XIX SEMEAD
Seminários em Administração

novembro de 2016
ISSN 2177-3866

BATTERY GLOBAL VALUE CHAIN AND ITS TECHNOLOGICAL CHALLENGES FOR ELECTRIC VEHICLE MOBILITY

AILTON CONDE JUSSANI
FACULDADE DE ECONOMIA, ADINISTRAÇÃO E CONTABILIDADE DA UNIVERSIDADE DE SÃO PAULO - FEA/USP
ADMINISTRAÇÃO
ailtoncj@uol.com.br

JAMES TERENCE COULTER WRIGHT
FACULDADE DE ECONOMIA, ADINISTRAÇÃO E CONTABILIDADE DA UNIVERSIDADE DE SÃO PAULO - FEA/USP
DA-FEA
jtwright@usp.br

UGO IBUSUKI
UNIVERSIDADE DE SÃO PAULO (USP)
POLI
ugoibusuki@yahoo.com.br

BATTERY GLOBAL VALUE CHAIN AND ITS TECHNOLOGICAL CHALLENGES FOR ELECTRIC VEHICLE MOBILITY

1. INTRODUCTION

Although oil prices have presented a downward trend, more than 712,000 electric vehicles were sold worldwide in 2015, mainly in the United States, Japan, China, South Korea and Germany. In Brazil, until the end of 2015, just over 840 electric and hybrid vehicles were licensed (ANFAVEA, 2016, p. 61).

The alternative development for internal combustion engine, either for purely electric car or hybrid car, has attracted the Brazilian researchers attention. However, outside of Brazil, the issue about electric vehicle development is well known. Thereby, Chan states that the successful production and marketing of electric vehicles depends on overcoming many challenges, including availability of products with displacement of autonomy at an affordable cost; availability of efficient and easy to use infrastructure; availability of business model to leverage the cost of batteries (CHAN, 2011).

Aside from these challenges, scientific articles are constantly reporting new progress in this area. For example, Xinghu (2010) from the introduction of electric vehicles in China analyzed the shortcomings in the energy sector. Du, Ouyang and Wang (2010) studied business solutions for the mass penetration of electric vehicles first generation in China. Kudoh and Motose (2010) studied the preferences of Japanese consumers in the use of electric vehicles.

Thus, for these authors the traditional mobility based on fossil fuels is going to end. The transition to electric vehicles is a revolution in mobility standard and it represents the trend for the future. About that trend, the former Saudi Arabia Oil Minister in the 1970s, Sheik Ahmed Zaki Yamani, said: "The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil” (THE ECONOMIST, 2016).

The Japanese, South Korean, Chinese and German automotive industry, have shown increasing concern about oil fueled mobility. Japanese and South Korean industries are more experienced in the production and marketing of light electric vehicles on a large scale. Thus, studying the electric vehicles’ global value chain and Brazil's potential participation in this chain becomes important activity for Brazilian researchers.

Within this context, the adoption and development of technologies for electric vehicles cannot ignore Brazil, the fourth largest consumer of automobiles in the world (OICA, 2015). Thus, Brazil needs to clearly understand where it can explore opportunities in this new global value chain. The research problem of this study can be stated as follows: What are the main features of battery global value chain in Japan and South Korea?

1.1 Objectives and Justification

The research focus is to identify the main features of battery global value chain for urban light electric vehicle versions in South Korea and Japan. These two countries, unlike other countries, have met the challenges of mass production and sales of electric vehicles for over two decades. In addition, their research provides some insights into the potential participation of Brazil in this value chain. The study aims to verify the main technological challenges concerning battery value chain for electric mobility.

Thus, discussions on the feasibility of Brazil automotive industry development based on electric propulsion are expected. In Brazil, other global value chains are the study subject of foreign researchers. For example, the study by Sturgeon et al. (2013) about Brazilian industry participation in the global value chains of following industries: aerospace, electronics and medical equipment. None electric vehicles global value chain study was found.

It is justified the need to generate more understanding of this economic sector, because a preliminary review of the national literature on the study subject, has produced few Brazilian papers result. A search with key words "electric car" and "electric vehicles" in traditional database (WEB-OF-SCIENCE, 2015) highlighted the low involvement of Brazilian Academy in the knowledge creation on that subject. Therefore, this seems to confirm that many researchers are involved in traditional automotive industry studies and they have not yet turned their attention to electric vehicles.

2. THEORETICAL FRAMEWORK

According to Porter (1998), value chain is the relationship among the company and its suppliers upstream and downstream. That value chain approach is utilized to analyze the company core competencies to achieve cost reduction and differentiation. There are two types of value chains: primary activities, including inbound logistics, operations, distribution logistics, marketing, sales and service; and support services, such as infrastructure, human resource management, technology development and acquisition.

This approach has been extended to global value chain analysis based on global supply and logistics. In recent years, many industries have become geographically distributed networks with global supply activities in various countries. Within these networks, some sites may be specialized in certain activities and, the value added to them can be distributed among several locations, i.e., they may cover several countries and companies. Thus, it is defined the concept of GVC, Global Value Chain (STURGEON et al., 2013).

The global value chain is utilized to analyze company core competencies to achieve cost reduction and product differentiation, thereby increasing productivity and profits, and finally, the macroeconomic growth of a country. An intervention that responds to chain deficiencies (e.g., non-compliance with established technology standards) moves the company to more sophisticated capital niche with intensive qualification.

Fournier et al. (2011) state that in the electric vehicle industry, batteries and its electronic components stand out in the value chain as result of significant technological challenges. Besides that, batteries have less durable components. According to Castro and Ferreira (2013), there are four types of batteries competing for establishing a standard for the electric vehicle industry: PbA (lead acid); lithium-ion battery; NiMH (nickel metal hydride) and sodium, also known as ZEBRA, Zero Emission Battery Research Activity, fully recyclable and tending to be cheaper than lithium batteries.

Batteries have different durabilities according to the technology used, the type of usage and storage conditions. The factors that affect battery durability are extreme temperatures, recharge overage and full battery discharge. Manufacturers estimate useful battery life at 150,000 km and 5 years of durability. With regard to lithium-ion battery, Dinger et al. (2010) explore the value chain stages, as shown in Figure 1.

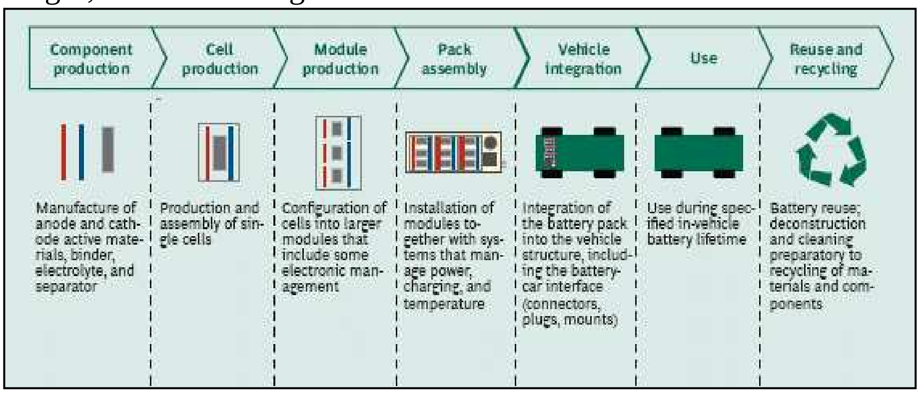

Figure 1 - Lithium-ion batteries value chain
SOURCE: DINGER et al., 2010, p. 2

Figure 1 presents the relationships complexity involving global value chain. The process involves the development of activities, production, marketing and distribution scattered around the world, e.g., production stages shared between different firms in different countries. The central focus of this study proposal is to identify the main features of the battery production global value chain for electric mobility. Thus, it is intended to verify the possibilities for Brazilian participation in this value chain.

3. RESEARCH METHODOLOGY

This exploratory research has mixed methods of data gathering, i.e., triangulation. According to Duffy (1987), the concept of triangulation relates several methods, data and theories in the study of a common phenomenon. With regards to data collection, documents available from companies were analyzed; plants and R&D centers were visited to performing interviews with executives. The interviews had the objective to verify different aspects that influence the investment of financial resources in the production of the electric vehicles, and identifying technical aspects considered important in the global value chain for lithium-ion batteries.
Semi-structured interviews were utilized to obtain primary data. The interviews lasted about 90 minutes and were performed over the months of April and May 2015 at Japanese and South Korean companies, that were involved in the production and sales of batteries. Furthermore, there were dialogues with Brazilian researcher in energy sector from CPqD. In Chart 1 is presented information about the respondent role or function, company name and city where the interviews took place.

Chart 1 – Companies and executives interviewed

ROLE / FUNCTION	INSTITUTION	CITY
Executive Chief Engineer Battery Business Division	Hitachi Automotive Systems, Ltd.	Ibaraki
Vice Chairman Executive Managing Director	Japan Auto Parts Industries Association	Tokyo
Head of the Research Automotive Parts Industry	Waseda University	Tokyo
Director / Product Planning	Samsung SDI Co., Ltd.	Seoul
Director R&D Planning Group / R&D Division	Hyundai Motor Group	Namyang
Power Systems Researcher	Fundação CPqD Centro de P&D	Campinas

SOURCE: The authors, 2015

Before the interviews, a collaborative pre-test toward performing the validation concerning the script of issues was applied to operations management specialist at the Mercedes-Benz Ltda company.

4. RESEARCH RESULTS

Battery power in an internal combustion vehicle is utilized for starting the engine and other functions such as electronic fuel injection, ignition of lights, air conditioning, etc. Besides these functions, battery power in electric vehicle is also responsible for supplying power to the electric engine that will move the vehicle, i.e., the lithium-ion battery will replace the fuel tank. According to Rosolem (2012), as lithium is a small and light element, lithium batteries have higher power level and energy per mass unit. In addition, for those applications where size and weight are important requirements, the lithium-ion batteries are suitable.
The rechargeable battery is the product that has the largest growth potential of lithium compounds – it is not an abundant ore and its reserves are concentrated in a few countries. In Figure 2 approximately 60% of lithium reserves are concentrated in South America in

Argentina, Chile and Bolivia. Brazil has 0,5% of the lithium world reserves (US GEOLOGICAL SURVEY, 2016).

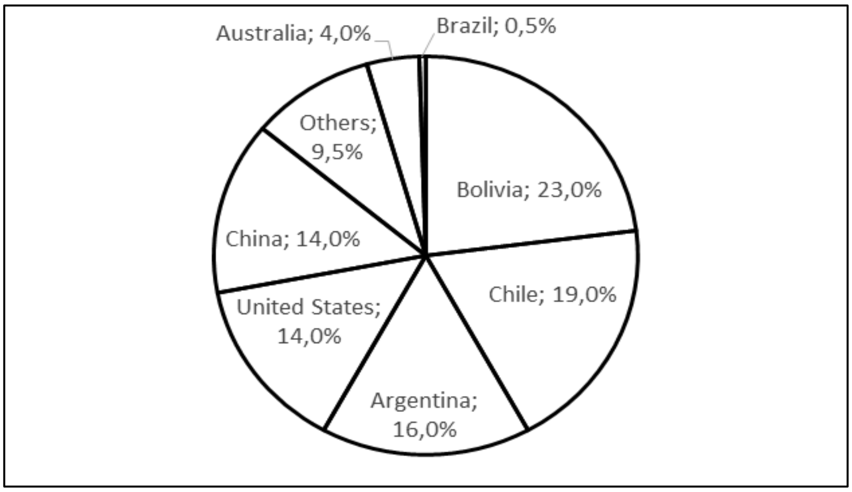

Figure 2 - Lithium world reserves
SOURCE: US GEOLOGICAL SURVEY, 2016, p. 95

Within the global value chain, ensuring lithium supply has become priority for battery companies in Asia. Respondents stressed the importance of strategic alliances and joint ventures among lithium exploration companies, battery suppliers and vehicle manufacturers. For example, GM Korea utilizes LG Chem battery at Spark EV 2015 model, and i-MiEV Mitsubishi model has chosen battery from GS Yuasa Japanese provider. Samsung SDI, company in South Korea, has been contracted by BMW to supply batteries for its i3 models (pure electric) and i8 (hybrid).

As lithium is recyclable, an increase in recycling industry of this type of battery is expected, as suggested by Dinger et al. (2010) in battery value chain. Thus, low performance traction batteries could be reutilized as power storage at homes. Chart 2 summarizes advantages and disadvantages of lithium-ion batteries. That chart is based on respondents responsible for electric vehicle projects in Japan and South Korea. Brazilian researcher in energy sector also has contributed.

Chart 2 - Lithium-ion batteries advantages and disadvantages

ADVANTAGES	DISADVANTAGES
• High energy density in small room • No gas emissions • Can be installed in a shared environment with electronic equipment • Electronic control built-in battery (BMS) • No maintenance • High current peaks supported • Recharge time (1-3 h) • Lifetime over 20 years • Reduced environmental impact	• Small performance at low temperatures • Indispensable reliable BMS and adequate performance • Small deviations from operating voltage may reduce its useful lifetime • Only manufacturer / supplier can make corrections of batteries • Little knowledge about performance and operation in the long run

SOURCE: Adapted by the authors based on interviews, 2015

In the lithium-ion battery production, one of the difficulties faced is the usage of clean rooms and high purity components. Building the factory from Greenfield investment is expensive because the equipment is automated. Therefore, the method for cells production, modules and packs, may interfere with battery performance. Thus, it is verified the value chain importance in production of cells, modules and packs that was suggested by Dinger et al. (2010). Chart 3 presents battery technological challenges for electric vehicles.

Chart 3 - Lithium-ion batteries technological challenges

#	BATTERY TECHNOLOGICAL CHALLENGES	WHY THE CHALLENGE HAS TO BE OVERCOME?
1	Getting high reliability	Technology in development. Types of degradation are unknown. Thus, there may be unexpected failures.
2	High performance (Deep discharge cycles)	The higher the number of cycles, the better the useful lifetime. R&D are conducted to produce batteries that overcome the current degradation problems.
3	High energy density, low weight and volume (Wh / kg and Wh / l)	The higher the energy density, the lower the weight and volume, and higher autonomy.
4	Wide operating temperature range	In low or high temperatures (outside the range between 15 ° C to 30 ° C) the battery performance decreases and degradation processes will occur
5	Reduced recharging time	This challenge is important because, in internal combustion vehicles, the fueling time is fast.
6	Competitive costs	Being more competitive than internal combustion vehicles.
7	Safety	Between lithium and electrolyte that is used in the battery. Researches are being developed in plate materials, additives, separators, electrolytes areas, as well as more robust BMS systems.
8	Energy density range between 25 kWh and 80 kWh	Materials with high energy density and lighter weight will result in greater autonomy.

SOURCE: Developed by the authors based on interviews, 2015

These challenges lead to the ideal stage that lithium-ion battery need to achieve. For example, in Chart 3, section 7, the electrolyte operates at a well defined voltage range. If the range limit is exceeded, it may result in adverse reactions. The outcome could burn the battery.

In order to address this challenge, the Japanese company Kuraray (2016) that produces battery separators (separates the anode from the cathode) is investing efforts in R&D to produce supercapacitors in activated carbon basis (it is one fifth of Li-ion mass). The goal is to deliver a safe charge of about 200 km driving range (WASEDA UNIVERSITY, 2015).

Finally, one should note that lithium mining could be a path for Brazil to become a part in the battery global value chain, i.e., components production (DINGER et al., 2010). This argument is justified in two ways. First, Brazil has technology and experience in mining provided by the Vale Company. As shown, large lithium reserves are in neighboring countries in South America. Second, Argentina is a MERCOSUL member and it could be beneficial to both countries to extract lithium for traction batteries.

5. FINAL CONSIDERATIONS

The introduction of electric vehicles worldwide will be responsible for a rearrangement of the automotive industry. An electric engine is simpler than an internal combustion engine. In this perspective, for example, the requirement for maintenance is less frequent, and there is no need for lubricating oil.

However, the main technical challenges faced by electric vehicle are the battery lifetime as well as the need for a specific charging infrastructure. Nowadays, with existing technology, one cannot obtain the same autonomy of an internal combustion vehicle, in competitive cost basis. One way to overcome this limitation is to install a battery-charging infrastructure in cities, roads and rural areas. The battery-recharging station would have the same functions as today’s gas stations, disseminated around the country.

Furthermore, Brazil will face challenges and opportunities in developing high-value activities within electric vehicles global value chain. Uncertainties regarding public policies and industrial policies hinder the coming of foreign investment for electric vehicles development.

In a public policies context for developing battery global value chain, it is suggested to map the value chain of components and highlighting those that can or should be produced in Brazil for strategic technology development. The same procedure can be adopted with regards to manufacturing processes.

To ensure in Brazil the electric car deployment, a strategy for automakers and initial purchasers is required, so that customers become interested in the product (VELLOSO, 2010). Thus, there should be tax incentives from the government; incentives for technological development for companies; the maintenance of emission regulation process and bring new technological standards as result. That outcome takes into account the fuel productive chain as well the vehicle productive chain.

Despite the lack of investment by Brazilian vehicle manufacturers in this technology, power utilities indicate the possibility of investment together with the automotive industry, as seen with the Fiat automaker and the Itaipu Hydroelectric Power Plant (VE, 2016).

Finally, the results should be considered in view of some restrictions. They occur from later findings out of the empirical data.

It is important to highlight the research limitations, i.e., only two Asian countries were studied. Certainly, the research results should not be over generalized and should not be extended to include a larger universe of countries and companies. If this research is repeated, the result might be different. The qualitative studies do not intend to generalize results (COOPER; SCHINDLER, 2011).

Among suggestions for future research is a study of the battery industry study in the light of Porter’s five forces theory. Besides this suggestion, it would be interesting to repeat the same methodology for batteries global chain in other electric vehicles segment, such as electric bus.

These suggestions deserve detailed future studies since Brazil has an interesting opportunity that justifies mobilization efforts to develop a new automotive market.

REFERENCES

ASSOCIAÇÃO NACIONAL DOS FABRICANTES DE VEÍCULOS AUTOMOTORES - ANFAVEA. (2016). **Anuário da indústria automobilística brasileira 2016**. São Paulo. Disponível em: < http://www.anfavea.com.br/anuario.html>. Acesso em: 31/05/2016.

CASTRO, B. H. R; FERREIRA, T. T. (2013). **Veículos elétricos**: Aspectos básicos, perspectivas e oportunidades. BNDES Setorial 32, 2013, p. 267-310. Available on: <http://www.bndes.gov.br/>. Accessed on: 11/08/2015.

CHAN, C. C. (2011). **25th International Electric Vehicle Symposium 2011**. Available on: <http://ww-w.evs24.org/wevajournal/vol4/-foreword.html>. World EV Journal. v. 4.

COOPER, D.; SCHINDLER, P. S. (2011). **Métodos de pesquisa em administração.** 10. ed. Porto Alegre: Bookman.

DINGER, A.; MARTIN, R.; MOSQUET, X.; RABL, M.; RIZOULIS, D.; RUSSO, M.; STICHER, G. (2010). **Batteries for electric cars**: challenges, opportunities, and the outlook to 2020. BCG. Available on: <http://www.bcg.com/documents-/file36615.pdf>. Accessed on: 21/03/2015.

DU; J.; OUYANG, M; WANG, H. (2010). **Commercial solution to mass penetration of first generation battery electric vehicle in China.** Shenzhen, China. World EV Journal. v. 4, p. 890-896.

DUFFY, M. E. (1987). **Methodological Triangulation**: A vehicle for merging quantitative and qualitative research methods. Image: the Journal of Nursing Scholarship. v. 19, n. 3, September, p. 130-133.

FOURNIER, G.; HINDERER, H.; SCHMID, D.; SEIGN, R.; BAUMANN, M. (2011). **The new mobility paradigm:** Transformation of value chain and business models. Enterprise and Work Innovation Studies, v. 8, p. 9-40.

KUDOH, Y.; MOTOSE, R. (2010). **Changes of Japanese Consumer Preference for Electric Vehicles.** Shenzhen, China. World EV Journal. v. 4, p. 880-889.

KURARAY. (2016). **Chemicals and resins, fibers and textiles, high performance material.** Available on: <http://www.kuraray.co.-jp/en>. Accessed on: 21/03/2016.

ORGANISATION INTERNATIONALE DES CONSTRUCTEURS D'AUTOMOBILES – OICA. (2015). **Sales Statistics.** Available on: <http://www.oica.net/category/sales-statistics/>. Accessed on: 08/08/2015.

PORTER, M. (1998). **Competitive Strategy:** Techniques for Analyzing Industries and Competitors, New York.

ROSOLEM, M. F. (2012). **Bateria de íon-lítio:** Conceitos básicos e potencialidades. Caderno CPqD Tecnologia. Campinas, v.8, n.2, p.59-72, jul-dez.

STURGEON, T.; GEREFFI, G.; GUINN, A.; ZYLBERBERG, E. (2013). **Brazilian manufacturing in international perspective:** A global value chain analysis of Brazil's aerospace, medical devices and electronics industries. CNI, Sep.

THE ECONOMIST. (2016). **The future of energy:** The end of the Oil Age. Available on: <http://www.economist.com/printedition/-2003-10-25>. Accessed on: 21/03/2016.

US GEOLOGICAL SURVEY. (2016). **Mineral Commodity Summaries 2016**: Lithium. Available on: <http://dx.doi.org/10.3133/70140094>. Accessed on: 31/05/2016.

VEÍCULO ELÉTRICO - VE. (2016). **Itaipu: Projeto Veículo Elétrico**. Available on: <http://www.itaipu.gov.br/tecnologia-/veiculos-eletricos>. Accessed on: 21/03/2016.

VELLOSO, J. P. R. (2010). **Estratégia de implantação do carro elétrico no Brasil**. Instituto Nacional de Altos Estudos. Rio de Janeiro: INAE.

WASEDA UNIVERSITY. (2015). **Research on hybrid vehicles, electric vehicles, and fuel cell vehicles power train**. Research Institute for Automotive Electric Power System. Available on: <http://www.waseda.jp/nextgv/en/laboratory/labo_nakagaki>. Accessed on: 20/04/2015.

WEB-OF-SCIENCE. (2015). **Web of Science**. Available on: <http://apps.webofknowledge-.com>. Accessed on: 08/08/2015.

XINGHU, L. (2010). Energy issue of pure electric vehicle in China. Shenzhen, China. **World EV Journal**, v. 4, n. 1, p. 91-97.