SUSTAINABLE URBAN MOBILITY POLICIES: A COMPARATIVE ANALYSIS OF CHALLENGES AND INCENTIVES FOR ELECTRICITY-POWERED TRANSPORTATION IN BRAZIL AND CHINA

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ABSTRACT: Energy transition is present in all public policies today, especially in the context of the Paris Agreement and 2030 Agenda, catalyzed by the high population concentration and the need to mitigate climate change. An alternative to this reduction is the electrification of urban transport, in which China is a pioneer and has been serving as an example for Brazil. The question raised in the article is which effective public policies have been adopted by Brazil and China for the electrification of their transport sector and how Brazil could learn with the Chinese regulatory experience. To answer this question, it will discuss the commitments assumed by both countries for the urban transport electrification (centered in buses) aiming at environmental sustainability. Firstly, it will analyze the urban mobility policies adopted at the federal and municipal level, focused in two of the biggest cities of the world: São Paulo and Shenzhen. The aim is to explore the context of the rise of sustainable urban mobility involving buses, and what are the legal measures adopted in the countries; secondly, it will be examined the impacts of electric transport on the energy system and its challenges; and, finally, the lessons learned by Brazil based on the Chinese experience will be addressed. The methodology will involve the analysis of doctrine, official documents, and systematization of the Brazilian and Chinese legislation.

KEYWORDS: Sustainability – Transports – Electric Bus – Brazil and China - Internal Legal Laws - International Convention

Introduction

Nowadays, many countries have been concerned about environmental pollution and the development of energy transition, especially in the urban scenario. They have perceived some mechanisms for achieving sustainable urban mobility and reducing pollutants, in line with international commitments and national regulations. Electric vehicles (EVs) and the electrification of fleets are considered a mechanism for this. EVs are those that use electric motors for propulsion and the electricity can be obtained in different ways: 1. connected directly to the external source of electricity, through plugs or using overhead cables; 2. using the electromagnetic induction system; 3. from the reaction of hydrogen and oxygen with water in a fuel cell; or 4. through mechanical braking energy (regenerative braking) when braking the vehicle[1].

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[1] DELGADO, Fernanda. COSTA; José Evaldo Geraldo. FEBRARO, Julia. DA SILVA, Tatiana Bruce. Electric cars. 7ed. Rio de Janeiro: FGV Energia, 2017, p. 15, Available at:<

The electrification of vehicles is already a reality in the city of Shenzhen, the fourth largest city in China, with 12 million inhabitants. The city was the most advanced in terms of EV and public buses (100%), taxis (nearly 100%), and logistic vehicles (24%) in 2018[2]. China's massive investment in education, with an emphasis on technical education, has made this country increasingly stand out in the production of high-tech goods, notably in sectors such as energy and transport[3].

This movement is in accordance with China's commitments with the Paris Agreement to cut CO2 emissions per unit of GDP by more than 65% from 2005 levels, increase the share of non-fossil energy to around 25% and raise forest stock volumes by 6bn cubic meters from 2005 levels, as well as bringing the installed capacity of wind and solar to more than 1,200 GW. In 2020, China added a fourth target in the basket: to achieve net-zero emissions before 2060[4].

However, China's reality was not always like this. China's development model promoted a significant increase in greenhouse gasses (GHG) emissions due to the strong participation of fossil sources in its energy matrix (mainly mineral coal). Because of the difficulties raised for the country's energy security and the increase in dependence on oil, China was obliged to reflect about alternatives. Thus, this landscape combined with the commitments to reduce GHG emissions oriented the country to adopt various measures to promote renewable sources.

Brazil is also very concerned about sustainability and the goal of reducing pollutants. The government has committed to reducing GHGs in line to the Paris Agreement. The country is committed to reduce GHG emissions by 37% in 2025, with a subsequent indicative reduction contribution of 43% in 2030, in relation to the emission levels estimated for 2005.[5] It also promised reach an estimated share of 45% of renewable energies in the composition of the energy matrix in 2030[6] and adopted the 2029 Decennial Energy Plan (PDE), an energy planning instrument that aims to optimize the expansion of energy supply in a sustainable manner.

The cities of Shenzhen in China and, in Brazil, São Paulo, have almost equivalent populations and similar demands for transportation. The difference is that Shenzhen has 100% of electric fleets, and São Paulo has committed to widen its electric fleet, which is still insufficient to follow the sustainable and populational demands.

In this sense, this article aims to understand the reality of electrified buses in both cities. The research is divided into four stages: (i) the analysis of the historical context and

https://bibliotecadigital.fgv.br/dspace/bitstream/handle/10438/19179/Caderno%20Carros%20Eletricos-FGV-BOOK%20VFINAL.pdf >.

[2] KOBASHI, Takuro et al. Techno-economic assessment of photovoltaics plus electric vehicles towards household-sector decarbonization in Kyoto and Shenzhen by the year 2030. Journal of Cleaner Production, v. 253, 2020, p.2.

[3] PEREIRA JR, Amaro Olimpio, op. *quote,* p. 106.

[4] CARBON BRIEF Clear on Climate. Q&A: What does China's new Paris Agreement pledge mean for climate change? Available at: https://www.carbonbrief.org/qa-what-does-chinas-new-paris-agreement-pledge-mean-for-climate-change/#:~:text=The%20submission%20means%20China%20has,net%2Dzero%20emissions%20before%202060. Accessed on: September 20th, 2023.

[5] MINISTRY OF SCIENCE, TECHNOLOGY, INNOVATION AND COMMUNICATIONS. Paris Agreement. Available at:< https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/sirene/publicacoes/acordo-de-paris-e-ndc/arquivos/pdf/acordo_paris.pdf >. Accessed on August 13, 2023.

[6] MINISTRY OF THE ENVIRONMENT. Paris Agreement. Available at:< https://antigo.mma.gov.br/clima/convencao-das-nacoes-unidas/acordo-de-paris.html >. Accessed on August 22, 2023.

commitments adopted on sustainable urban mobility; (ii) the exam of the policies and legal incentives at federal and municipal levels for the implementation of electric buses in São Paulo and Shenzhen; (iii) the understanding of the impact of electric vehicles on the Brazilian energy system and its challenges; and, finally, (iv) the analysis of Brazil's lessons from the Chinese experience. In the end, the goal is to understand the reality of electric bus transportation in the two cities and their internal practices towards increasing their fleets.

1.HISTORICAL CONTEXT IN THE INTERNATIONAL COMMITMENTS ON SUSTAINABLE URBAN MOBILITY

According to Amaro Olimpio Pereira Junior, on the one hand, China has a vast mastery over the best practices in the exploitation of fossil fuels. It intends to make large investments in the next decade for the expansion of its hydroelectric matrix, to reduce its dependence on these fonts. On the other hand, Brazil, a country with extensive experience in exploiting its water potential for energy generation, has large reserves of mineral coal that are still little explored or obsolete technologies are used, with little efficiency and a high level of pollution[7].

The United Nations Conference on Environment and Development (Rio-92), also known as Eco-92, was the United Nations (UN) event that marked the awakening of global awareness for improving air quality in cities, by reducing GHG emissions and replacing fossil fuels with alternative energies[8]. Since then, International Organizations have been encouraging goals to reduce the emission of polluting gasses, the growth of ecological movements, investments in renewable sources and technologies to collaborate with sustainability. ECO-92 resulted in the international treaty of the United Nations Framework Convention on Climate Change (UNFCCC). The Convention has the ultimate objective of stabilizing greenhouse gas concentrations in the atmosphere at a level that will prevent any dangerous anthropogenic disturbance of the climate system [9].

The United Nations Environment Programme (UNEP) is an example of the leading global environmental authority in raising awareness about green development and finance, sustainable consumption, low-carbon development, as well as environmental laws and circularity. The Climate and Clean Air Coalition is the only global effort uniting governments, civil society and the private sector, committed to improving air quality and protecting the climate in the coming decades by reducing short-lived climate pollutants in all sectors. For the coalition, reducing man-made methane emissions and supporting the electrified vehicle fleet is one of the quickest and most cost-effective strategies to reduce the rate of warming and contribute to global efforts to limit the temperature increase to 1.5°C.

[7] PEREIRA JUNIOR, Amaro Olímpio. The rise of China and opportunities for Brazil in the energy and transport sector. Bulletin of International Economics and Politics, 2013, p. 122.
[8] VAZ, Luiz Felipe Hupsel; BARROS, Daniel Chiari; CASTRO, Bernardo Hauch Ribeiro de. Hybrid and electric vehicles: suggestions for public policies for the segment. BNDES Setorial 41, p. 295-344, 2015, p. 301.
[9] SCOVAZZI, Tullio. Dal Protocollo di Kyoto all'accordo di Parigi. Rev. Faculty of Law Federal University of Minas Gerais, v. 78, 2021, p. 471.

Another relevant international treaty was the Kyoto Protocol (KP) [10], the first that addressed the emission of GHGs that has already been overtaken by the Paris Agreement[11]. This agreement is an international treaty on climate change, adopted in 2015. China's current climate commitment under the Paris Agreement can be summarized as "double carbon" objectives, that is, reaching the peak of carbon dioxide emissions (CO2) before 2030 and "make every effort to peak sooner", and achieve carbon neutrality before 2060 (meaning net zero emissions of all greenhouse gasses) [12].

Among the 196 countries that signed the Paris Agreement in 2015, the main signatories are the G-20 countries, which account for most of the world's carbon dioxide emissions. These include China, the countries from the European Union, India, the United States, and Brazil. The agreement establishes that all signatory countries must collaborate with climate innovation, clean sources, allied to technology, with protection of the ecosystem, to reduce gas emissions, allied to their economies and industries. It also recognizes that sustainable lifestyles and sustainable patterns of consumption and production play an important role in addressing climate change.

In Article 5.2 of the Paris Agreement, parties are encouraged to take measures to implement and support the reduction of emissions resulting from forest degradation, and the increase of forest carbon stocks for integral and sustainable management. In addition, art. 6.4 (b) highlights the need to mitigate greenhouse gas emissions while promoting sustainable development, as well as encouraging and facilitating participation in the mitigation of greenhouse gas emissions by public and private entities. Article 7.7 (e) strengthens the resilience of socio-economic and ecological systems, namely through economic diversification and the sustainable management of natural resources.

With increasingly intense urbanization, there is concern that the increase in the fleet and population growth will undermine the goals of reducing gas emissions. However, beyond energy from renewable sources, the electrification of vehicle fleets appears as a great tool to help the main purpose of environmental sustainability.

To understand how Brazil and China have achieved environmental sustainability through policies to promote the electrification of bus fleets or public transport, it is necessary to understand the international commitments they have made, to measure the degrees of institutional and effective progress.

To achieve the goals established in international instruments, Brazil has committed to promoting new standards of clean technologies, expanding energy efficiency measures and low-carbon infrastructure, in addition to reaching an estimated share of 45% of renewable energies in the energy matrix by 2030, increasing from 28% to 33% the share of renewable energy sources other than hydropower [13]. Another Brazilian objective is to reduce, already in 2025, 37%

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[10] MINISTRY OF THE ENVIRONMENT. Kyoto Protocol. Available at:< https://antigo.mma.gov.br/clima/convencao-das-nacoes-unidas/protocolo-de-quioto.html >. Accessed on August 16, 2023.

[11] MINISTRY OF THE ENVIRONMENT. Paris Agreement. Available at:< https://antigo.mma.gov.br/clima/convencao-das-nacoes-unidas/acordo-de-paris.html >. Accessed on: August 13, 2023.

[12] HONGQIAO, Liu. The 'Chinese Way' to decarbonisation. Available at: < https://www.boell.de/en/2022/03/02/chinese-way-decarbonisation >. Accessed on August 16, 2023.

[13] Laira Augusta Freitas et al. Analysis of electric vehicles in the logistics sector in urban centers. Dissertation (Master 's) - Universidade Nove de Julho - UNINOVE, São Paulo, 2019. p. 17.

of its emissions in relation to 2005 levels and reach neutrality of emissions in 2060[14]. The National Environmental Policy (PNMA), Law 6,938/81[15] and the Efficient Propulsion Systems Project (PROMOB-e)[16], which aims to support Brazil in establishing the conditions for the dissemination of electric mobility, contributing to the formulation and implementation of public policies aimed at the electrified automotive sector are also instruments for Brazil to achieve these goals and the stipulated goals.

The National Environment Council (CONAMA)[17], advisory and deliberative body of the National Environment System-SISNAMA, provides, in Conama Resolution No. 401[18], the regulations for manufacturers, importers and the maximum limits for lead, cadmium and mercury and the and standards for the environmentally sound management of portable cells and batteries, lead-acid batteries, automotive and industrial, and cells and batteries in electrochemical systems.

China is very concerned about the issue, with decarbonization at its core to deal with the climate change emergency. To this end, it has made international commitments to climate change and has also taken part in initiatives to electrify vehicles. The Copenhagen Accord formulated by Brazil, China, India, South Africa, and the United States in 2009 was produced in negotiations by a group of 26 countries, and was a declaration that recognized the need to establish strong measures to hold the increase in global temperature to within 2 °C. The agreement was neither decisive nor legally binding, but it was an important milestone in China's commitment to CO2 emission reduction public targets.[19]

According to 2019 data from the National Energy Agency (IEA), China is the largest battery electric bus market in the world with 460,000 units (99% of the world market). The city of Shenzhen stands out with 16,000 battery electric buses, the largest electric fleet in the world[20]. In 2017, Shenzhen became the world's first metropolis with an all-electric urban fleet. The city currently has the largest electric bus fleet on the planet, consisting of 16,359 thousand e-buses,

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[14] DOS SANTOS, Guilherme Ramos et al. THE IMPACT OF ELECTROMOBILITY: ELECTRIC VEHICLES, THE ENVIRONMENT AND THE ENERGY INFRASTRUCTURE IN BRAZIL. South American Development Society Journal , v. 7, no. 21, 2021, p. 247.

[15] BRAZIL, Law No. 6938, of August 31, 1981 . Provides for the National Environmental Policy, its purposes and mechanisms for its formulation and application, and makes other provisions. Brasília, DF: Official Gazette of the Union, 1981. Available at: < https://www.planalto.gov.br/ccivil_03/leis/l6938.htm >. Accessed on August 13, 2023.

[16] NATIONAL ELECTRIC MOBILITY PLATFORM. PROMOB-e, 2017-2021, Electric Mobility for Brazil. Available at:< https://www.pnme.org.br/biblioteca/promob-e-2017-2021-portugues/ >. Accessed on August 16, 2023.

[17] Institute for the Environment and Renewable Natural Resources . Batteries. Available at:< https://www.gov.br/ibama/pt-br/assuntos/emissoes-e-residuos/residuos/pilhas-e-baterias >. Accessed on August 18, 2023.

[18] CONAMA RESOLUTION No. 401, of November 4, 2008 Published in DOU No. 215, of November 5, 2008, Section 1, pages 108-109. Establishes the maximum limits of lead, cadmium and mercury for cells and batteries sold in the national territory and the criteria and standards for their environmentally adequate management, and other measures. Available at:< http://conama.mma.gov.br/?option=com_sisconama&task=arquivo.download&id=570 >. Accessed on August 20, 2023.

[19] COP15 / MOP5 - Copenhagen, Denmark (December 2009). March 2020. Available at:<https://cetesb.sp.gov.br/proclima/conferencia-das-partes-cop/cop-15-mop-5-copenhague-dinamarca-dezembro-de-2009/>. Accessed on August 20, 2023.

[20] BERMUDEZ, Tatiana; CONSONI, Flávia L. op. *quote,* p.8.

surpassing the electric bus fleet of major cities such as New York, Los Angeles, New Jersey, Chicago, and Toronto, together [21].

The countries' energy transition and the development of sustainable technologies, especially urban mobility in Brazil and China, are still at different levels. However, countries have encouraged the implementation of public transport powered by electricity, especially buses and trolleybuses.

2.THE LEGAL STANDARDS AND INCENTIVE POLICIES IN BOTH COUNTRIES FOR THE IMPLEMENTATION OF THE MEANS OF TRANSPORT POWERED BY ELECTRIC ENERGY

Legislation has a fundamental role in enabling the implementation of electrified means of transport, providing commitments, and establishing incentives. Incentive policies include the widespread installation of charging stations, licensing fee exemptions, subsidies and general government incentives for the installation of electric buses [22]. In this sense, it will be addressed the federal legislation of Brazil and the municipal legislation in São Paulo regarding the decarbonization commitments and those related to fostering the electrification of bus fleets.

2.1BRAZIL AND SÃO PAULO

A. BRAZILIAN FEDERAL LEGISLATION

The electric fleet may encompass conventional electric buses as trolleybuses. The difference is that the electric trolleybus contains two rods that connect with cables arranged over the path of the vehicle, which runs on wheels and does not need rails [23]. The first trolleybus system[24] in Brazil was inaugurated in São Paulo in 1949. The type of technology implemented in trolleybuses is similar to the electromotor system developed by Dr. Ernst Werner Von Siemens and presented to the public in 1882 in Berlin [25].

As in this study we will focus on the electric buses, it is important to highlight that nowadays, the Federal government, represented by the Ministry of Regional Development (MDR), is discussing different criteria for the implementation of electric buses as part of the Urban Public Transport Fleet Renewal Program (Refrota)[26], and municipalities are also streamlining their public policies to this end.

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[21] BRITO ANTUNES, Verônica Nascimento; DOS SANTOS SILVA, Jacilene; DO CARMO HERMIDA, Camila, op. *quote,* p. 250.

[22] DELGADO, Fernanda; COSTA, José Evaldo Geraldo. FEBRARO, Julia. DA SILVA, Tatiana Bruce., op. *quote,* p. 40.

[23] ESTADÃO. Sustainable mobility: do trolleybuses still have a place in cities? Available at: < https://summitmobilidade.estadao.com.br/sustentabilidade/mobilidade-sustentavel-o-trolebus-ainda-tem-espaco-nas-cidades/#:~:text=Em%20compara%C3%A7%C3%A3o%20a%20%C3%B4bus%20conventional,with%20gases%20nem%20polutes%C3%A7%C3%A3o%20sonora .> Accessed on August 20, 2023 .

[24] Breathe São Paulo. The Trolleybuses. Available at: http://www.respirasaopaulo.com.br/Trolebus%20-%20Problemas%20e%20solucoes.htm . Accessed on August 22, 2023.

[25] SILVA, Maria Annalyanne Pereira da. Main trends and challenges in the implementation of electric vehicles in the road freight transport sector. 2022, p.28.

[26] MINISTRY OF INTEGRATION AND REGIONAL DEVELOPMENT. REFROTA program. August 7, 2020. Available at: < https://www.gov.br/mdr/pt-br/assuntos/mobilidade-e-servicos-urbanos/programa-refrota >. Accessed on August 20, 2023.

In a legal perspective, this goal relates to the Brazilian Constitution not only from an urbanistic point of view, but also environmental. The Brazilian Federal Constitution of 1988[27] raised the concern of the ecologically balanced environment to provide quality of life to the Brazilian people. This provides for the need to control the production, sale and use of techniques, methods and substances that pose a risk to life, quality of life and the environment.

Although the stimulus to other "modern" sources of renewable energy is still incipient in Brazil compared to the world average, it is important to bear in mind some Brazilian legislative initiatives. The first instrument adopted in Brazil to facilitate the use and expansion of the supply of electricity with incentives for alternative sources was the Alternative Sources Incentive Program (Proinfa), instituted by Brazil through Law No. 10,438/2002, which, although ambitious [28] did not fully achieve its objectives[29].

Then, Law No. 12,187/2009[30] was created in the scope of the National Policy on Climate Change, making the reduction of GHG emissions mandatory. Few years ago, the Senate approved Bill No. 6539/2019 that modified Law No. 12,187/2009 to include the commitments assumed by Brazil in the Paris Agreement[31].

Focused on the topic of urban environmental sustainability and transports, Law No. 12,587/2012[32] established the principles, guidelines, and objectives of the National Urban Mobility Policy (PNMU), aiming to guide the actions of both the Federal Government and the States and Municipalities to foster urban mobility. Among the guidelines set out in the PNMU is the use of renewable and less polluting energies in mobility systems stands out[33]. The adoption of electric buses in public transportation fits precisely in this guideline.

In this sense, it is important to point out that the new Brazilian industrial policy for the automotive sector, called Route 2030 is also in line with the past policies that combine urban transportation and sustainability. This policy aims to support technological development, competitiveness, innovation, vehicle safety, environmental protection, energy efficiency and improvement in the quality of Brazilian automobiles. The second phase of the Route 2030 is still under discussion and proposes actions for electromobility. Among these are: attracting investments to the country, including the assembly of hybrid and electric vehicles and their components; creation of a working group focused on hybrid and electric vehicles with a view to preparing a new National Plan for the Development of Electromobility in Brazil [34]. According to Margarete Gandini, director of the Department of Development of High-Medium Technological Complexity Industry at the Ministry of Development, Industry, and Commerce

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[27] BRAZIL. Constitution of the Federative Republic of Brazil. Brasília, DF: Federal Senate. Available at:< https://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm >. Accessed on: August 13, 2023.

[28] Law No. 10.438, of April 26, 2002. Available at: <https://www.planalto.gov.br/ccivil_03/leis/2002/l10438.htm >. Accessed on August 22, 2022.

[29] PEREIRA JUNIOR, Amaro Olimpio, op. *quote,* p . 120.

[30] Law No. 12.187, of December 29, 2009. Available at:< https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm >. Accessed on August 22, 2023.

[31] Bill No. 6539, of 2019. Amends Law No. 12,187, of December 29, 2009, which institutes the National Policy on Climate Change - PNMC, to update it in the context of the Paris Agreement and the new challenges related to it to climate change. Available at: <https://www12.senado.leg.br/radio/1/noticia/2021/11/03/aprovado-projeto-que-atualiza-a-politica-nacional-sobre-mudanca-do-clima > . Accessed on August 1, 2023.

[32] Law No. 12.587, of January 3, 2012. Available at:<https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12587.htm>. Accessed on August 22, 2023.

[33] PASCOAL, ET; FURTADO, AE; FERREIRA FILHO, Valter Silva, op. *quote,* p.2.

[34] PASCOAL, ET; FURTADO, AE; FERREIRA FILHO, Valter Silva, op. *quote,* p.9.

(MDIC), the production of electrified vehicles will be intensified with the new automotive policy rules and the resumption of working groups to relaunch the National Electromobility Plan[35].

The public policies involved also encompass public financing to meet the targets imposed by mandatory rules. BNDES Finem Mobilidade Urbana is a program created to foster the financing of electric buses. It allows financing from R$ 20 million for investment projects of public interest focused on urban mobility. Among them, financing for the acquisition of buses and trucks that are hybrid, electric, or powered by clean fuels [36]. The initiative supports undertakings that reduce energy consumption in buildings, production processes, power plants, electrical networks, public lighting, and/or increase the efficiency of the national energy system[37].

Recently, the Federal Government's new Growth Acceleration Program (PAC) for Development and Sustainability intends to invest R$ 48.8 billion from 2023 to 2026 in sustainable urban mobility. The program will induce innovations in management, regulation, and technologies for urban transport, such as the use of renewable energies to reduce CO2 emissions. The Program Urban Mobility portfolio includes public and private investments and Public-Private Partnerships (PPPs).[38]

B. MUNICIPAL LEGISLATION OF SÃO PAULO

In this context, the concern with the reduction of GHG has become central to the municipality of São Paulo, the biggest city of Brazil and the most important financial center of the country. The preliminary environmental policy that incorporated low emission in SP was the one which established trolleybuses in São Paulo, that is, Law 14.933/2009 - the Climate Change Policy for the Municipality of São Paulo. Article 5 of the Law sets a target of reducing the municipality's anthropogenic emissions of the greenhouse gases listed as a priority in the Kyoto Protocol of 30%. Article 6, II, a, encouraged the provision of public transport with an emphasis on a bus system with lower polluting potential and no greenhouse gas emissions with emphasis on the rail network, subway, trolleybuses, and other means of transport[39]. In recent years, the electric fleet in the State of São Paulo was still mostly represented by trolleybuses. The trolleybuses are present in three corridors, in the city of São Paulo, while the hybrid buses are the second fleet in volume, and then electric buses.

The same legal measure determined that the operators of the Urban Passenger Transport System of São Paulo must promote the progressive reduction of fossil carbon dioxide (CO2)

[35] EPBR. Novo Rota 2030 pretende intensificar produção nacional de veículos elétricos. Available at: <https://epbr.com.br/novo-rota-2030-pretende-intensificar-producao-nacional-de-veiculos-eletricos/>. Accessed on September 20th, 2023.

[36] PASCOAL, ET; FURTADO, AE; FERREIRA FILHO, Valter Silva, op. *quote,* p. 8.

[37] BNDES Finem - Environment - Energy Efficiency . Available at:< https://www.bndes.gov.br/wps/portal/site/home/financiamento/produto/bndes-finem-eficiencia-energetica >. Accessed on August 1, 2023.

[38] BRAZILIAN FEDERAL GOVERNMENT. Efficient and Sustainable Transportation. Growth Acceleration Program (PAC). 2023. Available at:<https://www.gov.br/casacivil/novopac/cidades-sustentaveis-e-resilientes/mobilidade-urbana-sustentavel>. Accessed on August 1, 2023.

[39] Law No. 14,933 of June 5, 2009. Institutes the Climate Change Policy in the City of São Paulo. Available at:< http://legislacao.prefeitura.sp.gov.br/leis/lei-14933-de-05-de-junho-de-2009 >. Accessed on August 20, 2023.

emissions, and toxic pollutants emitted in the operation of their respective fleets, through the gradual use of cleaner and more sustainable fuels and technologies [40].

More contemporary, Municipal Law No. 16,802/2018[41] specified annual schedules with the targets for cutting pollutants that will be required by bus concessionaires over 20 years. The Law deals with the use of less polluting energy sources and less greenhouse gas generators in the urban public transport fleet of the Municipality of São Paulo. The trend is that most of the current fleet of diesel buses (14,400 units) will be replaced by electric and hybrid buses or powered by other renewable energy technologies [42].

In September 2019, the transport authority of São Paulo (SPTrans), the public transport operator in the city, published a tender for the operation of around 14,000 urban buses. The grants set ambitious targets to reduce greenhouse gas emissions from 2028 to 2038. The bidding process is in line with the city of São Paulo's goals. Also in 2019, a pilot project by SPTrans incorporated 15 electric buses with the battery manufactured by the Chinese automaker BYD, which represents the largest fleet of this type in Brazil [43].

In the most recent policy of the city, under the government of Mayor João Doria (2017-2018), large investments in urban transport infrastructure were announced for the construction of Bus Rapid Transit (BRT) and Bus Rapid Service (BRS) São Paulo. Although considered low-cost when compared to the subway, these projects show little significant improvements both from the point of view of urban mobility and the reduction of atmospheric pollution[44].

It is estimated that 11,008 electric buses will start running in Brazil by 2030. An investment of around US$ 3.6 billion, with São Paulo, Rio de Janeiro, and Salvador accounting for 84% of the market[45]. Most public transport service contracts are for a period of more than 15 years, through public tenders. To make the installation of electric buses viable, the new tenders and contracts need to provide for business models that support the implementation of new technologies in the public transport system, by including financial and technological incentives and guarantees[46].

Despite the legal measures created by the municipality of São Paulo to thrive the electrification of the fleet and achieve GHG reduction for the next years, there are some barriers to the adoption of electric buses such as lack of operational knowledge, technical limitations, inflexible procurement practices, non-scalable financing, institutional limitations, and stagnant

[40] BERMUDEZ, Tatiana; CONSONI, Flávia L. op. *quote,* p.8.
[41] Law No 16.802 of July 27, 2018. Available at: <https://www.al.sp.gov.br/repositorio/legislacao/lei/2018/lei-16802-27.07.2018.html>. Accessed on August 1, 2023.
[42] PASCOAL, ET; FURTADO, AE; FERREIRA FILHO, Valter Silva, op. *quote,* p.9.
[43]Inter-American Development Bank (IDB) and Ministry of Regional Development (MDR). Transition to Zero Emission Urban Mobility Brasília: Editora IABS, 2021, p. 48. Available at:< https://www.gov.br/mdr/pt-br/assuntos/mobilidade-e-servicos-urbanos/CRTransioZeroEmissosemconsideraes.pdf >. Accessed on August 20, 2023.
[44] PEREIRA JR, Amaro Olimpio, op. *quote,* p. 121.
[45] CABRINI, Ju. By 2030, Brazil will have more than 11,000 electric buses. Estadão, February, 2023. Available at:<https://mobilidade.estadao.com.br/inovacao/onibus-eletrico/>. Accessed on September 19, 2023.
[46] GUIDE TO ELECTROMOBILITY Guidelines for structuring projects in public transportation. Ministry of Regional Development (MDR) with the Inter-American Development Bank (IDB) and WRI Brazil. February, 2022, p. 22. Available at:<https://www.gov.br/cidades/pt-br/central-de-conteudos/publicacoes/mobilidade-urbana/Guia_Eletromobilidade.pdf>. Accessed on September 19, 2023.

pilot projects[47]. Therefore, to make electric buses viable, Brazil and São Paulo need to take a global view of their implementation. Finally, for the implementation of electric buses and trolleybus fleets according to Brazilian federal rules and the legislation of São Paulo, it is necessary to also bear in mind important tools for the effective operation of electric collective transportation, such as to analyze the type of battery, charging method, diagnosis of the public bus transport system, emissions analysis, market study, and testing protocols.

2.2 CHINA AND SHENZHEN

A. CHINESE FEDERAL LEGISLATION

China Ministry of Science & Technology of China established the national High Technology Research and Development Program (or 863 Program) in 2001.This program involved the main research institutes, manufactories, and universities related to the automotive industry in China[48]. It certainly reveals the Chinese political choice to combine education, science and technology, government incentives, and private sector – a long term success formula to develop a leading sector.

In 2005, China enacted a new Renewable Energy Law supporting the renewable industry, in addition to a series of regulations and requirements for its suppliers to operate in the electricity grid, such as financial incentives, research and development subsidies and fees preferred for projects with renewable matrices[49]. This Law was an important achievement in China's commitment to electric transportation as a way of reducing fuel dependency and helping to preserve the environment.

In 2009, the central government of China adopted the Program Thousands of Vehicles, Tens of Cities (TVTC) featuring some subsidy policies with monetary incentives to encourage the electric bus fleet and selected Shenzhen, as one of the 10 pilot cities[50]. The (TVTC) is China's first step to move from the laboratory stage to market deployment. This program was implemented with city-based pilot projects focused on the use of electric vehicles in public transport[51]. This project was achieved through a combination of Chinese government funding and subsidies from the Shenzhen Municipal Finance Commission and was also favored by economic service models[52]. Financial subsidies were provided to encourage EV procurement including: (1) direct payments to approved auto manufacturers and (2) subsidy levels determined based on the rate at which petrol can be saved.

The development and circulation of electric buses received a kick-off from the Chinese Federal Government through tax incentives. In June 2012, the Ministry of Finance responsible for formulating fiscal and taxation policies, issued the Notice on the Purchasing of electric buses

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[47] Tumi E-BUS Mission. This international coalition supports 20 cities to become leaders in electric buses and promotes exchanges that will benefit hundreds of other cities around the world. WRI BRAZIL. Available at:<https://www.wribrasil.org.br/projetos/tumi-missao-onibus-eletricos>. Accessed on September 19, 2023.

[48] CONSULATE GENERAL OF THE PEOPLE'S REPUBLIC OF CHINA IN NEW YORK. National High-tech R&D Program (863 Program). Available at:<http://newyork.china-consulate.gov.cn/eng/kjsw/std/201603/t20160305_5520599.htm>. Accessed on September 24, 2023.

[49] PEREIRA JR, Amaro Olimpio, op. *quote,* p. 116.

[50] The main cities are Pequim, Xangai, Shenzhen, Hangzhou, and Beijing.

[51] LI, Ying; ZHAN, Changjie; DE JONG, Martin; LUKSZO, Zofia. Business innovation and government regulation for the promotion of electric vehicle use: lessons from Shenzhen, China. Journal of Cleaner Production , v. 134, 2016, p. 372.

[52] BRITO ANTUNES, Verônica Nascimento; DOS SANTOS SILVA, Jacilene; DO CARMO HERMIDA, Camila., op. *quote,* p. 250.

for Urban Public Transport Enterprises exempted from Vehicle Purchasing Tax. The tax exemption represented a considerable amount of money to stimulate the replacement of the old fleet with an electric one and this policy lasted from January 1st, 2016, to December 31st, 2020. The Ministry of Industry and Information Technology released the Safety Technical Conditions for Electric Buses, which put higher requirements on the diffusion of batteries to ensure safe operation. At that time electric buses were already considered a reality, which was why there was so much concern about the regulation and safety of electric buses.

In 2012, China adopted the Energy Conservation and New Energy Vehicle Industry Development Plan drawn up for the period 2012-2020. It created a strategic program for the development of electric vehicles in China. The program emphasized China's electric strategic orientation to transform the automobile industry while promoting the country's industrialization[53]. In this sense, it is important to highlight that this plan is an example of the clear orientation of the Chinese government in intrinsically combining sustainability and industrialization because both purposes thrive together.

According to Planet Smart city[54] (2018), China is the country with the largest number of smart cities in the world, with around 500 pilot projects. These projects began in 2012 when the Chinese government started the national development program for smart cities, seeking to encourage the use of the most current technological innovations (artificial intelligence, internet of things, among others), to favor the flow of traffic, improve employment and make public buildings more efficient in terms of energy. The city of Shenzhen is a great example of a smart city serving as a development model with a strong presence in advanced technologies and sustainability [55].

Another initiative announced by the federal government, in 2015, is the Made in China 2025 (MiC 25) development policy, which oriented Chinese factories to manufacture technological products, aiming for innovation, quality with a mastery of low-carbon technologies, car intelligence, lightweight materials, and better drive batteries[56].China seeks to end its reliance on international technology and upgrade its industrial capability and smart manufacturing by ensuring that innovation, product quality, efficiency, and integration drive manufacturing[57]. This policy can be seen in the government's incentives for the manufacture of electric buses, in which Chinese manufacturers are developing all the technology, from the battery to the structure of the bus.

China organizes its public policy priorities in five-year plans and the issue of electrifying the public transport fleet has been included in the latest five-year plans. The 13th Five-Year Plan (2016-2020) sets out China's most important national strategies for the five years following its implementation. Among the planned objectives is the improvement of the electric vehicle industry in an integrated way, the improvement of batteries and charging

[53] BISPO, Scarlett Queen Almeida; CECHIN, Alícia. Electric vehicles: how is China preparing to become the world's biggest power in the segment?. Brasilia, IPEA, August, 2023, p. 50.
[54] "Smart cities" are defined as those that promote energy efficiency, quality of life and environmental, social and economic sustainability. They attempt to satisfy population demands without compromising socio-economic development and environmental preservation.
[55] BRITO ANTUNES, Verônica Nascimento; DOS SANTOS SILVA, Jacilene; DO CARMO HERMIDA, Camila, op. *quote,* p. 247.
[56] BISPO, Scarlett Queen Almeida; CECHIN, Alícia. Electric vehicles: how is China preparing to become the world's biggest power in the segment?. Brasília: IPEA, August, 2023, p. 59.
[57] Made in China 2025. Institute for Security & Development Policy. June, 2018, p. 3.

infrastructure, with the aim of building a globally competitive energy battery industrial chain[58]. Succeeding this guideline, the 14th Five-Year Plan (2021-2025) provided the construction of an ecological Chinese civilization, reassuring the purpose of reducing carbon to achieve zero emissions targets, promoting the green transformation of economic and social development[59].

Regarding tax incentives, on April 1, 2018, China announced the official application of the parallel management method of average fuel consumption and electric power vehicle for passenger vehicle enterprises, which is known as "credit policy double"[60]. The double credit policy is a way of referring to the Parallel Management Regulation for Average Fuel Consumption by Companies and credits for new energy vehicles. Manufacturers are required by the Corporate Average Fuel Consumption (CAFC) credit requirements to manufacture fuel-efficient vehicles, and to meet the credit requirements for electric and hybrid vehicles, they must produce these vehicles. If manufacturers exceed established targets, they get extra credits; noncompliance, however, results in deficits[61].

In September 2020, the Central Government pledged a “dual carbon target” (carbon peak before 2030 and carbon neutrality before 2060). In fact, authorities have stepped up measures for decarbonizing electricity generation and transport since the 2010s spanning across replacing dirtier fossil fuels with low carbon and renewable energy, popularizing EV and decarbonizing water and air transport activities[62]. In 2020, with the publication of the New Energy Vehicle Industrial Development Plan for 2021 to 2035 by the Central Government announced a new round of subsidies so efforts to be expanded with coordination between the various players (companies in the sector, universities, research centers), now focusing on assembly and integration technologies for vehicles and systems, and on improving manufacturing technologies for key components with lower costs and higher performance, such as automotive chips, operating and general control systems, advanced motors and batteries, and fast charging systems.

The Chinese government's strategies and policies have shown positive results towards development of domestic industry combined with gas reduction targets. A great example of this coordination was the development of the BYD manufacturer, encouraged by the Thousands of Vehicles, Tens of Cities (TVTC) program.

BYD Ltd. is the largest local electric vehicle manufacturer in Shenzhen, specializing in IT, automobile, and new energy technologies. BYD's products include passenger vehicles, buses, cabs, logistics, sanitation, and official cars, and it is also developing for the foreign market, occupying 90% of the electric bus market in the United States in 2019. BYD's products include passenger vehicles, buses, cabs, logistics, sanitation, and official cars, and it is also

[58] BISPO, Scarlett Queen Almeida; CECHIN, Alícia. Electric vehicles: how is China preparing to become the world's biggest power in the segment?. Brasília: IPEA, August, 2023, p.60.
[59] BISPO, Scarlett Queen Almeida; CECHIN, Alícia. op. *cit,* p.66
[60]YANG, Dong-xiao. MENG, Juan. YANG, Lei. NIE, Pun-yan. WU, Qian-ge. Dual-Credit Policy of new energy automobiles in China: Inhibiting scale or intermediary of innovation?. Energy Strategy Reviews, v. 43, 2022, p.2.
[61] CHEN, Zhinan.; HE, Hui. How will the dual-credit policy help China boost new energy vehicle growth?. International Council on Clean Transportation. 2022, p.1-2.
[62] Decarbonization strategy in Shenzhen and Singapore. Research Office Shenzhen and Singapore Legislative Council Secretariat, 2022, p.9. Available at:<https://www.legco.gov.hk/research-publications/english/2022in03-decarbonization-strategy-in-shenzhen-and-singapore-20220706-e.pdf#page=11&zoom=100,0,921>.Access in September 2023.

developing for the foreign market, occupying 90% of the electric bus market in the United States in 2019[63].

The company has received the benefit of Chinese legislation to expand its operations in the manufacture of electric buses and electric cars. BYD has become the most innovative and independent domestic car brand and leads the development of electric vehicle manufacturing in China[64]. The Thousands of Vehicles, Tens of Cities (TVTC) Program has encouraged the Chinese government to invest more in the development of the electric transport industry and companies such as BYD (the largest Chinese electric vehicle producer), located in Shenzhen, have benefited by selling electric buses to 300 cities in other countries, such as Japan, Europe, the USA, and others.

In sum, all these policies and incentives are made by the Chinese federal government to foster environmental sustainability in China, and it has been reassured in the new Five-Year Plan, the cornerstone of the Chinese legislation. The electrification of vehicles is undoubtedly one of the main tools of China for it, which has been more precisely addressed by its municipalities and their legal framework. All the policies indicate one important issue: to China, fostering sustainability and protecting the environment are as important as industrialization, and both may help each other to evolve together.

B. MUNICIPAL LEGISLATION

The Shenzhen municipal government has taken a strong lead in designing high-level institutional arrangements to promote the expansion of EVs and coordinate the roles of different stakeholders to limit the market for conventional vehicles and give priority to electric ones[65]. Shenzhen is a reference city in the implementation of autonomous electric buses, investing in operations and charging infrastructure. It adopted a type of bus in which a five-hour charge supports 250 kilometers of driving, sustaining almost a whole day of operation [66]. The early phase of electric bus adoption faced challenges, including the need for large capital investments, the mismatch between vehicle and battery life, and insufficient charging facilities.

The Regulations on the Administration of Passenger Transport for City Buses and Trams (Decree No. 5, issued in 2017 by the Minister of Transport) is a franchise model to allow companies operating charging facilities, bus, and battery production companies to enable the production of electric buses and electric cars[67]. The local government has managed to develop charging infrastructure and promote the local electric vehicle market[68]. In the bus field, the

[63] BISPO, Scarlett Queen Almeida; CECHIN, Alícia. op. *quote,* p.43

[64] LI, Ying; ZHAN, Changjie; DE JONG, Martin; LUKSZO, Zofia. op. *cit,* p.377.

[65] LI, Mengnan; YE, Haiyi; LIAO, Xiawei; JI, Junping; MA, Xiaoming. How Shenzhen, China pioneered the widespread adoption of electric vehicles in a major city: Implications for global implementation. Wiley Interdisciplinary Reviews: Energy and Environment, v. 9, no. 4, 2020, p.12.

[66] GRAY, A. Shenzhen just made all its buses electric, and taxis are next. 02 Nov. 2018. Available at:< https://www.weforum.org/agenda/2018/11/shenzhen-just-made-all-its-buses-electric-and-taxis-are-next>. Access in September 2023.

[67] LUMIAO, Li; ZHANHUI, Yao. New Energy Buses in China Overview on Policies and Impacts. China Automotive Technology and Research Center Co, Ltd CATARC. Published by: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Beijing, 2020, p.7.

[68] LI, Ying; ZHAN, Changjie; DE JONG, Martin; LUKSZO, Zofia. Business innovation and government regulation for the promotion of electric vehicle use: lessons from Shenzhen, China. Journal of Cleaner Production, v. 134, 2016, p.6.

Shenzhen Government endows the franchise rights to the charging facility operators, thus enabling them to step into the industrial chain of new energy vehicles and forming the "Shenzhen model" characterized by "financial leasing, separation of vehicles and battery, and integration of charging and maintaining"[69].

Shenzhen issued the "Shenzhen Transport Sector Energy Saving Regulation" and the "Shenzhen Energy Saving and New Energy Vehicle Regulation" at the start of its electric vehicle development, both setting out long-term goals and targets for Shenzhen EV development[70]. In terms of administrative arrangement, the Shenzhen Municipal Development and Reform Commission is responsible for overall coordination, and the Shenzhen Municipal Transport Commission is specifically tasked with promoting the development of the EV market, with the support of several different government agencies [71].

To achieve the "dual carbon target", a Chinese national policy announced in 2020 by the city of Shenzhen, it is expected to reduce carbon intensity by a further 18% during 2020 to 2025 and attain carbon peak before 2025[72]. The policies are geared towards replacing coal and oil in power plants in Shenzhen, promoting generation and import of electricity from renewable energy, promoting new energy and electric vehicles, decarbonizing maritime and aviation sectors and emission caps and permit trading for heavy polluters.

In 2017 the city reached the milestone of 100% of its bus fleet becoming electrified. Electrification began with the TVTC program in 2009. Shenzhen's municipal franchise model initiative, created in the city to enable the production, operation, and cost reduction of electric buses, resulted in the global electrification of the city's fleet.

The Municipal initiative in Shenzhen has also shown positive results in terms of bus circulation on a larger scale and in a shorter period of time. A great example of success is the Potevio New Energy Co Ltd. It is an EV charging company, founded in 2010, and it was one of the first state-owned enterprises in China focused on the construction and operation of charging networks for electric vehicles. Currently, the company operates 50,000 charging points in over 50 cities in China. In 2010, the Shenzhen government and Potevio Ltd. agreed to jointly accelerate the promotion of electric buses in Shenzhen.

The bus companies, Potevio, financial leasing companies, and electric buses production companies have been cooperating to achieve the operation of electric buses, forming a "financial leasing, separation of vehicles and battery, and integration of charging and maintaining" model[73]. Basically, the companies sign a contract to buy and sell the electric buses. Potevio separates the leasing of batteries from vehicle bodies to the Shenzhen Bus Group. For the leasing of EV bodies, Potevio offers the Shenzhen Bus Group an eight-year lease for EV bodies. Shenzhen Bus Group Ltd. is an electric bus manufacturing company founded in Shenzhen, founded in 1975 is a domestic industry that provides most buses and public

[69] ZHANG, Qihang. Analysis of "Shenzhen Model" for New Energy Vehicle Promotion in Public Transportation. In: IOP Conference Series: Earth and Environmental Science. IOP Publishing, 2019. p.2.
[70] LI, Mengnan; YE, Haiyi; LIAO, Xiawei; JI, Junping; MA, Xiaoming., op. *quote,* p.4.
[71] LI, Mengnan; YE, Haiyi; LIAO, Xiawei; JI, Junping; MA, Xiaoming., op. *quote,* p. 4.
[72] JIANG, Qi; YIN, Zhigang. The Optimal Path for China to Achieve the "Dual Carbon" Target from the Perspective of Energy Structure Optimization. School of Mining, Liaoning Technical University, June, 2023, p.1.
[73] ZHANG, Qihang. op. quote, p.2.

transportation services to citizens of Shenzhen. Its largest shareholder (55%) is the Shenzhen Municipal Commission for Supervision and Administration of State Assets (SASAC)[74].

The company initiative works as the leasing company pays the purchase price of the bus (without the battery), with a deduction for the tax subsidies offered by the city of Shenzhen. The battery is purchased or leased from the charging facility operator Shenzhen Lineng, which receives financial subsidies from both the central government and the municipality of Shenzhen and the buses are leased and Shenzhen Lineng provides a guarantee to the leasing company. The "Shenzhen Model" adopted by the city ends up making it possible for electric buses to circulate, since the cost is lower and there is a significant reduction in the financial expenses of the bus companies.

The process of full electrification took about 8 years and the fact that electric vehicle manufacturing companies such as Potevio and BYD Bus Group grew in parallel as a result of federal legislation and incentives that influenced the result.

The municipality of Shenzhen has extended its intention to decarbonize to achieve the goals of the Federal Government including the electrification of 100% of the taxi fleet and is committed to promoting the increase of electric vehicles especially with tax incentives and the population. Thus, Shenzhen shows that the decarbonization policy in combination with the implementation of a long-term policy to adopt electric buses could be a great achievement for the cities.

3. THE BRAZILIAN CHALLENGES IN THE ELECTRIFICATION ON BUS FLEETS

Concerning challenges to the electrification of bus fleets in Brazil and China, on the one hand, Brazil has the challenge to implement electric buses in its infrastructure that connect the country's major economic centers. On the other hand, the Chinese still need to increase their energy grid with renewable energies. While in Brazil the problem of dependence on the road network, local infrastructure, such as roads, is reflected, above all, in terms of increased costs and loss of competitiveness, in China, due to the larger dimensions of its economy and infrastructure, the struggle against pollution and the search for efficiency energy are more challenging than in Brazil[75].

There is some production of electric buses in Brazil, but it is still too incipient for the demand of a continental country, and of the city of São Paulo, considering that it, along with its metropolitan area, has 20 million habitants. In July of 2023 it was announced that Brazil will have five electric bus manufacturing companies in the coming years: two from Higer Bus, two from BYD and the recently opened Eletra plant in São Bernardo do Campo (SP)[76]. The imports of electrical buses, including the chassis and batteries could be an alternative. However, importing high value-added goods is expensive and time-consuming. There is another challenge

[74] LI, Ying; ZHAN, Changjie; DE JONG, Martin; LUKSZO, Zofia. Business innovation and government regulation for the promotion of electric vehicle use: lessons from Shenzhen, China. Journal of Cleaner Production, v. 134, 2016, p. 377.

[75] PEREIRA JR, Amaro Olimpio, op. *quote,* p. 122.

[76] MOBILIZE BRASIL. Brazil will have another electric bus factory. July, 2023. Available at: <https://www.mobilize.org.br/noticias/13708/brasil-tera-mais-uma-fabrica-de-onibus-eletricos.html#:~:text=Com%20o%20an%C3%BAncio%20de%20hoje,Bernardo%20do%20Campo%20(SP)>. Accessed on September 2023.

connected not only to the factoring of the bus itself, but also its auto parts of the bus components. The new value chain of sustainable vehicles implies that vehicle manufacturers will have to cooperate with their production line to other players to coordinate the process, to attend to the demand, and to comply with its contracts. The battery manufacturers, for example, must be in full coordination with the chassis manufacturers, otherwise the vehicle will not be able to operate. Thus, all these players need to be interconnected for the development of electric vehicles to succeed in terms of production and to provide electrical buses to countries and cities[77].

Larger loads of energy would not be a problem for Brazil as it is in China, because it can already support the increase in demand for electricity. For example, locally, even if there is an additional increase, according to São Paulo Power and Light Company (CPFL) data, the city will be able to manage and will not run out of energy, according to a simulation. São Paulo Power and Light Company (CPFL) also carried out simulations of the penetration of electric vehicles in its concession area. Considering a share in the total vehicle fleet of 4% to 10% by 2030, the additional electricity consumption caused by these vehicles would increase from 0.6% to 1.6%, which would be fully manageable by the Brazilian electrical system, which already is used to dealing with much larger load swings than predicted in the simulations [78].

The insertion of EVs, mainly with external energy supply, represents an important change in the current technological model based on road transport[79]. According to Amaro Olimpio Pereira Junior[80] the road base causes the level of atmospheric pollution to be high in large cities, caused by the burning of fuels, in addition to the increasing problems of urban mobility [81]. In this context, grid connected EVs, such as light rail vehicles and trolleybuses, are considered a mature technology in which eventual innovations will be incremental.

In this sense, the Environmental Company of the State of São Paulo (CETESB), the agency responsible for controlling, inspecting, monitoring, and licensing activities that generate dirt, encourages the renewal of fleets and the use of vehicles with less polluting impact such as electric vehicles, the expansion of structural networks and the creation of a differentiated electricity tariff for public transport, and a tariff policy that favors alternatives with low polluting impact.

However, it is impossible to discuss the electrification of the bus fleet without dealing with the waste generated by this new technology. Patrícia Iglesias, former president of CETESB, points out that the regulation of electronic waste in Brazil is still timid. It points out that the Technological Waste Law of the State of São Paulo, Law 13,576, of 2009, uses the expression "technological waste", defined in its art. 2.º as "domestic appliances and electronic equipment and components for domestic, industrial, commercial use or in the service sector that are in disuse and subject to final disposal, such as: III – energy accumulators (batteries and cells). The

[77] DELGADO, Fernanda. COSTA, José Evaldo Geraldo. FEBRARO, Julia. DA SILVA, Tatiana Bruce., op. *quote,* p. 50.
[78] DELGADO, Fernanda. COSTA, José Evaldo Geraldo. FEBRARO, Julia. DA SILVA, Tatiana Bruce., op. *quote,* p. 79
[79] PASCOAL, ET; FURTADO, AE; FERREIRA FILHO, V. S., op. *cit,* p.11.
[80] Professor of the Energy Planning Program of the Coordination of Graduate Engineering Programs of the Federal University of Rio de Janeiro (PPE /COPPE/UFRJ). Federal University of Rio de Janeiro (PPE /COPPE/UFRJ). Visiting researcher at Ipea's National Development Research Program (PNPD). Ipea. E-mail: <amaro@ppe.ufrj.br>.
[81] PEREIRA JR, Amaro Olimpio, op. *quote,* p. 121.

Law established that the responsibility for the destination of technological waste will be jointly and severally between the companies that produce, sell, or import electronic products and components.

The study "The path to decarbonization of the automotive sector in Brazil", carried out by the Boston Consulting Group (BCG) in partnership with the National Association of Automotive Vehicle Manufacturers (ANFAVEA), shows, in a first scenario, that the hybrid and electric car market in Brazil will have a participation of 12% in 2030 and 32% in 2035, considering a scenario in which the country still has lower levels of electrification and incentives. In the second scenario presented, in which the country invests in electrification, including production and purchase incentives, the share of hybrid and electric vehicles rises to a level of 22% in 2030 and 62% % in 2035 [82]. It means that public policies have a central role in the maximization of the production, that will attend to demand created also by legal means, considering the decarbonization commitments created by the federal and local governments to achieve the Paris agreement goals and to foster environmental sustainability.

Moreover, the issue of fewer local companies factoring electrical buses in Brazil is a great obstacle to fostering it in the country and to municipalities to fulfill their commitments. An alternative in the next few years, as it was already mentioned, could be import it. However, one question that arises is about the environmental responsibility of these foreign manufactures. According to Law 13,576, of 2009 from the State of São Paulo, foreign manufacturers would apparently also be jointly and severally liable with the seller and the importer by electronic waste, including batteries. It is important to question if, in the future, if producers and importers of electrical buses and batteries could be issued by the governments (from the State of São Paulo or other regions) in terms of civil responsibility regarding the destination of technological waste.

4. LEARNINGS FROM BRAZIL BASED ON THE CHINESE EXPERIENCE

Finally, it is crucial to mention that the encouragement for cooperation between China and Brazil and the internalization of new production techniques is already on course with the presence of Chinese manufacturers in Brazil. There is a BYD plant in Campinas and a new plant in Bahia, which will increase local production. BYD is an example of an electric vehicle factory, including electric buses, that has succeeded in China. The federal and municipal public policies such as the creation of charging infrastructure, a strong internal production chain, with a system of "financial leasing", separating vehicles and batteries, and integrating charging and maintenance are largely responsible for the success of 100% electric buses in Shenzhen.

In São Paulo as well as in Shenzhen bus recharges take place in an average period of 14 hours, lasting between two and four hours [83]. The next step for both cities is to foster technological innovation and efficiency in the use of inputs and reduce this time lapse for recharging, but sustainably. It would reassure that energy efficiency and renewable energies are now on the agenda of government strategies[84].

[82] OSHIMA, Eduardo Issamu. Barriers and facilitators for the adoption of electric cars in Brazil. Dissertation, Fundação Getulio Vargas, School of Business Administration of São Paulo, 2023, p. 11-12.
[83] BRITO ANTUNES, Verônica Nascimento; DOS SANTOS SILVA, Jacilene; DO CARMO HERMIDA, Camila, op. *quote,* pp 253.
[84] PEREIRA JR, Amaro Olimpio, op. *quote,* p. 107.

The Chinese legal devices allied with the five-year plans reveal an instrumentality of the policy of transport electrification. However, China still faces environmental challenges linked to the disposal, recycling, and reuse of vehicle components, especially batteries. That is, the waste management of electrical devices derived from electric buses is still an issue that has been dealt with in China and will have to be addressed soon in Brazil.

China also faces some challenges in building a domestic battery production chain in which the current gaps are filled, for example through investments in the refining and processing of raw materials, in the manufacturing and recycling of batteries[85]. The government emphasizes the coordination of efforts to build an efficient battery recycling system to recycling system to reduce pressure on the reserves of key strategic minerals[86]. Brazil, which intends to implement and expand its e-bus fleet, should observe Chinese strategies for battery disposal and recycling as a way of reducing any externalities throughout the production chain. The development of specific legislation for the disposal of bus batteries and electric vehicles in general can help the country create a highly connected infrastructure.

In China, in 2012, the Chinese government started the National Smart Cities Development Program,[87] seeking to encourage the use of high technology resources in the management of urban space. Faced with the problem of the emission of pollutants into the atmosphere and the international commitments adopted, the city of Shenzhen was somehow forced to take measures to slow down and reduce environmental impacts. The electrification of 100% of the buses was a measure that combined the development of a potential technology with the result of alleviating a latent problem.

The Brazilian Federal Law No. 12.305/2010, known as the National Solid Waste Policy, provides for the integrated management and management of solid waste, including hazardous waste, to the responsibilities of generators and public authorities through reverse logistics. However, this Law does not concern the electric vehicle battery market. There is a latent question regarding the lifetime and disposal of batteries, a discussion that is still in formation and will need regulation to avoid waves of solid waste generation without post-treatment [88].

Brazil and China have committed themselves to carbon neutrality and are two central countries for discussions on combating global warming. Brazil has important elements such as land availability and vast water resources, which China does not have in abundance. At the same time, China is a leader in the production of electric cars [89], which could have potential for expanding manufacturing to other developing countries such as Brazil, helping the country to

[85] FERREIRA DA CRUZ, Robson. Industrial policies for the electric bus production chain: lessons learned and experiences based on international benchmarking in the United States, China, Mexico and the Netherlands. United Nations publication LC/TS. Santiago, 2023, p. 29.
[86] FERREIRA DA CRUZ, Robson., op. *quote,* p.31.
[87] A smart city is one that makes use of technological innovations to benefit the lives of individuals, performing urban services in an efficient way, thus improving the quality of life of the population, and modifying the connection that involves local institutions, companies and individuals.
[88] PROMOB-E. Norms and regulations for mobility for Electric Vehicles in the framework of Brazil. Rio de Janeiro, July 2020, p. 1-62. Available at: < https://www.pnme.org.br/biblioteca/normas-e-regulamentos-para-a-mobilidade-eletrica-no-enquadramento-do-brasil/ >. p.56. Accessed on August 17, 2023.
[89]BRAZILIAN CENTER FOR INTERNATIONAL RELATIONS. China's XIV Five-Year Plan Prospects for Sino-Brazilian Cooperation. Available at:< https://www.cebri.org/media/documentos/arquivos/XIVPlanoQuinquenalDaChinaPersp.pdf >. Accessed on August 22, 2023.

achieve its commitments with the Paris Agreement and the cities like São Paulo, to make possible the electrification of their bus fleets.

São Paulo is part of a pilot project by SPTrans that has electric buses that are operating on lines in the southern part of the city. The city of São Paulo is starting to operate 50 new 100% battery electric buses in September of 2023 with the participation of the national industry, the first step in a plan to reach 2,600 units by the end of 2024. São Paulo's total fleet is around 13,000 buses and until now only 18 were electric, running in pilot projects. In the model implemented in São Paulo, it is up to the concession operator to choose the bus manufacturer, the charging technology and even the electricity supplier, since the new volume of electric charge makes bus companies eligible to enter the free energy market[90].

The Chinese experience, in the city of Shenzhen for instance, can be very valuable for Brazil and for the city of São Paulo if it is observed. China has a lot of subsidies from the federal government and municipal strategy plans for sustainable urban development. The franchise model, with development bank loans, and a long-term policy have also been largely responsible for the development of high-end local manufacturers, and it could be observed by the Brazilian government.

5.CONCLUSIONS

The next step towards environmental protection is to reorient economic sectors to produce sustainable goods looking at urban transportation. It is connected not only to renewable energies, but also clean air, the reduction of GHG emissions and the contention of the greenhouse effect, and a more well-being of citizens in urban centers.

Paris Agreement and other international agreements have also played an important role in changing the Chinese mentality to achieve the global environmental goals. Brazil, as a signatory to these international conventions, is already concerned about and aligned with the global objectives of reducing pollutants, as already observed in national and municipal legislation. All these laws need to be coordinated with the objective, which must be achieved through a well-structured internal plan.

The commitments on reduction of GHG assumed by China and Brazil, as well as Shenzhen and São Paulo symbolize the current world movement towards urban decarbonization, and a great tool to better achieve it is to electrify urban bus fleets.

China invested in the expansion of electrical vehicle and electrical battery factories in its territory. Brazil has started a\this process to follow the same path. Undoubtedly, electrical vehicles plants in the Brazilian territory will be important to diminish transition costs with imports and to accelerate the process of decarbonization. It would be also important to overcome possible supply problems in times of crisis or resource crunches. Battery charging, cost, lifetime and driving autonomy are the main issues under debate and the greatest difficulties for the penetration of electric vehicles in the market, as well as the charging infrastructure, which is not properly available [91].

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The legal measures adopted by China and the city of Shenzhen based on short- and long-term plans are success factors in the uptake of electric buses. The autonomy that the Shenzhen government gained by stimulating a cost-cutting policy in the production of the entire bus infrastructure made it possible for the combustion-powered fleet to be replaced at a similar cost to a combustion-powered bus. The Five-Year Plan is a cornerstone with achievable goals, a mandatory framework to foster full collaboration between all the players involved in the project, such as the government, manufacturers, banks, companies for the implementation of the charging structure, and battery suppliers.

The TVTC Program was the kick-off to encourage Shenzhen and other Chinese cities to promote an increase in the electric bus fleet to achieve the national goal of reducing gas emissions and lowering pollution levels. Subsidy policies with monetary incentives were responsible for instrumentalizing the entire plan. Brazil can and must learn with China to develop a strong national policy in coordination with individualized plans for each Brazilian city, taking into account the different structures present in cities.

It expects that there will be an increase in the circulation of electric buses in Brazil in the next few years. The future of the market is promising, and most likely China will be dominating the battery production market, which may result in a certain dependence on this raw material over the years. It seems that the problem of "disposal" and environmental treatment of electric vehicles and their batteries is a serious problem and a common challenge both for China and Brazil. It is necessary for systemic planning for the lifespan of electrified public transport and the treatment or reverse logistics of the batteries.

Finally, the discussion of the implementation of the electric bus fleet is extremely important for the quality of urban mobility, especially in large cities. This implementation is linked to the concept of Smart City and should help to achieve Brazil's targets for reducing gas emissions, as China has already done. Considering the international commitments assumed by Brazil and China with sustainability, reduction of the emission of polluting gasses, and concern for the environment, it is necessary to certify that the components and resources necessary to move electric buses will honor not only providing renewable electric energy, but also deal with the responsible disposal of solid waste to keep true the green purpose.

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