A Strategic Evaluation of Battery Industry Development in the DRC-Zambia Region and Beyond

Figure 1: Battery Industry image, created by DeepAI

Thesis Graduation Project | MSc Complex Systems Engineering and Management | Faculty of Technology Policy and Management

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Executive Summary

The global pursuit of sustainability goals has led to many electrification efforts, and correspondingly, increasing battery demand. While electric vehicles remain the dominant driver, batteries are also increasingly used for stationary applications to increase electricity grid stability, which has proven necessary due to fluctuating renewable energy supply. This growth has made battery manufacturing a strategic industrial sector. Countries are increasingly looking to position themselves within the battery mineral value chain, in which China effectively holds a dominant position across all segments. However, for many of its battery minerals, which are considered critical minerals, it relies on Africa.

Zambia, and especially the DRC, play a crucial role in this value chain due to their mineral endowments, which include cobalt (the DRC produces approximately 70% of the world's cobalt). Despite these endowments, these countries see only a small portion of the total value created in the value chain. Most of the value lies in more downstream activities, such as cell manufacturing and assembly, in which the DRC and Zambia play no role. Recent efforts have sought to capture more value, such as the DRC-Zambia Battery Plant initiative.

This thesis investigates whether this is feasible and whether a more viable alternative lies within regional coordination. The main research question is: *"How can enabling conditions for battery manufacturing development be used to assess the feasibility of the BEV initiative between the DRC and Zambia, and what alternative pathways exist for battery industry development in the region?"*

To answer this, three sub-questions are addressed. First, global success and failure determinants were identified in past and established battery industries and categorised using the PESTLE framework (Political, Economic, Social, Technological, Legal, Environmental). These determinants include industrial policy, infrastructure, regulatory quality, access to finance, and technical expertise. Second, Zambia and the DRC were benchmarked against these determinants. Zambia emerged as a much stronger candidate for battery industry development than the DRC. It has relatively strong institutions, governance, and a strong regulatory environment. On these determinants it even scored similarly or better than some established manufacturing countries like China and Hungary. The DRC, by contrast, faces severe challenges across all PESTLE dimensions. It scores particularly poorly in governance, workforce skills, and innovation. Third, to support a fully integrated Central-Southern African battery value chain, South Africa was included due to its strong industrial capabilities, automotive sector, and battery-related expertise. With this essential component, a regional strategy could be designed by matching battery value chain process complexities to the three countries' national capabilities to create national specialisations. Next, the Regional Innovation Systems framework is used to identify required coordination institutions, knowledge infrastructure, and coordination mechanisms.

The final strategy proposes that the DRC could expand on intermediary cobalt refining, Zambia develop precursor production, and South Africa establish battery subcomponent and pack manufacturing. It already has pack assembly and recycling/reuse capabilities, which it could expand. Additional key recommendations include the establishment of a SADC Battery Council, based on the European Battery Council, the development of specialised training programmes, and the pooling of regional demand and investment capabilities. However, the success of this strategy is largely dependent on national-level implementation. Each country must perform its due diligence, which includes institutional reforms, targeted policy development, and financial mobilisation.

Contents

1. Introduction

The global pursuit of sustainability goals to lower greenhouse gas emissions has increased the demand for electricity worldwide, with many applications and processes being electrified (O'Keefe et al., 2024). This has caused a dramatic surge in global battery demand (McKinsey, 2023). While electric vehicles (EVs) have been the primary driver, batteries are also increasingly used for electricity grid stability and renewable energy integration (IEA, 2024c). As this growth is expected to continue over the coming decades, battery manufacturing has become a strategic industrial sector for many countries. In response, governments worldwide are positioning themselves within the battery mineral value chain (BMVC), in which China currently holds a dominant position across all stages (Greitemeier et al., 2025).

However, China depends heavily on external sources for the raw materials needed for battery production. Several African countries play a key role in this, most notably the Democratic Republic of the Congo (DRC), which accounts for over 70% of global cobalt mine output (Statista, 2025), and Zambia, known for its copper reserves within the Copperbelt region, which it shares with the DRC. Other relevant minerals include lithium, nickel, graphite, and manganese (Zalk, 2024). Despite this central role in supplying critical minerals, the DRC and Zambia capture only a minimal share of the total value added in the BMVC (Deberdt, 2024).

There are two main reasons for this. First, most value creation occurs in more complex downstream stages, such as cell manufacturing and assembly, which are exclusively performed outside of Africa (Cervantes Barron et al., 2024). Second, while African countries mine many of the critical minerals needed for these processes, much of the extraction is controlled by foreign companies, often Chinese, due to colonial legacies and recent acquisitions to secure supply (Gulley et al., 2019).

In an effort to move beyond extractivism and capture more value, African governments have long aimed to industrialise their mineral sectors. A recent example is the Battery and Electric Vehicle (BEV) initiative between the DRC and Zambia, which aims to create a special economic zone to host a regional battery industry for producing precursors and potentially EV batteries (UNECA, 2024). However, past industrialisation efforts have struggled due to structural barriers such as weak infrastructure, technological imitations, macroeconomic instability, and political uncertainty (AfDB, 2021; UNCTAD, 2020).

Given this track record, it is crucial to carefully assess the feasibility of the DRC-Zambia initiative before major commitments are made. Strategic decisions of this nature depend on many interrelated complex factors. To address these, this thesis uses the PESTLE framework, which allows for a structured assessment of Political, Economic, Social, Technological, Legal, and Environmental conditions that influence industrial development (European Commission, 2025).

While policy reports and academic studies increasingly see the potential and role of Africa in the BMVC, few have examined whether countries like the DRC and Zambia actually meet the conditions required to develop a battery industry. Existing studies are often fragmented and offer general policy recommendations without a structured feasibility assessment. This thesis addresses this gap by integrating global insights with region-specific analysis and contributes a replicable framework for systematically assessing whether a country or region possesses the conditions required for battery industry development.

2. Literature Review

To understand the feasibility of battery industry development in the DRC-Zambia region, a multidisciplinary approach is required that combines insights from global BMVC dynamics, region-specific studies, and industrial development. This chapter reviews the existing body of literature relevant to this thesis to get a better understanding of the context and to identify where knowledge gaps remain. It begins with a structured overview of the initial literature review using the PRISMA methodology, which was used to establish a research direction. This is expanded upon with the literature knowledge gained throughout the thesis process. The chapter concludes by identifying a gap in the literature.

2.1. Initial Literature Review

To perform this, the PRISMA methodology was used. This consists of four steps: identification, screening, eligibility, and inclusion (Moher et al., 2010). By exploring different databases (e.g. ScienceDirect, Google Scholar, and Scopus) using keywords related to the geographical scope and BMVCs, a total of 11 articles were identified. This process is visualised below in Figure 2.

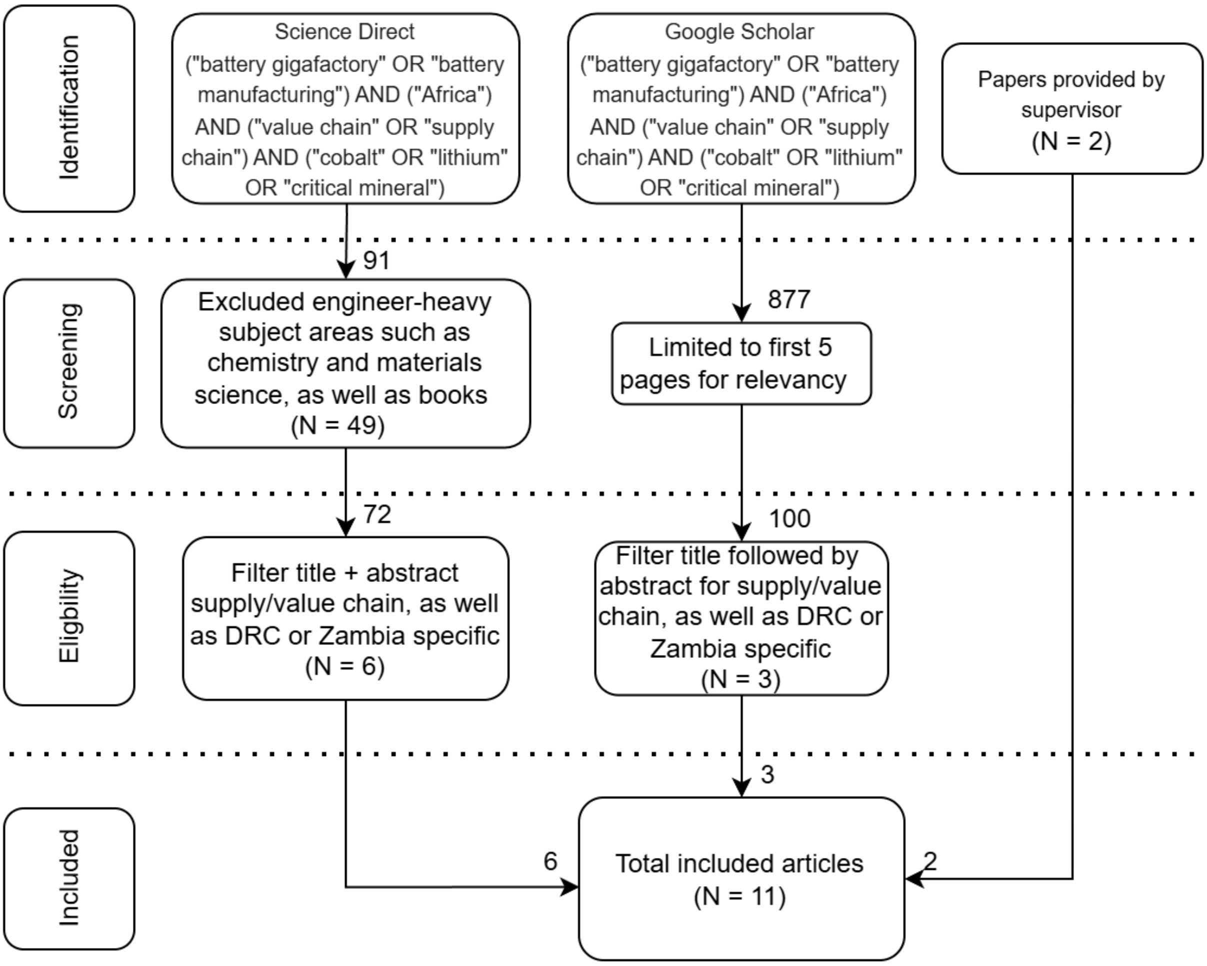

Figure 2: PRISMA search process

An analytical table of these articles can be found in Appendix 11.1, in which the title, date, geographical scope, key topics/findings, and the type of study are presented. This table shows that BMVCs have become increasingly important and are covered through techno-economic, socio-political, engineer, and policy-focused perspectives. There are also some articles that focus specifically on the potential in certain African countries. Examples include: "Will Congo Move up the Battery Supply Chain" (Deberdt, 2024) and "A Battery Industry in the Central African Copperbelt?" (Musasa and Lutandula, 2024).

After this initial review, which helped identify a knowledge gap centred around the feasibility of the BEV initiative between the DRC and Zambia, the literature review was expanded with the knowledge and sources gained throughout the thesis. The following section will go through the different findings, which are divided into two parts: Global Insights on Battery Value Chains, and African Perspectives on Battery Industrialisation.

2.2. Expanded Literature Review

Global Insights on Battery Mineral Value Chains

A recurring theme is the uneven global distribution of battery manufacturing. While mineral extraction is concentrated in resource rich countries such as Australia, the DRC, China, and Indonesia, most of the value-added activities are dominated by China, South Korea, and Japan. More recently, some EU countries now host large battery manufacturers. This is an example of a response by many major economies to establish their own battery manufacturing capabilities to improve industrial sovereignty and energy security (Martinus and Nunez Picado, 2021).

The BMVC is characterised by large barriers to entry at mid- and downstream stages due to large technological and industrial requirements. Studies by Brodd and Helou (2013), Liu et al. (2021), and more recently Reinsch et al. (2024), highlight this disparity between up- and downstream segments of the BMVC due to processes requiring precision engineering, large capital investment, advanced intellectual property, or even reliable electricity.

Policy-oriented studies, such as by X. Wang et al. (2022), Montmasson-Clair et al. (2021) and Bridge and Faigen (2022), show that battery industrialisation also depends much on institutional capacity and coordination, as well as market conditions. China's success has been attributed by many to its long-term industrial strategy and vertical integration across the entire value chain. This has positioned China in a unique position where they have much more control over all stages of the BMVC than other battery manufacturing countries. Where the Chinese presents a top-down approach, the European Battery Alliance presents a model for public-private coordination around infrastructure, R&D, and regulations.

Collectively, these examples show a multi-dimensional understanding of battery industry development. However, this is only collectively. No studies synthesise the enabling conditions for battery industry development, as most studies look only at a part of the BMVC, and from a specific perspective, not a general one. Additionally, the studies remain extremely centred around countries with established battery manufacturing capabilities, which also have relatively strong infrastructure, R&D, and regional demand to name a few enabling conditions. Therefore, it remains unclear how these insights can be used by resource-rich but industrially weak nations to capture more value from BMVCs.

African Perspectives on Battery Industrialisation

To gain more insight in this, there are also some studies, although much less, that investigate possibilities for battery industrialisation in Africa. Historically, there have been many failed initiatives and commitments to industrialise African nations. According to the AfDB (2021), this can be attributed to structural constraints which includes limited infrastructure, unreliable energy supply, limited access to capital, skills gap, weak public-private coordination, and low regulatory predictability. These barriers are reflected in studies by Ado et al. (2025) and Karkare and Medinilla (2023), who argue it will be very challenging for African countries to leverage their critical minerals due to the abovementioned barriers. They recommend actions such as targeted industrial policy, ensure market access, private-public coordination, and improving human rights. Deberdt (2024) concludes that it is unlikely that the DRC will be able to develop a battery industry in the short to medium term. There has also been research by BloombergNEF (2021) to investigate the costs of producing battery precursors in the DRC, which concludes that the levelized costs are very similar to that of the U.S., China, and Poland. However, if the value chain were to become integrated, meaning that the cobalt would not need to be acquired at spot prices, it would of course be significantly lower. Again, to realise such an industry, it suggests an improvement of infrastructure, R&D, market demand, and a strengthening of the DRC's institutions.

While some of the abovementioned examples take a more general perspective, they mostly look at the barriers and potential present in African countries. Additionally, in relation to the DRC-Zambia initiative, there is currently no feasibility study.

2.3. Knowledge Gap

While the reviewed literature offers important contributions to understanding the dynamics and development of BMVCs, it remains fragmented. Most studies focus on isolated segments of the value chain or approach it from a single disciplinary perspective. As a result, there is a lack of integrative research that bring together the different perspectives which together form the overall set of conditions required for successful battery industry development.

This gap is especially apparent in the African context. Although numerous studies identify barriers such as poor infrastructure, political instability, or limited human capital, these factors are typically examined in isolation. Research by Deberdt (2024, Ado et al. (2025), and Karkare and Medinilla (2023) provide important insights into specific constraints, but do not assess how these conditions interact to shape the overall feasibility of industrial development. Furthermore, much of the literature on African countries remains descriptive or normative: policy proposals are often presented without a grounded evaluation of whether the underlying conditions are present to support them, or even whether the final goal is realistic.

At the same time, global research on battery industry development tends to focus on countries with already mature industrial ecosystems. These studies often assume access to reliable electricity, technical expertise, established infrastructure, and strong supportive institutions and policies. As such, their findings offer limited guidance for less industrialised countries that do not possess these preconditions.

Despite the increasing interest in the role of Africa in BMVCs, there is currently little structured, and no comparative assessment of whether countries like the DRC or Zambia are realistically able to develop their own battery industries. Nor is there sufficient literature that considers how these countries could realistically upgrade their roles within the BMVC. This gap, which is integrative, comparative, and feasibility-oriented in nature, is one that this thesis seeks to address.

3. Research Design

The previous chapter outlined a clear knowledge gap: the absence of an integrative understanding of the enabling conditions for battery industry development, as well as the lack of a feasibility assessment of the DRC-Zambia initiative. This chapter sets out the research objective, the central research question and sub-questions, and the overall structure of the study. It concludes with a brief reflection on the thesis' relevance to the MSc Complex Systems Engineering and Management (CoSEM) programme.

3.1. Research Objective and Questions

Building on the identified knowledge gap, the objective of this study is threefold: (i) to assess the conditions that enable battery manufacturing development, (ii) to assess the feasibility of the DRC-Zambia initiative, (iii) to explore alternative regional pathways for, possibly more realistic, battery manufacturing development.

These objectives lead to the following main research question: *"How can enabling conditions for battery manufacturing development be used to assess the feasibility of the BEV initiative between the DRC and Zambia, and what alternative pathways exist for battery industry development in the region?"*

To answer this main research question, the following sub-questions are answered sequentially, each in its own chapter:

1. *"What conditions influence the success or failure of developing a battery industry, based on global past and present cases?"*
2. *"How does the context of the DRC-Zambia region compare to the identified conditions for successful battery industry development?"*
3. *"What strategic design can support the development of a regional battery industry, and what policy recommendations can guide this design?"*

3.2. Outline of the Thesis

The structure of the thesis follows the sequence of the research sub-questions, but before it addresses these, it also provides the theoretical and contextual background. Chapter 4 provides a background overview of the global battery mineral value chain (BMVC), and examines its main processes, key minerals, major international actors, and trends. This is to provide context for later assumptions and comparisons. Chapter 5 outlines the methodology. Then, Chapters 6, 7, and 8 sequentially answer the three sub-questions, followed by the discussion and conclusion in Chapter 9.

3.3. Relevancy to the MSc CoSEM

This thesis fits well within the CoSEM MSc programme and the Energy specialisation. It addresses a large and socio-technical problem: how to design a viable battery industry in the DRC-Zambia region through regional coordination. The work combines technological perspectives (e.g. by describing battery mineral value chain processes and assigning complexity levels) and institutional and policy analysis by using typical CoSEM frameworks, namely PESTLE and Regional Innovation Systems.

It also has a clear design element through a regional strategy, which tackles technical and coordination challenges, such as infrastructure gaps, knowledge transfer, and stakeholder alignment. It proposes system-level interventions such as the establishment of new institutions and expanding existing agreements and models.

Overall, this reflects what CoSEM essentially does: applying multidisciplinary methods to engineer and manage complex systems.

4. Background on Battery Mineral Value Chains

4.1. Introduction to the Battery Mineral Value Chain

The Battery Mineral Value Chain (BMVC) refers to the interconnected stages involved in the sourcing, processing, and transformation of raw materials into battery subcomponents and batteries. These are primarily lithium-ion batteries used in electric vehicles (EVs), grid storage, and portable electronics. These stages span from the extraction of critical raw materials to refining, cell and module manufacturing, assembly, and recycling (Hund et al., 2020; IEA, 2023b).

As global efforts to decarbonise intensify, the BMVC has emerged as a strategically important industrial sector. Batteries are not only crucial for electrifying transport and enabling intermittent renewable energy sources, but also serve as a key connector in national strategies for industrial competitiveness and technological sovereignty (Zalk, 2024). The rise of electric vehicles and grid-scale storage has led to exponential growth in battery demand. According to BloombergNEF (2021), global demand for lithium-ion batteries is expected to grow more than fivefold between 2020 and 2030.

Control over BMVCs has become increasingly important in industrial and foreign policy as countries seek to reduce their dependency on access to critical raw material supply chains. The concentration of processing and manufacturing capabilities in a select few countries, particularly China, has raised concerns over supply chain resilience and strategic vulnerability (Greitemeier and Lux, 2025; Zalk, 2024). At the same time, mineral-rich but industrially underdeveloped regions are exploring pathways to capture more value by participating in more downstream processes.

4.2. Key Stages and Processes in the Battery Value Chain

Figure 3 visualises the production stages of the BMVC. It consists of: (i) raw material extraction, (ii) processing and refining, (iii) subcomponents production (iv) cell manufacturing, (v) cell pack assembly, and (vi) end-of-life. Some stages are relatively simple, while others can be extremely complex and capital-intensive.

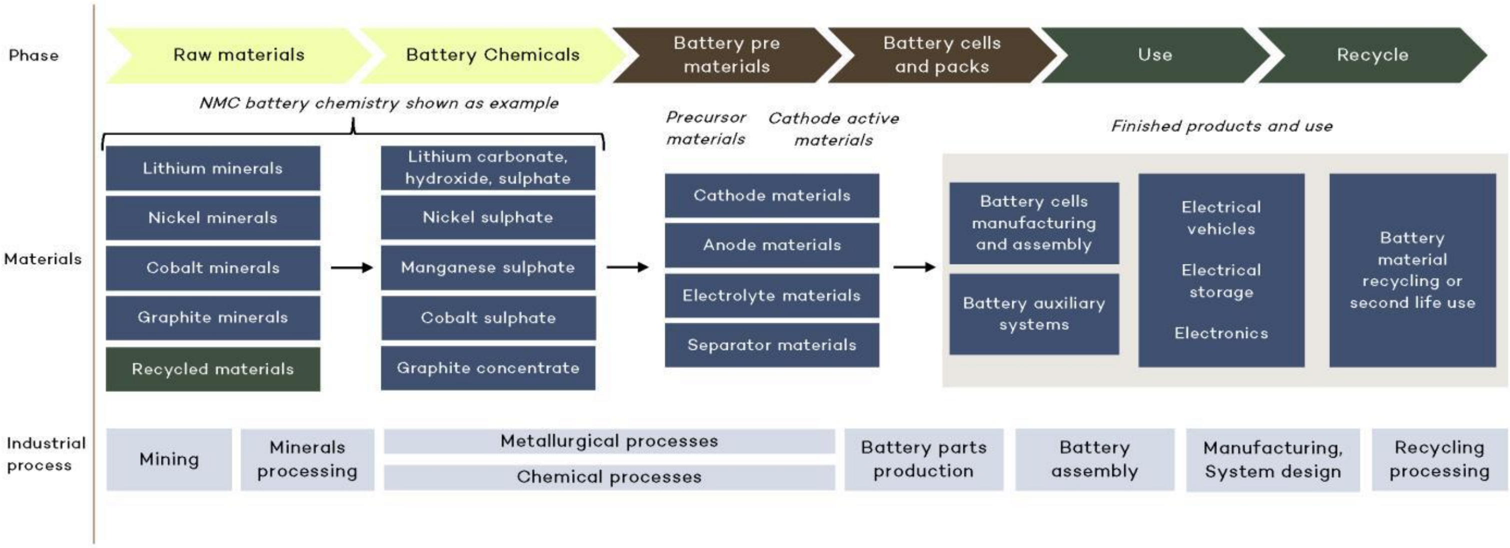

Figure 3: BMVC processes (*Battery Value Chain | AFRY*, 2025)

Raw Material Extraction

This first stage involves the mining of key battery-relevant minerals, including lithium, cobalt, nickel, graphite, copper, and manganese. These resources are highly concentrated geographically. For example, the DRC accounts for about 70% of global cobalt output, Indonesia dominates nickel production, and lithium is extracted in large quantities from Australia and South America's "lithium triangle" (IEA, 2024f; USGS, 2024). Extraction methods vary by material: lithium can be extracted from hard rock (spodumene) or bines, while cobalt and copper are typically mined from large-scale or artisanal open-pit operations. Although this stage is less technologically complex than later stages, it is resource-intensive in terms of land, labour, and water (especially for lithium). It is also frequently associated with environmental degradation, deforestation, and poor safety or labour conditions, particularly in countries with weak institutions and regulatory oversight (Amnesty International, 2016; Deberdt, 2024).. In many cases, mine permitting alone can take up to a decade (Sharmili et al., 2023)

Processing and Refining

Once extracted, minerals must be processed into high-purity compounds suitable for cell production. For lithium, this typically involves calcination and leaching to produce lithium hydroxide; cobalt and nickel undergo roasting, solvent extraction, or high-pressure acid leaching to create metal sulphates. Graphite is refined using either high-temperature purification or chemical processes using hydrofluoric acid (Montmasson-Clair et al., 2021; Sharmili et al., 2023). These processes demand substantial chemical engineering expertise and industrial-scale infrastructure. Purity requirements typically exceed 95% for battery-grade precursors (Grageda et al., 2020). This stage generates significant wastewater and emissions and requires reliable, low-cost energy. Globally, China leads in this phase despite having much less raw material production, refining roughly 60% of the world's lithium and 74% of its cobalt (Greitemeier et al., 2025; IEA, 2024f)

Subcomponents Production

Refined materials are then used to produce key battery subcomponents: cathodes, anodes, electrolytes, and separators. Cathode production involves combining lithium compounds with metals such as cobalt, nickel, and manganese to form active materials like NMC (Nickel Manganese Cobalt), LFP (Lithium Iron Phosphate), or NCA (Nickel Cobalt Aluminium). These are typically formed through co-precipitation or other mixing techniques and applied as slurries to aluminium foils. Anode production involves purifying and shaping graphite, then coating it onto copper foils. Both steps require precision machinery, extremely energy-intensive drying, and micro-scale quality control (Sharmili et al., 2023). Together, cathode and anode manufacturing account for a substantial share of total production costs and energy use, at up to 46% and 20% respectively (Accenture and Fraunhofer, 2024).

Electrolytes are produced by mixing lithium salts with organic solvents to allow for ion mobility, while separators (typically polyethylene or polypropylene films) are designed to prevent short circuits while allowing the abovementioned ion flow. Electrolytes and separators, although less capital-intensive than the electrodes (cathodes and anodes), are decisive in a battery's safety and lifespan (Sharmili et al., 2023). Again, China dominates this phase, accounting for 90% of cathode capacity, 97% of anode capacity, and 60% of electrolyte production (IEA, 2024e)

Cell Manufacturing

At this stage, electrodes, separators, and electrolytes are integrated into complete battery cells. The process involves slurry mixing, coating, calendaring (precision rolling to control thickness), stacking, electrolyte filling, and formation cycling. Many of these steps require cleanroom technologies and high degrees of automation. The electrolyte filling and formation steps alone can account for over 60% of total manufacturing equipment costs and a third of overall manufacturing costs (Accenture and Fraunhofer, 2024; Nekahi et al., 2025; Sharmili et al., 2023). Precision and consistency at the micron scale are critical for performance metrics, safety, and yields, making this the most complicated process within the value chain (Attia et al., 2025).

Pack Assembly

The battery cells are combined into modules and assembled into final battery packs, with integrated cooling systems, battery management software, sensors, and safety systems. While this stage is less chemically complex, it still demands mechanical precision and system integration expertise. Battery packs must conform precisely to the form factors of their final applications, especially in EVs, and typically undergo extensive safety and thermal testing (Liu et al., 2021). Due to the weight of battery packs, this process often occurs near EV assembly sites to minimise logistics costs and make it easier to ensure form factors. It also allows car manufacturers to be more flexible with experimenting. Tesla's Nevada facility and Volkswagen's Salzgitter plants are examples of close cell-pack integration (Reinsch et al., 2024)

End-Of-Life

As battery deployment scales up, the importance of efficient end-of-life processing grows. This phase includes second-life use (e.g. for stationary storage) and recycling. Recycling uses pyrometallurgical, hydrometallurgical, or direct methods to recover valuable materials such as lithium, cobalt, nickel, and copper. While technically feasible, recovery efficiency, cost-effectiveness, and collection logistics remain significant challenges (Attia et al., 2025). Regulatory frameworks such as the EU Battery Regulation (2023/1542) are beginning to require collection and recycling targets. China has implemented similar producer responsibility systems, but global capacity remains far behind production (European Union, 2023; Sharmili et al., 2023).

4.2. Major Global Actors

The global BMVC is characterised by an uneven distribution of industrial capabilities and resources. While certain countries dominate the upstream extraction of specific minerals, others control refining, component manufacturing, and battery cell assembly. This division is reinforced by a relatively small number of large firms, often supported by state-led industrial policies. The following section maps the dominant countries and firms across the key stages of the BMVC introduced in the previous section.

Raw Material Extraction

Cobalt production is heavily concentrated in the DRC, which accounts for approximately 70% of global output. Most of this cobalt is exported in raw or minimally processed form (IEA, 2024g). Lithium, by contrast, is primarily produced in Australia, with China and Chile also playing significant roles. In South America, lithium is extracted from brine deposits located in the so-called “lithium triangle”, which includes Chile, Argentina, and Bolivia (USGS, 2024). Nickel production is dominated by Indonesia, which supplies around 62% of the global market. The country has recently implemented export restrictions and strategic investments to move up the value chain and expand its industrial capacity (Lahadalia et al., 2024). Graphite, both natural and synthetic, is overwhelmingly controlled by China, which holds an estimated 82% market share. Minor production is also present in Madagascar and Mozambique (IEA, 2024g). Copper production is much more geographically fragmented than other battery minerals. Chile is the leading producer with 23% of global output, followed by the DRC at 14%, and Peru at 10% (IEA, 2024g).

Processing and Refining

Although raw material extraction is geographically dispersed, China dominates mineral refining across nearly all major battery inputs: lithium (57%), copper (46%), cobalt (74%), and graphite (93%). Nickel refining is the only exception, with Indonesia leading at 44%, followed by China at 21% (IEA, 2024g). China has also been able to create refining hubs to pool resources and infrastructure, located in provinces like Jiangxi and Guangdong (Kulik et al., 2025).

Major firms include Rio Tinto and BHP Group from Australia, Zijin Mining and Jiangxi Copper from China, CMOC Group Ltd from the DRC, and PT Aneka Tambang from Indonesia.

Cathode and Anode Material Production

China also dominates the production of cathode and anode active materials, accounting for around 90% of global cathode manufacturing capacity and over 97% of anode production (IEA, 2024d). However, this dominant position is mainly due to their large domestic demand for LFP batteries. FOR NMC chemistries, which offer high energy density and are preferred in the West, China’s market share is lower at around 50%, with South Korea, the EU, and the USA capturing smaller but significant shares (Inclán and Wicke, 2023). Major firms include CATL and BTR from China, LG Chem from South Korea, BASF from Germany, and Hitachi Chemicals from Japan.

Cell Manufacturing

China accounts for over 75% of global lithium-ion battery cell production capacity, led by major firms including CATL, BYD, and CALB (IEA, 2024d). Other major actors include South Korea, Japan, the EU, and the USA. Japan historically held a strong position, with Panasonic being the worldwide major producer, but has steadily lost market share to China. LG Chem from Korea remains a strong worldwide producer, as well as Samsung, SDI, and SK On. In Europe and the USA, manufacturing capacities have been increasing via Tesla, Northvolt, ACC, and FREYR.

Cell Pack Assembly

This phase is typically located close to end-use markets, most notably automotive assembly plants. EV makers such as Tesla, BYD, Volkswagen, and Ford have thus chosen to perform this step themselves, or in close collaboration with suppliers such as CATL or BYD. For example, Tesla, which is well known for its gigafactories, has collaborated with CATL to design the factories and received the individual cells necessary for assembly from CATL, Panasonic, and LG Chem.

End-Of-Life

China currently leads global battery recycling capacity, supported by national policy mandates and vertically integrated industrial actors. The EU and the USA are investing in upgrading their recycling ecosystems, but capacity remains limited. Major players include GEM Co. and Brunp Recycling (a subsidiary of CATL) in China, Redwood Materials from the US, and Umicore from Belgium.

When looking at the expected lithium-ion battery manufacturing capacities in 2025, China holds 2.93TWh, the USA 0.44TWh, the EU 0.33TWh, and the rest of the world 0.27TWh (IEA, 2023c).

4.3. Geopolitical Dependencies and Strategic Risks

The global BMVC is increasingly shaped by geopolitical interests. As the energy transition accelerates and battery demand surges, control over critical minerals, processing capacity, and manufacturing technologies have emerged as a strategic power. This section briefly explores these geopolitical relationships.

Supply Chain Concentration

A defining characteristic of the BMVC is the extreme geographic concentration of processing and manufacturing in China. While countries such as Australia, Chile, the DRC, and Indonesia dominate raw material extraction, the midstream and downstream stages are overwhelmingly controlled by China, which accounts for over 60% of lithium refining, 90% of cathode and anode production, and over 75% of cell manufacturing capacity (Greitemeier and Lux, 2025; IEA, 2023d).

This asymmetric structure has raised concerns among many Western governments and industries about supply chain vulnerabilities. Particularly due to trade restrictions, export controls, or geopolitical conflicts. There is a good recent example of this: “China hits back at

US tariffs with export controls on key rare earths” (Jackson et al., 2025). The US and EU have both classified battery-related minerals as critical raw materials and have been implementing policies to reduce their dependency on Chinese supply chains.

Industrial Policy and Resource Nationalism

Simultaneously, producer countries such as Indonesia and the DRC are increasingly looking to assert more control over their resources. Export bans, firm requirements, and downstream investment are part of a broader effort to capture more local value and avoid being stuck into low-value extractive roles. However, these strategies also introduce risks of trade disputes and can discourage foreign investment, especially if the context is deemed unstable to investors (Lahadalia et al., 2024; Zalk, 2024).

Technological and Regulatory Competition

Technological competition in the BMVC is increasingly centred around control over intellectual property and production knowledge. Greitemeier and Lux (2025) show that while China leads in patent volume across nearly all stages of cell manufacturing, its influence remains limited due to low citation impact and fragmented patent ownership. In contrast, Japan and the United States maintain smaller but more influential patents, reflecting deeper integration across the value chain. Steps like cell formation and ageing remain under-patented yet strategically valuable, which can suggest opportunities for emerging actors. As countries integrate IP strategy with industrial policy, patents become not only indicators of innovation, but also tools of strategic leverage.

At the same time, regulatory instruments are increasingly used to shape competitive conditions. The EU Battery Regulation 2023/1542 mandates traceability, recycling, and due diligence standards that serve not only environmental goals, but also function to stabilise the industry and attract investment. There are similar regulations and quotas in China to set standards and create a stable investment climate. Similarly, the US Inflation Reduction Act provides subsidies and tax incentives to domestic or allied supply chains. Together, these mechanisms establish rules that favour regional players and may act as non-tariff barriers and thus increase international competition.

4.4. Technological and Market Trends

Technological innovation and shifting market demand are rapidly reshaping the global battery industry. While current manufacturing capacity is largely aligned around lithium-ion battery chemistries, there are promising alternatives that may completely alter the existing supply chains and the strategic positions and relevance of existing regions and firms. At the same time, demand-side shifts, particularly in electric mobility and renewable energy, are expanding the range of battery applications and accelerating the need for storage solutions.

Battery Chemistry and Design Trends

The dominant lithium-ion chemistries currently in use are nickel manganese cobalt (NMC), nickel cobalt aluminium (NCA), and lithium iron phosphate (LFP). Each chemistry has its trade-offs in energy density, cost, safety, and raw material dependency. NMC and NCA batteries offer high energy density, which makes them more suitable for long range EVs, but rely on critical and expensive materials like nickel and cobalt. LFP, by contrast, is cobalt-free, cheaper, and more thermally stable, but with significantly lower energy density.

Over the past years, LFP has gained significant market share, particularly in China, where they are widely used in urban EVs and stationary storage. Their success is driven by a combination of lower cost, local supply chains, and sufficient performance for short-to-medium range vehicles. Recent market reports indicate that LFP batteries accounted for over 40% of EV battery demand in 2023, and their adoption is shifting to Western markets as well (IEA, 2023b).

More recently, solid-state batteries are widely regarded as a transformative next-generation technology. By replacing the flammable liquid electrolyte with a solid material, these batteries promise better safety, faster charging, and higher energy density. However, there currently remain significant technical hurdles, such as lithium dendrite growth and high manufacturing complexity and costs (Zhao et al., 2023). Most projections do not anticipate large-scale deployment in the coming few years, though firms like Toyota and QuantumScape are investing heavily in R&D (Business Wire, 2024; Heights, 2025).

Demand Growth and Application Shifts

The largest driver of battery demand remains the rapid expansion of the EV market. EV sales exceeded 14 million globally in 2023 and are projected to reach over 30 million by 2030, with China, the US, and the EU as leading regions (IEA, 2024d). But beyond mobility, stationary energy storage is emerging as a key application. Variable renewable energy sources such as solar and wind are intermittent in nature, meaning that for these applications to be fully utilised at a large scale, energy storage is a necessity. While different behavioural and system solutions are being implemented, such as peak shaving and load shifting, grid-scale storage is inevitable. According to IEA projections, installed grid-scale battery storage capacity is expected to increase nine- to 14-fold from 86GW in 2023, depending on the scenario (IEA, 2024e).

Stationary applications require different performance characteristics than EVs, such as high cycle life, lower energy density, and lower safety constraints, which may favour alternative chemistries. Sodium-ion batteries and flow batteries, for example, are gaining attention for their low cost, ease of sourcing, and long operational lifetimes, despite their relatively low technological maturity, with the EU providing several large R&D subsidies (European Commission, 2024).

5. Methodology

This chapter outlines the research approach used to address the main research question: *"How can macroeconomic factors be used to assess the feasibility of the battery gigafactory initiative in the DRC-Zambia region, and what alternative pathways exist for battery industry development in the region?"*

5.1. Research Approach

This study uses a qualitative, exploratory, and comparative research design (Creswell and Creswell, 2018). It is of a qualitative nature because it aims to understand the complex dynamics of several macroeconomic factors that influence battery industry success, rather than the analysis of certain macroeconomic datasets associated with the countries that host battery industry or the battery industry itself. It is also exploratory, given the limited academic literature that addresses the dynamics between the different macroeconomic success factors, especially in the context of sub-Saharan Africa, as discussed in the knowledge gap. The design is also comparative, as it aims to systematically compare the different macroeconomic conditions of the DRC-Zambia region with the global macroeconomic benchmarks derived from existing or previous battery industries worldwide. Using this approach, the strengths and weaknesses of the DRC-Zambia initiative can be identified on a strategic level, as well as regional alternatives for battery industry development.

5.2. Analytical frameworks

To analyse the feasibility of battery industry development in the DRC-Zambia region, this study applies two complementary analytical frameworks: the PESTLE framework and the Regional Innovation Systems (RIS) framework. PESTLE provides a structured assessment of the external macroeconomic environment, while RIS focuses on the internal dynamics of innovation, institutional capacity, and stakeholder interaction. Together, these frameworks align with the exploratory and comparative nature of the research, enabling a broad contextual analysis.

5.2.1. PESTLE framework: A Macroeconomic Feasibility Assessment

The PESTLE framework is a widely used strategic analysis tool for identifying and categorising external macroeconomic conditions that influence the success or failure of initiatives or interventions. PESTLE stands for **Political**, **Economic**, **Social**, **Technological**, **Legal**, and **Environmental** factors. It is particularly used for research aimed at understanding the context of interventions or initiatives. Table 1 highlights the PESTLE dimensions along with several parameters that are commonly used.

Dimension	**Key Parameters**
Political	Governance structure and stability; policy coherence; credibility of industrial strategy; public-private coordination.
Economic	Cost conditions (labour, energy, logistics); macroeconomic stability; access to capital; trade agreements.
Social	Demographics and skilled labour; societal support; community engagement; social infrastructure (housing, transport, etc.).
Technological	Presence of RD and innovation institutions; technology access and transfer; workforce competencies; innovation infrastructure.

Legal	Legal transparency and predictability; international norm alignment; implementation capacity for industrial regulations.
Environmental	Carbon intensity and renewable energy; environmental impact assessments; compliance with regulations; reputational risks.

Table 1: Common PESTLE parameters

PESTLE has been widely used as an analytical framework in both academic and policy literature to understand the variety of strategic-level factors that influence industrial development. Across its distinct dimensions, there are numerous examples from the battery industry that illustrate context-specific enablers and constraints.

In the Political dimension, Germany's success in battery manufacturing is partially credited to EU-aligned industrial strategies and strong institutional coordination, while South Africa's efforts have seen institutional fragmentation (Martinus and Nunez Picado, 2021; Montmasson-Clair et al., 2021). In the Economic dimension, Poland was able to attract substantial battery investment due to its relatively low labour costs and access to the EU market, whereas Chile struggled with financing constraints and a weaker macroeconomic environment (Irarrazaval and Carrasco, 2023). For the Social dimension, the town of Skellefteå illustrates the need for robust social infrastructure, as the town had to expand its services significantly to accommodate Northvolt's workforce (OECD, 2023). In terms of Technology, East Asia's battery dominance is closely tied to long-term investment in innovation systems. A great example of this is China's Huizhou cluster, Japan's NEDO, and South Korea's KEIT (CORFA, 2025; Greitemeier et al., 2025). The Legal dimension is well-illustrated by the EU's Battery Regulation 2023/1542, which mandates sustainability and traceability standards for battery production and reuse, which offers long-term predictability, thereby mitigating investor risk (European Union, 2023). Lastly, for the Environmental dimension, Sweden and Norway have successfully branded their battery production as "green", due to their highly renewable energy-mix reliant on hydropower. In contrast, Indonesia has faced international backlash for harmful environmental practices such as deep-sea nickel disposal (Jones et al., 2020).

Beyond these dimension-specific examples, broader academic applications further demonstrate the versatility of PESTLE. De Andres et al. (2017) used PESTLE to assess investment risks for ocean energy technologies in Europe, concluding that environmental regulation, policy coherence, and technological readiness jointly shaped investment feasibility. Gupta et al. (2025) proposed a hybrid fuzzy AHP-TOPSIS method to quantify PESTLE risk factors in automotive supply chains, enabling more structured prioritisation of mitigation strategies. The European Commission regularly applies PESTLE to support context assessments, particularly in development cooperation and industrial policy planning (European Commission, 2025).

PESTLE is also frequently used together with the well-known SWOT analysis to inform strategic decision-making in both public and private sectors. For example, Widodo et al. (2019) assessed the business model of an e-commerce firm using PESTLE-SWOT integration; Zaurez Afshar and Hussain Shah (2025) evaluated competitiveness in a public sector organisation; and Amega et al. (2024) examined how power companies in emerging economies address reliability and safety challenges by classifying PESTLE dimensions under SWOT categories.

These examples demonstrate that the PESTLE framework is both academically grounded and practically versatile. Its application across a wide range of context supports its use in this study as a structured tool for identifying and categorising the enablers and barriers to battery industry development. In the following section, each PESTLE dimension is examined in more detail, highlighting the specific types of conditions that influence the feasibility of battery industry development, with a few examples of how these condition shape shaped real-world cases.

In this thesis, the PESTLE framework is used to answer the first and second sub-questions. It is particularly suitable for several reasons: (1) It provides a comprehensive and structured foundation to identify determinants for battery industry development across diverse global contexts, while also providing a strategic overview; (2) It allows for comparative assessment between global cases and the DRC-Zambia context, as well as regional alternatives; (3) It aligns with the qualitative and strategic-level nature of this research, relying on secondary data sources.

However, some trade-offs must also be acknowledged. The PESTLE framework is inherently descriptive and dependent on the availability and consistency of secondary data. This is an issue particularly relevant in sub-Saharan Africa, where data may be outdated, incomplete, or inconsistent. Moreover, while PESTLE effectively maps the broad strategic-level context, it tends to overlook institutional interactions and stakeholder dynamics. These aspects are only partially addressed through the complementary framework RIS, which will be introduced in the next section. Nevertheless, important meso- and micro-level, as well as actor-specific aspects, remain beyond the scope of either framework.

5.2.2. RIS framework: Guiding Regional Policy Design

The Regional Innovation Systems (RIS) framework is a conceptual tool used to understand how innovation emerges from the interaction between firms, institutions, and policy actors within a specific regional context. Developed by Asheim and Gertler (2009), RIS shifts the focus from individual firms to the systemic conditions that enable or constrain innovation-driven development.

Application of RIS in Literature

The RIS framework has been widely applied to examine how institutional configurations and actor collaboration shape regional innovation dynamics.Tödtling and Trippl (2005) distinguish between three types of RIS: metropolitan, old industrial, and peripheral. They argue that each type requires differentiated policy strategies, particularly with regard to institutional coordination and knowledge infrastructure. Asheim and Coenen (2005) further contribute to the framework by analysing how different knowledge bases (e.g. analytical, synthetic, and symbolic) interact with RIS structures to influence innovation performance. Their findings highlight the importance of tailoring policy support to the dominant knowledge base and industrial profile of a region. Meanwhile, Doloreux and Parto (2005) review RIS applications in both advanced and emerging contexts, showing that institutional fragmentation and weak coordination mechanisms often limit the success of RIS-based policies in less developed regions.

Application of RIS in this Thesis

These studies demonstrate that while RIS is most commonly used as a diagnostic framework, its conceptual structure also offers a foundation for designing institutional components in regions seeking to establish or expand industries. In this thesis, the RIS framework is not used to assess the current innovation capacity of the DRC-Zambia region. Rather, it is used in a design-oriented way to inform policy strategies and actor configurations that could support the development of a regional battery industry in Central-Southern Africa. RIS complements the PESTLE-based feasibility analysis by identifying the institutional, organisational, and systemic components that need to be developed to create a foundation fit for battery manufacturing development.

Several core components of the RIS framework are particularly relevant in this context. These include the development of knowledge infrastructure, such as technical education and the role of universities and innovation institutes in supporting skills and research capacity. Intermediary organisations, such as innovation hubs or public-private partnerships, can help reduce coordination failures and connect stakeholders across sectors. Effective policy coordination between vertical and horizontal layers and sectors of governance, such as energy, education, and trade, is essential to ensure a coherent and long-term industrial strategy. Clarifying the roles of industrial actors, including SMEs (Small and Medium Enterprises) and public enterprises, is also crucial for supporting local participation and integration along the value chain. Finally, system-level interaction mechanisms such as industry clusters, R&D partnerships, and collaboration platforms are key to supporting collective learning and dynamic industry development.

5.3. Data sources

This study relies primarily on secondary data sources, in line with its macroeconomic and strategic-level scope. These include academic literature, industry reports, and policy documents. The use of such sources allows for the synthesis of diverse perspectives across the different PESTLE domains relevant to battery industry development.

Academic sources were identified through a structured literature review process outlined in section 2.1, using databases such as Scopus, ScienceDirect, and Google Scholar. Selection criteria included relevance to battery value chains, regional industrialisation, and innovation policy, with a preference for sources published after 2019 to ensure relevance to the rapidly evolving sector. Policy and industry reports, such as those by the World Bank, UNCTAD, the IEA, and national governments, provide grounded insights into current conditions.

For sub-question one, the selection included case studies and analyses of battery industry developments in countries such as Germany, China, Sweden, and Australia, with industry and policy reports by Business Sweden (2023), and Martinus and Nunez Picado (2021) providing key insights. For sub-questions two and three, country-level indicators related to infrastructure, energy mix, demographics, and governance capacity are sourced from global data repositories such as the World Bank, Statista, and the IEA. Where possible, triangulation is applied to increase validity and compensate for gaps in a single source.

6. Macroeconomic Determinants for Battery Industry Development

The objective of this chapter is to identify the macroeconomic conditions that have contributed to both the success and failure of existing and failed battery industries worldwide. This addresses the first sub-question of the study: *"What macroeconomic factors determine the success or failure of establishing a battery industry, based on global past and present cases?"* The findings of this chapter serve as a benchmark for the assessment of the DRC-Zambia initiative's feasibility in the next chapter.

To structure the analysis, the PESTLE framework is applied, which categorises macroeconomic conditions into six domains: Political, Economic, Social, Technological, Legal, and Environmental. By examining international experiences, such as positive examples in China and Germany, as well as less successful experiences in Sweden and Chile, this chapter synthesises overlapping factors

The chapter is organised into six sections, respectively each of the PESTLE dimensions, followed by a summary table to have a concise overview of the macroeconomic determinants and their positive or negative impact.

6.1. Political

Political factors are directly or indirectly present in almost all elements of battery industry development, or any industry. From shaping investment confidence and industrial capability to determining what land can be used, infrastructure development, and (financial) incentives. For countries aiming to develop a battery industry, political institutions and will must not only be stable, but also strategically aligned to guide the long-term, capital-intensive transformation.

6.1.1. Strategic Policy Coherence and Leadership

Globally, countries that have succeeded in developing a battery industry share a trait: long-term, strategically aligned policy frameworks. In Germany, the success of the Leipzig-Dresden-Berlin battery triangle reflects the coordinated efforts between federal ministries, EU industrial strategy (e.g. the European Battery Alliance), and large firms like Tesla and EAS batteries. The Verbund system that BASF uses is an excellent example of how horizontal and vertical coordination within industrial zones (*BASF Verbund*, 2024), together with strong state support, can develop an efficient and resilient industry (Martinus and Nunez Picado, 2021). In fact, they are planning to build a new Verbund site in Zhanjiang, which is recognised as one of the most important battery industry clusters in China (X. Wang, 2021).

Similarly, Japan's Kansai region has benefited from a multi-decade-long strategic policy support to enhance battery technology innovation, complemented by a Battery Strategy Research Centre. These institutions not only provide subsidies and R&D support, but also serve as intermediaries to align different stakeholders. This has been noted to be a critical ingredient in Japan's Battery cluster's longevity and resilience (Business Sweden, 2023).

China's approach, which is by far the dominant producer of all aspects in the battery value chain, with 70% of all EV batteries ever having been produced in China (IEA, 2025d), has been top-down and directive, currently leveraging the Made in China 2025 strategy and electric vehicle targets to drive domestic demand, provide subsidies, and protect domestic producers through the exclusion of foreign firms from subsidies (X. Wang et al., 2022). While this has raised international concerns over market failures, it also shows how deliberate government planning and temporary protectionism can help develop an industry.

6.1.2. Implementation Capacity and Institutional Strength

However, political will and ambition alone are not sufficient. The historical credibility of institutions and their actual capacity are better indications of whether the wills and ambitions are able to translate into physical outcomes. As an example, in Chile, despite resource advantages with large lithium deposits, the weak enforcement of public-private agreements and the inability to manage the different interests led to the failure of several BMVC upgrading initiatives (Irarrazaval and Carrasco, 2023; Martinus and Nunez Picado, 2021).

This can also be seen in South Africa, where there are significant ambitions to develop a battery industry, but these ambitions sadly have not yet been realised due to fragmented policies, limited agency coordination, and under-resourced governance institutions (Cloete, 2020; Montmasson-Clair et al., 2021). Although there have been good efforts to develop the right skills and expertise, for example, through the Energy Storage Consortium. Despite the translation of these ambitions into initiatives and roadmaps, the realisation of these has been hindered by the lack of horizontal collaboration between agencies and stakeholders (e.g. energy supply, minerals, trade, infrastructure).

6.1.3. Political Stability, Transparency, and Investor Risk

Political risk, including corruption, unpredictable government directions, and weak contract enforcement, play a crucial role in the decision-making process of firms when determining whether to perform large investments. Countries with clear permitting processes, predictable industrial policies, and transparent governance frameworks are more likely to attract battery-related foreign investment. For example, Australia is viewed as a possible site for battery industry hub development, and is overall seen as a relatively wealthy and stable country. Despite this, even Australia faces challenges due to the lack of coordination between different governmental, institutions and limited long-term political will to be able to upgrade their battery value chain (Martinus and Nunez Picado, 2021).

In Europe, efforts to secure battery manufacturing have also shown the importance of political and regulatory predictability. The EU Battery Regulation, adopted in July of 2023 (European Union, 2023). This regulation seeks to improve sustainability and traceability across the battery supply chain, while also accelerating permitting procedures and clarifying regulatory processes to attract investment. However, despite these efforts, one of the largest bankruptcies in 2024 worldwide was in the European battery manufacturing sector, with Sweden's Northvolt. Reasons include production problems, financial struggles, changing market conditions, geopolitical instability, and leadership challenges (Carbon Credits, 2025). Northvolt itself mentions "a series of compounding challenges including rising capital costs, geopolitical instability, subsequent supply chain disruptions, and shifts in market demand" (Northvolt, 2025b)

In summary, while political stability and transparency do not necessarily guarantee successful battery industry development, their absence has consistently deterred investment and prevented the scaling-up of existing industries.

6.1.4. Governance Innovation and Flexibility

Where we see large-scale battery industries, there are also adaptive, flexible, and well-coordinated institutions, rather than rigid and long processes. For example, in Nevada, USA, the establishment of the Tesla Gigafactory was facilitated not only by large tax incentives, but also by ultra-fast permitting, land zoning pre-approval, and other direct services by regional and federal government (Cooke, 2020).

6.2. Economic

The economic feasibility of battery industry development depends on a multitude of related economic aspects: production costs, market proximity, access to (foreign) capital, predictable demand, and a suitable macroeconomic context. These include production costs, capital access, market demand, energy inputs, and the broader macroeconomic environments, all of which are explored using global cases.

6.2.1. Cost Competitiveness and Market Access

Cost competitiveness remains a central economic determinant. Countries like China and Poland have attracted large battery manufacturing facilities through their relatively low labour and energy costs, strong existing manufacturing infrastructure, and direct access to large consumer markets. The LG Chem plant in Poland, for example, benefits from relatively low wages, skilled workers, and access to the EU single market with its huge demand for EVs (IEA, 2024c).

Germany has succeeded in establishing many large battery manufacturing plants, including Tesla, by leveraging its highly skilled labour force and existing industrial know-how. Despite the obvious higher wages and existing competition, the existence of many chemical firms, logistic network and infrastructure has made it an attractive place for high-end battery production (Martinus and Nunez Picado, 2021).

If both high-wage countries such as Germany and the Nordic countries, as well as lower-wage countries like Poland and China, are suitable for battery production, then the question arises: are wages truly a decisive factor? A comparative cost analysis of battery manufacturing in the U.S. and China shows that while labour and electricity costs are consistently lower in China, the overall cost gap narrows significantly at gigafactory scale. At that scale, economies of scale and automation-driven efficiency reduce the relative impact of location-based cost differences (Brodd and Helou, 2013).

Brodd and Helou (2013) also explore the costs of different components, of which cell components remain by far the largest driver. In the U.S., it accounts for 73.63% of total production costs at 35 million produced cells, increasing to 79% at 350 million cells. In China, these shares are even higher: 81.38% and 82.18%, respectively. Although this source may be somewhat outdated, it is reasonable to assume that with increasing scale and automation, the relative share of labour costs has likely decreased further, reinforcing the limited role of wages as a determining factor in modern, large-scale battery production.

6.2.2. Capital access and investment risk

Battery manufacturing is capital-intensive. Successes often involve substantial upfront investment, either stimulated by the state, large firms, or both. Tesla's gigafactory in Nevada, for example, was supported by an estimated 1.25 billion dollars in state tax incentives and local infrastructure support (Backman, 2014).

These are numbers that emerging economies often struggle to match. For example, South Africa and Chile have made a strong commitment to develop their battery industries, but their high interest rates, currency volatility, and limited long-term state-supported financing mechanisms have shown to be a large constraint to the realisation of their commitments (Cloete, 2020; Irarrazaval and Carrasco, 2023).

China in contrast, has systematically reduced investment risk through large-scale state support, also by means of large financial incentives. Battery and EV companies in China, at least Chinese ones, have benefited from a mix of low-interest state-backed loans, R&D funding, and direct subsidies tied to production volumes or other performance indicators (X. Wang et al., 2022). Not only has this accelerated the scale-up of domestic champions, for example the largest battery manufacturer worldwide CATL, but it has also facilitated market-entry for newer firms by lowering risk.

For example, between 2009 and 2023, China spent a total of over 230 billion dollars in subsidies to support EV and battery manufacturing (Ezell, 2024). Even after phasing out some of its very favourable EV purchase subsidies in 2022, China continues to use other industrial credit tools and regional subsidies to promote upstream processes (IEA, 2023b). This has effectively mitigated investment risk and helped position China as the dominant player in the global battery value chain.

6.2.3. Energy usage and mix

Energy is another significant cost component in battery manufacturing, especially in energy-intensive stages such as cathode active material production, cell formation, and dry room operations (Liu et al., 2021). While labour costs may decrease at scale due to technology efficiency, energy costs may rise on a larger scale and are a strongly location-dependent factor that can strongly influence an investment decision.

Countries with low-cost and reliable electricity, particularly from renewable sources, are shown to be favoured by battery producers. For example, Sweden and Norway have leveraged their abundant hydropower to attract manufacturers like Northvolt and FREYR, marketing their batteries as both low-cost and low-carbon (Business Sweden, 2023). This provides a direct cost advantage, but also a reputational and regulatory benefit, as firms feel pressure to decarbonise their processes under framework such as the EU battery regulation 2023/1542.

Beyond electricity prices, grid reliability and infrastructure quality are equally, if not more important, to ensure smooth processes. In some emerging markets, including parts of India, Latin America, and Africa, firms have cited frequent power outages and unstable grids as significant obstacles to investment decisions (ACRT Staff, 2025). In Ethiopia, for example, Thomas and Fung (2022) estimate that power outages increase firm costs by 15%, as companies were required to invest in alternative power sources to deal with interruptions.

Some countries aim to remedy this by aligning their energy policy with industrial development objectives. In Chile for example, large-scale solar projects in the Atacama region have been set up to help the processing of lithium, both to reduce costs and improve sustainability (Irarrazaval and Carrasco, 2023). Similarly, Germany's industrial strategy increasingly focuses on integrating (green) hydrogen into energy-intensive industries by providing the necessary infrastructure and supporting production capacities.

Another relevant example comes from Zimbabwe, where a Chinese-led mining project has shown the opportunities and challenges of integrating local energy production into new energy-intensive industries. This is usually performed through a Corporate Power

Purchase Agreement (CPPA), but was deemed too unreliable by the Chinese investors, who instead opted to invest in their own local solar power generation, in addition to the CPPA (Y. Wang et al., 2024)

6.2.4. Transport and Export Infrastructure

In addition to energy access, the battery industry requires robust transport and logistics infrastructure, including reliable road, rail, and port networks (Hobi, 2025). These systems are essential for moving heavy, high-volume inputs (like minerals) and outputs (cells and packs) efficiently across domestic and international markets. Zalk (2024) argues that adequate infrastructure is a necessary precondition to perform more downstream industrial processes, and also shows has its absence has historically prevented sub-Saharan Africa from moving up the value chain.

Successful battery plants have shown to often see their location chosen next to favourable infrastructure, or have their own infrastructure developed for better access. For example, the Tesla gigafactory in Germany now has its own main railway line to Wroclaw, and its own autobahn exit (Cooke, 2020). The Tesla gigafactory in China even has its own connection to Shanghai through a Maglev train. The same can be seen in northern Sweden, where the locations for battery plants were carefully chosen to be connected near rail corridors, ports, and industrial zones with shared utilities (Business Sweden, 2023).

6.2.5. Domestic Market Demand and Regional Integration

Beyond access to global markets, the presence of strong domestic or regional demand is a critical economic factor in an investment decision for battery industry. A significant local market allows firms to scale up production, which allows for economies of scale and to more flexibly adapt to local consumer needs. Especially in recent times of increased volatility, tariffs, and trade wars.. For example, while China stimulated the battery manufacturing industry directly, a large part of the 230 billion dollars investment mentioned earlier came from subsidising EV demand. This allowed manufacturing firms to rely on an increase in demand to expand (X. Wang et al., 2022).

In emerging economies, however, domestic demand for EVs or grid stabilising solutions are relatively to extremely low, as they often lack the necessary infrastructure. This limits the ability of firms to rely on (increasing) local demand. Initiatives like the African Continental Free Trade Area (AfCFTA) have sought to bundle demand to help in this (WEF, 2023). However, weak transport infrastructure, non-tariff barriers and low alignment between countries' policies have severely limited the realisation of this potential.

6.3. Social

The social dimension of battery industry development relates to the availability and quality of labour, skills and education systems, local communities, and societal acceptance of industrial activities, especially when limited local added value and resource extraction are involved. The more abstract nature of this some aspects of this dimension makes it sometimes an overlooked dimension during investment decisions, but it can significantly impact the feasibility and pace of development, as well as the social legitimacy.

6.3.1. Skilled Workforce and Education Systems

Battery manufacturing is technically complex and increasingly automated, which requires skilled workers with electrochemical, mechanical, and digital backgrounds.

Typically, countries that host large battery industries also have good technical universities, continued training after study, and industrial retraining programs. Dual education systems, in which work is combined with a formal study, have also proven to be excellent at providing industrial sectors with highly skilled workers, with examples coming from Germany and South Korea (Martinus and Nunez Picado, 2021)

These skilled workers are something that many emerging economies face shortage of. Technicians, engineers, operators, all are in high demand. While there is often no shortage of available and young workers, their skill levels limit the ability of many of the local populations to participate in more downstream processes, including those of the battery industry. Instead, countries often opt for expats with higher skill levels, which in turn can lower political support as the added value is not shared with the local communities (UNCTAD, 2020).

There are countries, as well as multinational firms, that have seen success in emerging economies by offering highly specialised and targeted industrial skill training programs. A good example of this is South Africa's Energy Storage Consortium, which has resulted in a, albeit relatively small, but highly specialised workforce (Montmasson-Clair et al., 2021). At the same time, due to misalignment with national industrial policy, such programmes have often not been able to realise their potential and remain small-scale. This, as seen earlier with other PESTLE dimensions, again points to the need to align several layers of governments, industry stakeholders, and investors to ensure that skills development aligns with industry goals.

6.3.2. Social Infrastructure and Population Growth

Battery plants, especially ones on a giga scale, can rapidly transform the nearby towns and regions in which they are located. As they need a largely expertly trained workforce, they are reliant on workers who move close to their work, which places pressure on housing, healthcare, education, and transport infrastructure, especially in regions where the capacity is already limited. A recent example of this is in Skellefteå, Sweden, where the gigafactory Northvolt Ett, as well as the recycling facility Revolt Ett, are located. Hobi (2025) explores how the municipality coordinated with Northvolt and to expand housing and other social services and infrastructure to accommodate the approximate 3,000 new workers, including their families. Without such support, this integration can create significant frictions between the new firm and the local communities.

While Hobi only looked at the direct new workers and their families, other research suggests that the scale is much larger. As the more upstream processes and supporting segments of the battery value chain can require up to four to six times more labour than the gigafactory itself (Business Sweden, 2023). This implies the need for regional planning, as industries often attract other industries to create industrial zones or are designed as such. This streamlines the need for infrastructure, utilities, and other services.

6.3.3. Labour Relations and Community Acceptance

Battery-related industrial activities, particularly the downstream processes of mining and refining, can generate large social frictions due to bad labour practices, which are sadly common. While the next chapter will take a closer look at the DRC-Zambia region, the case of the DRC is a clear example of this. It has extremely dangerous working conditions, often next to no worker protections, and often involves child labour (Amnesty International, 2016).

This has also tarnished the reputation of firms that use cobalt in their processes, as cobalt is often directly associated with these poor working practices.

Beyond (poor) labour conditions, local community acceptance plays a decisive role in project continuity. In parts of Latin America, for example, there has been large opposition to battery-industry-related projects, as the local communities felt insufficiently consulted and/or unfairly treated regarding value sharing (UNCTAD, 2020). Perceived exclusion or exploitation, whether through underemployment of local workers, insufficient investment, or lack of transparency, can cause local resistance, which in turn can delay permitting and cause troubles for the long-term continuity of a project.

To account for this, some governments work with formal community engagement structures. Chile's National Lithium Strategy 2023 (Gobierno de Chile, 2023) is one example, requiring community involvement during the licensing process, and allocating a portion of revenues from lithium production to local communities. While this can delay licensing and permitting processes, such policies do increase the social accountability of battery plants.

Even in high-income countries, where labour rights are better protected, social legitimacy and social legitimacy cannot be taken for granted. Tesla's gigafactories for example have faced much critique over poor and unsafe working conditions, high injury rates, long shifts, and anti-union practices, sometimes even threatening personnel into joining or forming a union (Greenhouse, 2023). Tesla's Fremont plant has been repeatedly visited by the Occupational Safety and Health Administration and has seen emergency calls at a rate of more than one a day originating from the factory. Additionally, there have been many work-related injuries that have gone unreported (Cooke, 2020). This has led to public criticism and large reputational damage, despite Tesla being an industry leader.

6.3.4. Societal Acceptance

Public perception plays an increasingly important role in the long-term support for battery industry development. While technical and financial feasibility are more important in the initial development of an industry, societal backing is vital for sustained policy support and investment stability. Without societal acceptance, governments can halt financial support. In countries like Sweden and Norway, there is strong support for sustainable projects, especially for projects like Northvolt, whose energy mix is fully renewable. In its public communications, Northvolt highlights the importance of its green and stable energy as a competitive edge over other battery manufacturers, which reflects the view of the public (Business Sweden, 2023).

However, in many emerging economies or less politically stable contexts, public support is less strong. Unequal value sharing, foreign domination of national resources, or environmental damage can diminish trust in battery-related investments (Gulley et al., 2019). This can lead to local resistance, protests, or political backlash, which increases investment risk or can hinder developing or existing projects, even when other parts, such as the economic or technological feasibility, seem favourable.

6.4. Technological

Technological conditions influence both the competitiveness and long-term viability of a battery industry. These include innovation ecosystems, domestic R&D capacity, intellectual property, and the ability to adapt and utilise the most recent technologies. Countries with strong technical universities and collaboration between academic and private institutions are often better positioned to develop high-tech industries. At the same time, a lack of technological capabilities can influence a country's ability to perform the more value-adding downstream processes.

6.4.1. Innovation Systems and R&D Capacity

Strong innovation systems, with R&D as its foundation and realised by academic collaboration and industrial knowledge development, have been key to countries like Japan, South Korea, Germany, and China in maintaining leadership across battery technology segments. Japan's early dominance was driven by institutions like "National Institute of Advanced Industrial Science" (AIS) and "New Energy and Industrial Technology Development Organisation" (NEDO), which acted as bridges between early academic research and industry (AIST, 2025; Martinus and Nunez Picado, 2021; NEDO, 2025). South Korea followed a similar path by aligning government-backed R&D institutions like the Korea Evaluation Institute of Industrial Technology with commercial actors to improve manufacturing efficiency and competitiveness (CORFA, 2025).

In Germany, the role of Fraunhofer Institute, the IPCEI programme, and public-private initiatives like the European Battery Alliance (EBA) have been pivotal to its success. Innovation policy aimed at all segments of the value chain, from raw materials, cell production, integration and recycling, while also supporting standardisation. This enables efficiency gains through all levels of industry.

Meanwhile, China's current innovation advantage originates from tight integration between large scale R&D efforts and very rapid commercialisation and expansion. With consistent policy support, Chinese firms like the world market leader CATL have been able to scale new technologies quickly, sometimes surpassing international competitors by more than one generation of technologies by investing in applied research and vertically integrated production lines (Greitemeier and Lux, 2025).

6.4.2. Knowledge Transfer and Workforce Integration

Technological capabilities do not originate from, nor are they limited to, one firm. They are supported by aligned industrial policy, industry-wide experience, and continuous improvements. The previously mentioned successes of Japan's Kansai region and South Korea battery manufacturers also function as local learning hubs, in which technological diffusion has steadily improved domestic production capabilities. Similarly, in China, a dominant battery manufacturing hub has emerged, called the Huizhou cluster (Montmasson-Clair et al., 2021). It has been shaped by intense historical competition between leading firms such as CATL, BYD, and CALB. This competition was strongly influenced by targeted national strategies. The resulting ecosystem has rapid innovation cycles, continues to create manufacturing efficiency improvements, and hosts an increasingly self-sufficient supply chain, making it part of the foundation for China's dominance in global battery markets (Liu et al., 2021)

6.4.3. Intellectual Property

Technological leadership in the battery industry is closely tied to the production and control of intellectual property (IP). Countries that have developed strong battery industries also consistently rank among the top in global patent applications for cathode materials, electrolytes, battery management systems, and new solid-state technologies (Greitemeier and Lux, 2025).

For example, CATL and BYD have maintained tight control over their signature chemistry and manufacturing techniques, which have allowed them to scale rapidly and protect their technological edge. Their innovation has been supported by state-led incentives, such as prioritised patent examination, export control protections, and target subsidies linked to production output and technological milestones (X. Wang et al., 2022). This policy environment, coupled with China's scale advantage and vertically integrated industrial structure, has helped transform local firms like CATL into world leaders in battery cell innovation, particularly in LFP (Lithium Iron Phosphate) and NMC (Lithium Nickel Manganese Cobalt Oxides) compositions (Pelegov and Pontes, 2018). These firms now dominate global IP filings related to battery safety, energy density, and cost efficiency, positioning China as the global leader not only in battery manufacturing, but also in battery innovation.

In contrast, most African and many Latin American countries have limited historical intellectual property filings. Their participation in the global value chain is largely constrained to downstream processes, limiting their capacity to capture high-value segments (Attia et al., 2025; Bridge and Faigen, 2022). Even countries with technical aspirations, such as South Africa and Chile, often struggle to retain ownership over their innovations due to weak patent ecosystems, limited R&D investment, and a high dependency on foreign technology transfer.

To counterbalance this, international collaborations such as the EBA and Battery Passport initiative attempt to enable innovation capacity and reduce their dependency on China. Similarly, initiatives in Brazil and India aim to localise parts of the battery technology through joint ventures, university partnerships, and IP creation schemes (Lema et al., 2024). However, despite these efforts pale in comparison to the established maturity and scale of China's IP ecosystem.

6.5. Legal

Legal and regulatory frameworks play a crucial role in shaping the feasibility of battery industry development. Stable, enforceable legal environments, covering land use, permitting, environmental compliance, intellectual property protection, and safety standards, provide certainty for investors, enabling long-term planning. When frameworks are ambiguous, slow, or inconsistently enforced, they can cause delays and raise the perceived risks of industrial projects. This section outlines relevant international approaches to battery regulation, with a focus on transferable lessons for a regional battery industry in Central-Southern Africa. Most of the policies are sourced from the IEA policies database (IEA, 2025).

6.5.1. European Union

The European Union offers the most comprehensive legal approach to regulating and supporting battery industry development. Regulation 2023/1542, which replaces the earlier Battery Directive 2006/66, mandates stricter sustainability and safety requirements, including sourcing disclosures, carbon footprint accounting, and minimum recycled content targets. It also strengthens producer responsibility and standardises labelling to support transparency and traceability.

In addition, the 2018 Strategic Action Plan on Batteries sets out a policy agenda, from transparently sourcing raw materials and financing R&D to developing a skilled workforce. Notably, it explicitly calls on its nations to simplify and accelerate permitting procedures for both pilot productions and industrial projects. The EU's approach demonstrates how legal coordination and supportive frameworks can shape a cohesive and sustainable battery ecosystem. The EU's goal is to become a global leader in sustainable battery manufacturing.

6.5.2. China

China's regulatory framework reflects a strong emphasis on lifecycle integration, industrial zoning, and material efficiency. The 2024 "Specifications for the Comprehensive Utilisation of Waste EV Batteries", issued by the Ministry of Industry and Information Technology, mandates firm-level traceability through the national EV Monitoring and Management Platform, sets recovery targets (e.g. 98% for copper/aluminium), and introduces safety, coding, and infrastructure standards for repurposed products (IEA, 2024).

Meanwhile, the 14th Five-Year Plan on the Circular Economy promotes battery recycling innovation, establishes traceability mandates for end-of-life batteries, and sets national standards for reuse and collection (IEA, 2024). These policies highlight how China supports its battery industry through industrial zoning to bundle infrastructure and knowledge, clear regulatory oversight, and integration of circular economy principles, which are all enablers for long-term investment.

China has implemented a range of policy instruments to reinforce lifecycle management, material efficiency, and industrial competitiveness. Its "2024 Specifications for the Comprehensive Utilisation of Waste EV Batteries", issued by the Ministry of Industry and Information Technology, mandates that battery firms operate in designated industrial zones to cluster knowledge and infrastructure and comply with traceability requirements via the national EV Monitoring and Management Platform. The policy also introduces R&D investment obligations

6.5.3. South Korea

South Korea approaches battery industrialisation through high-level strategic planning and export-oriented support. Its 2024 Mission-Centric Strategic Roadmap for Critical and Emerging Technologies (IEA, 2023) identifies batteries as a strategic technology and promotes institutional reform, public R&D investment, and workforce development to secure technological sovereignty. The roadmap places a strong emphasis on battery performance targets, mineral independence, and traceability throughout the supply chain.

In addition, South Korea's Ministry of Economy and Finance has introduced targeted support programmes, including funding tied to specific battery chemistries such as lithium iron phosphate and sodium-ion. These measures aim to strengthen South Korea's cost-competitiveness and innovation leadership. It also aims to expand battery exports to Europe and Southeast Asia.

6.5.4. Japan

Japan's battery strategy is grounded in long-term industrial planning, circular economy integration, and resilient supply chain design. The GX Green Transformation Policy: Batteries (IEA, 2024), led by the government's Battery Supply Chain Resilience Support Projects, aims to establish 150GWh of yearly national capacity by 2030. It funds R&D, solid-state battery development, and material recovery innovations, while promoting the use of stationary battery applications for grid stability, which not only drives industrial growth but also domestic demand.

This is complemented by the Battery Industry Strategy launched by Ministry of Economy, Trade, and Industry (METI, 2022), which sets a global ambition of 600GWh production capacity (domestic and abroad) for its national firms, to reach a global market share of 20%. The strategy also emphasises international cooperation to secure critical minerals and harmonise international battery standards. While Japan operates in a very different policy context, its commitment to both upstream resilience and downstream demand creation offers strong enabling conditions.

6.6. Environmental

Environmental considerations have been increasingly important in shaping battery manufacturing strategies worldwide. These include the carbon intensity of production and regulations for recycling and waste management. While environmental constraints can pose barriers to entry, they also serve as a possibility for industrial differentiation, competitiveness, and investment attraction.

6.6.1. Emissions from Battery Manufacturing

Battery manufacturing is one of the most carbon-intensive stages in the EV value chain. Life cycle assessments estimate that manufacturing lithium-ion batteries can account for nearly 50% of a vehicle's lifetime emissions, primarily due to the energy required for producing cathode materials and cell assembly (BloombergNEF, 2021). As such, the emissions profile of batteries is highly sensitive to the region's energy mix. Countries like Sweden, which highly rely on hydropower, can offer significant emission reductions, and can also use this to market their batteries as more sustainable than the competition, like Northvolt does: "Green batteries for a blue planet" (Northvolt, 2025). This shift is expected to become increasingly important, with some firms also relying on their own sustainable electricity production. For example, Tesla's large number of solar panels on its gigafactories (Cooke, 2020), or separate solar fields for mining operations (Y. Wang et al., 2024).

6.6.2. Recycling and Circularity

Regulatory approaches to end-of-life battery management are rapidly evolving. For example, the EU's Regulation 2023/1542, or China's Specifications for the Comprehensive Utilisation of Waste EV Batteries, introduce targets for minimum recycled content and extended producer accountability. In China, battery manufacturers must operate within regulated zones and use national monitoring platforms to improve traceability (Sharmili et al., 2023). Despite technical challenges with regard to different battery chemistries and lacking (global) standards, nations with better circularity can gain an edge in reducing their dependency on international critical mineral supply chains (Business Sweden, 2023), a very hot strategic topic for many nations.

6.6.3. Environmental Standards as a Competitive Edge

Predictable and clear environmental regulations are increasingly seen as a competitive advantage for host regions instead of barriers. Northern Europe, for example, has built investor trust through consistent environmental standards, use of renewable energy, and early adoption of circular economy principles (Business Sweden, 2023). In contrast, inconsistent or weak environmental regulations, such as in Latin America or Southeast Asia, can heighten operational risks, especially with OEMs and investors becoming increasingly sustainably conscious.

6.6.4. Local Environmental Impact

While battery production supports decarbonisation efforts, its ecological footprint can impact local environments. Gigafactories consume large amounts of energy and water, especially during electrode drying and electrolyte production, leading to pressure on local utilities (Attia et al., 2025). For example, lithium operations in Chile's Atacama Desert have used over 60 billion litres of water annually, worsening drought and harming the local ecosystem (Jones et al., 2020).

Manufacturing and refining activities also generate toxic waste and emissions. Cobalt and nickel processing can contaminate soil and water if according measures are not taken, with documented respiratory and agricultural impacts near facilities in China and the DRC (Bridge and Faigen, 2022). Indonesia has been disposing its nickel waste in the nearby deep-sea, drawing global criticism due to its potential ecological risks (Jones et al., 2020).

These examples show the importance of local regulations to mitigate environmental damages, ensuring that battery manufacturing contributes to sustainability goals not only indirectly through decarbonisation, but also by avoiding direct ecological damage.

6.7. Synthesis of Macroeconomic Determinants of Battery Industry Feasibility

This section synthesises the key macroeconomic determinants of battery industry development identified across the six PESTLE dimensions in the previous sections. Table 2 below presents these findings, categorised by their respective PESTLE dimension. It serves as the benchmark for evaluating the feasibility of the DRC-Zambia battery initiative in chapter seven, as well as for the exploration of alternative regional pathways.

PESTLE Dimension	Determinants of Battery Industry Development
Political	- Long-term industrial strategy and strategic policy on national and regional levels - Alignment between different institutions and coordination with industry actors - Strong public-private mechanisms, including transparent permitting frameworks and implementation capacity - Credible enforcement of agreements to stabilise investor expectations - Political stability and regulatory predictability to support long-term investment decisions
Economic	- Cost-competitive conditions including labour, energy, and access to raw materials - Access to investment capital and financial incentives such as subsidies, state loans, and tax relief - Low-cost, reliable, and increasingly renewable energy infrastructure for energy-intensive processes - Efficient road, rail, and port infrastructure to enable regional integration and exports - Presence of domestic and regional demand to support economies of scale and reduce demand volatility - Stable macroeconomic and trade conditions, including inflation control and clear trade policies and/or agreements

Social	- Skilled and technically trained workforce with access to retraining and dual education systems. - Absorption capacity regarding housing, healthcare, and transport infrastructure to accommodate domestic and international workforce migration - Fair labour practices and community engagement to generate legitimacy and prevent local resistance. - Broad societal acceptance of industrialisation efforts for stable, long-term societal support
Technological	- Strong national innovation systems supported by universities, research institutes, and funding - Knowledge transfer via industrial clusters and cooperation across the value chain. - Creation and protection of intellectual property to enable technological competitiveness
Legal	- Comprehensive regulatory frameworks that set long-term sustainability, safety, and circularity targets - Strategic long-term legislation aligning permitting, industrial support, and technological growth goals - Legally enforced standards on battery reuse, recycling, and traceability - National laws supporting battery production through tax reliefs, increased domestic demand, and direct state investment or support
Environmental	- Carbon intensity of production is highly dependent on regional energy mix, a sustainable mix can enable 'green branding' - Battery circularity and recycling regulations reduce dependency on raw material imports - Clear environmental laws increase investor confidence and reduce reputational risk. - Gigafactories can have strong local ecological impacts, requiring strong environmental governance to mitigate damages

Table 2: Identified determinants, categorised using PESTLE

Taken together, the determinants outlined in this synthesis demonstrate that battery industry development is shaped by a wide range of interdependent conditions across political, economic, social, technological, legal, and environmental domains. However, based on the characteristics of the nature of industrial development, some conditions are likely to play a more central role than others.

Political and economic factors can reasonably be considered among the most influential. Industrial policy, institutional coordination, investment incentives, and infrastructure are often prerequisites for establishing basic production capacity. Without a predictable policy environment and aligned institutions, private actors face heightened uncertainty, which increases investment risk and lowers the likelihood of large-scale infrastructure commitments. Similarly, economic factors such as low-cost, reliable energy, and access to capital are critical because they directly affect operational viability and competitiveness. As such, these two dimensions can be regarded as more foundational.

Technological and legal conditions also play a significant role, especially in high-tech industries such as battery manufacturing. Especially the technological dimension is decisive in whether a country or region can move into more complex mid- and downstream activities. Innovation capacity, knowledge transfer mechanisms, and clear regulatory frameworks contribute to the ability to meet quality and safety standards, compete internationally, and adapt over time. Legal conditions, while often overlooked, play a vital role in standardising production, ensuring safety, and enforcing intellectual property rights. Therse are particularly important when trying to gain international market access to adhere to international standards.

Social conditions are more mixed in their immediate impact. On one hand, the availability of a technically trained workforce is often a decisive constraint, as battery processes rely on skilled operators, engineers, and technicians. Training systems and vocational retraining programmes can directly affect whether a country can realistically participate in mid- or downstream activities. On the other hand, broader social infrastructure, such as housing, healthcare, or cultural acceptance, tends to influence long-term continuity and scaling rather than initial feasibility. These aspects become more important once an industry matures and workforce and quality of life start shaping talent retention and public legitimacy.

Environmental factors, while increasingly important from a sustainability and export perspective, are unlikely to directly affect feasibility. Strong environmental regulations can raise the cost of production, but can also boost competitiveness by enabling firms to pursue "green branding" in markets where sustainability standards matter (e.g. the EU). However, in the early stages of development, environmental conditions are more likely to be treated as externalities, especially in a weak enforcement context. This makes them relevant for long-term viability, international legitimacy, and public acceptance, but typically less critical for short-term feasibility.

Overall, the synthesis should not be read as a hierarchy or fixed set of conditions, but as a structured overview of the different types of conditions that may shape the feasibility of battery industry development. Political and economic factors typically serve as minimum thresholds for feasibility, while technological, legal, and selected social factors determine the potential scope and complexity. The relative importance of each condition also depends on the industrial stage, the existing capabilities of the country or region, and the specific context.

7. Strategic Feasibility Assessment of Battery Industry Development in the DRC-Zambia Region

This chapter compares the macroeconomic determinants identified in chapter four to the specific case of the DRC-Zambia. In doing so, it addresses the second sub-question of this thesis: *"How does the context of the DRC-Zambia region compare to the identified determinants for successful battery industry development?"*

By systematically assessing the six dimensions of PESTLE in the region, this chapter evaluates whether the current context can support the development of a competitive and sustainable battery industry.

Each of these PESTLE dimensions has its own section and thus closely follows the structure of chapter four, allowing for analytical consistency. The chapter concludes with a synthesis of the findings that summarises the overall feasibility of the initiative and highlights strengths and weaknesses of potential battery industry development in the region.

7.1. Political Dimension

The political dimension plays a key role in shaping the feasibility of battery industry development, especially on the long-term. In the previous chapter, five conditions were identified that influence this: (1) the presence of a long-term industrial strategy and strategic policy at national and regional levels; (2) effective alignment between institutions and coordination with industry actors; (3) strong public-private mechanisms with transparent permitting and implementation capacity; (4) credible enforcement of agreements and contracts to stabilise investor expectations; and (5) political stability and regulatory predictability to support long-term investment decisions.

As some of these conditions overlap, this section is split into three parts. The first focuses on strategic vision and policy alignment, examining whether both countries have coherent long-term goals and possess the institutional coordination to follow through on them. The second examines governance capacity and public-private engagement, including implementation frameworks, enforcement credibility, and public-private projects. The third considers the broader context of political stability and regulatory predictability, which can be decisive for investor confidence.

7.1.1. Strategic Vision and Policy Alignment

Zambia: Coherent and Institutionalised Strategy

Zambia's current industrial development strategy is anchored in the Ministry of Commerce, Trade and Industry's National Industrial Policy (2018) (NIP), which is aligned with its Vision 2030 aimed at "transforming Zambia into a prosperous middle-income economy" (Ministry of Commerce, Trade and Industry, 2013). The NIP sets out a clear long-term goal: to transform Zambia into a diversified and export-oriented industrial economy, with a focus on increasing manufacturing's share of GDP from 8% to 15% and doubling employment in the sector by 2027.

This strategy is supported by several institutional instruments. For example, the 2023-2027 Implementation Plan for Development Cooperation (Ministry of Finance and National Planning, 2023) provides a concrete roadmap, detailing how national budgets, foreign investments, and donor activities should align with industrial goals, and how all these different cash flows can be monitored. Coordination takes place across ministries, notably between the Ministry of Commerce, the Zambia Development Agency (ZDA), and the Ministry of Finance.

There is also coordination with private sector stakeholders, for example, through the Public-Private Dialogue Forum (PPDF). Organisations such as the Zambia Association of Manufacturers (ZAM) and the Zambia Chamber of Commerce and Industry (ZACCI) are regularly consulted in policy design and implementation, although the influence of industry actors varies heavily by sector.

Throughout the different layers of government, alignment with regional and international frameworks is also evident. These include the Southern African Development Community (SADC), Common Market for Eastern and Southern Africa (COMESA), and the African Continental Free Trade Area (AfCFTA).

The government has also positioned industrial ambitions as a pillar in their diplomatic relations. For example, through its leadership position in the binational battery value chain initiative with the DRC (Economic Commission for Africa, 2022), supported by the tripartite memorandum of understanding (Snyder, 2022) (MoU) with the United States and the DRC. These examples show not only high-level intent, but also a degree of continuity and institutionalisation across governance layers. The initiative is supported by coordination structures such as the Battery Council, chaired by the heads of state of Zambia and the DRC, and sector-specific working groups covering infrastructure, skills, R&D, and legal dimensions.

DRC: High-Level Intent but Strategic Gaps Remain

The DRC has expressed strong political intent to participate in regional value chains and move beyond raw material extraction. This is most clearly reflected in its co-leadership of the DRC-Zambia battery value chain initiative (Economic Commission for Africa, 2022) and its participation in the tripartite MoU with the US.

However, the DRC currently lacks a formalised national industrial strategy at the same level of institutional maturity as Zambia. Investment governance relies heavily on the 2002 Code Des Investissements (Kabila, 2002) and the operations of the Agence Nationale pour la Promotion des Investissements (ANAPI), which provides project-by-project incentives rather than sector-specific strategic direction. While this flexibility can attract short-term investment, it does not support long-term coordination or enable strategic planning across institutions.

Efforts to build institutional infrastructure for industrialisation have started with the development of a pilot Special Economic Zone (SEZ) in Maluku in 2014, targeting agro-industrial, pharmaceutical, and manufacturing activities. This has since been supported by a decree from 2020, which specifies the tax and customs benefits granted to investors operating in these zones (ANAPI, 2025). However, Maluku remains the only designated pilot zone, while other areas identified as suitable for SEZs are still “currently in search of developers.” Publicly available information on the operational status of Maluku is limited, with vague statements such as “the process of implementing the Maluku AZES is well advanced” and “construction work on the infrastructure is imminent” being the primary indicators of progress (ANAPI, 2025).

In addition to the missing national industrial strategy, coordination mechanisms also seem absent. While multiple agencies such as ANAPI, the Ministry of Industry, and provincial authorities are involved in case-by-case aspects of investment and, to some extent, industrial development, there is no clear mechanism that links these actors through a shared policy framework or decision-making process. Public-private partnerships also seem limited. The Fédération des Entreprises du Congo (FEC), the country's main employers' federation, is active in economic dialogue and research, and represents a broad range of business interests across different sectors (FEC, 2023). However, its involvement in shaping industrial development strategy, particularly in high-tech industries such as battery value chains, appears extremely limited. Without consistent and institutionalised engagement with industry actors, industrial policy will remain fragmented and on a case-by-case basis, driven by external partnerships or isolated initiatives rather than an aligned national vision, which is necessary for the development of a battery value chain.

7.1.2. Governance Capacity and Public-Private Engagement

Zambia: Functional Framework, Moderate Capacity

Zambia's Public-Private-Partnership (PPP) environment is governed by the PPP Act No. 18 of 2023 (National Assembly of Zambia, 2023), which outlines the roles, responsibilities, and procedures for project development, approval, and monitoring. This provides guidance to the national-level PPP Council of Zambia, as well as the PPP department under the Ministry of Finance, which is responsible for proposals, feasibility studies, contract negotiation, and performance monitoring.

In its most recent "Status on PPP Projects" update, it has 17 PPPs, of which 2 are handed back, 3 are in operation, 6 are under implementation, and 6 are on commercial close. These projects cover a wide variety of sectors, including the improvement of trading facilities, prisons, infrastructure, and real estate, but notably, no manufacturing activities (Ministry of Finance and National Planning, 2024). Beyond these centralised efforts, Zambia strongly encourages regional PPPs, again mainly in infrastructure and real estate efforts.

Despite these efforts, Zambia continues to face implementation and scaling challenges. According to the 2024 National Decentralisation Conference, bottlenecks include limited feasibility studies, high turnover of staff in contracting authorities, insufficient financial and legal expertise, and difficulties achieving financial close, particularly for subnational or medium-scale PPPs (Cabinet Office, 2024)

Recognising these gaps, the Zambian Development Cooperation Strategy 2023-2026 outlines investments in legal staffing, infrastructure, and decentralised capacity building to improve project deliveries, especially on the subnational level (Ministry of Finance and National Planning, 2023). These efforts align with Zambia's moderate performance in the World Bank Government Effectiveness Index, where it ranked in the 28th percentile in 2023, down from 29th in 2018 and 36th in 2013. At the end of the following DRC section, a comparison will be made with the DRC and other countries that have established battery industries.

DRC: Ambitious Legal Design, Constrained Implementation

The DRC, like Zambia, enacted a PPP law in 2018 (N°18/016, 2018), which provides the legal basis for public-private partnerships. The law outlines key principles of competition, transparency, and national expertise promotion and allows for a variety of contracts. The law is complemented by Decree No. 21/.04 and Decree 23/38, both developed in collaboration with the AfDB (Ministère des Finances, 2021).

While this legal framework is comprehensive and solid on paper, its implementation remains very limited. As of 2024, the Unité de Conseil et de Coordination de la gestion des contrats (UC-PPP), an institutional body tasked with overseeing PPP projects, lacks a national strategy, operationalised projects, and internal capacity to manage contracts. To address these gaps, the government has launched a capacity-building programme under the Congolese Economic Recovery Support Project, funded by the AfDB, which includes technical assistance, the creation of a national PPP portfolio, and the development of a communication and training strategy (African Development Bank, 2021; Ministère des Finances, 2021)

Despite these steps, the PPP framework remains largely aspirational. Although the law designates various actors, including regulatory bodies and provincial authorities, as responsible for PPP implementation, there is no indication of a centralised institution with operational capacity comparable to Zambia's PPP department within the Ministry of Finance. The absence of a functioning project timeline and a lack of publicly accessible information further weaken the credibility of the framework. As of 2024, there is no evidence of completed PPP contracts in infrastructure, let alone in industrial development. These initiatives show high-level intent, but they also indicate the limited maturity and institutional fragility of the DRC's PPP ecosystem.

This contrast is also reflected in the World Bank's Government Effectiveness Index. In 2023, Zambia ranked in the 28th percentile, indicating moderate administrative performance. The DRC, in contrast, ranked in the 4th percentile, placing it among the lowest-performing countries globally. These figures indicate not only a large gap in institutional maturity, but also a fundamental difference in the state's overall implementation capacity and ability to implement PPP initiatives. When benchmarked against countries with established battery industries, as explored in the previous chapter, such as South Korea, Germany, Japan, Hungary, or the US, all of which rank above the 63rd percentile, it becomes clear that both Zambia and especially the DRC face serious governance-related barriers to industrial development, see Figure 4.

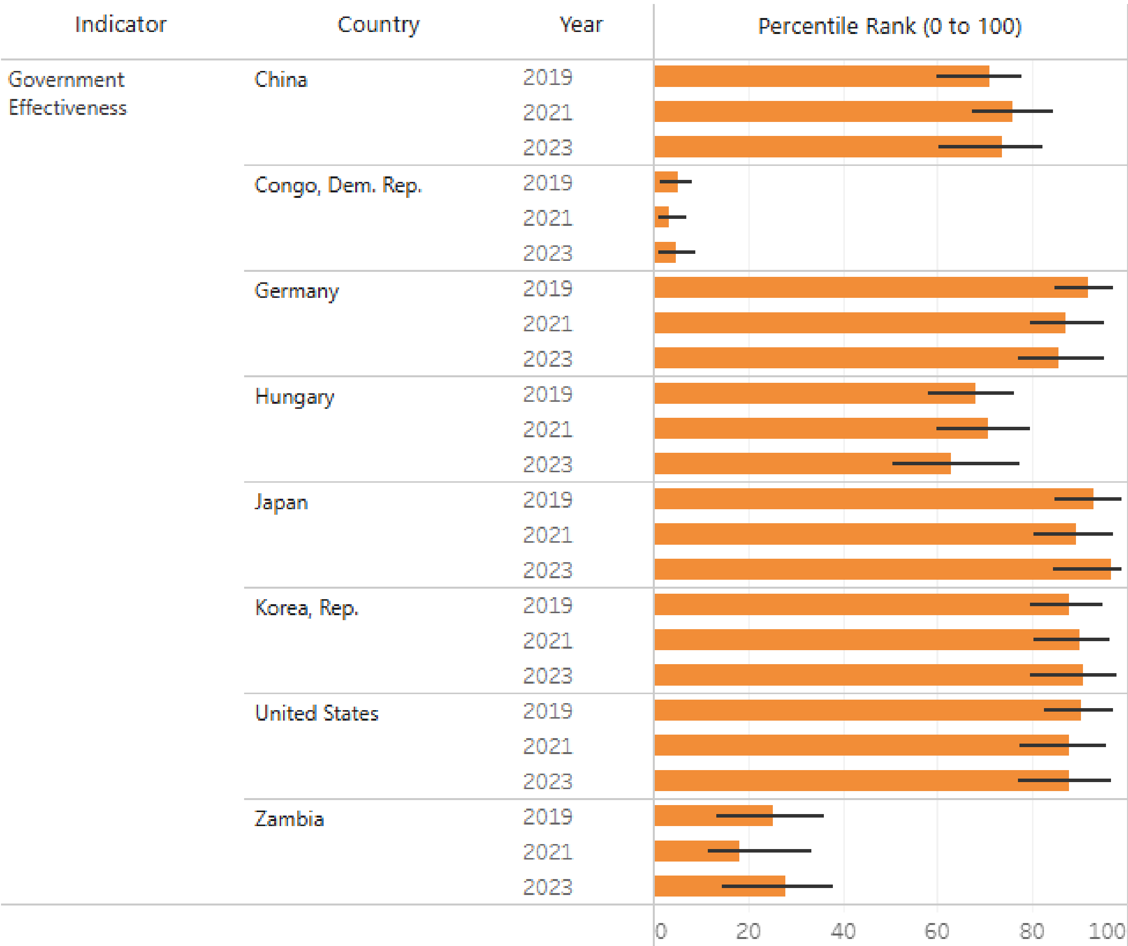

Figure 4: Government Effectiveness Indicators (World Bank, 2025)

7.1.3. Political Stability and Regulatory Predictability

Zambia: Moderate Stability with Incremental Reforms

Zambia has maintained relative political continuity since its return to a multiparty democracy in 1991. Since then, changes in government have occurred through regular, largely peaceful elections. The ruling United Party for National Development (UPND) came to power in 2021 under President Hakainda Hichilema, marking the third peaceful transition of power since 2001. However, not all transitions were uncontroversial. The 2001 election, which brought Levy Mwanawasa to power, was accompanied by allegations of electoral fraud, causing widespread criticism from citizens, as well as international parties.

Despite these tensions, Zambia's governance indicators have shown gradual improvement. According to the World Bank's Worldwide Governance Indicators, Zambia ranked in the 53rd percentile for Political Stability and Absence of Violence/Terrorism in 2023, up from 44th in 2019. Similarly, its score on Control of Corruption improved from the 28th percentile in 2019 to 37th in 2023 (World Bank, 2025c). These trends suggest increasing trust in government and institutions and an increasingly predictable political environment.

Findings from the BTI Transformation Index (2024) are less positive. While Zambia has formal institutions and hosts an electoral democracy, the report showcases large governance challenges. The presidency remains dominant, parliamentary oversight is weak, and horizontal accountability is insufficient. Although the peaceful transfer of power in 2021, despite the large political shift, was positive, the BTI report also warns of large remaining barriers, such as politicised law enforcement and executive overreach, which hinder institutional effectiveness. While Zambia's political institutions are described as relatively stable, they are constrained in practice by limited checks and balances (BTI, 2024b).

Political turmoil also remains a concern in the country. In the months leading up to the 2021 elections, both the United Nations and Amnesty International condemned incidents of political violence, intimidation of opposition parties, and restrictions on civil rights (Amnesty International, 2021; United Nations, 2021). In fact, as recently as 2024, both the United Nations and Amnesty International again called for the immediate termination of arbitrary arrests, repression of freedom of expression and right to peaceful assembly (Amnesty International, 2024; United Nations, 2024). This shows that while Zambia outperforms many other African countries on many indicators, it remains vulnerable to political volatility.

In response, the government has invested in regulatory and institutional reform to improve transparency and investor confidence. The introduction of the Risk-Based Regulation in 2024, developed in collaboration with the World Bank, the EU, and the Organisation of African, Caribbean, and Pacific states (OACPS), aims to prioritise monitoring resources to risk exposure while reducing compliance burdens for low-risk sectors, implemented by the Business Regulatory Review Agency (BRRA, 2024). They also oversee stakeholder collaboration and the implementation of Regulatory Impact Assessments across different ministries to enhance consistency. While institutional capacity for these efforts varies across regions, these frameworks and first steps showcase a significant step towards better regulatory predictability and efforts in long-term planning.

DRC: Instability and Regulatory Uncertainty

The DRC continues to struggle with political instability, institutional fragility, and ongoing armed conflict. President Félix Tshisekedi's re-election in 2023 was accompanied by logistical issues, including delayed openings of polling stations, malfunctioning voting machines, and missing voter lists. This caused many to raise concerns about the legitimacy of the process, particularly in areas where voter access was heavily disrupted (Ahmed, 2023). In response, several opposition parties rejected the results and demanded a re-run (Mednick and Kamale, 2023).

These events indicate a deeper and larger structural weakness. The DRC's political landscape is characterised by fragmented party alliances, a weak opposition, and a dominating ruling party, all of which undermine democratic processes (BTI, 2024a). Furthermore, according to the BTI Transformation Index, the country's institutions remain "severely dysfunctional", with a ruling elite, limited horizontal accountability, and a political system that is heavily centralised around the presidency. The justice system lacks independence capabilities, and parliament rarely provides effective checks on executive authority. Additionally, the existing formal democratic structures are often subject to political interference. In one sentence, the report describes the DRC's governance as: "The government has no intention to promote the collective well-being of the Congolese people". Democratic institutions exist on paper but are often circumvented or manipulated in practice.

The fragile institutional setting is reinforced by widespread security issues. Recently, the resurgence of the M23 rebel group since 2021 has destabilised large parts of eastern DRC, resulting in mass displacement and undermining state authority. It also aims to overthrow the DRC government, which it considers to be dysfunctional (McKenna, 2025).

The implications of this volatility, both political and for security, are reflected in global benchmarks. In 2023, the DRC ranked in the 6th percentile for both political stability and control of corruption, while Zambia ranked 53rd and 37th respectively. These figures again reveal a large institutional gap and how both countries, but specifically the DRC, fall short of governance norms of established battery economies. However, China and the US actually score lower than Zambia on Political Stability, although the US is within the margin of error. As with government effectiveness, these indicators are shown in Figure 6: Political

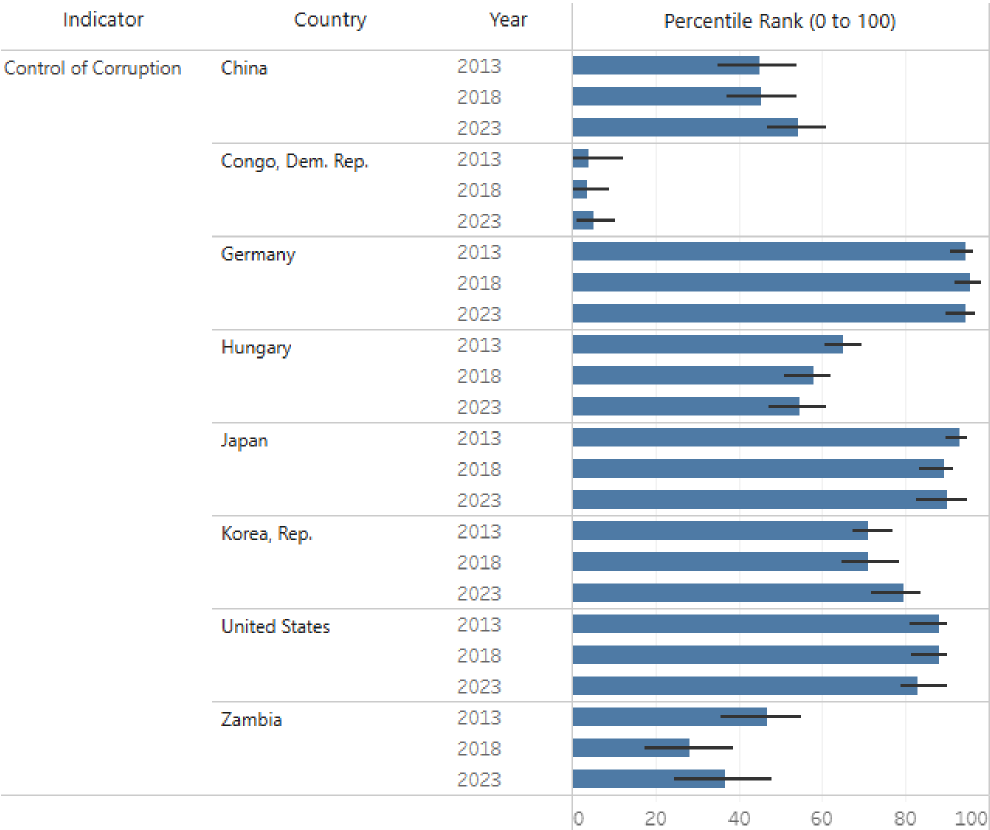

Figure 5: Control of Corruption Indicators (World Bank, 2025)

Stability and Absence of Violence/Terrorism Indicators (World Bank, 2025 and Figure 5: Control of Corruption Indicators (World Bank, 2025.

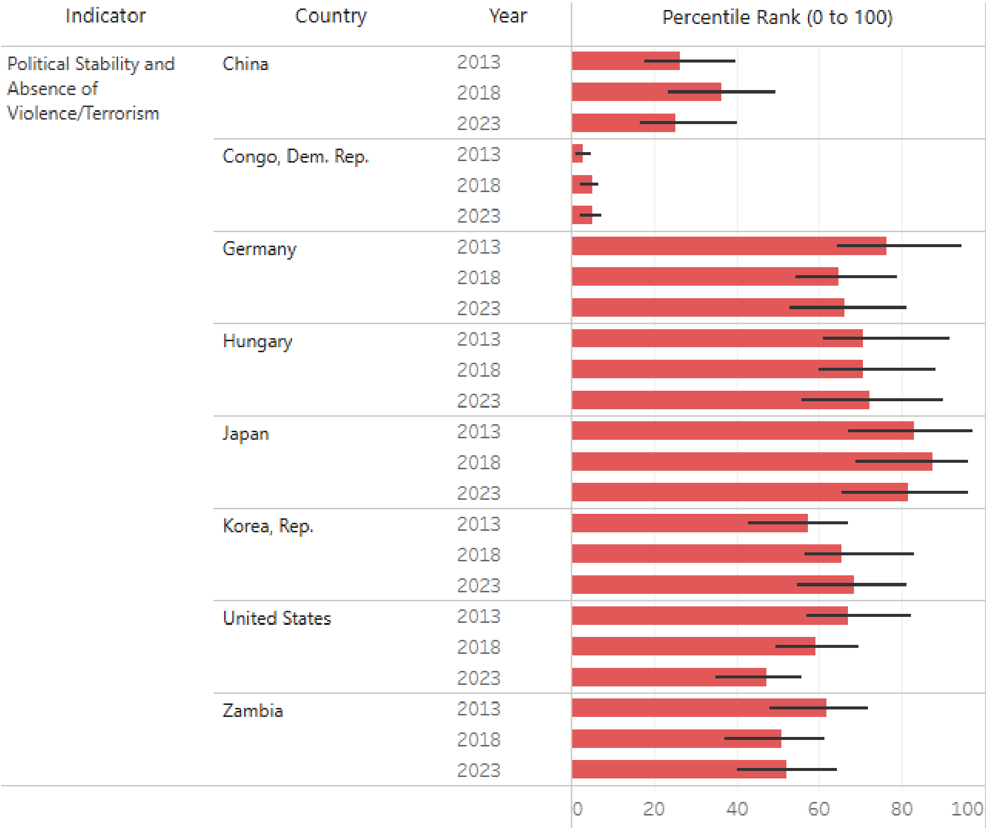

Figure 6: Political Stability and Absence of Violence/Terrorism Indicators (World Bank, 2025)

The economic dimension is critical in determining whether a battery industry can be both competitive and sustainable in the DRC-Zambia region. As identified in chapter four, six key conditions shape the viability of this industry: (1) cost-competitive production factors, including labour, energy, and access to raw materials; (2) access to investment capital and financial incentives such as subsidies, state loans, or tax relief; (3) reliable and increasingly renewable energy infrastructure to power energy-intensive processes; (4) efficient road, rail, and port infrastructure to support regional integration and export readiness; (5) the presence of sufficient domestic and regional demand to reduce dependence on volatile external markets; and (6) stable macroeconomic and trade conditions, including inflation control, foreign exchange stability, and coherent trade policy frameworks.

To avoid overlap, these six conditions are grouped into four related themes. The first section explores cost-competitiveness, based on a variety of production factors. The second examines energy and transport infrastructure, evaluating their reliability, costs, and connectivity. The third addresses the overall investment climate, including macroeconomic stability and access to finance options. The final section considers market conditions, including domestic and regional demand to support a large battery industry.

7.2.1. Cost Competitiveness

Zambia: Low Input Costs

Labour costs in Zambia are relatively low by international standards. As of January 2024, the minimum monthly wage was 2310.10 ZMW per month (Wage Indicator, 2025), or about 80 euros as of May 2025. This offers a clear cost advantage over many industrialised countries. However, labour productivity in Zambia lags far behind at $5.2 per capita per hour (International Labour Organisation, 2025), due to limited technical training and a very limited developed high-value-adding sectors. The World Bank (2024) mentions that although Zambia has improved access to education, the quality of labour market remains a key challenge, exemplified by the productivity of its formal sector declining between 2014 and 2021.

Zambia also holds a strong position in terms of raw material availability, which is one of the main drivers for the DRC-Zambia battery industry initiative. It is among the world's top producers of copper, which forms the backbone of its most productive sector, mining. Copper is also an essential part to battery production, as it is used to transport electrolytes between the cathode and anode. As a by-product, Zambia also produces cobalt, although at much lower volumes than the DRC. Although there are still other minerals that need to be sourced for battery production, this can be a competitive advantage.

With electricity being a significant cost post to battery production, as discussed by (Brodd and Helou (2013), Zambia is in an extremely favourable position, with tis average electricity price for businesses at $0.037/kWh, much lower than electricity prices in countries such as China ($0.092), USA (0.147), Japan (0.207), or Germany (0.286) (Global Petrol Prices, 2025). This is largely thanks to Zambia's reliance on hydropower, which supplies over 85% of its electricity (IEA, 2022b).

DRC: Abundant Resources and Low Input Costs

The DRC's minimum monthly wage is set at CF319,000, or 97.24 euros as of the 31st of December, 2024. This is, however, a doubling of what it was before that, at CF155,650, or 48.62 euros (Bankable Africa, 2025), which shows that it is not at all a stable indication. Despite these relatively low wage levels, the country faces significant challenges in labour productivity. The World Bank notes the DRC as one of the poorest countries globally, with an estimated 73.5% of its population living on less than $2.15 a day in 2024 (World Bank, 2025d). Labour productivity per hour is extremely low, at $2.4, 43% lower than Zambia's (International Labour Organisation, 2025). This is partly due to its poorer education system, which hinders the development of higher value-adding skills.

However, the DRC possesses significant mining capacities for minerals essential for battery production. Just like Zambia, copper and cobalt, but in much larger volumes than Zambia. It is by far the largest producer of cobalt in the world, with over 70% of globally mined cobalt, and the second-largest producer of copper (Statista, 2025). Cobalt also plays an important role in battery manufacturing, as the NMC chemistry is quite popular in EVs. However, the mining sector in the DRC faces large challenges, with loud concerns over environmental and labour practices, governance and shareholder issues.

Similar to Zambia, electricity prices for businesses in the DRC are relatively low at 0.068 (Global Petrol Prices, 2024), which is higher than Zambia, but still lower than countries with established battery industries. Again, this is largely due to its reliance on hydropower, which supplies close to 100% of its electricity (IEA, 2022a).

7.2.2. Energy and Transport Infrastructure

Zambia: Expanding Capacity but Structural Limitations

As of April 2024, the country's total installed capacity is 3,871MW (Ministry of Energy, 2024), with hydropower contributing to over 3150MW. However, climate change has been ramping up the frequency of extreme weather events, with 2015, 2018, 2020, and 2021 seeing extreme droughts (World Bank, 2024). With the country heavily reliant on hydropower, this led to reduced water levels in reservoirs, causing generational deficits and, by extension, blackouts (Gondwe, 2024).

In response to these challenges, Zambia has been investing in renewable energy sources, mainly solar. Notable examples are at the Lusaka South Multi Facility Economic Zone (LSMFEZ) (54MW), Itimpi and Riverside (34MW) and another at LSMFEZ (34MW), all deliver between 2022 and 2024 (Ministry of Energy, 2024). There is even a 60MW solar power station under construction, accompanied by a 20MWh battery energy storage system, expected to be operational in a few months (Jowett, 2024).

To further guide its energy sector development, the Zambian Cabinet has approved the Ministry of Energy's Integrated Resource Plan for 2024, a 30-year roadmap to ensure Zambia's future energy sufficiency and surplus in a cost-effective manner (Ministry of Energy, 2021). This includes generation, transmission, and distribution infrastructure. Additionally, there are also several off-grid renewable energy projects, of which the largest is a 1MW hydropower station in the Chinsali District (Ministry of Energy, 2024). There are also regulatory and financial frameworks to support additional renewable energy initiatives.

Zambia's transport infrastructure is also seeing significant developments to support demand and stimulate economic growth. It aims to "build up to 10,000 km of high-quality single- and dual-carriage roads throughout the country" (International Trade Administration, 2024c). This includes PPP projects such as the $577 million agreement with Macro-Ocean Investment Consortium for the Ndola-Lusaka dual carriageway project (Lusaka Times, 2023).

Zambia also has some railway connections. Zambia Railways Limited operates a 1062km network running from Livingstone to Chililabombwe, with certain extensions and international links, such as to Mozambique (ZRL, 2021). However, the network faces significant limitations due to ageing infrastructure and underinvestment. This has caused the train speeds to be generally slower than trucks. The Ndola to Luanshya line has even been completely closed, needing a complete reconstruction (Logistics Cluster, 2025a).

Still, there are opportunities. The US International Trade Administration reports that Zambia is currently looking for foreign investment to expand its railway network, specifically to enhance mining logistics. An example of this is the Lobito (a major port in Angola) corridor, which is connected to Zambia and has seen several MoUs and agreements that promise investment (International Trade Administration, 2024d). Additionally, the China Civil Engineering Construction Corporation will invest $1.4 billion to upgrade the Tanzania-Zambia railway (Miriri, 2025). This railway was originally constructed through Chinese investment between 1970 and 1975.

But Zambia is also a landlocked country, which brings inherent logistical challenges, especially for globally export-oriented industries. Without direct access to seaports, Zambia is reliant on regional port corridors through neighbouring countries to handle its intercontinental imports and exports. These include railway access to Dar es Salaam (Tanzania), Nacala, Beira, and Maputo (Mozambique), as well as Richards Bay and Durban (South Africa). While this provides essential access to global markets, it also results in higher transport costs, longer transport times, and a vulnerability to disruptions in neighbouring countries' infrastructure or governance. As such, Zambia's landlocked geography remains a large disadvantage for industrial exports.

This is also reflected in international benchmarks. According to the World Bank's Logistics Performance Index, which scores countries on a scale from 1 to 5, Zambia received an overall score of 2.53 in its most recent available assessment. This places it below the global average of 3.0. It shows particular weaknesses in infrastructure (2.3) and logistics competence (2.48). It performs better on international shipments (3.05) and timeliness (3.05) (World Bank, 2025a). In contrast, other countries with established battery industries have much higher scores: 3.8 (US), 4.1 (Germany), 3.9 (Japan), 3.7 (China), 3.2 (Hungary), and 3.8 (South Korea).

DRC: Large Energy Potential and Infrastructure Gaps

In 2022, the DRC's total installed electricity capacity was 2980MW, of which 98% came from hydropower (Mubenga et al., 2023). The Inga I and II dams alone amount to 351MW and 1,424MW respectively. But this is only the installed capacity. In reality, due to maintenance issues and underinvestment in grid infrastructure, the output is significantly lower (International Trade Administration, 2024a). Additionally, the DRC has one of the largest hydropower potentials in the world at over 100,000MW (African Development Bank, 2020). Despite millions of dollars of donor funding, only 19% of the population has access to electricity, with about 41% in urban areas and only 1% in rural areas. The government aims to increase this to 32% by 2030. This heavily impacts health, education, and the income-generating potential of the DRC. In fact, most of the realised electricity generation capacity projects were funded by mining companies to power their facilities (International Trade Administration, 2024a). This is supported by Law No. 14/011 in 2013, which liberalised the electricity sector, a large change from the historic public monopoly (*LOI N° 14/011 DU 17 JUIN 2014 RELATIVE AU SECTEUR DE L'ELECTRICITE*, 2014).

There are two regulatory bodies that were created after this law: the Autorité de Régulation de l'Électricité (ARE) and the Agence Nationale de l'Électrification et des Services Énergétiques en milieux rural et périurbain (ANSWER), respectively responsible for market oversight and rural electrification. While this framework is in place, the implementation record remains weak, with rural access to electricity at only 1%. Additionally, the agencies continue to suffer from limited staffing, inadequate digital systems, and standardised PPP contracts (ARE, 2024). This can also be illustrated by comparing per capita capacity: Zambia, with over 20 million inhabitants and 3870MW, has 0.194kW per capita. The DRC, by comparison, has only 2980MW for more than 105 million people, equivalent to just 0.028kW per capita.

In parallel to the energy challenges, the DRC faces large constraints in its transport network. The national road network is approximately 152,000km long, of which only 3,000km are paved. These paved roads are also often in poor condition due to underinvestment and a lack of maintenance (Ministère des Infrastructures et Travaux Publics, 2022). But there are also successes. According to the Agence Congolaise des Grands Travaux (ACGT) in 2024, recent urban efforts have seen 80% completion rates, although heavily concentrated in the capital region.

Railway infrastructure, however, is in critical condition. The national operator Société Nationale des Chemins de Fer du Congo (SNCC) manages a network covering more than 3,600km in southeastern Congo, which mainly services mining provinces. However, only a portion of this network is operational and suffers from outdated tracks, signal systems, and machinery (Logistics Cluster, 2025b). Train speeds are slow at 15 to 30km/h. The SNCC network does connect to Zambia to Angola but is highly dependent on future investments that have stalled in recent years.

This is also reflected in the World Bank's Logistics Performance Index, where it received an overall score of 2.50, extremely similar to Zambia's score of 2.53. This consists of infrastructure (2.3), international shipments (2.5), logistics competence (2.4.), and timeliness (2.8). Like Zambia, it places the DRC well below global average and far behind countries with established battery industries.

7.2.3. Investment Climate and Macroeconomic Stability

Zambia: High Growth, Volatility, and Constrained Foreign Investment

Zambia has made recent efforts to strengthen its macroeconomic conditions, following a period of fiscal difficulties in 2020 and a $1.3 billion agreement with the IMF in 2022 (IMF, 2024). These efforts include subsidy reductions, more revenue mobilisation, and greater transparency in public financial management. Over the past decade, Zambia's inflation rate has fluctuated considerably, often ranging between 7 and 11%, but also with large peaks up to 25% in 2016, 2020, 2021, and again in 2024 and 2025, with inflation currently at 15.3% in May of 2025 (Trading Economics, 2025a). These recurring spikes highlight Zambia's vulnerability to food prices, fuel costs, and exchange rate pressures.

Zambia's currency, the kwacha, has also experienced significant depreciation since the mid-2010s, largely due to volatile and declining copper prices. Public debt to GDP ratio currently stands at 114.9% (IMF, 2025). This, in combination with high interest rates, constrains public investment. The central bank of Zambia has an inflation target rate of 6-8%, but this has not been reached in the last five years. As a result, interest rates have hovered between 8-15.5%, with it standing at 14.% as of May 2025 (Trading Economics, 2025b).

As a result, foreign direct investment (FDI) inflows into Zambia have also declined, as can be seen in Figure 7: FDI flows Zambia (Macro Trends, 2023), from $2.1 billion in

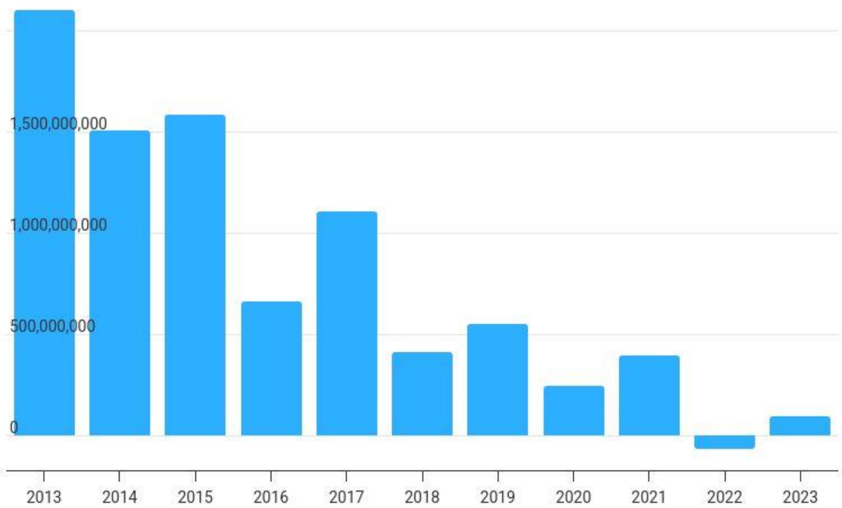

Figure 7: FDI flows Zambia (Macro Trends, 2023)

2013 to only $91 million in 2023. This reflects investor concerns over macroeconomic instability, policy unpredictability, and overall challenges for business. The government has been seeking to boost this investment climate through the 2023-2026 Development Cooperation Implementation Plan, which outlines reforms to streamline licensing, harmonisation of taxation systems, and increase the digital capabilities of public services (Ministry of Finance and National Planning, 2023).

The US Department of State's 2023 Investment Climate Statement for Zambia highlights several persistent issues: corruption, inconsistent application of regulations, and a lack of transparency in government procurement processes. Despite this, there are signs of potential, also for the battery industry. In September of 2024, China Jiangxi International Economic and Technical Cooperation invested $30 million in Zambia's Chibombo province for Lithium-Ion battery manufacturing, although details about components and end-products remain unclear (CJIC, 2025; Ministry of Information and Media - Zambia, 2024). This investment is separate from the DRC-Zambia battery value chain initiative.

DRC: High Growth, Volatility, and High Extractive-Driven Investment

The DRC has experienced strong average GDP growth over the past decade, averaging 6.7% annually. This is similar to Zambia's growth rate, but much more driven by the extractive industry. At the same time, inflation has been extremely volatile. It reached a high of 35.7% in 2017 and a low of 0.1% in 2015. In the last five years, inflation has hovered between 11.4 and 19.9%, with current levels at 21.% (Focus Economics, 2025a).

In contrast to this price instability, public debt has remained low and relatively stable, ranging between 17.9 and 33% of GDP over the last ten years (Focus Economics, 2025c). This low debt burden may indicate limited investment capacity, but it also shows a cautious fiscal stance. It can be interpreted as a sign of long-term solvency and caution.

FDI has also remained relatively stable despite political shifts and rebellious movements like M23 in Eastern DRC. Between 2013 and 2023, FDI ranged between $932 million and $1.68 billion (Macro Trends, 2025). This can largely be explained by the continued attractiveness of its extractive sector, which continues to draw investment. While this does not directly support battery manufacturing, it is part of its larger value chain and shows investor confidence in at least one sector despite other volatile conditions.

At the same time, the overall investment climate remains filled with barriers. According to the International Trade Administration's Investment Climate Statement from 2024, the DRC suffers from weak contract enforcement, corruption, and large bureaucratic inefficiencies. Investors often name legal uncertainty, regulatory inconsistency, and limited resources in the judicial system as barriers. Public-private partnerships are underdeveloped, as discussed in section 7.1.2.

Access to domestic finance also poses another major constraint. The central bank's policy interest rate has fluctuated extremely between 2% and 25% over the past ten years, and has remained at 25% since 2022 in an effort to combat high inflation and currency depreciation (Focus Economics, 2025b). This severely limits borrowing and thus investment by the private sector and is an especially large barrier to capital-intensive investments such as manufacturing or infrastructure.

7.2.4. Domestic and Regional Demand

Zambia Domestic Demand: Limited with Little Potential

Zambia's domestic market for EV batteries remains extremely limited. As of 2023, fewer than 100 EVs and hybrids were registered nationally (Kuhudzai, 2024). However, there are some policy efforts and infrastructure developments that can indicate the first steps toward larger demand.

For instance, the government has removed import duties on EVs and provides further tax exemptions for locally produced EVs (Kuhudzai, 2023). ZESCO, the national utility company, is rolling out public charging infrastructure in several towns, with two stations already operational in Lusaka and five more announced across the country (EV Charging Stops, 2023; Zambian Observer, 2022).

Private actors are also entering the domestic market. BYD partnered with Pilatus Motors in 2024 to launch models in Zambia, and there are also prospects for buses to be electrified (Kuhudzai, 2024).

Despite these steps, high vehicle costs, limited purchasing power, and weak infrastructure remain significant barriers that are unlikely to change without further investment. As such, demand is expected to remain extremely low.

DRC: None

The DRC currently shows no observable domestic demand for EV batteries. There are no recorded national EV policies or fiscal incentives, and no public registration data for EVs or hybrids is available. Given the country's low electrification rates, as discussed in 7.2.2, the domestic market for EV batteries remains undeveloped.

Regional Demand: Emerging Opportunities

While domestic demand for EV batteries in Zambia and the DRC remains severely limited, several African countries are experiencing EV adoption and EV manufacturing, which present potential export markets for battery components produced in Zambia and/or the DRC.

Morocco has established itself as a leading EV manufacturing hub in Africa, with approximately 600,000 EVs manufactured in 2024 (Jivraj, 2025). With nearly 80% of its exports going to the EU, where EV adoption is expected to continue rising, this represents an enormous potential. It has also attracted substantial investment, such as a $1.3 billion agreement with Chinese battery manufacturer Gotion High-Tech to construct a manufacturing facility of 20GWh, with the potential to expand to 100GWh (Kang, 2024).

South Africa is also developing its EV market, with the government introducing large tax incentives on investments in electric and hydrogen-based vehicle manufacturing. It also already has a significant car manufacturing industry, which accounts for 21.9% of the country's manufacturing output and 14.7% of its total exports (Kuhudzai, 2025a). Large automotive brands like Ford, Volkswagen, BMW, and Toyota have established manufacturing capabilities in the country and also aim to develop EV manufacturing capacities (Nolan, 2025).

In East-Africa, Kenya and Rwanda are seeing developments in electric mobility. A Nairobi-based startup BasiGo is assembling electric buses to slowly replace polluting diesel-based ones in an effort to combat air pollution (Wangari, 2024). The government also plans to deploy 10000 EV charging units by 2030. There is also demand for electric motorcycles (AfricaNews, 2023). In Rwanda, there is also a significantly developing demand for electric motorcycles, where Ampersand offers a battery-swapping network to support over 4,000 motorcycles (Kuhudzai, 2025b).

In 2024, Ethiopia went as far as to ban the import of ICE-vehicles (Internal Combustion Engine), the first in the world to do so. This was done at a time when the country had only a single charging station (Vuka, 2025). This was done in an attempt to lower fuel prices and the country's reliance on fuel imports, which was straining the economy. It has also lowered import taxes on EVs, although not eliminated.

These examples show a growing regional demand for EVs and their related components. While most countries remain in the very early stages of adoption, they highlight potential for a regional battery manufacturing industry in which Zambia and the DRC could play a role. However, when compared to more established battery manufacturing countries such as China, Germany, South Korea, or the US, it must be noted that these are also paired with both strong national and regional battery demand. This reinforces the need for an export-oriented strategy if battery production in Zambia and/or the DRC becomes a reality.

7.3. Social Dimension

The social dimension plays an important role in shaping the feasibility and legitimacy of battery industry development. For industrial developments to succeed, they need skilled labourers and support from their environment. In the case of high-tech industries such as battery manufacturing, they require highly skilled workers. In chapter four, four key social conditions were identified that will be assessed for the DRC-Zambia region in this section: (1) the availability of a skilled and technically trained workforce with access to retraining and dual education systems; (2) absorption capacity regarding housing, healthcare, and transport infrastructure to accommodate domestic and international workforce migration; (3) fair labour practices and mechanisms for community engagement to generate legitimacy and prevent local resistance; (4) broad societal acceptance of industrialisation efforts for stable, long-term support.

As with the Political and Economic sections, some of these conditions will be merged due to analytical overlap to avoid redundancy. This section is organised into three sections. The first explores human capital and workforce development. The second focuses on social absorption capacity. And the third examines community engagement, labour practices, and societal acceptance.

7.3.1. Workforce and Training Systems

Zambia: Expanding Access, but Limited Alignment with Industry Needs

Zambia has a relatively young and growing labour force. In 2023, the labour force participation rate stood at 62%, with a female to male ratio of 83% (World Bank, 2025e). Although the Ministry of Labour and Social Security reported very different findings in 2023, with a total participation rate of 43.8% (59.3% urban and 30% rural). Nevertheless, the country faces significant challenges in translating this workforce into one fit for a high-tech manufacturing industry.

The quality of education, for example, remains a major barrier. According to the World Bank, while Zambia has made significant progress in improving access to education, the quality itself remains poor, with high dropout rates and a disparity between taught skills and market needs (Al-Samarrai et al., 2024). This mismatch is especially problematic for high-tech industries like battery production, which require competencies in fields such as chemistry, process engineering, and quality control. When looking at the highest educational attainment, only 7.9% have a certificate or diploma, 3.1% a bachelor’s degree, and 0.4% a master’s degree or higher (Ministry of Labour and Social Security, 2023).

To improve this, several national initiatives have been introduced to improve the workforce skills. The government’s 8th National Development Plan from 2023, for example, emphasises human capital development and skills upgrading as national strategic priorities. This includes support for TEVET institutions (Technical Education, Vocational and Entrepreneurship Training), and a specific focus on partnerships with industry to provide dual education possibilities (Ministry of Finance and National Planning, 2022). However, implementation remains challenging. Many training institutions face chronic underfunding, outdated curricula, and weak links with the private sector (UNESCO, 2024b).

Additionally, there are also significant differences in training opportunities. Urban areas like Lusaka and the Copperbelt provinces provide much greater possibilities for technical training, resulting in educational inequality.

DRC: Skills Deficit and Poor Education System

The DRC faces a profound mismatch between labour market demand and the skills of its workforce. According to the International Labour Organisation's State of Skills Report (2020), the country's training programs are highly fragmented, underfunded, and poorly aligned with the needs of a more modern economy. Nearly 88% of the total economy is informal, and while 65% of the population is of working age, many are susceptible to migration. Additionally, only 8% of the population has enrolled in higher education.

UNESCO (2024a) also notes that the Congolese education system has low retention and quality. Access to secondary and tertiary or higher education is highly unequal, with rural populations and especially girls disproportionately excluded. The literacy rate among youth aged 15-24 is only at 77% for males and 63% for females. This makes it extremely difficult to develop the necessary competencies for high-tech manufacturing.

While there are national efforts to improve the TEVET sector, these efforts face major barriers and are often unable to be implemented. Severe shortages of qualified teaching staff, outdated training materials, and a lack of coordination with private actors are named among the main reasons (International Labour Organisation, 2020).

These issues are reflected in international indicators. According to the World Bank's Human Capital Index of 2020, which gives a score between 0 and 1 to represent "the amount of capital a child born today could expect to attain by age 18", the DRC scores just 0.366, among the lowest in the world. Zambia scores slightly better at 0.397 but still falls short of the global average at 0.56. To zoom in more on education and skills, we can also look at the learning-adjusted years of schooling, which combines education quantity and quality. The DRC scores 4.53 years, and Zambia 5.04 years, indicating low educational performance.

In comparison, countries with established battery industries perform slightly better: China (9.27), the US (10.56), Hungary (10.27), South Korea (11.68), and Japan (11.74). Lastly, in Figure 8, a visual comparison is provided for Harmonised Test Scores, which reflect the quality of education. In this figure the same countries are encircled with a colour: the DRC, Zambia, China, United States, Hungary, South Korea, and Japan. Also these results show significantly lower performances from both Zambia, but again, especially the DRC.

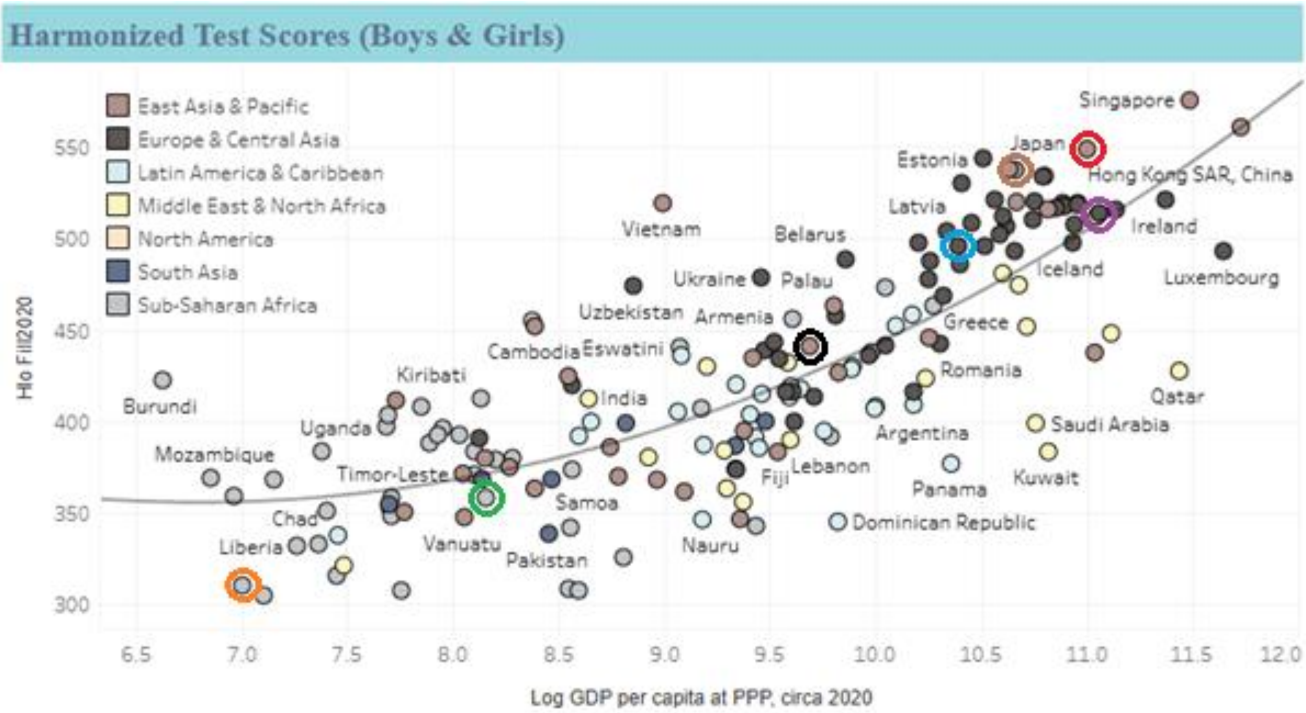

Figure 8: Harmonised Test Scores (World Bank, 2020)

7.3.2. Social Absorption Capacity

Zambia: Housing and Healthcare crisis

Zambia faces a national housing deficit of 1.5 million units, which is projected to double by 2030. This is largely attributed to a combination of rapid population growth and urbanisation. Approximately 70% of the urban population resides in informal settlements, which often are not connected to basic water and electricity utilities. In the capital Lusaka, for example, only about 21% of households have access to these utilities, in other urban areas, this is at 16% (World Bank, 2022c). These conditions will make it extremely challenging to accommodate an influx of workers without separate funding dedicated to them.

The healthcare system also faces large challenges. In 2022, the country had approximately 0.297 physicians and 2.147 nurses per 1,000 people (Trading Economics, 2022a, 2022b). The World Health Organisation (2016) uses a threshold of 4.45 physicians and nurses per 1000 to deliver essential health services. As such, the combined number of 2.44 physicians and nurses falls significantly short of this threshold. Additionally, there is a large inequality between urban and rural areas. For instance, 46% of rural households in Zambia live more than 5 kilometres from the nearest health facility, compared to only 1% of urban households (Zulu et al., 2022).

Childcare services are also a critical part of social infrastructure for working parents, especially women. In Zambia, the availability of formal childcare services is very limited. In fact, usually one talks about childcare in Zambia, they talk about children who live in poverty, are abandoned, have become orphans, or are abused (Ministry of Community Development and Social Services, 2017).

DRC: Significant Housing and Healthcare Strains, Potential Childcare

The DRC, like Zambia, is facing a significant housing crisis with a deficit of 4 million units. Again, this is attributed to rapid population growth and urbanisation, marked by 45% of the deficit coming from Kinshasa alone (Expobeton, 2025). Also in Kinshasa, approximately 75% of residents live in informal settlements that lack basic utilities. Additionally, there is no well-organised sector in the DRC to produce social housing, including the building materials (UN-Habitat, 2023). All in all, this is comparable to Zambia, meaning that an influx of workers would be difficult to accommodate without targeted investment.

The DRC has approximately 0.2 physicians and 1.2 nurses per 1000 people, totalling 1.4 health workers (World Bank, 2022a, 2022b). This is significantly lower than the WHO's threshold of 4.45, resulting in extremely large strains. This is partly due to the impact of conflicts, but also due to severe underfunding and a lack of skills (World Bank, 2025d). There is also a large disparity between urban and rural healthcare, with rural populations often being remote and lacking transportation infrastructure.

For childcare, there seems to be more information than in Zambia, thanks to a study done by Donald et al. (2024) at Harvard. They show that while there is a large demand for childcare services, only 4% of children are nationally enrolled in childcare. The main reason for this is that it is assumed that women can easily bring children to their, often agricultural, work. When this is not possible, they can often rely on family networks. However, this is still promising for workers in high-tech manufacturing sectors, who are often better paid than the average worker and thus may have the means to afford childcare.

7.3.3. Community Engagement, Labour Practices, and Societal Acceptance

Zambia: Weak Enforcement and Global Reputational Risks

Zambia has ratified all ten fundamental conventions of the International Labour Organization, and also all four priority governance conventions. Out of the 177 technical conventions, it has only ratified 35. However, out of the 49 ratified conventions, only 40 are in force (NormLex, 2025b). This means there is still a lot of work to be done to promote labour practices.

Despite their strong formal commitment to these standards, implementation and enforcement remain inconsistent. The Ministry of Labour and Social Security has made recent progress in monitoring, with over 2300 workplace inspections in 2022 related to child labour (U.S. Department of Labor, 2022). It is unclear how many regular inspections are conducted, but the Ministry of Labor and Social Security has stated that they have "inadequate resources, including an insufficient budget, limited office space, inadequate training, and a lack of transportation and fuel". While this is an improvement from earlier years, it suggests that enforcement is still too limited to guarantee labour protections at scale.

Additionally, the International Trade Union Confederation's Global Rights Index of 2023 places Zambia at rating 4: a "Systematic violations of rights". However, countries such as the UK, US, Greece, Hungary, but also the DRC have the same rating, though the index also includes more severe categories (5 and 5+) (ITUC, 2023). From the perspective of international importers, this may pose serious reputational and ESG (Environmental, Social, and Governance) risk.

That said, community engagement practices in Zambia are relatively more advanced than in many peer countries. The government encourages firms operating in SEZs to integrate local communities in decision-making processes. The Zambia Association of Manufactures also urges its members to adopt ESG practices, arguing that good labour and community relations are good for business (Lindunda, 2023). However, these are only encouragement and urges, a more formalised framework for community engagement is absent.

Societal acceptance of industrialisation in Zambia generally is good, as it offers better paying jobs than regular, often agricultural, jobs. Yangailo and Chambani (2023) have also examined the impact of industrialisation on economic growth in Zambia, concluding that it has a significant positive impact on economic growth.

DRC: Weak Fundamentals and Large Reputational Risks

The DRC has ratified 8 of the 10 fundamental ILO conventions, 2 of the 4 priority governance conventions, and only 27 of the 177 technical conventions. Of the 37 conventions it has ratified, only 32 remain in force (NormLex, 2025a). In comparison to Zambia, this shows a significantly weaker formal commitment to international labour standards.

However, this metric alone does not directly correlate with a country's ability to successfully develop a battery manufacturing sector. Several major countries show similarly poor ratification levels. China, for instance, has ratified only 7 of the 10 fundamental conventions, 2of 4 governance conventions, and just 19 technical conventions. Japan performs slightly better at 8, 3, and 39 respectively. The US only 2, 1, and 11, making it the worst performer.

Although the DRC's ratification record is not exceptional, it not uniquely poor in global context. Still, low adherence to international labour norms, especially in combination with other reputational damages, such as the existing abuses of child labour and slavery in the cobalt mining sector (Amnesty International, 2016), can cause large reputational risks. In supply chains where ESG compliance is increasingly important, this can undermine investor confidence.

As in Zambia, formal mechanisms for community engagement are limited. While environmental and social impact assessments are legally required for large-scale projects, their implementation is often inconsistent. Most of the actual community engagement falls on the initiatives of individual companies. For example, some mining companies have taken responsibility to translate some of their economic gains to benefits for the surrounding communities. Examples include schools, utility access, and medical assistance (Peter, 2019).

Despite these efforts, many communities remain sceptical of industrial projects due to their associations with mining efforts, which have historically caused displacements, human rights abuses, and environmental degradation (Adebayo, 2023). This has damaged trust in both companies and governmental institutions. As such, societal acceptance of industrialisation is more fragile and more reliant on transparent engagement strategies with communities. Without community involvement and tangible benefits, industrial projects risk facing resistance.

7.4. Technological Dimension

This technological readiness of a country is a another key determinant to its ability to host complex manufacturing industries such as batteries. Three conditions were identified in chapter four that are particularly relevant: (1) the presence of a strong national innovation system, supported by research institutions, universities, and public or private R&D funding; (2) the ability to transfer knowledge effectively across firms and stages of the value chain; (3) the creation and protection of intellectual property. These factors essentially examine whether a country can absorb external knowledge and technologies, but also whether it can adapt and refine them. In the following section, the Zambia and the DRC are assessed against these conditions.

7.4.1. National Innovation Systems

Zambia: Relative Strength but Low Performance

According to WIPO's Global Innovation Index (GII)of 2024, Zambia ranks 116th out of 133 economies, while placing 13th among 27 Sub-Saharan countries and 30th among lower-middle-income economies. It scores within the top 100 on foundational inputs such as institutions, human capital, and infrastructure. However, it ranks near the bottom globally on creative outputs and knowledge and technology outputs. This disconnect suggests that while Zambia possess a relatively solid foundation, it lacks mechanisms to convert this into innovative outcomes. This is also reflected by the GII’s labelling of Zambia as “inefficient” in its input-to-output performance.

In 2020, Zambia counted seven public and 63 private tertiary knowledge institutions, heavily concentrated in Lusaka and around the Copperbelt (Dietz, 2020). The sector has grown rapidly, with two new public universities and five private ones established between 2015 and 2020. However, these institutions remain primarily education-oriented. Zambia received a score of 0.0 for R&D activity in the GII, which shows the absence of significant research production or funding. This is partially caused by the lack of a dedicated national science and technology policy, resulting in fragmented governance, poor coordination, and limited public interest in research positions.

Several efforts have been made and are being made to address these gaps. For example, the UNESCO has collaborated with the Ministry of Science and Technology to support STI (Science Technology and Innovation) policy reforms (UNESCO, 2023). Similarly, the World Bank has several programmes, such as the Eastern and Southern Africa Higher Education Centers of Excellence, aimed at building collaborative research capacity and delivering quality postgraduate education with a total budget of $148 million (World Bank, 2025b).

However, these initiatives remain limited in scope and rely on external funding. Without a coherent science and technology policy and the accompanied investment, Zambia will continue underperforming on technological domains critical to battery manufacturing, or other high-value industries.

DRC: Low Input and High Fragmentation

The DRC is not featured in the GII 2024 rankings, indicating a lack of comprehensive data on its innovation ecosystem. Considering that the GII has 31 countries in its index, this represents significant challenges in measuring and benchmarking the country's innovation performance on a global scale. According to the data that is available, R&D expenditure was 0.41% in 2015, which is low compared to the global average of 0.98%.

The DRC does, however, have a large and growing number of higher education institutions. According to Congo Education, there are 62 universities in the DRC, as well as many more private ones. As in Zambia, most of these universities are primarily focused on teaching, and not on research activities. The government acknowledges that the sector remains fragmented and poorly coordinated in its "Document de Politique de la Recherche Scientifique de la République Démocratique du Congo", saying that there remains an absence of national fund for scientific research, with very weak cooperation between research institutions and productive sectors (Ministère de la Recherche Scientifique et Innovation Technologique, 2021).

Despite these weaknesses, the same document outlines formal commitment to address these weaknesses and proposes a national strategy built around institutional reform, capacity building, and stronger integration of research into economic planning. It prioritises the creation of a national fund for research, the development of regional innovation centres, and closer coordination between universities, technical ministries, and industry stakeholders. However, as of 2025, there is no evidence that this has resulted in measurable improvements.

7.4.2. Knowledge Transfer and Cooperation with Industry

Zambia: Emerging Collaborations and Structural Weaknesses

Zambia's performance in knowledge and technology outputs, as mentioned in the previous section, remains a significant concern. According to the GII, it ranks 130th out of 132 economies in this category, which indicates limited success in translating research input into economic benefits. Despite this, Zambia performs much better at "Business Sophistication". It ranks 82nd on University-Industry R&D Collaboration and 72nd on State of Cluster Development.

A key institutional actor in this domain is the National Technology Business Centre established in 2002 under the Ministry of Technology and Science. It aims to facilitate technology transfer, foster innovation, and support entrepreneurial activities (NTBC, 2025). Despite this mandate, the published projects it works on are relatively limited, and it is unclear how it enhances collaboration between universities and industry. A recent qualitative interview-based analysis by Jembere et al. (2023) found that Zambia uses Public-Private Development Partnerships to strengthen links between vocational institutions and the private sector. Initiated by the Ministry of Technology and Science, they show promise in improving workplace-relevant training and knowledge transfer. However, it also suffers from weak institutional embedding and retention of personnel.

Additionally, a study by Kaira and Phiri (2021) shows that while many respondents from universities had good levels of knowledge management, it was poorly used in these institutions. The institution itself did not have the necessary policies or strategies to effectively manage knowledge. This shows that there is still much improvement to be made, not just within the institutions themselves, but also in the collaboration with industries.

DRC: Highly Fragmented and Misaligned with Industry

With the DRC not included in the GII index and other sources such as The Global Economy having very limited, often outdated, data, it reflects a structural weakness in its innovation system, or at least a lack of transparency thereof. In the report of the Ministère de la Recherche Scientifique et Innovation Technologique (2021), it is mentioned that the interaction between research institutions, universities, and the industry, is weak. Additionally, while there are certain programs and projects that have generated positive and useful outputs specifically for the DRC, this is rarely coordinated or even shared with relevant industry actors, especially the smaller ones. Clear research objectives are absent, causing misalignment between research and industry needs.

There have been efforts to improve this, such as the bilateral agreement between South Africa and the DRC to improve institutional collaboration (Department of Science and Innovation, South Africa, 2023). However, the overall knowledge transfer infrastructure remains extremely weak and misaligned with industry.

7.4.3. Creation and Protection of Intellectual Property

Zambia: Modern Legal Framework, Low Patent Activity

Zambia has established a comprehensive legal framework for intellectual property protection, aligned with international standards, in the form of Patents Act No. 40, Zambia (2016). There are also complementary legal frameworks which include the Industrial Designs Act No. 22, Zambia, (2016), and the Layout-Designs of Integrated Circuits Act, Zambia (2016). The Patents and Companies Registration Agency serves as the institution responsible for overseeing filings and enforcement of IP rights in Zambia.

Despite these robust legal frameworks, patent activity in Zambia remains very limited. In 2023 there were only 14 patents applications, of which only 5 were by residents. In the same year, there were 17 patents granted, of which only one was by a resident (WIPO, 2024b). Additionally, there is no mention of Zambia in its report: “Making Innovation Policy Work for Development” (World Intellectual Property Organisation, 2024).

In an in depth-analysis of international patenting trends regarding gigafactory battery cell production by Greitemeier and Lux (2025), there is also no mention of Zambia, or even Africa for that matter. In this regard, China dominates, followed by Japan, the US, the EU, Korea, and the rest of the world only has a share of about 5%. As for its extractive sector, there are a few patents, such as the one by Alexander Mining PLC (Laniyan, 2018), for a method regarding cobalt leaching.

Lastly, Zambia’s participation in international treaties, such as the Paris Convention and the Patent Cooperation treaty, enables Zambia to protect their IP rights beyond its borders. Still, this can be challenging and resource-intensive.

DRC: Outdated Framework, Extremely Low Activity

While the DRC does have a legal framework for intellectual property protection, namely the Law No. 82-001 on Industrial Property, Democratic Republic of the Congo (1982), it is extremely outdated and not aligned with international standards. It does have a regulatory body responsible for overseeing IP rights in the DRC, the Directorate of Industrial Property, which is part of the Ministry of Industry, but its capacity is limited.

In 2023, the WIPO's database lists no available data on patent applications or grants from the DRC. The DRC is also absent in its global report. This suggests a total absence in the creation of intellectual property or a systemic failure to register and submit patents. Despite the country's leading role in global cobalt extraction, there are no recorded DRC-originated patents relating to cobalt extraction or refinement. This shows a strong contrast with established battery manufacturing countries such as China, Japan, or the US (Greitemeier and Lux, 2025).

7.5. Legal Dimension

A robust legal environment heavily influences both the long-term feasibility and present possibilities for a battery industry. In chapter four, four key conditions were identified: (1) a comprehensive regulatory framework with long-term targets for sustainability and circularity; (2) strategic legislation aligning permitting, industrial support, and innovation; (3) enforceable standards for battery reuse, recycling, and traceability; and (4) legal instruments supporting battery production through fiscal incentives and public investment.

However, due to the limited regulatory development in both Zambia, but especially the DRC, examining all four conditions separately would result in significant redundancy. To avoid this, the four different sections have been merged into two. The first examines the regulatory framework for sustainability goals, lifecycle, recycling, and traceability, combining (1) and (3). The second focuses on the regulatory environment for industrial development, including permitting procedures, investment incentives, and institutional alignment, combining (2) and (4).

7.5.1. Sustainability Targets, Lifecycle, and Traceability

Zambia: A Relatively Strong Legal Foundation, No Battery-Specific Rules

Zambia has established a foundation for sustainability and lifecycle goals through the Environmental Management Act (2011), which later environmental policies are based on. It includes sections on Environmental Management Strategies, Strategic Environmental Assessment, Environmental Impact Assessment, Extended Producer Responsibility regarding waste, as well as Public Participation in Environmental Decision-Making. Although no battery-specific regulations currently exist, the responsible Agency could bring these under these regulations through minor regulatory changes.

For example, through the Extended Producer Responsibility, which covers the prevention of waste generation, recovery, re-use, and recycling, if the Zambia Environmental Management Agency deems batteries or its subcomponents to fall under this regulation. Overall, this shows not only intent of the Zambian government to sustainability goals, but also a relatively effective translation into its regulatory framework. However, enforcement remains challenging due to capacity problems and overall quality of rule of law. Figure 9 and Figure show Zambia's relative performance on Rule of Law and Regulatory Quality, at the end of the coming DRC section. It also includes a comparison with the DRC and established battery manufacturing countries. On Rule of Law, it performs at the 32nd percentile, down significantly from previous years. Regulatory Quality has remained stable at the 34th percentile. This is a significant contrast with most countries with established battery manufacturing industries, who mostly perform at the 60th percentile (Hungary) or much better (US, China, Japan, Germany, Korea), with the exception of China, which performs around the 40th percentile.

Additionally, Zambia's commitment to sustainability is also reflected in its Renewable Energy Strategy and Action Plan (2022) and the MoU between the EU and Zambia on a Partnership on Sustainable Raw Materials Value Chain (2023), which also includes the "promotion and investment in circular economy value chains for the recycling, reusing and remanufacturing of CRMs (Critical Raw Minerals)".

DRC: Modest Framework, Weak Implementation

The DRC has also established a legal foundation for sustainability and lifecycle management through its Loi N° 11/009 Portant Principes Fondamentaux Relatifs à La Protection de l'Environment (2011). It includes principles such as sustainable development, public participation, and requiring strategic environmental assessments. It also mentions waste reduction, recycling, and waste management, and prohibits the import and dumping of foreign waste. However, the framework is not as extensive as Zambia's, and while many subjects are considered, they are not very detailed.

However, implementation remains challenging. As an example, while Article 17 mentions the creation of a "Conseil National de l'Environment et du Développement Durable", or a National Council for the Environment and Sustainable Development, a search for this institution was unable to return anything. This is reflected in international rankings on Regulatory Quality and Rule of Law, which are presented in Figure 9 and Figure , on which it performs extremely poorly, at the 8th and 5th percentile respectively.

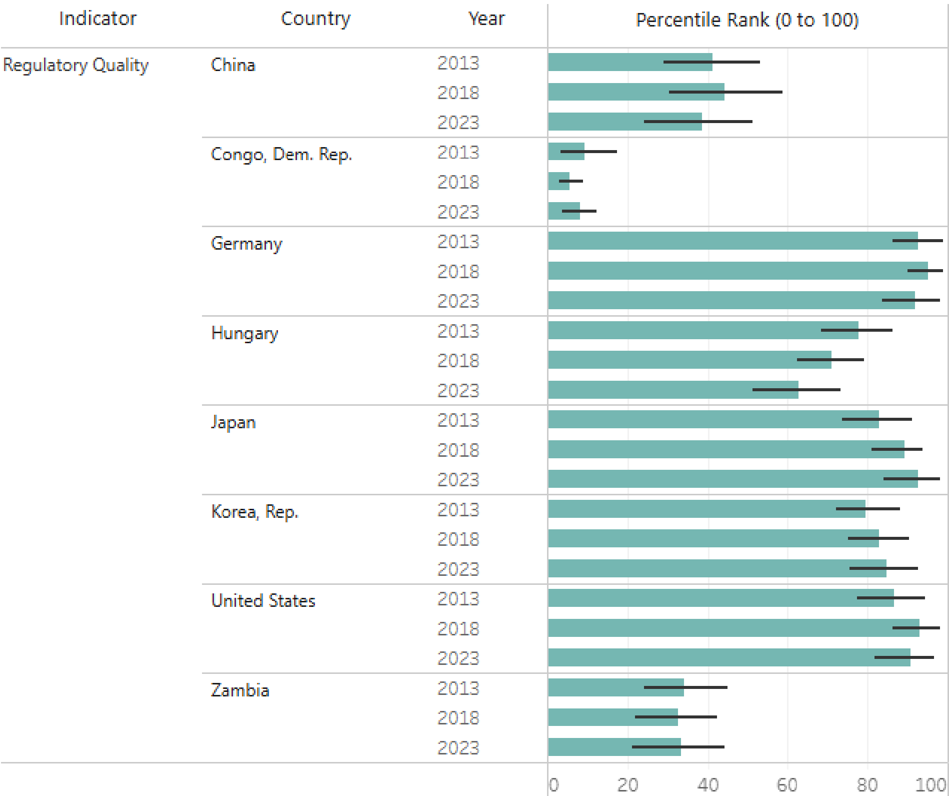

Figure 9: Regulatory Quality Indicator (World Bank, 2025)

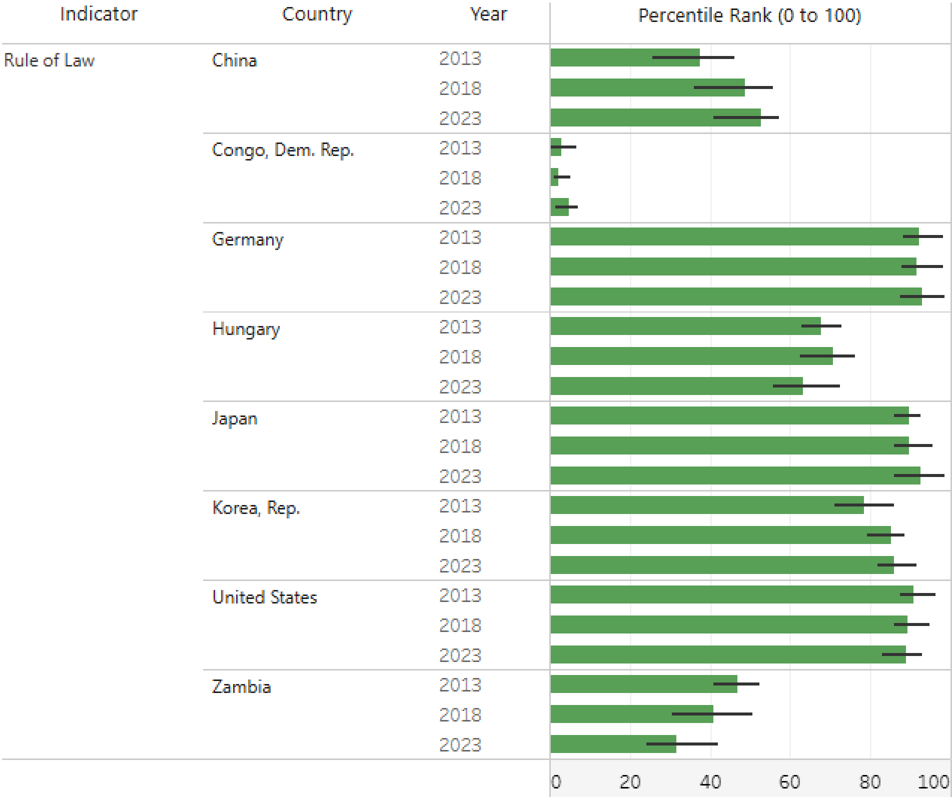

Figure 10: Rule of Law Indicator (World Bank, 2025)

7.5.2. Strategic Support for Industrial Development

Zambia: Supportive Framework, Limited Capacity

Zambia's legal framework for promoting industrial development and permitting is mainly overseen by the Zambia Development Agency (ZDA) Act No. 17 (2022), which is the sixth iteration of the law originating from 2006. The act provides a legal basis for investment incentives and permitting for business operating in certain priority sectors, which includes manufacturing and renewable energy. For example, firms who invest $500,000 or more in a Multi-Facility Economic Zone are eligible for duty free imports on capital assets such as machinery, as well as accelerated depreciation possibilities and an exemption on dividend tax, all for five years.

The ZDA also oversees access to land for investors, as well as utilities and business licences. It also coordinates with the Zambia Environmental Management Agency (ZEMA) who oversee Environmental Impact Assessments (EIA). This coordination is meant to streamline application processes and avoid delays.

However, operational challenges are common. The World Bank (2024) mentions that many investors still face inconsistent licensing requirements from municipalities, as well as overlapping mandates between national and subnational institutions. Additionally, the ZEMA has limited capacity, especially outside of Lusaka, which can result in delays in EIAs. These are mandatory for manufacturing facilities, manufacturing can often be damaging to its surroundings. This results in regulatory unpredictability, which can hinder investor trust, especially in risky capital-intensive manufacturing sectors. The World Bank also notes that different agencies, such as the ZDA and ZEMA, have poor coordination and often work inefficiently.

DRC: Outdated Framework, Weak Institutional Capacity

The DRC's investment and permitting framework is based on its *Code des Investissement Loi n° 004/2002* (2002), which outlines general rules for both national and foreign investors. It offers opportunities for fiscal benefits such as tax exemptions and import duty reliefs, particularly concerning so-called high-priority sectors. These incentives and permissions are overseen by the ANAPI, which evaluates applications on a case-by-case basis. While this does allow for flexibility, in practice, the legal foundation lacks detail and institutional maturity, resulting in inconsistent implementation. Investors often name difficulties in navigating the regulatory landscape for incentives, as well as clarity on eligibility and enforcement, as a barrier (International Trade Administration, 2024b)

Permitting processes are also further complicated by regulatory gaps and low agency capacity. While Decree N° 14/019 (2014) requires EIAs for projects that could damage its environment, the responsible agency, the Agence Congolaise de l'Environnement, suffers from significant capacity restrictions, which often result in delays. According to Osei and Effah (2023), the DRC's environmental permitting framework is inefficient, ineffective, and in need of an update.

7.6. Environmental Dimension

While the Environmental Dimension can be said to play a lesser role than other dimensions, it can still significantly influence the public legitimacy of a battery industry. And if done properly, it can also be used for a manufacturer's advantage for "green" branding. The perceived conditions identified in chapter four were: (1) the carbon intensity of production, which largely depends on the energy mix; (2) battery circularity and recycling capabilities to reduce dependency on critical mineral imports; (3) the clarity and enforcement of environmental regulations; (4) strong governance enforcement to reduce ecological damages.

As with previous sections, to avoid redundancy, some conditions are merged. In this case, this results in two sections. The first focuses on environmental sustainability in production and resource use, merging (1) and (2). The second combines conditions (3) and (4), focusing on environmental risk governance, including clarity of regulations and their enforcement.

7.6.1. Renewable Energy and Recycling

Zambia: Highly Renewable, Less Reliable

Zambia's energy mix is heavily reliant on hydropower, which accounts for over 85% (Ministry of Energy, 2024). With hydropower being a sustainable source, it positions the country to market itself as a low-carbon manufacturing location. However, there are also negatives to hydropower. For example, Zambia has been susceptible to droughts, especially in recent years, which has led to blackouts (World Bank, 2024). While less commonly known, it can also be associated with severe negative ecological impacts. A study by Qiu (2024) mentions the "damaging of local ecosystems, deforestation, and pollution".

To improve energy reliability, Zambia has been investing in solar energy, sometimes even connected with battery storage systems (Jowett, 2024). This diversification can strengthen the reliability of the overall electricity grid. However, Zambia currently lacks battery-specific circularity regulation, and the Environmental Management Act (2011) only provides general Extended Producer Responsibility that could be adapted to battery waste and recycling.

DRC: Highly Renewable, High Potential, Low Access

The DRC holds one of the world's largest hydropower potentials at over 100,000MW (African Development Bank, 2020). Its current energy mix is also nearly entirely composed of hydropower at 99.6% (IEA, 2025a). This makes the DRC an ideal candidate for low-carbon industrial production, in theory. However, electrification is extremely low, and an energy-intensive industry could be expected to put significant strain on the electricity system. Much of the infrastructure is outdated, insufficiently maintained, resulting in much lower output than capacity.

While Law N° 14/011 (2014) liberalised the energy sector and created a formal regulatory structure with overseeing bodies, implementation remains weak. Industrial self-generation is permitted and already used in the mining sector. A study by Y. Wang et al (2024) also suggested this for Chinese companies looking to establish or expand extractive activities in Zimbabwe. If coordinated properly, this could also benefit local communities

7.6.2. Environmental Risk Governance and Regulatory Enforcement

Zambia: Structured, but Fragile

Zambia has established a governance framework through the Environmental Management Act (2011), which requires Environmental Impact Assessments, Strategic Environmental Assessments, and introduces Extended Producer Responsibility. These legal instruments are designed to regulate the environmental impacts of firms, especially of manufacturing or extractive firms, which can have significant damaging impacts. The ZEMA is responsible for enforcing these regulations.

However, enforcement remains a structural challenge. The World Bank (2024) reports frequent delays in EIA processes due to limited staffing, especially outside of Lusaka. The ZEMA is noted to have insufficient resources, work inefficiently, and be poorly aligned with other agencies. This can contribute to investor uncertainty, as well as increase the risks of ecological damage due to non-compliance.

This is reflected by Zambia's performance on Yale's Environmental Performance Index (2024). The country ranks 83rd out of 180 with an overall score of 46.7 (out of 100), which shows a moderate performance. But scores vary significantly per subcategory. While Zambia has high scores in Biodiversity and Habitat (83.7), it scores much lower on Environmental health (19.1) and Climate Change (39.4). For the condition analysed in this section, Environmental Health is especially relevant. This is because these are decided by subcategories that can be negatively impacted by manufacturing industries, such as waste management, air quality, and drinking water. This shows that Zambia's regulatory environment and its enforcement are not ready to oversee a battery industry.

DRC: Minimal Framework, Minimal Oversight

The DRC does have laws in place to regulate environmental risks. The main ones are Loi N° 11/009 (2011), which outlines general environmental protection rules, and N° 14/019 (2014), which makes EIAs mandatory for potentially harmful projects. These laws show some intent for sustainable development, ecological precaution, and public participation. However, they lack detail, institutional maturity, and are outdated.

The agency responsible for implementation, the Agence Congolaise de l'Environnement, faces major challenges. Among these are a lack of staff, technical capacity, and overall enforcement capacity. A study by Osei and Effah (2023) concludes that the framework and implementation thereof is inefficient, ineffective, and in need of an update.

This creates large uncertainty for potential investors, especially for a potentially ecologically damaging, capital-intensive, and energy-intensive battery industry.

These issues are also reflected in international indicators. The DRC scores poorly on Yale's Environmental Performance Index (2024a), with rank 128 out of 180, and a score of 39.5 (out of 100). However, when we zoom in on subcategories relevant to battery industry, an even worse performance is noted. These include Air Quality (8.1), Drinking Water (25.6), and Waste Management (23.9). For waste management, they score a 1 (out of 100) on Controlled Solid Waste and Waste Recovery Rate. This shows that the country is far from being able to monitor or mitigate environmental impacts linked to heavy industry.

7.7. Comparative Evaluation of Battery Industry Conditions in Zambia and the DRC

To conclude the analysis, Table 3 provides a comparative overview of all identified conditions that can influence battery industry development in Zambia and the DRC. It is organised according to the six PESTLE dimensions, with sub-conditions derived from the conditions identified in Chapter 4. By using colour coding, this synthesis highlights where each country shows relative strengths and where there are still significant barriers. Three colours are used for this: green (enabling), brown (moderate), and red (barrier).

Condition	Zambia	DRC
Political		
Strategic Vision and Policy Alignment	Strong policy documents, moderate execution	Vision exists, but lacks detail and execution
Governance Capacity and Public-Private Engagement	Moderate implementation capacity	Very weak institutional execution
Political Stability and Predictability	Relatively stable with turmoil	Extremely low stability and predictability
Economic		
Cost Competitiveness	Low Input Costs	Low Input Costs
Infrastructure (energy and transport)	Decent roads and grid, but unreliable	Severe deficiencies
Investment Climate	Improving, but constrained	High uncertainty and risk
Domestic and Regional Demand	Extremely limited domestic, some regional potential	Nonexistent domestic, some regional potential
Social		
Workforce and Training	Not fit for high-skill, improving education	Not fit for high-skill, poor education system
Social Absorption Capacity	Severe barriers in housing in healthcare	Near-critical housing and healthcare
Community Engagement and Labour	Moderate labour practices, decent engagement	Poor compliance and weak engagement
Technological		
National Innovation Systems	Moderate foundations, very weak output	Minimal capacity, no coordination
Knowledge Transfer and Industry Cooperation	Emerging initiatives, limited structure	Next to no systemic collaboration
Intellectual Property	Strong legal framework, low activity	Outdated law, very low activity
Legal		

Sustainability, Lifecycle, Traceability	Moderate law, poor enforcement	Basic law, weak details and enforcement
Industrial Support and Permitting	Moderate foundation, but little capacity	Some support, very unclear, little capacity
Environmental		
Renewable Energy and Recycling	Highly renewable, unreliable, no recycling	Completely renewable, unreliable, no recycling
Environmental Governance	Moderate laws, very weak enforcement	Weak rules and enforcement

Table 3: Comparative Assessment of DRC and Zambia using PESTLE findings.

The table shows that Zambia displays a relatively balanced and moderate landscape, with many brown indicators across all dimensions except social, where it has two red areas. This suggests that while challenges remain, especially in the social domain, Zambia has already established a functional baseline for some industrial development. Institutional responsibilities are generally well-defined, strategic policy documents exist, and permitting procedures, while sometimes delayed, are grounded in legal frameworks. However, critical constraints remain in technical education, innovation output, and investment confidence. These do not exclude potential development, but they do require targeted interventions to move to more realistic implementation.

By contrast, the DRC's profile is overwhelmingly red across all dimensions. Despite its vast reserves of cobalt, copper, and hydroelectric potential, the DRC lacks nearly all of the identified conditions for battery industry development. Policy remains disconnected from implementation, the legal system is outdated and fragmented, and permitting and investment processes are unpredictable. These foundational weaknesses create an environment of structural uncertainty that actively deters long-term and/or large-scale investment. While raw materials remain its core strength, these cannot, on their own, drive industrialisation efforts.

The synthesis also reveals that neither country, even Zambia, currently possesses the foundation to support battery manufacturing independently. Notably, both countries show significant weaknesses in downstream prerequisites, including innovation systems and skilled labour for more complex processes, and domestic demand for battery usage. This points to a central insight: the potential for a fully integrated BMVC lies not within a single nation, or even two, but in the broader region.

Taken together, this comparative assessment demonstrates that the DRC and Zambia are unlikely to succeed in implementing their initiative in its current bilateral form. p

8. A Strategic Design for the Development of a Regional Battery Industry

The previous chapter showed that while the DRC and Zambia play critical roles in the global BMVC, neither is currently ready to host a competitive battery industry on its own or bilaterally. Technical, institutional, and infrastructural barriers pose significant challenges in the short term. This chapter explores whether a regionally coordinated strategy could offer a more viable alternative to allow the DRC and Zambia to capture more value from the BMVC. The hypothesis is that by distributing roles based on their current capabilities and strengths, a Central-Southern African BMVC could be developed. This would require alignment between national specialisations, infrastructure, and innovation systems, a process that may be enabled through existing cooperative agreements such as the SADC and AfCFTA.

To explore this, the chapter addresses the sub-question: *"What strategic design can support the development of a regional battery industry, and what policy recommendations can guide this design?"* To answer this question, the chapter first argues why regional coordination could work. Second, it determines what BMVC processes can be feasibly performed in each country by matching the complexity of the different processes with the countries' capabilities. In doing so, it proposes a realistic division of specialisations. Finally, the Regional Innovation Systems framework is applied to assess what coordination mechanisms, knowledge systems, and supporting institutions would be required to support an integrated regional BMVC. These elements guide a coherent regional strategy.

8.1. Why a Regional Approach

Although both the DRC and Zambia play a critical role in the existing global BMVC, they face major barriers if they want to develop their own value chain or perform more mid- and downstream processes. These barriers include limited infrastructure, a limited pool of technically trained workers, and fragmented institutions. Whether on their own or bilaterally, these countries are currently unlikely to support a fully integrated battery industry.

Instead of attempting to overcome these challenges, regional coordination offers a more feasible route. By specialising in specific functions within the value chain and aligning at the regional level, a collective of countries can meet the diverse requirements needed for a fully integrated BMVC.

This model of functional specialisation has proven successful in other sectors and regions. One example is the Nordic Battery Collaboration, where Finland, Norway, and Sweden have each taken on distinct roles to complement each other's strengths. These roles range from raw material extracting and processing to battery manufacturing, assembly, and R&D (Business Sweden, 2023). This coordination was realised through joint investment strategies, policy alignment, and roadmaps. Although a major actor within the value chain, Northvolt, has declared for bankruptcy this year, more than 150 other firms operate across raw-material, active-material, cell, pack, integration, and recycling segments. These are supported by roughly 100 research organisations and institutions. This large collaboration has enabled the region the build a value chain that none of the individual countries could have supported alone, or at least, not as effectively.

Closer to the Central-Southern African context, the SACU (Southern African Customs Union) automotive sector shows how functional specialisation can create a regional industrial ecosystem. In this ecosystem, South Africa serves as the assembly hub where major automotive firms are located. There are three industrial clusters for this in Gauteng, KwaZulu Natal, and Eastern Cape, with large automotive firms such as BMW, Ford, Toyota, VW, and Mercedes (InvestSA, 2025). Smaller SACU members like Lesotho and Eswatini provide labour-intensive components to these industrial clusters, such as textile elements and wiring harnesses (Jakob Engel, 2015; Sanon and Slany, 2023). While this model remains centred around South-Africa, it allows for the smaller and less industrialised SACU members to participate in high-value manufacturing activities. This is coherent with SACU's work programme and vision, which uses "Industrialisation through the development of regional value chains, investment, and export promotion" to "serve as an engine for regional integration and development" (SACU, 2022).

An even more complex example is found in the European aerospace industry. Airbus has allocated specific production responsibilities across Europe, an example of which is the iconic Airbus Beluga, used to transport aircraft parts: wings and landing gear are made in the UK, the tail and doors in Spain, the fuselage in Germany, and the nose and centre of the plane in France, where the final assembly also takes place (EM Airplane, 2024).

These cases showcase that geographically dispersed but aligned production networks can thrive in technically advanced industries, provided that there is adequate infrastructure, investment, and well-aligned international policies. The next section suggests a functional-specialisation strategy for Central-Southern Africa by identifying which stages of the BMVC chain are technically and institutionally realistic for each country to assume based on their capabilities.

South Africa as a hub for complex manufacturing processes

South Africa offers several of the elements that the DRC-Zambia context lacks, namely industrial capabilities that are potentially able to perform complex processes. Manufacturing has a share of about 13% of GDP, which is significantly higher than other regional countries (Trading Economics, 2023). It also has battery manufacturing knowledge and the ability to effectively transfer this knowledge, thanks to institutions such as the Council for Scientific and Industrial Research, the South African National Energy Development Institute, and the Energy Storage Consortium, which offer training, pilots, and R&D efforts (CSIR, 2025; Montmasson-Clair et al., 2021; South African Government, 2017).

Infrastructure enables these assets. There are several large ports which combined saw a throughput of over four million TEU (Twenty-Foot Equivalent Unit) (CEIC, 2022). Private firms in the battery sector have already begun to leverage these assets. For example, Solar MD has constructed a facility in Cape Town capable of assembling 3GWh of lithium-iron-phosphate packs annually, although it has no manufacturing capabilities (Labuschagne, 2025).

Equally important is South Africa's record of large industrial policies, such as the Automotive Production and its successor, the Automotive Masterplan 2035 (Ministry of Trade, Industry, and Competition, 2018). As mentioned previously, this has established three industrial clusters in which many large automotive firms are located. This success shows that South Africa is capable of supporting a large industrial policy, which could be translated to battery manufacturing.

South Africa also brings with it large financial possibilities. Financial development institutions such as the Industrial Development Corporation, which have assets of over 150 billion Rand (about 7.4 billion euros) and funded over 22 billion Rand in 2022/2023 (IDC, 2024). They also mention critical minerals and battery value chains as one of their priority industrial pathways. Another institution is the Public Investment Corporation with 2.7 trillion Rand in assets, which regularly invests in regional projects.

To compare this with the DRC and Zambia, we can look at world indices used in chapter five. For example, on governance indicators from the World Bank, it performs better than Zambia in every category except Political Stability and Absence of Violence/Terrorism (World Bank, 2025c). It sees billions of dollars in FDI yearly, with $3.44 billion in 2023 as the latest data point (Macro Trends, 2023). It received a 3.7 on the Logistics Performance Index, which is significantly higher than Zambia's and the DRC's at around 2.5. On World Bank's Learning Adjusted Years of Schooling, it scored 5.60, where the DRC and Zambia scored 4.53 and 5.03 respectively (World Bank, 2020). While its performance on the GII is moderate at 69th place overall, it ranks 51st on knowledge creation, 68th on knowledge diffusion, 33rd on R&D collaboration, and 40th on cluster development, which are all essential to developing a battery manufacturing industry and significantly higher than Zambia (WIPO, 2024a).

Taken together, these assets position South Africa as a potential specialisation country in the more complex mid- and downstream processes. Its role would complement, and not replace, the ambitions of its northern peers, Zambia and the DRC.

8.2. Functional-Specialisation

This section translates the broader argument for regional coordination into a concrete allocation of specialisations along the BMVC, based on the relative complexity of each process and the specific conditions of the DRC, Zambia, and South Africa. The goal is to design a division of labour that is both technically and institutionally feasible across the region and create a fully aligned BMVC.

To do this, the six core processes of the BMVC, as described in 4.1, are each assigned a rough complexity score ranging from 1 (low) to 5 (high). These scores are not objective measurements but serve as comparative indicators based on key requirements: capital intensity, technical expertise (primarily chemical and mechanical), infrastructure needs, and energy intensiveness. This approach allows for a structured assessment of how well each country is equipped to take on specific roles within the BMVC.

Table 4 presents this allocation, matching each process stage to the relative strengths and limitations of the three countries. For analytical consistency, subcomponent production and cell manufacturing are treated as separate stages, although in practice they are often integrated within the same industrial facilities. In the case of South Africa, which is best positioned to pursue both, the rationale applies to both stages. By contrast, Zambia may be better suited to focus on subcomponent production, such as cathodes and anodes, for export to more industrially advanced partners like South Africa.

BMVC Phase (with complexity rating)	***DRC***	***Zambia***	***South Africa***
Raw Material Extraction (1-2)	Strong existing mining capabilities, especially for cobalt and copper.	Strong existing mining capabilities for copper, also some cobalt.	Strong mining capabilities, but limited copper and cobalt reserves compared to the DRC and Zambia. Strong

			for manganese and vanadium.
Processing and Refining (3)	Currently only performs copper refining (Carla, 2022), but has potential due to relatively simple processes. While the processes are energy-intensive, the DRC has large hydropower potential, also off-grid.	One cobalt and six copper refineries (Carla, 2022), with potential for expansion due to a solid institutional and regulatory foundation. However, limited energy reliability.	Existing refineries for cobalt, copper, manganese, and nickel (Carla, 2022). However, the availability of electricity is extremely limited, with frequent blackouts, which poses a large barrier.
Subcomponent Production (4)	Very limited potential, severe infrastructure, institutional, and expertise deficits.	A significant step up from the previous phase and more suited for mid- to long-term after precursor capabilities are established.	There is currently only lead-acid-based production, but the industrial capabilities and know-how for Li-ion are present (Montmasson-Clair et al., 2021). Afrivolt is looking to establish
Cell production (5)	Far too complex for current capabilities.	Far too complex for current capabilities.	Li-ion cell manufacturing (Assay, 2025). There has also been a pilot for Li-ion manufacturing and R&D since 2017 (World Bank Group, 2023).
Pack Assembly (3)	While potentially feasible, it is largely dependent on local EV manufacturing demand, which is absent.	While feasible, largely dependent on local EV manufacturing demand, which is currently absent.	Already many firms that import cells for assembly, like Solar MD, First Battery, Freedom Won. With a large local automotive industry, while largely ICE-based (Internal Combustion Engine), there is potential for EV manufacturing.
End-of-Life (3-4)	No formal recycling capabilities or prospects.	No formal recycling capabilities or prospects. Some regulatory potential through Extended Producer Responsibility.	Established battery recycling and reuse infrastructure for both Li-ion and lead-acid. Examples include Revov and First Battery, Established Extended Producer

			Responsibility legislation, which includes batteries (IEA, 2025b).

Table 4: Matching of BMVC processes to DRC, Zambia, and South Africa

The functional alignment in Table 4 shows that the DRC is mostly fit for the extraction of minerals. It holds a dominant position in cobalt mining and already hosts 11 cobalt processing plants and 21 for copper (Carla, 2022). However, while it has some copper refining capacity, there are currently no cobalt refineries, making this a largely untapped area for value capture. Expanding into cobalt refining would be a logical next step, but it remains largely constrained by weak governance, limited infrastructure, and a lack of technical expertise. The complexity of all other BMVC stages currently exceeds the DRC's capabilities.

Zambia, by contrast, is more favourably positioned to enter and scale the refining and precursor phase. With one cobalt and six copper refineries already in operation, the basic industrial foundation for chemical upgrading is present (Carla, 2022). This progress is supported by a more stable regulatory and institutional environment. If Zambia successfully expands its refining base and develops precursor production, it could eventually move into subcomponent production for export, allowing it to move deeper into the midstream segment of the BMVC without requiring the infrastructure and expertise for full cell manufacturing.

Among the three countries, South Africa is by far the most industrially advanced. Although it has less strong mineral endowments, it benefits from large manganese and vanadium reserves, which are relevant to NMC and vanadium redox flow batteries chemistries respectively. It also has operational refining facilities for cobalt, copper, manganese, and nickel (Carla, 2022). While it regularly has electricity shortages, which poses a significant challenge, the country possesses a mature industrial base, including a large automotive sector. Several companies already assemble battery packs using imported cells from China, and there is a growing R&D base, including a battery manufacturing pilot project. These developments position South Africa as the most likely candidate to scale into subcomponent and cell production. It also leads already leads in end-of-life processes, with functioning recycling infrastructure and formal producer responsibility legislation in place.

8.2.1. Application of the Regional Innovation System framework

In the methodology chapter, five key components of RIS were identified. These are: Knowledge Infrastructure, Intermediary Organisations, Policy Coordination, Industrial Actor Roles, and System-Level Interaction. These are the components that will be used throughout this section to determine what is currently in place and what is lacking.

Knowledge Infrastructure

South Africa possesses several research institutions concerned with the BMVC. These are connected through the South Africa Energy Storage Consortium (Montmasson-Clair et al., 2021). Members include the Council for Scientific and Industrial Research (CSIR), University of Limpopo (UL), University of the Western Cape (UWC), Nelson Mandela University (NMU), Mintek, South Africa Nuclear Energy Corporation (NECSA), and the University of Witwatersrand (Wits). Together, these institutions perform R&D on the whole BMVC, from cell/battery fabrication (CSIR, UWC, Wits), electrode chemistry (CSIR, UWC, UL and WITS), to battery recycling (Mintek). However, while its original mandate was to create intellectual property within the BMVC, it has not been able to keep up with other major countries and has largely shifted to developing skilled professionals. It has been able to do so successfully (Montmasson-Clair et al., 2021).

Zambia also has a few notable research institutions, but they lack battery-specific R&D and learning programmes. Still, the Copperbelt University and University of Zambia, for example, provide engineering degrees for relevant metallurgy and chemical processes (Musasa and Lutandula, 2024). Though this is mostly directed at mining, processing, and refining. However, as we established in the previous section, this is also the part of the value chain in which Zambia could look to capture more value.

The DRC's universities have minimal capacity beyond mining-oriented degrees. In chapter five, it was concluded that it produces next to no intellectual property, even in the mining sector. It has, however, recently launched the Centre of Excellence for Advanced Battery Research in 2022, although it is unclear what this has achieved since (UNECA, 2022). If the DRC wants to upgrade its processing, but especially refining capabilities, it will need to update its training programs to focus on this.

Intermediary Organisations

South Africa already possesses functioning intermediaries. The Energy Storage Consortium for research coordination and skills development, GreenCape for the EV market (Green Cape, 2025), and development organisations that can provide grants, such as the IDC and DBSA, which have already mentioned battery manufacturing as a priority. Zambia's Development Agency and DRC's ANAPI play generic investment promotion roles, but have not shown any commitments related to the BMVC. They do promote manufacturing industries in general. From a regional point of view, the SADC Cooperation in Standardisation and the SADC Centre for Renewable Energy and Energy Efficiency could play intermediary roles. However, neither is currently focused on the BMVC (SADC, 2025). This shows that there is a critical intermediary gap for BMVC upgrading. There is however, an overarching organisation, the SADC, of which the DRC, Zambia, and South Africa are all members. An alliance that has proven successful is the European Battery Alliance. The SADC could mirror this by creating a SADC Battery Alliance, which would play an intermediary and coordinating role.

Policy Coordination

At the regional level, two broad frameworks already provide a foundation for coordinated policy, but both require adjustments to include BMVC upgrading.

First, the SADC Industrialisation Strategy provides a long-term roadmap for overall industry upgrading, which includes upgrades from raw-material extraction to mineral beneficiation and manufacturing. It claims to be aligned with national plans, the African Union's Agenda 2063, and global trade commitments (SADC, 2015). However, it remains generic and does not include any steps related to the BMVC.

Second, the African Continental Free Trade Area (AfCFTA), which is the world's largest free-trade zone, eliminates most tariffs and simplifies international logistics. In principle, this should allow for the ease of movement of raw cobalt or cobalt sulphates and copper films from the DRC to Zambia, and precursors to South Africa.

A coordination more specific to the BMVC is the creation of a coordination framework, with support from Afreximbank and the UNECA, between the DRC and Zambia. It aims to create an Operating Company under the Afreximbank to establish an SEZ. This

SEZ aims to harmonise permits and bundle infrastructure and fiscal incentives for battery manufacturing. If this is implemented successfully, this model could be extended into a tripartite framework to include South Africa, or it could be replicated to directly link Zambian precursor production to South African cell manufacturers.

Industrial Actor Roles and System Interaction

Industrial Actor Roles are largely already covered in Table 4, in which the DRC could aim to expand its processing and possibly refining capabilities; Zambia could expand its refining capabilities and aim for precursor production, and possibly expand to battery subcomponent production in the future; South Africa could establish cell subcomponent and production, as well as expand its recycling and reuse capabilities.

However, there are still industrial actors that have not been mentioned yet, namely the suppliers of equipment. The Lithium-ion BMVC relies on highly specialised kilns, dry-rooms, calendaring lines, and formation cyclers (Sharmili et al., 2023). These are assets that few African firms could procure on their own. To support this, a dedicated Battery Equipment Procurement Commission could be established jointly by the Industrial Development Corporation of South Africa, the Zambian Development Agency, the DRC's ANAPI, and the African Development Bank. By pooling resources and demand for these assets, this commission could secure volume discounts from international OEMs and ensure that installation and training are bundled. This would also reduce coordination failures and help align production capacities across countries to create a more streamlined value chain.

Equally important are the physical links between these countries. Appendix 11.2 shows that all three countries are technically connected by rail. The DRC's Lubumbashi hub is connected to Zambia's Copperbelt line, which in turn joins the corridor to South Africa's network. In practice, as mentioned in 7.2.2, much of this is currently of poor quality due to decades of underinvestment and deferred maintenance.. Shah (2025) has made a railway map showcasing the railway plans according to the African Union's Agenda 2063. This includes a plan for 2033 for high-speed railway connectivity between the DRC, Zambia, and South Africa, which would connect the three countries through high-quality rail tracks. However, implementation challenges are large, with many questions regarding financing and political coordination. For this corridor, the potential SADC Battery Alliance could help with political coordination, and the Industrial Development Corporation could help with financing. Of course, they would not be the sole financiers, as the railway brings benefits to many more actors than those associated with the potential regional BMVC.

8.2.2. Operationalising the Strategy

To make the strategy actionable, each component of the RIS framework must be translated into interventions. Table 5 outlines the key gaps that currently hinder an integrated Central-Southern African BMVC, how to address them, and the institutions that could lead these efforts. Together, they form the strategy that could support a regional BMVC.

RIS component	Key Gaps	Regional Actions	Relevant Institutions
Knowledge Infrastructure	Zambia lacks training for precursor production; the DRC lacks training for chemical refining, especially cobalt	Expand Zambia's engineering programs to cover precursor production methods. Develop chemical	Public universities in the DRC, Zambia, and South Africa,

		refining training modules in the DRC. These programs and trainings can be set up in partnership with regional institutions such as the South Africa Energy Storage Consortium.	Energy Storage Consortium (SA), education ministries of DRC and Zambia
Intermediary Organisations	No regional platform exists to coordinate and develop a regional BMVC, including standards and policy	Establish a SADC Battery Alliance, based on the European Battery Alliance, for coordination, development of standards, pool resources	SADC, Afreximbank, UNECA
Policy Coordination	SADC industrialisation strategy lacks specific BMVC content; current SEZ framework is bilateral	Add a BMVC roadmap to the SADC Industrialisation Strategy or a new strategy by the SADC Battery Alliance; Extend SEZ into a tripartite agreement, or use it as a base for a battery corridor	(New) SADC Battery Alliance, UNECA, AfreximBank, national ministries of industry and trade
Industrial Actor Roles	Barriers to entry for individual firms due to equipment costs.	Establish a Battery Equipment Procurement Commission to pool regional demand for precursor and cell production lines to get volume discounts and bundle installation and training	National firms, IDC-SA, ZDA, ANAPI, AfDB
System-Level Interaction	Current railway connections are of poor quality, at least in DRC and Zambia	Establish a Logistics Working Group under the SADC Battery Alliance to coordinate corridor investment and governance. Align these efforts with the African Union Agenda 2063.	(New) SADC Battery Alliance, Zambian Railways, Société Nationale des Chemins de Fer du Congo, SADC

Table 5: The Regional Strategy

While the actions in Table 5 focus on regional coordination and system-wide interventions, the overall success heavily depends on national-level efforts. Each country, particularly the DRC and Zambia, will need to translate their ambitions and the proposed actions into domestic policies and institutional reforms. As outlined in Chapter 5, this requires addressing gaps in physical infrastructure, energy availability and reliability, skills development, and innovation capacity. For the DRC, this means making significant improvements to its institutions, governance structures, regulatory environment, and political stability to support even modest BMVC upgrading. Zambia will need to form concrete battery policies and financial support to support a precursor industry. South Africa, while it has the industrial know-how and is more financially and institutionally ready, will still need to create targeted industrial policy for battery manufacturing and ensure alignment across its horizontal and vertical layers of government. Without such national efforts, regional coordination risks stalling at the commitment stage, as with many African initiatives.

9. Discussion and Conclusion

This chapter reflects on the outcomes of the research and draws conclusions about the feasibility of battery industry development in the DRC-Zambia region and a potential regional alternative. It discusses how the findings relate to the existing literature, addresses key limitations, and proposes future research directions.

9.1. Discussion

The research began with a synthesis of enabling conditions for battery industry development across the political, economic, social, technological, legal, and environmental dimensions. Rather than aiming to determine a hierarchy of importance, the goal was to produce a comprehensive benchmark to evaluate industrial feasibility in the DRC and Zambia.

This benchmark of enabling conditions is one of the most significant contributions of this study. Rather than offering a fixed set of criteria, it provides an interpretive framework based on patterns identified across global literature. The key insight that emerged is that industrial development in the battery sector is rarely driven by access to raw materials. In fact, literature and industry experience increasingly challenge the assumption that resource endowments are an essential strategic advantage. Studies such as Greitemeier et al. (2025) and Montmasson-Clair et al. (2021) support the idea that downstream and midstream segments of the BMVC are more dependent on infrastructure, technological capability, investment climate, and stable policy than on local mineral supply.

This has important implications for both research and policymaking. It positions mineral-rich countries not as inevitable industrial winners, but as actors whose success depends on their ability to address institutional and infrastructural gaps. The findings of this thesis are consistent with the literature that argues that system-based approaches are more important than input-focused. Studies using the RIS framework, for example, apply this thinking by emphasising that coordination, knowledge and institutional learning are critical for successful industrialisation.

The comparative assessment in Chapter 7 illustrates this well. Although the DRC holds unmatched mineral wealth and renewable energy potential, its performance across political, institutional, and technological dimensions severely limits the feasibility of short- to mid-term industrial upgrading. Zambia, while also facing significant challenges, scores significantly higher across all dimensions, including on institutional quality and legal infrastructure. Interestingly, some of Zambia's scores on governance indicators approach or exceed those of established battery manufacturing countries like Hungary or China.

Regarding the DRC-Zambia initiative, this research shows that without deep institutional reforms and better policy alignment, the initiative risks becoming aspirational rather than actionable. To make the initiative more realistic, the thesis therefore suggests a regional approach by including South Africa, which has strong industries, including an automotive industry, and BMVC-related expertise.

It suggests functional specialisation to leverage the different strengths of the DRC, Zambia, and South Africa. This aligns with the concept of "smart specialisation", which is often found in EU policy and RIS literature. Importantly, it means that not every country needs to establish all segments of the BMVC to develop the entire regional BMVC so that all involved countries can benefit from industrial upgrading.

At the same time, this strategy would require careful implementation. The creation of new governance bodies like the SADC Battery Alliance, pooled procurement mechanisms, and specialised training programmes must be matched by each nation's political will and long-term financial commitment. If successfully implemented, it could mitigate one of the main recurring weaknesses, fragmented industrial policy and governments.

9.2. Limitations

Some limitations in this thesis must be acknowledged, some of which are inherent to the chosen methodologies, while others are due to the specific context. First, the identification of determinants in Chapter 4, meant to be both positive and negative, primarily focuses on positive success factors identified in the literature. This is largely due to the literature itself, in which enabling determinants are well-documented. In industry reports, for example, risks or negative factors receive little attention. As a result, the research may underemphasise the negative determinants for battery industry development.

Second, the qualitative nature of this research has made it difficult to determine which determinants are more enabling or constraining than others. During analysis, it became clear that not every dimension is equally important, which is discussed in the interpretation. However, a ranking of these determinants, while considered, would have been methodologically difficult.

Third, there are several practical limitations in data access and language, especially for the DRC. Much of its documentation from institutions, such as ANAPI, is only available in French. While the researcher can read French, English remained the primary search and working language, meaning that some sources may have been overlooked. Additionally, many of the indices used reflect national-level averages, while industrial performance is often highly localised in clusters. For example, while countries may score poorly on overall education indicators, local mining may demonstrate far better performance. Chapter 5 also partially relies on journalistic and grey literature sources, due to limited academic data. This introduces the risk of outdated or unreliable information.

Fourth, the battery industry is evolving rapidly. While sources from 2020 or later were prioritised, there have been remarkable shifts since. For example, a report from Ember Energy (2025) shows a rapid decline in global battery prices and acceleration in manufacturing capacities, largely attributed to R&D developments. The relevance of some sources and, consequently, some of the results of this research, are therefore highly time-sensitive.

Finally, the use of the Regional Innovation Systems framework brings with it some inherent constraints. It was originally developed to analyse existing innovation systems, but in this research, it is used as a design-oriented framework to guide the strategy. Additionally, RIS places a strong emphasis on knowledge systems and can undervalue other enablers like financial capacity and physical infrastructure. The strategy does address these enablers to a certain extent to ensure analytical consistency with the PESTLE framework, but nevertheless, these enablers may have received less analytical attention.

9.3. Future Research

Several promising directions for future research emerge from the limitations and design choices of this thesis, both within an African scope and broader BMVC studies.

First, while Chapter 4 identified many enabling and some constraining conditions for battery industry development, it was already mentioned that not all determinants contribute equally to success or failure. Future research could explore the relative weight of these conditions through mixed-methods case studies or a quantitative expert survey approach. This could help decision-makers to prioritise different elements of the broader enabling environment.

Second, while this thesis mainly uses a regional lens in its design, it also highlights the importance of national efforts to translate regional coordination into actual outcomes. Further research could therefore look at national implementation pathways in greater detail, including the design of industrial policies, financing mechanisms, and strategies for skill and innovation system upgrading, especially in the DRC and Zambia.

Third, the analysis has primarily adopted a strategic and institutional perspective. Future work could complement this with a more technical, engineering perspective. Research into the possibilities for different battery chemistries according to regional mineral endowments, for example, or a cost-benefit analysis of different production technologies for developing countries.

Finally, the strategic and institutional perspective of this study is inherently top-down. Future research could adopt a more bottom-up approach by investigating how firms, training centres, local governments, and communities engage with BMVC opportunities. This would contribute to a more inclusive development of BMVC upgrading and ensure added value for local communities.

Together, these research directions can help refine and challenge the strategy of this thesis and contribute to a more effective and context-sensitive strategy for BMVC upgrading across Central-Southern Africa, or even the whole of Africa.

9.4. Conclusion

This thesis set out to answer the following main research question: *"How can enabling conditions for battery manufacturing development be used to assess the feasibility of the BEV initiative between the DRC and Zambia, and what alternative pathways exist for battery industry development in the region?"* To address this question, the research was structured around three sub-questions, each contributing a layer of analysis.

The first sub-question asked: *"What conditions influence the success or failure of developing a battery industry, based on global past and present cases?"*

This was addressed by examining the literature and policy on global cases, structured around the six PESTLE dimensions. The findings revealed that battery industry development is shaped by a wide set of interdependent conditions, ranging from strategic policy and infrastructure to technical expertise and environmental regulation. Additionally, success was shown to rely less on natural resource endowments than commonly assumed, and much more on the broader quality of the enabling environment. Countries that have managed to build battery manufacturing capacity, such as China, South Korea, and Germany, achieved this through long-term strategic planning, large-scale investment in knowledge systems, and coherent and well-aligned policy design.

The second sub-question asked: *"How does the context of the DRC-Zambia region compare to the identified conditions for successful battery industry development?"*

Here, a comparative PESTLE assessment was conducted with the identified set of conditions from the previous sub-question. Zambia demonstrates considerably more favourable conditions than the DRC across all dimensions, particularly in terms of political stability, legal frameworks, and institutional capacity. Although significant challenges remain, for example in skilled labour and innovation systems, its policy and regulatory quality approach or slightly exceed the levels of some established manufacturing economies like China and Hungary. The DRC, while rich in minerals and potential renewable energy, suffers from extreme institutional fragmentation, unclear regulation, poor infrastructure, and weak governance. These systemic issues represent major barriers to upgrading within the BMVC. This meant that the DRC-Zambia initiative, in its current form, is unlikely to succeed.

Chapter 8 addressed this by answering the third sub-question: *"What strategic design can support the development of a regional battery industry, and what policy recommendations can guide this design?"*

The thesis proposed a strategy of functional specialisation across the DRC, Zambia, and South Africa. Rather than each country, or the DRC and Zambia bilaterally, trying to develop a full BMVC, they could each focus on segments that align with their institutional, infrastructural, and technical capabilities. The DRC's role would focus on raw material extraction and possibly intermediary cobalt refining; Zambia could aim to scale up precursor production, and in the mid-term, move toward subcomponent production and exports; South Africa, with its stronger industrial base and R&D capabilities, is best suited to take on the midstream and downstream segments, including cell production, pack assembly, and end-of-life. This design was informed by the RIS framework, which was also used for the later strategic design, which provides targeted interventions to address structural gaps. These include training programmes, the establishment of a regional policy coordination platform like the SADC Battery Alliance, pooling procurement resources, and establishing knowledge transfer mechanisms.

By answering the main research question, this thesis shows that the identified enabling conditions can serve as a valuable benchmark for both assessing feasibility and designing realistic battery industry strategies. In the case of the DRC-Zambia initiative, the findings suggest that while its bilateral structure may be unable to overcome institutional and infrastructural barriers, it can still become a stepping stone. If embedded within a broader regional strategy that leverages the comparative advantages of regional peers like South Africa, the initiative could unlock meaningful industrial upgrading and capture more value in the BMVC across Central-Southern Africa.

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11. Appendices

11.1. Analytical table for the initial literature review

Title	**Reference**	**Geographical scope**	**Key topics/findings**	**Type of study**
Prospects for Development and Integration of African Battery Value Chains	Zalk, 2024	Africa: Marocco, South Africa, Zambia, DRC	Li-ion batteries, EV demand, Battery Value Chain, African mineral deposits, Geopolitical implications, Policy options	Policy analysis
A Battery Industry in the Central African Copperbelt? Regional and Geopolitical dimensions	Musasa and Lutandula, 2024	Copper belt (DRC and Zambia)	African mineral deposits, DRC and Zambia battery plans, intercontinental partnerships, mine ownerships, potential for downstream value addition, geopolitical implications	Policy analysis
The Cost of Producing Battery Precursors in the DRC	BloombergNEF, 2021	Africa, DRC	High potential for African countries in BMVC, high potential for NMC-batteries[1] policy implications	Techno-Economic analysis
Will Congo move up the battery supply chain? Strategic capitalism, friendshoring, and localized manufacturing in the time of the green transition	Deberdt, 2024	DRC	DRC resource nationalism, support from US, infrastructure and workforce challenges, DRC key player in green transition, policy implications	Socio-Economic Analysis
SADC Futures of Mining: Implications of Large-Scale EV Adoption	Cloete, 2020	SADC member states, includes DRC and Zambia	Opportunities and Risks for SADC members, infrastructure and governance challenges, geopolitical pressure, need for regional cooperation	Industry analysis
The EV Revolution: Critical Material Supply Chains, Trade, and Development	Jones et al., 2020	Worldwide	Potential for resource rich countries like DRC, strong institutions and policy necessary, geopolitical, technological, and environmental risks	Supply chain analysis
Green industrialisation: Leveraging critical raw materials for an African battery value chain	Karkare and Medinilla, 2023	Africa	High potential and complexity to add value to African BMVC, regional cooperation imperative, policy implications	Policy analysis
Africa's international trade paradox, technology transfer, and value chain upgrade	Ado et al., 2025	Worldwide (GVC[2]), Côte d'Ivoire, DRC, Ghana, Nigeria, Chad, Niger	Paradoxes/barriers to overcome before GVC value can be added to African countries, high potential, policy implications	Techno-Economic analysis
A comparative assessment of value chain criticality of lithium-ion battery cells	Manjong et al., 2023	Worldwide	Graphite, Lithium, Cobalt, and Nickel have high criticality, LFP battery best performance criticality/environmental, recommends transition to low- or cobalt-free batteries	Comparative analysis

[1] Nickel-Manganese-Cobalt
[2] Global Value Chain

Value addition for who? Challenges to local participation in downstream critical mineral ventures in Zambia	Cervantes Barron et al., 2024	Zambia	Dominance of foreign entities in upstream extraction, challenging landscape for local companies, lack of enabling environment for local companies, need for policy reform	Socio-Economic analysis
Advancing mineral-energy nexus for development (MEND) in Africa: A case study of Chinese lithium mining project in Zimbabwe	Wang et al., 2024	Zimbabwe	Power supply challenges for mining investment, potential for local electrification, framework for development to benefit investors and locals, need for local collaboration	Case study

11.2. Overview of African Railways

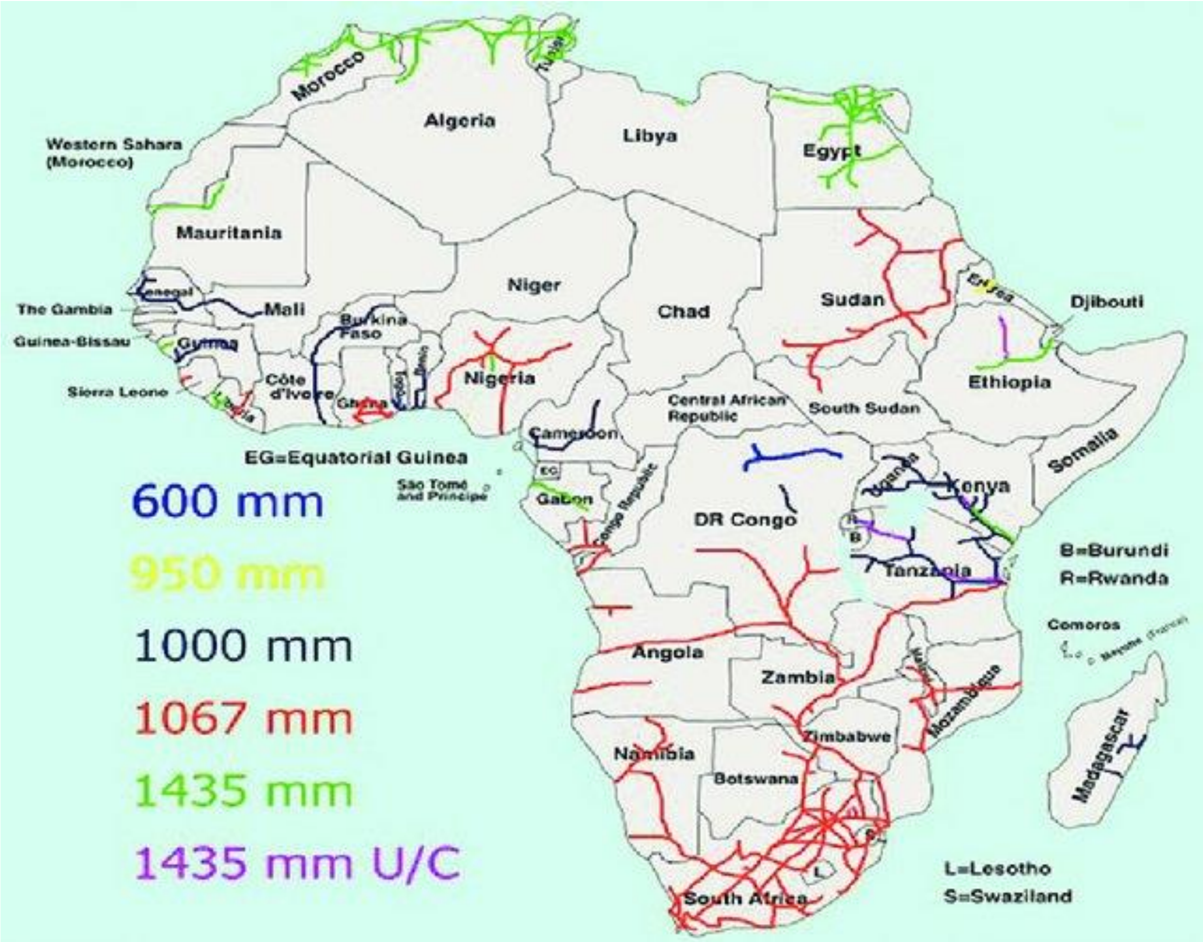

Figure 10: Overview of Railways in Africa (Irandu and Owilla, 2020)