Lithium-Sourcing Roadmap for India

Strategies to secure a robust and responsible battery supply chain

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Lithium-Sourcing Roadmap for India: Strategies to secure a robust and responsible battery supply chain

September 2023

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Photo: iStock

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Executive Summary

Lithium is a key mineral used in lithium-ion (Li-ion) battery technologies and is anticipated to play a pivotal role in driving the uptake of electric vehicles and stationary storage applications over the next decade (International Energy Agency [IEA], 2021). Its criticality is reflected in its inclusion in the critical minerals list of eight major global economies (the United States, European Union, Japan, Canada, Australia, China, Republic of Korea, and India), one of only three minerals to be included in an assessment by all eight countries (the others being tungsten and cobalt) (Chadha et al., 2023). In 2023, India reaffirmed lithium's importance by designating it as a "critical" mineral along with 29 other minerals (Ministry of Mines, 2023a). The IEA also forecasts that lithium for clean energy will see the fastest growth in global demand among different critical minerals, growing by 17 times between 2022 and 2045 under the IEA's net-zero scenario, underscoring its unique importance in driving the energy transition (IEA, 2023a).

India's geostrategic allies and competitors have long recognized the importance of lithium in maintaining their industrial competitiveness and have taken steps to secure access to lithium resources through direct investments in overseas mines and long-term supply agreements, as well as setting up processing and refining capabilities. In contrast, Indian companies have thus far played a negligible role in the lithium battery supply chain, which, if left unaddressed, may create energy and economic security risks for the country. A lack of decisive action to secure a lithium supply in the coming decade could leave India behind in the race to develop a Li-ion battery manufacturing base and stymie the development of key industries such as electric vehicles and stationary storage applications, hindering India's economic growth and job creation potential.

This report aims to provide a strategy to guide policy-makers in sourcing lithium responsibly to promote clean energy manufacturing in India, with the broader aim of supporting low-carbon economic growth, creating equitable jobs, and helping to mitigate climate change impacts. While recent research has mainly focused on the entire critical minerals landscape, this report aims to go deeper into a specific mineral's supply chain and analyze strategies by mineral-rich nations and consumer nations as well as company-level initiatives to secure lithium supply. The report can support several Indian ministries, state-owned enterprises, such as Khanij Bidesh Limited (KABIL), as well as industry actors in India seeking to establish a presence in the global lithium supply chain.

The report demonstrates that reserves, production, and processing for lithium are geographically concentrated, thereby creating security of supply concerns. The top three lithium-producing countries control more than 90% of the world's production (U.S. Geological Survey, 2023). Furthermore, 60% of global lithium-processing capacity is concentrated in China (IEA, 2022a). Moreover, the top five lithium-supplying companies account for about half of global lithium production (IEA, 2022a). This concentration makes net lithium-importing countries vulnerable to supply shocks ranging from production challenges to extreme weather events. Any setbacks may result in higher prices and slow down the adoption of key technologies. In 2021 and 2022, lithium prices increased significantly, before moderating in 2023. This contributed to a 7% increase in the prices of Li-ion batteries

in 2022 (BloombergNEF, 2022), highlighting the impact of lithium's price volatility on clean energy technologies. China's extensive efforts over the past few decades have afforded it a considerable head start in the lithium supply chain and pose a formidable challenge for other countries looking to diversify supply chains. Beijing has adopted a three-fold strategy to secure lithium supply by 1) increasing foreign investment in overseas mines, 2) leveraging the Belt and Road Initiative to forge partnerships with mineral-rich nations, and 3) expanding domestic production. China's dominance in lithium processing also provides it with advantages in cost and planning certainty as it builds its clean energy industry.

Rising geopolitical tensions and supply constraints have prompted countries lacking significant lithium reserves to swiftly devise policies to establish more resilient supply chains. The United States, South Korea, Japan, and European countries are actively taking measures to support their companies in gaining a foothold in the lithium supply chain. This has led to various multilateral frameworks, such as the Mineral Security Partnership, which India recently joined, and several bilateral agreements. Japan and South Korea can provide important lessons for India in the use of state-owned institutions to support the overseas exploration and production of critical minerals. The importance of obtaining a critical mineral supply and the risks of disruption are leading advanced economies to enact a range of new industrial policies. In the United States, for example, the crucial policies on critical minerals are part of the Inflation Reduction Act, legislation that focuses on a broader buildout of the clean energy industry. Likewise, in Europe, the Critical Raw Materials Act is part of the larger Green Deal Industrial Plan.

Mineral-rich nations, such as Australia, Chile, and Argentina, are exploring ways to capture more value from their lithium production by pursuing midstream and downstream opportunities, such as in mineral refining as well as cathode and anode production. Chile garnered attention with its new mining strategy, which requires new lithium projects to be public–private partnerships in which the Chilean state will hold a majority share. The openness to foreign direct investment in the mining industry in Australia and Argentina makes them safer and stronger partners for India, which has made positive progress through memorandums of understanding in both countries.

However, it is important to emphasize that international mining companies are looking for partnerships with private companies so memorandums of understanding won't guarantee access to lithium supplies for India. The Indian government should assist its state-owned enterprises or public sector undertakings, such as Khanij Bidesh Limited, in pursuing partnerships, but it is also important to partner with domestic private companies, such as original equipment manufacturers, to reduce the offtake risk of the sourced lithium. India could potentially gain a foothold within mineral-rich economies by helping to provide financing and technical support for joint mineral exploration and local value addition in these nations, which could facilitate the supply of minerals for Indian companies. This strategy could also help India position itself as a leader in the Global South, fill the financing gap in developing economies, and gain increased access to mineral supply.

The report forecasts lithium demand under two different scenarios—Business as Usual and the Accelerated Deployment of Clean Energy Technologies. The analysis indicates that overall lithium demand is likely to increase between 10 and 40 times from 2022 to 2030 under

the two scenarios, making it imperative for policy-makers to undertake urgent planning to secure lithium supplies through equity investments and offtake agreements in international producing mines. India can also leverage its growing geopolitical heft to establish international partnerships. The report also highlights India's comparative advantages in lithium refining, which need to be encouraged with the right incentives and policy support. In the following decades (2030–2050), India can anticipate that domestic lithium production and recycling may help offset demand.

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Abbreviations and Acronyms

BRI	Belt and Road Initiative
CATL	Contemporary Amperex Technology Limited
CRMA	Critical Raw Materials Act
DLE	direct lithium extraction
DoE	Department of Energy
DRC	Democratic Republic of the Congo
ESG	Environmental, social, and governance
ESS	Energy storage systems
EU	European Union
EV	electric vehicle
GBA	Global Battery Alliance
GHG	greenhouse gas
IEA	International Energy Agency
IRA	Inflation Reduction Act
ISGF	India Smart Grid Forum
J&K	Jammu and Kashmir
JV	joint venture
KABIL	Khanij Bidesh Limited
LFP	lithium ferro phosphate
LiB	lithium-ion battery
MOU	memorandum of understanding
MSP	Minerals Security Partnership
NCA	nickel cobalt aluminum
NMC	nickel manganese cobalt
OEM	original equipment manufacturers
OPEC	Organization of the Petroleum Exporting Countries
PIB	Press Information Bureau
PSU	public sector undertakings
RPO	Renewable Purchase Obligation
SOE	state-owned enterprises
SQM	Sociedad Química y Mineral
UAE	United Arab Emirates
USGS	United States Geological Survey

1.0 Introduction

India made a commitment at the 26th United Nations Climate Change Conference (COP 26) to reach net-zero emissions by 2070, and has ambitious near-term targets of deploying 500 GW of non-fossil electric power capacity by 2030 (Government of India, 2022). The country has also signed up internationally for the EV30@30 campaign, with the aim of achieving a 30% electric vehicle (EV) sales share by 2030 (Clean Energy Ministerial, n.d.). The anticipated clean energy transition to meet these targets is likely to rapidly increase the country's demand for critical minerals, such as lithium. India is mainly reliant on imports to meet its current needs but must secure a reliable supply of critical minerals to achieve Prime Minister Modi's vision of becoming self-reliant (or "Aatmanirbhar Bharat") (Gupta et al., 2016). However, the lithium supply chain involves several risks that could pose unique challenges for India.

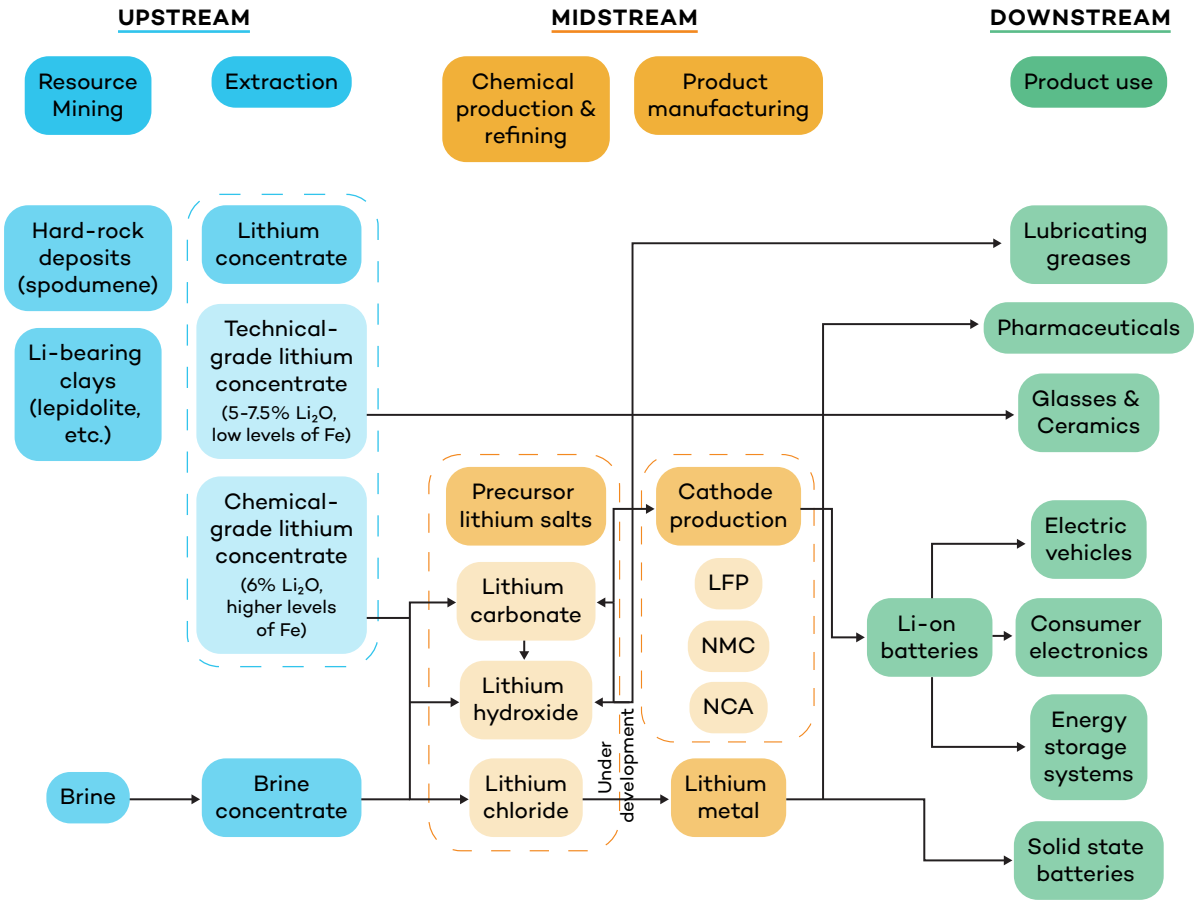
First, the extraction of lithium is heavily geographically concentrated, which brings security-of-supply concerns. The top three lithium-producing countries control more than 90% of the world's production (United States Geological Survey [USGS], 2023). Furthermore, 60% of global lithium-processing capacity is concentrated in China (International Energy Agency [IEA], 2022a). Second, the rapid increase in global demand for lithium, coupled with inadequate investment in mining, is likely to cause a supply deficit that is anticipated to contribute to greater price volatility. Indeed, after more than a decade of price declines, average costs for lithium-ion (Li-ion) battery packs increased 7% year on year to USD 151/kWh in 2022 (BloombergNEF, 2022). According to BloombergNEF, this was mainly driven by higher costs for raw materials, such as lithium. The IEA found that lithium prices increased seven-fold between May 2021 and May 2022 (IEA, 2022a). Although prices have moderated recently, price volatility remains a threat, which could aggravate energy security concerns, delay the clean energy transition, and make it unaffordable for emerging economies, such as India (Moerenhout et al., 2023). The best approach to guard against future price volatility could be to localize a larger share of the battery supply chain. Indeed, battery pack prices globally in 2021 were 40%–60% higher than in China, which hosts the largest share of manufacturing (Singh, Ghate, Ningthoujam, Gupta, Sharma, et al., 2022).

India is mainly reliant on imports of Li-ion cells from other countries and currently has limited domestic assembly operations for modules and battery packs (Singh, Ghate, Ningthoujam, Gupta, & Sharma, 2022). Although the Li-ion cell manufacturing industry is at a nascent stage, several companies from the United States, the European Union (EU), and China have already engaged in long-term lithium offtake agreements with resource-rich nations; hence, India could find its options for a future lithium supply constrained when its domestic manufacturing industry matures (See Table 4 for examples of offtake agreements).

Box 1. India's recent lithium discovery in Jammu and Kashmir

India's recent find of 5.9 million tons of lithium resources in Jammu and Kashmir (J&K) could be significant since it represents about 6% of the total identified lithium resources in 2023 (USGS, 2023). However, international experience shows it takes, on average, 16.5 years from the discovery of critical minerals to production (IEA, 2021). In addition, J&K's resources are currently at an inferred G3 stage,[1] so further exploration will be needed to determine the extent of the reserves that are economically recoverable (Press Information Bureau [PIB], 2023a). Moreover, India will need to secure access to capital and technology to extract lithium (potentially through the involvement of international companies) as well as build processing and refining infrastructure. The uncertainty surrounding the scale of the reserves, coupled with the long time lag before production commences, means that India cannot be complacent in sourcing lithium externally to meet its clean energy manufacturing ambitions.

Figure 1. A representation of the lithium value chain



Source: Authors' representation based on Hao et al. 2017 and Zhao et al., 2023.

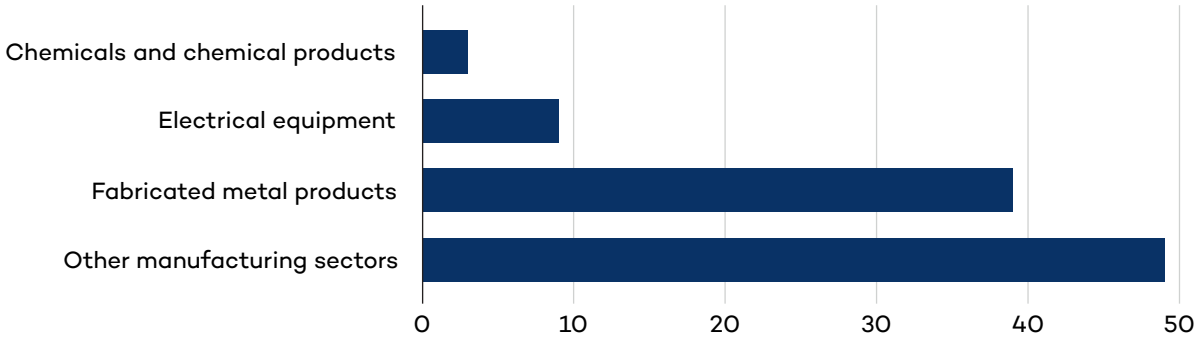
[1] Nations Framework Classification, suggesting the reconnaissance and prospecting stages have been completed. After this, general exploration (G2) and detailed exploration (G1) need to be undertaken to fully understand the nature of the lithium deposits, including the ore grade (United Nations, 2018).

A lack of lithium supply is also a major constraint in attracting investment into battery cell manufacturing. A study by the International Institute for Sustainable Development found that India's limited access to critical minerals is one of the key bottlenecks faced by companies when investing in India's EV ecosystem, particularly in the high-value Li-ion cell production (Moerenhout et al., 2022). Therefore, government support to secure these minerals is critical to promote further investment in the midstream and downstream segments of the EV value chain. Consultations with government experts suggest that subsidies in downstream industries through the production-linked incentive schemes will trickle up to components and mining/processing; however, private companies contest this and highlight a need for dedicated policies and incentives to promote lithium investment in the country (Moerenhout et al., 2022).

2.0 The Use of Lithium in Different Sectors

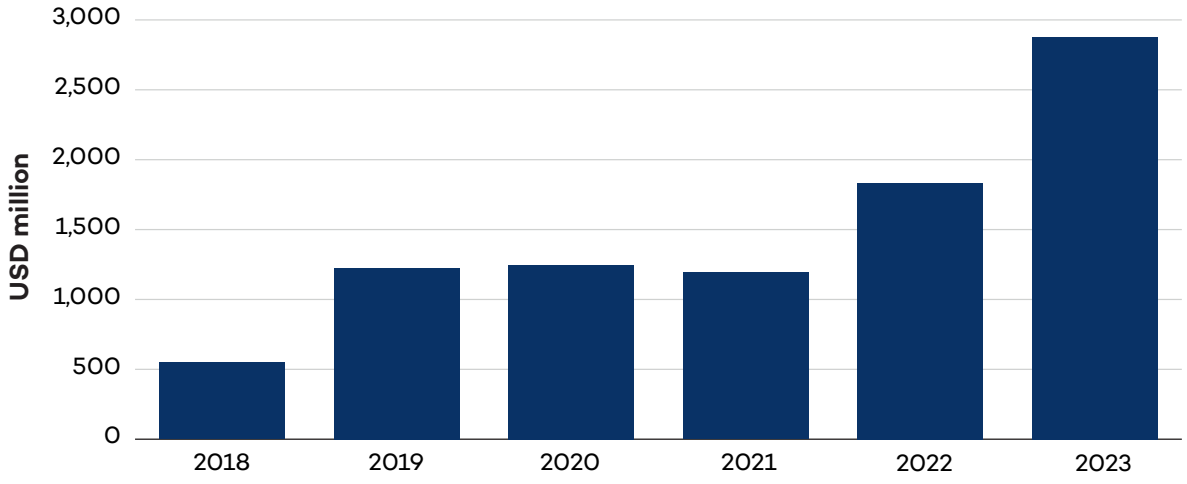
Lithium is currently used for a variety of applications in India and globally, but the share of clean energy technologies in the total demand for lithium globally is expected to reach almost 90% by 2040 (IEA, 2021). Hence, the focus of this study is primarily on the use of lithium in Li-ion batteries for low-carbon technologies, such as EVs and battery energy storage systems (ESS).

Figure 2. Share of lithium demand from different industries (average between 2017–18, 2018–19, and 2019–20)



Source: Adapted from Chadha et al., 2023.

Figure 3. India's Li-ion imports have been growing rapidly from FYs 2018–2023



Source: Ministry of Commerce and Industry, n.d.

According to data from India's Ministry of Commerce and Industry, the country's imports of Li-ion batteries increased from USD 384.6 million in 2018–19 to USD 2.8 billion in 2022–23 (Figure 3). This growth is largely driven by imports from China and South Korea, which are the largest suppliers of lithium and Li-ion batteries to India (Ministry of

Commerce, n.d.). These batteries contain significant quantities of embedded lithium, and a continued dependence on imports poses a risk to India's energy security and economic development, particularly as the demand for Li-ion batteries is anticipated to grow rapidly in the coming decade.

Below is a summary of the key sectors that will require lithium supply over the next decade.

2.1 Electric Mobility

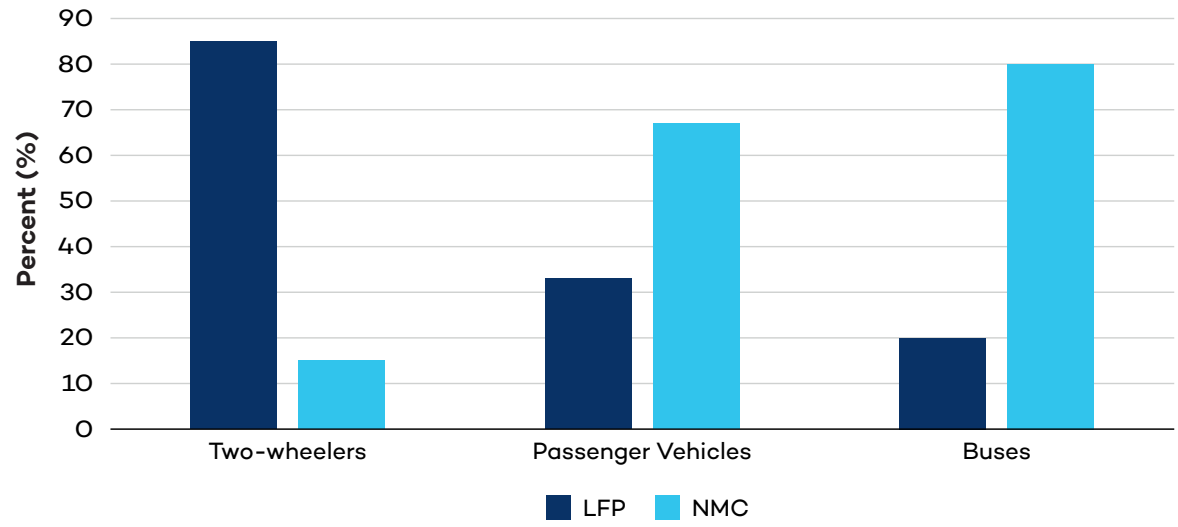
India has set a target of having an EV share of 30% of all personal cars, 70% of commercial vehicles, and 80% of two- and three-wheelers by 2030 (The Economic Times, 2021). The country has also committed internationally to the EV30@30 campaign, which will mean a 30% EV sales share by 2030 (Clean Energy Ministerial, n.d.). In order to meet this target, the country will need to significantly increase the production of Li-ion batteries to offset its growing reliance on imports.

The types of mineral resources used in Li-ion batteries vary by technology (Appendix A). However, lithium is crucial to maintain battery performance, longevity, and energy density, which is reflected in its use in nickel manganese cobalt oxide (NMC), lithium nickel cobalt aluminum oxides (NCAs), and lithium ferro phosphate (LFP), the dominant battery chemistries used in EV technologies (IEA, 2022a). Indeed, unlike cobalt, which can be substituted in the LFP battery chemistry, lithium is likely to remain a key battery ingredient for the foreseeable future (Castelvecchi, 2021). Most of the emerging battery technologies will continue to rely on lithium, such as solid-state batteries, where lithium will remain essential in the anode component (Singh, Ghate, Ningthoujam, Gupta, Sharma, et al., 2022). There are notable exceptions, such as the sodium-ion battery chemistry, which was commercially introduced in 2021 by Contemporary Amperex Technology Limited (CATL), a major Chinese battery manufacturer, but is yet to be widely deployed (IEA, 2022a).

Lithium used in batteries generally comes from two sources: brines in Latin America and hard rock (specifically spodumene), prominently in Australia. Australia's lithium is typically processed into lithium hydroxide, which is used in the NMC batteries but can be further processed to lithium carbonate. Lithium from brines in South America is more easily processed into lithium carbonate, which is more frequently used in LFP batteries. According to Benchmark Mineral Intelligence, hard-rock sources of lithium currently make up 60% of the global mined lithium supply and are forecast to continue to do so through to 2030 (Benchmark Minerals Intelligence, 2023a).

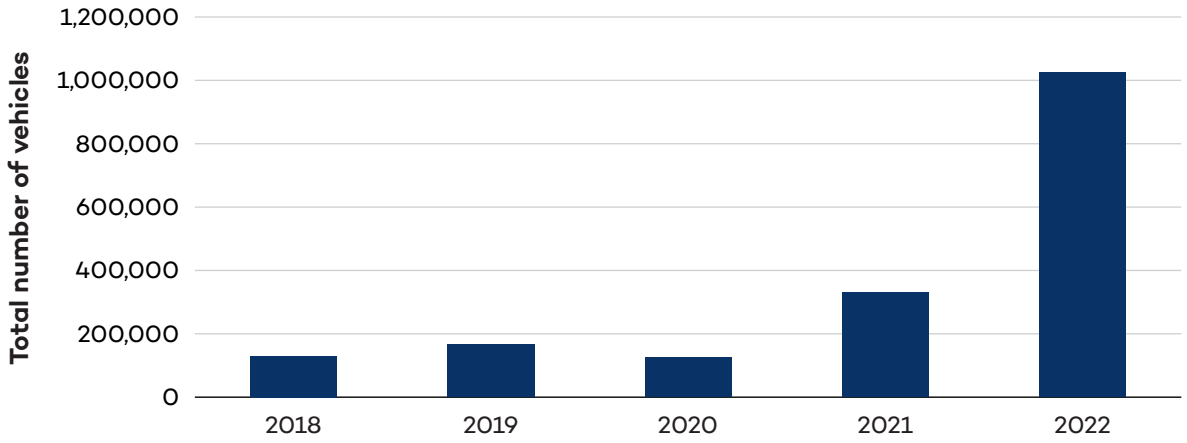
Although the LFP batteries that use lithium carbonate are less energy dense, they are considered cheaper and safer and can run more cycles than NMC batteries that use lithium hydroxide (Moerenhout & Jobet, 2023). Therefore, LFP batteries hold significant promise for India given their low cost and durability in higher temperatures. They can also cut the reliance on other critical minerals such as nickel and cobalt. Aside from brine and hard rock, lithium-clay sources are in various stages of development or exploration in Mexico and the United States (USGS, 2023).

Figure 4. Battery chemistries used in India for different vehicle segments in 2021



Source: Adapted from EY et al., 2022.

Figure 5. Annual battery EV sales in India from FY 2018 to FY 2022 (total number of vehicles)



Source: Vahan Dashboard, 2023.

India's union and state governments have launched several initiatives to promote EV adoption, including the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles scheme, which provides financial incentives for EV purchasers and manufacturers. The policy provides incentives targeted at promoting the adoption of two- and three-wheelers, buses, and commercial vehicles, which account for a significant proportion of the country's vehicle fleet. Furthermore, 26 states (out of a total of 28 states) have launched their own EV policies, which include both demand incentives and additional incentives for battery manufacturers to localize production (Climate Trends, 2023). The impact of these policies is being reflected in India's EV sales. Over the past year, the country's EV sales have grown over 200% from 331,000 in 2021 to over 1 million in 2022 (Figure 5), suggesting that there is a growing momentum in this sector, which could balloon India's import dependence on Li-ion batteries if left unchecked.

2.2 Stationary Energy Storage

One of the key applications of Li-ion batteries is stationary energy storage, which is essential for promoting grid flexibility and integrating intermittent renewable energy into the electricity grid. India has set a target of achieving 500 GW of non-fossil power capacity by 2030 (Government of India, 2022). The Central Electricity Authority has forecast that India will need to deploy battery ESS of 236 GWh capacity to meet its storage requirements by 2032 (PIB, 2023b). Achieving this target will require significant investments, with Li-ion batteries being one of the most promising storage technologies. Although there are several other ESS technologies, Li-ion batteries have reached an inflection point of becoming commercially viable for grid applications (India Smart Grid Forum, 2019). Sodium-ion batteries are now under development and can definitely add to India's stationary storage needs, given that they are heavier and have less energy density, making them less suitable for vehicles. That said, there will likely still be a reliance on existing Li-ion batteries.

Battery ESS will play an important role in several areas of the power grid, including behind-the-meter applications, distribution and transmission systems, and large-scale centralized renewable generation facilities (Singh, Ghate, Ningthoujam, Gupta, & Sharma, 2022). In 2022, the total amount of power from ESS that had been commissioned or under construction was around 85 MWh, with a pipeline of projects totalling 4.6 GWh, reflecting emerging momentum in this sector (Singh, Ghate, Ningthoujam, Gupta, & Sharma, 2022). Moving forward, India's storage requirements are likely to increase significantly since the Ministry of Power announced an Energy Storage Obligation in 2022, which recommends that stored renewable energy comprise 4% of total consumption by 2030 (Ministry of Power, 2022).

2.3 Non-Low-Carbon Technology Applications

Li-ion batteries are also extensively used for other applications like electronic devices. The mobile and electronics industry in India is fast growing and is likely to rely on high-performance batteries, such as Li-ion batteries, across a wide range of applications (Singh, Ghate, Ningthoujam, Gupta, & Sharma, 2022). A study by NITI Aayog and RMI concluded that "mobile phones, power banks, IT hardware, telecom devices, smart agriculture, defence electronics, and other portable devices all require high density and safe integrated batteries" (Singh, Ghate, Ningthoujam, Gupta, & Sharma, 2022, p. 23).

Lithium is also used in the lubricant, glass, and ceramics industries. In India, its current main use is in the pharmaceuticals, medicinal chemicals, and botanical products industry, which constitutes about 39% of its demand (Chadha et al., 2023).

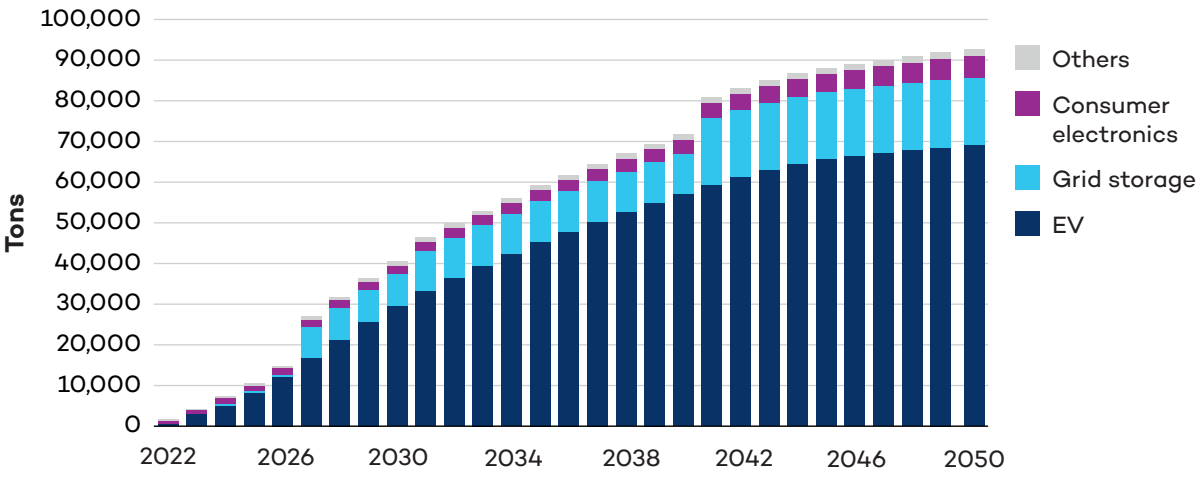
3.0 Forecasted Lithium Demand in India

This section provides an overview of the lithium demand estimates in India over a period from 2022 to 2050, focusing on various categories, including two-wheelers, three-wheelers, four-wheelers (passenger and commercial), buses, grid storage, freight, and others (behind-the-meter—residential and commercial, consumer electronics, and rail and defence). The estimates have been prepared under two scenarios: Accelerated Deployment of EVs and Grid Storage and Business as Usual. The methodology used to estimate the lithium demand across categories under the two scenarios (Accelerated Deployment and Business as Usual) is available in Appendix B, which details the steps followed in analyzing and forecasting India's lithium demand from 2022 to 2050. Appendix C also includes a breakdown of lithium demand among different EV segments (two-wheel, three-wheel, four-wheel, buses etc.).

3.1 Lithium Demand in India (Accelerated Deployment Scenario)

Figure 6 illustrates that EVs are the primary driver of lithium demand in this scenario. The share of EVs in total lithium demand increases significantly from 24% in 2022 to 69% in 2030. Additionally, the share of grid storage also experiences notable growth, rising from 0% in 2022 to 19% in 2030. The total annual lithium demand surges from 1,634 tons in 2022 to 40,499 tons in 2030.

Figure 6. Estimated annual lithium demand in India under the Accelerated Deployment scenario (in tons)



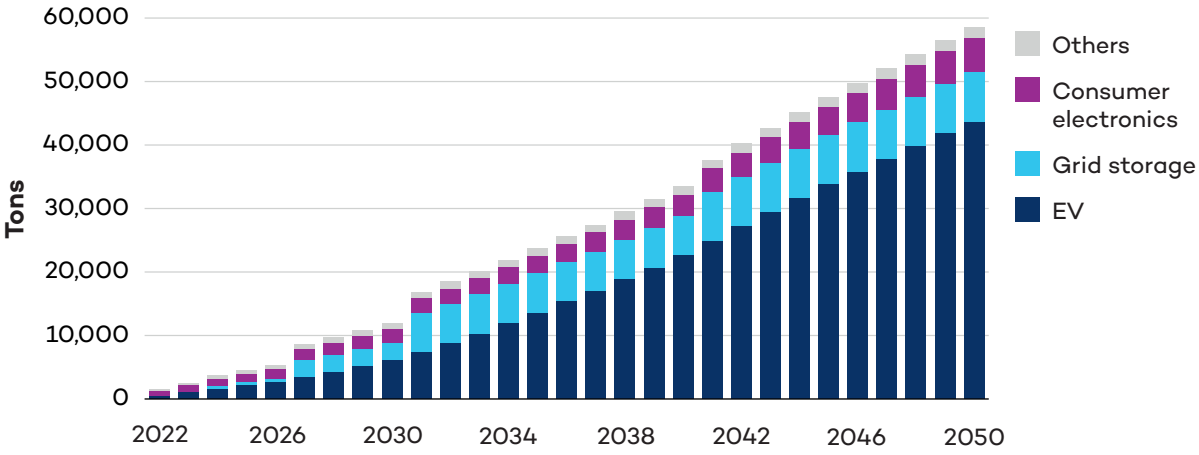
Source: Authors' forecasts.

3.2 Lithium Demand in India (Business-as-Usual Scenario)

Figure 7 presents lithium demand under the Business-as-Usual scenario. It also highlights that EVs will be the primary driver of lithium demand but with a lower share compared to the

Accelerated Deployment scenario. The share of EVs in total lithium demand increases from 24% in 2022 to 50% in 2030. Meanwhile, the share of grid storage also grows, reaching 22% in 2030. The total lithium demand rises from 1,634 tons in 2022 to 11,398 tons in 2030.

Figure 7. Estimated annual lithium demand in India under the Business-as-Usual scenario (in tons)



Source: Authors' forecasts.

3.3 Demand for Lithium in India (Across Sectors)

Table 1 presents the estimated lithium demand in India across different categories for the years 2022, 2025, 2030, 2040, and 2050 under both the Accelerated Deployment and Business-as-Usual scenarios. It provides a comprehensive overview of the lithium demand trajectory for each sector over time. Notably, the demand for lithium in the Business-as-Usual scenario for 2030 is approximately 30% of the lithium demand in the Accelerated scenario, highlighting the potentially large variance that policy-makers will need to consider. Additionally, the table shows that the demand for lithium in grid-level storage begins to accelerate after 2025 under both scenarios.

Table 1. Lithium demand across categories in India based on the two scenarios

Lithium demand (tons)	2022	2025	2030	2040	2050
Accelerated Deployment					
EV	391	8,075	29,473	57,034	68,976
Grid storage	4	479	7,800	9,920	16,576
Consumer electronics	929	1,399	2,181	3,440	5,427
Others	310	586	1,045	1,340	1,782
Total (in tons)	**1,634**	**10,538**	**40,499**	**71,734**	**92,760**

Lithium demand (tons)	2022	2025	2030	2040	2050
Business as usual					
EV	391	2,062	6,036	22,557	43,602
Grid storage	4	479	2,736	6,184	7,800
Consumer electronics	929	1,399	2,181	3,440	5,427
Others	310	586	1,045	1,340	1,782
Total (in tons)	**1,634**	**4,525**	**11,998**	**33,521**	**58,610**

Source: Authors' analysis (see Appendix B for detailed methodology).

We conclude, from our analysis, that overall lithium demand is likely to increase between 10 to 40 times from 2022 to 2030 based on its uses in end applications under the two scenarios, making it imperative for policy-makers to undertake urgent planning to secure lithium supplies through equity investments and offtake agreements in international producing mines. In the following decades (2030–2050), India can focus on joint exploration and recycling to become more prominent.

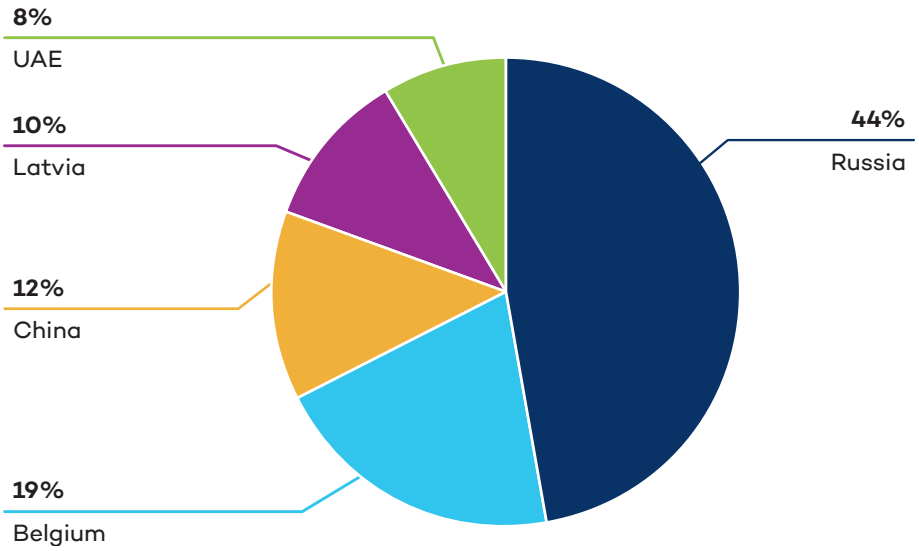
Among different sectors, EVs, particularly four-wheeled passenger cars, are expected to be the main driver of lithium demand in India over the next few decades, under both the Accelerated Deployment and Business-as-Usual scenarios. It is crucial for policy-makers and industry stakeholders to consider these estimates while planning for the sustainable growth of the Li-ion battery industry and ensuring sufficient supply to meet the rising demand.

4.0 India's Lithium Imports and Trade Partners

India's imported lithium compounds in 2021 amounted to USD 24 million for lithium oxide and hydroxide, and USD 9 million for lithium carbonates (UN Comtrade, n.d.). These figures are currently limited due to India's nascent progress in battery cathode manufacturing. However, to achieve the government's target of localizing the value chain by promoting domestic cathode and battery cell production, these import numbers are likely to increase in the coming years.

In 2021, India's primary import partners for lithium hydroxide were Russia (44%), Belgium (19%), China (12%), Latvia (10%), and the United Arab Emirates (UAE) (8%).

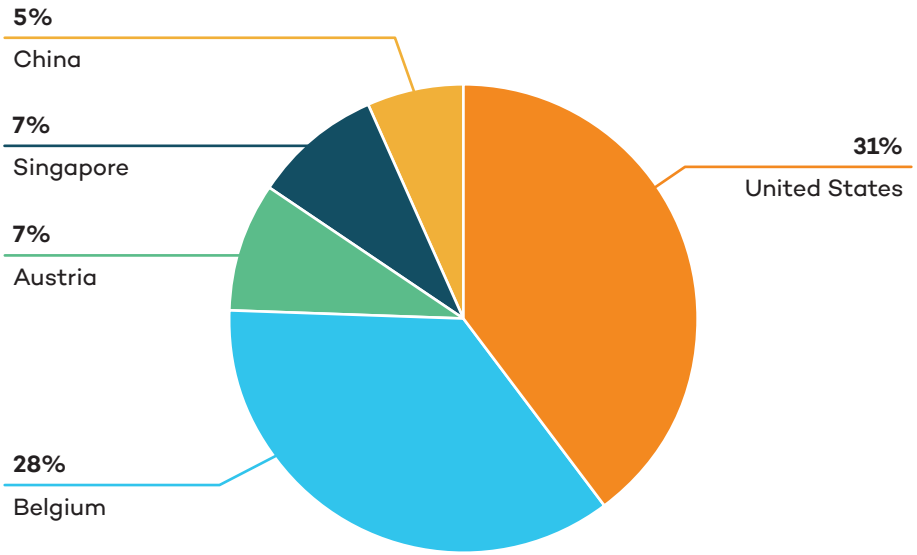
Figure 8. India's import partners for lithium hydroxide in 2021



Source: UN Comtrade database, UN Comtrade, n.d.

For lithium carbonate, the largest trading partners were the United States (31%), Belgium (28%), Austria (7%), Singapore (7%), and China (5%).

Figure 9. India's import partners for lithium carbonate in 2021



Source: UN Comtrade database, n.d.

India's current top trade partners for lithium do not align with the countries possessing the largest lithium reserves or production worldwide, with the exception of China and Russia. Indeed, Belgium, Latvia, Singapore, and the UAE are trading hubs with no substantial reserves. Aside from Russia and China, none of the current trading partners are among the top eight lithium-producing countries globally (USGS, 2023). Given India's focus on increasing its domestic manufacturing of battery components, it is imperative to diversify the supplier base and establish partnerships with mineral-rich nations. Moreover, a few of India's largest suppliers will need to follow mandates on domestic sourcing requirements for critical minerals supplied to their industries, such as under the EU's Critical Raw Materials Act (CRMA), so India might find its current supply options, like Belgium, constrained in the future (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2023).

India is actively developing new trade partnerships and free trade agreements to secure a stable supply of lithium. One example is the Australia–India Economic Cooperation and Trade Agreement, which has a section on critical minerals cooperation (Australian Government Department of Foreign Affairs and Trade, n.d.) Khanij Bidesh Limited (KABIL), a state-owned company with a mandate to source critical minerals for India, has also signed agreements with Argentinian state-owned enterprises (SOEs) Jemse, Camyen, and Yacimientos Petrolíferos Fiscales to explore sourcing lithium and other mineral assets in Argentina (Business Standard, 2022). Similarly, KABIL has signed a memorandum of understanding (MOU) with the Australian Department of Industry, Science, and Resources for joint investment in lithium assets (PIB, 2022). While these steps are positive, it is important to note that they do not guarantee supplies and necessitate the undertaking of specific operations, such as partnerships with international mining companies.

5.0 Strategies of Key Importing Countries

Rising geopolitical tensions and supply constraints have prompted countries lacking significant lithium reserves to swiftly devise policies that can establish resilient supply chains. It is crucial to highlight China's extensive efforts over the past two decades, which have afforded it a considerable advantage in the supply chain and pose a formidable challenge for other countries to diversify supply chains. This context must be considered when evaluating the policies and strategies adopted by other nations, as they are still in their nascent stages. Nonetheless, the United States, South Korea, Japan, and numerous European countries are actively taking measures to support their industries in gaining a foothold in the critical minerals supply chain.

5.1 China

The dominance of China in the lithium supply chain cannot be overstated. In 2021, the country accounted for 75% of Li-ion battery cell production, over 70% of cathodes, and more than 60% of lithium processing (IEA, 2022a). Although China contains sizeable lithium reserves, it is mainly dependent on raw lithium imports from Australia and Latin American countries, specifically Chile, Argentina, and Bolivia, because they are of a higher quality and lower cost. Over the past decade, China has exhibited a proactive and effective approach in securing a stable lithium supply from major supplier nations.

In terms of production, China directly secured approximately 40% of the 93,000 tons of raw lithium mined globally in 2021 (Katwala, 2022). Despite its lower share of global lithium reserves compared to other countries, China currently ranks as the third-largest producer of lithium, trailing behind Australia and Chile (USGS, 2023). Chinese companies have established a significant upstream presence in recent years through an extensive acquisition spree, acquiring stakes in mines worldwide. Tianqi Lithium owns stakes in Sociedad Química y Mineral (SQM), Chile's largest mining company, as well as Greenbushes, Australia, the world's largest lithium-producing mine (de la Jara, 2018; Kawase, 2020).

China's lithium sourcing strategy comprises three key elements, as highlighted below.

5.1.1 Foreign Direct Investment

Several Chinese companies have focused on gaining a foothold in the upstream segment of the EV battery supply chain by investing in lithium projects at home and abroad. In addition to mining companies such as Tianqi Lithium and Ganfeng Lithium, even battery and electric car makers have increased their investment in mining operations to secure their supply chains.

Chinese companies are trying to consolidate their market lead in EVs and other sectors of the energy transition through contracts and agreements with international mineral companies. In China, outbound direct investment increased to USD 3.5 billion, an increase of 33% on a yearly basis by value, mainly in the areas of lithium mining (Global Times, 2023).

More recently, a few mineral-rich nations are demonstrating a willingness to curb Chinese investment to reduce the country's dominance in the supply chain. Australia and Canada are united in this common objective, but they have differed in their strategy toward China. Canada adopted a more confrontational stance in 2022 by demanding that three Chinese companies immediately divest from junior mining companies in Canada for national security reasons (Cecco, 2022).

In contrast, Australia has taken a more cautious approach since Chinese companies have made significant mineral investments in Australia. China is also Australia's main trade partner and the primary destination for Australian exports of iron ore, lithium, and other commodities. Nevertheless, Australia's Critical Minerals Strategy consistently references the need for attracting investment from "like-minded partners," and Australian policy-makers are wary of Chinese investments in strategic sectors, leading to the recent blockage of a Chinese company's bid to increase its stakes in an Australian rare earth element miner (Needham, 2023).

Table 2. Lithium contracts undertaken by major Chinese companies in 2022–23

January 2022	In January 2022, the Chilean government awarded **BYD** a contract to extract 80,000 metric tons of lithium over the next 20 years. BYD, which is one of China's largest car companies, recently announced its intention to focus entirely on EVs (SMM, 2022). In January 2022, **Zijin Mining** Group completed its acquisition of Neo Lithium Corp. and took over the Tres Quebradas Lithium Project in Catamarca Province, Argentina, with a reserve of 1.67 million tons of lithium (Zijin Mining, n.d.-a).
April 2022	In April 2022, **Zhejiang Huayou Cobalt** acquired the Acadia lithium mine in Zimbabwe, with a plan to produce 50,000 tons of lithium carbonate-equivalent lithium concentrate (Huayou Cobalt, 2023).
May 2022	In May 2022, **Zijin Mining** bought a 15% stake in the Manono lithium-tin project in the Democratic Republic of the Congo (DRC). The Manono project is believed to contain one of the world's largest lithium-rich deposits capable of development through open-pit mining (Zijin Mining, 2022).
June 2022	In June 2022, **Jiangxi Ganfeng Lithium**, the largest Chinese lithium compounds producer, which already owns two major lithium assets in Argentina, moved to acquire Lithea Inc., which operates the Pozuelos and Pastos Grandes Lithium Project, a pre-development asset in Salta Province, Argentina (Ng, 2022).

5.1.2 Belt and Road Initiative

China's Belt and Road Initiative (BRI),[2] sometimes called the New Silk Road, is a highly ambitious infrastructure project plan. In the past decade, the program has expanded to

[2] The BRI aims to create a vast network of railways, energy pipelines, highways, and streamlined border crossings across the world. In addition to physical infrastructure, China has financed several "special economic zones" (or industrial zones) and encouraged countries to embrace its technology, such as the 5G network powered by Huawei.

Africa, Oceania, and Latin America, significantly expanding China's economic and political influence in these regions (McBride et al., 2023). China has used the BRI to launch new lithium, nickel, and cobalt mining projects, pursuing a joint investment model. There has been a growing tendency for Chinese electric car makers and mining companies to leverage existing BRI relationships with resource-rich countries to secure the upstream mining segment of the EV battery supply chain. This is highlighted by the strong growth in lithium investments in Argentina, Bolivia, and, to a certain extent, Chile, which are all members of the BRI (McBride et al., 2023).

Indeed, just after Chile joined the BRI in 2018, Tianqi Lithium Co. agreed to pay USD 4.1 billion for a 24% stake in SQM, Chile's largest lithium producer (de la Jara, 2018). In September 2019, Chile began marketing its lithium reserves to China in a "lithium investment tender," a program that aims to provide discounted lithium in exchange for a commitment to build battery-related production facilities in the country to develop Chile's local EV battery supply chain. Although the new Chilean lithium strategy is anticipated to have an impact in attracting new foreign players, China's commitment to investing in Chile was demonstrated through BYD's announcement of a new LFP cathode plant in 2023 that will be able to rely on premium-priced Chilean lithium carbonate. This demonstrates that Chinese–Chilean cooperation for new lithium extraction projects is not off the table since Chinese companies may be willing to incur more risk that goes alongside Chile's nationalization strategy (Jobet et al., 2023).

China's overseas development finance activities, as underpinned by its BRI strategy, have also contributed to its dominance of the critical mineral landscape. Between 2000 and 2017, China financed 690 projects related to mining (Lu et al., 2023). Asia and Africa received the highest number of financing activities, with Russia, Brazil, and Vietnam ranking as the top three countries in terms of funding received (AidData, 2021). Out of these projects, 69 were specifically allocated to the mining sector, while others supported infrastructure development.

The majority of financing was directed toward project development and construction, although some funding was allocated to activities like geological surveys, mineral exploration, joint research labs, and mineral testing laboratories. The country's Exim Bank issued the most loans, totalling 203, followed by China Development Bank (AidData, 2021).

5.1.3 Domestic Production

China launched the National Mineral Resources Plan to create a roadmap for the development of the country's "mineral resources exploration, utilisation, and protection" from 2016 to 2020 (IEA, n.d.-b, para. 1). The policy lists 24 strategic minerals, identifies four different types of minerals, and outlines strategic objectives for each classification:

- "to encourage exploration of minerals in short supply";
- "to regulate the amount of minerals with traditional advantages";
- "to cut production of minerals with excess capacity"; and
- "to ensure supply of minerals in strategic emerging industries." (para. 2)

Rising geopolitical tensions and localization policies being pursued by several resource-rich nations have reinforced China's commitment to domestic production. For example, in November 2022, the Canadian government ordered three Chinese investors to divest their minority holdings in publicly traded Canadian lithium mining companies (Shakil & Liu, 2022).

In recent years, the Chinese government has gradually shifted its strategic focus from overseas investment to domestic exploration. The National Security Strategy (2021–2025), launched by the Chinese government in 2021, proposes to shift the country's reliance on the imports of key mineral resources toward domestic resources.

In early 2023, Zijin Mining proposed in its annual report to pursue new opportunities for domestic exploration and to increase investment in China and neighbouring countries. This appears to be a continuation of its ongoing strategy following six domestic mining acquisitions in 2022 (Zijin Mining, n.d.-b).

Environmental, social, and governance (ESG) issues have affected Chinese raw lithium mine development. There have been concerns about unlicensed and environmentally damaging mining, which sparked government investigations and temporary closures of several ore-processing operations in Jiangxi province. "It has been reported that the investigations threaten up to 13% of global lithium supply," with a lack of clarity on how long these shutdowns will last (Office of the Chief Economist, Department of Industry, Science and Resources, 2023, p. 151).

5.2 The United States and the Mineral Security Partnership

The United States is actively prioritizing the development of lithium resources within its own borders, recognizing the significance of critical minerals like this. For example, its Department of Energy (DoE) has granted a substantial USD 700 million loan to ioneer Limited to develop lithium carbonate processing capacity, marking the first time the department has directly supported domestic lithium production (Johnson, 2023). Additionally, the DoE has provided loans to facilitate the advancement of direct lithium extraction technologies for potential application in the country (DoE, 2022). The Bipartisan Infrastructure Bill has also introduced incentives for comprehensive geological surveys to enhance the exploration of critical minerals throughout the United States (Bipartisan Infrastructure Law Investments, 2023).

In addition, the U.S. DoE shortlisted 12 lithium-based projects, funded with USD 1.6 billion from the 2022 U.S. Bipartisan Infrastructure Law, to support the development of new commercial-scale domestic facilities to extract and process lithium, manufacture battery components, recycle batteries, and develop new technologies to increase U.S. lithium reserves (USGS, 2023).

In terms of international frameworks, the United States is implementing measures to encourage the production of critical minerals in allied nations through the local content provisions outlined in the Inflation Reduction Act (IRA). To qualify for half of the USD 7,500 tax credit, countries with which the United States has free trade agreements must extract,

process, and/or recycle at least 40% of critical minerals domestically in 2023, with increasing targets of 50% in 2024, 60% in 2025, 70% in 2026, and 80% from 2027 to 2032 (Minott & Nguyen, 2023). This incentivizes critical mineral production and processing in allied states, ensuring that cathodes and cells used in the United States are sourced from these nations. Prior to the IRA, the United States had already taken steps to promote exploration, mining, and processing projects in Canada by opening up the Defense Production Act.

Furthermore, the United States has played a key role in establishing international partnerships aimed at improving access to critical minerals. The Minerals Security Partnership (MSP) originally brought together countries such as Australia, Canada, Finland, France, Germany, Italy, Japan, South Korea, Sweden, the United Kingdom, the United States, and the European Union to strengthen critical mineral supply chains. India became the newest member of the MSP on June 22, 2023, thereby becoming the only emerging economy in the partnership (The White House, 2023). Member countries are joined through the shared objectives of diversifying supply chains and demonstrating commitment to combating climate change while upholding high ESG standards in mineral extraction.

The primary objective of the MSP is to employ government funds to support and enhance supply chain diversification. The partnership considers offering loan guarantees or debt financing for critical mineral projects, which can be located in any country, not exclusively MSP member nations (Holzman, 2022). However, projects must adhere to the MSP's established ESG and mining principles for consideration. Jose Fernandez, the American Undersecretary of State for Economic Growth, Energy, and the Environment, emphasized the importance of ESG standards, stating that they are fundamental to partners' objectives and aim to avoid a "race to the bottom" by promoting a "race to the top" (Northey, 2023).

The partnership focuses on projects across the entire value chain, encompassing mining, processing, and recycling. The MSP's primary focus is on projects already in development that require support rather than greenfield projects. After evaluating over 170 projects worldwide, the partnership is currently directing its attention to 16 projects, with the expectation of announcing several by the end of 2023 (Northey, 2023). These selected projects will not only receive financial support but also benefit from the strong backing of the MSP, which will help mitigate risks and enable member countries to advocate for reforms and policies that strengthen the critical mineral supply chain. The partnership remains open to various support mechanisms, including technical guidance, loans, financing through institutions like the U.S.'s International Development Finance Corp. or export credit agencies, and political risk insurance. There is a lack of clarity on whether MSP member states will be eligible for the entire offtake from MSP-financed projects and on the potential division of supplies among its members.

Potential benefits of India's MSP membership could include new flows of investment into India's critical mineral industry. They could also include cooperation on research and development and information sharing among partners. And Indian overseas mineral investments could conceivably benefit from participating in MSP-pooled financing in strategic projects that have been strongly vetted.

More broadly, India's partnership in the MSP signals its willingness to align with the United States and its allies, and the willingness of that political bloc to partner with India. Such an alignment will provide India with an important network of global allies in the increasingly geopolitical landscape of critical minerals. This may prove essential moving forward, as India will have access to a broader pool of technical, financial, market, and scientific resources. However, the MSP partnership will also come with strings attached. Most notably, the MSP is very much a principle-oriented partnership, and it is likely to be expected that India abide by the MSP Principles by gradually aligning with the ESG-oriented approach of current MSP partners.

5.3 Germany and the EU

India can draw valuable insights from Germany given its status as a prominent manufacturing and automobile hub striving to reduce its reliance on imports from China. As an active member of the EU and the MSP, Germany is relying on strategic alliances to fortify its lithium supply chain. The government, led by Chancellor Olaf Scholz, is trying to expand partnerships with Australia and Canada to secure essential minerals. Scholz personally visited the "Lithium Triangle" to engage with Latin American leaders and promote German investment in new lithium projects (MacDonald, 2023). Additionally, Scholz is advocating for the EU-Mercosur trade agreement to strengthen ties between Europe and South America (Gonzalez, 2023).

Aside from Germany's direct initiatives, the EU has proposed the CRMA to help boost supplies of critical minerals, including lithium, and reduce dependency on nations, such as China (Office of the Chief Economist, Department of Industry, Science and Resources, 2023). Draft legislation released in March 2023 suggests that the EU aims to set up a central purchasing agency for critical materials and intends to encourage member states to speed up approval processes for new mines and processing plants (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2023). The CRMA introduces explicit domestic targets for critical mineral extraction (10%), processing (40%), and recycling (15%) by 2030 as a percentage of the EU's annual critical mineral consumption (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2023). The CRMA also sets out a target for the EU to not rely on a single country for any more than 65% of imports for any single mineral. Unlike the IRA, the CRMA has not yet tied its domestic targets to any explicit tax credits or similar incentives. It may struggle to shift supply chains in the absence of incentives to meet the legislation's targets. However, it increases the likelihood that upcoming lithium projects within the EU, such as in Finland, will be mainly used to cater to demand from Germany and other European nations.

There are two notable policy measures on the horizon that present potential options for India and warrant further examination from its policy-makers:

1. Germany is in the process of establishing a state fund of approximately USD 2.2 billion dedicated to supporting domestic and international mining of minerals crucial for the green energy transition (Kowalcze & Nienaber, 2023). Reports suggest that this fund is slated to commence operations in 2024. This initiative exemplifies countries' efforts to create novel mechanisms that enhance supply chains and foster domestic manufacturing.

2. Chancellor Scholz envisions Germany assisting mineral-rich nations in building processing infrastructure for domestic mineral processing, thus reducing their dependence on China for such activities (Reuters, 2023a). This proactive step represents another endeavour to mitigate Germany's overreliance on China. Moreover, this move allows Germany to forge robust partnerships with resource-rich countries, effectively securing minerals for domestic production.

These policy measures showcase Germany's commitment to strengthening its mineral supply chain and reducing dependence on external sources. India can consider these examples as it explores its own strategies for enhancing its supply chain resilience and promoting domestic manufacturing capabilities.

5.4 Japan and South Korea

Japan and South Korea have effectively utilized state-owned institutions to bolster their overseas exploration and production of critical minerals. The Japan Organization for Metals and Energy Security (JOGMEC) and the Korea Mine Rehabilitation and Mineral Resources Corp. (KOMIR) have partnered with private companies to enhance domestic mineral security. JOGMEC and KOMIR offer various forms of support, including direct investments, equity financing, and loan guarantees. Importantly, both institutions collaborate with private companies on these projects rather than leading them outright. Their involvement lies in fostering relationships between mining companies and private entities, without being purely state directed or state financed (Vekasi, 2022). These institutions exemplify the potential of leveraging state-run industrial policy to ensure mineral security and support domestic production.

5.4.1 Japan

JOGMEC has achieved notable success in diversifying Japan's reliance on Chinese rare earth minerals. Following a diplomatic incident in 2010 when China imposed an export ban on rare earths to Japan, the country embarked on reducing its dependence on Chinese rare earths over the next decade (Bradsher, 2010). In 2010, Chinese rare earths accounted for approximately 90% of Japan's imports, which decreased to 58% by 2020 (Hui, 2021). JOGMEC's investments in overseas projects played a crucial role in driving this reduction.

The organization's budget encompasses financing for exploration, asset acquisition investments, exploration loans, and debt guarantees (IEA, 2022b). For instance, JOGMEC established a decade-long partnership with the Australian-based company Lynas Rare Earths. Starting with a USD 200 million investment in 2011, JOGMEC has provided financial support to Lynas, enabling them to expand production. Additionally, JOGMEC has restructured Lynas' debt on two occasions to ensure the company's fiscal stability (Hui, 2021). In March 2023, JOGMEC offered Lynas USD 134 million in funding in exchange for a 65% feedstock share from their Mount Weld project (Iannucci, 2023). In the realm of lithium, JOGMEC is assisting Japanese companies, like Toyota, in accessing this critical mineral (Argus Media, 2018).

5.4.2 South Korea

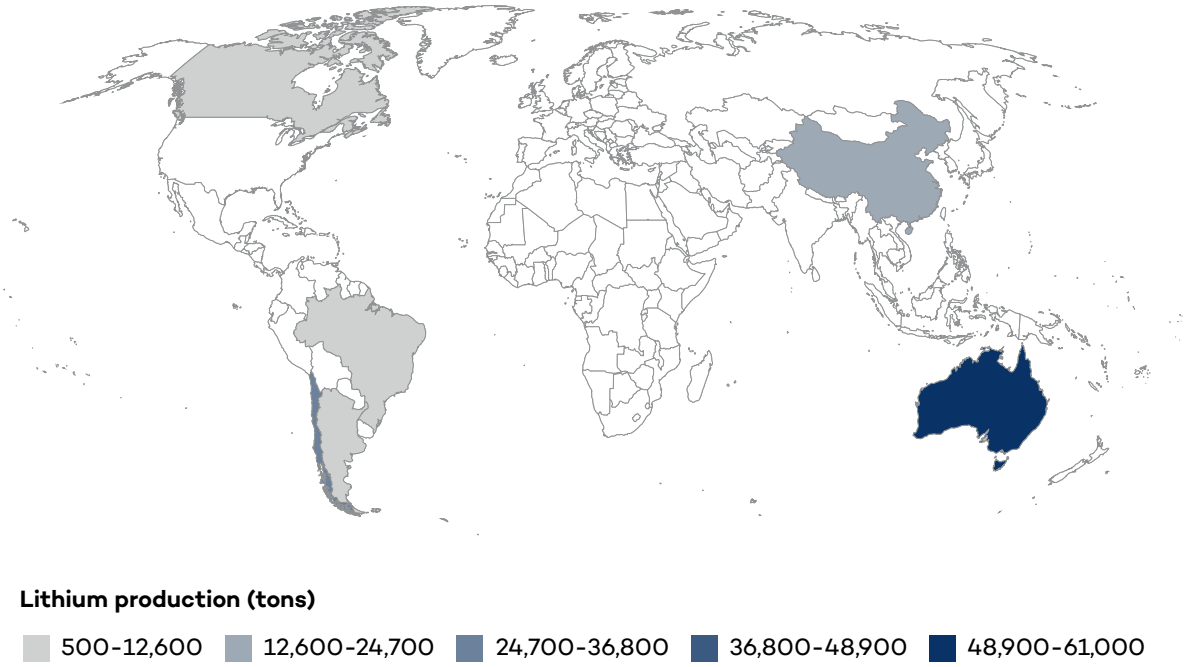
KOMIR, on the other hand, focuses its overseas investments primarily on initial mining project exploration. Between 2009 and 2022, 70% of KOMIR's overseas projects were exploration-oriented, as they can fund "up to 80% of overseas research projects by resource development companies" (Vekasi, 2022, p. 28). Like Japan and other Western nations, South Korea employs KOMIR to reduce its dependence on China for critical minerals. Notably, KOMIR holds an approximately 77% ownership interest in a copper mine in Mexico and, through a Korean consortium, a 45% interest in a nickel mine in Madagascar (KOMIR, n.d.). KOMIR continues to collaborate with Korean companies, such as LG Chem, offering diplomatic support in their efforts to secure lithium. Indeed, POSCO Holdings recently announced the construction of the country's first lithium hydroxide plant in South Korea, with brine sourced from Argentina (Green Car Congress, n.d.).

The success of JOGMEC and KOMIR underscores the importance of state-backed initiatives in facilitating the exploration, production, and acquisition of critical minerals, thereby supporting domestic mineral security. These examples can serve as valuable lessons for India in seeking to bolster critical mineral supply chains and reducing its dependency on external sources. The strategy of using SOEs to secure minerals is contingent on these companies being run professionally and provided sufficient resources to succeed. In addition, public sector undertakings (PSUs) like KABIL need to work with the private sector to guarantee successful offtake of acquired lithium.

6.0 Global Supply of Lithium

The extraction of critical minerals is heavily geographically concentrated. The top three lithium-producing countries control more than 90% of the world's production (USGS, 2023). This creates supply vulnerabilities in cases of disruption and limits diversification opportunities for importing countries.

Figure 10. Geographical distribution of estimated lithium production globally in 2022 (tons)



Source: USGS, 2023.

Lithium resources totalling 98 million tons have been discovered globally, but resource-rich countries have varying extraction capacities. These resources are highly concentrated in South America, especially in Bolivia (21 million tons—of largely untapped resources), Argentina (19 million tons), and Chile (11 million tons); their dominant position makes them known as South America's "Lithium Triangle." As of early 2023, over 80% of lithium production flows from 17 mineral operations of varying capacities: six in Australia, two in Argentina, two in Chile, and five in China (U.S. Geological Survey, 2023).

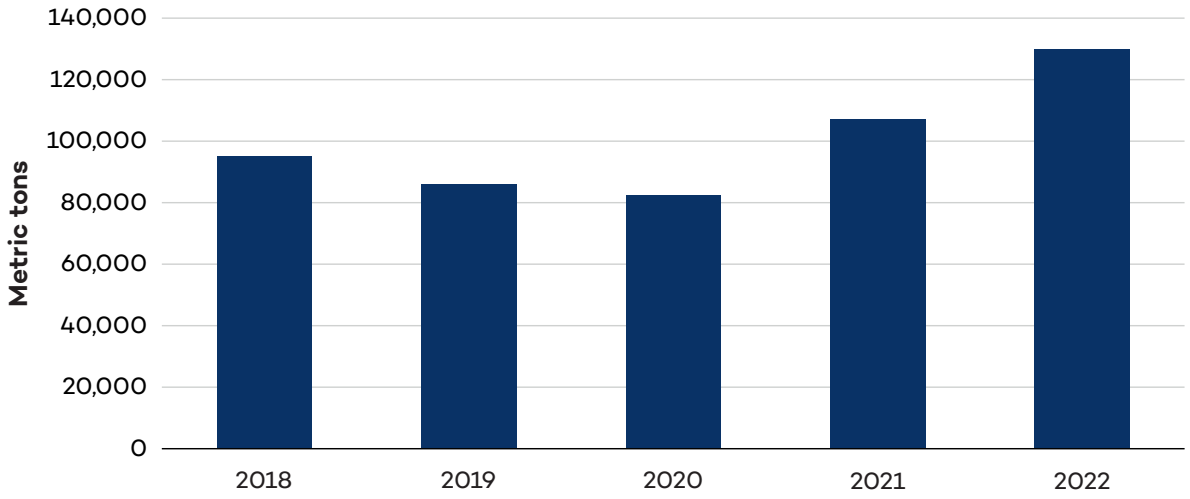
Table 3. Reserves and production of the four largest lithium-producing countries

Country	Lithium reserves (million tons)	Estimated lithium production (tons), 2021	Estimated lithium production (tons), 2022
Australia	6.2	55,300	61,000
Chile	9.3	28,300	39,000
China	2	14,000	19,000
Argentina	2.7	5,970	6,200

Source: USGS, 2023.

The production of lithium has increased significantly over the past 5 years, rising from 95,000 metric tons in 2018 to 130,000 tons in 2022 (Figure 11). In contrast, global lithium demand has almost doubled from 2017 to 80 kt in 2021, of which demand for EV batteries accounts for 47%, up from 36% in 2020 (IEA, 2022a).

Figure 11. Global lithium production (2018–2022) (metric tons)



Source: USGS, 2023.

Processing

The majority of lithium-processing capacity (around 60%) is found in China (IEA, 2022a). Around 29% and 10% of processing is taking place in Chile and Argentina, respectively, where lithium from brines is directly processed into lithium carbonate within the country (IEA, 2021). The EU and the United States have very little lithium refining capacity (IEA, 2022a).

Similarly, Australia processes very little, despite being the largest producer of lithium worldwide. Australia's 2022 Critical Minerals Strategy is now targeting the expansion of downstream processing (Department of Industry, 2023). Toward 2032, China will maintain its dominant ownership of lithium chemical production. While the United States and Australia

will grow the most percentage-wise, China will more than triple its current capacity and retain far more than half of lithium processing by the end of the decade (Benchmark Minerals Intelligence, 2023b). Data suggests that most of the planned projects are still being developed in incumbent regions, with nearly 49% of planned lithium refining facilities in China, followed by 16% in Argentina and 11% in Australia (IEA, 2023a)

Figure 12. Geographical distribution of lithium processing (by country)

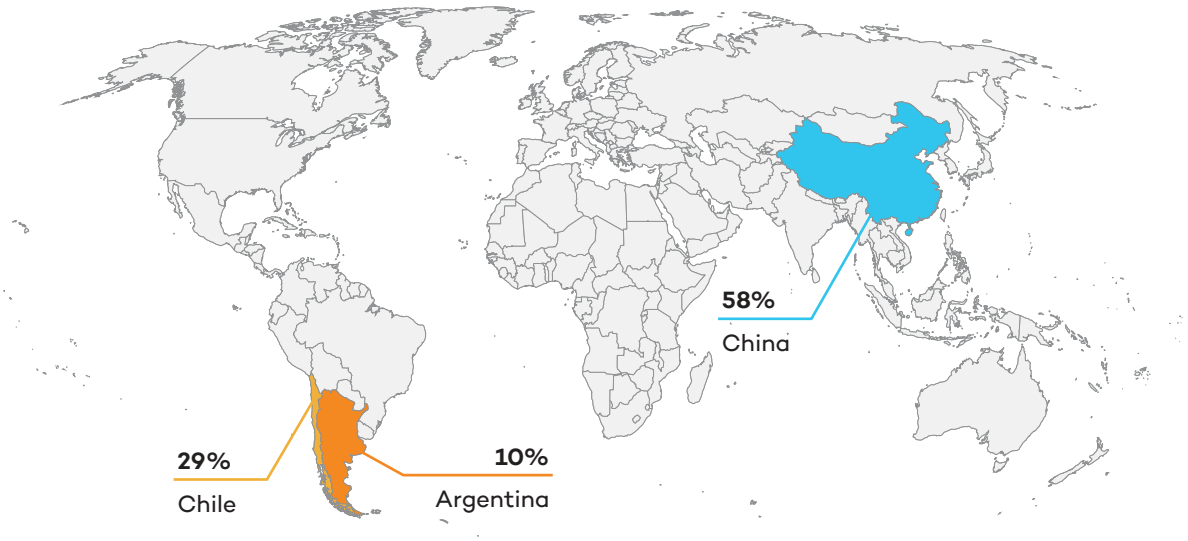


Table 4. Global share of lithium processing (by country).

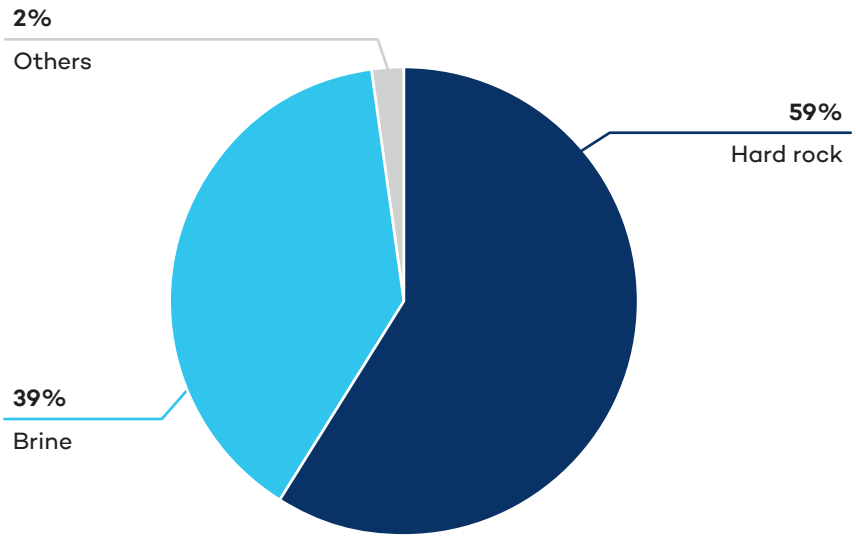
Country	Lithium processing (% of world total)
China	58
Chile	29
Argentina	10

Source: IEA, 2021.

6.1 Key Resource-Rich Nations

The main extraction types of lithium are brine-based in Argentina, Chile, and China; mineral-based (or "hard rock mining") in Australia, Brazil, China, the DRC, and several African countries; and lithium-clay sources, which are in various stages of development or exploration in Mexico and the U.S. (U.S. Geological Survey, 2023). "Lithium brines are concentrated salt water containing high lithium contents and are typically located in the high elevation areas of Bolivia, Argentina and Chile in South America with Chile being the largest producer" (IEA, 2022a, p. 21). In contrast, lithium hard rock (or spodumene) is found mainly in Australia, Europe, and Africa.

Figure 13. Share of lithium production from different ores in 2023



Source: Adapted from Benchmark Minerals Intelligence, 2023a.

The next section will focus on the four countries—Australia, Chile, Argentina, and Bolivia—that represent the most promising sourcing opportunities for India based on these countries' scale of reserves, current levels of production, and existing trade and investment agreements with India. The section will also highlight risks (political, environmental, and social) in each country that could affect direct investments or offtake agreements by Indian state and private companies. This list should not preclude India from assessing other lithium development opportunities, such as in Canada and Africa.

6.1.1 Australia

Australia is the largest global producer of lithium, accounting for about half of the total world production in 2022, despite only containing the world's second-largest lithium reserves, reflecting the expertise gained in its long-standing mining industry (USGS, 2023). Australia's lithium production is forecast to grow from 333,000 tons of lithium carbonate equivalent in 2021–22 to 661,000 tons by 2027–28 (Office of the Chief Economist, Department of Industry, Science and Resources, 2023).

India's growing geopolitical alignment with Australia, as reflected in their joint membership in the MSP and Quadrilateral Security Dialogue (or Quad), makes Australia a priority country for lithium sourcing. The two countries have also signed the India-Australia Economic Cooperation and Trade Agreement, with a section on critical minerals, reflecting the growing commercial ties between the two countries (Ministry of Commerce and Industry, n.d.). This section notably includes eliminating tariffs for a range of important minerals, which is likely to facilitate increased Indian imports of Australian critical minerals. It will also further incentivize Indian investments in Australian critical mineral projects, as offtake agreements will grow more lucrative with lower tariffs (Australian Government Department of Foreign Affairs and Trade, n.d.).

Greenbushes, in the state of Western Australia, is the world's largest hard-rock lithium mine, contributing 22% of the global lithium market (IGO, 2022). It is owned and operated by Talison Lithium, a private company owned by joint venture (JV) partners Tianqi Lithium Corporation/IGO Limited JV (51%) and Albemarle Corporation (49%), an American mining company and the largest lithium producer worldwide (Talison Lithium, n.d.). There are four other operational hard-rock mines in the legacy mining region of Western Australia (Kurmelovs, 2022). Two other mines are currently in the planning stage, with additional mine proposals at various stages of development (Kurmelovs, 2022).

Australia is also looking to promote domestic value addition and reduce its dependence on China by gaining a foothold in lithium refining, such as through the AUD 1.3 billion Modern Manufacturing Initiative, which aims to invest in domestic recycling and clean energy projects (IEA, 2023b). Australia's Federal Resources Minister, Madeleine King, also reiterated the country's focus on critical minerals extraction and refining by stating, "The focus on the extraction and refining of critical minerals needs to become, I think, something of a national mission, akin to the foundation of our iron ore industry in the 1950s and our LNG export industry in the 1990s" (Parker, 2022, para. 12).

Australia's first refined lithium was produced in the form of lithium hydroxide from the Kwinana plant in May 2022. The plant is owned by a JV between Tianqi Lithium (51%) and IGO (49%), again reflecting the difficulty in reducing dependence on Chinese companies in the supply chain. There is another refining facility under construction, the Kemerton lithium hydroxide processing facility plant, which is a JV between Albemarle Corporation (60%) and Mineral Resources (40%) (Parker, 2022). However, the Australian refining sector faces challenges, including significant construction delays, cost overruns, and labour shortages, which could dampen the sector's growth (Alyabyev et al., 2023).

Australia's strategic plan seeks to position it as an ESG leader. One of the six focus areas in Australia's 2023–2030 Critical Minerals Strategy is "Promoting Australia as a World Leader in ESG Performance" (Department of Industry, Science and Resources, 2023, Section 4). Australian critical mineral projects generally require strong ESG credentials to receive a social licence to operate, meet regulatory standards, and attract investment. The emphasis on ESG has strategic value for the country. By further strengthening its ESG performance and promoting the role of ESG in directing capital and trade flows, Australia stands to gain various benefits. These include receiving price premiums for its minerals, preferential market access to downstream markets, and higher levels of international investment. As the global ESG movement accelerates, Australia has a vested interest in ensuring ESG continues to gain traction, which can benefit its domestic economy from the resulting market changes.

Key Concerns

The greenhouse gas (GHG) emissions intensity for lithium chemicals derived from hard-rock sources in Australia is three times higher than that of brine-based production found in Latin American countries, as it involves a much more energy-intensive process linked to the crushing of the ore (Benchmark Minerals Intelligence, 2023a). These adverse climate impacts must be mitigated by switching to renewable energy in the extraction and processing value chain. In addition, the processing of hard-rock lithium is more water-intensive than that of

brine-based sources, based on a life-cycle assessment analysis, which could create community opposition over competing uses (Benchmark Minerals Intelligence, 2023a). Aside from total water withdrawal extraction, the environment where the extraction occurs also matters. For example, a small withdrawal in a salt flat could have an adverse impact. Also, water from a brine processing facility cannot be recovered once evaporated, unlike water from hard rock, which can potentially be recycled.

Hard-rock mining in Australia has not experienced the same level of community opposition as brine operations in Latin America, but an application to construct a tailings storage cell to serve a refinery was withdrawn, following 200 protest submissions from neighbouring farming communities (Loney, 2019). The rights of Indigenous communities need to be properly considered in the mining process. The destruction of 46,000-year-old shelters by the Rio Tinto Group when engaged in expanding an iron ore mine led to the state of Western Australia amending its Aboriginal Cultural Heritage Act 1972 (Wahlquist, 2020). However, the amendments were criticized by civil society groups as being unduly favourable to mining companies.

6.1.2 Chile

In 2016, Chile was the largest producer of lithium in the world, but Australia has surpassed it in recent years. In 2018, Tianqi Lithium became the second-largest shareholder in SQM, Chile's largest lithium miner (de la Jara, 2018). Similarly to Australia, Chile is also looking at capturing more value addition by moving downstream in the battery value chain. China's BYD, the world's largest EV manufacturer, was planning to build a USD 290 million lithium cathode factory in the country, according to Chilean economic development agency CORFO (Reuters, 2023b).

The country's lithium production is concentrated in two companies, SQM and Albemarle, in mainly one region: salt flats in the Atacama desert, with a need to diversify supply sources (Chile has identified 18 salt flats where lithium could be produced). It also needs to attract more companies to deploy investment and technology to increase production in a sustainable manner (Moerenhout & Jobet, 2023).

In Chile, lithium is designated as a strategic resource based on an act passed in the 1970s (Vásquez, 2023). This has resulted in lithium being tightly regulated in Chile, with its development reserved for the state or private companies that get a special permit from the government. This makes it imperative for the Indian government to play a more active role in supporting state-owned companies in pursuing partnerships for lithium development in Chile.

On April 20, 2023, the Chilean government announced its new National Lithium Strategy (Government of Chile, n.d.), with the announcement that public–private partnerships between a new state-owned lithium company and private investors were mandatory for future lithium projects in the country, with the state exercising a majority control in new projects. President Gabriel Boric's announcement mentioned that existing contracts with SQM and Albemarle will not be terminated, but the state will aim to take a stake in these contracts. SQM's contract expires in 2030, and Albemarle's expires in 2043 (Juricic, 2023).

Lithium producers in Chile pay royalties ranging from 6.8% to 40% of the lithium export price, which is considered steep compared to the royalty structure in Argentina (Vásquez, 2023). They also contribute to local community projects, with Albemarle, providing 3.5% of its revenue to nearby Indigenous communities, and SQM transferring 1.7% of its revenue to local communities, in addition to other contributions (Vásquez, 2023).

Key Concerns

There has been a significant debate within the country on the environmental and community aspects of mining, which has resulted in a growing political opposition to the industry. The main concerns include the following.

Socio-Environmental Concerns

Indigenous communities have previously blocked mines in Chile's Atacama Desert, protesting social inequality and environmental degradation. There are also concerns over water stress in the region, but a study found that lithium mining accounted for less than 10% of freshwater usage and its brine extraction does not correlate with changes in either surface-water features or basin-water storage in the region (Moran et al., 2022). That said, past mining activities, like copper mining, are indeed water intensive and have contributed to tensions between local communities and mining companies, leading many Chilean copper companies to now invest in desalinization capacity.

Lithium Cartel

President Boric has also proposed the creation of a lithium cartel, similar to the Organization of the Petroleum Exporting Countries (OPEC), and has strengthened relations with Argentine president Alberto Hernandez and Bolivian president Luis Arce. Mineral-rich nations see an opportunity to follow OPEC's approach and dominance of the oil market, using production, pricing, and trade coordination to achieve a favourable long-term price environment.

Despite a series of trilateral meetings between Chile, Argentina, and Bolivia, the formation of a lithium OPEC would require the support of regional provinces, which are presently not aligned with the national governments' positions on nationalization. Nonetheless, critical mineral producers may still attempt to form cartels in the future, which are likely to lead to market disturbances, given the tightness of the lithium market.

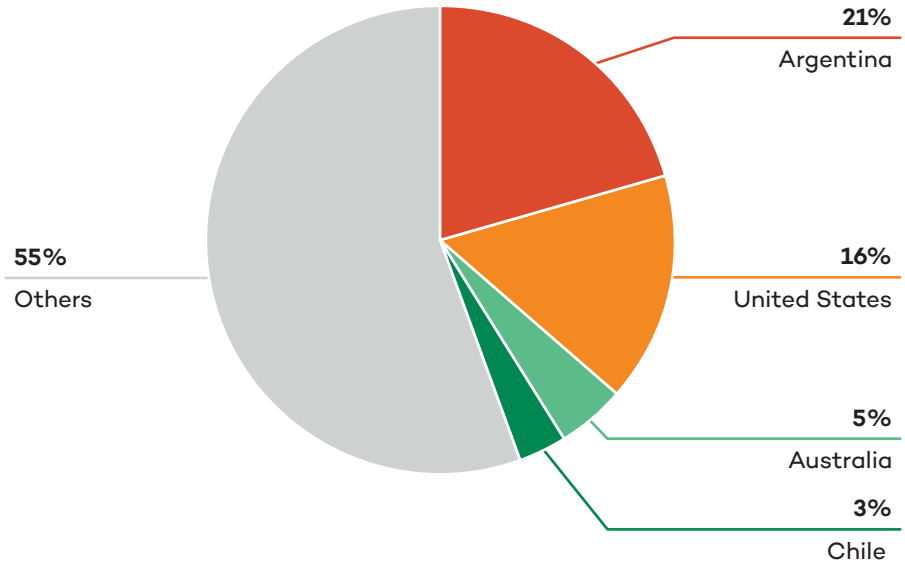
6.1.3 Argentina

Argentina is another significant lithium-exporting nation, and had more lithium projects in the pipeline than any other country in the world in 2022 (Li & Gilbert, 2022). Its openness to private investors and the "pro-market" model have marked it in stark contrast to its neighbours like Chile and Bolivia, where state control over the sector is much more pronounced (Sigal, 2023).

This is partly a consequence of the lithium-mining sector falling under a 1993 law passed by the country's then-market-friendly government, which encouraged mining investments through tax incentives and low royalties (Vásquez, 2023). This favourable regulatory environment and tax structure have been key for attracting lithium investment, with additional

incentives offered, such as a relaxation of foreign exchange controls; a 30-year guarantee of tax stability; a fixed 3% royalty rate; and mineral concessions granted for an unlimited period of time (Vásquez, 2023).

Figure 14. New lithium-mining projects around the world (in the pipeline)



Source: Adapted from Li and Gilbert, 2022.

Key Concerns

The main concern over lithium mining in the country is its poor macro-economic fundamentals. However, the lithium industry has remained insulated from the country's economic upheavals so far due to a political consensus between national and provincial governments on the economic importance of developing its lithium reserves (Vásquez, 2023).

Recurring financial crises in Argentina have led to runaway inflation and its currency, the peso, to lose two thirds of its value since 2018, affecting overall economic prospects for the country. Given the long time frame to start a lithium mine, this macro-economic instability should be a key consideration for Indian investors, who must explore the use of currency-hedging instruments.

6.1.4 Bolivia

Lithium-development contracts in Bolivia, the country with the largest untapped resources, have been highly contested and coveted by international companies. However, tight government control, grassroots opposition, and lack of infrastructure have posed hurdles in the past in attracting investment into lithium mining. The cost of lithium extraction is higher in Bolivia, as the country's lithium deposits are usually mixed with other minerals, such as magnesium, and are located at a lower altitude and more humid area than salt flats in Argentina and Chile, requiring more time to evaporate (Sanders, 2022).

In 2018, Bolivia relaxed restrictions to permit private investment, with its state-owned company forming a JV with a German firm (Nienaber, 2020). The German government made considerable diplomatic efforts to secure this partnership, recognizing its potential significance. However, due to vehement protests from local communities, the Bolivian government ultimately overturned the agreement, resulting in the German firm's exclusion from the lithium project (Deutsche Welle, 2019). Experts suggest there were other concerns, such as Germany's stringent ESG requirements and Bolivia's demand for domestic value addition.

In June 2023, Bolivia signed lithium agreements with the Russian state nuclear firm Rosatom and China's Citic Guoan Group to build new lithium carbonate processing plants (Ramos, 2023). This follows a similar agreement in January 2023 with CATL reflecting a potential shift in the country's position on exploiting its lithium reserves. Bolivia has also permitted the construction of two direct lithium extraction (DLE) processing plants with a planned capacity of 45,000 tons of lithium carbonate per year. DLE technologies aim to tackle the environmental and techno–economic shortcomings of current practices in extracting lithium by avoiding brine evaporation from ponds, but their commercial viability is yet to be proven (Vera et al., 2023).

7.0 Strategies Adopted by Companies to Secure Lithium

The largest lithium-producing companies include the following (Kumar, 2023):

- Albemarle (United States): Major clients include Tesla and Panasonic;
- Sociedad Química y Minera de Chile (Chile): Major clients include LG Energy Solution and SK Innovation;
- Tianqi Lithium (China): Major clients include CATL;
- Ganfeng Lithium (China): Major clients include Tesla, LG Chem, Samsung, and Volkswagen;
- Mineral Resources Ltd. (Australia): Major clients include Panasonic and Samsung;
- Allkem Limited (Argentina): Major clients include Toyota;
- Livent Corporation (United States): Major clients include Tesla and General Motors;
- Lithium Americas (Canada): Major clients include General Motors;
- Global Lithium (Australia): Major clients include SK Innovation; and
- Lake Resources (Australia): Major clients include SK Innovation.

Today, key projects in upstream production and processing of lithium are often JVs between lithium mining and chemical companies. For example, many Chinese companies have started acquiring lithium mining rights in Latin America and Africa (Go, 2022). Tianqi Lithium owns a 26% share in Greenbushes Australia and 22% in SQM's operations in Chile. Ganfeng Lithium has several stakes in projects in Argentina, the U.S., Mexico, and Australia. CATL and Huayou Cobalt have stakes in projects in the DRC, and Sinomine has stakes in lithium projects in Canada and Zimbabwe (Mehdi & Moerenhout, 2023).

Chinese companies are not the only ones investing in overseas projects. For example, Mineral Resources partnered with Albemarle to build a hydroxide-processing facility in Australia. Albemarle holds a 49% stake in Talison Lithium in Australia; Wesfarmers partnered with SQM to build a hydroxide-processing facility in Australia (Buckley & Pollard, 2022), and Mineral Resources has JVs with Ganfeng Lithium and Albemarle (Kumar, 2023). In a sign to create market power, Livent and Allkem have recently announced their merger to create a USD 10.6 billion lithium producer, making the new company the fifth-largest lithium producer (Benchmark Minerals Intelligence, 2023c).

Besides JVs, several original equipment manufacturers (OEMs) are also taking stakes directly into lithium projects by means of offtake agreements or immediate equity participation. BYD, Volkswagen, Mercedes-Benz, Stellantis, General Motors, Ford, and others are moving aggressively on vertical integration and offtake agreements to "de-risk" upstream investments and production (Evans & Ker, 2023). One of the most notable examples is General Motors's recent announcement of a USD 650 million investment in a U.S. lithium mine to secure offtake (Bushey & Dempsey, 2023).

7.1 Supply Challenges and OEM Strategies

The scarcity of lithium reserves, coupled with the growing demand for EVs, has compelled OEMs and battery manufacturers to pursue upstream strategies in securing adequate supply. In the next decade, it will be challenging for a company to establish a foothold in the battery and EV market without ensuring a reliable lithium supply, regardless of their Li-ion battery design. While the price of lithium has been volatile in recent years, companies have prioritized supply security over price considerations due to projected demand outpacing miners' capacity to meet it. Shin Hak-cheol, CEO of Korean battery cell manufacturer LG Chem, on February 13, 2023, emphasized the importance of securing raw materials, stating, "Our first and foremost priority is to secure enough raw materials for the future" (Bloomberg, 2023).

According to Tanya Skilton, director of purchasing for EV critical minerals at General Motors, the "race" for critical minerals is "a zero-sum game" because "resources are a finite limit (sic)" (Dempsey & Campbell, 2022, para. 3). Benchmark Mineral Intelligence predicts a 12.5% lithium supply shortage by the end of the decade due to the increasing demand for EVs (Moores, 2023). This shortage will not result from limitations in reserves but rather from insufficient capital investments in lithium mines and the long time frame to scale up production. The lack of investment, combined with intense competition among OEMs, has created a tight and volatile market, compelling companies to venture upstream to guarantee supply and support mining companies in acquiring financial investments for new projects.

The response from OEMs and battery manufacturers has been clear: they are forging direct offtake agreements and supply contracts with mining companies to secure a steady lithium supply for the next decade. In their pursuit of supply assurance, OEMs have expanded their options by making direct investments and equity stakes in mining companies and projects to support mining endeavours. Thomas Schmall, the CEO of Volkswagen, said, "The bottleneck for raw materials is mining capacity—that's why we need to invest in mines directly" (Waldersee, 2023, para. 5). The CEO of Mercedes-Benz, Ola Källenius, stated that direct involvements with mining companies would have previously been "the job of the commodity markets"; however, it now "makes sense" to make direct deals with mining companies because of the potential for demand constraints by the end of this decade (Dempsey & Campbell, 2022, para. 7).

7.2 Offtake Agreements and Equity Investments

Large lithium-mining companies are shifting their focus away from short-term agreements in the spot market due to the expectation that lithium fundamentals are going to remain strong. Despite the anticipated increase in capacity in 2023, market forecasts by Benchmark Mineral Intelligence suggest that long-term lithium supply may not be sufficient to meet demand (Benchmark Minerals, 2023). As a result, lithium prices are expected to cover the cost of production until the early 2030s, allowing companies to maintain strong operating margins (Morales, 2023).

Given these favourable conditions, mining companies are inclined to retain a certain percentage of their production for the spot market while establishing longer-term relationships through offtake agreements linked to market prices at beneficial rates. A few

large lithium producers still engage in very long agreements spanning 8 to 10 years, and they are generally less interested in short-term contracts unless there is a potential for a more sustainable partnership.

Offtake agreements for lithium resemble those for other natural resources and are currently tied to market prices. This means that companies do not benefit from waiting for lower spot-market prices. An example of a common offtake agreement is provided by the announcement of an agreement between mining company ioneer and Prime Planet Energy & Solutions, a JV between Toyota and Panasonic. The agreement specifies the volume of lithium carbonate to be delivered by ioneer annually over a period of 5 years, with the price adjusted quarterly based on an agreed price formula tied to the market price.

Table 5. Sample agreement between ioneer and Prime Planet Energy & Solutions

Product: Lithium carbonate	
Contract duration	5 years
Volume	4,000 tons per annum (tpa)
Price	Adjusted quarterly based on the agreed price formula
Currency	USD per metric ton

Source: Falk, 2022.

Most offtake contracts include a "take or pay" clause, which obligates the offtaker to pay for the mineral regardless of whether they actually take delivery. This clause protects the financial interests of the mining companies. To safeguard the offtakers, the contract also includes liquidated damages that impose fines on the mining companies if they fail to deliver the agreed-upon lithium on time. Liquidated damages are particularly important in the mining industry, where project delays due to permitting and construction issues are common.

Equity investments, although relatively new in the lithium market, can be seen as a form of long-term offtake agreement, and are likely in response to the investment needs of smaller mining companies. Car manufacturers and cell manufacturers provide direct equity to mining companies or specific projects in exchange for exclusive access to a mining project or a significant supply of lithium. For instance, General Motors established an equity partnership with Lithium Americas in 2023, investing USD 650 million, “the largest-ever investment by an automaker to produce battery raw materials,” to secure exclusive access to lithium at the Thacker Pass project in the United States (General Motors, 2023, para. 2). BYD, Stellantis, LG Chem, and SK On have also made direct equity investments in mining projects. BYD became the third-largest shareholder of Chengxin Lithium by investing USD 300 million, which granted the firm access to lithium at a more favourable price.

7.2.1 The Benefit of Offtake Agreements for Mining Companies

Equity investments and offtake agreements prove to be advantageous for OEMs, battery manufacturers, and mining companies. These legally binding contracts offer opportunities

for growth and expansion, particularly for smaller mining companies known as junior miners. Unlike larger mining companies, junior miners are more receptive to equity investments and longer-term offtake agreements, actively seeking new partnerships given their difficulties in accessing finance. Given the substantial capital requirements of new mining projects, with construction costs reaching up to USD 1 billion, a combination of debt and equity is used for funding.

However, accessing debt financing is possible only when the project is de-risked and the mining firm demonstrates the capability of repaying the debt. The level of risk associated with the project influences the interest rate, thereby impacting the overall project cost. Offtake agreements are an effective way to de-risk a project, eliminating potential revenue uncertainties and providing reassurance to potential debt holders. Ultimately, these offtake agreements enable mining companies to secure low-cost debt for the project by significantly reducing risk. Through equity contributions and long-term offtake agreements, mining companies can expand production and address the potential demand shortage expected by the end of the decade. Although offtake agreements help to reduce financial risk, comprehensive de-risking strategies must also involve technical and ESG considerations.

Table 6. Offtake agreements for lithium between major OEMs and mining companies

OEM/battery manufacturer	Mining company	Mine location	Details
Stellantis	Vulcan Energy Resources	Australia	USD 52 million equity investment by Stellantis that gives an 8% stake in Vulcan and a 10-year offtake agreement (Reuters, 2022a)
General Motors	Lithium Americas	Nevada, United States	USD 650 million investment in Lithium Americas in return for exclusive access to lithium at Thacker Pass
Ford	ioneer	Nevada, United States	5-year binding offtake agreement to supply Ford's JV with SK Innovation (Scheyder, 2022)
Ford	Liontown	Australia	5-year lithium spodumene agreement including a USD 200 million debt facility from Ford for Liontown to continue development of lithium mine (Reuters, 2022b)
BMW	Ganfeng Lithium	Australia	USD 599 million 5-year offtake agreement
LG Chem	Piedmont Lithium	United States	USD 75 million equity investment into Piedmont for 4-year agreement (Shi, 2019)

OEM/battery manufacturer	Mining company	Mine location	Details
LG Energy Solutions	Compass Minerals	Utah, United States	6-year offtake agreement (Business Wire, 2022)
CATL	Yacimientos del Litio Bolivianos (YLB)	Bolivia	Chosen as part of a consortium to develop Bolivia lithium. The consortium will invest USD 1 billion.
Tesla	Liontown	Australia	5-year offtake agreement for lithium spodumene (Reuters, 2022b)
Toyota/ Panasonic	ioneer	United States	5-year offtake agreement
SK On	SQM	Chile	5-year offtake agreement (SK Innovation, 2022)
SK On	Lake Resources	Australia	SK On acquires 10% of Lake Resources in return for a 5-year offtake agreement (SK Innovation News Channel, 2022).

7.3 Accessing Lithium Supply for Smaller Companies

OEMs or automakers that are in the early stages of scaling up their EV manufacturing may not find it a viable option to establish direct investments with mining companies. Instead, these OEMs will rely on larger battery manufacturers to procure the necessary minerals. Battery manufacturers of significant scale, such as CATL, LG Chem, and Panasonic, already have established partnerships with mining companies and possess the required resources and capital for undertaking offtake agreements, as highlighted in Table 6.

For automakers that are committed to fair mining practices and robust ESG considerations, it becomes crucial to trace the origin of all minerals in their supply chain. This task becomes challenging when the automakers lack control over the supply chain. While some progress has been made through discussions with automakers, obtaining transparency regarding the original mineral source from the battery cell manufacturer remains difficult. If mineral traceability is a vital consideration, automakers should insist on receiving this information right from the outset of any partnership with cell manufacturers. This need for transparency across the battery supply chain has led to the creation of the Global Battery Alliance (GBA). The GBA is a public–private collaboration platform founded in 2017 to help establish a sustainable battery value chain by 2030. The GBA aims to increase supply chain transparency through several initiatives, such as the 1) Battery Passport Action Partnership, 2) Critical Materials, and 3) Energy Access & Circularity (Global Battery Alliance, n.d.).

8.0 What Are Lithium Mining Companies Looking for?

In discussions with prominent mining companies and government officials in Chile, Argentina, and Australia, we have gathered insights into their preferences for potential partnerships. As the demand from governments, OEMs, and battery manufacturers continues to rise, it becomes crucial for the Indian government and Indian companies to understand the expectations of these leading mining companies.

At the government-to-government level, the Indian government, represented by KABIL, has signed MOUs with Argentina and Australia. While establishing these strong diplomatic relations holds significance, it is important to note that mining companies are private entities, and MOUs between governments do not guarantee any offtake agreements or partnerships with lithium mining companies. For instance, the Australian government lacks the authority to compel Australian mining companies to directly engage with the Indian government or Indian OEMs based solely on the MOU signed between the two nations. In fact, one prominent lithium company has mentioned that these MOUs hold little weight for them, as they have the freedom to sell to whomever they choose. The primary criterion for evaluating offtake agreements lies in their commercial viability.

Due to the tight lithium market and the willingness of major OEMs to make substantial investments to secure a reliable supply, mining companies have little incentive to negotiate lower offers or create customized processes for specific clients. If Indian companies seek to obtain lithium, they must be willing to adhere to market processes, particularly when dealing with major mining companies.

Large mining companies like SQM and Albemarle are seeking 3-to-5-year contracts that provide guaranteed offtake agreements. Previously, when lithium spot market prices were higher, these companies favoured shorter contracts to capitalize on the increased prices. Junior mining companies, on the other hand, may still seek longer-term agreements extending beyond 5 years, as they need to mitigate project risks further. This is influenced by the high cost of capital. Nevertheless, even smaller companies have the option to pursue partnerships.

When engaging with offtakers, major lithium companies are interested in establishing true partnerships that extend beyond financial backing for projects. Mining companies expressed a desire for partnerships that encompass various aspects, such as providing access to used batteries for recycling purposes, collaborating with reliable business partners committed to fulfilling contractual obligations, engaging in joint investments and exploration of new lithium deposits, and partnering with forward-thinking entities knowledgeable about the next generation of Li-ion battery materials.

For smaller mining companies or junior miners, legally binding offtake contracts play a crucial role in their expansion. New mining projects are extensive and require substantial capital investments, with total construction costs often reaching billions of dollars. These projects are financed through a combination of debt and equity. However, to secure access to debt financing, mining companies must demonstrate that their projects are de-risked and capable

of repaying the debt. The lower the risk associated with the project, the lower the interest rate on the debt, resulting in overall cost reduction.

Offtake agreements serve as an effective means of de-risking mining projects. They lower revenue risks and provide assurance to potential debt holders. Ultimately, offtake agreements enable mining companies to access low-cost debt, as the projects become significantly de-risked. Bernard Rowe, managing director at ioneer, mentioned that the offtake agreement with Ford grants them access to low-cost debt for expanding their production projects. Through equity investments or long-term offtake agreements, mining companies can expand production and contribute to alleviating potential demand shortages expected by the end of the decade.

Various actors within the battery supply chain, including Indian companies, can collaborate with mining companies. These collaborations extend to battery cell makers, cathode manufacturers, and OEMs. Mining companies recognize the importance of battery cell makers as key players and the lynchpins of the battery supply chain. Nevertheless, they are open to working with OEMs that do not have expertise in lithium but understand the importance of procuring lithium for their vehicles. In this respect, Indian companies can also team up with battery producers to make sure they have reliable access to future lithium resources.

8.1 ESG Challenges and Frameworks

Lithium companies need additional investment to also comply with ESG requirements. Compared to cobalt and copper, lithium has had relatively fewer ESG concerns (Michaels et al., 2022). However, due to the increased demand for lithium, several environmental and social challenges have come to the forefront in recent years.

Environmental Concerns

Lithium production has an impact on water consumption. Water pollution through freshwater ecotoxicity is especially a threat, more so than freshwater eutrophication (IEA, 2021). While the potential impact per weight of extracted material is higher than other critical minerals, the total weight of global lithium needs is much lower than other elements such as cobalt, copper, and nickel. Hard-rock mining has lower amounts of water consumption but higher amounts of freshwater consumption than lithium from brines. Lithium from brines risks affecting water levels in arid areas, even if more scientific research is needed to understand its exact impacts. The impacts of brine extraction on groundwater levels are mainly due to its effect on impacts such as lowering groundwater levels (Sebrell & Kearney, 2022). Brine water itself cannot be used in either agriculture or for human consumption because of its high salt content. This problem is especially important since more than half of worldwide lithium production is happening in areas with high water stress (IEA, 2021). As a result, there is a push from local communities to reduce water consumption and regulators to increase the amount of lithium yield. Regardless of the choice of DLE methods, this will require additional investment.

With respect to GHG emissions, lithium mining and processing produces relatively low emissions compared to other minerals, such as class 1 nickel, aluminum, or cobalt (IEA,

2021). Lithium production from brines, especially, has low GHG emissions. Lithium production from hard rock is about three times more emissions intensive than that from brines (Benchmark Minerals Intelligence, 2023a). The goal is to reduce carbon emissions by electrifying some of the mining value chain and by using green hydrogen. This, too, requires significant investment.

Social Concerns

There has been a history of community opposition to mining, and lithium mining is no different. This is often linked to the lack of community participation and consensus before a project and the failure to appropriately share benefits with local communities through royalties, remittances, and employment. It could also be linked to the community's perception of the environmental impacts of lithium mining or processing (Petavratzi et al., 2022). The lack of meaningful consultation and involvement of local communities can lead to the termination of lithium projects, which occurred recently in Bolivia and Serbia (Michaels et al., 2022).

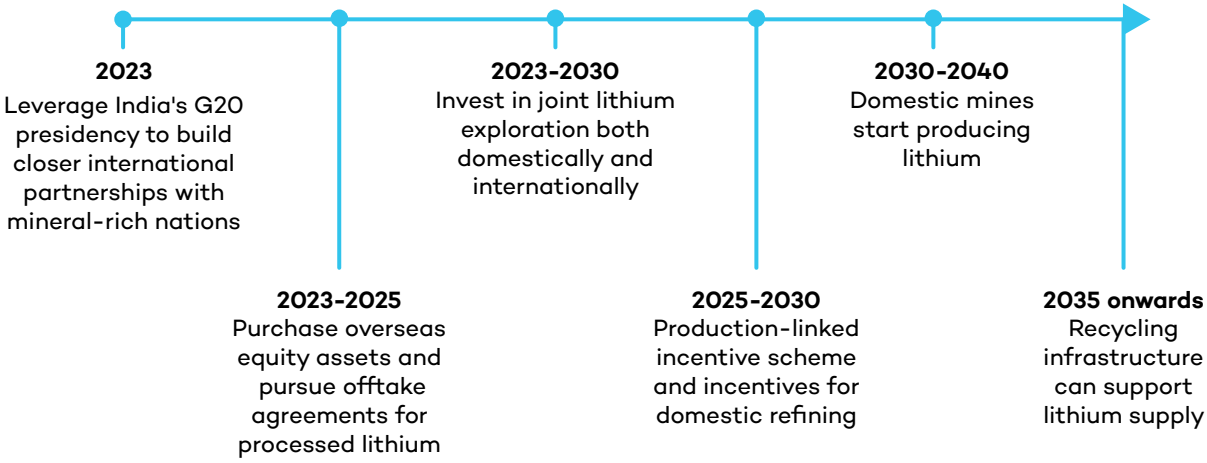
A failure to address these ESG risks may expose governments and businesses to ESG-related regulatory, ethical, and reputational criticisms (Michaels et al., 2022). It could also inhibit investment into the lithium supply chain from large institutional investors. The Organization for Economic Co-operation and Development's Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas provides a framework for companies to apply due diligence (Organization for Economic Co-operation and Development, 2021).

Indian policy-makers will need to assess what role ESG will take in their outward engagement, measuring the disadvantages—such as more barriers to investment in developing economies—and advantages—such as increased geopolitical and trade alignment with industrialized economies and the future of the market. For its domestic lithium resources, as well, India will need to carefully balance the need to accelerate mining production with compliance on ESG standards. Given the country's desire to export Li-ion batteries and vehicles, ensuring an environmentally friendly mining process can be essential to attract investment from large international companies given the growing scrutiny of the battery value chain's footprint.

9.0 Policy Recommendations

Given the anticipated growth in lithium demand in India, it is essential for policy-makers to consider a range of short-term and long-term strategies to secure lithium supply. Figure 15 highlights specific strategies and a tentative timeline to adopt them based on the growth in demand highlighted in the section on Forecasted Lithium Demand in India (Section 3).

Figure 15. Proposed timeline of interventions for sourcing lithium by India



9.1 Streamline the Exploitation of Domestic Lithium Resources

India has significant untapped potential resources of lithium, particularly in the states of Karnataka, Rajasthan, and Jharkhand. The Ministry of Mines estimates that around 30% of India's obvious geological potential has been explored, and less than 1% of the global exploration budget is spent in India (Ministry of Mines, 2023b). The government should seek to significantly increase the exploration budget and consider a state-backed guarantee for companies engaged in critical minerals exploration. State-backed policies can play an important role in incentivizing initial mineral exploration as market-based approaches may not function well due to higher perceived risks. India could look toward the example of Germany, which created a state-backed fund to support domestic and international mineral exploration.

The Indian parliament has recently approved new legislation to amend the Mines and Minerals (Development and Regulation) Act, of 1957, to permit private exploration and mining of six critical minerals, including lithium, by declassifying them as atomic minerals. The legislation also includes several measures, such as shifting control over auctions of critical minerals from the state to central governments and introducing exploration licences for deep-seated and critical minerals. These are important steps, but a study by the Center for Science and Economic Progress, identified challenges with the current framework and provided targeted recommendations to streamline this process (Chadha et al., 2023b). India also needs to build the necessary processing and refining infrastructure to maximize the use of its potential domestic resources.

9.2 Focus on Cultivating Partnerships Across the Supply Chain

For countries like India that do not currently have the adequate mineral resources to be self-sufficient, it is paramount to build or strengthen existing partnerships along the lithium supply chains. Even for resource-rich countries like Australia, achieving 100% localization in the supply chain is highly unlikely, which provides an opportunity for India to pursue partnerships with key actors in the supply chain. However, to do so, it is important to understand the motivations of mineral-rich nations, particularly their interest in capturing domestic value addition.

The renewed desire for value addition in mineral-rich nations may present both opportunities and threats for India. For example, if India were to primarily seek to source unprocessed minerals from mineral-rich countries while building its own domestic processing capacity, it may encounter obstacles. On the other hand, India could potentially gain a foothold within mineral-rich economies by helping provide financing and technical support for local value addition in mineral-rich nations, which could serve as an offtake agreement for Indian companies. Such a strategy would allow India to position itself as a leader in the Global South, fill the financing gap in developing economies, and gain increased access to mineral supply.

9.2.1 Focus on Australia and Argentina, but Don't Rule Out Chile

India should focus on continuing to strengthen bilateral relationships with Australia and Argentina by pursuing partnerships with companies in these countries. The MOUs signed with both countries along with the Australia–India Critical Minerals Investment Partnership and free trade agreement with Australia are unique opportunities for India. Australia is the largest producer of lithium and looking to expand its presence across the value chain. The Australian government provides a safe investment environment and supports the sector. KABIL should continue to work with partners in Australia. Leading lithium experts believe that Argentina is strongly open to investment opportunities in the lithium sector as the country seeks to expand its production. Furthermore, the prevalence of both NMC and LFP batteries in the Indian EV ecosystem highlights the need to source both lithium hydroxide and lithium carbonate in the future, which can be derived from Australia and Argentina, respectively.

Chile, the second-leading producer of lithium with the largest reserves, could also be a potential partner for India because of its evolving business environment. The Chilean government's plan to exercise state control over the lithium sector has created uncertainty in the industry, and its policies will need to be carefully considered by market actors before investing there. This might open a possibility for state-backed Indian companies, such as KABIL, to invest there, since government-to-government partnerships might play an essential role in guaranteeing supplies, in contrast to other contexts where purely commercial partnerships have become very competitive.

Bolivia's actions toward Germany in the recent past demonstrate that community-led opposition and geopolitical issues can quickly disrupt the lithium supply chain. However, Chinese and Russian companies have engaged in the Bolivian lithium supply chain recently, so the country shouldn't be completely ruled out as a potential sourcing option for India.

Australia's and Argentina's openness to foreign direct investment in the mining industry makes them safer and stronger partners for India. However, it is important to remember that mining companies are looking for partnerships with private companies. The Indian government should assist its SOEs (or PSUs), such as KABIL, in pursuing partnerships, but it is also important to partner with domestic private companies, as well, to be an offtaker of the processed mineral.

9.2.2 Partner With the Private Sector

The government has launched initiatives to explore and mine these resources overseas, including a JV between the state-owned Mineral Exploration Corporation Limited and the National Aluminium Company Limited, called KABIL, to explore lithium and other minerals overseas. KABIL and NMDC, a state-owned iron ore mining company, can choose to follow Japan's and South Korea's lead by supporting and facilitating the private sector in acquiring stakes in overseas critical mineral mines or processing facilities. NMDC has signed an MOU with Hancock Prospecting for prospecting and mining of lithium in Australia.

It is imperative to work with the private sector to guarantee successful offtake of the acquired lithium and ensure the correct ore grade is prioritized. ONGC Videsh, the overseas subsidiary of ONGC, an Indian oil and gas PSU (or SOE), has previously partnered with private companies, such as Reliance Industries and Mittal Investment Sarl to jointly bid for international oil and gas blocks, as they bring in access to low-cost capital (Madan, 2007). However, it should be noted that KABIL would need to pursue partnerships with OEMs and battery manufacturers to source lithium. Given the company's lack of experience in mining lithium, KABIL should also consider partnerships with international lithium mining companies or acquiring a stake in a junior miner.

9.2.3 Partner With South Korea and Japan

Japan and South Korea are both experienced in mineral financing and exploration through state-owned companies and could make excellent partners for India. India could consider forming trilateral partnerships with a resource-rich country and Japan or South Korea to invest in mineral projects overseas that would provide lithium to Japanese or Korean battery-cell manufacturers. In return, the cell manufacturers could manufacture their cells in Indian-based factories for Indian vehicles.

Interviewed experts and industry actors agree that JVs are the quickest way for India to begin manufacturing batteries domestically. Partnerships with JOGMEC and KOMIR could enhance these ventures. OVL previously signed an MOU in 2006 with JOGNEC (the former title of JOGMEC) with the intent of jointly bidding for oil and gas blocks in Southeast Asia, Libya, and Russia, highlighting the precedence for such partnerships with Japanese SOEs (Madan, 2007). Japanese and Korean auto companies have a strong market presence in India—Suzuki and Hyundai account for over 50% of the Indian vehicle market, and Kia, Toyota, and Honda are also among the top seven-largest vehicle providers in the country (Statista, n.d.).

9.3 Support and Incentivize Domestic Lithium Refineries

According to the IEA, China currently dominates the lithium refinement process, accounting for 60% of lithium processing (IEA, 2022a). Australia, the leading 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 and usage. By June 2022, 97% of Australian lithium was exported to China, highlighting the lack of a global alternative to China in the processing industry.

Currently, there is only one lithium-refining facility in the planning process in India. Manikaran Lithium Private Limited signed an MOU with the state government of Gujarat to develop a lithium refinery. Manikaran had previously partnered with Neometals of Australia; however, it is now looking to secure its own lithium supply through offtake agreements or equity agreements (Pillay, 2023).

The Indian government, at either the state or national level, should incentivize companies to develop lithium-refining plants in India. The government could do this through an additional production-linked incentive scheme for critical minerals or by assisting and supporting refining companies in obtaining the land and permits needed for plants, as well as providing incentives to reduce their capital costs. India is a prime candidate for the development of lithium refineries because of its experience in chemical processing, strong port and trade infrastructure, a large future domestic battery market of battery demand, lower capital cost, and trade frameworks with both Australia and Chile.

India was recently named as the "next chemicals manufacturing hub" by McKinsey (Fischer et al., 2023), and its chemical processing sector is ranked sixth in the world based on revenues (International Trade Administration, 2022). Chemical manufacturing is currently supported by state and national governments, including the Petroleum, Chemicals & Petrochemicals Investment Regions. These states—Andhra Pradesh, Gujarat, Odisha, and Tamil Nadu—are predefined chemical zones that are easier to develop.

These four states are also prime locations for the development of lithium refining, as they can utilize both government support and easy access to the ports. India's extensive port and trade infrastructure would allow the country to import lithium concentrate from Australia or other partners to use for domestic use or export. Compared to potential competitors, capital expenditures for a new processing facility would be lower in India. According to Fischer et al. (2023), total infrastructure costs are 70% lower in India compared to other chemical processing countries.

Domestic lithium refineries allow India to take advantage of its partnership and free trade agreement with Australia. Lithium spodumene imports from Australia would benefit from the free trade agreement; however, once the lithium is transferred to China or another third-party country for processing, the lithium hydroxide or carbonate is not under the free trade agreement. Australia is developing its own refineries; however, competition for its lithium will be strong, as international automobile companies will want to use their services to meet requirements under the IRA.

Finally, developing lithium refineries today would prepare India for future domestic lithium production. To take advantage of the full value of the lithium deposits in J&K, India should process the lithium domestically. Building out refineries now with imported lithium would build a strong refining sector that is prepared for a domestic supply of lithium.

9.4 Leverage India's Growing Geopolitical Influence in Forging Partnerships

India could better leverage growing international geopolitical influence and recent membership in the MSP to achieve its critical mineral objectives. As the only emerging economy invited to join the MSP, India is in a unique position as both a large consumer of critical minerals and a potential representative of emerging economies' interests (many of which are resource-rich nations). India must leverage international partnerships to coordinate the several alliances that are currently being developed, including the Sustainable Critical Minerals Alliance and the Critical Minerals Club, by creating an international framework on critical minerals cooperation. A few of these alliances overlap, while others compete.

These alliances may follow country interests and geopolitical alignment, but the exclusion of emerging economies from these blocs affects the feasibility of a just energy transition that many industrialized countries publicly support (Moerenhout et al., 2023). It is also unclear how effective these closed alliances will be in promoting diversified and resilient supply chains without the inclusion of mineral-rich emerging economies. Within a G20 context, there needs to be deliberation on integrating emerging economies in critical mineral partnerships. India can play an important role in facilitating this discussion. This can also prevent the creation of critical mineral cartels like OPEC and recent nationalization trends in mineral-rich nations, which could negatively impact supply chain security and delay the clean energy transition.

India should also seek to build closer cooperation with industrialized countries, particularly the United States, Australia, and Canada, which are engaged in the Critical Minerals Mapping Initiative, which aims to build a diversified supply of critical minerals (IEA, n.d.-a). The initiative will help to develop a better understanding of critical mineral resources, determining geologic controls on critical mineral distribution, identifying new sources of supply through critical mineral potential mapping, and promoting critical mineral discovery in all three countries. India will likely need access to technology to explore its domestic lithium reserves and can leverage these countries' expertise in harnessing its identified reserves and untapped resources. At the same time, it will also be important for India to act quickly to build stronger relationships with mineral-rich developing economies, as many industrialized economies are already taking similar initiatives.

9.5 Create Recycling Infrastructure

Incentivizing and establishing lithium recycling infrastructure may eventually lower the demand for lithium imports, help India secure lithium in the medium term, and create a network that is prepared for eventual domestic lithium production. This would include building the infrastructure and system to collect used batteries, creating regulations, and building processing facilities. Lithium recycling is specifically useful for India because of the

prevalence of two-wheeler and three-wheeler vehicles. These vehicles have shorter life cycles compared to four-wheeler vehicles, leading to earlier recycling. Supporting the companies working to create the lithium recycling infrastructure today will help build strong partnerships with mining companies.

As mentioned in a previous section, mining companies prefer to create partnerships with countries or companies where recycling programs exist. The mining companies want access to the lithium so they can process it and sell it again. Establishing the recycling system will demonstrate to mining companies that India is a quality partner. Finally, establishing the recycling infrastructure early will ensure that India is able to produce domestic sources of lithium over the next decade once the recycling system is strong and ready. Like refining plants, the recycling program will allow India to capture and retain more of the value of Li-ion batteries for both domestic use and exports, and help offset a portion of India's future lithium demand.

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Appendix A

Lithium Demand for Different Battery Chemistries

The amount of lithium required in each type of lithium battery cathode varies depending on the specific chemistry and design of the battery. Here are some approximate values for commonly used cathode materials based on data from the Argonne Laboratory Battery Pac model:

Lithium cobalt oxide (LCO): LCO cathodes typically contain around 10%–15% lithium by weight, with the remainder consisting of cobalt, oxygen, and other minor elements.

Lithium nickel manganese cobalt oxide (NMC): NMC cathodes typically contain around 5%–10% lithium by weight, with the remainder consisting of nickel, manganese, cobalt, oxygen, and other minor elements.

Lithium iron phosphate (LFP): LFP cathodes typically contain around 6%–8% lithium by weight, with the remainder consisting of iron, phosphorus, oxygen, and other minor elements.

Lithium titanate (LTO): LTO cathodes typically contain around 0.5%–2% lithium by weight, with the remainder consisting of titanium, oxygen, and other minor elements.

Table A1. Different lithium battery chemistries with their lithium requirement

Battery chemistry	Lithium requirement	Lithium requirement (kg/kWh)	Description
Lithium cobalt oxide ($LiCoO_2$)	High	0.35–0.45	This is one of the most commonly used battery chemistries due to its high energy density, but it has a relatively short cycle life and can be unstable at high temperatures.
Lithium manganese oxide ($LiMn_2O_4$)	Low to medium	0.07–0.11	This battery chemistry has a lower energy density than LiCoO2 but has a longer cycle life and is less prone to thermal runaway.
Lithium iron phosphate ($LiFePO_4$)	Low to medium	0.07–0.10	This battery chemistry has a lower energy density than LiCoO2 but is more stable, has a longer cycle life, and is less prone to thermal runaway. It is commonly used in electric buses and stationary energy storage systems.
Lithium nickel cobalt aluminum oxide ($LiNiCoAlO_2$ or NCA)	High	0.17–0.23	This battery chemistry has a high energy density and good cycle life, but it can be unstable at high temperatures. It is commonly used in EVs with long ranges.
Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$ or NMC)	Medium to high	0.15–0.20	This battery chemistry has a high energy density, good cycle life, and is relatively stable at high temperatures. It is commonly used in EVs and stationary energy storage systems.
Lithium titanate ($Li_4Ti_5O_{12}$)	Very low	0.02–0.03	This battery chemistry has a low energy density but is very stable and has a long cycle life. It is commonly used in fast-charging applications such as electric buses and grid storage systems.

Appendix B

Methodology: Lithium demand estimation in India across different categories for the period 2022–2050 based on Accelerated Deployment and Business-as-Usual scenarios

Lithium is a critical element used in the production of batteries for electric vehicles (EVs), energy storage systems, and other electronic devices. These steps outline the methodology employed to estimate the future demand for lithium across various categories in India for the years 2022–2050. The lithium demand for two-wheelers, three-wheelers, four-wheeled passenger vehicles, four-wheeled commercial vehicles, buses, grid storage, freight, and others (behind-the-meter, residential and commercial, consumer electronics, and rail and defence) is estimated. The estimation of lithium demand is done for two scenarios. The first scenario is based on the Accelerated Deployment of EVs and Grid Storage while the second one is based on the Business-as-Usual scenario.

Step 1:

The annual forecasts for category-wise EV sales except freight vehicles for the period 2022–2050 are sourced from the report "Pathways to Atmanirbhar Bharat: Harnessing India's Renewable Edge for Cost-Effective Energy Independence by 2047" (Abhyankar et al., 2023). The forecasts are sourced for two scenarios from the report—Drive Clean and Business as Usual. The battery size for electric two-wheeled, three-wheeled, four-wheeled passenger and commercial vehicles, and buses are assumed at 2 Kwh, 5 Kwh, 40 Kwh, 60 KWh, and 250 KWh according to the report "Lithium-Ion Battery (LiB) Manufacturing Landscape in India: Market Trends and Outlook" (Gulia et al., 2022). It is assumed that the share of lithium chemistry will be 100% in all EV categories starting in 2030. The battery type assumed for each category is based on the best-selling model in India. Thus, nickel manganese cobalt oxide (NMC) chemistry is chosen for electric two-wheelers and three-wheelers while lithium ferro phosphate (LFP) chemistry is chosen for four-wheelers and buses. The lithium metal intensity is assumed as 115.25 tons/Gwh for the NMC battery type and 96 tons/Gwh for the LFP battery type. The lithium intensity multiplied by battery size and demand forecast provides us with the lithium-demand estimate for EVs in India.

Step 2:

The battery storage forecasts (in GWh) for grid storage for India in the Accelerated Deployment scenario are sourced from the report "Pathways to Atmanirbhar Bharat: Harnessing India's Renewable Edge for Cost-Effective Energy Independence by 2047" (Abhyankar et al., 2023). The battery storage forecasts for grid storage in India in the Business-as-Usual scenario is sourced from the report "Need for Advanced Chemistry Cell Energy Storage in India (Part I of III)" (Singh, Ghate, Ningthoujam, Gupta, & Sharma, 2022). The lithium battery chemistry assumed for grid-level storage is LFP, and the lithium metal intensity is assumed as 96 tons/Gwh. The lithium demand for grid storage is obtained by multiplying battery storage forecasts by lithium intensity.

Step 3:

The battery forecasts for freight and "others" categories in India for the year 2030 are sourced from the report "Need for Advanced Chemistry Cell Energy Storage in India (Part I of III)" (Singh, Ghate, Ningthoujam, Gupta, & Sharma, 2022). The compound annual growth rate for freight and "others" categories between 2026 and 2030 in the report is assumed for the subsequent decades, to estimate battery demand. The lithium demand in the Accelerated Deployment and Business-as-Usual scenarios is assumed to be the same due to lack of solid evidence of accelerated deployment in the "others" category. The battery chemistry assumed for freight vehicles is LFP and for "others" categories is NMC. The lithium intensity multiplied by battery forecasts provides us the lithium demand in freight and "others" categories.

Step 4:

The individual demand projections from each category were aggregated to arrive at the total estimated lithium demand for India across various categories and the two scenarios.

The replacement demand for batteries has not been considered in the lithium demand estimation due to a lack of market data on replacements. It is important to acknowledge that uncertainties and variables exist, and periodic reassessment and refinement of the methodology will be necessary to reflect changing market dynamics and technological advancements.

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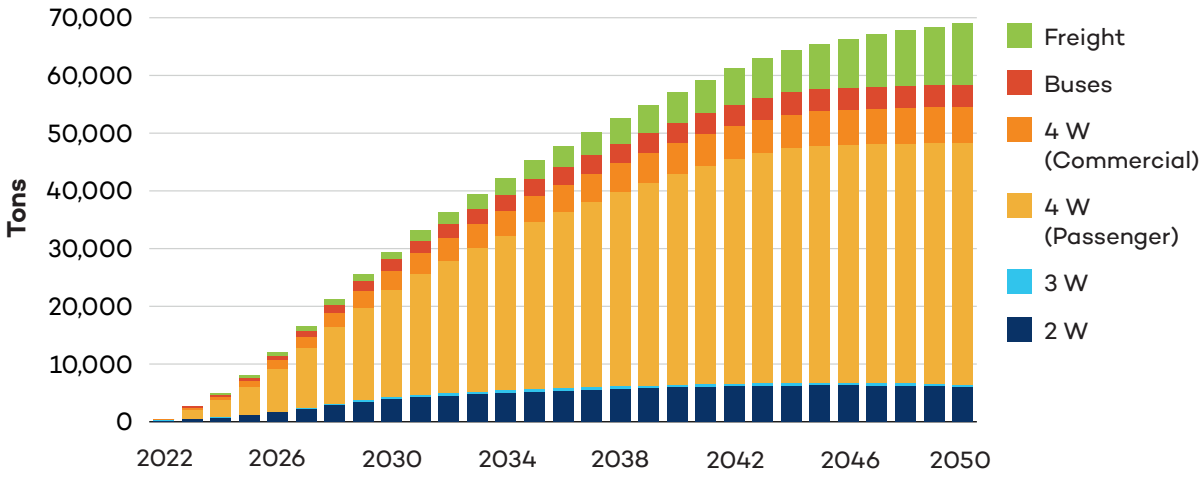
Appendix C

Lithium Demand in Electric Vehicles by Segment in the Accelerated Deployment Scenario

Figure C1 showcases the lithium demand in electric vehicles (EVs) by segment in the Accelerated Deployment scenario. The data indicates that the four-wheeler passenger car segment drives the lithium demand in the EV category. The share of passenger four-wheelers in total lithium demand within the EV category increases from 42% in 2022 to 63% in 2030.

Figure C1. Lithium demand in EVs by segment (Accelerated Deployment

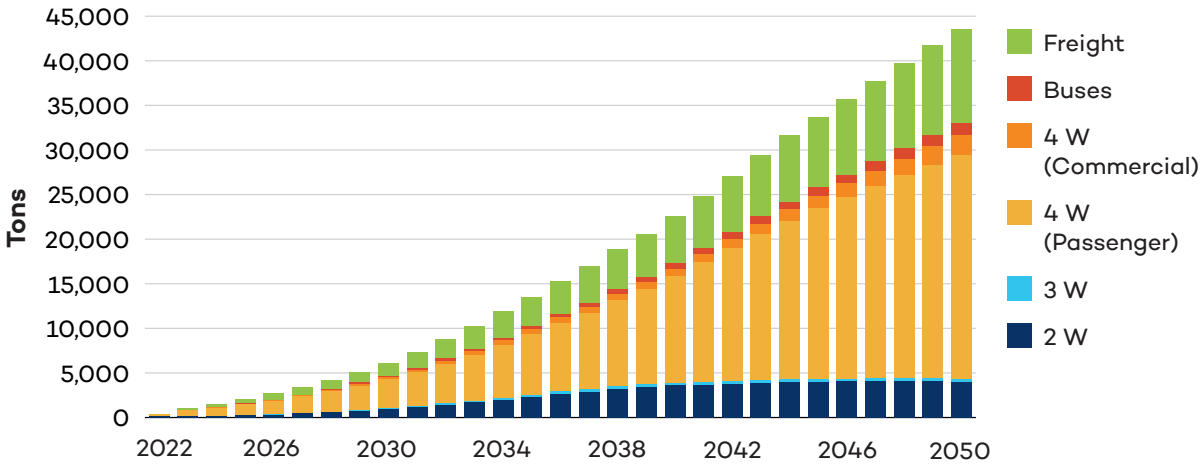


Source: Authors' forecasts

Lithium Demand in EVs by Segment in the Business-as-Usual Scenario

Figure C2 demonstrates the lithium demand in EVs by segment in the Business-as-Usual scenario. As observed, the four-wheeler passenger car segment remains the primary driver of lithium demand in the EV category. The share of passenger 4-wheelers in total lithium demand within the EV category increases from 42% in 2022 to 52% in 2030.

Figure C2. Lithium Demand in EVs by Segment in the Business- as -Usual Scenario



Source: Authors' forecasts

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