EVALUATING THE

ELECTRIC VEHICLE BATTERY SUPPLY CHAIN

AND SCOPE OF INDIGENIZATION

MAKE IN INDIA

International Copper Association India
Copper Alliance

Customized Energy Solutions
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10 YEARS IESA
India Energy Storage Alliance

Evaluating the Electric Vehicle Battery Supply Chain and Scope of Indigenization

Submitted to

International Copper Association India (ICAI)

Submitted by

Customized Energy Solutions India Pvt. Ltd

On behalf of the

India Energy Storage Alliance (IESA)

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1 Introduction

Electric vehicles (EVs) play a vital role in achieving the country's net zero-emission goals. The government of India has set an ambitious target for EV deployment by 2030 and beyond. The key components in an EV comprise— a battery, powertrain (motor, powertrain), chassis, etc. a battery has the maximum cost-share (45-50%) in the total vehicle, followed by the powertrain cost (15-20%). Further, the battery cells and motor are the key components in a battery and powertrain. The key components/materials used in making cells/batteries and motors are currently imported.

To fulfill future demand for batteries and motors in the EV deployment, the country needs to develop a complete value chain domestically. To develop the indigenous battery ecosystem, the government of India has announced a target of 50 GWh advanced cell chemistry (essentially Lithium-ion batteries) and 5 GWh niche battery technology manufacturing by 2024. In a recent development, three companies have signed the production-linked incentive (PLI) agreement to kick-start building ACC battery Giga factories in the country. A production-linked incentives scheme has been introduced to support these manufacturing plants.

Most equipment and raw materials will be imported to set up these large-scale manufacturing plants. Therefore, it requires a detailed analysis of India's existing battery and EV motor manufacturing ecosystem and its preparedness for large-scale manufacturing. There is a need to strategize— the raw material supply chain, technology transfer, and R&D to develop new and innovative technologies and equipment, financial framework, policy and regulatory framework, skill development programs, etc., to support domestic manufacturing. Therefore, through this collaboration, International Copper Association India (ICAI) and India Energy Storage Alliance will identify the crucial gaps associated with the domestic manufacturing of batteries, EV motors, and related components and recommend suitable solutions.

This report outlines India's current ACC battery manufacturing supply chain ecosystem. It includes estimating the short-term and long-term demand for ACC batteries in the Indian market, examining the current and future share of various battery chemistries in the global and Indian EV market, applications, and demand of copper in EV components (batteries and motors), characterization of existing ACC battery chemistries, identifying challenges in the supply chain of ACC battery manufacturing w.r.t. manufacturing, raw material availability, technology availability, policy and regulatory, etc. It also covers the existing safety standards across the battery manufacturing value chain. The report's last section provides recommendations to address the policy gaps in the current battery manufacturing ecosystem.

These aspects will be discussed in detail in the following sections of this report.

2 Global Demand for Advanced Chemistry Cell Batteries

With the increased focus on reducing greenhouse gas emissions, the demand for green transportation and renewable energy will increase significantly. To fulfill the increasing demand, the market for ACC batteries is expected to grow considerably in the coming years. The estimations by CES suggest that around 1300 GWh and 3000 GWh of ACC batteries would be needed by 2025 and 2030. Figure 1 provides the trend in global demand for ACC batteries and the share of respective market segments in the projected capacity.

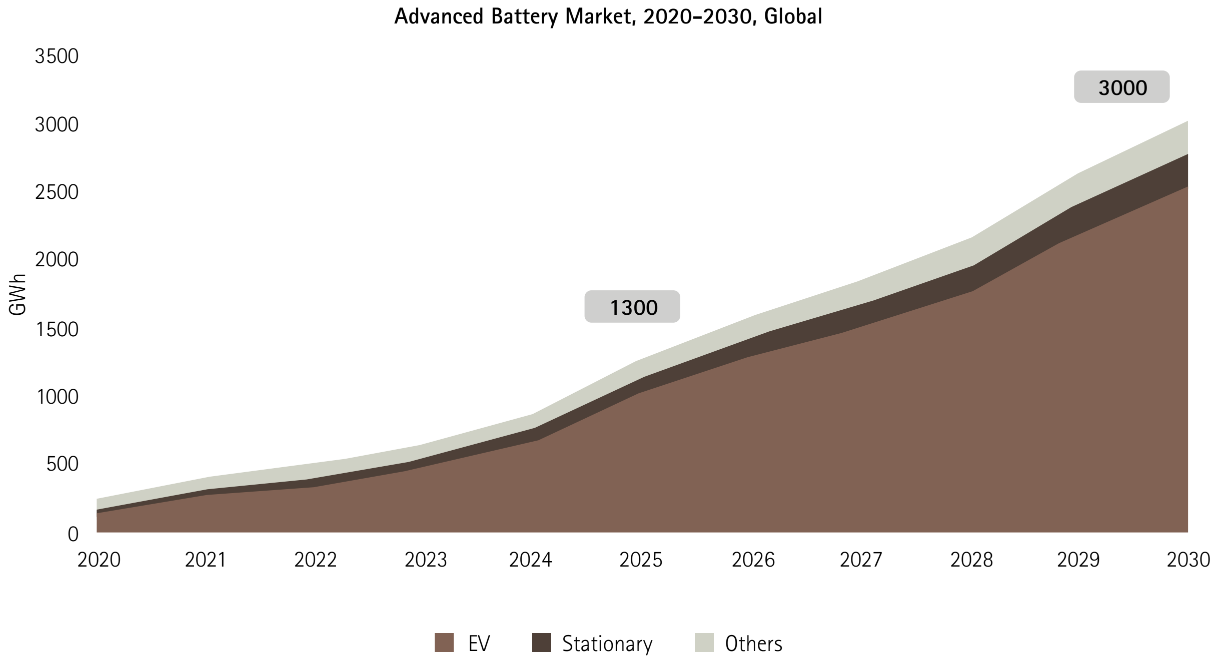


Figure 1: Trend in the Global ACC market by 2030

- The ACC battery market is expected to grow at a CAGR of ~29% by 2030.
- The total market will likely be at 1300 GWh by 2025 and 3000 GWh by 2030.
- The Electric Vehicle market will have a share of ~82% in the total battery capacity.
- The other application in the chart includes power tools, electronic gadgets, etc.

2.1 Key Drivers for the Growth in the EV Sector

- Global EV Initiative (EVI) has contributed significantly to the accelerated growth of EVs in past years. It is a multi-governmental policy forum that facilitates a knowledge-sharing platform to boost EV deployment.
- Sales of electric cars have increased manifolds in 2021. It accounted for ~9% of the global car market share in 2021, four times the market share in 2019. This growth was driven by China and Europe with a total market share of ~85%, followed by the U.S at a 10% share of global electric car sales.
- Consumer and government spending increased in 2022. Consumer spending increased eight times to ~250 USD billion in the last five years. Similarly, the government has spent around USD 30 billion in the form of subsidies, tax duty waivers, etc.
- New electric vehicles with enhanced driving range are being introduced in the market. Around 450 electric car models were introduced in 2021.

2.2 Technology-wise split of Advanced Chemistry Cell Batteries

The figure below shows the future trend in the technology for advanced battery chemistries. The trend indicates that nickel-rich cathode chemistries and a blend of both will dominate the market in the coming decade.

- The mainstream technology, NMC 532/622, will continue to dominate the market till the inception of other high Nickel chemistries between 2024-2026. On the contrary, Cobalt-rich chemistries such as LCO and NMC 111 will lose their market share due to the high cost associated with Cobalt.
- The solid-state, fully/semi-dry electrolyte chemistries will gain a marginal share in the coming 5-10 years. However, the mass production of solid-state batteries for EVs will be possible after 2030.
- The LFP chemistry is expected to gain a significant market share as some new and emerging technologies, such as blade cells, cell-to-pack, etc., will attract a significant market share in passenger BEVs.
- Chemistries such as LMO/LTO shall grow in the next ten years due to increasing applications in low-priced BEV, PHEV, and HEVs.
- The research and development efforts in developing cheaper materials (High Mn NMC, Sulfur) for cathode materials should see a marginal increase in their market share over the next ten years[1].

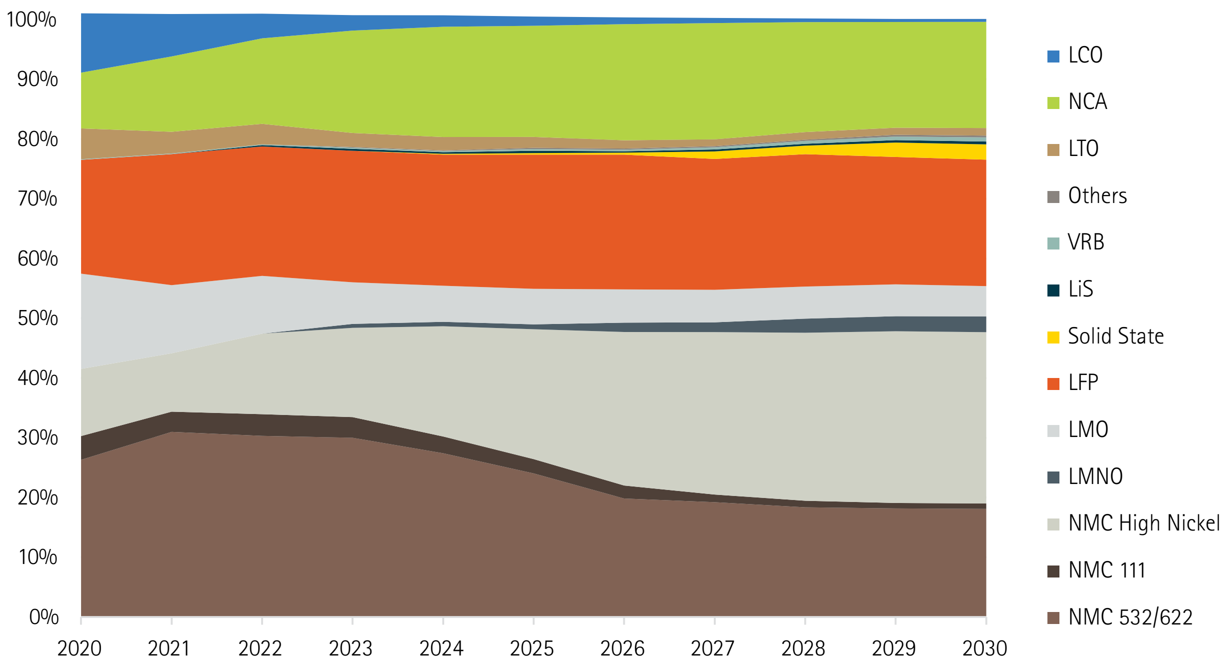


Figure 2: Technology-wise split of various battery chemistries by 2030

2.2.1 Key EV OEMs and battery specifications

The table below shows the market share of battery chemistry in the four-wheeler EV segments. The market is dominated by Nickel based chemistry, followed by LFP and LMO[2].

[1] Source: CES and IESA analysis

[2] The Latest Trends in Electric Vehicles Batteries - PubMed (nih.gov)

Table 1: Key Global EV OEMs and their battery specifications

EV Models	Battery Producer	Voltage (V)	Capacity (Ah)	Battery Chemistry
Nissan LEAF	AESC	3.65	56.3	NMC
Renault Zoe e-tech electrique	LG Chem	2.08	130	NMC
Smart fortwo Electric	LG Chem	3.65	52	NMC
Volvo XC40	LG Chem	-	-	NMC
VW e-Golf	Samsung SDI	3.70	37	NMC
Tesla Model S	Panasonic	3.60	3.4	NCA
Tesla model 3	Panasonic	3.60	4.75	NCA
Audi e-tron GT	LG Chem	3.65	64.6	NMC
BMW i3	Samsung SDI	3.68	94	NMC
Hyundai KONA Electric	LG Chem (Umicore)		60	NMC
Kia Niro	SK Innovation	3.56	180	NMC
Mitsubishi iMiEV	Li Energy Japan	3.70	50	LMO

Requirement of crucial metals by 2030

The chart below shows the ratio of crucial metal requirements in 2030 compared to 2021 in advanced cell chemistry batteries.

- The requirement for Nickel, graphite, Aluminium, and copper will increase significantly.
- With the adoption of high nickel content chemistries, there is a 16 to 17-fold increase in the requirement for Nickel.

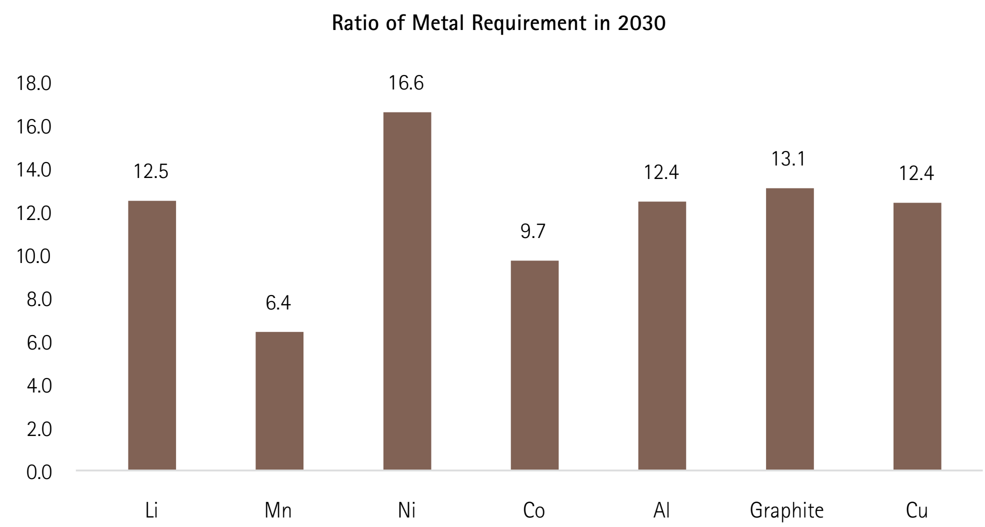


Figure 3: Ratio of crucial metals in batteries by 2030

The figure below provides an estimate of the critical metal requirements (in tons) in ACC batteries by 2030. The copper demand will increase to 1,791,000 tons from 138,000 tons in 2020.

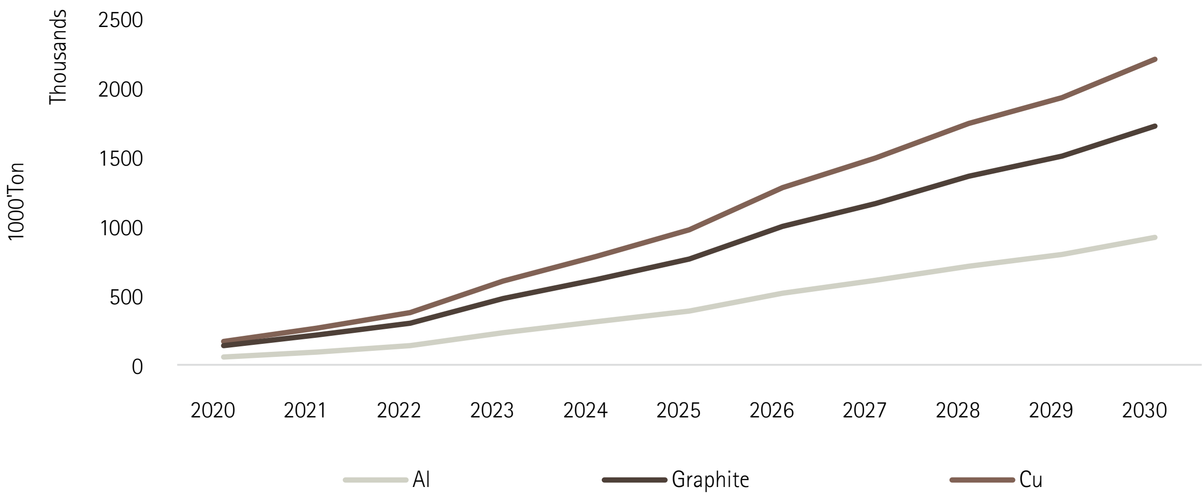


Figure 4: Requirement of critical metals by 2030

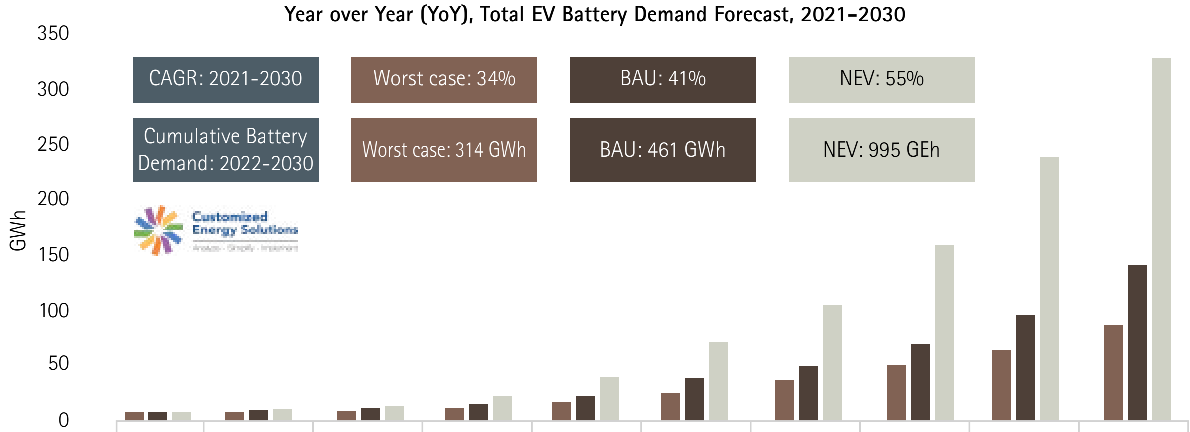
3 Indian Demand for Advanced Chemistry Batteries

The demand for batteries in the EV sector will range between 314 GWh to 995 GWh by 2030. The range is defined based on three different scenarios[3]. These scenarios are explained below.

Worst case scenario:	Business as usual:	National EV Scenario (Best case):
the growth in the EV sector will be slow, and hence the total demand for batteries will be ~314 GWh. Li-ion batteries will comprise 257 GWh of the market share.	the same growth trend will continue, and around 461 GWh batteries will be required. Li-ion batteries will comprise 406 GWh of the market share. Figure 1 and Figure provide the trend in the battery demand growth in EV segments between 2021-2030.	under the national EV scenario, the market is envisaged to proliferate owing to the policy support from the government. Demand for 995 GWh batteries is estimated by 2030. Li-ion batteries will comprise 941 GWh of the market share.

As per the CES estimates, the EV market tends to grow at a CAGR of ~42%, ~49%, and 63% under the worst case, business as usual, and NEV scenarios between 2021 to 2030. Similarly, the battery demand will grow at a CAGR of 34%, 41%, and 55% in the scenarios mentioned above. The following points may contribute to this growth.

- Government Policies and subsidy programs to incentivize the upfront costs
- Increasing fuel prices and consumer awareness about the benefits of EVs
- Advancements in EV technology and entry of new market players
- Implementation of stringent emission norms (CAFÉ norms from 2022) and commitments from fleet aggregators, e-commerce companies, and corporates will drive the sales
- A continuous reduction in battery prices has helped significantly reduce the upfront costs of EVs. EVs are expected to reach parity with ICE vehicles by 2024-2025.
- Other factors, such as advancements in EV technology, local manufacturing, economies of scale, etc.

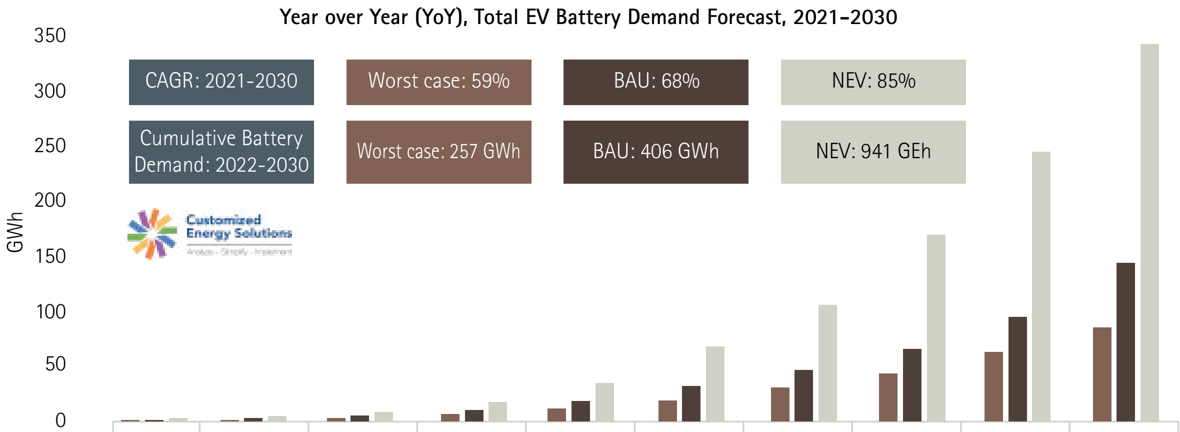


	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Worst Case	6.5	8.1	9.8	13.0	17.0	26.0	37.0	50.0	65.0	88.0
BAU	6.5	9.0	12.0	16.0	24.0	40.0	51.0	70.0	97.0	142.0
NEV	6.5	10.0	14.0	23.0	40.0	72.0	106.0	160.0	240.0	330.0

Worst Case BAU NEV

Figure 5: Trends in EV Battery market by 2030

[3] Source: CES and IESA analysis



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Worst Case	1.3	2.4	3.7	6.9	11.0	19.0	30.0	42.0	60.0	82.0
BAU	1.3	3.4	6.0	10.0	18.0	31.0	45.0	64.0	91.0	136
NEV	1.3	4.4	8.3	17.0	33.0	65.0	100.0	160.0	230.0	324.0

Worst Case BAU NEV

Figure 6: Trends in Lithium-ion battery market by 2030

E-Two wheelers (2W) and E-four wheelers (4W), followed by three-wheelers (3W), will drive the market growth for ACC batteries in the EV sector. The figure below provides a break-up of the estimation of battery market demand by various segments in the EV sector.

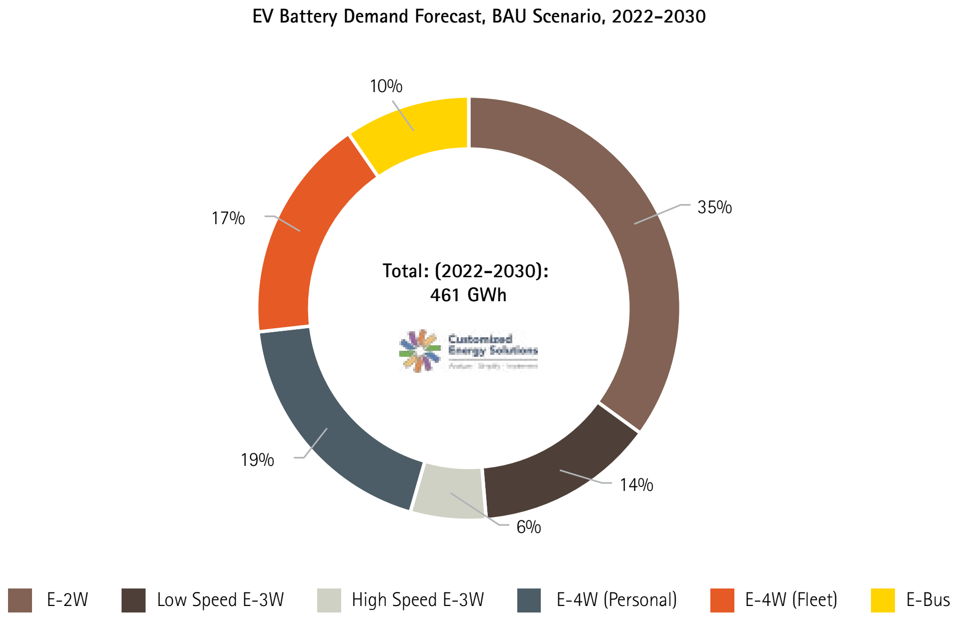


Figure 7: Demand forecast for EV batteries in various segments

3.1 Technology-wise split of Advanced Chemistry Cell Batteries

Two Wheelers (2W) Segment: The battery market share for the 2W segment was dominated by NMC chemistry (~70%), followed by LFP and NCA chemistries with a market share of ~30%. The figure below shows the split of various battery chemistries in the 2W segment.

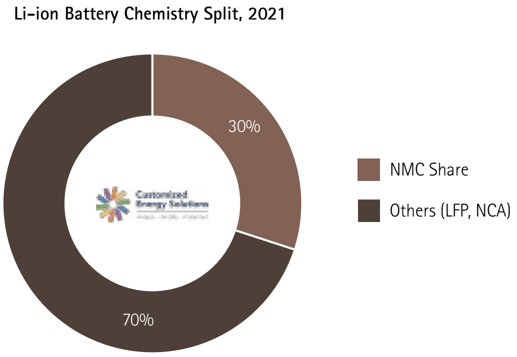


Figure 8: Market Share of Lithium-ion batteries in the 2W segment

3.1.1 Key EV OEMs and battery specifications

The Key OEMs engaged in 2W manufacturing with the specifications of batteries are provided in the table below.

EV OEMs	Model	Pack Voltage (V)	Capacity (Ah)	Battery pack size (KWh)	Battery Chemistry
Bajaj	Chetak Electric	48	63	3	NCA
TVS	iQube	48	54	2.25	NMC
Ather	450X	51.1	57	2.9	NMC
Revolt	RV 400	72	44	3.2	NMC
Jitendra	JMT 1000 HS	60	34	2	NMC
	Aura	72	40	2.9	NMC
Pure	ePluto	60	42	2.5	NMC
Kabira Mobility	KM3000	60	74	4.4	LFP
OLA	S1 Pro	48	83	3.97	NMC

EV OEMs	Model	Pack Voltage (V)	Capacity (Ah)	Battery pack size (KWh)	Battery Chemistry
Okinawa Scooters	R30	48	28	1.34	NMC
	Ridge+	60	29	1.74	
	Praise Pro	72	28	2	
	I-Praise+	72	46	3.3	
Ampere By Greaves	Rio Series	48	28	1.3	NMC
	Magnus	60	30	1.8	
	Zeal EX	60	28	1.68	
Hero Electric	Optima HX	51.2	30	1.53	LFP
	Photon HX	72	26	1.87	LFP
	NYX N23a	50.4	38	1.9	NCA
	N61a	50.4	43	2.17	NMC
Tunwal E-Vehicles	Strom ZX	60	26	1.56	NMC
	Mini Lithino	48	26	1.2	NMC

Three Wheelers (3W) Segment

India's three-wheeler (3W) segment is categorized into low-speed and high-speed 3Ws. The low-speed segment is dominated by lead acid batteries (~98%), and the remaining is Lithium-ion batteries (2%). For the high-speed 3Ws, LFP chemistry with prismatic form factor dominated the market with an estimated share of 70%, followed by NMC chemistry (30) %. In the case of the battery-swapping models, NMC is the most prevalent chemistry. The figure below provides the percentage share of various chemistries in 3W segment.

Batery Chemistry Split: High Speed e-3W

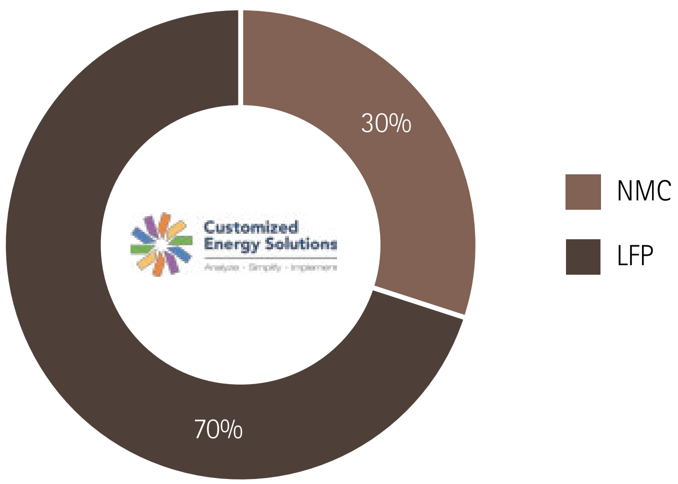


Figure 9: Market Share of Lithium-ion batteries in the High-Speed 3W segment

Key EV OEMs and battery specifications

The Key OEMs engaged in 3W manufacturing with the specifications of batteries are provided in the table below.

EV OEMs	Model	Pack Voltage (V)	Battery pack size (KWh)	Battery Chemistry
Mahindra ELECTRIC	Treo Yarri (e-rickshaw)	48	3.7	LFP
	Treo (e-Auto, L5M)		7.4	
	Treo Zor (e-Auto, L5M)		7.4	
KINETIC GREEN	Kinetic Safar (e-rickshaw)	48	3.1, 4.1	LFP
	Kinetic Safar Star (L5N)		4.2	NMC
	Kinetic Safar Jumbo (Pickup)		8.2	LFP
PIAGGIO	Ape E-City (L5M, Swappable)	48	4.5 (1.5*3)	NMC
	Ape E-City FX (L5M, Fixed)		7.5	
	Ape E-City Extra (L5M, Fixed)		8	
	Urban ET (L5M)	48	4.8	LFP
	Taskman Cargo (L5N)		7	
YC ELECTRIC VEHICLE	Yaatri Super (e-rickshaw)	48	4.3	LFP

Four-Wheeler Segment

For the 4W EV segment in India, the battery market was dominated by LFP chemistry with a share of 71%, followed by NMC chemistry (29%). Leading players like Tata Motors and Mahindra are using the LFP chemistry, while players like MG, Hyundai, and Audi are using battery packs with NMC chemistry.

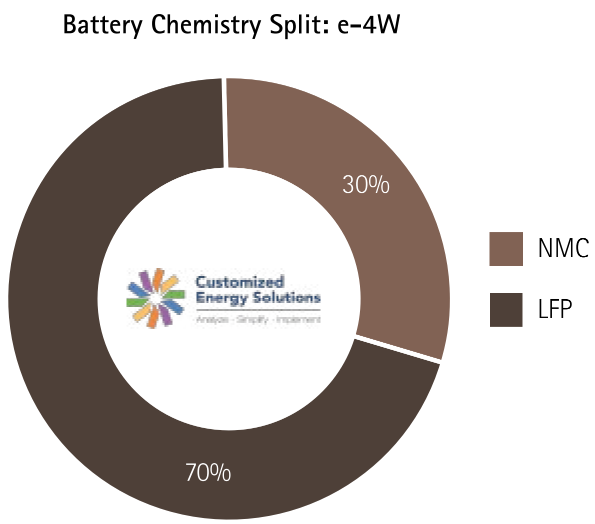


Figure 10: Market Share of Lithium-ion batteries in the 3W segment

Key Takeaways:

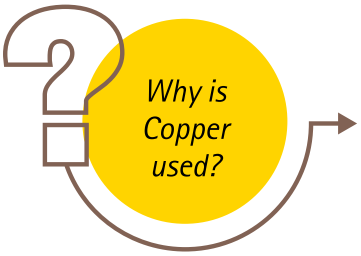
- Demand for ACC batteries will increase significantly in the global and Indian markets.
- Electric vehicles will have a significant (~80%) share in the battery market demand.
- The mainstream Lithium chemistry, NMC, will dominate the market in the coming decade, followed by LFP chemistry.
- The key global and Indian EV OEMs have deployed NMC and LFP chemistry-based batteries.

Actions Required:

With the increasing demand for ACC batteries, it is crucial to evaluate the preparedness of the battery industry in terms of manufacturing capabilities, raw materials supply chain, technology availability, policy and regulations, skill requirement etc.

4 Applications of Copper in Lithium-ion Batteries

Copper is used in collector foil, electrical tabs, connections, and functional items in a cell.



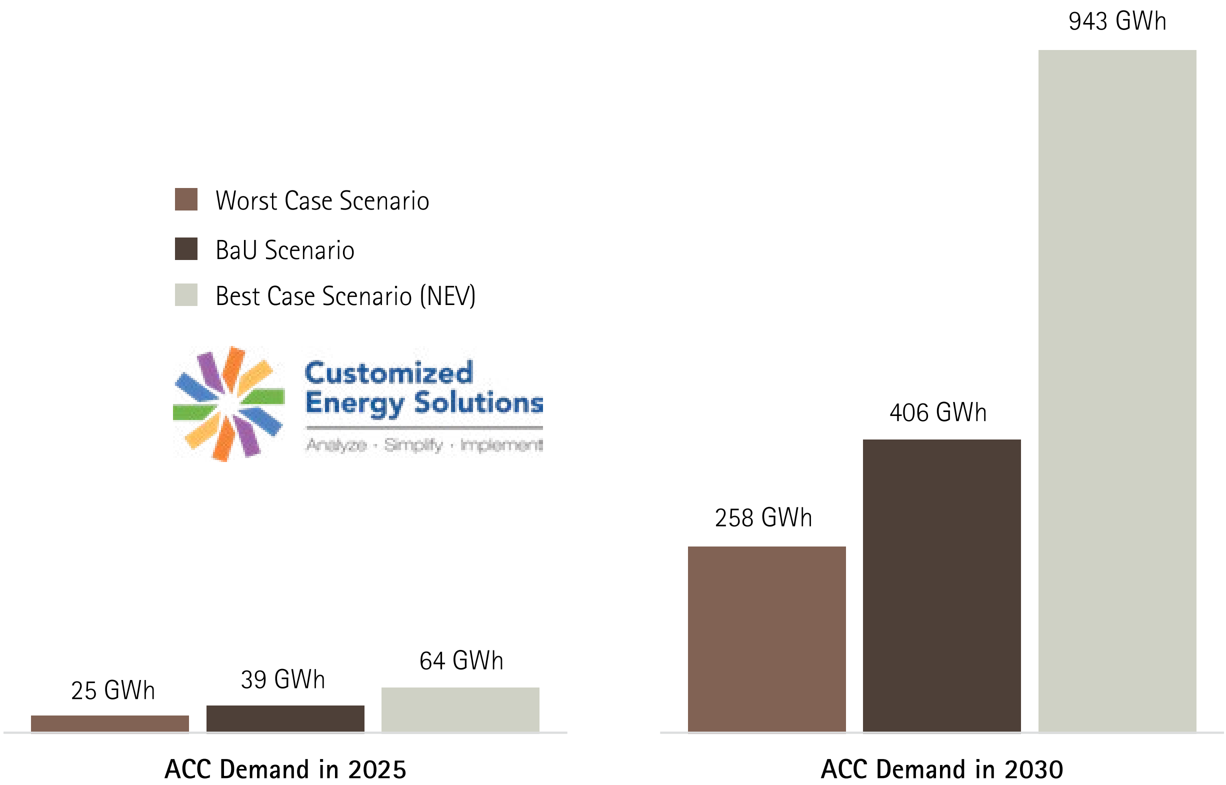
- Offers good conductivity (nearly as conductive as silver)
- Better ductile properties
- Affordable in terms of price compared to other metals (Gold, Silver, etc.)

4.1 Copper Requirement in Batteries

It is reported that 0.2 to 0.4 kg of copper is used per kWh of Lithium-ion cells. The detailed assumptions used in the calculations are as follow:

Lithium Cell Chemistry	Copper requirement (kg/kWh)
NMC	0.2
LFP	0.4

ACC battery demand used in the calculations for copper foil in LiBs is provided below:



Based on the battery demand for EVs by 2025 and 2030, the figure below provides the estimated quantity of copper in Li-ion batteries[4].

- In the worst-case scenario, around 5,000 to 10,000 and 51,000 to 129,000 tons of copper would be required by 2025 and 2030.
- In the BaU scenario, around 7,700 to 19,000 and 81,000 tons to 162,000 tons of copper would be required by 2025 and 2030.
- In the best-case scenario (NEV), around 12,800 to 25,600 and 188,000 tons to 376,000 tons of copper would be needed in Li-ion cell manufacturing for EV applications by 2025 and 2030.

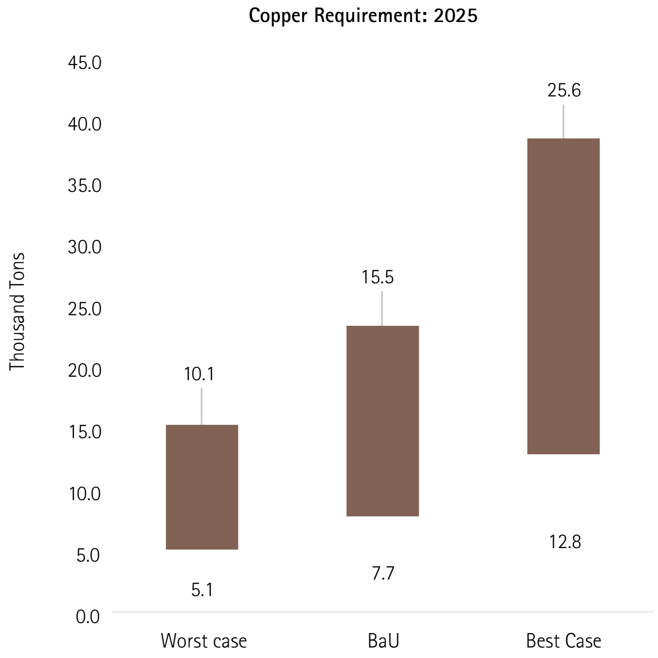


Figure 11: Copper Requirement in ACC batteries by 2025

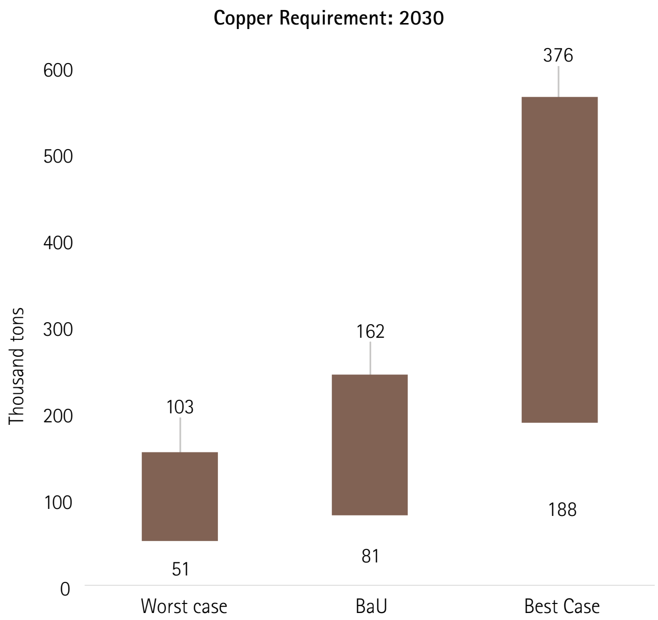
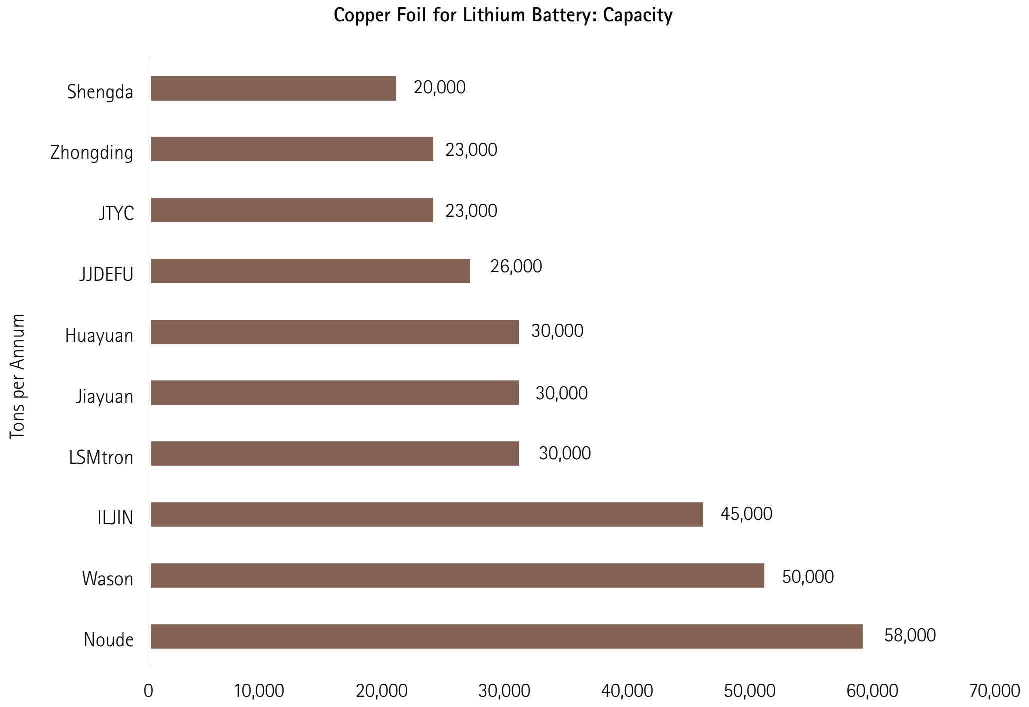


Figure 12:Copper Requirement in ACC batteries by 2030

[4] Source: CES and IESA analysis

Global Production of Copper foil for Lithium Batteries

With the increasing demand for copper in ACC batteries, the capacity of copper foil production is also increasing globally. In 2022, the top 10 companies have around 335,000 TPA installed capacity for copper foil production for Lithium battery applications. The figure below provides the details of the top 10 global companies that were engaged in copper foil production. It can be observed that ~80% of the copper foil capacity is put up by Chinese companies, followed by ~20% of Korean manufacturers.



Trends in Copper Foil Thickness

The global trend in copper foil thickness shows the current standard is around 6 µm. The figure below shows that over the years, it has reduced from 12 µm to 6 µm. Some of the Chinese companies are working on lesser than 4 µm[5].

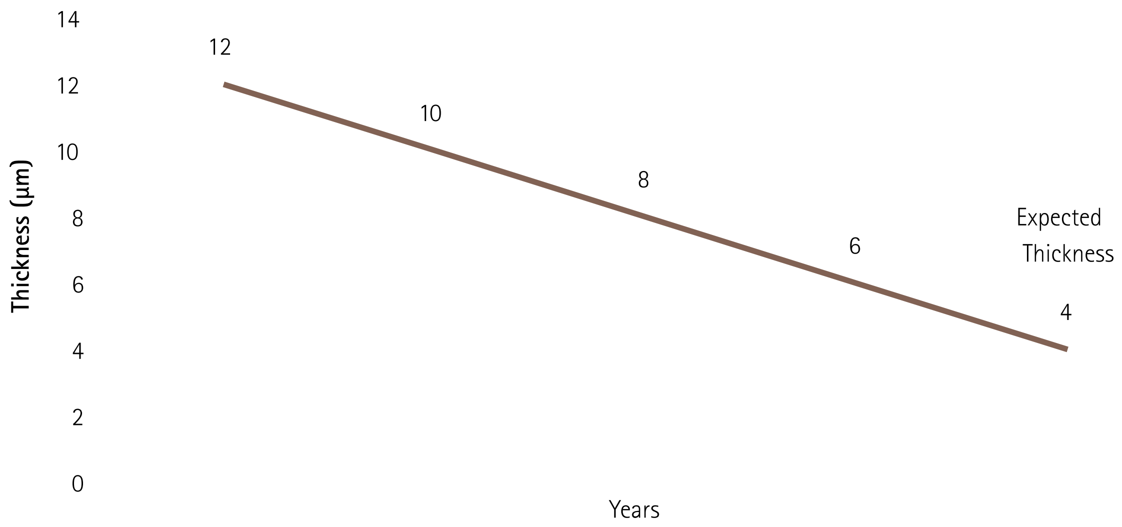


Figure 13:Trend in Copper Foil Thickness (µm)

[5] https://www.takomabattery.com/lithium-battery-current-collector-material-copper-foil-and-aluminum-foil

Key Takeaways:			
Copper comprises around 7% of the total weight of an ACC battery.	The demand for copper will increase at a CAGR of ~55% by 2030. Around 188,000 to 376,000 tons of copper will be needed in LiB cell manufacturing by 2030.	The current global standard for battery-grade copper foil thickness is 6 µm. Presently, the copper foil for domestic LiB cell manufacturing is imported.	Chinese companies dominate battery-grade copper foil production.

Actions Required:
Need to assess the gaps in the Indian copper manufacturing industry and recommend suitable solutions to address the bottlenecks to facilitate battery-grade copper foil manufacturing.

5 Mapping of Battery Upstream Supply Chain Players in India

The ACC battery manufacturing value chain has six stages (mining to recycling). Figure 1 provides a schematic representation of the ACC supply chain levels. The upstream level of the supply chain includes the mining and processing ores into critical metals. The middle stream consists of the materials that can further be processed for applications in cathode, anode, electrolyte, and separator. The downstream level comprises the production of cells, battery pack, and recycling of used batteries.

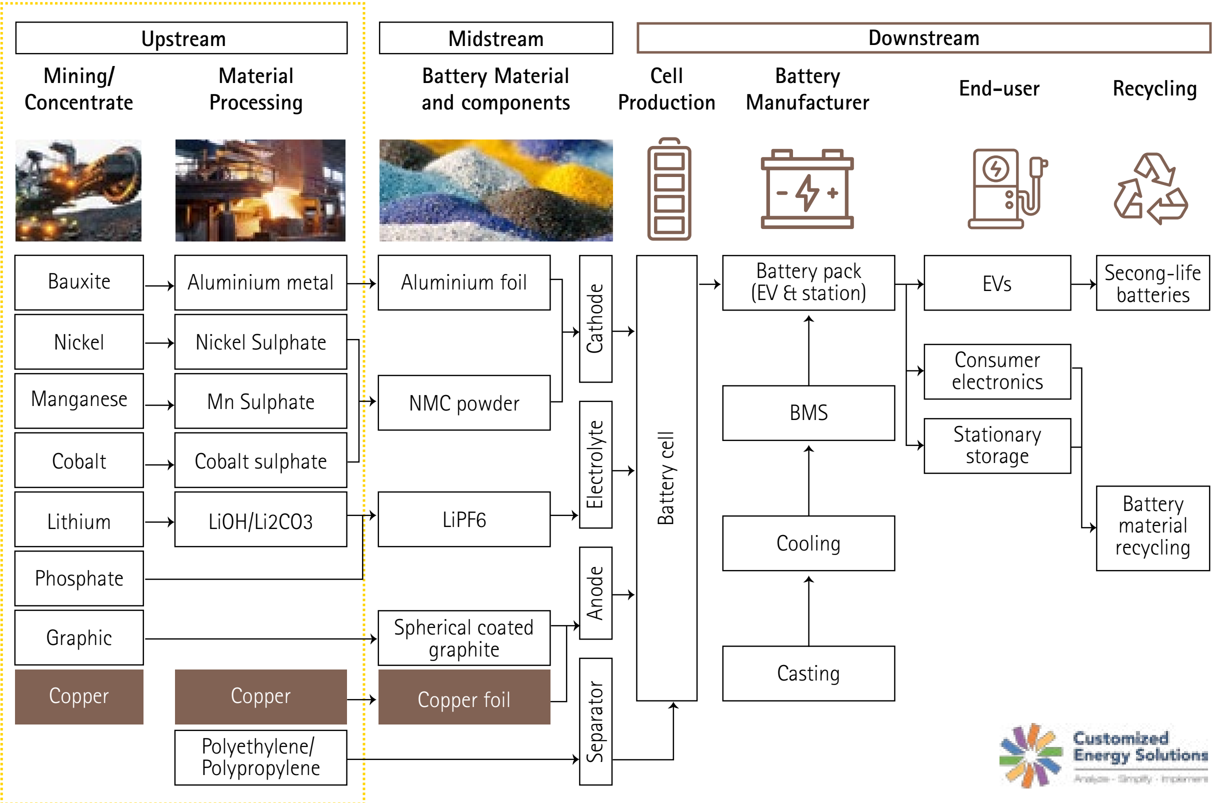


Figure 14: ACC battery value chain

5.1 Advanced Chemistry Batteries Characteristics

The ACC batteries (Specifically Lithium-ion batteries) offer great performance characteristics. It includes higher energy density, long cycle life, safety features, etc. The table below provides a detailed comparison of various LiB chemistries and their performance characteristics. As per the table, NMC and LFP chemistries offer better performance characteristics.

Table 2: Characteristics of ACC batteries

	LMO	NMC 611	NMC 622	NCA	LFP	LTO-LMO
Energy Density (Wh/kg)	140–158	220–240	240–260	240–270	130–143	75–84
Power Density (W/kg)	30–60	40–60	40–60	40–60	25–45	600–800
Cycle life	800–1,000	3,000–3,500	3,800–4,000	1,000–1,500	3,800–4,000	8,000– 10,000
Battery Chemistry	Gr, Li, Mn	Gr, Li, Mn, Ni, Co	Gr, Li, Mn, Ni, Co	Gr, Li, Ni, Co, Al	Gr, Li, Fe	Li, Ti, Mn
Safety (Thermal Stability)	High (250°C)	Medium (210°C)	Medium (210°C)	Low (150°C)	High (400°C)	High (250°C)
Round-trip efficiency	95%	94%	93%	90%	95%	97%

	LMO	NMC 611	NMC 622	NCA	LFP	LTO-LMO
Available C Rates	C/4–3C	C/4–2C	C/4–2C	C/4–1C	C/4–2C	C/4–10C
Depth of Discharge (DoD)	80%	90%	90%	80%	90%	90%
Maximum Operating Temperature (°C)	55	55	55	55	65	65

5.1.1 Materials used in the upstream-level supply chain components

The material composition and quantity may vary for various types of ACC batteries. The figure below lists various components, sub-components, and materials used in multiple ACC cell and battery manufacturing.

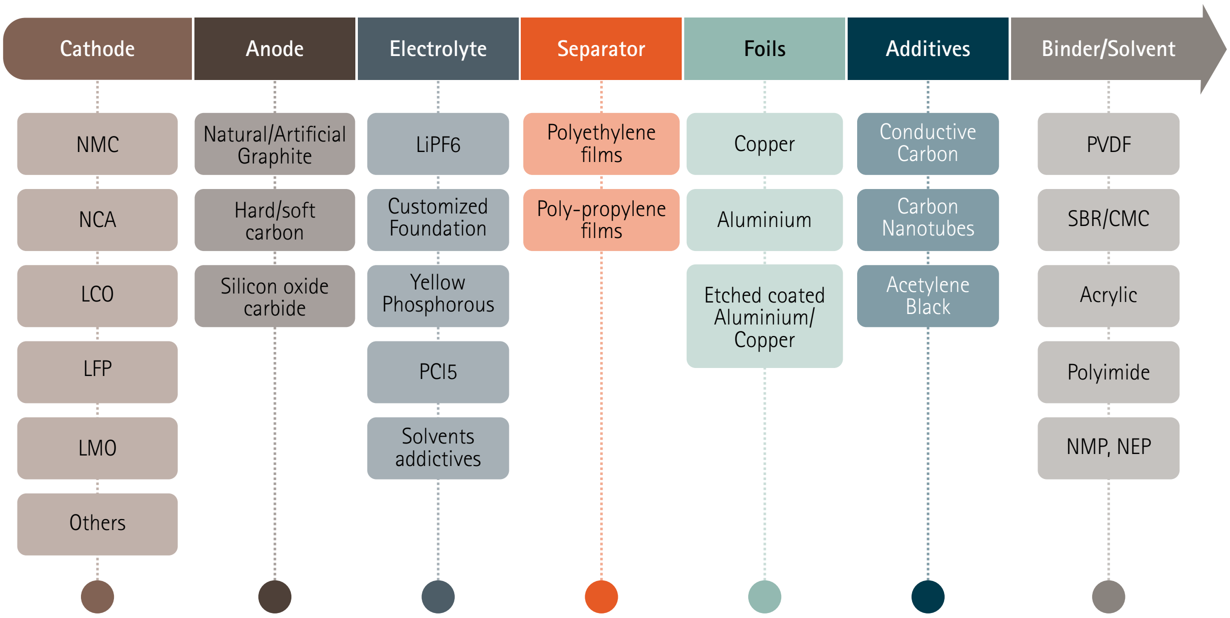


Figure 15: List of Materials used in different ACC Battery Chemistries

5.1.2 Material Composition in Key ACC battery Chemistries

The key components used in a LiB are—cathode, anode, current collectors, electrolyte, separator, etc. the details of materials and quantity used in LFP and NMC battery chemistries are provided in table 3 and table 4.

Table 3: Material Composition for LFP Chemistry

Component	Material	Quantity (kg/kWh)
Cathode	LFP Powder	2.2
	Conductive Powder (Carbon)	0.03
	Binder (PVDF)	0.11
Anode	Graphite anode	1.2
	Binder (SBR)	0.06
	Conductive Powder (Carbon)	0.02

Component	Material	Quantity (kg/kWh)
Anode C.C	Copper Sheet	0.4
Positive C.C	Aluminium Sheet	0.2
Electrolyte	Battery Electrolyte	1.1
Separator	Battery Separator	14.9
	Other Items	0
Total		**20.22**

Table 4: Material Composition for NMC Chemistry

Component	Material	Quantity (kg/kWh)
Cathode	NMC Powder	1.39
	Conductive Powder (Carbon)	0.02
	Binder (PVDF)	0.05
Anode	Graphite anode	1.03
	Binder (SBR)	0.03
	Conductive Powder (Carbon)	0.01
Anode C.C	Copper Sheet	0.18
Positive C.C	Aluminium Sheet	0.08
Electrolyte	Battery Electrolyte	0.8
Separator	Battery Separator	9
	Other Items	0
Total		**12.59**

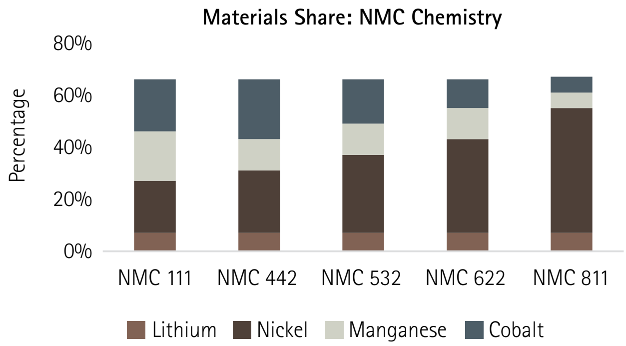
Material Composition for various Cathode Active Materials (CAMS)

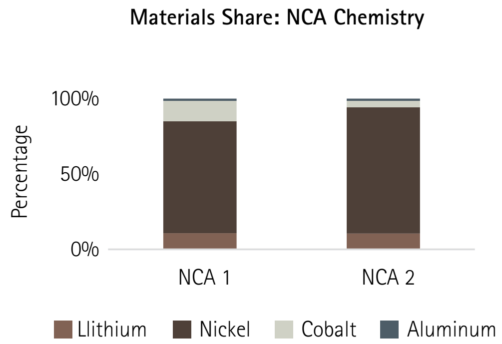
The material composition for cathode active materials varies for different chemistries. The tables below provide the percentage composition of various chemistries.

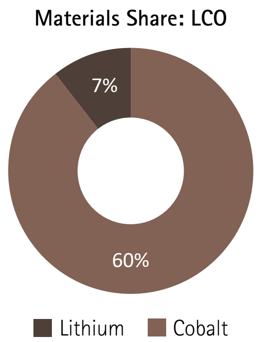
Materials Weight (%)	Cathode Active Materials (CAMS)				
	NMC 111	NMC 442	NMC 532	NMC 622	NMC 811
Lithium	7%	7%	7%	7%	7%
Nickel	20%	24%	30%	36%	48%
Manganese	19%	12%	12%	12%	6%
Cobalt	20%	23%	17%	11%	6%

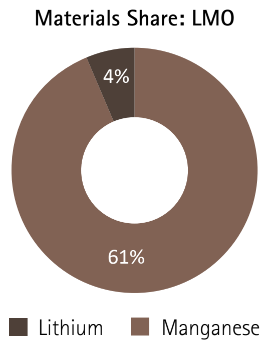
Materials Weight (%)	Cathode Active Materials (CAMS)	
	NCA 1	NCA 2
Lithium	7%	7%
Nickel	49%	56%
Cobalt	9%	3%
Aluminum	1%	1%

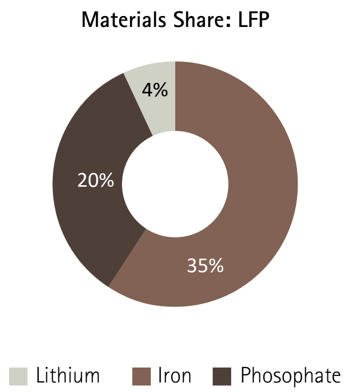
Further the pictorial representation of material composition percentage in CAMs for difference LiB chemistries is provided below.











5.2 Manufacturing Capabilities in India

Currently, the manufacturing of the below-mentioned components (Figure 12) is at various stages of development (planning, pilot scale, commercial scale). As the manufacturing ecosystem advances, by 2025 and 2030, the industry envisages achieving large-scale manufacturing capacities to cater to the growing demand for ACCs.

Our interactions with Industry suggest that the precursor materials to manufacture cathode, anode, and electrolyte are being developed indigenously. As shown in the figure below, cathode active materials (NMC, LFP), Anode materials (Synthetic, Natural graphite, mesocoke, LTO), electrolyte materials (LiPF6, electrolyte solutions, cathode binder materials (PVDF) are at various stages of development. Further, the plans for Aluminum foil manufacturing are in process.

Cathode	Anode	Electrolyte	Other Materials
• Cathode active materials (NMC, LFP) • PVDC	• Synthetic graphite • Spherical coated natural graphite • Mesocoke • LTO	• $LiPF_6$ • Electrolyte Solution	

Figure 16: Current Manufacturing ecosystem of upstream supply chain components in India

5.2.1 Domestic Manufacturing Capacity and Demand fulfillment

As mentioned in the previous sections, the domestic manufacturing capacities for upstream supply chain components are at various stages (Prototype, pilot, commercial applications). A few players have already built the capabilities and have announced plans for large-scale production in the coming years. Based on our interactions with the key players involved in the upstream level of the supply chain, most of these capacities would be able to fulfill the demand for 50 GWh PLI capacities. The table below shows that the demand fulfillment for Anode and cathode materials will be 100% by 2030. Similarly, the players engaged in Electrolyte, Binder, etc., are also ramping up their capacities to fulfill the demand under the ACC PLI scheme.

Table 5: Demand fulfillment potential by domestic manufacturing

Components		Capacity in TPA (2025-2030)	Fulfillment of domestic content for 50 GWh PLI (%) (2025-2030)
Anode		~300,000	100%
Cathode	NMC	~70,000	100%
	LFP	250,000	100%
Electrolyte		~12,000	30%
Binder			~50%

5.2.2 Mapping Upstream Supply Chain Component Manufacturers

With the recent progress in the manufacturing plan, the Indian battery manufacturing Industry is gearing up to contribute to the domestic value chain. The figure below provides the list of manufacturing players involved in various components. As mentioned earlier, these capacities are presently under different development stages.

Component	Company
Anode Material	epsilon carbon, Himadri, Tirupati Graphite
Cathode Materials	BASF We create chemistry, epsilon carbon, ALLOX, 50Hertz Creating Balance, Vrinda Li-ion Batteries, Infinite Elements

Component	Company	
Electrolyte	GFL Gujarat Fluorochemicals	Neogen Chemicals Ltd.
Cathode Binder	GFL Gujarat Fluorochemicals	Navin Fluorine International Limited
Aluminum Foil	Aditya Birla Hindalco	

Figure 17: The key players in the upstream supply chain manufacturing

Current Sourcing Mix for Raw Materials

This section provides the current share and future estimations of the raw material sourcing for upstream supply chain components. The industry envisages a significant value addition beyond 2030. The table below provides the percentage share of existing and future sourcing mix of various raw materials.

Table 6: Existing and Future Sourcing Mix for Supply Chain[6]

Component	Existing sourcing mix (%) (2022-25)		Future Sourcing Mix (%) (2025-30)	
	Domestic	Imported	Domestic	Imported
Anode	20	80	90	10
Cathode	-	100	30	70
Electrolyte	20	80	60	40
Binder	30	70	60	40

Cell Manufacturing Announcements in India

In addition to the companies that have signed the PLI agreement for cell manufacturing, many other companies are planning to set up their facilities in the country. The CES has estimated around 140 GWh manufacturing of cells by 2030.

5.2.3 Supply Chain for The Balance of Material Components

A list of components is required to assemble these materials in the form of cells. The table below provides a list of components used in the Lithium-ion cell assembly and global and Indian manufacturers and suppliers for these components.

[6] Source: CES-IESA analysis (based on industry input)

Table 7: Balance of materials component providers

Component	Global Supplier/Manufacturers	Indian Supplier/Manufacturers
Aluminium tab	Xiamen Tmax Battery Equipment Limited, MSE Supplies LLC, Avocet precision metals	
Nickel/Copper tab	Shandong Gelon Lib Co., Ltd., Avocet Precision metals	Tremor Alloys, S. K. Enterprises
Seal pin	Ametek	
Anode sealing gasket	Solvay	Yati infotech solution
Safety Vent	Donaldson, Porex, SS Elebruss	Technology International, SS Elbruss
Can	Hudson Technologies, Gem manufacturing Co, Peterson manufacturing LLC, EUBACO	
Connectors	Antek, Shandong Gelon Lib Co., Ltd, Zhejiang Zhente Electrical Co., Ltd.	Hesham industrial Solutions
Overcharge safety device (OSD) membrane	Synderfiltration	
Shrink Tube	Volsun, Dee Five Shrink Insulations Private Limited, Rotima	Dee Five Shrink Insulations Private Limited
Bottom retainer	Digi-Key Electronics, SLS Innovations ABS	
Nail safety device		
Bottom insulator	NJK insulators, ELECTROLOCK INC., Oerlikon	
Top insulator cover	NJK insulators, ELECTROLOCK INC, Sai Corporation	Vijaya Sai Dip Moulding
Top plate	Schott, Nippon Light Metal Co.,Ltd	Das trading Co.
Terminal plate	Schott, Bangteng Hardware Electronics Technology Co Ltd, MACFOS Pvt ltd	Nuway Industries Ensto India Private Limited
Connection Plate	Schott, MACFOS Pvt. Ltd.	

5.3 Challenges in Domestic Manufacturing1

This section highlights the challenges with technology, raw materials, manufacturing, policy, regulations, etc. for upstream supply chain development. Details are discussed as follows.

Raw Material:

Presently, the precursor materials to manufacture the upstream supply chain components are imported. Further details for various components are explained in the section below.

Cathode active materials- Cathode materials for NMC-based chemistries are fully imported, whereas, for LFP-based battery chemistry, there is a significant value addition domestically.

Anode Materials- Presently, synthetic anode material can be produced indigenously; however, with the growing demand, there can be a shortage of coal tar (precursor material), and the industry might have to import petroleum coke from countries like the USA and the EU. Also, due to the limited availability of natural graphite and mining restrictions in India, natural graphite may have to be imported.

Electrolyte- The precursor materials, such as Lithium carbonate (Li_2CO_3)/ Lithium Hydroxide ($LiOH.H_2O$), Solvents for the electrolyte solution, yellow Phosphorous, and Fluorspar are fully imported due to unavailability in India.

Other Materials: Materials such as separators, aluminum foil, copper foil, etc. are other crucial materials used in ACC manufacturing. Presently the precursor materials required to make these components are being imported.

Technology/Equipment

Presently the key equipment used in the manufacturing of cathode materials (kilns, furnaces, and milling), anode materials (Milling & Shaping, coating, finishing), electrolytes, etc., is imported.

Manufacturing

The manufacturing capabilities for upstream/intermediate-level supply chain components are at various stages of development (planning, pilot scale, commercial) in the country. Barring a few players, most of the manufacturing capacities are operating at small scales; however, with the recent development in the ACC PLI scheme, many players are planning to put up or expand the existing manufacturing capacities.

Policy and Regulatory

Presently, no specific policies and regulations are directed to support the development of a domestic supply chain for upstream and intermediate materials/components. Further, there is no clarity on receiving the financial benefits from the PLI scheme that will be provided to the ACC manufacturers.

Skilled Manpower

The ACC manufacturing ecosystem is developing, and technical know-how currently needs to be improved in the industry. Battery manufacturing is a complex process requiring skilled manpower to operate the equipment. Therefore, technical collaborations with global players are needed.

Other Challenges

- The initial cost of technology (capital investment) is higher in specific components.
- Manufacturing of some components is highly working capital intensive.
- Taking environment clearances is a lengthy process and eventually delays the projects
- Issues in taking loans from banks—banks require confirmation of orders in case of funding requirements for large expansions.
- Huge investment is required for R&D
- Delays/Uncertainty in getting land approvals for project set-up

5.3.1 Challenges Specific to Copper Foil Manufacturing

- The global standard for copper foil thickness is 6 µm; however, the Indian copper Industry is making 30 µm. To achieve the desired thickness levels, a significant technological upgradation is required.
- The initial capital investment is higher to set up battery-grade copper foil manufacturing in the country.
- Demand uncertainty w.r.t. the copper foil of specific grade and thickness (used in the battery industry).
- Copper foil making is an energy-intensive process[7].

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[7] Information compiled based on industry interviews

Key Takeaways:		
Indian ACC manufacturing supply chain industry is progressing well. The ACC PLI scheme has provided a great start.	To achieve the 50 GWh of cell manufacturing under the ACC PLI scheme, most of the precursor raw materials and equipment will be imported.	In the long term (2030 and beyond), the industry envisages a maximum value addition in terms of the raw materials and domestic manufacturing of equipment.

Actions Required:

Industry requires support in terms of policy and regulations to facilitate large-scale manufacturing. It includes— financial incentives, Strategic and regulatory assistance, focused R&D, and skill development.

6 Policy and Regulations in India

To promote the domestic manufacturing of ACC batteries in India, the government of India has introduced favorable policy programs at the Central and State level.

6.1 ACC Production Linked Incentive Scheme

The production-linked incentive program supports the domestic manufacturing of ACC battery capacity of 50 GWh with an outlay of INR 18,100 crore. The key highlights of this scheme are summarized below.

Budget Outlay	Production Target	Incentive Support	Capacity Allocation
INR 18,100 crore	50 GWh	• To achieve domestic value addition of 25% initial two years and increase it to 60% in the next five years • The incentives will be disbursed over a period of five years	5 GWh to 20 GWh

Ten companies submitted the bids in January 2022; results were announced by the Ministry of Heavy Industries (MHI) in March 2022. Four companies, namely Rajesh Exports Limited, Hyundai Global Motors Company Limited, Ola Electric Mobility Private Limited, and Reliance New Energy Limited, were selected to benefit from the PLI scheme. On 28th July 2022, three companies—Reliance New Energy Ltd, Ola Electric Mobility Pvt Ltd, and Rajesh Exports Ltd signed the agreement under the PLI scheme and are all set to kick-start the building process of ACC battery Giga factories in the country[8].

- The incentives under the Faster Adoption and Manufacturing of Hybrid and Electric vehicle (FAME) scheme were directed to promote electric vehicles that use advanced battery technologies such as Lithium-ion batteries.
- The import duties on the import of cells and assembled battery packs were increased to encourage the domestic production of cells/batteries in the countries.
- The Ministry of Mines has signed an MoU with the Australian government to enable the procurement of critical minerals/materials used in ACC battery manufacturing
- Also, a PLI scheme for Niche Battery chemistry with a cumulative capacity of 5 GWh is being drafted and will be announced soon.

6.2 State-Level Incentives

With the recent development in the ACC PLI scheme, the state governments have also taken initiatives to promote the domestic manufacturing of batteries in their respective states. The table below summarizes the incentives provided by the state governments[9].

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[8] https://pib.gov.in/PressReleasePage.aspx?PRID=1846078

[9] Source: Information compiled from various documents, reports, press releases etc.

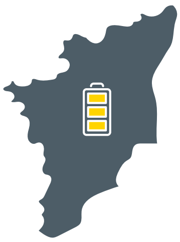
Table 8: State-level incentives to promote battery manufacturing

State	Incentives			
	Electricity	Land	Capital Subsidy	Other Incentives
Gujarat	■	■	■	
Tamil Nadu	■	■	■	
Maharashtra	■			■
Karnataka		■	■	■
Telangana			■	■
Uttar Pradesh		■	■	
Haryana				■

Gujarat

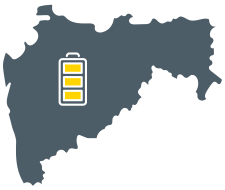
- The state provides the cheapest electricity tariff of ~INR 4.65/kWh to support battery manufacturing.
- A 50% subsidy is provided on the total cost of land.
- A 12% capital subsidy on the total capital investment cost is provided.

Tamil Nadu



- The state has subsidized the electricity tariff at INR 6.35/kWh to support the manufacturing industry
- A subsidy of 50% is provided on the total land cost.
- The state government provides a capital subsidy of 24%.
- Other incentives include environmental protection subsidy (up to 25% for setting up the environmental plant), a training subsidy (4000/month for males and 6000 for females for six months)

Maharashtra

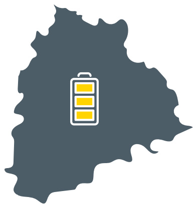


- The electricity tariff in Maharashtra is INR 7.02/kWh. Additionally, a power tariff subsidy of INR 1/kWh for ten years and a 100% electricity duty exemption are provided for 15 years.
- The state provides 100% exemption on the state GST for ten years.

Karnataka

- The state provides INR 1/kWh as a power tariff subsidy for five years and 100% exemption on electricity duty for five years
- It provides a 25% land subsidy for up to 50 acres.
- A 12% capital subsidy on the total capital investment cost is provided.
- Provides 1% production-linked incentives on the turnover of five years of commercial applications. The desired value addition is 50% to avail of the incentives.

Telangana



- The state provides a subsidized electricity rate, INR 5.56/kWh. It provides a 100% exemption on electricity duty and a 25% power subsidy for five years. The power subsidy is capped at five crores.
- The state provides a capital subsidy of 30 crores.
- 100 % exemption on the state GST for seven years, capped at five crores.

Uttar Pradesh

- The state provides a subsidized tariff of INR 6.40/kWh with a 50% electricity duty exemption for ten years.
- It provides a 25% land subsidy
- The state provides a capital subsidy of 15%.

Haryana

- A subsidized tariff of INR 6.45/kWh with a 100% exemption on electricity duty for seven years.
- 100 % exemption on the state GST for ten years.
- Financial assistance of INR 36,000 per annum to employ local youth in the industry.

The government of India has introduced the ACC PLI scheme to support the manufacturing of advanced chemistry cells through financial incentives. Further, a few states have also introduced some incentives in the form of electricity subsidies, capital subsidies, land subsidies, etc., to encourage industry players to put up their plants.

7 Technical and Safety Standards

The development of standards to ensure the safe operations of batteries in industrial, electric vehicles, stationary applications, secondary applications, etc., has been progressing well. Presently, technical standards exist across the battery's value chain (manufacturing to end-of-life) around the globe as well as in India. The table below summarizes the key standards that enable the safe operations of batteries in various applications. Further, there are standards to ensure the safe handling of batteries during reuse or second-life applications of retired EV batteries.

Standard	Title	Scope	Status
IEC 62619: 2022	It specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications, including stationary applications.	These standard addresses safety testing at the cell level. It includes tests for short circuits, overcharging, thermal abuse, and drop and impact testing. IEC 62619 also includes functional safety tests at the battery level, including voltage and current control, to prevent overcharging and overheating control.	The first edition came in 2017 and then got revised in May 2022
IEC 62660-3: 2022	It specifies test procedures and acceptance criteria for the safety performance of secondary lithium-ion cells and cell blocks used for the propulsion of electric vehicles (EV), including battery electric vehicles (BEV) and hybrid electric vehicles (HEV).	• New method for the internal short-circuit has been added. • Vibration test has been deleted • Test conditions for overcharge have been partially revised	The first edition came in 2016 and then got revised in March 2022
ISO 6469-1:2019	Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS)	It specifies safety requirements for electrically propelled road vehicles' rechargeable energy storage systems (RESS) to protect persons.	Active
ISO 6469-1:2019/ FDAMD 1	Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS) — Amendment 1: Safety management of thermal propagation.		Under development
ISO 26262-1:2018	Road vehicles — Functional safety		Active
UL 9540	Safety standard for an energy storage system (ESS) and equipment intended for connection to a local utility grid or standalone application	It designates key issues associated with ESS. These include: Safety of the battery system Functional safety Fire detection suppression Containment Environmental performance And more	Active

Standard	Title	Scope	Status
UL9540A	It is a test method for evaluating thermal runaway propagation for battery energy storage systems.	This test will not give you the certificate! Instead, it will provide data for manufacturers to see if their product meets the regulations. The Test Hierarchy of UL9540A There are four stages in the UL9540A test method: • Cell Level Test At this level, UL looks at whether a cell can exhibit thermal runaway. It also checks its characteristics and flammability. • Module Level Test In this stage, the main goal is to determine if thermal runaway propagates with the module. They will also find out the heat release and gas composition. • Unit-Level Test Now they will look at the whole unit and see the following. Firstly, they find out how quickly fire spreads. Then they will look for its heat and gas release rates and other hazards. • Installation Level Test Lastly, they do an installation test. This is an optional test, but its goal is to determine the effectiveness of the product's fire protection.	Active
UL 2271	This Standard covers the safety aspects of battery pack modules for light electric vehicles (LEVs). These include bicycles, hoverboards, golf carts, all-terrain vehicles (ATVs), motorcycles, and many more.	Batteries must be able to comply with a series of construction, performance, electrical, mechanical, and environmental tests. Some examples of different electrical tests are over-charging, over-discharging, short-circuiting, imbalanced charging, and operation at the maximum specified temperature. In addition, batteries must be able to withstand mechanical tests such as vibration, shock, crush, drop, and rollover. They also must pass environmental tests such as immersion and thermal cycling between extreme cold and hot temperatures and meet our rated water ingress specifications.	Active

Standard	Title	Scope	Status
UL 2580	Batteries for use in electric vehicles	This standard evaluates the electrical energy storage assembly's ability to withstand simulated abuse conditions safely and prevents any exposure of persons to hazards because of the abuse. This standard evaluates the electric energy storage assembly and modules based on the manufacturer's specified charge and discharges parameters at specified temperatures.	Active
UL 2054	Household and commercial batteries	This standard covers the certification requirements for portable primary (non-rechargeable) and secondary (rechargeable) lithium-ion batteries power supply applications in goods.	Active
UL 1642	UL1642 certification requirements cover lithium-ion batteries for technician-replaceable or user-replaceable applications. UL1642 certification requirements are also intended to avoid the risk of injury to persons due to fire or explosion when user-replaceable lithium-ion batteries are removed from a product and discarded.	UL1642 certification requirements cover technician-replaceable lithium-ion batteries that contain 5.0g or less of metallic lithium. **All Test Items of UL 1642 Certification** • Short-Circuit Test • Abnormal Charging Test • Crush Test • Impact Test • Shock Test • Vibration Test • Heating Test • Temperature Cycling Test • Low Pressure (Altitude Simulation) Test • Project Test	Active

Battery Repurposing Standards

Standard	Title	Scope	Status
UL 1974	Safety evaluation for Repurposing Batteries	• It covers the sorting and grading process for cells, battery packs, modules, and electrochemical capacitors to be repurposed.	The first edition came in October 2018— currently operational.
IEC 63338	The general guidance for the reuse of secondary cells and batteries	It covers— • Guidance on the environmental aspects and safety risks of the reuse of cells and batteries • Guidance on original manufacturer caution statements on the applicability of a product for reuse	Released in January 2021—currently in the draft stage.
IEC 63330	Requirements for reuse of secondary batteries	• It specifies the requirements for the reuse/repurposing of secondary batteries and battery systems • Facilitate the procedure to evaluate the performance and safety of used batteries and battery systems for reuse/repurposing	Released in June 2021—currently in the draft stage.
IEC 62933-4-4	Environmental requirements for BESS using reused batteries in Various installations and aspects of Life cycles	• It describes the environmental issues associated with BESS, using reused batteries • Also addresses the environmental impacts of BESS, including the impacts on humans.	Released in July 2021—currently in the draft stage.

8 Recommendations and Way Forward

With the present announcements for financial assistance under the ACC PLI scheme, it is believed that incentives will be provided to cell/battery manufacturers. Presently, there is no clarity on sharing these incentives with the cell active material manufacturers. Therefore, the industry engaged in precursor material manufacturing for the anode, cathode, electrolyte, etc., seek some support from the government to develop the domestic manufacturing industry. This will help achieve the self-reliance goals under the Aatmanirbhar Bharat mission and bring cost competitiveness among domestic cell/battery manufacturers.

To strengthen the domestic supply chain, the industry recommends the following incentives through this survey.

- **Capital subsidy:** The capital investment required to set up the manufacturing facilities is higher in the initial deployment phases. Therefore, a capital subsidy can encourage industry participation in facilitating the large-scale manufacturing ecosystem. The IESA member companies engaged in materials supply chain manufacturing propose the following subsidy structure.
  - A subsidy of 25% on land costs
  - A subsidy of 20% on the plant and machinery expenses
  - 100% reimbursement of land conversion charges
  - Reimbursement of stamp duty and registration fee.

- **Working capital subsidy:** Special incentives (in the form of operational subsidy) to support the working capital requirements would help run the operations efficiently.

- **Low-cost financing:** Loans with lower interest rates and longer tenure can be provided. Provided the importance of ACC batteries in realising the net zero emissions goals, financing can be considered under priority sector lending.

- **Import duty exemption:**
  - *Raw materials:* The critical materials to manufacture these precursor materials are imported. Therefore, a duty exemption on the imports of raw materials/minerals will be helpful during the initial years of operations. For copper foils, the copper concentrate is imported from countries like South Africa and attracts an import duty. To promote the manufacturing of copper foil in India, an import duty exemption on copper concentrate would be helpful.
  - Import of capital equipment for raw material production.

- **Subsidy/Exemption in electricity tariff:** Exemption in electricity duty with a discounted power tariff will bring down the electricity expenses in some energy-intensive processes. Further, to promote the utilization of renewable power, the interstate transmission charges could be waived.

- **Support to promote the export of domestic products:**
  - Benefits in the form of export incentives, duty waivers/concessions, and foreign trade agreements with cell manufacturing countries should be helpful.
  - *Income tax benefits for exports:* A full exemption on income tax for exports can be considered to promote the export market. Earlier, the Ministry of Commerce, Industry, and Department of Commerce offered an income tax exemption for exports in SEZ units. The scheme was introduced in 2010 with a timeframe of ten years; for the initial five years, there was a 100% exemption followed by 50% in the subsequent five years.
  - A credit guarantee scheme can help promote the export market by providing credit risk insurance services to offset the risk of non-payment by international buyers.

- **Other financial incentives:**
  - To support the reduction of carbon footprint by substituting coal-based energy with renewable energy. This will complement the net zero emission goals and enable a sustainable manufacturing ecosystem.
  - To promote circular economy in the battery manufacturing value chain.
  - To promote R&D in advanced materials and emerging battery technologies.

- **Strategic and Regulatory measures**
  - Government can facilitate collaborations with countries to support sourcing critical minerals/materials and technology for manufacturing.
  - Support domestic manufacturing by levying duties on imported products (semi-finished/finished goods)
  - Some materials (such as coal tar used in synthetic anode production) should be considered strategic resources, and their applications can be reduced in other sectors

- **Specific to Copper**
  - Copper foil manufacturing is capital intensive, therefore capital subsidy to support the initial investments would be required.
  - Electricity duty exemption and subsidized power tariff to support energy-intensive processes.
  - Import duty structure needs to be revised in favor of precursor materials.
  - Ease in technology transfer from the global countries to set up battery-grade copper foils in the country.
  - Techno-commercial studies to be conducted to understand the feasibility of battery grade copper manufacturing in the country.

Summary

The ACC PLI scheme provides a great stimulus for the industry to enter the ACC battery manufacturing ecosystem. As the report explains, some progress has started in supply chain component manufacturing. In ACC manufacturing, significant value addition happens at the upstream level of the value chain. Hence the government must devise an incentive program to encourage the large-scale adoption of precursor material manufacturing. This will attract domestic and overseas investors to put up manufacturing plants in the country. It fulfills the ACC PLI scheme's mandate and aligns with the Aatmanirbhar Bharat mission's objective.

Further, this report highlights the significance of copper foil in the ACC battery value chain. Currently, the industry needs to gain awareness of the future volumes of copper and its challenges in terms of the supply chain and technical know-how. Therefore, it requires a detailed assessment of copper applications, and gaps in the existing ecosystem and recommend suitable solutions to address the supply chain and manufacturing gaps for battery grade copper manufacturing in the country.

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