‘’Moving up’’ in the global battery value chain: A socio-technical analysis on Democratic Republic of Congo

by

Vasileios Fragkoulis

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Student number: 5842573

<u>Thesis committee</u>
Chairman: Professor Aad Correlje
First supervisor: Professor Gideon Ndubuisi
Second supervisor: Professor Linda Kamp

Executive summary

The Democratic Republic of Congo (DRC) is endowed with vast reserves of cobalt, a metal playing a very substantial role in the global energy transition. As the world shifts towards sustainable energy solutions, particularly through the electrification of transport, the demand for key minerals like cobalt and lithium is rising. This presents a unique opportunity for the DRC to elevate its position within the global battery value chain (GBVC). However, despite its rich mineral resources, the DRC's current role remains limited primarily to raw material exports, leaving significant space for growth in high value-added activities.

This thesis explores the research question: *"Can the DRC leverage its abundant cobalt resources to upgrade in the battery value chain?"*. The study aims to bridge the knowledge gap by assessing the potential of the country to upgrade within the chain. This is done by identifying challenges that the DRC faces and exploring opportunities for upgrading within the value chain.

The research is structured around several sub-research questions that examine the global landscape and governance of the battery value chain, the DRC's current integration, and both the challenges and opportunities for future upgrading. The primary analytical tool employed is the Global Value Chain (GVC) framework, which provides a structured methodology to assess the complex network between the companies and the economic activities that are executed throughout the world. By applying this framework, the study identifies where value is created within the battery value chain and how the DRC can move towards higher-value activities.

In summary, the opportunity identified for the DRC is in the upstream sector of the battery value chain and more particularly in the refining stage. Nevertheless, the outcome is not encouraging for the DRC due to substantial barriers that the country must overcome. The country faces deficits in infrastructure, especially in energy and transportation systems, which rise operational expenditures. This in conjunction with the political instability has a negative implication on the attractiveness of the DRC as an investment environment, so country 's

progress is hindered. Furthermore, the limited control that local institutions have over cobalt mines does not give the chance to the DRC to take strategic decisions that are beneficial for the development of country ‘s capabilities. In addition, transparency and human rights problems within the mining sector make investors more reluctant due to the need in the market for compliance with international ESG standards.

Substantial improvements in the DRC ‘s investment environment are necessary to strengthen country ‘s position in the global battery industry, so some recommendations for both government policies and corporate strategies are made. Local institutions should build more strategic collaborations with companies in other countries of African Union that have the capacity to support refining activities. At the same time, they must increase their awareness for international standards and start applying them in order to become more trusted partners globally. Policy recommendations from the government are also essential , including financial incentives for foreign investors and improvements in the judicial system. In this way, the DRC can create a more competitive environment in the refining segment of battery value chain and may have more chances for upgrading.

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ASM	Artisanal and small-scale mining
CAC	Central African Copperbelt
CAP	Cobalt Action Partnership
CATL	Contemporary Amperex Technology Limited
CCCMC	Chinese Chamber of Commerce for Metals, Minerals & Chemicals
CMOC	China Molybdenum Company Limited
DRC	Democratic Republic of Congo
ENRC	Eurasian Natural Resources Corporation
ERG	Eurasian Resources Group
ESG	Environmental, Social and Governance
EV	Electric Vehicle
EW	Electrowinning
FCAB	Federal Consortium for Advanced Batteries
FDI	Foreign Direct Investment
GBVC	Global Battery Value Chain
GVC	Global Value Chain
HHI	Herfindahl–Hirschman Index
ILO	International Labour Organisation
KCC	Kamoto Copper Company
LCO	Lithium Cobalt Oxide
LIB	Lithium-ion battery
NGO	Non-Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
RCI	Responsible Cobalt Initiative
RMAP	Responsible Minerals Assurance Process
RMI	Responsible Mineral Initiative
RRA	Risk Readiness Assessment
SSH	Stratiform Sediment-Hosted
UN	United Nations

1.Introduction

Despite its abundant natural resources, the African continent has a substantial percentage of its population lacking access to reliable and affordable electricity. The World Bank estimates that around 600 million residents in Africa do not have access to electricity (The World Bank, 2021). This energy deficit not only hampers socio-economic development but also underscores the urgency for a paradigm shift. Furthermore, Africa is quite susceptible to the far-reaching consequences of environmental degradation and highly relied on fossil fuels leading to a substantial increase in greenhouse gas emissions. Recognising the imperative for change, a transition to more sustainable energy technologies becomes not just beneficial but essential for fostering a resilient and inclusive future for the continent.

Moreover, there is a global commitment to decarbonising the transport sector due to the sharp rise in CO2 emissions during the last decades. Between 1990 and 2019, the global population increased by 46 percent, while the amount of global CO2 emissions in the transport sector increased from 4.61 Gt to 8.22 Gt, accounting for 17 percent of the global GHG emissions. Considering the role of this sector in climate change, the achievement of the global goal of climate neutrality by 2050 necessitates decreasing the carbon footprint in transportation (Niri et al., 2024). Apart from this, there is the intermittency problem of the fluctuating energy generated from renewable energy sources, such as solar and wind. To balance this mismatch between energy supply and demand, the use of Li-ion batteries is required (Deng, 2015). Thus, Li-ion batteries are a solution for both transport sector through Electric Vehicles (EVs) and electricity generation market.

The growing demand for both electricity storage and Electric Vehicles (EVs) is a driving force for the high demand for lithium and cobalt. As an illustration, to meet the net-zero emissions targets, the electric vehicle market demand for lithium and cobalt will increase 26-times and 6-times, respectively, between 2021 and 2050 (Niri et al., 2024). In Africa, many countries are endowed with these minerals, which are very critical for the manufacture of rechargeable batteries. More precisely, high amounts of lithium resources exist in Democratic Republic of Congo (DRC) and Zimbabwe. As for the cobalt, the DRC has the largest mineral reserve, equivalent to 48% of the global cobalt reserve (Andreoni et al., 2023).

DRC can benefit from its cobalt resources and become an important player in the battery value chain. Nevertheless, the DRC ’s role in the global battery value chain remains limited to raw material exports, which in conjunction with the social challenges accompanied by the cobalt extraction underscores the need for strategic interventions. The African Continental Free Trade Area (AfCFTA) is an agreement aiming to support the DRC ‘s position as a central hub for the global clean energy transition. By leveraging the abundant cobalt resources in the DRC and facilitating the integration of other key minerals from across Africa, the AfCFTA seeks to attract investments and drive the development of a reliable battery manufacturing ecosystem (ECA, 2021).

Another effort from the DRC in the context of upgrading in the battery value chain is the historic cooperation agreement between Zambia and the DRC. Encompassing a strategic framework for bilateral collaboration, the agreement aims to unlock their economic potential, creating jobs and establishing a robust battery value chain. By establishing the DRC-Zambia Battery Council, the implementation of this cooperation will be overseen, while financial and advisory support from entities like Afreximbank, which is the Trade Finance Bank for Africa, will fasten the operationalisation of this ground-breaking agreement (Africa Renewal, 2022)

In summary, the DRC is endowed with vast amounts of one of the most critical minerals in the battery manufacturing industry. Batteries will play a substantial role in both the decarbonisation of transport sector and the advancement of renewable electricity market, so the DRC might have an opportunity. This opportunity aligns with insights from a McKinsey's study. According to McKinsey, the battery value chain is well established in China and South Korea, but due to the very encouraging market trends for EVs, they believe that the battery-cell manufacturing market will likely consolidate around 10 to 15 players globally. This will be driven by the significance of scale to reduce production costs and the winners will be those that will act in the following years (Campagnol et al., 2022). Although the timing and market trends are very encouraging, a thorough analysis assessing whether a developing country like the DRC can upgrade in the global battery value chain (GBVC) is missed. The objective of this thesis is to cover this knowledge gap by identifying specific challenges and opportunities for the DRC. Thus, the overarching research question is:

"Can the DRC leverage its abundant cobalt resource to upgrade in the battery value chain?"

To answer this question, the thesis is divided into the following sub-research questions:

i. What is the global landscape and governance structure of the battery value chain?
ii. How is DRC currently integrated in the global battery value chain and what explains the observed pattern of integration?
iii. What are the DRC's upgrading opportunities and challenges in the global battery value chain?
iv. How can the DRC incentivise the development of battery value chain by implementing policies?

2. Literature Review

In this thesis, we are going to apply an upgrading framework analysing the opportunities of the DRC to find a place in the global battery value chain where the DRC can add value and increase its market share.

Some studies including suggestions for developing countries to upgrade in global value chains have been conducted. The John Humphrey 's study examines the participation of developing countries in global value chains, and more specifically the upgrading of agricultural and manufacturing capabilities. One quite significant suggestion is that the involvement of both technological capabilities and market access is necessary, and this can be done through local and national efforts. In addition, firms must consider the integration into global markets as a learning opportunity and make explicit investments supported by public agencies to maximise this opportunity. Another important point is that upgrading strategies must adapt to the evolving nature of global value chains, because new configurations may make previous upgrading strategies more challenging. The suggestions mentioned can be supported by the development of policies classified into three categories (Humphrey, 2004):

i. General upgrading policies, which support upgrading regardless of the specific nature of global value chain.
ii. Facilitating participation policies, which help the participation of companies in globally dispersed production systems.
iii. Context-specific policies, which support enterprise level upgrading in the context of the challenges and opportunities presented by contemporary value chain linkages.

According to Victor Kummritz 's study, policies play a quite substantial role in unlocking opportunities for economic upgrading through integration in global value chain. More precisely, this study emphasises on the significance of infrastructure and connectivity from buyer's perspective as well as the increase of productivity from a seller 's perspective. This is quite meaningful for the DRC, because the country needs the infrastructure development in the refining stages and the rise in productivity to compete China in the global battery value chain. Some of the policies suggested are the investment and trade ones, because they enhance openness, so the integration in the global value chain is easier. Additionally, the study highlights the diverse mediating effects of policies across different stages of economic development, so more tailored approaches to formulation and implementation of policies are needed (Kummritz et al., 2017).

Another study by Pipkin et al. (2017) conducted a comprehensive analysis of 45 case studies about primary product and light manufacturing industries in developing countries to identify the consequences of upgrading processes and propose a framework for industrial upgrading opportunities (Induced search framework). Their analysis suggests that increased state capacity may emerge when state interventions align with the demands of companies responding to market vulnerabilities. This collaborative engagement between firms and state authorities, spurred by shocks in the market, fosters effective partnerships, so the framework of value chain analysis describes two main stages: vulnerability factors prompting search and local institutional contexts supporting it. These dynamics impact the extent and effectiveness of industrial upgrading initiatives, including workforce productivity, skills enhancement, and local acquisition of proprietary knowledge-based assets. Overall, the framework aims at offering a 'roadmap' to bring greater analytical leverage to the consideration of local institutional environments in value chain research (Pipkin et al., 2017).

Another useful study clarifying the ways that can lead to a ''moving up'' in the global supply chain was conducted by Cattaneo et al. (2013). In particular, ''moving up'' entails dynamic movement within the value chain towards stages of production that yield higher value-added activities and increased benefits. This movement is characterized by four identified paths: process upgrading, product upgrading, functional upgrading (increase in the skill content of production) and chain or inter-sectoral upgrading (move from one industry to another). Task bundling becomes essential in a consolidated global value chain landscape, where lead firms expect intermediaries to provide comprehensive packages with higher service content.

Furthermore, ''moving up'' the value chain involves creating knowledge behind products, often necessitating diversification into service tasks and the promotion of service exports (Cattaneo et al., 2013).

Gereffi et al. (2022) analysed two distinct strategies for economic development that China has pursued: ''upgrading from above'' and ''upgrading from below''. ''Upgrading from above'' involves central government initiatives, such as the Made in China 2025, and the Belt and Road, aimed at transitioning China towards higher value-added industries and fostering domestic consumption. As for the ''upgrading from below'', it encompasses local government policies, Foreign Direct Investment (FDI), firm-level innovation, and labour market shifts that translate national initiatives into tangible industrial growth on the ground to drive economic transformation and technological progress (Gereffi et al., 2022).

In addition, China 's participation in the global value chain has evolved through three phases. The first phase was export-oriented industrialization, where the country leveraged its abundant labour and natural resources to attract foreign investment and become a major exporter by 2006. The second phase consisted of a shift towards domestic markets and investment in response to global economic crises and rising costs at home, leading to a decline in the trade to GDP ratio and in the relative importance of FDI in China's economy. In the third phase, starting around 2015, China pursued advanced manufacturing and indigenous innovation, aiming to reduce reliance on low-tech products and focus on high-tech goods and services, driven by initiatives to strengthen the digital economy and promote Chinese brands globally (Gereffi et al., 2022).

Overall, there are upgrading frameworks for global value chains including policy recommendations in the literature. Nonetheless, specific opportunities for developing countries with complex structure like the DRC should be identified to suggest tailored policies and regulations that will be effective. Therefore, conducting a socio-technical analysis and applying an upgrading framework that identifies the biggest opportunities for the DRC would lead to a specific path through which the country can gain significant market share and upgrade the global battery value chain. This thesis is geared toward attaining this feat.

3.Research Approach

3.1 Theoretical background of GVC framework

Global value chains (GVCs) represent the full spectrum of activities that firms and workers perform to bring a product from its initial conception to production and its final demand. Such wide range of activities encompass design, production, marketing, and distribution. In the context of globalization, these activities are often distributed across different firms worldwide, forming complex inter-firm networks (Gereffi et al., 2011). To understand and analyze these complex networks, a framework with a structured methodology is necessary.

In this thesis, the main tool that is used is the GVC framework in the context of DRC 's upgrading in the global battery value chain. The framework has its roots in the work of Michael Porter in the mid 1980s, who wanted to develop a strategic tool helping businesses understand the activities that create value for their customers. It incorporates information about how global industries such as the battery-electric industry are organized by examining the interactions and connections of the different actors involved. By focusing on these inter-linkages, the analytical approach uncovers the dynamic flow of economic and organizational activities among players across various sectors and geographic regions. In this way, organizations can identify where value is created and understand how they can move to higher value activities. This perspective is particularly useful for emerging players including those from poor countries to assess if there are any upgrading opportunities for them. Additionally, the value chain analysis serves as a valuable tool for policymakers, helping them understand the broader environment and make informed decisions to ensure the efficient allocation of resources within the domestic economy (Kaplinsky et al., 2016).

The methodology of GVC framework consists of some specific steps that can be applied in all GVCs and include implications on upgrading at a corporate or national level. In his study, Gereffi identifies four dimensions in this regard including: the input-output structure, the geographic scope, the governance structures, and the institutional context.

3.1.1 Input-output structure

The first step is the identification of main activities and segments within a GVC including the entire input-output process that transforms raw materials into final products and services. The most typical segments in a chain are research and design, inputs, production, distribution, and marketing, and in some industries the recycling of products (see Figure 1).

The input-output structure is represented as a series of interconnected value chain boxes, illustrating the flows of tangible and intangible goods and services at different stages, as it is shown in figure 1 (Gereffi et al., 2011). More detailed research is also needed to find the resources and capabilities required at each segment, so it becomes clear where value can be created. This is the reason for which value chains are seen as repositories for rent, which means that players 'rent' one or more stages of the value chain based on their capabilities. As a result, value creation is not evenly distributed across all activities, but it is concentrated in certain stages or functions of the value chain (see Figure 1). These activities illustrated in figure 1 are the most fundamental ones in most global value chains and can be classified into upstream, midstream, and downstream. Understanding where rents are generated and how they are distributed is crucial for identifying the higher-value activities in which firms should move to upgrade. Some types of rents are the following ones (Kaplinsky et al., 2016):

- Technology rents: having control over scarce technologies
- Human resources rents: having access to better skills than competitors
- Organizational rents: possessing superior forms of internal organization
- Marketing rents: possessing better marketing capabilities and/or valuable brand names

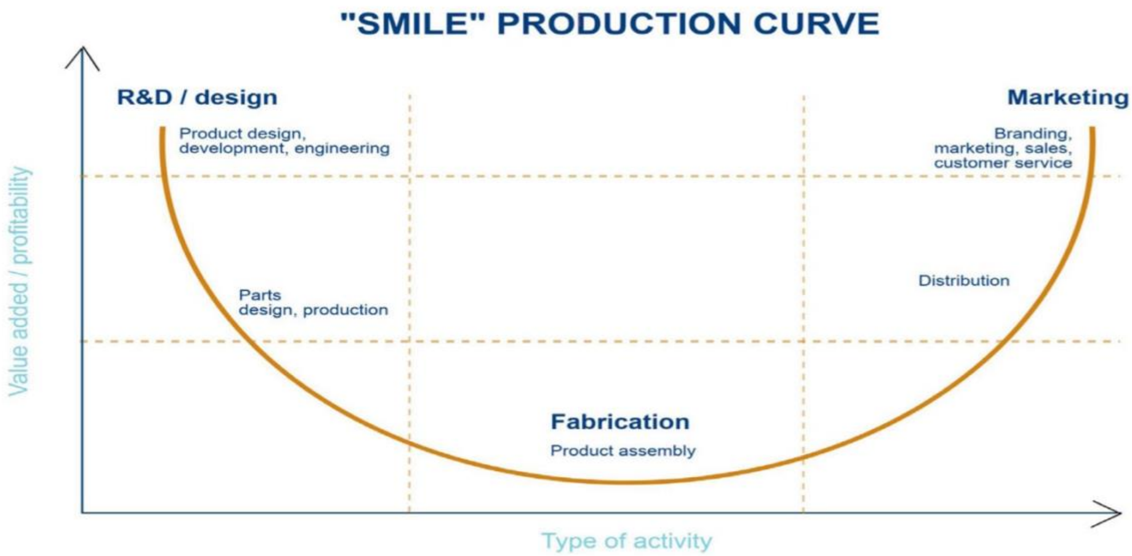

Figure 1 - Value-added distribution, Source: U.S. Grain Council

3.1.2 Geographic scope

Each segment identified in figure 1 has some actors participating and executing the associated activities. Different types of enterprises take part in an industry, and they can be classified into some categories based on their characteristics: global or domestic; state-owned or private; large, medium, or small. This classification of companies in conjunction with their mapping in the corresponding segment gives a holistic picture of the chain, which is quite helpful for the governance structure that is analyzed below (Gereffi et al., 2011).

Today, globalization has played a key role in increasing competitiveness in each segment of value chains, so activities within a chain are dispersed and carried out throughout the world. As a result, companies executing activities affect each other, so a geographical analysis is needed to identify the lead firms in each stage of the value chain (Gereffi et al., 2011). To determine which company is the leader in each segment and quantify this dominance, multiple indicators can be chosen, such as the share of segment value added and the control over a key technology (Kaplinsky et al., 2016). These lead enterprises have their business within particular countries, so information about the position of countries within the chain can be obtained, which helps companies identify opportunities in new regions where they can expand their operations.

3.1.3 Governance

The interactions of actors and power dynamics developed between them are also quite significant for upgrading. Governance refers to the mechanisms and structures that coordinate and regulate these interactions to ensure that there is some reflection of organization in the value chain. There are two different classifications of governance structure; both give valuable information about the authority relationships between players and the barriers for players aiming at upgrading in the value chain. The first one is the classification of organisational structure into market, modular, relational, and hierarchy (see figure 2) and involves three main parameters: the complexity of information transferred between actors; how easily the information for production can be codified; the level of suppliers' expertise (Gereffi et al., 2005):

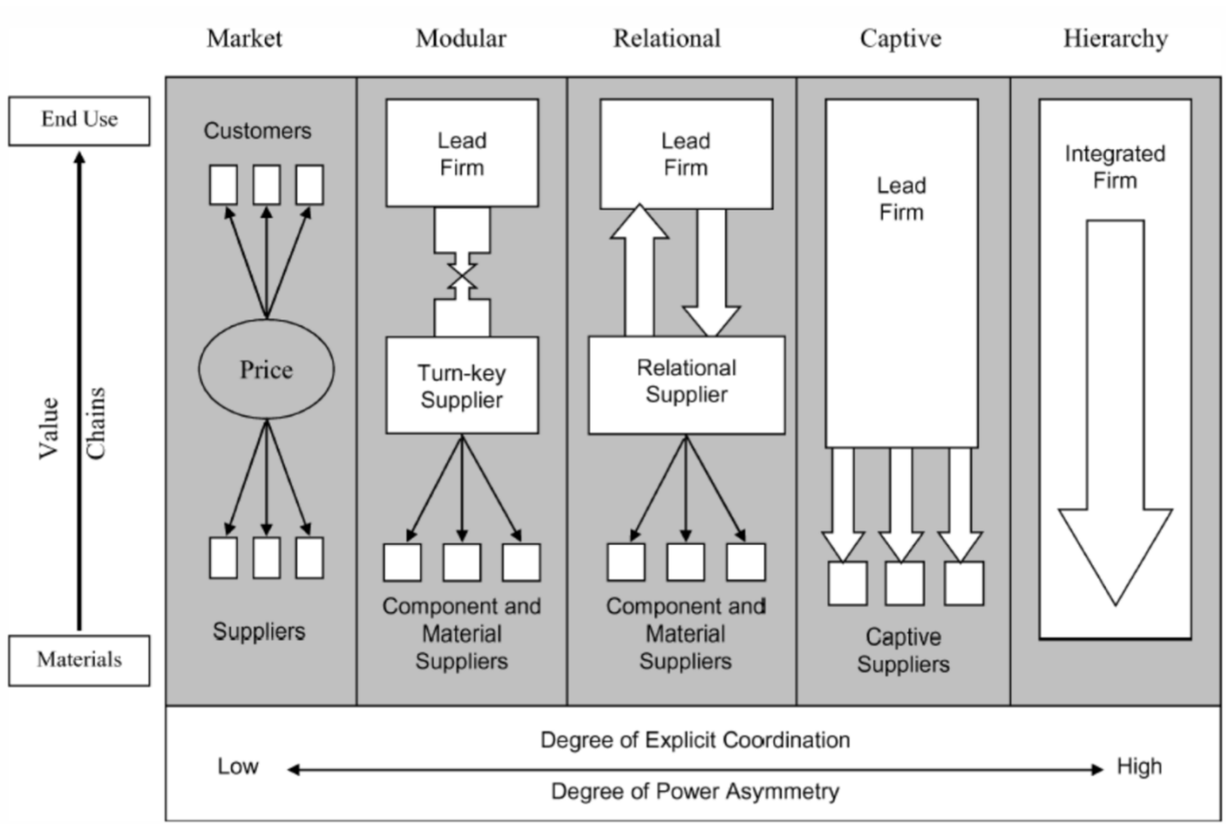

Figure 2-Five Global Value Chain Governance Types, Source: Gereffi et al., 2011

Market governance involves relatively simple transactions where information on product specifications is easily transferred. Moreover, suppliers can produce goods with minimal input from buyers, so weak relationships are developed between suppliers and buyers. Thus, it is challenging for suppliers to upgrade their capabilities substantially. The only way of upgrading in this category is cost reduction rather than technological advancement and for this reason price is the central mechanism in market governance (Gereffi et al., 2011).

Modular value chains allow the separation of components or modules that can be produced independently and integrated into the final product. Transactions are complex, but technical standards are used to facilitate interactions between the actors of the value chain and unify component, product, and process specifications. These standards involve instructions and requirements that are communicated between suppliers and buyers, so the ability to codify information is high in this type of value chain. The codification of complex transactions facilitates innovation that enables suppliers to improve their processes and product quality, so they can satisfy to a higher extent customers' specifications and invest across a wide range of clients. As suppliers gain more autonomy and capabilities, scalability in upgrading components or functions can be achieved (Gereffi et al., 2005).

Another category of organisational structure is the **relational value chain**, which includes complex transactions. The reason for this complexity is the motivation given by the suppliers to lead firms to outsource, so the nature of products exchanged requires strong partnerships between lead firms and suppliers. In contrast with the modular type of value chain, the knowledge exchanged is difficult to be codified due to the expertise required. Particularly, the capabilities of suppliers are quite high, and they are essential to meet the unique needs of lead firms, so it is difficult and costly for enterprises to replace the existing partners. In this way, long-term collaborations are very usual in relational value chains, which is very encouraging for existing suppliers to learn, innovate and upgrade in the chain. On the other hand, upgrading in this type of value chain for new entrants is challenging due to the difficulty of codifying knowledge (Gereffi et al., 2005).

Captive value chains are characterized by the significant control that the lead companies have over suppliers due to the lower capabilities of the latter ones to handle complex products.

Products in this type of organisational structure have a high level of complexity, like relational value chains, but suppliers lack the necessary expertise to meet the requirements independently. In this way, they have very few tasks and are locked in specific agreements, so lead firms exploit this opportunity by limiting supplier 's options and dominate the chain. This power asymmetry can create both challenges and opportunities for suppliers to upgrade. On the one hand, upgrading may be focused on meeting the specific requirements of lead companies rather than broader innovation. On the other hand, lead firms may support suppliers to improve their capabilities. Thus, economic upgrading can be achieved, but it is driven by dominant enterprises, so suppliers should improve their knowledge and skills to some extent to make better negotiations with lead players (Gereffi et al., 2005).

Hierarchy governance involves the vertical integration of lead firms within the chain, which means that these companies manufacture products in house. This structure is used when information cannot be easily codified or when complex products require high level of coordination. Therefore, dominant enterprises enter more segments of the chain and have significant control over all aspects of production. Innovation and capacity building for external suppliers are very difficult and upgrading opportunities for them are limited. Upgrading is more focused on internal processes and efficiencies, so this type of governance might lead to economic upgrading within a company (Gereffi et al., 2011).

The second distinction of governance structure is between buyer-driven and producer-driven, which was initiated by Gereffi in 1994 and was tailored to global commodity chains (Gereffi et al., 2011). In **producer-driven chains**, the pivotal role is played by producers, such as large manufacturers, which retain control over a technology or production process. They focus on investing heavily in large and advanced factories, while they out-source less profitable tasks to suppliers, over which they have substantial influence. This control ensures that suppliers meet producers' requirements, so producers build long term relationships with their suppliers to have reliable supply of goods. Moreover, manufacturers allocate significant amounts of money to innovation and development of new products and technologies to maintain competitive advantage in the market. Overall, the main characteristics of this type of chains are that they are capital intensive and long-term partnerships are developed between manufacturers and suppliers, so it is challenging for players aiming at entering these chains from both financial and network perspective. Industries like automobile and aircraft manufacturing are typical examples of producer-driven chains (Raikes et al., 2000).

In **buyer-driven chains**, key players are large retailers or brand-name companies that control design and marketing. This type of chains emphasizes on consumer preferences and market trends, so firms invest mainly in marketing and distribution strategies to capture market share. Production is often outsourced to various suppliers in different regions, which must meet the specifications of brand-owners. These chains have less capital-intensive production processes, so the barriers for new players to enter production are lower. However, gaining access to key buyers can still be challenging due to brand loyalty. The relationships between suppliers and buyers are more flexible and last for a shorter period compared to producer driven chains, because buyers can easily switch suppliers based on price and quality. Furthermore, new entrants must meet specific quality and compliance standards set by buyers. As a result, the lower barriers to entry production can encourage more competition and innovation among suppliers, but the power that buyers have can lead to price pressures on suppliers and limit their ability to capture value. Typical examples of this type of chains are consumer goods industries, such as garments and footwear (Raikes et al., 2000).

Recent developments in both producer and buyer driven chains present substantial challenges for firms wanting to upgrade within these value chains. More precisely, key activities such as design and marketing are central to the power of lead firms, especially in buyer-driven chains. These ‘intangible’ aspects are crucial for profitability and control, while ‘tangible’ activities like production have been commodified. This shift has created new divisions of labour and heightened the challenges for developing countries to enter a value chain. Research shows that barriers to enter intangible activities are growing faster than those in tangible ones, which makes upgrading difficult. These findings highlight the complex relationship between value chain governance and firm-level upgrading (Bair, 2005).

3.1.4 Institutional context

The institutional context within the GVC framework refers to the local, national, and international conditions and policies that shape the dynamics of globalization at each stage of the value chain. This context encompasses various factors including economic, social, and institutional dynamics, which collectively influence how value chains operate and how firms can upgrade. Economic conditions involve labour costs, infrastructure, and access to finance resources, so regions with good infrastructure and funding structure may attract more investments and move into higher-value activities. The Social context incorporates availability and skill level of the workforce including education and training opportunities. Moreover, institutions prioritising labour and human rights enhance their reputation and competitiveness. As for the institutional dynamics, tax policies, labour regulations and government funding for innovation and education can either accelerate or hinder economic growth, so it is very important for a region to combine these things in an effective way. Supportive policies can facilitate upgrading of firms by providing them with incentives to innovate. Overall, a strong institutional framework can foster collaboration between companies, educational institutions, and government agencies, which facilitates knowledge transfer and innovation. Thus, a quite attractive environment providing incentives for firms to invest in upgrading is created (Gereffi et al., 2011).

3.1.5 Identifying upgrading opportunities

Upgrading in global value chains involves improvement of capabilities and technologies, which leads to movement in higher-value activities and increase in benefits, such as profits. In this way, existing players holding a low-value position in the value chain can identify opportunities and upgrade their position, which represents the bottom-up process. Figure 3 presents a diagram on the different upgrading directions that can be followed by a midstream enterprise that currently has a low-value position. These patterns differ from industry to industry based on the input-output structure and the institutional context of each firm or country (Gereffi et al., 2011).

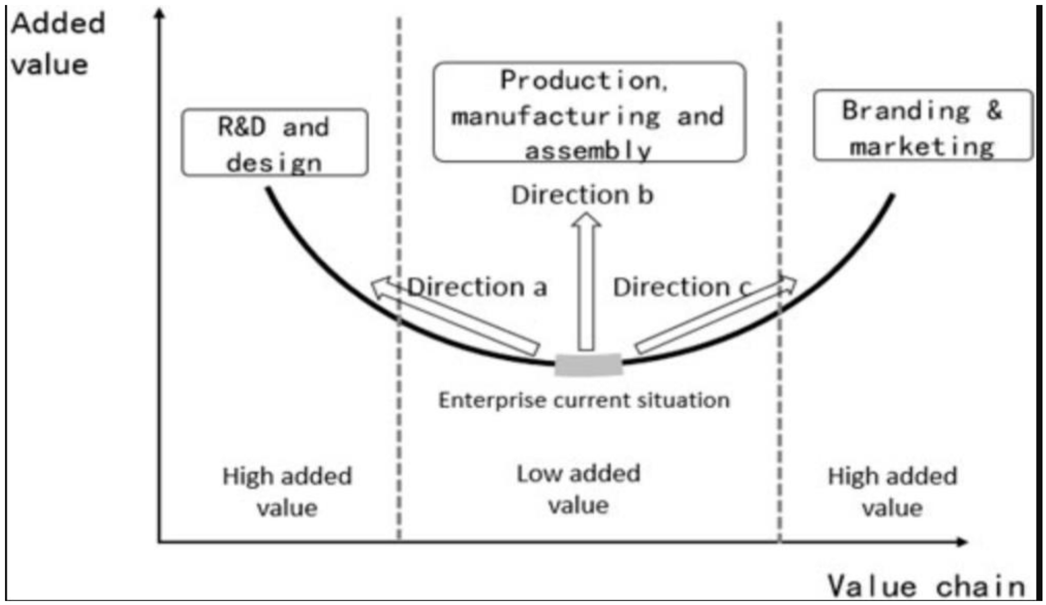

Figure 3-Upgrading paths for a midstream firm in value chain, Source: Gereffi et al., 2011

This was the initial interpretation of upgrading by Gereffi, which is defined as economic upgrading due to the emphasis on economic growth. Another type is the social upgrading, which is focused on the improvement in rights and entitlements of workers. Rights ensure that there is no discrimination in the professional environments and employees can express their opinion, while entitlements are related to the salaries and wellbeing of workers (Sharma, 2020).

In this thesis, economic upgrading is taken into consideration, because the upgrading of a developing country to higher-value activities is analyzed. To specify how upgrading can be achieved, the following types of pathways are described:

- *Process upgrading*: This type of upgrading involves improving the organization of production to increase the efficiency of internal processes within a firm and across different links in the value chain. It can be achieved by introducing new technologies and optimizing existing operations, so capital expenditure for equipment is necessary. In this way, companies can reduce their cost and waste, so they create a competitive advantage (Cattaneo et al., 2013).

- *Product upgrading*: This refers to the production of more sophisticated or higher-quality products within the value chain to meet market demand and outperform competitors. The value addition to products can be achieved through innovation, design improvement or incorporation of advanced features, so significant investments in R&D and new partnerships with stakeholders that can support the changes are needed (Cattaneo et al., 2013).
- *Functional upgrading*: It includes the change of mix of activities and the potential for entering more high value-added functions across different links of the value chain. This type of upgrading requires increase in the skill content of processes by enhancing capabilities of workforce and developing specialized skills to perform more complex tasks within the value chain. In this way, firms or countries optimize the allocation of activities and improve the overall chain configuration (Cattaneo et al., 2013).
- *Chain upgrading*: This involves moving to a new chain or to another industry within the existing value chain. Players expand the scope of their operations or enter new markets to capture additional value. This can be done by analyzing market trends and industry dynamics to identify potential pathways. Furthermore, collaboration with partners from other industries or chains might be needed to enter them (Cattaneo et al., 2013).

Although upgrading pathways are known and players have the information needed to assess whether movement in more profitable activities is feasible, it is important to acknowledge that companies, or more generally countries, often struggle to follow these patterns due to significant barriers that they face. The specific challenges that they face are analyzed elaborately in chapter 6.

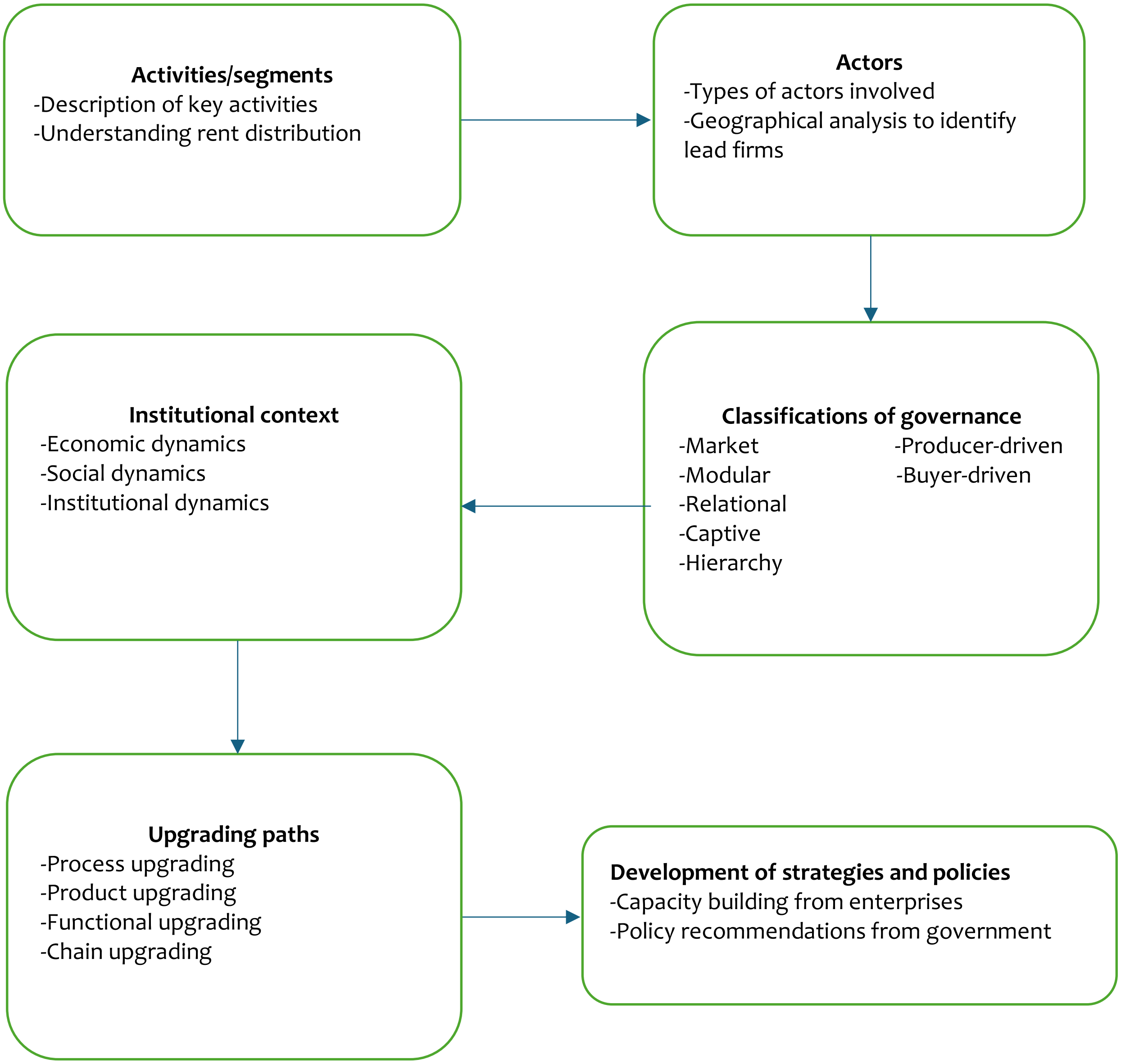

Figure 4-Methodology of GVC framework

3.2 Application of GVC framework in the global battery value chain

The GVC framework is chosen for analyzing the global battery value chain in the DRC mainly due to its complexity as a socio-technical system. Multiple stakeholders are involved, there are many innovation drivers during the last couple of years, and regulatory challenges have been introduced. As a result, a comprehensive framework identifying tailored opportunities for the DRC to upgrade in the global battery value chain is needed.

More details on how each sub-research question is approached are provided below:

i. What is the global landscape and governance structure of the battery value chain?

Firstly, the key activities across the battery value chain including energy infrastructure, equipment and capitalization costs are deployed. In this way, we can understand the stages that are rented and where value can be created in the whole chain. The most substantial type of rent in our study is technology, because the battery value chain is highly demanding from a technical perspective in all stages. The information needed is found from annual reports and websites of companies, where a lot of details related to their investment decisions and technologies are included. Next, players participating in each segment of the value chain are analysed and lead firms are identified. Furthermore, their interactions are analysed based on the different types of governance, which gives also valuable information for the barriers that new entrants may face to enter the value chain. After understanding the dynamics of relationships between suppliers and buyers, it is important to describe the institutional context of the DRC to specify their capabilities and see how effective the collaboration between public and private sector is.

ii. How is DRC currently integrated in the global battery value chain and what explains the observed pattern of integration?

Based on the lead players and the type of governance specifying the interactions between suppliers and buyers in the battery value chain, the exact placement of the country in the chain is found. More precisely, the two ways that a country or firm integrate in a value chain is vertical and horizontal. Vertical integration involves taking control of multiple stages of the production process, either by acquiring suppliers (backward integration) or distributors (forward integration). In this way transaction costs are reduced, and coordination is improved, so a company can enhance its competitiveness and ability to upgrade. As for the horizontal integration, it occurs when an enterprise expands its operations by acquiring or merging with other firms at the same stage of the value chain. This type of integration can increase firm 's market share and provide access to new customers, so growth is facilitated.

iii. *What are the DRC's upgrading opportunities and challenges in the global battery value chain?*

Understanding the capabilities and the institutional context of the DRC can give information for areas where value can be added. In this way, the most appropriate type of economic upgrading can be chosen to identify tailored opportunities for the DRC and make the upgrading feasible. Additionally, based on the segments of the value chain that are rented as well as the organisational structure of the chain, our study defines the local challenges and obstacles that the DRC must overcome to upgrade. In addition, a comparative analysis with China 's path and corresponding challenges with which Chinese companies dealt to transition to higher-valued industry activities should be conducted, so more valuable input can be given. As a result, an extensive literature review is carried out, including Gereffi 's study about the development of China in the battery industry, to understand the challenges that emerging markets are facing in the beginning of their journey before upgrading the value chain.

iv. *How can the DRC incentivise the development of battery value chain by implementing policies?*

The identification of opportunities and choice of the most appropriate type of upgrading for the DRC is the fundamental basis for companies to develop strategies and the DRC government to introduce policies supporting the private sector. Thus, specific policy recommendations implemented by the government authorities of DRC are suggested.

3.3 Data collection

The data used in my thesis are gathered mainly through desk reviews, literature reviews and annual reports, which are available online. More specifically, the implementation of the GVC framework requires data from literature review to understand its theoretical background and from companies 's annual reports to identify the activities and actors in the global battery value chain. Sometimes further data sources are necessary, such as firms' website, press releases and financial reports, to get more detailed information. Additionally, the comparative analysis conducted for the identification of challenges requires data from annual reports to make a comprehensive comparison of enterprises having businesses in the DRC with the Chinese ones.

4. Global landscape of battery value chain

4.1 Battery trends

In 2021, global cobalt production reached a peak at 170,000 tonnes/year, which is a sharp increase during the last decades compared to the amount of 50,000 tonnes/year in 1986, and the DRC supplied up to 70% of the global production (Savinova et al., 2023). In 2023, the cobalt production globally was around 230,000 tonnes/year and the DRC provided the industry with 171,371 tonnes/year accounting for 74% (Venditti et al., 2024). The production growth has been driven by the demand for battery storage, especially for EVs, as it is illustrated in the left side of figure 5. The Announced Pledges Scenario (APS) represents the emission reductions needed to achieve net zero emissions by 2050 based on the announced targets, while the Net Zero Emissions (NZE) scenario meets the Paris Agreement target of limiting average temperature increase to 1,5 °C by 2050 (IEA, 2024). Based on the demand forecast, the required cobalt supply to cover the EV demand will be above 300,000 tonnes/year by 2030 (IEA, 2024). Based on these trends, there might be many opportunities for the DRC to upgrade in the cobalt value chain and diversify in the very promising area of EV batteries.

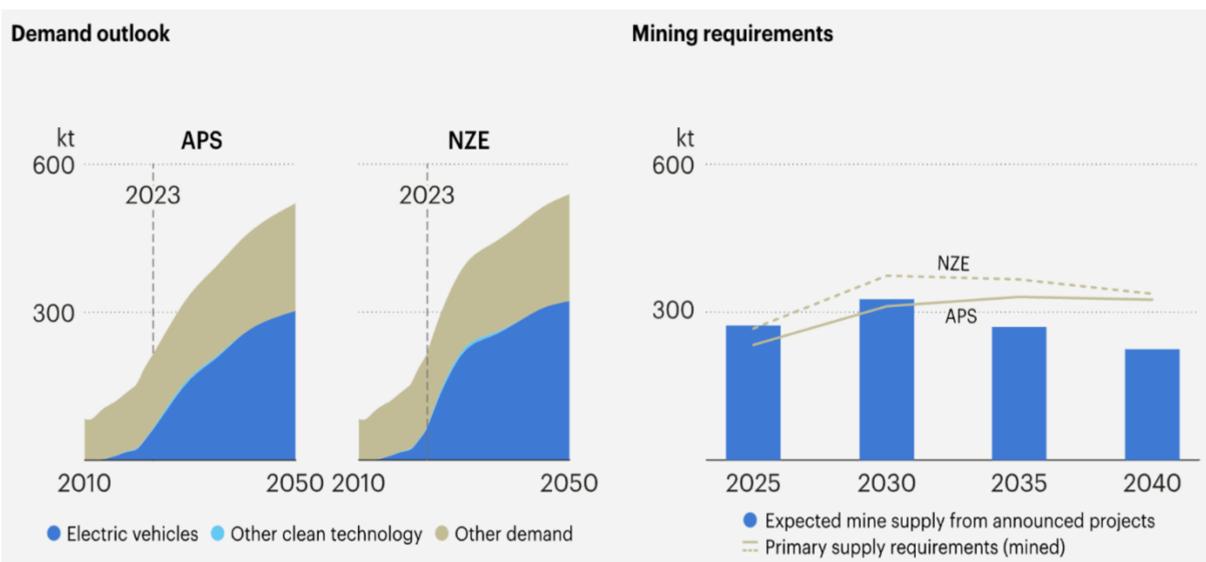

Figure 5- Cobalt supply (right) and demand (left) based on different scenarios, Source: IEA, 2024

4.2 Global battery value chain

The battery value chain involves a series of interconnected activities from the exploration of raw materials to the battery packaging. These activities are broadly classified into three segments along the battery value chain, leading to the flow of goods needed to produce the final product (see figure 6). Due to the global fragmentation of production, the various segments of the battery value chain are spread across several countries resulting into the so-called global battery value chain (see Figure 7).

Each segment of the value chain commands value which can be interpreted as the resource or rent gained. This value varies within and across different stages of the chain. For example, the production of battery cells from electrodes has the highest value addition by accounting for 35% of the total value chain. The value is reflected by the contribution of the stage to the total battery production cost, as it is illustrated in figure 7 (African Natural Resources Centre, 2021). The patterns of a country's integration and the activities in which they specialize determine their gains and the need for upgrading. This is influenced by the technological capabilities and capital cost used. In this chapter, we employ the GVC framework discussed earlier to better understand the global fragmentation of battery value chain and what upgrading opportunities there are for DRC.

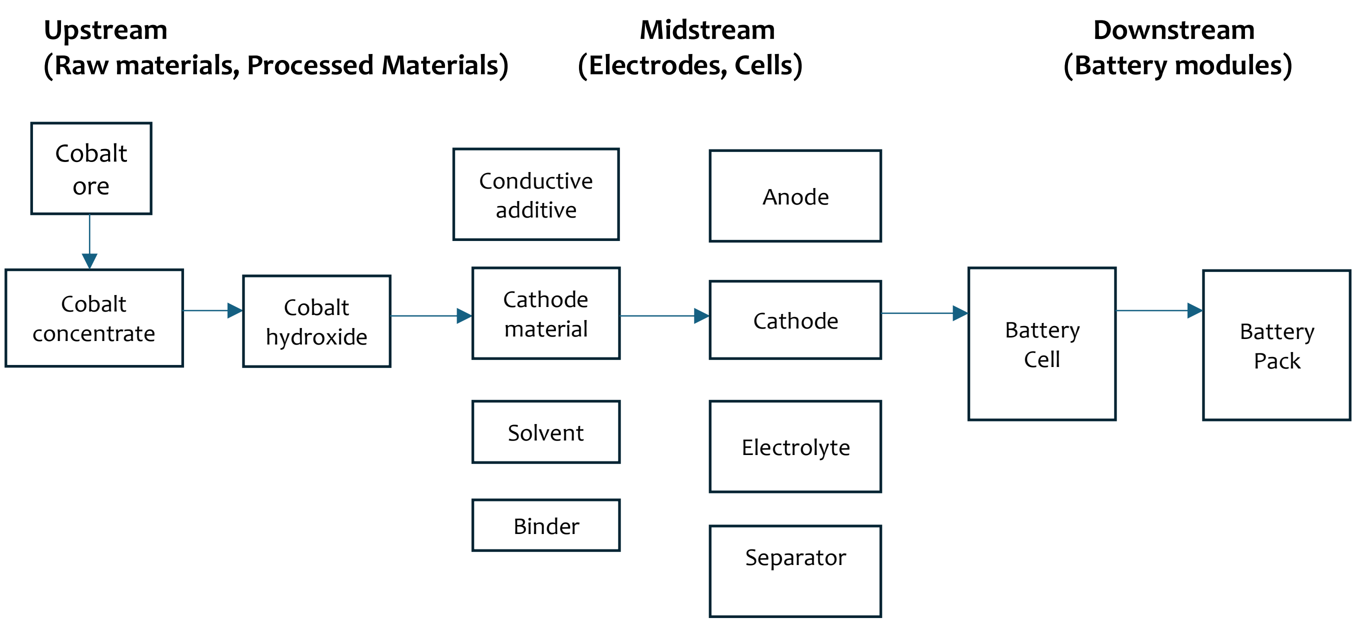

Figure 6-DRC 's battery value chain

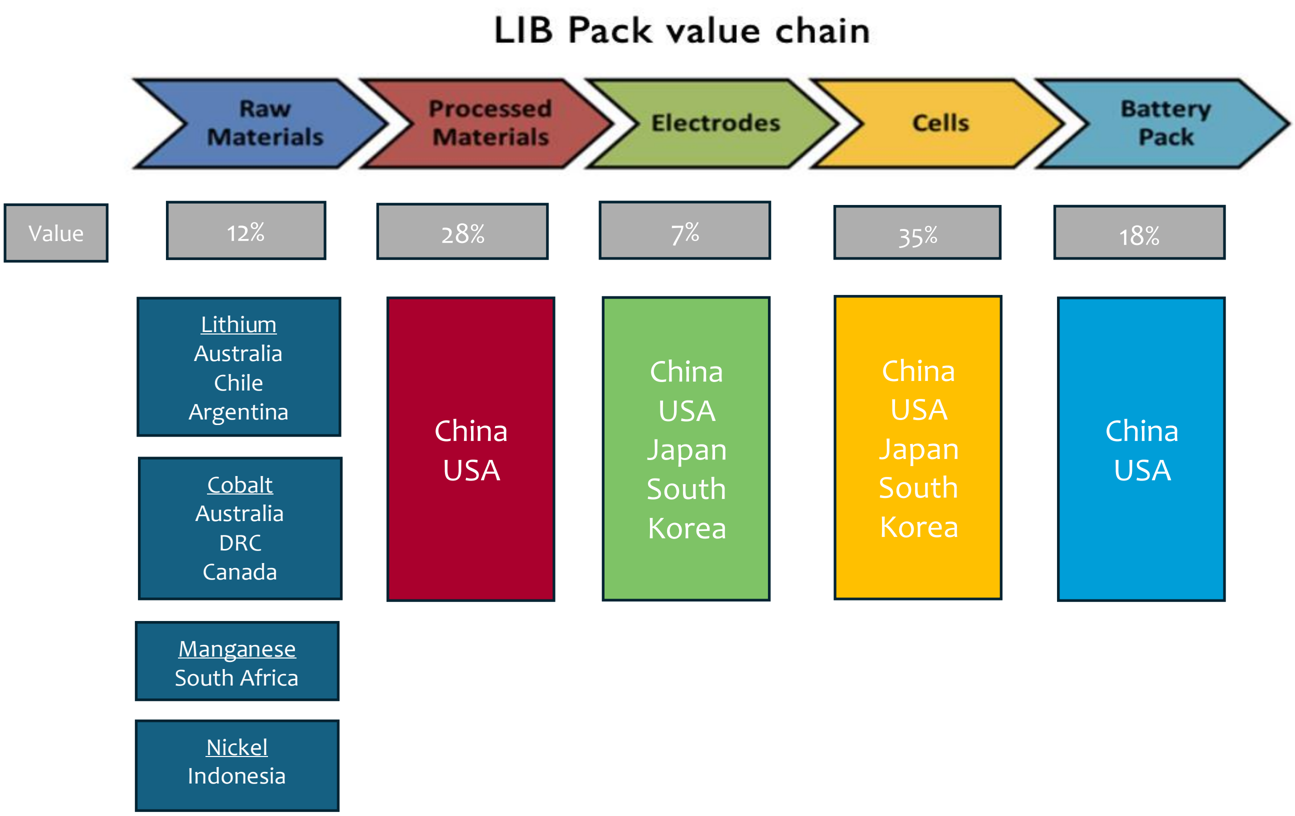

Figure 7-Global LIB value chain, Source: African Natural Resources Centre, 2021

4.3 Upstream sector

4.3.1 Input-output structure

Upstream activities encompass the initial stages of obtaining substantial raw materials needed for battery production, focusing on the exploration, mining, extraction and refining of nickel, manganese, lithium, and cobalt. Lithium is mainly extracted in Australia, Chile, and Argentina, while cobalt is sourced in DRC, Australia, and Canada. Furthermore, manganese is mainly extracted in South Africa and nickel in Indonesia (African Natural Resources Centre, 2021). The DRC is by far the largest cobalt producer globally, holding a significant position in the cobalt supply chain. At the same time, the country has lithium deposits, but there are no active mines currently (International Trade Administration, 2024). Therefore, this thesis is focused on cobalt to identify upgrading opportunities for the DRC in battery value chain.

This segment of the value chain involves the identification of cobalt-rich deposits through geographical surveys and geochemical analysis, which is followed by the mining, extraction and refining of cobalt via various processing methods. These stages are very important for ensuring reliable supply of cobalt in a form that can be further used in midstream and downstream sector (African Natural Resources Centre, 2021).

Exploration

Exploration is necessary to find the most valuable cobalt deposits that can lead to high productivity. Cobalt, which is a relatively abundant element in Earth 's crust, is found in high concentrations within different types of rocks. Its extraction primarily occurs as a by-product of copper and nickel extraction due to its low concentration in ores (Dehaine et al., 2021).

Zambia and the DRC, which are located in the Central African Copperbelt (CAC), have significant amounts of copper and cobalt, jointly accounting for around 70% and 55% of the global copper and cobalt reserve, respectively (Andreoni et al., 2023). The DRC has the largest global cobalt reserve. The predominant cobalt deposit type in the country is the Stratiform Sediment-Hosted (SSH) Cu-Co deposit. This type of deposit consists of three different zones: a weathered oxide zone extending to a depth between 70 and 150 m, followed by a mixed oxide-sulphide zone, and a sulphide zone that can be found below 250 m. The most abundant cobalt can be found in the sulphide zone and for this reason cobalt sulphides are the most common primary cobalt ore minerals exploited in the DRC (Dehaine et al., 2021).

The main technology used for cobalt sulphide zone exploration is geographical surveys, such as the Induced Polarization surveys that detect disseminated sulphide mineralization associated with cobalt ores in SSH deposits. These surveys identify ‘chargeable’ anomalies, which are an indicator of sulphide mineralization (Cross et al., 2021). Geochemical analysis is another exploration method including soil surveys that are widely used in the search of Cu-Co deposits in the Central African Copperbelt and considered one of the most efficient exploration tools. An important step of the process is the grid design and the soil sampling strategy requiring many different types of maps and safety equipment. Finally, the most expensive technique of exploration is drilling and there are various drilling machines utilized. Their efficiency depends on the volume and contamination of the sample obtained and on the depth of rock penetration (Kisumbule, 2014).

As for the resources needed, staff with high expertise is required, such as geophysicists, to conduct sample analysis in laboratories. Moreover, capital investment for an exploration project is around 6 million USD (Lydall et al., 2011). For this reason, junior companies involved in exploration projects are financed by institutional investors, mainly private equity firms. Major firms also participate due to the capacity they have to finance their own projects (African Natural Resources Centre, 2021).

Mining

Mining is the stage where cobalt ore is obtained from the earth crust. There are two widely used methods, open pit and underground mineral resourcing. In the open pit mines, excavators and shovels are used to remove the overlying rock and soil, while in the underground ones, drill rigs are made to construct tunnels and create access to the cobalt ore (Rashidi-Nejad et.al, 2014).

Open pit mining is more appropriate method for shallow and uniform deposits and can lead to higher production rate compared to underground method. The technologies used are simple, so the skills required can be easily found in the labour market. Furthermore, the initial capital cost for open mining activities is lower compared to underground methods, because the infrastructure required is less complex. Nonetheless, the cost can rise significantly depending on the depth of the open mine due to the need for more extensive waste removal. As it is illustrated in figure 8, the stripping ratio is expressed as the volume of waste material that should be removed to the volume of ore produced, so the higher ratio leads to a higher cost. Sub-level caving and block caving are the most widely known technologies in the underground mining, while the different ratios represent the open pit technology (Rashidi-Nejad et.al, 2014).

Block caving has high productivity, which is comparable to the one of open pit, but it involves risks related to geological uncertainties and the need for careful cave management. It is also quite capital-intensive, requiring significant upfront infrastructure. In particular, large modern projects range from 500 million to 10 billion dollars. Around 70% of capital expenditure is incurred before any revenue is generated, so the project can be very challenging. Nonetheless, this method has lower operating costs compared to the open pit technology, which can result to a lower total cost per ton in long term period (see figure 8). As for the skilled workforce, miners with expertise in underground operations and engineers familiarized with cave management are needed (Rashidi-Nejad et.al, 2014).

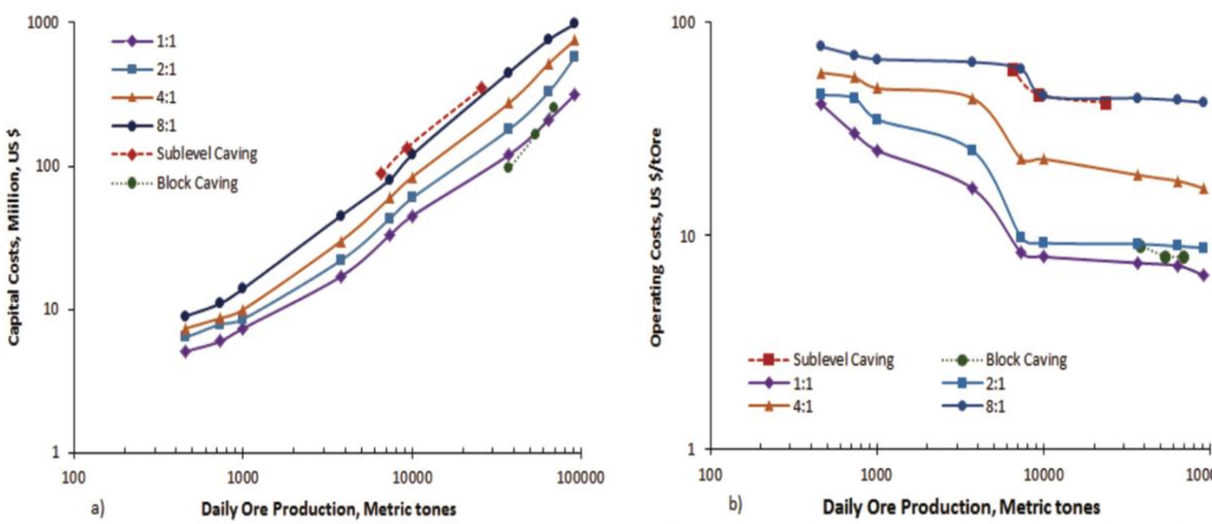

Figure 8-Capital expenditure (a) and operational expenditure (b) of mining operations, Source: Rashidi-Nejad et.al, 2014

Natural resource endowment of a country is an important step to integrate in the upstream segment of the value chain and the DRC has the advantage of geology, which is justified by the country's resource endowment in copper and cobalt deposits developed (Dehaine et al., 2021). However, the technological capabilities determine whether a country can move into higher value activities.

Extraction

After mining, extraction takes place where the cobalt-containing ore should be treated to obtain cobalt concentrate. The main processing routes that are widely applied are flotation and leaching. Prior to these methods, comminution may be necessary to reduce the size of ore particles and facilitate the extraction of valuable minerals. This process typically involves the use of high-capacity crushers and mills, which require significant capital investment and energy consumption. In particular, the average comminution energy consumption of a single mine is 14 kWh/ton, which is equivalent to the amount of energy needed to grind one ton of ore (Jose-Luis et al., 2019).

There are also certain pre-treatment processes that may be required before the flotation or leaching, which aim at reducing the gangue load to some extent and upgrading the cobalt-containing ore; gangue minerals have no commercial interest and must be separated from the valuable minerals during the ore processing. The first pre-treatment process is gravity concentration, which is a physical method through which cobalt is separated from some gangue minerals based on the differences in density. It is a low-cost technology, but still requires a considerable energy amount. Another pre-treatment process is magnetic separation through which the mineral is attracted to the magnet or magnetic contaminants are removed, thereby separating the valuable mineral. Depending on the paramagnetic properties of the mineral, this method can lead to higher recovery compared to gravity concentration. However, it is more expensive and energy intensive. Information about magnetic separation applied to cobalt minerals is limited and for this reason gravity concentration is the most widely used pre-treatment method for the separation of cobalt (Dehaine et al., 2021).

As for the main processing methods, flotation is the one through which the valuable minerals like cobalt and copper are further separated from gangue minerals based on their surface properties. The process is more effective for sulphide ores than oxide ones and requires substantial investment in flotation cells and reagents, which is the main equipment needed for a flotation plant. The specific energy needed for the concentration is around 42 kWh/ton of ore (Jose-Luis et al., 2019). Complete separation of copper and cobalt by flotation is not possible, so flotation concentrate is sent to a roaster to obtain the highest cobalt recovery, which needs additional fuel source for its operation and high temperatures (Crundwell et al., 2020).

Leaching is a hydrometallurgical process mainly applied in oxide ores, where the cobalt-containing ore is treated with a leaching solvent to selectively dissolve the cobalt minerals in a liquid phase. This process involves leach tanks, solvent extraction equipment and electrowinning cells, and requires a steady supply of chemicals. Therefore, the complexity of the required infrastructure and the energy needed for these processes are higher than the ones of flotation method, all contributing to higher capital expenditures (Crundwell et al., 2020).

Both pre-treatment and main extraction processes are quite energy intensive and require substantial infrastructure, so a processing plant with all the equipment for these processes is necessary. As it has been described, crushers/mills, gravity concentration/magnetic separation units and flotation/leaching units are needed for the construction of a complete processing plant. Therefore, integration in this segment is based on fuel sources, electricity generation and a wide range of chemicals to support the energy requirements of such plants. Moreover, logistics infrastructure is significant to facilitate transportation of ores from the mine to processing plants via rail and road systems. The fuel consumption of this transport is assumed to be 1.2 litres of diesel per ton of rock (Jose-Luis et al., 2019). Overall, mining activities in conjunction with extraction of cobalt concentrate account for 12% of total value chain. In particular, the production cost of both mining and extraction is 50$ and the total production cost of a Li-ion battery is 416 $/kwh, so in this way it is calculated the proportional contribution of a segment to the total value chain (African Natural Resources Centre, 2021). This means that this stage does not give so much value to the final product. However, it might be a very positive initial step for the DRC to leverage its position in the global battery value chain.

Refining

The final step in the upstream sector is the precipitation of cobalt concentrate. This process involving ion exchange or pH adjustment removes impurities and produces cobalt hydroxide, the form of cobalt utilized in battery cathodes (Crundwell et al., 2020). The capital cost of the ion exchange technology is substantial due to the resins required to selectively capture cobalt ions, while the pH adjustment method has a relatively lower cost. More precisely, the capital expenditure for the production of 9,000 tonnes cobalt hydroxide is 28.4 million $, while the operating cost is 60,3 million $ for the same amount of cobalt hydroxide (Swartz et al., 2009). As for the energy requirements, both methods consume moderate amounts of energy. This stage accounts for 28% of the total production cost, so it is the most valuable one in the upstream sector (African Natural Resources Centre, 2021). Production of resins for ion exchange is a very important parameter to integrate into this stage of battery value chain.

Overall, the activities done in the upstream sector are estimated to cost $168 in the total value chain, which accounts for 40% of the total production cost of a battery (416 $/kwh) (African Natural Resources Centre, 2021).

4.3.2 Geographical scope in the upstream sector

Thermo Fischer Scientific and Bruker are the main manufacturers of the instruments used for geographical surveys and geochemical analysis at the exploration segment of the value chain (Thermo Fischer Scientific, 2012). These firms are located in the United States and Germany, implying that countries (including DRC) integrated in the upstream segment of the battery value chain would rely on the import of this equipment from either USA or Germany.

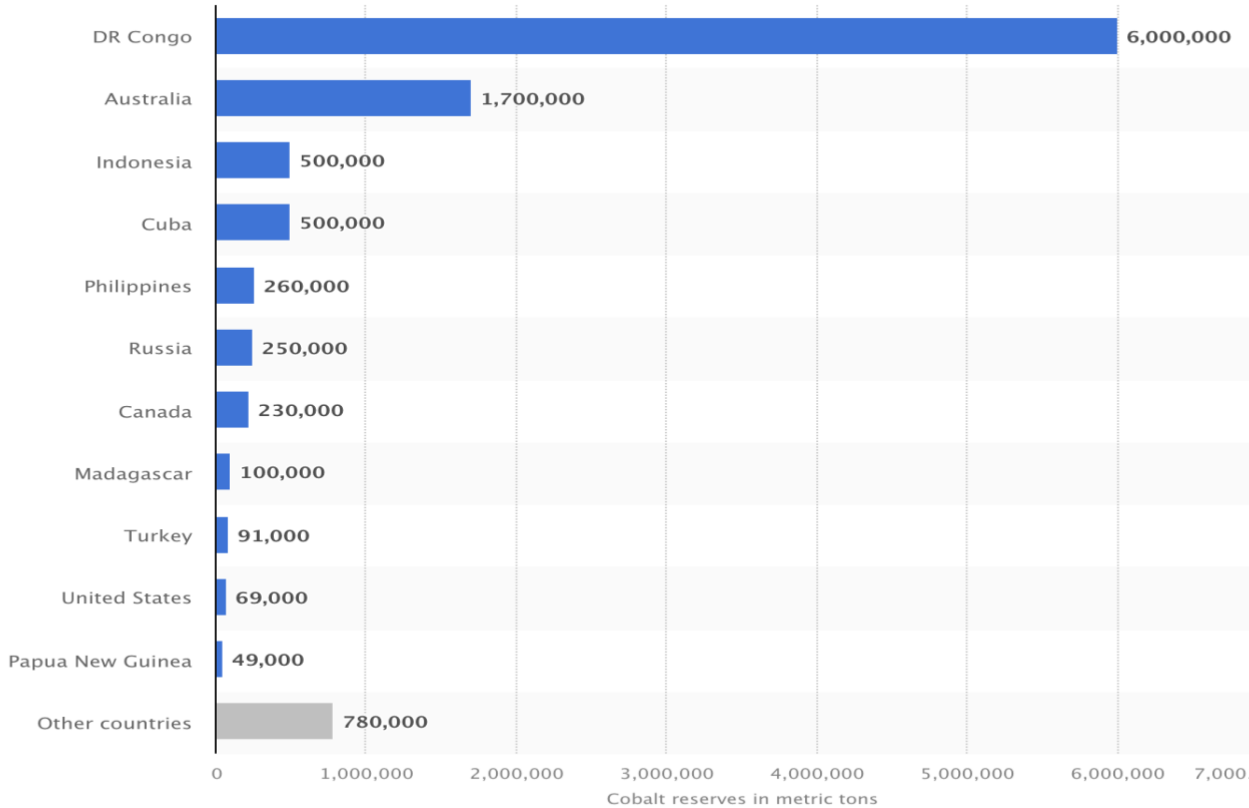

Figure 9-Global cobalt reserves in 2023, Source: Statista, 2024

Table 1-Global cobalt mine production in 2023

Country	**Production (tonnes)**	**Percentage**
DRC	170,000	74%
Indonesia	17,000	7%
Russia	8,800	4%
Australia	4,600	2%
Madagascar	4,000	2%
Philippines	3,800	2%
Other Countries	21,100	9%
Total	229,300	3%

Source: Venditti et al., 2024

Moving on, figure 9 illustrates the global spread of cobalt reserves, while Table 1 the cobalt mine production in 2023. As it is depicted, the DRC was by far the dominant nation in 2023, accounting for more than 50% of the global cobalt reserves and 74% of the world ‘s cobalt output. In particular, it produced 170,000 tonnes of cobalt, while the global annual production was 229,300 tonnes. Indonesia holds the second position by producing 17,000 tonnes, which is equivalent with 7% of the total output. The difference between these two countries highlights the magnitude of DRC ‘s dominance in the cobalt mining sector. Next, Russia produced a moderate number of tonnes, followed by Australia, Madagascar and Philippines, which account for approximately 2% of the global cobalt output. Overall, the DRC is a very substantial player in the mining sector, but further information about the enterprises involved in the DRC is needed to understand whether they are international or local.

The cobalt ore obtained from mines, especially the oxidised ore, is typically processed on site to produce cobalt concentrate. This is beneficial for the economic viability of mining companies by reducing transportation costs and facilitating the immediate sale of cobalt concentrate, which is a product with higher value compared to the ore (Shengo et al., 2019). More significantly, this activity entails higher value capture and can be considered a higher value-added activity compared to merely extracting the natural resource.

Figure 10 depicts the countries dominating the refining stage of the cobalt value chain. Although the DRC is the leading country in reserves of cobalt globally, China is by far the dominant country in the refining stage, controlling around 72% of the segment. This is attributed mainly to Jinchuan and Zhejiang Huayou Cobalt that have large refineries in China producing cobalt hydroxide. These two firms have a competitive advantage, because they also have cobalt mines in the DRC, so they can provide their refineries with their own raw materials (African Natural Resources Centre, 2021). In figure 10, the dominance of China is illustrated and there is also an estimation for 2030.

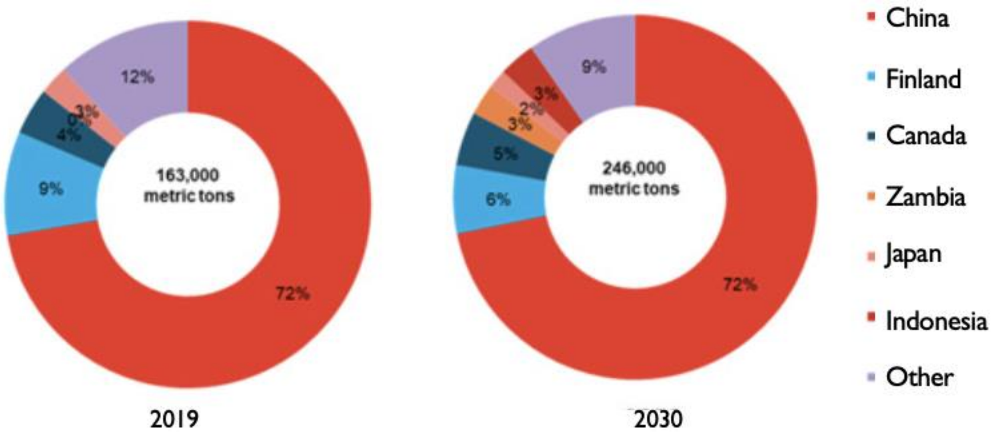

Figure 10. Control in cobalt refineries globally, Source: African Natural Resources Centre, 2021

4.3.3 Governance

The upstream sector of the battery value chain can be classified as captive mainly due to the high dependency of suppliers to buyers. Suppliers in this sector involved in mining activities cannot execute complex activities and lack the expertise to participate in the refining stage. Even Glencore controlling 23% of mines in the DRC has only one refinery in the DRC, where the government is a partner (African Natural Resources Centre, 2021). As a result, the buyers (mainly Chinese companies) control upstream sector by having significant influence over mining companies, which are locked in specific agreements and cannot upgrade easily (Bridge et al., 2022). Furthermore, some Chinese enterprises like CMOC and CATL have invested in the mining sector during the last years to hedge supply risks and increase their dominance in upstream sector. As a result, the power asymmetry is clear, which makes challenging the possibility of DRC 's upgrading in this sector.

4.4 Midstream sector

4.4.1 Input-output structure

Midstream activities are equivalent to 42% of the total value of battery and consist of a series of critical processes that connect the raw material processing (upstream) and the final assembly of battery packs (downstream). These activities play a substantial role in the transformation of low value raw materials into functional battery cells contributing to the efficiency, safety, and performance of the final product. Some of the stages included are the production of electrode materials and their integration in battery cells.

Manufacture of Electrodes

Production of electrodes involves the treatment of cobalt hydroxide and accounts for 7% of the total battery value chain. The cobalt hydroxide, which is obtained as a final product in the upstream sector, is thermally treated to convert into cobalt oxide, which is then mixed with other components, such as lithium, to form the cathode material, typically the Lithium Cobalt Oxide (LCO). Then, the active material is mixed with a conductive additive, a binder, and a solvent to form a slurry. The equipment needed includes intensive mixers and dispersers and the investment for these machineries varies from 18 to 34 million euros (Heimes et.al, 2018). The amount of energy needed for slurry is moderate, and specifically is below 0.1 kWh, as it is illustrated in figure 11 (Pettinger, 2017).

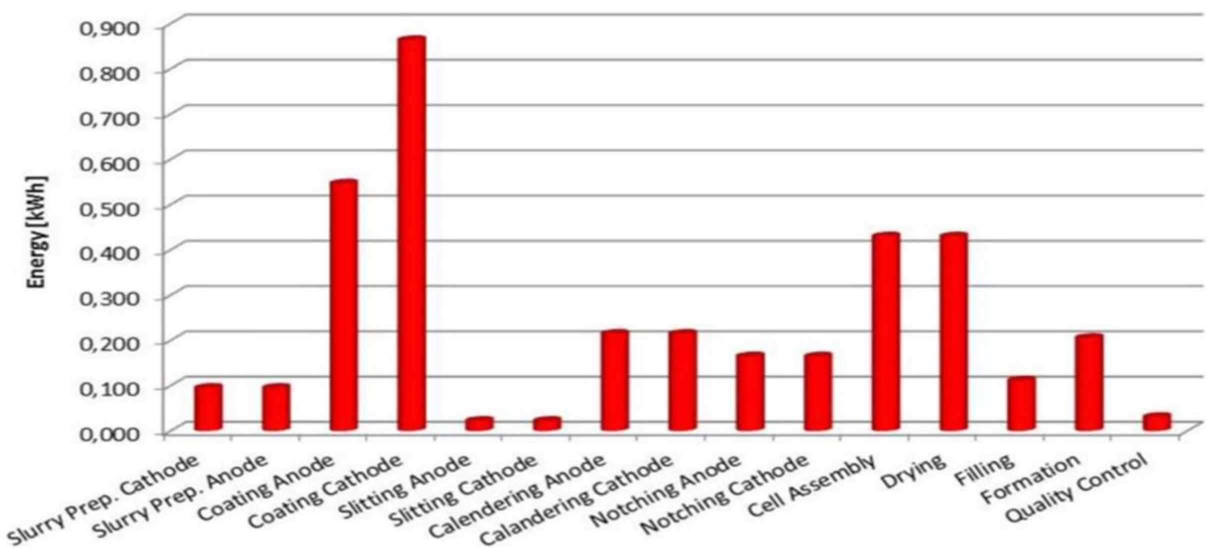

Figure 11. Energy demand by production steps for a 40 Ah Li-ion cell, Source: Pettinger, 2017

Then, the slurry coats a current collector using techniques like the doctor blade method, which is fast and ensures precise thickness, or the roll-to-roll manufacturing process, which allows for continuous processing, but it has limitations in material variety and scalability. Coating is the process with the highest energy expenditure in the midstream sector, requiring above 0,8 kWh (Pettinger, 2017). The coated foil is transferred to the dryer, where the solvent and binder are eliminated by supplying heat, leaving a thin layer of the cathode material in the current collector (Sharmili et al., 2023). The heat supplied by the dryer requires around 0,4 kWh, which is substantial amount of energy and for this reason this step is also quite energy consuming in the Li-ion battery production (Pettinger, 2017). Additionally, both coating and drying process are very expensive processes accounting for 20% of the total manufacturing cost of battery (Heimes et al., 2018). Overall, both coating and drying are very demanding stages for the manufacturers from both financial and energy perspective, and specific mechanical equipment is necessary.

Furthermore, the calendaring process might be required to reduce the thickness of the electrode, which leads to better adhesion to the collector and high energy density. This step demands moderate energy expenditure, which is equivalent with 0.2 kWh, and precise machinery (Pettinger, 2017). The equipment needed includes many different rollers and its capital expenditure ranges from 5 to 10 million euros (Heimes et al., 2018). After calendaring, the coated electrode is cut into individual sheets of the required size through the slitting process. Although the capital cost of slitting is lower than calendaring, it is a very crucial process, because the slitting electrode will be used in the battery cell and has an impact in the safety of the final product, the Li-ion battery. Therefore, high-quality slitting machinery and skilled labor are essential to ensure precision and safety (Sharmili et al., 2023).

To maintain high standards, a robust quality control infrastructure is necessary. This includes advanced testing equipment to evaluate the performance and safety of the electrodes (Sharmili et al., 2023). Investments in state-of-the-art quality control systems and ongoing maintenance are very important to ensure the reliability and efficiency of the manufacturing process. Overall, integration in this stage requires lot of effort including very precise machinery, highly skilled staff, and safety standards, while the value of the stage in the production cost of battery is relatively low (7%) compared to other stages of the value chain. Table 2 shows the capital cost for machinery and equipment required in electrode manufacture. The total capital cost for all these processes varies from 58 to 122 million euros, which is associated with the production of around 45 million pouch cells per year. Each pouch cell is considered a separate battery unit, so the total capital cost is enough to produce 45 million Li-ion batteries, which represents the annual production capacity of a battery manufacturing company (Heimes et al., 2018).

Table 2-Capital cost for electrode manufacture

Process	Capital cost (million EUR)
Mixing	18-34
Coating	16-35
Drying	16-35
Calendaring	5-10
Slitting	3-8

Source: Heimes et al., 2018

Assembly of electrodes and manufacture of battery cells

This is the most valuable stage in the whole chain accounting for 35%. The multiple electrode sheets comprising both anode and cathode are stacked together with separator layers and sealed to form a complete battery cell. During this process the cathode and anode sheets are inserted alternately into the separator, which is cut off in the end of stacking process. Then, the cell stack is positioned in the pouch foil to be sealed. The total capital cost for the equipment needed is between 18 and 27 million euros per packaging pouch (Heimes et al., 2018). Next, the battery cell undergoes the filling process through which the electrolyte is injected into the cell, which requires a low energy expenditure (0,1 kWh) (Pettinger, 2017). This very important process costs 6-12 million euros and activates the electrochemical reactions within the cell. Finally, the most challenging and expensive process is cell formation, where the first charging and discharging cycle takes place. This step costs 70-90 million euros and ensures that the battery cell is ready to operate (Sharmili et al., 2023).

Overall, assembly lines are the most substantial infrastructure in the midstream sector including automated equipment for cell stacking and filling electrolyte equipment. Integration in midstream sector requires very tailored equipment with employees having expertise, and a reliable electricity market due to the high energy amounts needed, as it is depicted in figure 11.

4.4.2 Geographical scope in the midstream sector

The most crucial actors in the midstream sector are those specialising in cathode and anode manufacturing as wells as those producing electrolytes and separators required for the battery cells. The control that enterprises have in this sector is determined based on the production of these components. As it is clearly illustrated in figure 12, Asian nations dominate in all stages of the midstream sector, with China having significant control. Although the DRC integrates in the upstream sector by having substantial natural resources, it is very difficult to upgrade in this sector. The country does not have refining plants to treat cobalt hydroxide and produce cathodes, as it is aforementioned in the description of upstream activities, because it lacks the different types of chemicals used and the specialised workforce required due to the safety standards associated with these processes.

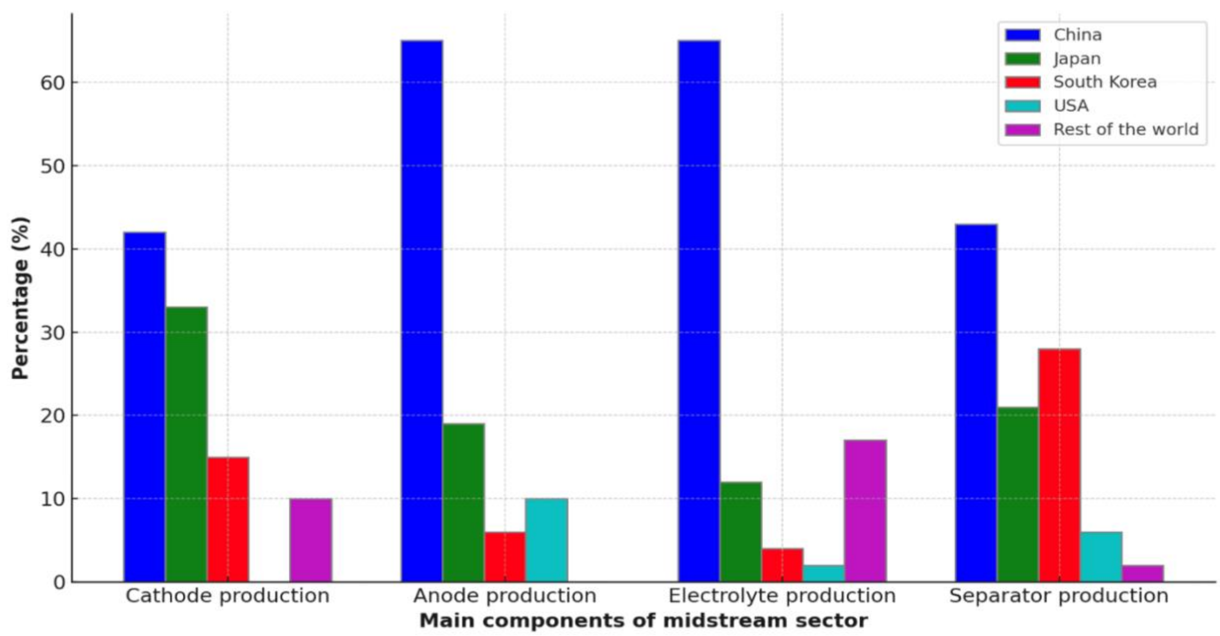

Figure 12-Control in midstream sector, Source: FCAB, 2021

In the cathode manufacturing, where the cobalt is one of the most substantial materials, the annual production is around 3 million tonnes per year and the most dominant actor is China.

More precisely, Chinese corporations, such as Zhejiang Huayou Cobalt, control 42% of cathode manufacturing at a global level. This is followed by Japanese enterprises like Nichia Chemical and Sumitomo which hold around 33% of the segment. European companies have limited control in this area, but they want to develop cathode manufacturing technologies and start having significant influence (FCAB, 2021).

In the anode manufacturing, Chinese companies are by far the global leader accounting for 65%, while the Japanese ones have some influence by controlling approximately 19%. As for the electrolyte solution production, Chinese firms have again most of the control holding 65%, with European companies having limited control. As for the manufacture of separators, Japan and South Korea play a very important role accounting together for 49% (FCAB, 2021). Overall, the midstream activities are very concentrated in the East, with China playing a key role as illustrated in Figure 12. It is difficult for the DRC to upgrade in these segments, because the country primarily produces cobalt and lacks the production of other necessary raw materials, such as graphite in anode production. Furthermore, the country does not have the required technological expertise to support advanced manufacturing processes involved. The research and development activities that can improve production techniques of anodes and separators are currently lacking (BloombergNEF, 2021).

There are some crucial factors that contributed to the successful trajectory of China in the midstream sector of battery value chain. Firstly, China developed its technological capabilities to a significant extent through Foreign Direct Investment (FDI). In particular, $27.8 billion were invested by foreign enterprises in more than 6,000 new joint ventures in 2016, which allowed Chinese companies to improve the quality and efficiency of manufacturing plants and scale up production (Gereffi et al., 2022). This is very crucial for upgrading in value chains where advanced technologies required to rent a specific segment (Kaplinsky et al., 2016). Unlike China, the DRC lacks the required infrastructure. The inadequate transportation network including roads and railways increase the operation costs and the energy infrastructure is underdeveloped, which make it difficult for investors to operate large-scale projects in the midstream sector (BloombergNEF, 2021). Moreover, Chinese firms ensured access to cobalt by investing in mines in the DRC, so they leveraged their position in the upstream sector. Other enterprises emphasized on R&D, which are also high-value activities of the upstream sector (Gereffi et al., 2022).

4.4.3 Governance

In the midstream sector, battery cell manufacturers are the dominant party and work very closely with their suppliers to optimize processes and improve the quality of battery cells. Thus, collaboration is crucial due to the specialized chemicals and the mechanical equipment required to produce electrodes. A high level of expertise by suppliers is necessary to supply these intricacies, so knowledge cannot be easily codified (Bridge et al., 2022). This in conjunction with the stringent safety standards that suppliers must meet reinforces battery manufacturers to establish long-term partnerships with their suppliers. As a result, this dynamic creates a governance structure characterized by relational interactions, where trust and mutual dependence are very important, so new entrants should have a significant level of technical expertise to be competitive.

4.5 Downstream sector

4.5.1 Input-output structure

The downstream sector accounts for 22% of the total production cost and includes the stages where the manufactured battery cells are integrated into final products, which are used in the industry. The ultimate goal of this sector is to meet the preferences of customers, which are related to the performance and compatibility of battery, and the regulatory requirements. In this way, high-quality battery technologies can be provided to both transport sector and electricity market.

Integration of cells in Battery pack

Battery cells produced in the midstream sector are integrated into a battery module with control electronics and thermal management systems. More precisely, cells are arranged in a specific configuration (series or parallel) to achieve the desired voltage and capacity. Copper or aluminium is used to form the necessary electrical connections in the cells and advanced techniques are used to ensure a secure connection between cells (Lewchalermwong et al., 2018). In addition, energy resources like the thermal management system are essential to power the assembly lines and maintain optimal environmental conditions for the sensitive components. Once the battery modules are assembled, multiple modules are integrated into the final battery pack. This process includes extra components, such as battery management systems, cooling systems, sensors, and insulation package (Sharmili et al., 2023). While high-quality materials and advanced manufacturing techniques are necessary to create robust and efficient battery packs, testing equipment and skilled workforce are also needed for quality assurance, so the safety and performance standards can be met.

Integration of battery packs into end products (EVs, storage systems)

The final stage of battery integration is tailored to the preferences of each consumer and requires considerable resources in terms of customization and compatibility testing. For the construction of electric vehicles (EVs), battery packs are integrated into the vehicles, which demands careful alignment with the vehicle's electrical system and rigorous performance testing to ensure the highest efficiency and reliability. Design engineers' contribution is very important to make sure that the battery pack is protected in case of collision, which is a typical challenge at this stage (Siemens, 2022). Moreover, software engineering tools are necessary to improve the integration of battery packs in EVs by optimizing parameters like weight and thermal performance (Silvas et al., 2017). Overall, an engineering team with expertise is required as well as testing facilities and quality control infrastructure.

In the context of energy storage systems, battery packs are incorporated into stationary systems to store electricity generated from renewable energy sources. This integration involves not only the physical assembly of the battery packs but also the installation of control systems to manage energy flow. Additionally, thermal energy systems are necessary auxiliary systems optimizing battery temperatures and ensuring safety. Other resources required include advanced software for energy management to ensure that the system responds effectively to supply and demand fluctuations of the grid. Ensuring compatibility with the energy grid and achieving optimal performance in varying environmental conditions also require specialized equipment including converters and inverters (Stecca et al., 2020).

4.5.2 Geographical scope in the downstream sector

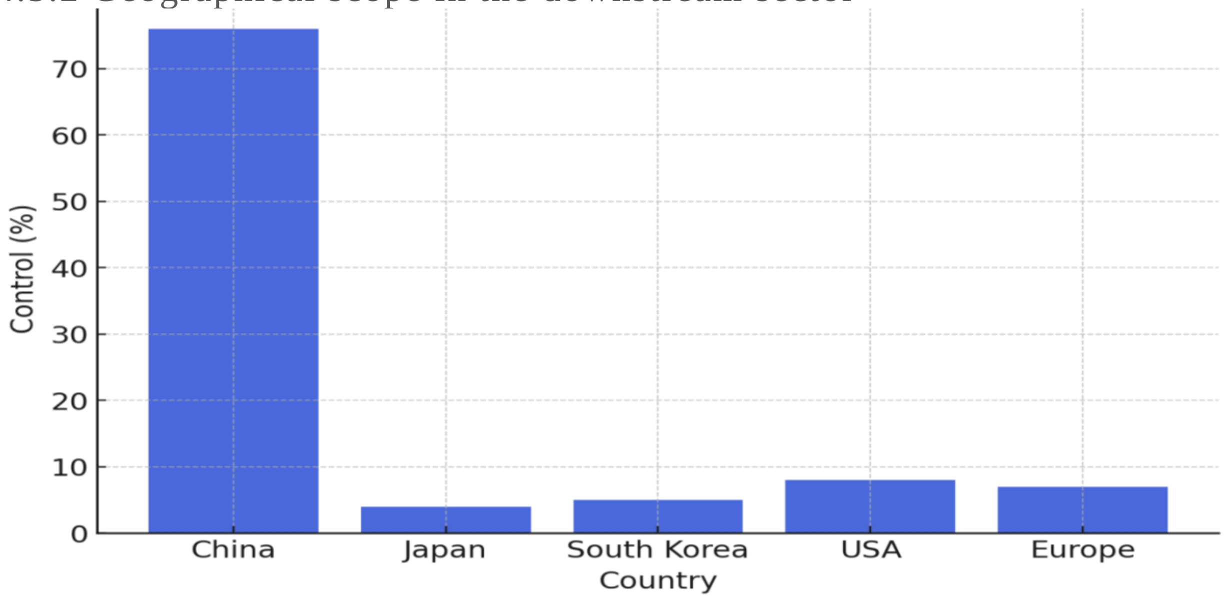

Figure 13-Control in downstream sector, Source: FCAB, 2021

The figure shows that the downstream sector of the value chain is highly concentrated in China. The crucial indicator showing the control in downstream sector is the battery production capacity measured in GWh. Battery production capacity is concentrated in Asia, especially in Japan, Korea, and China, with China represented around 76% of global capacity in 2020. This high level of concentration in conjunction with the fact that the DRC does not have the battery management systems required leads to significant barriers for the country to upgrade within the downstream sector (Sharmili et al., 2023).

At a corporate level, battery manufacturers have large-scale facilities known as gigafactories, where cells are fabricated, combined into modules, and assembled into packs. Global deployment of gigafactories has surged and it is estimated that over 280 plants are planned or are under construction by 2030, which is equivalent to around 6000 GWh of capacity, while the capacity in 2020 was 747 GWh (Bridge et al., 2022). This trend is mainly driven by automotive demand, particularly in regions like China and Europe, where the decarbonization of transportation is a priority. This is very encouraging for new entrants in the downstream sector, but understanding how much control the lead firms have is necessary to assess whether opportunities can be identified for the DRC.

The Chinese firm CATL is the most significant player holding above one quarter of the global market share by today and BYD has also quite substantial influence. Some lead corporations in the downstream battery sector from South Korea, such as Samsung SDI, and Japan, such as Toshiba and Panasonic, have made significant investments in cell manufacturing at various locations including the US and Europe (Bridge G. et al., 2022). Panasonic has already developed high operational capabilities at Nevada automotive battery factory and increased its production capacity at the Kansas factory last year. In addition, the Japanese firm is going to invest in the construction of new factories in North America to meet the growing demand in the area. In this way, the company aims at reaching a production capacity of 200 GWh by 2031, which is around four times higher than its current production (Panasonic, 2023). Overall, South Korea and Japan account for 5% and 4% of the global battery manufacture, respectively (Bridge G. et al., 2022).

Europe may be a quite major player in the industry in the following years. By 2025, European battery production capacity is projected to increase 13-fold compared to 2020 levels, driven by emerging battery manufacturers. As a result, Europe's share of global battery production is expected to rise from 7% to around 22% during this period (Bridge G. et al., 2022).

In the US area, Tesla stands out for its significant battery deployment, with 22.5 GWh of capacity deployed in the second half of 2020, nearly matching its closest competitors combined (Bridge G. et al., 2022). Elon Musk, who is the CEO of the firm, has implemented the vertically integrated model to control multiple stages in Tesla 's supply chain. In this way, the enterprise reduces both supply chain risks and transportation costs, so it has achieved to gain a significant technological advantage. It is quite crucial for the US to have more major players like Tesla in the following years to meet the future demand, which is expected to be above 300 kWh by 2025 (Mayoral, 2022). Currently, the US account for 8% of battery production and are the second largest battery manufacturer in the world, as it is shown in figure 13.

Overall, China ‘s dominance in the downstream sector creates some barriers for new entrants. China has built many large-scale gigafactories to support its massive production capacity, so its production costs have been reduced. This makes it difficult for new entrants to be competitive in price (Gereffi, 2022). Furthermore, the fact that Europe cannot currently support domestic LIB manufacturing creates an obstacle to remaining competitors in the EV market. The reason behind the lack of manufacturing is high transportation costs, supply risks, and time delays (Sharmili et al., 2023).

4.5.3 Governance

The downstream sector of global battery value chain for lithium-ion batteries (LIB) is characterized by intricate interactions between established battery producers, emerging battery manufacturers, and automotive original equipment manufacturers (OEMs). Automotive OEMs play a pivotal role as lead firms in this segment of value chain by driving decisions on production location, battery chemistry, and production rates through investment strategies and organizational coordination. Their need to secure access to battery technology has led to long-term contracts, direct investments in battery production, and joint ventures with battery cell producers (Bridge et al., 2022).

Automotive OEMs utilize long-term contracts and off-take agreements to secure a stable supply of batteries and essential raw materials. For instance, the Renault group has already had a long-term contract with LG for battery supply. Furthermore, big automakers like Tesla and BMW are increasingly securing direct agreements with battery mineral producers to ensure a steady supply of critical materials. Tesla has agreements with Piedmont Lithium for lithium and Glencore for cobalt, while BMW has similar agreements with Glencore for cobalt.

These strategies reflect OEMs' proactive approaches in managing their supply chains amidst growing EV demand (Bridge et al., 2022).

As a result, automakers have substantial influence over battery specifications, necessitating ongoing collaboration with battery manufacturers. The combination of their strong relationships with battery manufacturers but also with critical mineral suppliers and the expertise that suppliers acquire in battery technologies is an indicator that battery value chain can be classified as relational. This is an obstacle for the DRC, because knowledge cannot be codified, so the integration in downstream sector is quite challenging.

5.Tracing the battery value chain in DRC

5.1 Mining segment and history in the DRC

The mining segment in the DRC has a rich and complex history that has been shaped by the country 's vast mineral resources and the colonial exploitation. In particular, the DRC has a unique geographical position with significant amounts of diamonds, cobalt, copper, and gold. The mining and extraction of these minerals in the country are concentrated in the east, which is a major industrial area, as it is depicted in figure 14.

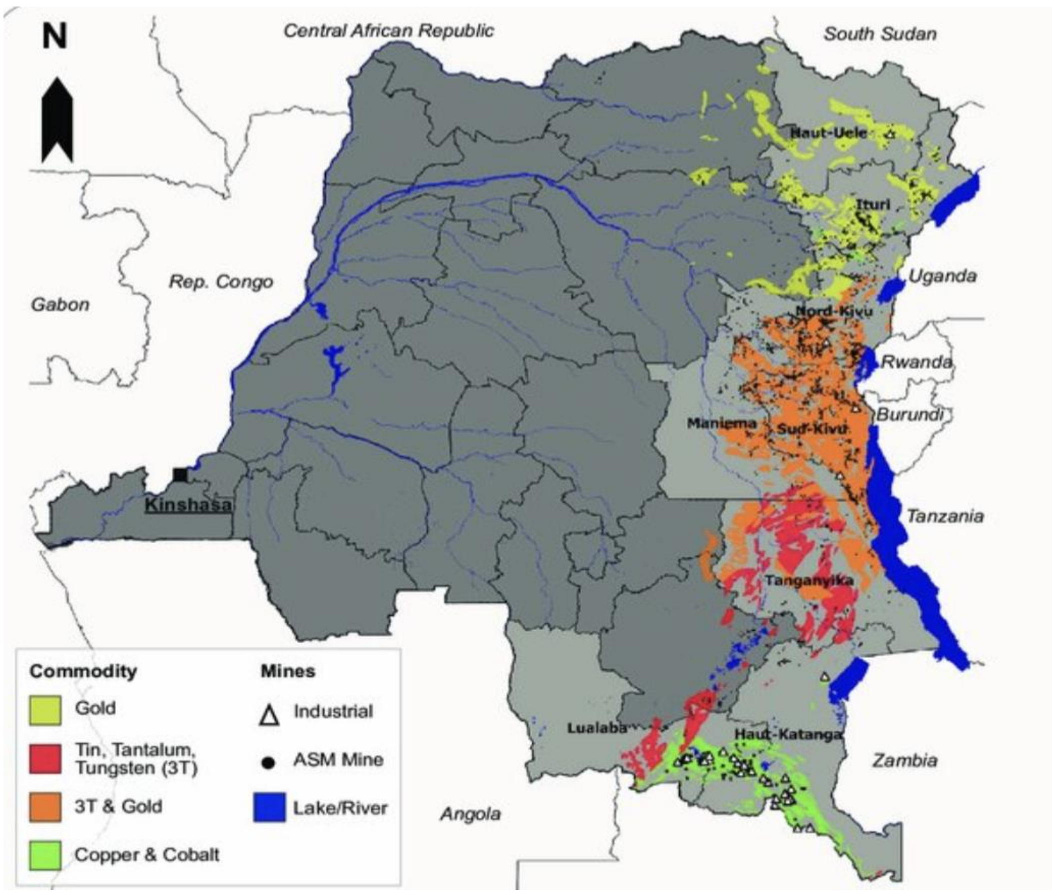

Figure 14- Major mining areas of important minerals in the DRC, Source: (Barume et al., 2020)

The mineral that has raised most of the interest at a global level since the beginning of 20th century is cobalt, because the DRC has the largest cobalt reserves. The first large cobalt deposits were discovered in 1914 by the Belgian enterprise Union Miniere. After the DRC 's independence from Belgian colonial in 1960, the country experienced political instability for 5 years, which is known as Congo crisis. In 1967, the government took over the majority of the mine assets and in this way the first state institution in the country was established, Gecamines (Gulley, 2022). For many years, it was a major player in the global mining industry by controlling a lot of the DRC 's deposits, but it was criticized for its management practises, especially regarding transparency. More precisely, it was named 'private gatekeeper' to exploitation rights, which led to some opaque deals that were not beneficial for the DRC government. Today, Gecamines is a junior partner in joint ventures with the LSM, which is quite important for both domestic and international markets (World Bank, 2021).

The DRC government privatized the mining industry in the early 2000s, so private firms took the lead in the segment. In this transition, the Artisanal and small-scale mining (ASM) started their business consisting of small-scale entrepreneurial operations that are active until now. There is a global concern during all these years for this kind of entrepreneurs related to the exploitation of children (Gulley, 2023). These miners are classified into formal and informal. The formal ones typically work in very small groups and produce around 1-3 tons of cobalt or copper ore. They operate under legal frameworks, so they may receive lower payments compared to informal miners due to the higher costs associated with formalization. The positive thing is that these employees work under safer working conditions including access to safety equipment and better health standards. On the other hand, informal miners lack formal legal status and their employers do not work through cooperatives, so they have conflicts with large scale companies (World Bank, 2021). The cobalt produced by all ASM is sold to traders, who then supply it to larger companies and refineries, mainly in China, as it is depicted in figure 15.

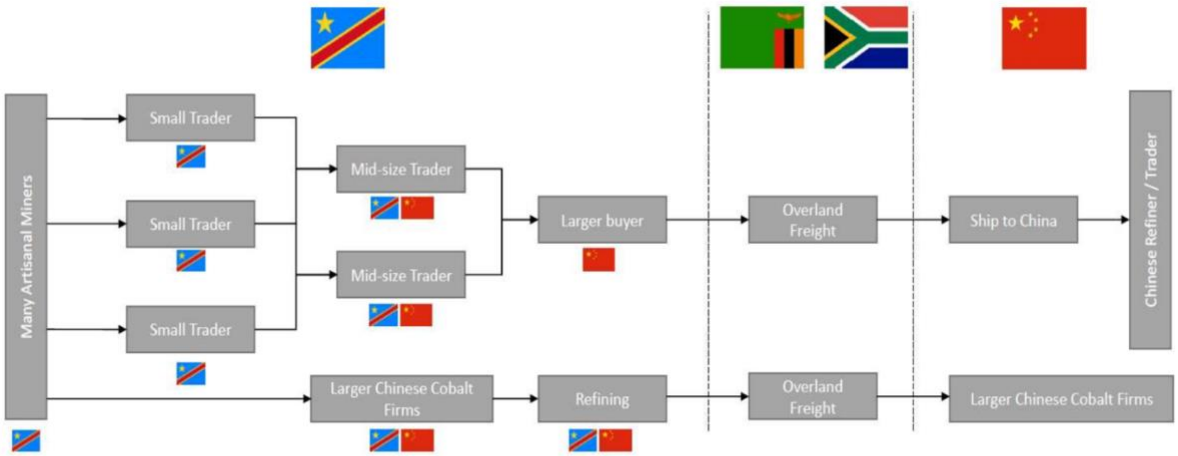

Figure 15- From ASM to refineries, Source: World Bank, 2021

As for the regulatory environment, the main law governing the mining segment in the DRC since 2002 is the Mining Code. It allows both foreign and local investors to own rights in the mines under the condition of establishing a domicile with a registered mining agent in the DRC. This facilitates the increase of foreign direct investment, while ensures local involvement that is crucial for upgrading in higher-value activities. Furthermore, the regulation aims at increasing transparency by incorporating requirements regarding environmental and social aspects. More precisely, an environmental impact study (EIS) and an environmental management plan (EMP) are necessary for the approval of a mining project (Gulley, 2022). Overall, the Mining Code covers many different aspects, so it gives some level of stability in the business environment of the DRC.

5.2. Institutional context

Economic conditions

The economic conditions in the DRC are complex and do not help the development of the mining sector significantly. There is a lack of infrastructure, which poses challenges for cobalt mining operations from an investor perspective. The decades of conflict and instability, especially in the east regions of the DRC, have contributed to this situation. More precisely, the inadequate transportation network, including roads and railways, prevent the supply of materials. These logistic bottlenecks have been exacerbated by crises like the COVID-19 pandemic, which triggered disruptions and added extra risk for the firms sourcing cobalt from the DRC (World Bank, 2021).

Access to finance is another critical issue in the DRC, where many ASM operations have businesses. The high risks considered by investors also include political instability and regulatory changes, which lead to higher risk premiums (World Bank, 2021). The DRC government is trying to increase the FDI, but some fiscal terms are significant barriers for investors. One of them is the amended Mining Code, which mandates at least 10% local ownership of mining firms to be owned by indigenous citizens. Thus, potential investors become more reluctant, because their profitability would be reduced due to joint operations. In addition, the poor business climate in the country marked by corruption, lengthy administrative procedures and an inefficient judicial system further hampers the ability of the DRC to attract substantial foreign investments that could facilitate upgrading (UNCTAD, 2023).

Social conditions

The social context in the DRC is quite problematic both from an employment condition and labour perspective. The unemployment rate is around 73%, and especially the youth unemployment rate is 70%, which means that a dramatically high percentage of university graduates cannot find a job (KPMG, 2014). Furthermore, the skill level varies substantially, which is attributed to the fact that many residents are working in an illegal framework, including those working in the artisanal and small-scale mining operations. These employees lack formal training and education, which limits their ability to be involved in more complex activities. Furthermore, the employees working in informal ASM operations must deal with precarious working conditions, which affects the overall skill development. It is also well-known that ASM operations do not respect human rights and there are many reports of child labour, which raises serious ethical concerns (World Bank, 2021).

Policy environment

Supportive policies are very important for a strong institutional context that fosters cooperation between private and public sector. An industrial policy support with effective date on August 2023 is the ASM Cobalt Normative Framework, which was created through the involvement of the DRC Minister of Mines. This framework is tailored to the Artisanal and Small-scale Miners (ASM) and its goal is to establish a pathway towards responsibly sourced cobalt by ASM. In this way, the DRC government enhance competitiveness and sustainability of firms operating in the mining sector. The implementation of the framework will be done in conjunction with the Responsible Minerals Initiative (RMI) (ASM Cobalt Normative Framework, 2023). The RMI provides tools and resources to help companies make sourcing decisions that improve regulatory compliance and support responsible sourcing globally, so that minerals supply chains contribute positively to social economic development (Cobalt Refiner Supply Chain Due Diligence Standard, 2021).

According to Magnus Ericsson 's study, transparency of mining enterprises is a huge problem preventing the mitigation of environmental and social risks, because 48% of cobalt producers do not publish accessible ESG reports (Ericsson et al., 2023). An initiative established by the Chinese Chamber of Commerce for Metals, Minerals & Chemicals (CCCMC) and the OECD in 2016 is the Responsible Cobalt Initiative. The aim of this initiative is to increase transparency of companies in upstream and downstream sector by addressing both environmental and social risks and promote the cooperation with the Government of the DRC and affected local communities. Some big companies included in the initiative are Zhejiang Huayou Cobalt (upstream sector) and Samsung SDI (downstream sector) (RCI, 2016).

Another standard developed through collaboration of RCI with RMI is the Cobalt Refiner Supply Chain Due Diligence Standard. Procurement responsibilities is the most significant part of this standard including due diligence and risk management. Corporations are encouraged to engage with actors in the supply chain to identify and mitigate risks. This can be achieved by introducing a supply chain policy that is complied with either Chinese Due Diligence Guidelines or OECD Guidance. Additionally, it is necessary to establish internal management support and strengthen relationships with suppliers to obtain the ''sensitive'' information needed and increase transparency. Companies that fall within the scope of the standard are the upstream ones processing cobalt ore or concentrates. The effective date of the standard was on January 2022, so very few companies have started complying with it including Glencore (CRSCDD, 2021).

5.3 Domestic upstream sector in the DRC

5.3.1 Input-output structure

Based on the history of the DRC in the mining segment, it is obvious that the country has played a substantial role in the mining and extraction of cobalt. As previously reported in Table 1 of section 4.3.2, the DRC accounts for about 74% of cobalt that was globally mined and extracted in 2023, which verifies country 's leading position in these segments until today. This position of the country is also justified by the fact that it holds the most substantial share of the world's cobalt reserves. In 2022, the global cobalt reserve was estimated at 8.3 million tons and the DRC had 4 million tons, which is equivalent to approximately 48% (Andreoni et al., 2023).

As for the refining stages, the DRC has minor involvement with China dominating, as it is depicted and analyzed in the geographical scope of the upstream sector (chapter 4.3.2). The path that China followed to become the lead player in this segment incorporates both public and private sector. In particular, state-owned enterprises (SOEs) have played a substantial role in the development of energy infrastructure, while the government allocated significant resources to build infrastructure, especially in the early stages of country 's reform. As for the private sector, many Chinese firms collaborated with foreign companies through joint venture businesses in the context of developing the local industrial infrastructure. In this way, advanced technologies and equipment are used, so there are modern refining plants in China, which can handle large volumes of cobalt concentrate. China has also the advantage of producing the resins that are necessary for this process, so the production cost is reduced (Sharmili et al., 2023). There are two main factors related to the environment of the DRC that justify its limited role in the most valuable stage of the upstream sector: infrastructure development and investment environment.

Beginning with the infrastructure development, it has been negatively affected during the last decades by conflict and instability, especially in the eastern regions where little progress has been made except near international trade zone. While some development has occurred around Lubumbashi and along the lower Congo River, this is not enough at a national level. Apart from the security reasons, the extreme weather conditions and in conjunction with the high freight tariffs in the transportation network hinder foreign firms to construct refining plants in the DRC (KPMG, 2014).

Reliable electricity infrastructure is another huge problem in the DRC, with transmission and distribution systems suffered, so it is very difficult for the country to integrate in energy consuming segments. The country is dealing with energy deficit, which necessitates many mining firms to operate with their own hydroelectric schemes, so the electricity cost is much higher than expected (KPMG, 2014). The energy deficit is reflected in table 3, where some key electricity indicators are presented for the DRC in comparison with China.

Table 3 – Key electricity indicators for China and DRC

	China	**DRC**
Total electricity production (GWh)	8,598,977	13,190
Electricity consumption per capita (MWh)	5.8	0.14
Access to electricity (% of population)	100	20.8
Industrial electricity consumption (TJ)	26,402	15,964,815

Source: IEA, 2021

There is a huge difference between the two countries in the electricity consumption per capita and the industrial electricity consumption, which poses a challenge for the development of new projects. To increase these two indicators, the DRC should exploit its energy sources to boost the electricity generation. Although the country has a huge hydropower potential estimated at 100,000 MW, it has already developed only the 2.8% of its total capacity (African Natural Resources Centre, 2021). This is quite problematic given the fact that only 20.8% of the population has access to electricity. For this reason, the government set a target of 60% access by 2025, which means a very significant expansion (KPMG, 2014). In 2020, the US government partner Power Africa, invested in two provinces of the DRC to provide solar energy systems. Furthermore, the government of DRC has assigned a project to its National Rural and Peri-urban Electrification and Energy Services Agency (ANSER), which aims at connecting 15 million extra residents to electricity by 2025, which is quite encouraging (U.S. Agency for International Development, 2023).

Another important step for the development of the infrastructure in the DRC is the collaboration with China in the context of the ''Angola Model''. China has been involved through a very interesting deal, where a copper company in the DRC exchanged its resources for infrastructure with two Chinese construction firms. In this way, China has more access to energy sources, while the DRC can raise capital and advance its infrastructure, so there are benefits for both parties (Jurenczyk, 2020). Additionally, there are projects were both public and private sector are involved. In one of them, Chinese companies built roads, railroads, hospitals, and universities in exchange for mining rights with Gecamines. Finally, the World Bank allocated significant funding to the country for infrastructure, particularly in energy and transportation system development (KPMG, 2014). In this way, there might be an opportunity for the DRC to upgrade in the high-value refining stages.

Concerning the investment environment, the inadequate infrastructure described in conjunction with the political instability makes the DRC a non-attractive environment for investors. Particularly in the east part of the country, a lot of projects cannot be finished according to the timeline due to shortages of electricity and water. Moreover, this region of the DRC is the most dangerous one, struggling with security issues, which affects investment decisions. Only Katanga, which is the largest industrial center of the country, is safe (KPMG, 2014). Some key governance indicators playing a substantial role for investors are presented in Table 4, where it is obvious that the DRC has quite low government effectiveness and political stability compared to China. The scale is from 0 to 100, with the higher numbers representing better governance performance.

Table 4- Key governance indicators for China and DRC

	China	**DRC**
Political stability and absence of violence	28.3	7.1
Government effectiveness	75.7	3.3
Control of corruption	56.2	4.3

Source: Worldwide Governance Indicators, 2021

Another issue is that the private sector in the country is underdeveloped, because the DRC is involved in the mining sector mainly through its state institutions. Thus, investors that may be interested cannot find easily local partners to develop their network. The UK tries to start businesses in the DRC through its Department for International Development (DFID). Its collaboration with the World Bank supports good governance and transparency in the mining segment of the DRC, which boosts economic growth (KPMG, 2014). Similar partnerships in the future will strengthen the business environment of the DRC, which is quite crucial for upgrading in the battery value chain.

5.3.2 Geographical scope of the domestic upstream sector

The analysis of domestic input-output structure, as presented in the previous chapter, shows that the DRC is involved only in mining and extraction of cobalt. While DRC's dominance in the mining and extraction stage suggests a promising future for the country in the processing stage, a deeper examination of the ownership structure reveals something different: most of the mining and extraction activities undertaken in the country is dominated by international enterprises that serves as first-tier suppliers to global lead processing firms in China and other developed countries.

Tables 5 and 6 show the landscape of mine ownership structure in DRC. Conceptually, the most common way of controlling a mine and its production is ownership. More precisely, a company should have ownership—either majority holding or partial ownership of the equity (at least 10%) through joint ventures- to have control. This means that the corporation has influence in the mine by introducing policies and taking part in strategic decisions, such as large investments and buying or selling subsidiaries (Ericsson et al., 2023). By knowing the percentage of interest and the amount of cobalt produced in each deposit, it is feasible to calculate how much control firms, and then countries, have in the mining sector. In Table 5, cobalt production per mine in 2023 is illustrated, with 171,371 tonnes of cobalt produced totally in the DRC. This number is calculated from data obtained for each mine in the DRC and for this reason is slightly different from the number presented in Table 1. Then, based on the ownership and production in the deposits of the DRC, the control of countries in the mining sector is depicted in Table 6, so it is clear the transition from a corporate to a national level.

Table 5- Cobalt mine ownership and production in the DRC

Cobalt mines in the DRC	Company	Origin	Ownership	Production (tonnes)
Tenke Fungurume Mining	CMOC	China	80%	20,250
	Gecamines	DRC	20%	5,063
Mutanda Mining	Glencore	Switzerland	95%	11,200
	DRC government	DRC	5%	589
Kisanfu (KFM Holdings)	CMOC	China	71.25%	27,000
	CATL	China	23.75%	9,000
	DRC government	DRC	5%	1,895
KOV, Mashamba East (Kamoto Copper Company)	Glencore	Switzerland	75%	27,600
	Gecamines	DRC	25%	9,200
Metalkol Roan Tailings Reclamation (RTR)	ERG	Luxembourg	100%	22,500
Ruashi	Jinchuan	China	75%	1,244
	Gecamines	DRC	25%	415

Deziwa	CNMC	China	51%	4,080
	Gecamines	DRC	49%	3,920
Luiswishi (Congo Dongfang Mining)	Zhejiang Huayou Cobalt	China	100%	10,000
Kinsevere	MMG	Australia	100%	5,000
Shituru	Pengxin	China	100%	7,000
Boss mining	ERG	Luxembourg	51%	1,530
	Gecamines	DRC	49%	1,470
Kambove Mining	CNMC	China	55%	1,328
	Gecamines	DRC	45%	1,087
TOTAL				**171,371**

Sources: CMOC, 2022; Glencore, 2023; ERG, 2022; Jinchuan, 2023; CNMC, 2022; Bujakera S., 2020; Crundwell et.al, 2020; Dehaine et. al, 2021

Table 6-Control of mining companies in the DRC

Company/Institution	Origin of company	Control
CMOC	China	28%
Glencore	Switzerland	23%
ERG	Luxembourg	14%
Gecamines	DRC	12%
Zhejiang Huayou Cobalt	China	6%
CATL	China	5%
Pengxin	China	4%
MMG	Australia	3%
CNMC	China	3%
Jinchuan	China	1%
DRC government	DRC	1%

The network of the mining environment in the DRC consists of international enterprises, local small mining companies and government institutions having their businesses in the region. As it is shown in Table 6, China Molybdenum Company Limited (CMOC) was the dominant party of mining sector in the DRC in 2023, surpassing Glencore, which was the global leader for many years. The Chinese firm has the largest share of cobalt production in the DRC, which is equal to 28%, through its substantial percentage of ownership in major mines, such as Tenke Fungurume Mining and Kisanfu (see Table 5). Glencore still holds a quite important position in the segment accounting for 23% of cobalt production. Then, ERG, which is based in

Luxembourg, fully owns the Metalkol mine, which justifies the significant contribution of the company in the total production.

Gecamines, which is the DRC ‘s state-owned firm, participates actively in many of these projects, but it has minority stakes, as it is shown in Table 5. This means that Gecamnines does not have significant influence over these assets, so its role is very dependent on the collaboration with the major international players. Additionally, the DRC government has very limited direct control in Mutanda and Kisanfu mines. Both the government and Gecamines control 13% of the cobalt production and it can be assumed that artisanal mining operations are incorporated in this percentage, because they do not report on their performance, so we do not have very reliable data for them. Overall, the country is integrated horizontally in the mining segment by having joint-venture businesses with the major mining firms, which reflects its limited control in this stage of the upstream sector.

5.3.3 Governance in the DRC

According to the chapter 4.3.3, the upstream sector of battery value chain is captive, so the DRC government is trying to give incentives to miners, which are the suppliers, to enhance their expertise and be more competitive. More precisely, the government has implemented some regulations to facilitate mineral exploration and extraction during the last decades. The liberalization of the mining sector in the 2000s, which was supported by the Mining Code, has led to the development of numerous mining projects. This influx of foreign capital has facilitated exploration activities in the DRC, as companies seek to capitalize on the country ‘s abundant cobalt resources. Additionally, the government in the DRC has engaged in partnerships with foreign investors, including Chinese state-owned enterprises, to enhance the exploration and extraction of these resources. The most famous contract was signed in 2000s and named Sicomines deal. This collaboration not only facilitated the extraction of cobalt, but also investments in developing infrastructure, including transportation network (Rubbers, 2020). In this way, partnerships can lead to economic growth of countries.

To further enhance its role and move up to refining stages, the DRC government adopts additional initiatives and policies that go beyond the extraction of cobalt. In particular, the government motivates the development of domestic refining plants by providing financial incentives, including tax breaks and subsidies for infrastructure, to the firms aiming at investing in this segment. In the context of taxation, the DRC also raised the tax on the exports of semi-processed materials so as to encourage firms to start investing in refining facilities locally (KPMG, 2014).

Nonetheless, these initiatives are not yet as efficient as the Belt and Road Initiative (BRI) that China implemented in its upgrading trajectory. The BRI was supported by large financial resources, such as investments from state-owned banks. In this way, China raised billions of dollars to allocate them to infrastructure projects, ensuring that the progress of projects is made without delays. At the same time, local enterprises played a substantial role in executing the BRI projects, because they were able to leverage their capacity to support large-scale infrastructure (Gereffi et al., 2022).

5.4 Midstream sector

Although the DRC has abundant cobalt resources, it has not been able to take part in the midstream sector of the battery value chain. The country cannot acquire knowledge from the joint ventures it has with companies involved in both upstream and midstream sector like Zhejiang Huayou Cobalt and Jinchuan. The main reason is that it lacks skilled workforce that can replicate the activities that joint partners do and being engaged in more advanced manufacturing. Especially, all the processes needed to mix cobalt hydroxide with other chemicals to produce the cathode require a specific level of expertise. Furthermore, the country does not have the energy infrastructure to support such an energy consuming sector like the midstream one. The current electricity network is inadequate, which is a barrier for the entry to refining stages of upstream sector, as it is aforementioned in chapter 5.1 (KPMG, 2014).

On the other hand, a typical example of a country that achieved to create a level of independency from its partners and participate in the midstream sector is China. It has achieved to dominate in all segments of the midstream sector, including both the manufacture of components and their incorporation in battery cells. This is attributed to several approaches and drivers. Firstly, Chinese enterprises grew their businesses through vertical integration. For instance, the upstream companies Zhejiang Huayou Cobalt and Jinchuan integrated in battery cell manufacturing, and this is reflected through buying new assets or making strategic partnerships and joint venture businesses. These firms expanded their control over more processes and in this way, they reduced production costs (Wang, 2022).

Another quite crucial factor was the significant investment in R&D. Midstream activities are quite complex involving many different materials and processes that are quite demanding, mainly from an energy perspective. In particular, the production of electrodes is very energy intensive (see figure 11), while the equipment associated with the assembly of electrodes in the battery cell requires substantial capital cost (Sharmili et al., 2023). Technological innovations largely helped improve the product quality and make the processes more efficient. Furthermore, the battery market competition is so strong that without continuous technological breakthroughs, it is very difficult for a firm to stay competitive (Wang, 2022).

5.5 Downstream sector

As a consequence of not being integrated in the midstream sector, the DRC does not take part in the downstream sector. China is by far the lead player also in the downstream sector, as it is depicted in chapter 4.5.2 (figure 13). The main factor contributing to this result is the comprehensive vertical integration, like the midstream sector. Chinese firms like CATL and BYD that initially were specialised in battery cell manufacturing, achieved to integrate in the production of battery packs and their integration in electric vehicles. To do this, they built the gigafactories, which required high capital expenditure. China raised $27.8 billion of FDI in 2015 to upgrade in higher value activities, which was mainly attributed to the stable political environment and the motivating regulatory framework (Gereffi et al., 2022). At the same time, safety standards are quite high in downstream sector, because these sectors affect to a great extent the properties of the final product. This is a main challenge for the DRC due to the lack of laboratories including testing equipment and stuff with required expertise.

Additionally, attracting Foreign Direct Investment (FDI) is difficult for the DRC due to the underdeveloped banking sector. The nature of FDI in the DRC is primarily concentrated in mining due to the country 's vast reserves of minerals including cobalt and copper. However, investments are also made in offshore oil fields. In 2022, FDI into the DRC was around $1.8 billion, which was driven by investments in offshore oil fields and mining. All these investments are necessary for supporting large-scale projects that local financial institutions cannot fully support due to their limited financial capacity. Citi, the only U.S. bank in the DRC, offers commercial services, but has very limited involvement in project financing. Some other banks, such as Rawbank and Trust Merchant Bank (TMB), allocate funding to small and medium-sized enterprises (SME). For instance, Rawbank received 15 million USD line of credit from the World Bank 's International Finance Corporation (IFC) to finance reliable SME projects (International Trade Administration, 2024).

6. Opportunities and challenges for the DRC

6.1 How could the DRC enter the refining segment

The DRC 's position in the upstream sector of the battery value chain seems promising to follow a functional upgrading. The country currently exports semi-processed forms of cobalt, like cobalt concentrate, which limits its value addition. Since Zambia will hold around 3% of the cobalt refining segment by 2030, the historic cooperation of the DRC with Zambia and the establishment of the DRC-Zambia Battery Council could be beneficial towards upgrading in the refining stage, which is a higher value activity (Africa Renewal, 2022). Thus, the DRC expects to become a more competitive player in the cobalt refining market and for this reason the DRC 's Ministry of Primary, Secondary and Professional Education has already established a collaboration with the Brookings Institution on the Optimizing Assessment for All (OAA) initiative. The initiative aims at equipping residents of the DRC with the level of expertise required to participate in refining activities (Kim et al., 2019). Despite these efforts and the privilege of large availability of raw materials that the country has, there are various barriers preventing the DRC from advancing its capabilities and become a competitive player in the global refining market.

6.2 Challenges for the DRC to upgrade in the refining segment

Understanding the following challenges is quite crucial for assessing the feasibility of functional upgrading in the global battery value chain.

1. *Lack of infrastructure*

The country has substantial infrastructure deficits including limited energy supply and poor transportation network. The energy deficit is significant with less than 21% of the population having access to electricity and very low electricity consumption per capita, as it is shown in Table 3 (Worldwide Governance Indicators, 2021). This has a quite negative impact on industrial activity, as reliable energy is quite critical for energy intensive processes like refining. In addition, the inadequate transportation system associated with the high freight tariffs raises the operation costs in mining and extraction activities and prevents the expansion of the country in the refining stage of upstream sector, where logistics is very important for the operation of the plants needed (KPMG, 2014).

2. *Political instability and government issues*

Based on the governance indicators (see table 4), the DRC ranks very low in political stability and control of corruption (Worldwide Governance Indicators, 2021). There are frequent disruptions in mining projects due to political conflicts that increase the risk associated with such high capital-intensive segments like refining. This in conjunction with the unpredictability triggered by corruption decreases investor 's confidence.

3. *Investment environment in the DRC*

The combination of poor infrastructure with political instability creates an unattractive environment for foreign investments. Many projects are delayed and have higher cost than the one planned due to the electricity deficits and the security issues. Investors' uncertainty is reflected in the fact that the DRC was ranked at 183 out of 189 countries regarding its business environment (KPMG, 2014). Although there have been some efforts to improve the investment environment, such as the partnerships with China (Angola model and Sicomines deal), they are mainly focused on cobalt extraction rather than moving to refining activities (Jurenczyk, 2020). The government has given some tax incentives in the context of initiatives to promote domestic refining, but these initiatives are not enough compared to the Belt and Road Initiative (BRI) implemented by China.

4. *Limited local control in mining and extraction*

Although the DRC is the lead country in cobalt production based on its geology, international firms have significant control over most cobalt deposits, which is a very significant barrier according to table 5. The country 's rich mineral resources have attracted international interest, so foreign enterprises have become majority shareholders in most of the cobalt deposits. These companies have considerable influence over strategic and investment decisions within the mining sector in the DRC. On the other hand, the DRC 's state institution Gecamines has very limited control and lack both the financial resources and industrial expertise to compete with the lead players. As for the artisanal mining operations, many of them lack transparency and are not under a legal framework, so they cannot contribute to large scale upgrading in another segment of the upstream sector (World Bank, 2021).

5. *Type of governance in the upstream sector*

The governance structure from chapter 4 leads to another challenge for the DRC in its pursuit to upgrade to higher value activities. The upstream sector is characterized by a captive governance structure, where processing companies (buyers) dominate. More precisely, Chinese enterprises control 72% of the refining segment (see figure 10), so they have substantial influence over mining companies, which are the suppliers in the upstream sector. This dominance creates a dependency for the DRC 's mining sector on these processing firms, which makes difficult the moving up of the country.

6. *Lack of transparency*

As it is analyzed in the institutional context of the DRC, transparency is a huge problem with which the country has been dealing for many years, especially in the mining segment (Ericsson et al., 2023). Despite its vast mineral wealth, the DRC cannot ensure that its cobalt mining sector operates ethically. The industry has been struggling with human rights abuses, including child labor, poor working conditions, and environmental degradation (World Bank, 2021). These issues have led to increased scrutiny from international corporations who are seeking more ethically and sustainably sourced materials for their products.

The rise of initiatives such as the Responsible Cobalt Initiative is a step towards addressing these issues and limit the operation of ASM to some extent. However, achieving full transparency and ethical compliance in the DRC's cobalt mining industry remains a complex task. For the DRC to fully integrate into the battery value chain in a sustainable manner, stronger governance and enforcement of labor laws will be necessary.

7. Conclusion and recommendations

In summary, although the DRC has vast cobalt resources, the potential for functional upgrading in the refining stage of the upstream sector is not encouraging. The country confronts significant challenges including lack of infrastructure and competition from international lead players. In addition, the weak governance and institutional context make the environment in the DRC unattractive for investors, so the country cannot build the required capacity to upgrade. As a result, the potential of the DRC for moving in the refining stage of the battery value chain is very limited. Significant improvements in industrial infrastructure, political environment and financial incentives are necessary to make the investment environment of the DRC more attractive.

7.1 Strategies and policies suggested

To address the challenges, development of strategies by state institutions and policies by the DRC government are needed to create an enabling environment for upgrading. Institutions should focus on capacity building and cooperation with suppliers, customers, and industry associations to facilitate the implementation of their strategies. As for government authorities, they can play a quite substantial role by creating a conducive policy environment that incentivize investments in private sector.

The partnership between the DRC and Zambia presents a strategic opportunity to develop local refining capacity, but it is not enough. The DRC 's state institutions should leverage more regional synergies by establishing joint ventures with firms having businesses in other countries of African Union. South Africa has a quite mature mining sector with decades of experience in processing a wide range of minerals. South African enterprises have developed advanced technologies in cobalt refining, with a capacity around 900 tons per year at Base Metals refinery. Furthermore, the economic context in this region is very encouraging with many financial institutions having substantial capital resources to support large-scale projects (Yager, 2019). As a result, DRC 's institutions can acquire knowledge and expertise, and have access to advanced technologies in refining sector. In this way, an integrated regional refining industry can be shaped that could serve as a platform to attract foreign direct investment

(FDI), which may give the opportunity to Gecamines to become competitive in global refining market.

To further enhance their chances for upgrading, local state institutions and small-scale firms should adopt international ESG standards. By complying with global benchmarks, they can improve their reputation and become a trusted partner of big international players. This effort can be reinforced by active participation in industry initiatives promoting sustainable practices. In this way, institutions prove their commitment to responsible sourced minerals, which is a quite important factor for investors.

Apart from the strategies followed by enterprises and institutions, the government should also contribute to the effort of upgrading. The context-specific type of policy could be applied, as it in analysed in chapter 2, to provide tailored suggestions to the DRC based on the challenges and opportunities identified (Humphrey, 2004). One policy recommendation is to leverage the existing tax incentives on dividends and loans, and reform the judicial system to improve the business climate.

Another beneficial policy is related to the expansion of upstream capabilities of the country. The government can build strategic partnerships with international firms specialising in processing and refining technologies. This would facilitate through the context of the Battery Council established between DRC and Zambia. Moreover, the DRC government can cooperate with the African Union to create a continental framework for upgrading in battery manufacturing industry.

7.2 Answering the research questions

Main research question
Can the DRC leverage its abundant cobalt resource to upgrade in the battery value chain?

To answer the main research question, the following four sub-research questions will be answered sequentially.

Sub-research question 1
What is the global landscape and governance structure of the battery value chain?

The Global Value Chain (GVC) Framework, which is structured in chapter 3, is used to give a holistic picture of the global battery value chain in chapter 4. It is applied for all the sectors of the value chain, including upstream, midstream, and downstream. Firstly, the activities give important information about the technological and capital requirements. Then lead players at a global level are highlighted and then the governance structure help understand the power dynamics and the relationships of the actors.

The DRC participates in the mining and extraction stages, while China dominates the refining stage of the upstream sector. This sector is characterized by captive governance structure, which means that mining companies in the DRC have limited expertise in complex activities and are driven by Chinese refining firms. As for the midstream sector, it adds the highest value in the total battery value chain, but it is controlled substantially from China. The downstream sector including the integration of battery packs in end products has high safety standards and is also mainly controlled by China. Furthermore, both midstream and downstream sector have relational governance structure justifying the long-term partnerships between suppliers and buyers, which makes challenging the entry of new players.

Sub-research question 2
How is DRC currently integrated in the global battery value chain and what explains the observed pattern of integration?

After applying the GVC framework at a global level, it is also used specifically for the DRC (chapter 5). From the analysis of technological and capital requirements needed to participate in each sector at a global level, the DRC is integrated in the upstream sector, and more precisely in the mining and extraction of minerals, mainly due its abundant cobalt resources and its long history in the mining segment. However, the implementation of the GVC framework in the upstream sector of the DRC, gives valuable input for the control that the country has in the mining segment. As a result, international enterprises dominate in the local mines of the DRC, with the country being integrated through the joint ventures of its state institutions with these lead players. In the refining stages, the DRC plays a very minor role mainly due to the infrastructure underdevelopment and the problematic investment environment. These reasons are substantiated by the weak electricity and governance indicators of the country compared to China.

Sub-research question 3
What are the DRC's upgrading opportunities and challenges in the global battery value chain?

Based on the analysis made for the DRC, it seems that there is an opportunity for the DRC to make a functional upgrading in the refining stages of the upstream sector. This can happen by levering the historic cooperation with Zambia that has invested in the refining of cobalt. At the same time, the social context in the DRC is going to be improved with more skilled workforce after the collaboration of the DRC government with Brookings Institution.

Nevertheless, there are some major barriers preventing the DRC from upgrading in the refining segment of battery value chain. Lack of infrastructure, including inadequate energy supply and poor transportation system, increase operational costs even in moderate energy-intensive segments like refining, so industrial progress is hindered. Additionally, political instability and corruption exacerbate uncertainty in the investment environment of the DRC, which makes investors reluctant. The comparison that is made with China 's trajectory to upgrading helps realize the extent of improvement needed in both energy infrastructure and political stability.

Despite efforts made to reinforce the investment climate, such as tax incentives and partnerships with neighbouring countries, the environment in the DRC remains quite challenging for an entrepreneur to start business. This becomes even worse by the limited local control over cobalt mines, as international enterprises have substantial influence over strategic decisions. In this way, Gecamines and the small-scale operations in the DRC cannot be competitive. The captive governance structure of the upstream sector further compounds the DRC 's dependency on international corporations, with Chinese firms as buyers of semi-processed cobalt dominating the upstream sector.

Another significant challenge incorporates transparency and human rights concerns in the cobalt mining industry of the DRC. As ESG regulations are introduced for both financial institutions and non-financial undertakings, lead international players are seeking ethically sourced materials. Some initiatives currently issued, such as Responsible Cobalt Initiative, and frameworks, such as ASM Cobalt Normative Framework, look promising, especially in the limitation of the illegal framework under which many small-scale companies in the DRC operate. However, creating a sustainable environment aligned with main international regulations requires robust governance reforms and more strict labour standards in the country.

Sub-research question 4
How can the DRC incentivise the development of battery value chain by implementing policies?

Finally, the DRC does not currently have the capacity to upgrade in the refining stages of the upstream sector, which is reflected in the strong challenges identified. Some suggestions for both government and state institutions are made to facilitate the upgrading of the DRC. Small scale companies and state institutions in the DRC should leverage on the partnership between the DRC and Zambia and develop more strategic partnerships with other African countries having capacity to support the refining stage like South Africa. At the same time, the government should develop policies tailored to the motivation of investments in refining plants. As for the government in the DRC, it should give further financial incentives to investors and reform the judicial system to tackle the political instability.

8.Discussion

8.1 Limitations on the GVC framework

There are some limitations to the approach applied in this thesis, as it is stated below:

In the description of governance structure of each sector in the value chain, the GVC framework did not help to analyse more elaborately the relationships between suppliers and buyers. The complexity of transactions and the difficulty to codify knowledge need extra tools to gain a deeper understanding and specify the power asymmetries in each sector.

Furthermore, the GVC framework emphasizes on the economic upgrading, so the social and environmental issues are not addressed in a detailed way, so some information might be missed. For instance, the labour market and the processes through which minerals are sustainably sourced are not analysed extensively, so the institutional context of the DRC may not be very comprehensive, which affects the challenges that the country faces.

Finally, due to time constraints, interviews with key stakeholders, including financial institutions, were not conducted, so this thesis relies only on publicly available data, which may restrict the depth of insights regarding the economic conditions in the DRC. Interviews with potential investors in the DRC could have given more reliable information about the challenges they face when they consider investments in the country. Moreover, such interviews might have provided valuable insights into how investors perceive the policy environment of the DRC, including the new regulations introduced.

8.2 Future research

This study makes an analysis at a national level to identify upgrading opportunities for the DRC in the battery value chain. Nonetheless, future research could benefit from a study more focused on a corporate level, which investigates the strategies of major companies in the upstream sector, such as Glencore and ERG. If in the GVC framework, qualitative and quantitative data for specific enterprises are gathered, researchers should acquire deeper understanding of the governance structure within the battery value chain. This approach would also lead to a closer examination of the factors driving these companies to remain in the upstream sector and not to expand into midstream and downstream sector. The strategic choices of these firms may give substantial information about the barriers preventing the functional upgrading of the DRC.

References

African Natural Resources Centre (2021). Lithium-Cobalt Value Chain Analysis for Mineral Based Industrialisation in Africa.

Africa Renewal (2022). Trade ties: Zambia and DRC sign cooperation Agreement to manufacture electric batteries, create jobs.

Andreoni A., Avenyo E. (2023). Critical Minerals and Routes to Diversification in Africa: Linkages, Pulling Dynamics and Opportunities in Medium-High Tech Supply Chains

ASM Cobalt Normative Framework (2023).

Bair J. (2005). From commodity chains to value chains and back again. *New Haven, CT: Yale University*

BloombergNEF (2021). The Cost of Producing Battery Precursors in the DRC

Bridge G., Faigen E. (2022). Towards the lithium-ion battery production network: Thinking beyond mineral supply chains. *Energy Research & Social Science, 89*

Bujakera S. (2020). Congo opens Chinese-owned Deziwa copper and cobalt mine. Retrieved from: https://www.reuters.com/article/idUSKBN1ZE14F/.

Campagnol N., Pfeiffer A., Tryggestad C. (January 2022). Capturing the battery value-chain opportunity.

Cattaneo O., Gereffi G, Miroudot S., Taglioni D. (2013). Joining, Upgrading and Being Competitive in Global Value Chains: A Strategic Framework.

Cobalt Refiner Supply Chain Due Diligence Standard (August 2021).

Cross B., Kirkland C. L. (2021). Petrological control on chargeability with implications for induced polarization surveys. *Journal of Applied Geophysics, 188*

Crundwell F. K., Du Preez N. B., Knights B. D. H. (2020). Production of cobalt from copper-cobalt ores on the African Copperbelt—An overview, *Minerals Engineering, 156.*

Dehaine Q., Tijsseling L. T., Glass H. J., Tormanen T., Butcher A. R. (2021). Geometallurgy of cobalt ores: A review. *Minerals Engineering, 180.*

Deng D. (2015). Li-ion batteries: basics, progress and challenges. *Energy Science & Engineering, 3(5).*

ECA (2021). Producing Battery Materials in the DRC Could Lower Supply-Chain Emissions and Add Value to The Country 's Cobalt

ERG (2022). Annual report 2022.

Ericsson M., Löf A., Löf O., Müller D.B. (2023). Cobalt: corporate concentration 1975–2018. *Mineral Economics.*

Federal Consortium for Advanced Batteries (2021). Executive Summary: National Blueprint for Lithium Batteries 2021-2030.

Gereffi G. (2001). Beyond the Producer-driven/Buyer-driven Dichotomy: The evolution of global value chains in the internet era. *IDS Bulletin, 32(3)*, 30

Gereffi G., Bamber P., Fernandez-Stark K. (2022). China 's New Development Strategies

Gereffi G., Fernandez-Stark K. (2011). Global Value Chain Analysis: A Primer

Gereffi G., Humphrey J. (2005). The governance of global value chains. *Review of International Political Economy, 12*

Glencore (2023). Annual report 2023.

Gulley A. L. (2023). China, the Democratic Republic of Congo, and artisanal cobalt mining from 2000 through 2020.

Gulley A. L. (2022). One hundred years of cobalt production in the Democratic Republic of the Congo. *Resources Policy 79*

Heimes H., H., Kampker A., Lienemann C., Locke M., Offermanns C., Michaelis S., Rahimzei E. (2018). Lithium-ion battery cell production process

Humphrey J. (2004). Upgrading in global value chains.

Jinchuan (2023). Annual report 2023.

Jurenczyk (2020). Analyzing China's "Angola Model": A Pattern for Chinese Involvement in Africa. (2020). *The Strategic Review for Southern Africa*, *42*(2), 43-61

Kaplinsky R., Morris M. (2016). A Handbook for value chain research.

Kim H., Tsangala J., M., Hedidar W., Care E. (2019). Integrating 21st century skills in the classroom in the Democratic Republic of the Congo

Kisumbule P. K. (2014). Geochemical Exploration for Copper - Cobalt in the Democratic Republic of Congo, Central African Copperbelt: A case study on PR851.

KPMG Global Mining Institute (2014). Democratic Republic of Congo. Country mining guide.

Kummritz, V., Taglioni, D., Winkler, D. (2017). Economic Upgrading through Global Value Chain Participation.

Lewchalermwong N., Masomtob M., Lailuck V., Charoenphonphanich C. (2018). Material selection and assembly method of battery pack for compact electric vehicle. *Materials Science and Engineering, 297*

Lydall M., I., Auchterlonie D., A. (2011). The Democratic Republic of Congo and Zambia: A growing global 'hotspot' for copper-cobalt mineral investment and exploitation

Mayoral A. (2022). U.S. Challenges in EV Battery Production.

MMG (2022). Annual report 2022.

Niri A., J., Poelzer G., A., Zhang S., E., Rosenkranz J., Pettersson M., Ghorbani Y. (2024). Sustainability challenges throughout the electric vehicle battery value chain. *Renewable and Sustainable Energy Reviews, 191.*

Panasonic (2023). Annual report 2023.

Pettinger K., H., Dong W. (2017). When Does the Operation of a Battery Become Environmentally Positive. *Journal of The Electrochemical Society, 164(1)*

Pipkin S., Fuentes A. (2017). Spurred to Upgrade: A Review of Triggers and Consequences of Industrial Upgrading in the Global Value Chain Literature. *World Development, 98*, 536-554.

Raikes P., Jensen M., F., Ponte S. (2000). Global Commodity Chain Analysis and the French Filiere Approach. *Economy and Society, 29(3), 390-417*

Rashidi-Nejad F., Suorineni F. T., Asi B. (2014). Open pit or block caving? A numerical ranking method for selection

Responsible Cobalt Initiative (RCI) (2016). Retrieved from: https://respect.international/responsible-cobalt-initiative-rci/.

Responsible Minerals Initiative (RMI) (2017). Retrieved from: https://www.responsiblemineralsinitiative.org/.

Rubbers B. (2020). Governing new mining projects in DRC. A view from the HR department of a Chinese company. *The Extractive Industries and Society 7, 191-198*

Sharmili, N., Nagi, R., Wang, P. (2023). A review of research in the Li-ion battery production and reverse supply chains. *Journal of Energy Storage, 68*.

Sharma M. (2020). Economic and Social Upgrading in Agriculture Sector: A Case of South Asia. *Journal of Applied Agricultural Economics and Policy Analysis, 2020, Vol. 3, 20-27*

Shengo M., L., Kime M.-B., Mambwe M. P., Nyembo T. K. (2019). A review of the beneficiation of copper-cobalt bearing minerals in the Democratic Republic of Congo. *Journal of Sustainable Mining, 18, 226-246*

Silvas E., Hofman T., Murgovski N., Etman P., Steinbuch M. (2017). Review of optimization strategies for system-level design in hybrid electric vehicles

Stecca M., Ramirez Elizondo L., Soeiro T., B., Bauer P., Palensky P. (2020). A Comprehensive Review of the Integration of Battery Energy Storage Systems into Distribution Networks. *IEEE Open Journal of the Industrial Electronics Society, 1, 46-65*

Swartz B., Donegan S., Amos S. (2009). Processing considerations for cobalt recovery from Congolese Copperbelt ores

The World Bank (2021). Report: Universal Access to Sustainable Energy Will Remain Elusive Without Addressing Inequalities.

Thermo Fischer Scientific (2012). Thermo Fischer Scientific introduces ultra performance packages for oil and gas and mineral exploration

U.S. Agency for International Development (2023). Power Africa in Democratic Republic of the Congo. Retrieved from: https://www.usaid.gov/powerafrica/democratic-republic-congo

Venditti B., Parker S. (2024). Visualizing Cobalt Production by Country in 2023

Wang X. (2022). How China Came to Dominate the Global EV Lithium-ion Battery Value Chain: Lessons and Opportunities for Africa. Centre for Business and Development Studies. Centre for Business and Development Studies. Policy Brief No. December 2022

World Bank (2021). Cobalt in the Democratic Republic of Congo

Worldwide Governance Indicators (2021).

Yager T., R. (2019). The Mineral Industry of South Africa