diagnoses considering the context of Brazilian cities and the country's institutional reality. The technical realization of a LCA, at the level of depth recommended by the standards, will contribute decisively to the assessment of impacts along the value chain. Thus, responsibility for possible damages and public policies will have elements for greater assertiveness and effectiveness of its actions.

6. APPENDIXES

6.1. INTERVIEWED PROFESSIONALS

NOVí and GIZ would like to thank the professionals in the electric mobility market interviewed between January and February 2019.

Table 7 | INTERVIEWED PROFESSIONALS

Name	Occupation area	Organization
Marco Gibram	Corporate Sales	Emove
Artur Bauab	Founder and CEO	Mymobility
Brenda Holz	Development - Kick-scooters	Tembici
Nicole Barbieri	Development - Kick-scooters	Tembici
Pedro Scaramuzza	Business development	Tembici
Rafael Alves	Industrial Director	Tembici
Danilo Lamy	Founder and CEO	Bikxi
Rodrigo Carvalho	Engineering department	Yellow
Gustavo Jorge	Purchase department	Yellow
Robert Loacker	Opportunities & Sales Management Director	Bosch
Stênio Freitas	Application engineer	Bosch
Marcos Palasio	Gasoline Systems Senior Manager	Bosch
Kathrim Hoffman	Communication and Public Relations	eMO – Berlin Agency for Electromobility
Tim Reinshagen	Sales and Service	Scooter Helden
Julia Boss	CEO	Wind Mobility
Julia Groeth	Communication and Public Relations	COUP

Note: Prepared by NOVí.

6.2. BIBLIOGRAPHIC REVIEW

Chart 3 | **MOBILITY VEHICLE IMPACT STUDIES**

Duce, A. (2011). *Life Cycle Assessment of Conventional and Eletric Bicycles*[29]. EMPA Materials Sciencie & Technology.

Ellingsen, L. Majeau-Bettez, G. Singh, B. Srivastava, A. Valøen, L. Strømman, A. (2013). *Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack.* Journal of Industrial Ecology[30].

Leuenberger, M. Frischknecht, R. (2010). *Life Cycle Assessment of Two Wheel Vehicles.*[31] ESU-SERVICES, Germany.

Leuenberger, M. Frischknecht, R. (2010). *Life Cycle Assessment of Battery Electric Vehicles and Concept Cars.*[32] ESU-SERVICES, Germany.

Lutsey, N. Hall, D. (2018). *Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions.*[33] International Council on Clean Transportation.

Manhart, A. Hilbert, I. Magalini, F. (2018). *End-of-Life Management of Batteries in the Off-Grid Solar Sector*[34]. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany.

Matheys, J. Timmermans, J. Autenboer, W. Mierlo, J. Maggetto, G. Meyer, S. Groof, A. Hecq, W. Bossche, P. (2009). *Comparison of the Environmental impact of 5 Electric Vehicle Battery technologies using LCA.*[35] International Conference on Life Cycle Engineering.

Matheys, J. Timmermans, J. Mierlo, J. Meyer, S. Bossche, P. (2009). *Comparison of the Environmental impact of 5 Electric Vehicle Battery technologies using LCA*[36].

Petrillo, A. Mellino, S. De Felice, F. Scudo, I. (2018). *Design of a Sustainable Electric Pedal-Assisted Bike: A Life Cycle Assessment Application in Italy.*[37] New Frontiers on Life Cycle Assessment – Theory and Application.

Trivedi, T. Liu, C. Antonio, A. Wheaton, N. Kreger, V. Yap, A. Schriger, D. Elmore, J. (2019). I*njuries Associated with Standing Electric Scooter Use*[38]. JAMA Network.

Weber, N. Rocha, B. Schneider, P. Daemme, L. Penteado, R. (2018). *Energy and Emission Impacts of Liquid Fueled Engines Compared to Electric Motors for Small Size Motorcycles Based on the Brazilian Scenario*[39]. Journal: El Sevier.

---

29. Duce, A. (2011). Life Cycle Assessment of Conventional and Electric Bicycles. EMPA Materials Science & Technology. Available at: < http://www. eurobike-show.com/eb-wAssets/daten/rahmenprogramm/pdf/LifeCycleAssessment_DelDuce_englisch.pdf>. Accessed 3/26/2019.

30. Idem item 24

31. Leuenberger, M. Frischknecht, R. (2010). Life Cycle Assessment of Two Wheel Vehicles. ESU-SERICES, Germany. Available at: <http://esu-services. ch/fileadmin/download/leuenberger-2010-TwoWheelVehicles.pdf>. Accessed 2/14/2019.

32. Leuenberger, M. Frischknecht, R. (2010). Life Cycle Assessment of Battery Electric Vehicles and Concept Cars. ESU-SERICES, Germany. Available at: <http://esu-services.ch/fileadmin/download/leuenberger-2010-BatteryElectricVehicles.pdf>. Accessed 2/14/2019.

33. Lutsey, N. Hall, D. (2018). Effects of battery manufacturing on electric vehicle life-cycle greenhouse gas emissions. International Council on Clean Transportation. Available at: <https://www.researchgate.net/publication/323118874_Effects_of_battery_manufacturing_on_electric_vehicle_life-cycle_greenhouse_gas_emissions>. Accessed 2/14/2019.

34. Idem item 12.

35. Idem item 26.

36. Idem item 26.

37. Petrillo, A. Mellino, S. De Felice, F. Scudo, I. (2018). Design of a Sustainable Electric Pedal-Assisted Bike: A Life Cycle Assessment Application in Italy. New Frontiers on Life Cycle Assessment – Theory and Application. Available at: <https://www.intechopen.com/online-first/design-of-a-sustainable-electric- pedal-assisted-bike-a-life-cycle-assessment-application-in-italy>. Accessed 2/14/2019.

38. Trivedi, T. Liu, C. Antonio, A. Wheaton, N. Kreger, V. Yap, A. Schriger, D. Elmore, J. (2019). Injuries Associated with Standing Electric Scooter Use. JAMA Network.

39. Weber, N. Rocha, B. Schneider, P. Daemme, L. Penteado, R. (2018). Energy and Emission Impacts of Liquid Fueled Engines Compared to Electric Motors for Small Size Motorcycles Based on the Brazilian Scenario. Journal: El Sevier, Energy 168 (2019).

6.3. BICYCLE COMPONENTS

Table 8 | **URBAN MOBILITY BICYCLE COMPONENTS**

Components	Materials	Average weight (Kg)	Total %	Source
Frame	Aluminum alloy	2.50	10.4	Estimativa
Handlebar	Aluminum alloy	0.23	1.0	Kalloy (2009)[40]
Stem	Aluminum alloy	0.23	1.0	Kalloy (2009)
Seat post	Aluminum alloy	0.60	2.5	Kalloy (2009)
Bearings	Stainless steel	0.60	2.5	Dt Swiss (2009)[41]
Tire	Aluminum alloy	0.30	1.2	Dt Swiss (2009)
Spokes	Steel alloy	0.10	0.4	Estimativa
Tire	Steel cable	0.19	0.8	Schwalbe (2009)[42]
	Rubber	0.56	2.3	Schwalbe (2009)
Pedal	Aluminum alloy	0.30	1.2	Wellgo (2009)[43]
Saddle	Plastic	0.03	0.1	Selle Italia (2009)[44]
	Steel alloy	0.24	1.0	Selle Italia (2009)
	Flexible foam	0.03	0.1	Selle Italia (2009)
Chain	Stainless steel	0.15	0.6	Shimano (2009)[45]
	Other	0.30	1.2	Shimano (2009)
Crank	Aluminum alloy	0.84	3.5	Shimano (2009)
	Stainless steel	0.24	1.0	Shimano (2009)
	Other	0.12	0.5	Shimano (2009)
Brake	Plastic	0.14	0.6	Shimano (2009)
	Aluminum alloy	0.28	1.2	Shimano (2009)
	Steel alloy	0.28	1.2	Shimano (2009)
Brake lever	Aluminum alloy	0.11	0.5	Shimano (2009)
	Plastic	0.11	0.5	Shimano (2009)
Chainring	Steel alloy	0.53	2.2	Shimano (2009)
Shift	Aluminum alloy	0.15	0.6	Shimano (2009)
Shift	Stainless steel	0.60	2.5	Shimano (2009)
Gear change	Plastic	0.68	2.8	Shimano (2009)
Cables	Steel cable	0.15	0.6	Estimativa
Other plastic components	Plastic	1.00	4.2	Estimativa
Other aluminum components	Aluminum alloy	2.00	8.3	Estimativa
Other electronics	Electronic equipment	0.50	2.1	Estimativa
Other steel components	Steel alloy	3.00	12.5	Estimativa
Electric engine	Steel, copper, plastics	4.40	18.3	Bionx, Flyer (2009)[46]
Lithium battery	Battery	2.60	10.8	Bionx, Flyer (2009)
TOTAL		**24.1**	**100**	

Nota: Elaboração NOVí. Adaptado de Leuenberger, M. Frischknecht, R. (2010)[47].

---

[40] KALLOY (2009) Kalloy Products. Available at: http://www.kalloyuno.com/products/grade-oe-5.html

[41] DT Swiss (2009) DT Swiss Products. Available at: https://www.dtswiss.com/en/support/catalogs/

[42] Schwalbe (2009) Schwalbe Products. Available at: https://www.schwalbetires.com/product_search

[43] Wellgo (2009) Wellgo Products. Available at: https://en.wellgopedal.com

[44] Selle Italia (2009) Selle Italia Products. Available at: https://www.selleitalia.com/en/

[45] Shimano (2009) Shimano Products. Available at: www.cycle-shimano.eu.

[46] Bionx (2009) Bionx flyer. Available at: http://ridebionx.com/

[47] Idem item 32.

6.4. ELECTRICAL SYSTEM COMPONENTS

Table 9 | **URBAN BICYCLE ELECTRICAL SYSTEM**

Component	Materials	Average weight (Kg)	Total%
Engine		4.4	
	Steel	2.2	29,3
	Copper	0.5	6,6
	Plastics	0.04	0,5
	Aluminum	1.3	17,3
	Magnets	0.22	2,9
Control module		0.5	
	Cables (PVC/PE)	0.2	2,6
	PWB	0.065	0,8
	Copper	0.01	0,1
	Plastics	0.025	0,3
	Electronics	0.2	2,6
Lithium battery		2.6	
	Structure	-	-
	Cells - lithium	0.026	0,3
	Cells - aluminum	0.598	7,9
	Cells - copper	0.338	4,5
	Electrolyte - lithium salt	0.52	6,9
	Electrode - graphite	0.416	5,5
	Electrode – $LiMn_2O_4$	0.624	8,3
TOTAL		**7.5**	

Note: Prepared by NOVÍ. Adapted from Duce (2011).

6.5. POTENTIAL IMPACTS OF THE PRODUCTION OF LITHIUM BATTERIES

Table 10 | **IMPACTS OF MINERAL EXTRACTION**

Stage	Process	Potential impacts
Mining beneficiation	Excavation and transport of materials (Li_2O at 1.5% to 7%)	● Human health ● Safety of workers ● Global warming (Consumption of fossil fuels and electricity) ● Emission of fugitive dust
	Classification in sieves, crushers and washing	● Global warming (Electricity consumption) ● Natural resources (water consumption) ● Storage of effluents in dams
	Transport of concentrated material (Li_2O at 5%) by road transport for processing	● Global warming (Fossil fuels consumption) ● Emission of fugitive dust ● Safety of workers ● Local traffic
Processing	Heat treatment at approximately 1,000 °C (decrepitation)	● Global warming (Consumption of fossil fuels)
	Grinding	● Global warming (Consumption of electricity)
	Sulfation, using sulfuric acid (H_2SO_4) at 250 °C	● Fugitive emissions ● Global warming (Consumption of electricity)
	Leaching and filtering	● Natural resources (Water consumption) ● Effluents
	Purification and drying Final product (Li_2CO_3)	● Global warming (Consumption of electricity)
International transport	Land transportation	● Global warming (Consumption of fossil fuels)
	International shipping	

Note: Prepared by NOVí. Adapted from Braga et al (2010)[48]*. It considers production in Brazilian territory.*

---

[48] BRAGA, P. F. A.; FRANÇA, S. C. A.; SANTOS, R. L. C. (2010) Panorama da indústria de lítio no Brasil. In: Anais do II Simpósio de Minerais Industriais do Nordeste. Part V – Outros. Campina Grande: CETEM/UFPE, 2010. p.237-247.

Table 11 | **IMPACTS OF BATTERY MANUFACTURING**

Stage	Process	Potential impacts
Electrode preparation	Mixture and coating	● Fugitive emissions ● Organic volatiles ● Global warming (Electricity consumption)
	Drying at 150 °C (10 hours)	
	Calendering	
Assembly	Dry room mounting (20 °C to -40 °C) Fit	● Global warming (Electricity consumption)
	Stacking, including separators	
	Welding, electrolyte inclusion and sealing	
Cell formation	Final sealing	● Global warming (Electricity consumption)
	Precharge	
Pack assembly	Assembly of cells with insulating material	● Global warming (Electricity consumption)
	Assembly of BMS - Battery Management System and Cooling System	
	Fixing in the pack, with aluminum and plastic structure	

Note: Prepared by NOVí. Adapted from Yuan (2017)[49]*.*

---

[49] Idem, item 27.

PROMOB-e

NOVI

cooperação
alemã
DEUTSCHE ZUSAMMENARBEIT

Por meio da:

giz Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

MINISTÉRIO DA
ECONOMIA

PÁTRIA AMADA
BRASIL
GOVERNO FEDERAL