Circular Economy as a Driver of the Energy Transition: Mapping the Management of Lithium-Ion Batteries in Brazil

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ABSTRACT

This study analyzes the role of the circular economy (CE) in Brazil's energy transition, focusing on the management of lithium-ion batteries (LIBs) used in electric vehicles (EVs). Through the framework of reflexive governance, it examines public policies, industrial initiatives, and innovation projects that promote sustainability in the LIB value chain. Initiatives such as the pilot production plant in Curitiba and the local production of batteries by companies like BYD and Bravo Motor Company highlight Brazil's capacity to foster innovation, reduce costs, and create local employment. Additionally, the integration of CE practices, such as recycling and reuse, enables more efficient resource management, aligning with global decarbonization goals. This study identifies key initiatives driving a transition towards a circular economy for a more sustainable future.

Keywords: sustainability transitions, electric vehicles, Governance reflexive, recycling

INTRODUCTION

The shift towards renewable energy has sparked debates on the sustainable management of natural resources, essential for producing clean technologies like LIBs. These batteries are crucial for advancing cleaner transportation through EVs, which are vital to achieving global decarbonization targets (Nurdiawati and Kumar, 2022). To meet international agreements and the NetZero goal, the supply chain of critical minerals—such as lithium, nickel, and cobalt—must be reevaluated, given the environmental and social challenges of their extraction (IRENA, 2023; IEA, 2024)

Brazil plays a crucial role in the transition to a sustainable economy due to its leadership in critical mineral production and its capacity for renewable energy generation (IBRAM, 2024b). With significant reserves of lithium, nickel, and graphite, and a robust mining sector, Brazil is well positioned to meet the growing global demand for LIBs. Its renewable energy matrix further supports a value chain with a lower carbon footprint, integrating CE practices (IBRAM, 2024b, 2024a).

This article maps the current policies, incentives, regulations, and key actors in Brazil's LIB value chain to promote sustainable management of LIBs in EVs and identifies key initiatives driving a transition towards a CE for a more sustainable future.

MATERIALS AND METHODS

This study employs a qualitative approach within the framework of socio-technical transitions towards sustainability, focusing on transition management at both the national (macro) and company (micro) levels. An extensive literature review of scientific articles, reports, and policy documents was conducted using multiple academic databases. A reflexive governance approach was utilized to analyze public policy tools in Brazil based on a framework that includes four governance phases: strategic (setting objectives and identifying issues), tactical (collaborating to develop strategies), operational (conducting experiments and innovation projects), and reflexive (assessing the effectiveness of actions and policies) (Fig.1). Our analysis specifically focused on the strategic and tactical phases. This choice was guided by the study's objective to understand how public policy and collaboration among various stakeholders can advance the adoption of CE practices in Brazil, particularly in the management LIBs for EVs. By concentrating on these phases, the study effectively evaluates the collaborative efforts and strategic planning processes necessary for establishing a robust CE model in Brazil (Loorbach, 2010; Jackson, A. J. Lederwasch and Giurco, 2014; Govindan and Hasanagic, 2018; Guzzo et al., 2022).

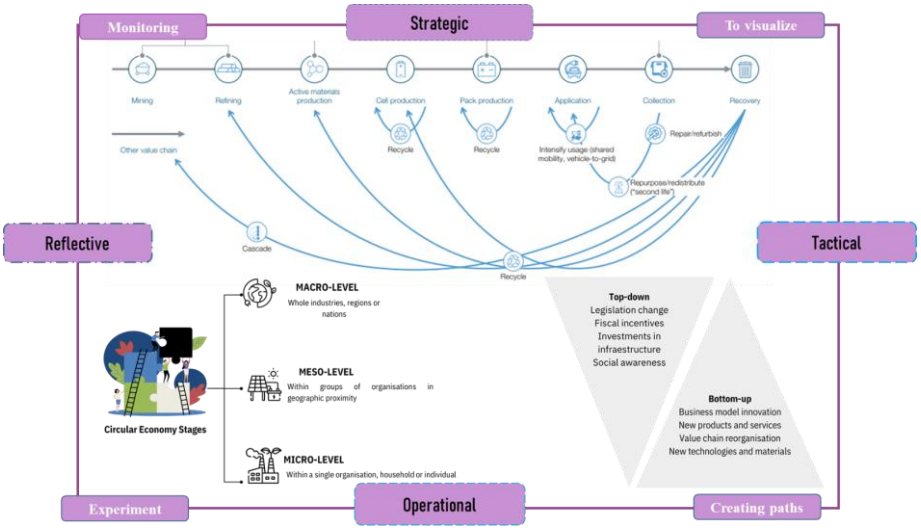

Fig. 1 *Framework* theoretical: Transition management for circular economy
Source: prepared by the authors on (Loorbach, 2010; Jackson, Lederwasch and Giurco, 2014; Govindan and Hasanagic, 2018; Global Battery Alliance, 2019; Guzzo *et al.*, 2022)

RESULTS AND DISCUSSION

The study examines Brazil's transition towards a CE and energy sustainability, focusing on strategic (visualizing) and tactical (creating pathways) governance stages. It highlights a collaborative ecosystem among various actors at both national (macro) and company (micro) levels, using top-down and bottom-up approaches to implement legislative changes and reorganize value chains. The World Economic Forum (WEF) 2024 report emphasizes Brazil's significant progress in energy transition, with 47% of its energy matrix and 88% of its electricity from renewable sources (IBRAM, 2024b; WEF, 2024). Brazil's substantial reserves of raw materials, such as graphite, rare earth elements, nickel, and lithium, position it strategically for local LIB production, promoting accessibility to the EV market and fostering CE through material reuse and recycling (IEA, 2024).

Brazil's initiatives align with the phases of reflexive governance—strategic, tactical (See Table 1) to enhance the sustainability of the LIB lifecycle. Key policies, such as Law No. 2327/21, which integrates reverse logistics for EV batteries, and the critical minerals policy, aim to ensure responsible waste management and secure mineral supply. Programs like the National Circular

Economy Strategy (ENEC) and MOVER further support innovation and waste reduction in the automotive sector (Agência BNDES, 2024; IBRAM, 2024b)

Table 1. Mapping of Initiatives for the Value Chain and Policy Instruments

Mining	Production of cell components	Pack production	Second life and recycling
Sigma lithium	BYD	Moura Group and CATL	CPqD, CPFL and BYD
Vale S.A	Bravo Motor Company	Pilot Plant in Curitiba	Center for Advanced and Sustainable Technologies (CAST)
National Graphite Company	Battery Manufacturing Center (BMC)	Moura, Stellantis	Energy Source, Re-teck and Lorene
	Cepetro	WEG	Tupy, BMW Group Brazil and SENAI Paraná

Public Private Public/Private

Policy Area/Instrument	Description	Accountable	Goals
Conservation of Strategic Minerals	National pro-minerals policy (Decree No. 11.108/22)	Ministry of Mines and Energy	Ensure the domestic supply of critical minerals, consolidate Brazil as a producer and exporter, and improve circularity in mineral production.
Electromobility	"Green Mobility and Innovation Program (MOVER)"	Ministry of Environment and Sustainable Development	Expanding sustainability demands in the sector, decarbonization and expanding Brazil's participation in the global value chains of the automotive industry
Circular economy	National Strategy for Circular Economy (ENEC)	coordinated by the MDIC, to encourage the efficient use of resources.	Promote innovation, reduce waste, finance CE and establish a national CE forum. Integrated into Nova Indústria Brasil (NIB).
Guidelines for VEs LIB administration	Law No. 2327/21: Modifies the PNRS to include specific reverse logistics for EV batteries.	Senator FLAVIO BOLSONARO	Establish a legal framework for reverse logistics of lithium-ion batteries.

Source: own elaboration

Specific projects, such as the pilot LIB production plant in Curitiba and collaborations with companies like BYD and Bravo Motor Company, showcase Brazil's ability to drive innovation, lower costs, and boost local economic development. Collaborative efforts with universities and research centers, including initiatives by UNICAMP and CPQD, focus on extending LIB lifespan and developing advanced recycling technologies, such as CAST's hydrometallurgical methods. These projects are vital for closing the material loop in the CE, enhancing sustainable resource management, and reinforcing Brazil's leadership in the global energy transition (Embrapii, 2024; SENAI, 2024).

CONCLUSION

Through the transition management cycle, particularly in strategic and tactical governance, both current issues and desired future outcomes are identified. The analysis shows that various actors are collaborating to promote a circular economy (CE) in Brazil, with incentives at macro and micro levels, including legislative changes and value chain reorganization. Although the market is still developing, Brazil is positioning itself as a leader in lithium-ion battery CE in Latin America, with initiatives spanning from raw material extraction to recycling. Brazil's reserves and production of key materials are vital for

reducing reliance on China. Nonetheless, robust government support is necessary to provide clear guidelines, establish market rules, and ensure security, thereby increasing predictability. While programs like MOVER have encouraged investment in research and development, sustained collaboration among the government, industry, and stakeholders is essential for addressing challenges and leveraging opportunities for sustainable mobility.

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