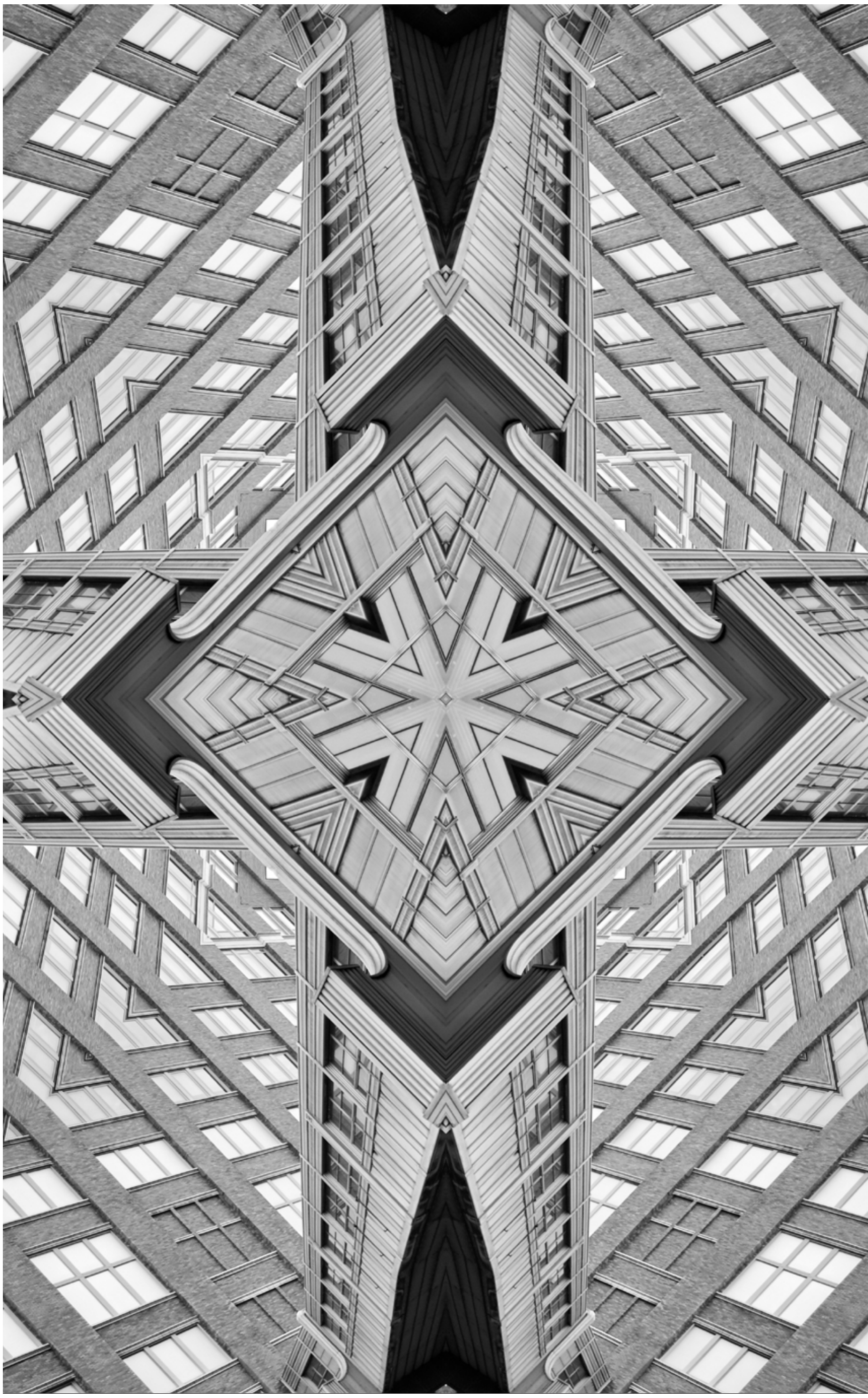
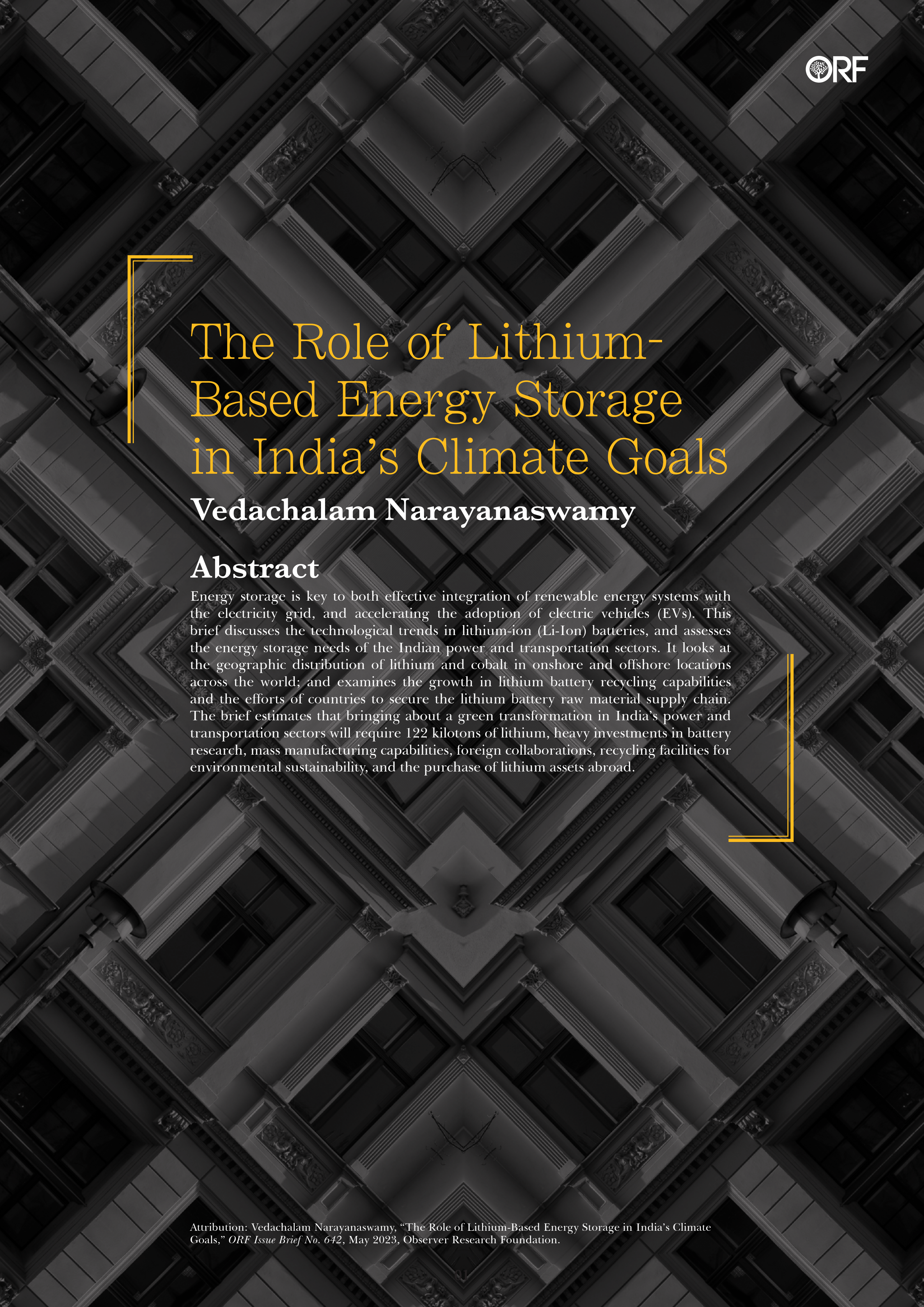
Issue Brief

ISSUE NO. 642
MAY 2023





The Role of Lithium-Based Energy Storage in India's Climate Goals

Vedachalam Narayanaswamy

Abstract

Energy storage is key to both effective integration of renewable energy systems with the electricity grid, and accelerating the adoption of electric vehicles (EVs). This brief discusses the technological trends in lithium-ion (Li-Ion) batteries, and assesses the energy storage needs of the Indian power and transportation sectors. It looks at the geographic distribution of lithium and cobalt in onshore and offshore locations across the world; and examines the growth in lithium battery recycling capabilities and the efforts of countries to secure the lithium battery raw material supply chain. The brief estimates that bringing about a green transformation in India's power and transportation sectors will require 122 kilotons of lithium, heavy investments in battery research, mass manufacturing capabilities, foreign collaborations, recycling facilities for environmental sustainability, and the purchase of lithium assets abroad.

Attribution: Vedachalam Narayanaswamy, "The Role of Lithium-Based Energy Storage in India's Climate Goals," *ORF Issue Brief No. 642*, May 2023, Observer Research Foundation.

Introduction

Global investment in clean energy technologies so far has reached US$ 2.6 trillion.[1] Following several global conferences over the last three decades, countries have set themselves minimum obligations to reduce their carbon footprint, and provide greater transparency and accountability in their generation and use of energy. India has committed to increase its cumulative non-fossil-fuel-based electricity generation capacity to 50 percent by 2030, reduce emission intensity by 35 percent from 2005 levels, and become carbon-neutral by 2070.[2]

Increased use of renewable energy and early transition to electric mobility will contribute to achieving these targets and reducing India's hydrocarbon imports bill. In the next decade, lithium-based batteries are expected to play a significant role in setting up Energy Storage Systems (ESSs) in power and transportation.

This brief discusses the key requirements for achieving a green transition in India's power and mobility sectors. The author used the India Energy Security Scenario 2047 (IESS 2047) modelling and simulation software[a] to make forecasts.

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[a] IESS2047 is an energy scenario building tool, which can be used to explore a range of potential future energy scenarios for India, for diverse energy demand and supply sectors, leading up to 2047.

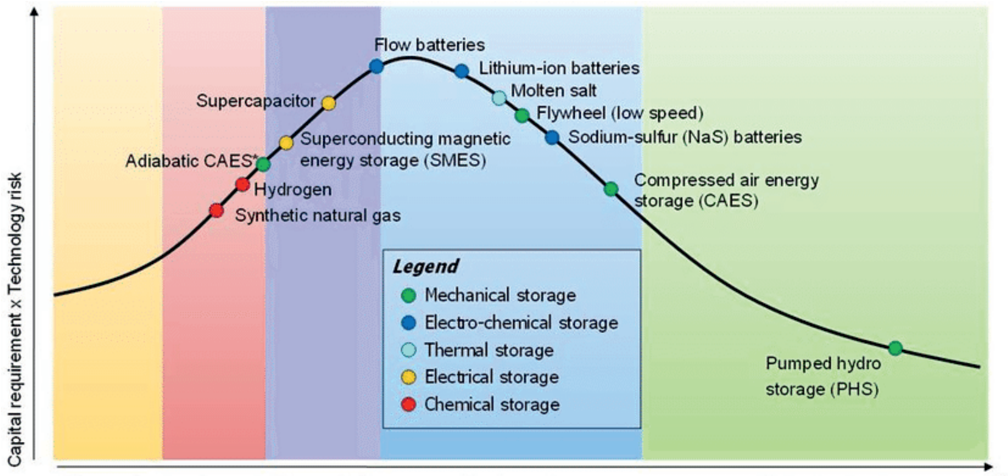
Overview of Lithium Battery Technologies

The first commercial lithium-ion (Li-Ion) battery was developed in 1985, and the technology has advanced since then. Its advantages include superior energy density (of 75-200Watt-hours per kilogram)[b] and specific density (of 150-315 Watt-hours per litre), cycle stability, efficiency, and reliability. Li-Ion battery technologies have a large footprint in portable electronics, renewable energy, smart electric grids, electric transportation including road vehicles and green/hybrid ships, along with applications in aviation, space and underwater.

The maturity level of the Li-Ion-based ESS compared with that of other technologies is shown in Fig.1.[3] Li-Ion cells use lithium transitional metal oxides as the cathode (negative) electrode, graphite as anode (positive) electrode, and non-aqueous carbonated liquids as the electrolyte. The charge and discharge of the cell occurs through intercalation and de-intercalation of the lithium ions. During the charging process, lithium ions are transferred across the electrolyte from the cathode to the anode. The performance of lithium cells varies significantly based on the electrode chemistry used.

Fig.1

Technological Maturity of Energy Storage Systems



Source: Mitali, Dhinakaran, and Mohamad[4]

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[b] Energy density is the amount of energy a battery contains compared to its weight, specific density is energy per unit volume. It is measured in watt-hours per kilo (Wh/kg) and watt-hours per litre (Wh/l).

The use of solid polymers as the electrolyte and lithiated[c] carbon has greatly improved the safety of Li-Ion cells. The main features of matured lithium based cell technologies are shown in Table1. LFP and LTO, in particular, reduce cost and increase safety. The cost/kWh is based on the US Department of Energy 2022 estimate on a usable energy basis for production at scale of at least 100,000 units/year. Lowering cobalt content in the composition of cathodes reduces cost and increases energy density, in combination with other anode technologies. Upcoming lithium metal cathodes are expected to improve performance without relying on cobalt, in combination with anodes made of silicon composites. Research on Li-air and Li-sulphur batteries is also fast progressing, but their technology readiness level is still far away. They may not be commercially available before 2030.[5]

Table 1

Comparative Features of Lithium-based ESSs

Feature	NMC-Graphite	NMC-LTO	LFP-Graphite
Energy Density (Wh/Kg)	200	100	140
Cost/kWh (US$)	150-200	450	320
Number of Charge-Discharge Cycles (CDC)	2500 at 80% depth-of-discharge	10000 at 80% depth-of-discharge	-

Source: Hadrien, Lagadic, and Louvet[6]

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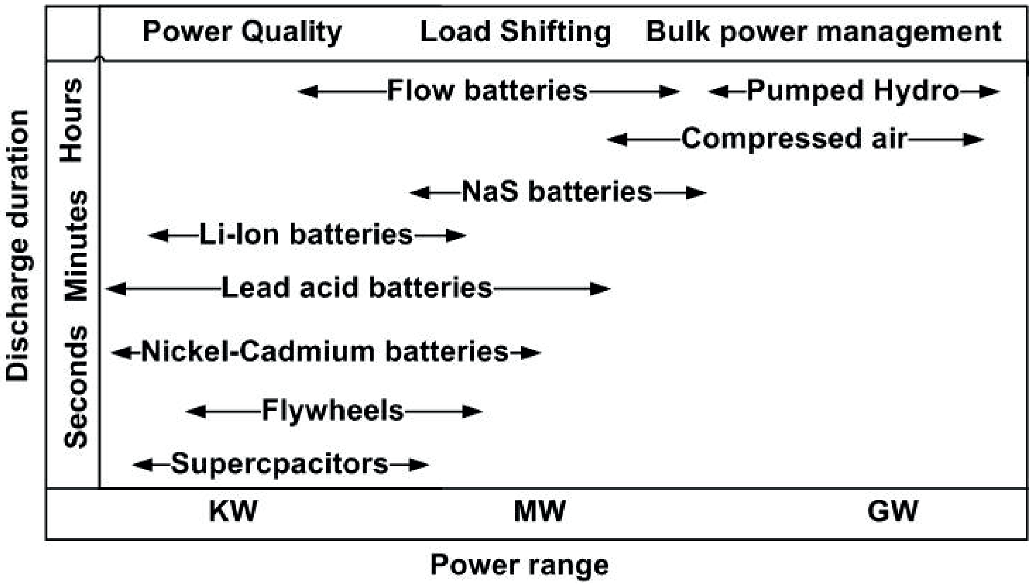
[c] Impregnated with lithium or a lithium compound

In the power sector, ESSs are required for effective management of demand shifts, peak reductions, frequency regulation, voltage support and renewable resources integration (see Fig.2).[7]

Fig. 2

Energy Storage Technologies Based on Application



Source: Author's own

Capacities of ESSs (excluding pumped hydro) installed globally are shown in Table2. Electro-chemical-based ESSs are the most widely used. The United States tops the list with a cumulative installed capacity of around 600MW distributed across 292 projects, followed by South Korea, Japan and Germany with 300, 250 and 120 MW, respectively.[8] Fig. 3 shows the share of different battery chemistries used in such storage catering to a range of power and durations.

Table2

Comparative Features of Li-based ESS

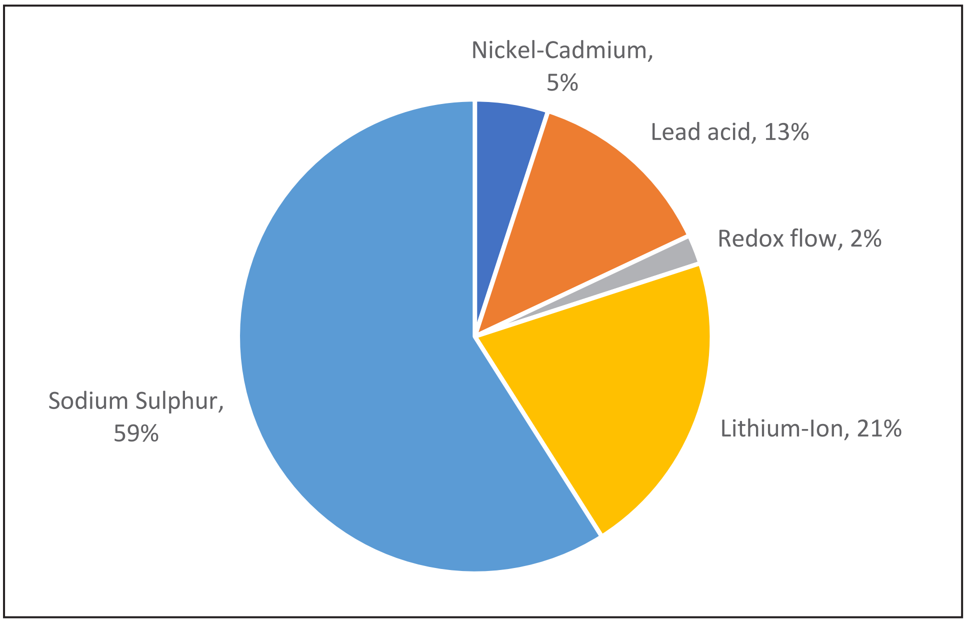
Technology	Number of projects	Combined capacity
Electro-chemical	1,056	4GW
Thermal storage	225	3.7 GW
Electromechanical	74	2.6 GW
Hydrogen storage	14	21 MW
Compressed air storage	2	5 MW

Source: U.S.Department of Energy and National Energy Technology Laboratory[9]

Globally, among electro-chemical-based ESSs, the share of sodium-sulphur (Na-S) batteries is 59 percent, Li-Ion 21 percent, lead-acid 13 percent, nickel-cadmium (Ni-Cd) 5 percent, and redox (reduction-oxidation) flow chemistries 2 percent. It varies between countries based on the nature of their power system demand and stability requirements, domestic availability of battery raw materials, and prevailing policies. In China, the use of Li-Ion, lead-acid and redox flow batteries is 74 percent, 17 percent and 9 percent, respectively; in Japan, Na-S, Li-Ion, flow and lead-acid batteries are used in the proportion 48 percent, 38 percent, 8 percent and 4 percent, respectively. Na-S batteries are dominant globally, including in Japan.[10]

Fig. 3

Share of Electro-Chemical ESS in Power Sector



Source: https://netl.doe.gov/

In India's power sector, around 11 percent of ESSs are used as backup for renewable power,[d] 16 percent for power quality management, and the remaining 73 percent to overcome power dips and outages. The software tool, 'India Energy Security Scenario (IESS) 2047, Modelling and Simulations',[11] has been used to forecast that if a determined effort is made,[e] cumulative renewable energy installed capacity will rise from around 119 GW in 2022 to 175 GW in 2030.

The increase in use of renewable energy, which will include around 10,000 distributed mini and micro grids (not connected to the main power grid) will call for much more storage capacity. This has been estimated at around 55 GW for energy and another 45 GW for power needs. The simulation results,

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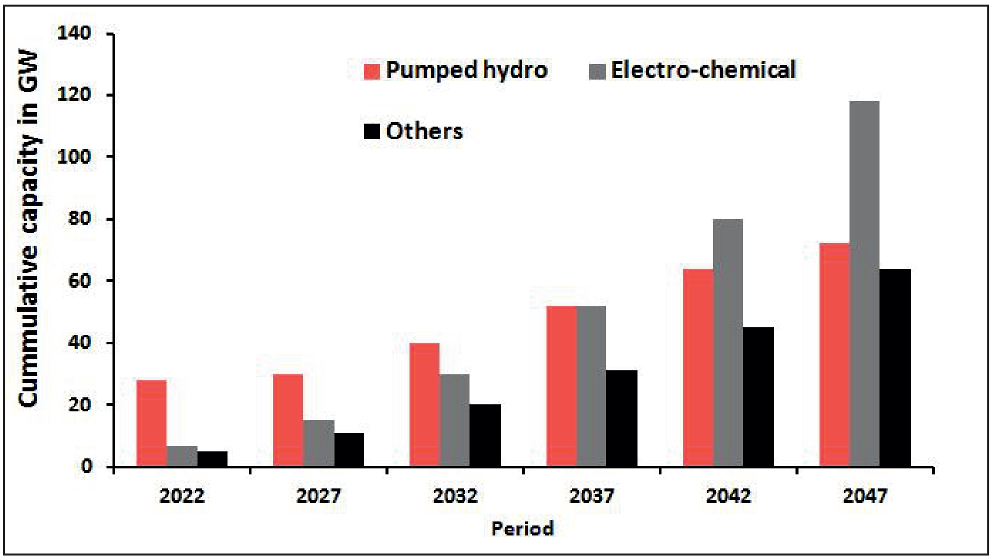
[d] Solar and wind energy are both inherently 'infirm' sources of energy, never available 24/7.

[e] If the gross domestic product (GDP) growth rate averages 8.7 percent, if the share of manufacturing in GDP grows annually by 1.13 percent, and urbanisation increases by 0.7 percent a year.

indicating the energy storage portfolio, categorised into pumped-hydro, electro-chemical, and other technologies in five-year intervals up to 2047 are shown in Fig. 4. According to these calculations, total investment in electro-chemical-based ESSs will surpass that in pumped hydro storage from 2037.

Fig. 4
ESS Portfolio till 2047

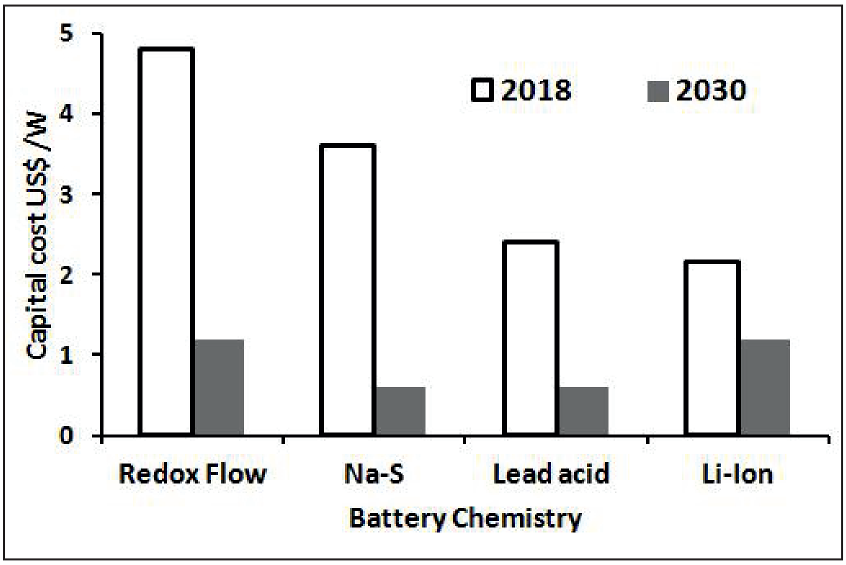


Source: Author's own

Capital cost requirements for electro-chemical-based ESS projects have been computed based on the installed generation capacity requirements predicted using IESS 2047 simulations and the capital cost model for various battery chemistries provided by the World Energy Council.[12] The costs of all electrochemical batteries, be they redox flow, Na-S, lead-acid or Li-ion, are expected to reduce over the decade (see Fig. 5).

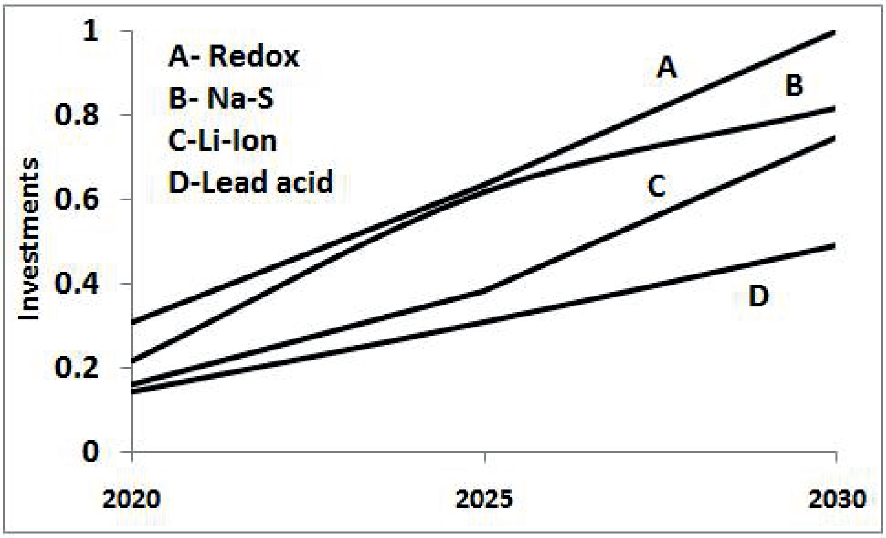
If electrochemical batteries alone are used to meet the ESS demand, total investment required till 2030 on each kind of battery is plotted in Fig.6. Lead-acid batteries are the cheapest, but are low on efficiency and energy density. Li-Ion is expected to be the most cost-effective.

Fig. 5
Capital Cost for Batteries (2020 and 2030)



Source: Author's own

Fig. 6
Comparative Cumulative Capital Costs for ESS, Different Battery Chemistries



Source: Author's own

The advantages of electric vehicles (EVs) are obvious: zero tail-pipe emissions, reduced overall emissions, increased energy security, and higher reliability.[f] The International Energy Agency (IEA) has also noted that EV manufacturing results in around 50-percent lower emissions than that of gasoline vehicles and 40-percent less than diesel ones.[13] Support for EVs from both policymakers and the automotive industry is steadily increasing, with governments mandating zero-emission vehicles, stringent fuel economy standards, and providing fiscal incentives (up to 40 percent in some countries) for EVs. The IEA forecasts that battery demand from EVs will grow 40 times between 2020 and 2040.[14] Globally, in 2020, use of EV vehicles instead of ICE ones lowered emissions by around 30 million tonnes of carbon dioxide ($MtCO_2$).

Table 3
EV and Charging Infrastructure, 2021

Country	% of Global		
	Electric Vehicles (Global stock 3.1 million)	Slow chargers (Total 0.3 million)	Fast chargers (Total 0.11 million)
China	40 %	41 %	74 %
US	24%	12%	6%
Japan	7 %	7 %	7 %
UK	4%	4%	2%
Germany	3%	7%	2%
Rest of the world	20%	29%	9%

Source:International Energy Agency[15]

By 2030, if current EV policies continue, the projected share of EVs in China's total vehicular fleet will be 50 percent, Japan's 37 percent, the US's 30 percent, Canada's 30 percent, and India's 29 percent. The global average is around 22 percent.

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[f] This is because their engines have fewer parts than the traditional internal combustion engines (ICEs).

The IEA releases a 'World Energy Outlook' every year where it analyses the impact of new energy policies enacted by governments, a 'New Policies Scenario' (NPS) of energy consumption. The first column in Table 4 records its global predictions for light-duty EVs (i.e. EV passenger cars) by 2030 made in its 2022 report. There is also a global campaign 'EV30@30', which aims to raise EV sales to 30 percent of global vehicle sales by 2030. The corresponding target figures are provided in the second column.[16]

Table 4

Forecast of EV Penetration and Advantages

Scenario	NPS	EV30
Sales	23 million	43 million
Stock	130 million	250 million
Fuel saving	2.5 million barrels/day	4.3 million barrels/day
Electricity demand	640 terawatt-hours (TWh)	1,110 terawatt hours (TWh)
Emission reduction	170 million tonne carbon dioxide (MTCo$_2$)	240 million tonne carbon dioxide (MTCo$_2$)

A World Health Organization (WHO) report has noted that 14 of the world's 20 most polluted cities are in India, making it all the more imperative for the country to adopt EVs. The National Electric Mobility Mission Plan (NEMMP) 2020, the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) (in two phases, FAME I (2015-19) and FAME II (2019-2024)), and the National E-Mobility Programme are all efforts towards achieving 30-percent EV penetration by 2030.[17]

Table 5
Salient Features of FAME

Category	FAME I (2015-19)	FAME II (2019-24)
Aim	Promotion of affordable and eco-friendly mass transport infrastructure	Electrification of public transport networks
Focus areas	Technology development, demand creation through incentives, pilot projects and building charging infrastructure	Increasing investments in charging infrastructure.

Table 6
Projected Usage of EVs in India by 2030

Mode	Number of vehicles (million)	Average Capacity/ Vehicle Kilowatt hours (kWh)	Total Gigawatt hours (GWh)
2-wheelers	62	1.8	111.6
4 -wheelers	15	15	225
Buses	0.26	212	55
Total			**391.6**

A number of states and union territories have also formulated their own EV policies.

Table 7

Strategies of Select States/UTs to Promote EV Adoption

State/UT	Goal	Strategies
Maharashtra	By 2025, 10 percent of all new vehicles registered should be EVs.	Price reduction of EVs, reimbursement for scrapping old vehicles, waiver of road tax and registration fees for EVS, incentives to manufacturers on extended battery warranty and EV buyback, incentives to service providers to set up charging stations, incentives to entities/start-ups for EV manufacturing, research and development
Delhi	By 2024, 25 percent of all new vehicles registered should be EVs.	Price reduction, reimbursement for scrapping old vehicles, interest subvention on loans, waiver of road tax and registration fees
West Bengal	To be the leading state in EV penetration by 2030.	100 percent state Goods and Services Tax (SGST) reimbursement to private companies to develop hydrogen generation and fuelling stations.
Tamil Nadu	To create a comprehensive EV ecosystem over the next 10 years.	Waiver of road tax and registration fees on EVs, waiver of permit fees on EV auto-rickshaws and taxis, exemption of electricity tax and stamp duty, capital subsidy to private operators/units to set up charging stations and make EV components, reimbursement of SGST to manufacturing units, reimbursement of employer's contribution to their employees' provident fund.

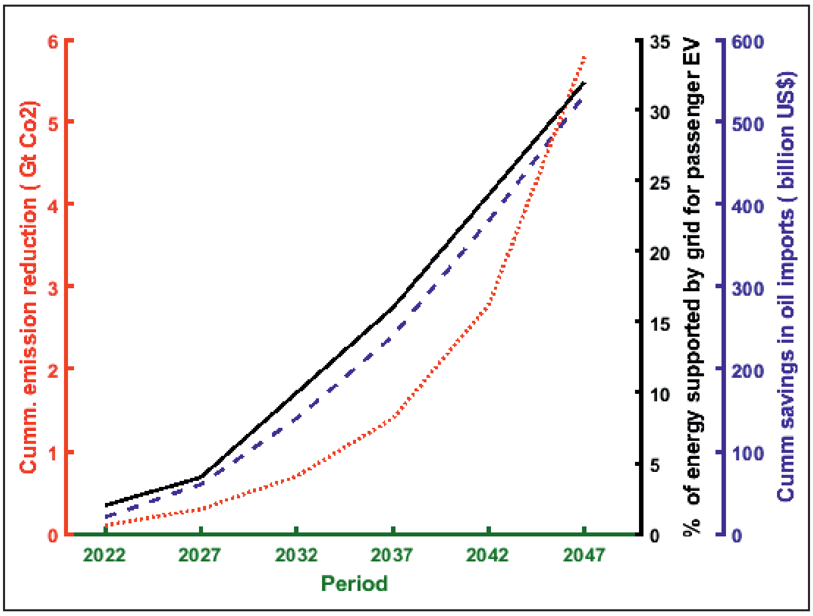
The key challenges in EV adoption are the higher vehicle cost, lack of battery technology know-how, higher battery import cost, less local availability of battery raw materials, and the possible impact of the battery charging infrastructure on electricity demand. Above all, making charging infrastructure widely available is vital; it is expected that this will happen over the next 10 years, putting the total cost of ownership (TCO) of an EV or an ICE vehicle on par. Globally, even today, 33 percent of all EV sales take place in only 14 cities where charging infrastructure is set up.

A key driver of India's national e-mobility programme is the FAME scheme. The second phase, begun in April 2019, focuses on charging infrastructure, allocating US$135 million to establish 2,636 charging stations across 62 cities in 24 states and UTs. In FAME I, charging stations were limited to megacities and national highways with just one public charging station per 3x3 km grid or 100km on national highways.

Many Indian states are also complementing the Centre's efforts with policies to meet local charging requirements. The GST Council (which regulates Goods and Services Tax policies) has reduced GST from 18 to 5 percent for charging stations.[18] Up to early 2023, under the FAME initiative, incentives worth US$ 32 million have been provided by the government, leading to 1.6 million EVs being sold (nearly 1 percent of India's vehicle population). Electric buses deployed so far are at 1,447, while 532 charging stations have been set up. This is estimated to have already saved 200,000 tonnes of fuel and reduced carbon dioxide (CO_2) emission by 400,000 tonnes.

Fig. 7

Growth of Grid-Based EV Charging Infrastructure



Source: Author's own

Using IESS 2047 simulations, it is seen that grid-backed charging infrastructure will support about 10 percent of on-road vehicles by 2030 (energy consumption around 140 TWh), and about 33 percent by 2047 (energy consumption 280 TWh). The rest of the EVs shall be charged using stand-alone captive systems or based on battery-swapping facilities. It will lead to crude oil import savings of US$150 billion by 2030 and US$530 billion by 2047. It will also reduce CO_2 emissions from the road transportation sector cumulatively by 1Gigatonne (1 billion metric tonnes) by 2030 and 5.5Gt by 2047 (see Fig.7).[19]

The current share of ESSs in India in various sectors, and the projected share in 2032, are shown in Table 8.

Table 8
ESS Requirements (2023 and 2032)

Sector	ESS Share by Sector	
	2023	2030
Grid support	19%	13%
Telecom	14%	5%
UPS & data centres	49%	14%
Electric mobility	18%	68%

Source: Indian Smart Grid Forum[20]

Lithium Requirements and Recycling

At present, total global lithium battery production capacity is around 8 GWh/year; factories to start after 2025 are expected to raise it to 35 GWh/year. This will need investments up to US$ 125 billion, which includes setting up 30 large battery manufacturing factories with cumulative capacity of 3.5 TWh by 2030. 'Large' is the operative word, since economies of scale play a key role in lowering costs of lithium battery production. An official study indicated that setting up a Li-Ion battery plant of 5 GWh/year capacity would cost US$ 148/kWh (total cost US$ 5 billion), but one with 200 GWh capacity would need just US$ 84/kWh. India's lithium requirement till 2030 has been estimated at around 0.2 kg/kWh, or 122 kilotons, to realise a total of 609 GWh (391.6 GWh for mobility and 218GWh for power) of energy (Table 6).[21]

Around half the world's lithium and copper production is currently concentrated in areas of high water stress. Lithium mining adversely affects water resources and protection of wetlands, extracting one ton of lithium requires around 2,000 tonnes of water. Mining lithium—and indeed many other strategic and rare metals—can also release toxic by-products. Further, spent lithium batteries, if left untreated, have health and environmental hazards. Thus, recycling Li-Ion batteries is vital.[22] Recycling not only pre-empts the need for disposal but also reduces the need for raw material for fresh batteries. Over 11 million tons of spent Li-Ion batteries will need to be recycled by 2030, but there are relatively few recycling units in place, with merely around 325 Kt per year capacity.[23]

Table 9

Li-Ion Battery Recycling Units (Existing and Planned)

Country	Recycling capacity (Kilotons/year)	
	Existing	Planned
China	188	-
Germany	54	-
France	20	-
Japan	11.7	-
United States	11	40
Canada	9.5	-
South Korea	8	12
Norway	8	-
Belgium	7	-
Finland	4	-
Switzerland	3	-
India	1.5	
United Kingdom	-	10
Australia	-	3
Total	**325 KT/yr**	

Sources: Windisch-Kern et al.;[24] *Baum et al.*[25]

Clear-cut guidelines for collection, storage, transportation, and recycling of spent Li-Ion batteries are still being worked on. It is estimated that by 2025, 9 percent of the total lithium batteries being used—as well as 20 percent of the cobalt batteries—will be recycled. A report by consultancy firm JMK Research and Analytics notes that the Indian Li-Ion battery recycling market is set to grow exponentially, from around 3GWh in 2020 to about 800 GWh by 2030, making recycling a US$1-billion opportunity.

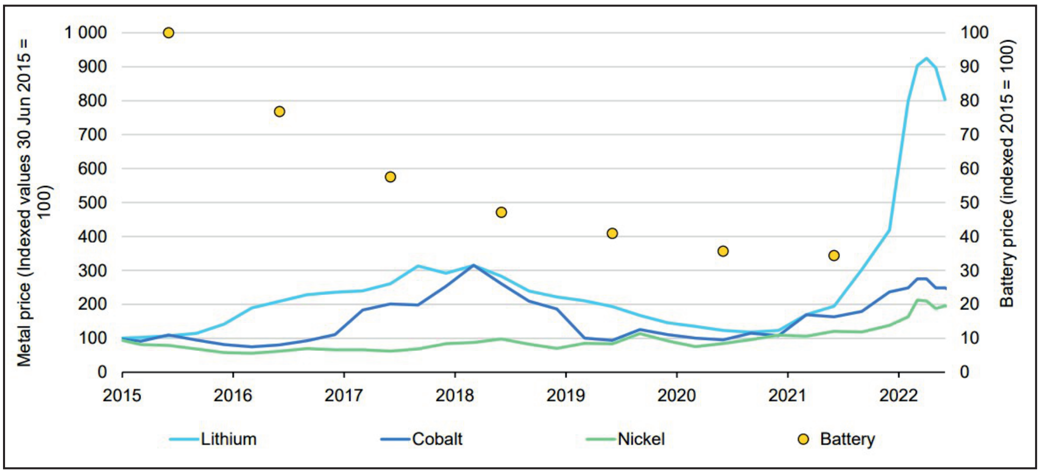
Challenges in Securing Lithium and Cobalt Resources

Raw materials comprise 40 percent of the cost of a battery, while the manufacture and packaging cost 30 percent each. The New Policies Scenario (NPS) maintains that, in the immediate future, Li-Ion batteries will be mostly lithium-nickel-manganese-cobalt (NMC) ones, with the NMC 622 type being 40 percent and the NMC 811 type being 50 percent, while the remaining 10 percent will comprise lithium-nickel-cobalt-aluminium oxide (NCA) batteries. Thus, Li-Ion batteries will also need large amounts of cobalt, manganese, aluminium and nickel, apart from lithium. The global requirement of these, up to 2030, is estimated as follows: cobalt 170 kilotons a year, manganese 105 kt per year, and nickel 850 kt per year. The lithium estimate is 155 kt per year. How accessible are these?

Nickel's global extraction is around 2,000 kt per year, and is mainly used for high-grade steel production. Only a small fraction is used for batteries. As for cobalt and lithium, in 2020, around 6 percent and 9 percent of their total demand, respectively, came from the EV industry. Their prices are currently as follows: manganese US$ 3,000 per ton, nickel US$ 20,000 per ton, lithium US$ 30,000 per ton, and cobalt US$50,000 per ton. The spot prices of cobalt and lithium have increased 2.5 to four times in the last four years (Fig.8),[26] mainly due to speculative stockpiling and strategic sourcing. This, in turn, has pushed battery prices up. The price of cobalt varied between US$40,000 and US$90,000 per ton in the years 2016-19 because of the political instability in the Democratic Republic of Congo (DRC), which caters to 70 percent of the global demand.

Fig. 8

Battery Metal Price Increase and Influence on Battery Price



Source: U.S. Geological Survey[27]

Lithium is called 'white petroleum' because of its growing economic importance. Moreover, lithium, cobalt and nickel resources are concentrated only in a few countries, as shown in Table10. Table 11 lists the top three mineral processing countries for each of these metals. Lithium production increased from 28,000 tons in 2010 to 95,000 tons in 2020.[28]

Table 10
Top Mineral Producing Countries

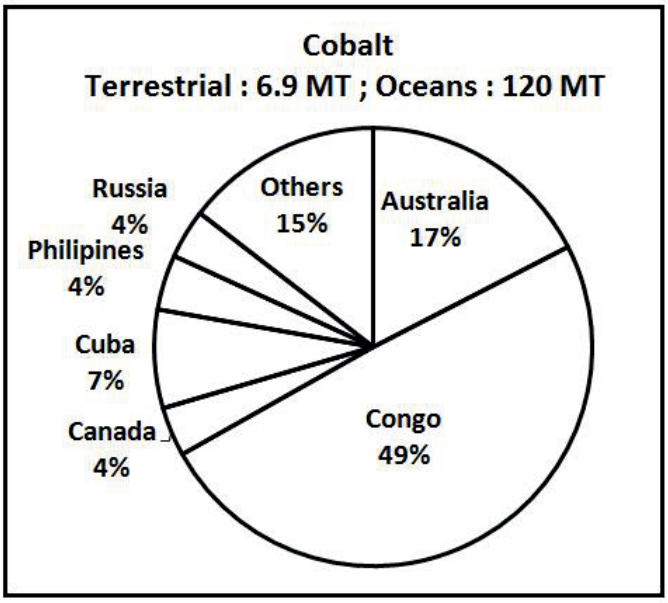
Mineral	Countries (by %)		
	1	2	3
Nickel	Indonesia (33%)	Philippines (10%)	Russia (9%)
Cobalt	Congo (70%)	Russia (7%)	Australia (5%)
Lithium	Australia (50%)	Chile (20%)	China (10%)
Rare earths	China (60%)	USA (15%)	Myanmar (12%)

Table 11
Top Mineral Processing Countries

Mineral	Countries (in %)		
	1	2	3
Copper	China (40%)	Chile (10%)	Japan (6%)
Nickel	China (35%)	Indonesia (10%)	Japan (5%)
Cobalt	China (65%)	Finland (10%)	Belgium (5%)
Lithium	China (55%)	Chile (24%)	Argentina(8)
Rare earths	China (85%)	Malaysia (10%)	-

The geographical distribution of cobalt is shown in Fig 9. The DRC hosts about half of the world's terrestrial cobalt resources, totalling 6.9 million tons. Deep Ocean beds host much more—about 120 million tons of cobalt resources—but nearly all of it is still unutilised.

Fig. 9
Geographic Distribution of Cobalt in Terrestrial Regions

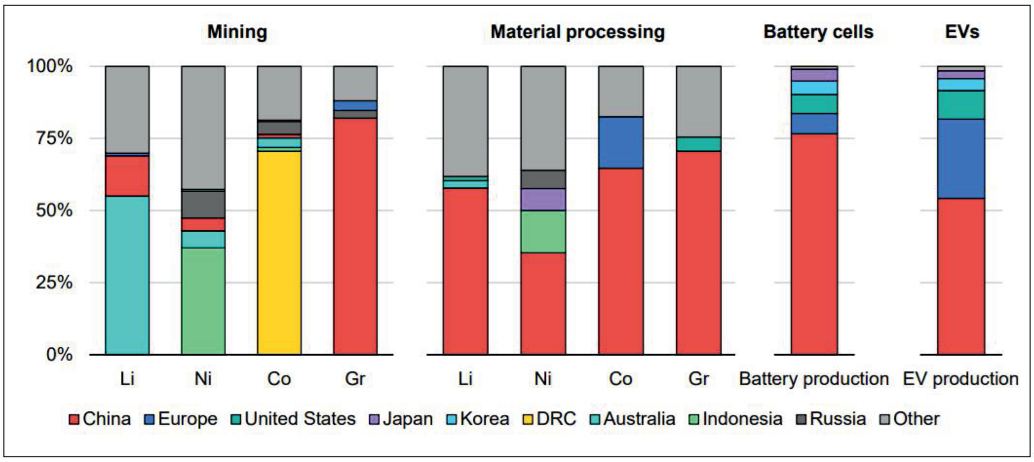


Source: U.S. Geological Survey[29]

The geographical spread of the Li-Ion battery supply chain is represented in Fig.10, with details of where lithium is mined, where it is processed, and where the majority of cells and EVs are manufactured. China is the fifth largest lithium producer globally, but Chinese companies control half of global lithium production and 70 percent of Li-Ion battery production.

Fig. 10

Geographical Distribution of Global EV Battery Supply Chain



Source: International Energy Agency[30]

Where does India stand? India has the largest manganese ore reserves in the world after Zimbabwe. Estimated reserves of manganese ore are 406 million tons, of which 104 million tons are proven, 135 are likely, and 167 are potential. It has 189 million tons of nickel, 93 percent of which is in one state, Odisha. Lithium resources are estimated at around 1,600 tons. Exploratory work to extract lithium is underway in several states, such as the brine pools of Rajasthan and Gujarat, the mica belts of Odisha and Chhattisgarh, and the Mandya region of Karnataka. The Ministry of Mines has created a joint venture of three companies[g] to form Khanij Bidesh India Ltd (KABIL), which seeks to acquire and develop strategic mineral assets overseas, especially lithium and cobalt, the latter of which India has no deposits at all. In February 2023, India announced the discovery of a 5.9-million-tonstash of lithium reserves in Reasi district of Jammu and Kashmir.

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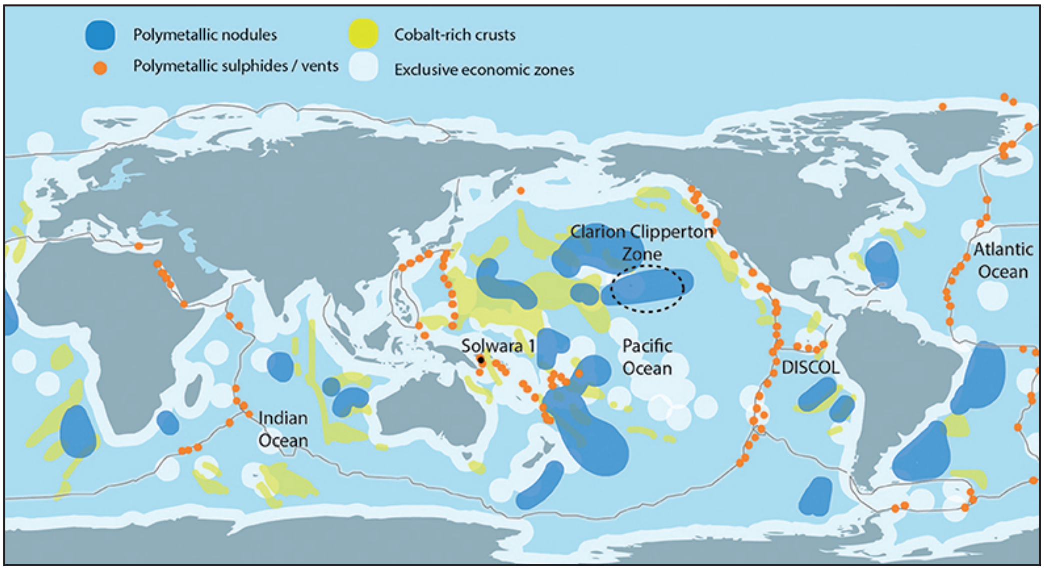
[g] These are the National Aluminium Company (NALCO), Hindustan Copper Ltd (HCL) and Minerals Exploration and Consultancy Ltd (MECL).

Underwater (blue) mineral resources include seafloor poly-metallic sulphides (which often contain copper) around hydrothermal vents,[h] cobalt-rich crusts on seamounts,[i] and poly-metallic manganese nodules on abyssal plains.[j] Potential sites for cobalt crust mining include the waters around the US owned Johnston Island's Exclusive Economic Zone, French Polynesia, the Republic of Kiribati, the Federated States of Micronesia and the Marshall Islands, all of them in Pacific Ocean (Fig.11). Poly-metallic nodule accumulations have been discovered in parts of the Pacific—the Clarion-Clipperton Zone (CCZ), the Penrhyn Basin, the Peru Basin—and in the Central Indian Ocean Basin (CIOB). However, given the environmental damage their mining can cause, eco-friendly methods of mining will first have to be developed.[31]

Fig. 11

Mapping the Main Marine Mineral Deposits



Source: Vedachalam, Ravindran, and Atmanand[32]

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[h] These are jet sprays from the ocean's crust caused by salt water percolating inside and often contain valuable minerals.

[i] Undersea mountains

[j] A plain along the ocean floor

The United Nations International Seabed Authority has issued 27 contracts, covering an area across the globe of more than 1.4 million square km, to various countries for mineral exploration, and to develop rules for commercial mining.

The economics of offshore mineral extraction depends on the harvesting technology used, the grade and tonnage of minerals obtained, and the oceanographic conditions. Technologies for seabed soil characterisation and crawler-based mining machines have been developed in countries such as India, Belgium and Spain, including India's Varaha, Belgium's Patania-II and Spain's Apollo II. The 35-ton Patania-II has demonstrated its operational capacity at a depth of 4,500 metres in the CCZ where it picked up the manganese nodules. The Apollo-II prototype has been tested off the coast of southern Spain over several kilometres of straight and curving soft muddy seabed, where it proved effective, but also brought some critical issues to light which will need further attention. Belgium is scheduled to launch Patania III in 2024 which will have a 'riser and lift' system to bring the extracted nodules to a surface vessel. India's Ministry of Earth Sciences-National Institute of Ocean Technology (MoES-NIOT)[33] has tested India's mining machine Varaha at a depth of 5,270 metres in the CIOB, where it was manoeuvred effectively across soft sediments and in deep waters. MoES-NIOT is augmenting Varaha with a crusher and high-capacity pump. The 6000m depth-rated Remotely Operated Vehicle (ROSUB6000) and 6000m depth-rated Autonomous Underwater Vehicle Ocean Mineral Explorer (OMe 6000) of MoES-NIOT enables sustained deep-ocean mineral exploration. Under the Deep Ocean Mission program, India is presently developing a 6000m depth-rated manned scientific submersible (Matsya6000) for enabling deep-ocean human missions and carrying out precise mapping of the deep-ocean mineral resources.[34]

With mining capacity demonstrated, the Environmental Impact Assessment (EIA) report to be submitted by these governments to the International Seabed Authority is awaited. A comprehensive seabed mining code for the seas beyond national jurisdictions will also have to be developed.

Conclusion

Recent assessments of battery technologies suggest that Li-Ion batteries will be the most used batteries for energy storage in the coming decade. To achieve India's ambitious climate goals, it needs effective policies to increase deployment of energy storage, both in the power sector and in electric mobility. It needs incentives to bridge the price gap between conventional vehicles and EVs, to build more charging stations, bring about standardisation, and maximise the economic value of lithium batteries by encouraging recycling, which will also promote environmental sustainability. However, it must ensure that the transition is smooth with minimal impact on the economy and employment. Investments in large-scale battery manufacturing facilities have been announced which will reduce the cost of batteries. Looking for lithium resources within India, and at the same time making strategic investments in mines overseas, are both essential.

At present, global Li-Ion battery installed capacity is around 500GWh—72 percent in China, 13 percent in the rest of Asia, 9 percent in North America, and 6 percent in Europe. It is predicted to rise to 3,000GWh by 2030, with China's share coming down to 67 percent and the rest of Asia's to 5 percent, while that of Europe and North America increases to 17 percent and 11 percent, respectively. The geographic distribution of the global Li-Ion battery supply chain and the strategic investments of high-lithium demand countries in mining operations are bound to impact pricing and competition.

China's domination of the global lithium chain is apparent. Though it is only the fifth largest lithium producer, it controls half of global lithium production. Other nations are also hard at work, to be sure. Japan has allocated around US$ 1 billion to subsidise distributed battery storage and energy-efficient technologies. It subsidises 66 percent of the cost for homes and businesses that install Li-Ion batteries. It hopes to produce half the world's batteries in the coming decade. The UK has announced the Faraday Challenge which involves an investment of US$ 0.32 billion on battery research. The US Department of Energy is investing US$8.7 million in research on commercially scalable manufacturing processes for both anodes and cathodes.

Conclusion

As for India, it imported Li-Ion batteries worth US$ 1.2 billion during 2018-22, which is expected to increase by around 50 percent by 2030. This needs to be reduced, and the government has started discussions with leading giga-battery manufacturers to set up production facilities in India. One US firm is investing US$ 500 million in a battery pack production facility in Gujarat.

Both automotive and cell manufacturers in India are still learning. It is essential to diversify India's battery portfolio, especially since its indigenous supply of both lithium and cobalt are currently negligible. Both the government and the private sector need to invest in research on alternative battery technologies, such as sodium-ion if India is to achieve its goal of net-zero emissions by 2070 as promised at the Glasgow Conference of Parties (COP) on climate change in 2021.

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