India's Potential in the Midstream of Battery Production

IISD REPORT

International Institute for Sustainable Development

INVEST INDIA
NATIONAL INVESTMENT PROMOTION & FACILITATION AGENCY

September 2023

Published by the International Institute for Sustainable Development

International Institute for Sustainable Development

The International Institute for Sustainable Development (IISD) is an award-winning, independent think tank working to accelerate solutions for a stable climate, sustainable resource management, and fair economies. Our work inspires better decisions and sparks meaningful action to help people and the planet thrive. We shine a light on what can be achieved when governments, businesses, non-profits, and communities come together. IISD's staff of more than 200 people come from across the globe and from many disciplines. With offices in Winnipeg, Geneva, Ottawa, and Toronto, our work affects lives in more than 100 countries.

Geneva Office

9 Chemin de Balexert
1219 Châtelaine
Geneva, Switzerland

Tel: +41 22 917 8683
Website: iisd.org
Twitter: @IISD_news

India's Potential in the Midstream of Battery Production

September 2023

Written by Tom Moerenhout, Siddharth Goel, Abhishek Bansal, Arishna Saxena, Kevin Brunelli, Chengxi Jiang, Lilly Lee, Anja Nilson, Qi Wang, and Huiying Xu

Photo: Shutterstock

Acknowledgements

This report is the result of an analytical exercise conducted by Columbia University, Invest India, and the International Institute for Sustainable Development (IISD). Part of this work was completed as part of a Columbia University SIPA's Capstone project, under the guidance of Professor Tom Moerenhout and in collaboration in a student team.

The authors are grateful for the input of all businesses, policy-makers, and sectoral experts who participated in in-depth interviews conducted over 6 months.

The authors would also like to thank three anonymous reviewers who provided useful comments and feedback. IISD and the Indian Council for Research on International Economic Relations thank the ClimateWorks Foundation for their support for this project. This report represents the research and views of the authors. The report may be subject to further revision.

Table of Contents

1.0 Introduction

According to both the International Energy Agency (IEA) and International Renewable Energy Agency, in order to avoid catastrophic climate change, the 2020s need to be the decade of power sector decarbonization, and the 2030s the decade to decarbonize the transport sector, which accounts for 37% of carbon dioxide (CO_2) emissions globally. One way to achieve this is through electric vehicles (EVs), demand for which has exploded over the past 3 years. Approximately 2.3 million electric cars were sold in Q1 of 2023, a 25% increase in sales compared to Q1 in 2022. Much of this growth is located in a few key markets, but China remains the leading market for EVs, accounting for 60% of global EV sales (IEA, 2023b).

This demand is expected to continue to rise over the next decade as countries move to meet net-zero goals. This ultimately presents a gigantic shift in automobile and automobile component manufacturing. To meet the growing demand, original equipment manufacturers (OEMs) and battery manufacturers are expanding production and building new manufacturing centres all over the world. Aside from China, which now has an emissions-per-capita ratio close to the European average, there are few lower- or middle-income emerging economies that participate strongly across the battery and EV value chain. This represents both a challenge with respect to achieving a just energy transition and an opportunity for productive growth.

In India, transportation currently accounts for 14% of greenhouse gas emissions. With over 300 million vehicles currently on the road and 200 more million to be added in the next two decades, India faces a massive challenge to electrify its road vehicles and reach its goal of net-zero by 2070 (IEA, 2023; Moerenhout et al., 2022). However, this challenge also provides India with a tremendous opportunity. As the 4th largest producer of automobiles (Organisation Internationale des Constructeurs d'Automobiles [International organization of Motor Vehicle Manufacturers], 2023), the transition to EVs provides a huge economic opportunity if India localizes EV and battery manufacturing.

India could become a hub for EV manufacturing and recycling with the right incentives and government policies that can meet strong domestic demand for EVs and take advantage of the growing manufacturing sector. India can immediately become a vital segment of the battery supply chain by producing battery cells and expanding mineral processing. This report summarizes consultations with over 25 companies and actors to determine what factors are crucial in the considerations of companies on where to invest and expand manufacturing.

This report will first give an overview of India's targets and current state of play (Section 2). It will then discuss battery supply chain fundamentals that need to be critically assessed to understand where India has the strongest comparative advantage (Section 3). We will then outline the key companies' decision-making factors and assess India's potential comparative advantage against each (Section 4).

2.0 India's Status in Battery Supply Chains

India has an ambitious goal for EV adoption—80% of two-wheeler and three-wheeler vehicles, 70% of commercial cars, 40% of buses, and 30% of private cars sales be electric by 2030 (NITI Aayog and Rocky Mountain Institute, 2019). India is pushing for stronger domestic EV adoption, with a target of 30% EV market share by 2030 (Pathak, 2021). The number of battery EVs sold in India almost quadrupled in 2022, compared to 2021, and electric car sales in Q1 of 2023 were double sales during the same period of 2022. Tata Motors, a leading Indian automotive manufacturer, accounted for more than 85% of the total 50,000 battery EVs sold.

The rise of India's battery supply chain is due in no small part to the government's Production Linked Incentive (PLI) scheme, which supports the production of 50 gigawatt-hour (GWh) battery cells by 2026 to reach its 2030 EV ambition. The PLI scheme has already attracted around USD 8.3 billion in investments for 30 GWh (Ministry of Heavy Industries, 2022). However, in 2021, India had less than 1 GWh of domestic battery cell manufacturing capacity (IEA, 2022), which is less than 1% of global production. India's 2030 EV target translates into total sales of more than 100 million EVs, and around an annual 145–158 GWh of battery demand by 2030 (Council on Energy, Environment and Water [CEEW], 2021). The 30 GWh manufacturing target from the PLI scheme will leave India short of the projected demand of 145–158 GWh, but companies are now investing themselves in gigafactories.

India is seeing a quick uptake in EV adoption in the smaller and shared mobility sector. In 2022, more than half of three-wheelers sold were electric (many of which still rely on lead acid batteries), and around a quarter of EV purchases were by fleet operators, including taxis (IEA, 2023b). Indian companies are constantly adding capacity plans to their portfolios. The biggest EV company in India in terms of revenue, Ola Electric, aims to double its electric two-wheeler manufacturing capacity to 2 million vehicles by the end of 2023 and to 10 million vehicles by 2028 (Toll, 2021). In battery terms, companies now have about 120 GWh of planned capacity by 2030 (Invest India, 2023a), and this total is growing. Tata Group recently announced a gigafactory of 20 GWh, with an initial investment of around USD 1.6 billion (Khanna, 2023).

3.0 Battery Supply Chain Fundamentals

3.1 Battery Chemistry

Battery chemistry matters because not all lithium-ion batteries are the same, which means that developing a competitive advantage might be linked to the local market's battery chemistry preferences. Global demand for lithium-ion batteries rose by 65% in 2022, and demand is expected to continue to grow as consumers transition to electric vehicles and manufacturers offer new EV models (IEA, 2023a).

The two most common versions of lithium-ion batteries are lithium iron phosphate (LFP) and nickel manganese cobalt oxide (NMC). NMC batteries, with 60% of the market share, are the most popular version of lithium-ion batteries. LFP batteries account for approximately 30% of the market share. China is a leading country for both battery chemistries but is especially dominant in LFP batteries. China accounts for 95% of the LFP market for light-duty vehicles, thanks to patent regulations. However, the patents for LFP ended in 2022, and additional non-Chinese companies are now beginning to produce more LFP batteries.

Both LFP and NMC battery chemistries have unique advantages and disadvantages (IEA, 2023a). In general, there is a trade-off between energy density (NMC wins) and cycle life, cost, temperature performance, and environmental impact (LFP wins):

- **Energy density:** The energy density of a battery refers to the amount of energy it can store per unit weight or volume. It is one of the most important metrics to consider when evaluating battery chemistry. NMC batteries have a higher energy density than LFP batteries, making them ideal for applications that require higher power output and longer runtimes.
- **Cycle life:** The cycle life of a battery refers to the number of charge-discharge cycles it can undergo before its capacity starts to degrade. LFP batteries have a longer cycle life than NMC batteries. For instance, LFP batteries can last for up to 2,000 charge-discharge cycles, while NMC batteries can last for up to 1,000 charge-discharge cycles.
- **Cost:** In terms of cost, LFP batteries are generally less expensive than NMC batteries. It should be noted, however, that the cost of NMC batteries is decreasing rapidly as the technology advances, and this has made them a more viable option for many applications. Compared to a decade ago, Li-ion battery price has come down by 80%, and it's heading toward the USD 100/kWh range now.
- **Temperature performance:** LFP batteries perform better than lithium NMC batteries at low temperatures. They can operate at temperatures as low as -20°C without any significant loss in performance. On the other hand, NMC batteries can experience a significant drop in performance at low temperatures. LFP batteries tend to perform better in high temperatures as well, having a higher ignition point compared to NMC batteries.

- **Environmental impact:** LFP batteries are often considered to be more environmentally friendly than NMC batteries, in the sense that LFP batteries do not contain any toxic heavy metals and can be recycled easily. Although it ensures better performance, NMC batteries contain cobalt, which is a rare and expensive metal.

Sodium-ion batteries (Na-ion) are another battery chemistry that is growing in production. This chemistry relies on sodium instead of lithium and other minerals, leading to a cheaper battery. Currently, however, only Chinese players are aggressively developing sodium-ion batteries at scale (Reid, 2023). However, sodium-ion batteries have less energy density than both the LFP and NMC batteries, leading to a shorter range. That is why they are often considered a potentially huge player in grid storage but possibly less so in transport. Currently, there is over 100 GWh of sodium-ion battery production planned by 2030, with most capacity being built in China (Benchmark Minerals Intelligence, 2023).

3.2 Battery Cell Manufacturing Stages

Understanding battery cell manufacturing stages is critical because one cannot expect to create an immediate full comparative advantage across the entire supply chain. It took China more than two decades to fully develop its dominance in these stages. Therefore, it is useful to focus efforts on the stages where India could have the most comparative advantage regionally and globally.

There are six major manufacturing segments in an EV lithium-ion-battery (LIB) production: cell cathode, cell anode, cell electrolyte, cell separator, cell assembly, and pack assembly. Several steps must take place in order to create each of these segments and the entire battery. Different actors—mining companies, refineries, cell component manufacturers, battery cell manufacturers, OEMs—are involved in each of these segments, creating an extensive supply chain. The LFP and NMC battery supply chain includes the following segments (Battery University, 2021):

- **Mineral extraction:** Minerals such as lithium, nickel, cobalt, manganese, graphite, and copper need to be mined using different types of methods. This stage is performed by mining companies and, depending on the mineral, has very different requirements.
- **Processing of critical minerals:** The raw materials must be refined into battery precursor materials before they can be used to create battery components. The refining process involves chemical processing and follows different steps. Each mineral will be processed before being combined in cathode active materials.
- **Battery cell component manufacturing:** The battery precursor materials are manufactured into specialized components that include cathode active materials, anode active materials, electrolytes, separators, and casings.
- **Cell production:** Cells are produced (often in gigafactories) by combining cathodes, anode, electrolytes, separators, and casings.
- **Module and pack assembly:** Cells are first grouped into modules, which are then integrated into battery packs that also include the necessary electronics and thermal management systems.

Throughout all of these steps, there is also rigorous testing for performance. The development of battery precursor materials from critical minerals includes particularly laborious qualification requirements. This is not a simple footnote because being able to guarantee sound qualification of materials is important—and increasingly a bottleneck that is affecting the pace of material development.

The value of each manufacturing segment in the supply chain is different. According to industry estimates, the battery cells, including materials and manufacturing, account for approximately 70% of the total value of a battery pack, while the assembly of the cells into a complete battery pack ready for use in a vehicle account for the remaining 30% of the total value (Li, 2023). Table 1 gives an overview of the component value by segments in LFP and NMC batteries:

Table 1. Overview of battery manufacturing segments and component value distribution

Manufacturing segments	**Component value for LFP** (in total battery Cost)	**Component value for NMC 532** (in total battery Cost)
Cell cathode: The cathode is the electrode in a battery cell where reduction takes place during discharge, and it has a positive charge.	30%	54%
Cell anode: The anode is the electrode in a battery cell where oxidation takes place during discharge, and it has a negative charge.	21%	14%
Cell separator: A membrane that separates the anode and cathode in a battery cell, allowing the flow of ions while preventing the electrodes from touching.	8%	5%
Cell electrolyte: A substance (usually a liquid or gel) in a battery cell that conducts ions between the anode and cathode, completing the circuit and generating an electric current.	10%	6%
Cell assembly: Cell assembly is the process of assembling the anode, cathode, separator, and electrolyte to create a complete battery cell.	27%	17%
Pack assembly: Pack assembly is the process of assembling multiple battery cells into a larger battery pack or module for use in applications such as EVs or grid storage.	4%	4%

As the table shows, importing cells and assembling battery packs is valuable and easy to do but does not capture the largest value add. This is what players in India are mostly doing today. Creating gigafactories for cell assembly is a more technologically complicated process and adds further value. The most value, however, is captured in cathode and cathode material manufacturing. In this segment, raw material costs matter the most, making up about 90% of cathode costs (Mehdi & Moerenhout, 2023). This makes the extraction and processing of battery minerals a highly strategic sector.

3.3 Regional Distribution of Battery Supply Chains

China currently dominates the global battery supply chain, from mineral processing to cell component and battery cell manufacturing. It will continue to be the global leader for the rest of the decade despite substantial investments in domestic manufacturing in the United States and Europe. China has less control over mineral extraction and to a large extent depends on mineral imports. Chinese companies have been engaging in longer-term offtakes and equity investments in miners to guarantee that supply.

The regional distribution of battery supply chains matters for two large reasons. First, it shows where supply chain risks can occur. Second, in battery supply chains, countries that are geopolitical opponents may still rely on each other. That means that a choice to diversify in battery supply chain manufacturing means not only taking into account competitive advantages with respect to battery chemistry choices and battery cell manufacturing stages, but also assessing potential supply chains and supply chain vulnerabilities. Different segments of the supply chain following mineral extraction have the following regional distribution:

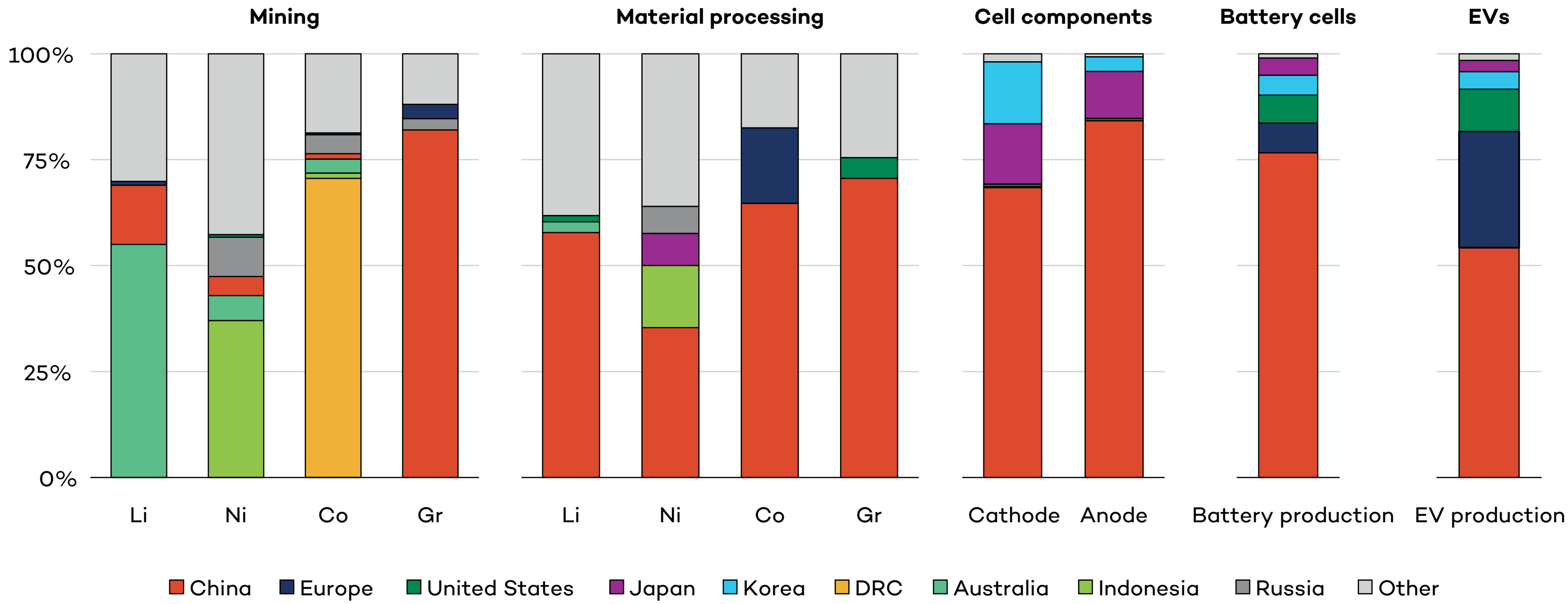
- **Mineral processing:** The minerals required for batteries must be processed into battery-grade materials before they can used to manufacture cell components. Mineral processing is dominated by China. China refines or processes over 50% of the minerals required for batteries—lithium, cobalt, graphite, and manganese (Chang & Bradsher, 2023). China accounts for 60% of lithium processing, according to the IEA (2023b). Australia, the leading lithium producer in the world, relies on China to refine its domestic supply of lithium spodumene. The Australian Bureau of Statistics reports that in every month of 2021, 85% of the total value of Australian lithium concentrate produced was exported to China for processing. By June 2022, 97% of Australian lithium was exported to China (Australian Bureau of Statistics, 2022).
- **Cell components—cathodes and anodes:** The production of cathodes and anodes is highly concentrated both geographically and within a small number of companies. For example, 55% of global cathode capacity is produced by only seven companies. Overall, 70% of cathode production takes place in China, followed by 15% in Korea and 14% in Japan. The leading cathode producers are Tianjin B&M Science and Technology and Shenzhen Dynanonic in China and Sumitomo in Japan (IEA, 2022). Global anode production is more concentrated than cathodes, with 85% of production capacity being located in China. Japan accounts for 11% and Korea only 3% of anode capacity. Additionally, four companies produce over 50% of global anode capacity. Ningbo Shanshan, BTR New Energy Materials, and Shanghai Putailai New Energy

Technology, all Chinese companies, are the three largest producers. Additionally, Japanese players also have a strong presence in the industry. Japanese anode material suppliers are typically Hitachi Chemical, JFE, Mitsubishi Chemical, Nippon Carbon and Nippon Steel, among which Hitachi Chemical primarily provides artificial graphite, JFE focuses on mesocarbon microbeads and Mitsubishi Chemical and Nippon Carbon are natural graphite suppliers (IEA, 2022).

- **Battery cells:** A total of 65% of battery cell production is dominated by three companies—CATL in China, LG Energy Solution in Korea, and Panasonic in Japan. However, China accounts for over 75% of global cell capacity (IEA, 2022). The United States will see significant growth in battery cell production in this decade due to the Inflation Reduction Act (IRA), which has led to a flurry of gigafactory announcements that will allow the US to supply 100% of its own cell needs by the end of the decade.[1] LG Energy Solution and Panasonic should continue to be major players in U.S. battery cell production as they take advantage of the IRA and partner with American car manufacturers to produce batteries in the United States. However, China will continue to be the leading battery cell producer.

[1] Not to be confused with cell component needs. The United States will be able to manufacture the cells it needs, but it will still rely on imports of cell components.

Figure 1. Geographical distribution of the global EV battery supply chain[2]



Source: IEA, 2022.

Notes: Li = lithium; Ni = nickel; Co = cobalt; Gr = graphite; DRC = Democratic Republic of Congo. Geographical breakdown refers to the country where the production occurs. Mining is based on production data. Material processing is based on refining production capacity data. Cell component production is based on cathode and anode material production capacity data. Battery cell production is based on battery cell production capacity data. EV production is based on EV production data. Although Indonesia produces around 40% of total nickel, little of this is currently used in the EV battery supply chain. The largest Class 1 battery-grade nickel producers are Russia, Canada, and Australia.

[2] Exclude cell component value; calculation based on NITI Aayog (2022).

4.0 Investment Decision-Making Factors and India's Midstream Potential

4.1 Company Decision-Making Factors

Based on literature reviews (Asaba et al., 2022) and interviews with more than 25 companies, experts, and organizations, we identified the most important factors for companies when it comes to deciding where to invest and set up midstream battery manufacturing facilities. The factors identified were:

- **Guaranteed demand or offtake:** The level of demand or firm offtake agreements for the product, specifically within the jurisdiction of the manufacturer and secondarily within the region with key trade partners.
- **Access to ecosystem and markets:** Free access to large or emerging markets is vital for companies. Also, benefits of aggregation economics and the positive externalities of co-locating with suppliers, competitors, and customers are well-researched, and companies within the supply chain are looking for a strong EV ecosystem (Alacer and Chung, 2009).
- **Access to transport infrastructure:** Strong transportation infrastructure, including a port system to allow easy access to international markets, is vital for companies within the supply chain.
- **Access to inputs:** Secure access to the necessary amount and required quality of raw materials/input is essential to guarantee uninterrupted production. That means critical minerals for cathode and anode manufacturing, cathodes and anodes for battery cell manufacturing, and battery cells for battery module and pack manufacturing.
- **Access to capital:** The degree of access for companies to private capital markets to raise sufficient capital is essential given the high capital investments needed in large manufacturing plants.
- **Access to low-cost and skilled labour:** Companies seek both low-cost labour to be cost competitive and a skilled labour force to produce batteries, a highly technical product that requires an advanced workforce.
- **Access to renewable electricity:** Battery manufacturers prefer access to renewable electricity to power their production in order to be as sustainable as possible.
- **Access to technology:** Cost reduction in several segments of the battery supply chain is linked to innovation, research and development (R&D), manufacturing efficiency, and quality control. Having access to technology to facilitate these steps improve competitiveness.
- **Access to land:** Mineral process and battery components and cell manufacturing require access to sufficient land rights to build large facilities.
- **Environmental, social, and governance (ESG) considerations:** Having sound ESG requirements and standards in place is essential for companies to be able

to operate smoothly since these standards help with permitting, access to capital, reputation to consumers, and so forth.

- **Access to supporting policies:** This includes policies to incentivize battery production through tax incentives, direct subsidies, and lower import tariffs on components. Since global competition for onshore manufacturing of battery supply chains is very high, incentive schemes can thread the needle for companies to decide on one location or the other.

While stakeholders in the midstream EV battery manufacturing value chain ranked all of these factors high in their considerations, their relative importance varied depending on whether companies were mineral processors, cathode/anode manufacturers, battery cell manufacturers, or battery pack assemblers. For instance, while subsidies and tax incentives were a top decision factor across all value chain segments, access to capital was especially important for cathode manufacturers, given the high level of upfront capital deployment that is required for R&D. This is especially due to the fact that a significant level of R&D testing and validation is needed for cathode manufacturers to send data to the cell manufacturers and secure offtake agreements.

4.2 Guaranteed Demand or Offtake

India's potential market for EVs is enormous, creating strong demand incentives to manufacture locally, and the country has a unique opportunity to establish itself in the battery value chain because of offtake from key global partners. However, additional and clearer incentives will need to be introduced to transition from potential demand to guaranteed demand. India is the largest manufacturer of three-wheelers and tractors in the world, the second-largest manufacturer of two-wheelers, the 3rd-largest manufacturer of passenger vehicles and the 3rd-largest global automobile market (Indian Energy Storage Alliance [IESA], 2023). Under the National Electric Mobility Mission Plan, the government targeted converting 30% of total transportation into EVs by 2030. This would represent about 145¬–158 GWh of battery demand, with an additional 40 GWh for power storage (CEEW, 2021). By 2035, this is expected to grow to 350 GWh of demand for EVs and 140 GWh of demand for storage (IESA, 2023). The IESA (2023) estimates that domestic capacity will reach 140 GWh in 2030 and 550 GWh in 2035.

India can also leverage its own demand growth. Nobody doubts the enormous demand potential in India in 5 years; however, there is room for the government to bridge a demand gap in the next 3 to 5 years as businesses report that the key driver here is actual demand or guaranteed offtakes, not potential demand. While India has been good at creating enabling policies for EVs, several players would like to see stronger and more defined regulations on battery uptake.

Demand potential is a key factor for cell manufacturers. Government policies such as the Faster Adoption and Manufacturing of Electric Vehicles in India (FAME) subsidy have helped to drive demand for EVs in India, but most players expect demand for EV 4-wheelers to pick up only in the late 2020s. Consulted OEMs have cited a desire for more subsidies targeted at 4-wheelers and trucks to help increase demand more quickly for those segments.

This guaranteed demand is essential in capital-intensive projects, such as gigafactories and cathode manufacturing plants. Guaranteed offtake is considered a key metric to gain access to private capital and, therefore, the lack of it currently hinders the ability of new cell and cathode manufacturers to raise necessary capital from private markets. Global multinational companies suggested that they might be more incentivized to enter the Indian market if they could partner with a cell manufacturer that would guarantee a certain level of offtake or if there were supporting capital investment subsidies.

The government is trying to bring multinational companies to partner with local companies or to establish manufacturing in India through onshoring requirements like the Production Linked Incentive scheme for Advanced Chemistry Cells (PLI-ACC) scheme. The onshoring requirements will force companies to manufacture locally if they want to take advantage of the enormous demand within the Indian market. However, additional incentives could be implemented across the value chain to make sure companies trying to localize to India have the partners and resources they need.

On the side of demand/offtake, consulted interviewees agree that India has specific short-term advantages with respect to mineral processing and cell manufacturing, but less so with respect to cathode and anode manufacturing. On the side of mineral processing, India has a unique opportunity to position itself as a reliable supplier as the global market looks to diversify the supply chain. The United States, Europe, and Australia are trying to expand the battery supply chain and gradually move away from China, which as noted earlier, dominates the processing of critical minerals after a decade of investment.

This is considered a geopolitical and supply bottleneck, and governments around the world generally—and democracies specifically—are now trying to loosen their grip on the supply chain (i.e., the IRA's location-based tax incentives). India can capitalize on its strong partnerships with the United States and Australia to find a niche role in the global market by building out mineral processing. There will be strong demand from Western countries if India is able to establish the infrastructure. India does not currently benefit from incentives under the IRA. However, if India is able to expand its mineral processing capabilities, its strong relationships with the United States and mineral-rich countries like Australia would make it a great candidate for a free trade agreement related to minerals to become IRA eligible. The United States has shown a willingness to create free trade agreements related to minerals with countries in order to meet domestic demand and loosen China's grip on the battery mineral supply chain. The IEA estimates that there needs to be an additional USD 90–210 billion invested in mineral processing capacity by 2030 to meet demand. However, China accounts for 70% of anticipated investments (IEA, 2022), although India has the potential to meet the growing demand for non-China-related mineral processing. India's recent joining of the Minerals Security Partnership is a step in the right direction, and it should continue to expand its partnership with the United States and Europe.

Besides cell manufacturing, realized demand and offtake contracts are also a top priority and challenge for cathode and anode manufacturers. While the cell market is growing in India and is expected to be more mature in 3–5 years, demand for cathodes is currently still in its early stages. Cell manufacturers, especially the companies in the PLI-ACC, are now starting to build their plants, but it will take some time for them to be able to provide a steady demand for cathode manufacturers. India has been good at creating enabling policies for EVs, and should now consider additional measures to guarantee actual sales. With the country's potential consumer demand for EVs being enormous, transferring potential demand into guaranteed demand can level up the goal of domestic manufacturing. Companies indeed stated that guaranteed off take is the only thing that counts for demand actual sales for manufactures. Thus, right now, in the shorter term, offtake is a key challenge.

Anode material production is likely to continue to be heavily dominated by China, which has almost all the top 10 anode material production companies—including the entire supply chain from mining through to production. It is important to note that anode materials have entered a phase of oversupply due to China's previous massive capacity expansion. ShangtaiTech, China's sixth largest anode material producers, paused production at one of its facilities in March 2023 indefinitely due to overcapacity. The overcapacity of graphite anode material means that the price will continue to be depressed. In this context, companies are unlikely to invest in new production capacity in India unless there is demand offtake or explicit localization requirements.

4.3 Access to Ecosystem and Markets

Australia is the world's leading lithium producer and has significant reserves of other minerals. However, it is reliant on China for processing. Raw lithium spodumene imports from Australia are covered under the free trade agreement between India and Australia. However, refined lithium in the form of hydroxide or carbonate that has been processed in China does not benefit from the free trade agreement. India's port system can allow it to establish local mineral processing to utilize its free trade agreement with Australia and export the refined minerals to battery manufacturers in Asia, the United States, and Europe. The location of mineral processing is especially important under the IRA.

In recent years, India has pursued the conclusion of several free trade agreements. It fast tracked negotiations with Australia, the United Kingdom, Canada, and the European Union, all important battery markets. It has also joined the Mineral Security Partnership, and it is conceivable that the United States will conclude a specific trade framework with India on battery materials (as it has done with Japan) in light of eligibility requirements for IRA subsidies. Besides the government, the state-owned enterprise-led joint venture KABIL was created to support access to critical minerals. Under the purview of KABIL, there have been several memorandums of understanding (MoUs) and relationships with mineral-rich countries developed (see below).

Interviewees stated that they are looking to set up production in proximity to other companies in the battery supply chain. For example, cathode producers want to be close to cell manufacturers. This creates a network effect as companies along the supply chain set up near to each other, lowering transport costs. Several Indian states have been successful at creating a local ecosystem to attract EV and battery manufacturers to support the battery supply chain. For example, Karnataka and Telangana have attracted Exide, Ola, Amaraja, and Allox to expand cathode manufacturing while setting up an MoU with Rajesh Exports. TDSG, Exide, Tata Chemicals, and Renon are setting up in Gujarat (Deutsche Gesellschaft für Internationale Zusammenarbeit, 2022) as Minda is setting up a Gigafactory with C4V in Haryana. By utilizing India's port system and internal infrastructure network, the country should be able to establish a robust local supply chain for mineral processing, component manufacturing, and battery cell production for domestic sales and exports to the growing global market.

4.4 Access to Transport Infrastructure

Access to quality transport infrastructure for the importing and exporting of goods is an important consideration for potential investors and companies. India has an extensive port system and internal infrastructure network that is extremely beneficial to companies throughout the battery supply chain. Companies can utilize India's robust and growing port system for the importation of minerals and exportation of refined materials, cells, or vehicles to foreign markets. Western states like Karnataka, which is trying to establish itself as an EV hub, offers companies the infrastructure needed to procure materials easily and transport their product for export or to domestic consumers.

India's port system and experience in exporting goods into the global market put it in a prime position to expand in mineral processing. The existing infrastructure and experience would allow India to quickly establish itself as a vital segment of the battery supply chain, regardless of whether or not domestic manufacturing of batteries expands this decade. For example, while continuing to establish the other segments of the supply chain, the existing network allows India to import critical minerals from allies like Australia and export them to other trade partners.

4.5 Access to Inputs

Access to lithium, nickel, cobalt, and manganese is imperative for companies along the EV value chain, and interviewees cited this as a challenge for cathode manufacturing in India. Whereas lithium is not substitutable across battery chemistries, LFP batteries do not contain nickel, cobalt, or manganese. Many interviewees considered LFP batteries as potentially the strongest choice for India, specifically since India produces 100% (and more) of its domestic iron ore demand (Government of India Ministry of Mines, 2023). LFP's relevance is especially obvious when comparing India to regional competitors China or Indonesia, who do have domestic access to nickel and cobalt.

With respect to anodes, graphite is the dominant material and can either be found naturally or be produced synthetically. Natural graphite mining is dominated by China (80%) (IEA, 2022), but global production is becoming more diversified as countries impose local production requirements for EVs. While India has the world's eighth-largest natural graphite resources (United States Geological Survey, 2023), the ability to extract them economically remains largely unexplored. Our interviewees noted that more conversations around India's natural graphite exploration have been started.

Synthetic graphite production is geographically sensitive in a different way from natural graphite. The best place for synthetic graphite production is in localities with major carbon sources, such as India, which can provide coking coal or coal tar as an input material. Currently, India's Epsilon Carbon has existing capacities in synthetic graphite for EV battery anodes through its subsidiary Epsilon Advanced Materials. The company manufactures synthetic graphite from coal tar-based feedstock and exports precursor anode material to China, Japan, and Europe. This means that future anode producers have the option of looking within India for raw materials.

Since cell manufacturing is still in a nascent stage in India, access to raw materials is currently not a major issue, but it was identified as a major potential obstacle by 2025–2027, when cell manufacturers expected to be ramped up to a higher capacity and higher local content percentages were required. Ensuring access to raw materials for themselves and local suppliers (e.g., cathode and anode manufacturers) will become increasingly important, and India currently still lags on securing their critical mineral supply chain compared to countries such as China, the European Union, the United States, and Indonesia. However, in the long term, the recently discovered lithium reserve could be helpful.

The Indian Joint Venture company KABIL is implementing several strategies to engage with key mineral producers such as Australia, Argentina, Bolivia, and Chile. KABIL signed an MoU with Australia that outlines a detailed collaborative framework for India to invest in lithium and cobalt assets in Australia. Under the umbrella of KABIL, a team of Indian geologists also visited Argentina to assess lithium exploration projects in Catamarca province. In Chile, KABIL is engaging with the state miner Empresa Nacional de Mineria to develop the framework to jointly pursue lithium projects. The central government has also entered into several bilateral engagements, specifically by signing MoUs with certain countries. For example, in 2022, the government signed an MoU with Argentina, specifically covering critical minerals (e.g., lithium) (Government of India Ministry of Mines, 2023).

4.6 Access to Capital

Across the battery supply chain (but especially for mineral processing and cathode manufacturing), access to private markets and capital is essential, given the size of the upfront capital required, including R&D and technology costs. Currently, many investors and capital providers are less knowledgeable about the material manufacturing segment in the EV battery manufacturing value chain. There is a lot of knowledge on EVs, cell manufacturing, and battery packs but very little on anode and cathode manufacturing or mineral processing. As a result, interviewees stressed that financiers need more education on the sector. This is especially true since offtake agreements are still in nascent stages as well.

Access to capital is also a major challenge for anode production, given the high capital expenditures associated with the projects. While manufacturers can negotiate subsidies with the state governments, there is no explicit guidance over subsidies for anode production. Our interviewees commented that international anode companies have chosen North America over India in the past because the international markets have more available capital and explicit subsidies.

Finally, the PLI-ACC has put cell manufacturing in the limelight and signalled government support for the sector, which has helped these companies gain access to private capital.

However, to meet the ~100 GWh target by 2030, more than USD 8 billion in investments is estimated to be needed across the Indian battery value chain, and demand/offtake is a large driver for where private capital will flow. Therefore, it is important for the government to address any demand/offtake issues because they might provide future obstacles to access to capital.

Compared to potential competitors, capital expenditures for a new mineral processing facility would be lower in India. According to McKinsey, total infrastructure costs are 70% lower in India compared to other chemical processing countries. The significantly lower cost of capital expenditures has made India the "next chemicals manufacturing hub" and India can use this cost advantage to expand into mineral processing for critical minerals for batteries (McKinsey & Company, 2023).

4.7 Access to Low-Cost and Skilled Labour

The cost of labour, land, and utilities is a major decision-making factor for companies and investors, and a strength of India's, especially its low labour costs. Interviewees believe that India is in a very strong competitive position to attract mineral processing, cathode and anode production, and battery cell manufacturing based on the cost of labour. India's low labour costs compared to global competitors and the size of its workforce can help attract companies.

Battery manufacturing is advanced technology that requires a highly skilled workforce to expand production. Currently, India's role in chemical manufacturing will allow it to expand local mineral processing. India's strong university system and engineering schools have the potential to be a major force in expanding the country's role in the battery supply chain. However, to unlock this potential, universities need to focus more on the battery supply chain.

Some local companies interviewed identified a shortage of skilled workers and the need to hire from abroad since India's battery manufacturing sector is still in its infancy. Therefore, there is an opportunity for the Indian government to incentivize universities to partner with the emerging EV battery companies on R&D and workforce development. India can provide the industry with a large pool of engineering and chemical talent to expand with if the universities can produce a skilled workforce.

Skill-development initiatives and subsidies have recently become prevalent across most states, offering companies the opportunity to claim a certain amount per month per worker for skill training. These programs aim to bridge the gap between the demand for skilled workers and the available workforce.

The government has also taken proactive measures to address the skills gap by establishing industrial training institutes (ITIs). These government-owned institutes play a vital role in training citizens in essential technical skills. Companies recognize the value of partnering with ITIs, as they not only fund these institutions but also have the opportunity to hire talented individuals who have received specialized training. Currently, the government is planning to introduce courses focused on EV technology at various ITIs. This initiative aligns with the increasing demand for skilled workers in the rapidly evolving field of EVs. By incorporating

EV technology courses into the ITI curriculum, the government aims to equip individuals with the necessary skills to contribute to the growth of the EV industry.

Furthermore, the Skill Development Department is actively working on implementing counselling services for students. This includes an emphasis on encouraging more institutes to offer training programs in remote areas. This strategy aims to minimize the need for individuals to migrate to urban centres in search of quality education and training opportunities. By expanding access to skill development in remote areas, the government seeks to ensure that every region has a skilled workforce to drive local economic growth.

Complementing federal efforts, various state governments in India have also introduced subsidies to incentivize companies to prioritize skill development. These subsidies are designed to assist companies in accessing the right skill sets for their operations while reducing the burden of training costs.

4.8 Access to Renewable Electricity

Mineral processing and battery cell manufacturing companies are looking for renewable electricity sources to power their energy-intensive processes in a sustainable manner. Renewable electricity sources are especially important for companies considering ESG requirements (discussed further in Section 4.11). Interviewees said renewable energy sources were available for businesses in almost all states.

India is 4th in the world in installed renewable energy capacity and has a target of 500 GW of non-fossil fuel-based energy by 2030 (Invest India, 2023b). In 2022, 92% of new generation capacity (15.7 GW) was wind and solar. The states of Rajasthan and Gujarat are leading the way in renewable generation capacity with strong renewable targets. Combined, they added 8.6 GW of new solar capacity (Lee, 2023).

However, coal remains the dominant source of electricity in India, accounting for over 70% of electricity generation in 2022 (Chye & Chew, 2023). Nationally, continued reliance on coal for electricity generation could be an issue in attracting battery supply chain companies to India. States that install more renewable energy sources will have a better chance of attracting battery supply chain-related investments.

4.9 Access to Technology

Access to technology was cited as an important factor, especially given the high level of innovation in cathode manufacturing. However, access to technology was a greater challenge because the technology currently resides outside of India, in China, Japan, South Korea, Europe, and the United States. In addition, LFP patents were Chinese-owned until 2022, making access to cathode chemistries challenging for Indian companies and other cathode manufacturers. The patent ended in 2022, which means that India will be able to use LFP technology going forward, but it will need to catch up to Chinese companies and companies in the United States that are beginning to produce LFP batteries.

Indian companies can get access to the technology through partnerships with foreign companies to lease the technology. India can also attract foreign companies to produce the technology locally. Companies cited India's strong university system as a way to improve their access to technology. As with improving the skilled workforce, partnerships with universities to expand R&D and improve technology will be important for India.

For anodes, India is currently developing the technology indigenously, but it remains in the early stage and needs additional R&D support. According to expert interviews, the process of developing technologies that enable a capacity expansion from 100 MWh to 1 GWh would take 3 to 4 years. Like elsewhere in the world, Indian anode companies still need time before they can compete with their Chinese counterparts.

Cell manufacturing requires high technological capabilities. India is currently importing cells from other countries, such as China, and many players have technology partnerships with international companies, such as TGSG's partnership with Toshiba (Japan) and Exide's partnership with Leclanché SA (Switzerland) (Deutsche Gesellschaft für Internationale Zusammenarbeit, 2022).

4.10 Access to Land

Mineral processing and the manufacturing of battery components and cells demand access to land to build large production facilities. Currently, companies are worried about the country's arduous and lengthy process for land permitting and obtaining land. In the World Bank's latest *Doing Business* (2020) report, India ranked 63rd out of 190 countries; however, on registering property, it ranked 150th. The government, either at the state or national level, will need to assist companies on land acquisition in order to allow companies to set up facilities.

4.11 ESG Considerations

To attract global multinationals (and as Indian cell manufacturers begin targeting markets like the EU), ESG considerations will become increasingly important. For multinational companies, especially ones headquartered in Europe and the United States, ESG requirements on their supply chain and production are becoming stricter and, therefore, an important factor in deciding where to invest. For example, the EU will be putting up an emissions-linked trade barrier on batteries in the coming years (CEEW, 2021). India is well positioned on renewable energy; therefore, the federal government should work with local governments to ensure that as EV hubs are being set up, they are powered by low-carbon power. The government can also help encourage the development of low-carbon manufacturing processes or provide incentives through taxes and higher production-linked subsidies for greener players.

Multinational companies would also like to see clearer Indian ESG guidelines and targets that could be used for ESG reporting in Europe and North America. Transparency is increasingly important as reporting requirements become more stringent. Therefore, ensuring that companies have the right reporting in place would also help make India more competitive in the battery midstream.

Production of the synthetic graphite required for anodes requires the largest energy input to heat the furnace to high temperatures (typically above 2,500 Celsius). Carbon emissions would increase substantially if fossil-based electricity is used for this process. However, emissions of carbon dioxide and other pollutants associated with the production of synthetic graphite can be minimized using advanced production technologies, as well as through the implementation of environmental management systems and pollution-control measures. One interviewee noted that green power is available in almost all states. That is, however, not always assumed by other companies.

4.12 Access to Supporting Policies

Nearly all interviewees highlighted that direct government support through financial instruments, such as subsidies and tax incentives, is a significant factor for mineral processing and manufacturing companies when considering investment opportunities. The United States IRA was specifically mentioned as an important tool to localize battery production. In India, both national and state-level policies exist to support companies in establishing mineral processing, cell component, and battery cell production within the country. Companies can take advantage of incentives at both levels of government.

Chemical manufacturing and mineral processing receive support from state and national governments, including the Petroleum, Chemicals & Petrochemicals Investment Regions (PCPIRs). The states of Andhra Pradesh, Gujarat, Odisha, and Tamil Nadu have been designated as PCPIRs, predefined chemical zones that offer favourable conditions for development. The Indian government aims to attract a combined total of USD 213 billion in investments by 2030 through these policies as the chemical sector continues to grow. These four states, with their government support and convenient access to ports, are locations that could be appealing for the development of mineral refining. Interviewees also emphasized the supportive nature of local governments.

Specific government support is also crucial for cathode manufacturing companies, as this process requires substantial upfront R&D and technology costs. Cathode manufacturers highlighted that subsidies targeting initial capital expenditures, technology, and R&D grants are the most beneficial, as opposed to production-linked incentives. Although such subsidies do not currently exist at the national level, some manufacturers have successfully negotiated state-level subsidies for R&D grants and upfront capital expenditures.

While national-level policies do not specifically target anode production, anode producers can negotiate subsidies with states. For instance, Epsilon Advanced Materials signed an MoU with the Government of Karnataka in 2022 to establish an anode material production plant, with the state facilitating registrations, approvals, and incentives for the company. Our interviewee noted that state subsidies for power, capital expenditures, and job creation in anode material production are ample.

Cell manufacturers benefit from the PLI-ACC scheme, which provides federal production-linked subsidies to three cell manufacturers: Rajesh Exports, Ola Electric Mobility, and Reliance New Energy, with production expected to begin by 2024. Additionally, companies like TDSG in Gujarat have announced plans to invest in scaling up local manufacturing for lithium-ion batteries. However, the current PLI target of 30 GWh (with the scheme reopening for an additional 20 GWh) falls short of the estimated 100 GWh required by 2030 to meet current demand forecasts and achieve 60% of local demand.

Furthermore, there is room for additional subsidies in the cell manufacturing segment that go beyond production-linked incentives. Although the PLI-ACC bidding process was successful, attracting 10 bids, major multinational corporations did not participate. Interviews revealed that one reason for this was that other countries offer higher levels of upfront subsidies and support to establish manufacturing facilities. The industry has also welcomed the lowering of customs duties on battery parts.

What is particularly interesting is that state government incentives can be customized for mega-investments (i.e., typically those exceeding USD 100 million). Every state in India has an industrial policy that outlines the incentives available to companies based on their investment size. In some cases, companies have provided a list of requests to states that would enable them to make the necessary investments. As an example, a US company was able to negotiate a subsidy of approximately 40% on capital expenditures from one of the southern states in India for battery cell manufacturing.

For global multinational companies, national-level financial support is important in determining which country or region to invest in next, as negotiating with state-level governments can be time-consuming. As a result, it is essential to provide a smooth pathway to negotiating investment plans. Indian companies are more flexible regarding the subsidy source, whether it comes from the federal or state government. Local companies cited attractive state subsidies, including tax exemptions, power and transport subsidies, and, in some cases, direct capital subsidies of around 20%. Overall, it can be concluded that India has ample support for companies seeking to implement mega-investments but that not all multinational EV and battery companies are aware of how to navigate the process.

Table 2. Overview of Indian federal-level policies

Policy	Policy focus	Outcome
NEMMP (2013–2020)[3]	• Direct subsidy: up to USD 394 for two-wheelers, up to USD 1,875 for cars, and up to USD 136,000 for buses • Grants for projects: public charging infrastructure	• Failed to achieve sales of 6–7 million hybrid and electric vehicles by 2020 but provided the initial boost for uptake of EVs
FAME 1 (2015–2019)[4]	• Direct subsidy: USD 100 million fiscal incentive to EV buyers, including also: • Grants for projects: pilot projects, R&D/technology development/public charging infrastructure	• 2,80,000 vehicles sold • Only 41% of allocated fund was utilized

[3] See Ministry of Heavy Industries, 2017.

[4] See Ministry of Heavy Industries, 2019.

Policy	Policy focus	Outcome
FAME II (2019–2024)[5]	• Direct subsidy: USD 1.5 billion fiscal incentive, with 86% to EV using advanced Li-battery and newer technologies, including also: • Grants for projects: charging infrastructure, administrative expenditure	• 7,66,478 vehicles sold • Sanctioned 2,877 charging stations
PLI-ACC (2020–2027)[6]	• Major goal: USD 2.49 Bn outlays to help set up 50 GWh of domestic battery manufacturing over the next 5 years • Fiscal subsidy: maximum base subsidy of USD 24/KWh for manufacturers • Land infrastructure: State governments can hand over possession of land to battery manufacturers at or below market price to establish manufacturing hubs; offer proximity to highways, trunk infrastructure facilities etc. • Permissions: State governments set up single window clearance mechanisms in a time-bound manner; provide potential graded duty structure to lithium-ion cells, battery packs, and ancillary components.	• 30 GWh were awarded to Rajesh Exports (5 GWh), Ola Electric Mobility (20 GWh), and Reliance New Energy Solar(5 GWh) in 2022. • The selected manufacturers are required to achieve at least 25% domestic value addition within 2 years and 60% domestic value addition within 5 years.

Table 3. Four major policy focuses in India at the state level

Policy focus	Policy content
EV targets and budgets	• Defined target for sales penetration and/or investments and/or charging infrastructure • Specific budget allocated for dispersing incentives such as State EV Fund

[5] See Ministry of Heavy Industries, 2022.

[6] See: Invest India, 2020.

Policy focus	Policy content
Demand-side subsidy for consumers	• Subsidy support for consumers for 2, 3, & 4-wheeler EVs in addition to FAME II • Road tax and registration fee exemptions • Subsidy for e-buses in addition to FAME II • Subsidy for tractors, e-cycles, and strong hybrid vehicles • Financing support through interest subvention (subsidy offered on interest rates) • Scrappage incentive • Retrofitting incentive • Electricity tariff benefits for consumers
Industry incentives	• Manufacturing incentives • R&D incentives or funds • Charging infrastructure incentives • Focus on battery recycling • Employment generation incentives • Focus on skill development • Promotion and creation of green zones
Focus on fleets, job creation, and charging infrastructure	• Formation of State EV cell and Steering Committee responsible for overseeing EV growth • Specific targets for fleet electrification • Targets or focus on job creation • Mandates for charging infrastructure

Source: Climate Trends, 2023.

5.0 Conclusion

India is emerging as a prominent player in the battery industry. The government's focus on cell manufacturing through the PLI-ACC framework reflects the country's strategic intent. However, the true value lies in capturing the entire supply chain, particularly in cathode material manufacturing, where minerals represent a critical cost component. Hence, there is a strategic imperative to develop mineral processing capabilities. While the PLI-ACC framework includes local content requirements, many companies argue that further support is needed to localize other aspects of the manufacturing supply chain, including mineral processing, cathodes, and anodes.

India has the potential to add value across the battery supply chain beyond gigafactories. The country's chemical sector expertise, favourable trade relations with key players such as South Korea, Japan, the United States, and the EU, and a growing network of free trade agreements offer opportunities for upstreaming processing. Furthermore, India possesses critical minerals such as manganese ore, graphite, and recently discovered lithium, providing a strong foundation for local supply and reduced dependence on imports.

Companies, both domestic and multinational, have emphasized the importance of upfront capital support, considering that other major jurisdictions worldwide are often offering similar schemes. India has experience in providing such support, particularly at the state level, which many Indian companies are aware of. However, it is crucial to communicate these schemes effectively to multinational battery and mineral processing companies to attract their investment and participation in the Indian market. With the right support and strategic initiatives, India can unlock its potential as a key player in the battery industry, first with respect to mineral processing and battery production, followed by establishing itself as a major hub for cathode and anode manufacturing as well.

References

Alcácer, J. & Chung, W. (2009). *Location strategies for agglomeration economies.* Harvard Business School. https://www.hbs.edu/ris/Publication%20Files/10-071_0d9abdef-8b7c-49b4-a3e9-c16aab5c2e35.pdf

Asaba, M. C., Duffner, F., Frieden, F., Leker, J., & von Delft, S. (2022). Location choice for large-scale battery manufacturing plants: Exploring the role of clean energy, costs, and knowledge on location decisions in Europe. *Journal of Industrial Ecology, 26*(4), 1514–1527. https://doi.org/10.1111/jiec.13292

Australian Bureau of Statistics. (2022). *Insights into Australian exports of lithium.* www.abs.gov.au/articles/insights-australian-exports-lithium

Battery University. (2021). *How are Li-ion batteries made?* https://batteryuniversity.com/learn/article/how_are_li_ion_batteries_made

Benchmark Minerals Intelligence. (2023). Over 100 Gwh of sodium ion battery capacity planned for 2030 as industry seeks alternative to lithium. *Benchmark Source.* https://source.benchmarkminerals.com/article/over-100-gwh-of-sodium-ion-battery-capacity-planned-for-2030-as-industry-seeks-alternative-to-lithium

Council on Energy, Environment and Water. (2021). *Financing India's transition to electric vehicles: A USD 206 billion market opportunity (FY21–FY30).*

Chang, A., & Bradsher, K. (2023). Can the world make an electric car battery without China? *The New York Times.* www.nytimes.com/interactive/2023/05/16/business/china-ev-battery.html

Chye, M., & Chew, C. (2023). *India's power output grows at fastest pace in 33 years, fuelled by coal.* Reuters. www.reuters.com/business/energy/indias-power-output-grows-fastest-pace-33-years-fuelled-by-coal-2023-04-05/

Climate Trends. (2023). *Analysis of state electric vehicle policies and their impact.* Climate Trends. https://imgs.mongabay.com/wp-content/uploads/sites/30/2023/03/09122500/Climate-trends-report.pdf

Deutsche Gesellschaft für Internationale Zusammenarbeit. (2022). *Battery ecosystem: A global overview, gap analysis in Indian context, and way forward for ecosystem development.*

Government of India Ministry of Mines. (2023). *Annual report 2022-23.*

India Energy Storage Alliance. (2023). *Overview of advanced chemistry cell (ACC) demand and manufacturing ecosystem in India.*

International Energy Agency. (2022). *Global supply chains of EV batteries.* https://www.iea.org/reports/global-supply-chains-of-ev-batteries

International Energy Agency. (2023a). *Energy technology perspectives 2023.* https://www.iea.org/reports/energy-technology-perspectives-2023

International Energy Agency. (2023b). *Global EV outlook 2023.* https://www.iea.org/reports/global-ev-outlook-2023

Invest India. (2020). *Production linked incentive (PLI) schemes in India.* https://www.investindia.gov.in/production-linked-incentives-schemes-india

Invest India. (2023a). *India's battery cell manufacturing potential.*

Invest India. (2023b). *Renewable energy in India - Indian power industry investment.* www.investindia.gov.in/sector/renewable-energy

Khanna, S. (2023). *India's Tata Group signs $1.6 billion EV battery plant deal.* Reuters. https://www.reuters.com/business/autos-transportation/indias-tata-group-signs-16-bln-ev-battery-plant-deal-2023-06-02/

Lee, U. (2023). *Solar and wind dominate India's capacity additions in 2022.* Ember. http://ember-climate.org/insights/research/india-data-story-2023/

Li, D. (2023). *Bottom-up battery cost model (BattMan 2.0)*. BloombergNEF. https://www.bnef.com/insights/22165

McKinsey & Company. (2023). *India: The next chemicals manufacturing hub.* www.mckinsey.com/industries/chemicals/our-insights/india-the-next-chemicals-manufacturing-hub

Mehdi, A., & Moerenhout, T. (2023). *The IRA and the US battery supply chain: Background and key drivers.* Columbia University Center on Global Energy Policy. https://www.energypolicy.columbia.edu/publications/the-ira-and-the-us-battery-supply-chain-background-and-key-drivers/#_edn9

Ministry of Heavy Industries. (2017). *National Electric Mobility Mission Plan.* https://www.dhi.nic.in/ddhi-sumen-v2/UserView/index?mid=1347

Ministry of Heavy Industries. (2019). *FAME Phase 2.* https://heavyindustries.gov.in/writereaddata/fame/famedepository/3-operational%20guidelines.pdf

Ministry of Heavy Industries. (2022). *Year-end- review of Ministry of Heavy Industries – 2022.* https://pib.gov.in/PressReleasePage.aspx?PRID=1887129

Moerenhout, T., Goel, S., Aneja, D. A., & Ray, S. (2022). *Investor perspectives on accelerating growth in the Indian EV ecosystem.* International Institute for Sustainable Development. https://www.iisd.org/publications/report/investor-perspectives-accelerating-growth-indian-ev-ecosystem

NITI Aayog. (2022). *Need for advanced chemistry cell energy storage in India.*

NITI Aayog & Rocky Mountain Institute. (2019). *India's electric mobility transformation: Progress to date and future opportunities.*

Organisation Internationale des Constructeurs d'Automobiles. (2023). *2022 production statistics.* https://www.oica.net/category/production-statistics/2022-statistics/

Pathak, K. (2021). Govt intends to have EV sales penetration of 30% for private cars by 2030: Nitin Gadkari. *The Economic Times.* https://economictimes.indiatimes.com/industry/renewables/gps-renewables-acquires-germany-based-proweps-envirotech/articleshow/102534289.cms

Reid, M. (2023). *Sodium-ion batteries: Disrupt and conquer?* Wood Mackenzie. www.woodmac.com/news/opinion/sodium-ion-batteries-disrupt/

Toll, M. (2021). Ola's popular 70 mph electric scooters to be built entirely by women. Here's why. *Electrek.* https://electrek.co/2021/09/13/olas-popular-70-mph-electric-scooters-to-be-built-entirely-by-women-heres-why/

United States Geological Survey. (2023). *Graphite.* https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-graphite.pdf

Published by the International Institute for Sustainable Development

Geneva Office

9 Chemin de Balexert
1219 Châtelaine
Geneva, Switzerland

Tel: +41 22 917 8683
Website: www.iisd.org
Twitter: @IISD_news

IISD

iisd.org