A SOCIO-TECHNICAL TRANSITION OF SUSTAINABLE LITHIUM INDUSTRY IN LATIN AMERICA

This paper applied the socio-technical transition theory (STT) in the context of the lithium industry as a key raw material towards the adoption of sustainable mobility systems and a low-carbon economy in the world. By adopting a multi-level perspective (MLP) analysis, this paper studies the geopolitical and policy arrangements in the "Lithium Triangle" (LT) comprising three South American countries – Argentina, Chile and Bolivia – to explore future scenarios among major industry and public actors in these countries.

Lithium, also called "the white gold of the 21st century", is the lightest and one of the most precious metals in the periodic table (Nacif and Lacabana, 2015). Lately, both the production of and global demand for lithium-ion batteries have grown considerably due to the impact of the climate crisis. A large quantity of lithium is required to manufacture batteries for electric vehicles (EVs). Therefore, lithium is an important material for enabling the transition to a more sustainable mobility and energy system (Golroudbary et al., 2019). Moreover, 56% of lithium is estimated to be used in batteries for different products (USGS, 2019), and the demand for EVs is forecasted to multiply exponentially, reaching 44 million units by 2030 (IEA, 2019).

South America's LT countries together possess more than 52% of the global lithium resources (USGS, 2019; Olivetti et al., 2017). The three countries have different national policies regarding the use and processing of lithium as part of the development of both the local lithium industry and international markets (Barandiarán, 2019). Consequently, LT countries have a sensible role in the global lithium industry and a successful EV transition. In this context, this paper aims to analyse two different scenarios or paths that arise by applying the STT (Geels, 2002) to the study of a sustainability transition to the lithium industry in three Latin American countries. This study mainly focuses on the mining and the international export of lithium, which comprises the first stage of the lithium industry value chain for EV batteries.

Taking a qualitative approach, the study adopts an MLP to explore the major mining policies and national lithium arrangements, industry challenges and future scenarios among major industry and public actors in these countries. The MLP is a framework that conceptualizes the dynamics and connections between technology and society. This tool considers three different levels of analysis: the socio-technical landscape (top level), the socio-technical regime (middle level) and the technological and innovation niches (bottom level) (Geels, 2002; Geels, 2004). With this aim, by analysing secondary data this study presents an overview of the ongoing development of niches and identifies possible future scenarios in the lithium industry within the LT countries of Argentina, Chile and Bolivia.

This paper unfolds the dynamics and characteristics of the socio-technical system in the LT. It reveals the general geopolitical contexts and national policies in the LT countries. Argentina, Bolivia and Chile are in possession of brine reserves of lithium located in high-altitude salt flats. Chile and Argentina play an important role in the production of lithium carbonate as part of the global lithium industry, respectively occupying the second and fourth places globally. The world's first lithium producer is Australia (60%), followed by Chile (19%), China (9%) and Argentina (7%) (USGS, 2019). The national policies regarding lithium extraction, processing and commercialization are different in the LT. Chilean and Argentinian lithium mines are leased to

multinational corporations allowing private companies to exploit and process the lithium. The corporations control the extraction process of the raw material and export lithium without treating it. In contrast, Bolivia does not restrict the export of lithium as raw material but plans to have control over the entire production chain. The goal is to play a key role in the process of adding value to lithium. The Bolivian state wants to carry out the extraction process and subsequent processes needed to obtain derivative materials and/or batteries as the final products. The exploitation and governance arrangements identified for the lithium industry in the LT countries are two. (1) *Public-private partnership* (PPP), as is the case in Chile and Argentina, where lithium mining activities are conducted by multinationals: SQM and Albemarle operate in Chile and FMC Lithco operates in Argentina. (2) *State-owned enterprise* (SOE), as is the case of Bolivia where the ownership of the lithium extraction is completely taken over by the state by Bolivia's public company, Yacimientos de Litio Bolivianos (YLB).

The findings of this paper also identified the main Stakeholders in the LT. Multiple actors operate within this institutional framework in LT, holding radically different agendas: governments, private local actors, multinationals (private foreign actors), state-owned companies, technological centres and universities, civil society and indigenous communities living in and around high-altitude salt flats. In the LT countries, governments are the actors promoting most of the innovative initiatives in the lithium industry. In the cases of Chile and Argentina, multinational lithium mining companies, universities and research institutes play a fundamental role in the technology transfer as well as in boosting local skills and capabilities.

As a result of this study, two future scenarios were identified to analyse the potential of STT towards sustainable future paths for LT countries. (1) *Transformation scenario* reflects incremental changes in the regime configuration of the lithium industry towards sustainable production and global value chain. Argentina and Chile follow a transformation pathway in which PPP is the dominant organizational arrangement for the lithium mining and processing industry that should play a major role in introducing clean technologies and niche markets. (2) *De-alignment and re-alignment scenario* is characterized by the shift from a regime where lithium extraction projects are carried out without foreign intervention under an SOE configuration. Bolivia is currently in a state of de-alignment and re-alignment.

This paper contributes to understanding the dynamics of the LT country's lithium industry through applying an MLP analysis. First, global lithium markets and their supply and demand levels have important effects in the three countries. They are very impactful on national economies, influencing national policies and support for lithium industry arrangements in the three countries. The dynamics in the EV demand not only instantly affect the upstream players in the supply chain of raw materials used to manufacture EVs but also the changes in supply, such as an under-supply scenario due to plummeting investments of upstream players to cover the increasing future demand, which directly concerns downstream players. Second, MLP analysis is a good framework for understanding the complexity of stakeholder relationships in the three LT countries. This research shows that trust should be built among the main national and international actors in the LT countries to strengthen inter-firm relationships in the two scenarios. Companies willing to work with LT countries should be aware of the power of national civil society and social movements in these countries. It is not enough to build good relationships only with suppliers and customers. In order to build long-term business-to-business relationships, these companies should foster good relationships with societal-related stakeholders, local governments, social movements for human rights and indigenous communities.

REFERENCES

Barandiarán, J. (2019). Lithium and development imaginaries in Chile, Argentina and Bolivia. *World Development*, *113*, 381–391. https://doi.org/10.1016/j.worlddev.2018.09.019

Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274. https://doi.org/10.1016/S0048-7333(02)00062-8

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, *33*(6–7), 897–920. https://doi.org/10.1016/j.respol.2004.01.015

Golroudbary, S. R., Calisaya-Azpilcueta, D., & Kraslawski, A. (2019). The Life Cycle of Energy Consumption and Greenhouse Gas Emissions from Critical Minerals Recycling: Case of Lithium-ion Batteries. *Procedia CIRP*, *80*, 316–321. https://doi.org/10.1016/j.procir.2019.01.003

IEA (2019). *EV Outlook 2019*. (2019). https://www.iea.org/reports/global-ev-outlook-2019

Nacif, F., & Lacabana, M. (Eds.). (2015). *ABC del litio sudamericano: soberanía, ambiente, tecnología e industria*. Centro Cultural de la Cooperación Floreal Gorini.

Olivetti, E. A., Ceder, G., Gaustad, G. G., & Fu, X. (2017). Lithium-Ion Battery Supply Chain Considerations: Analysis of Potential Bottlenecks in Critical Metals. *Joule*, *1*(2), 229–243. https://doi.org/10.1016/j.joule.2017.08.019

U.S Geological Survey. (2019). USGS Mineral Commodity Summary 2019. *Handbook of Environmental Chemistry*, *3*(703), 179–203. https://doi.org/10.1007/978-3-540-47108-0-4