PAN AMERICAN FINANCE

Gigafactory Report

2023

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Contents

1. EXECUTIVE SUMMARY

Executive Summary

The Rise of Electric Vehicles and Gigawatt-Scale Manufacturing

The transition to electric mobility worldwide is propelling an unprecedented scale of industrial investment in batteries. Over $300 billion is required in capex to meet electric vehicles' (EVs"') battery demand by 2030. Key is to make batteries available at cheap price and they should be locally sourced. Active policy push contributed to a spike in the Gigafactories' pipeline – since 2019, and the number of such projects announced rose by more than 400%. By April 2023, there were 360 such projects announced for gigawatt-scale manufacturing

High Activity in North America and Europe

The most interest is in upcoming projects in North America and Europe. US upcoming projects (announced and under-development) total about 1,000GWh by 2030. The Canadian pipeline is lower, at 145GWh, but rising as investors queue up. US Inflation Reduction Act (US IRA) policy support and incentives helped shape the Gigafactory investment contours in North America. Up until recently, subsidies did not drive the European Gigafactory opportunity. Instead, it was about European countries being regarded as high demand centers for electric vehicles and the necessity of diversifying away from a concentrated battery supply chain. Thus, pipelines are concentrated around industrial bases like Germany. Germany and Hungary account for about 40% of the pipeline's tracked capacity, worth 1,880GWh. Others in the lead include Italy, France, and Norway

Subsidy Free Growth

The Gigafactory investment landscape goes beyond government incentives. For one, the original equipment manufacturers (OEMs) in automotive and battery production spaces are leading the momentum in Gigafactory investment. About three-quarters of the global Gigafactory pipeline is based on OEMs' projects. It is notable how the Gigafactory business is forcing vertical integration - automotive OEMs are partnering with battery manufacturers, technology companies, recyclers and even mining companies. Gaining competitive advantage requires OEMs to acquire stakes in critical mineral assets. Cobalt, Nickel, and Lithium mining deals stand out for leading automakers

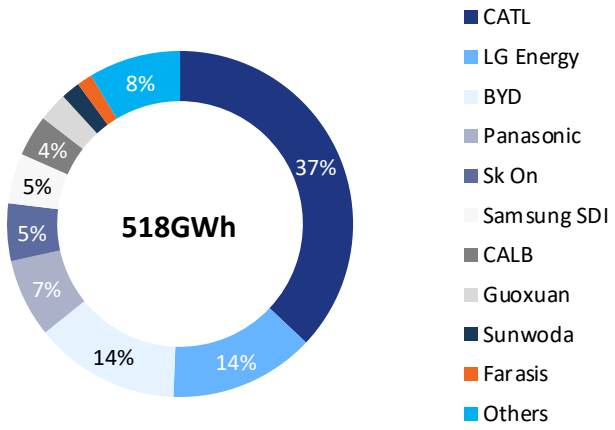
Critical Components and Outlook

The integrity of the supply chain might be the defining factor for most stakeholders. It involves access to critical minerals and processing capabilities. Also important is the role of technology. The dominance of Lithium-Ion is evident in the upcoming battery facilities. Yet, the encouraging results in alternatives, especially Sodium Ion, suggest that battery technology trends may not be as clear or predictable as expected. The demand for raw materials, equipment, and technologies will also increase as Gigafactories progress in the planning/development stages. With many unknowns, the evolving Gigafactory business holds learning opportunities across the spectrum. Therefore, the industry's outlook is one of significant flux to arrive at an equilibrium eventually

2. GIGAFACTORY PIPELINE

Battery Capacity, Market Share & Capacity Under Development

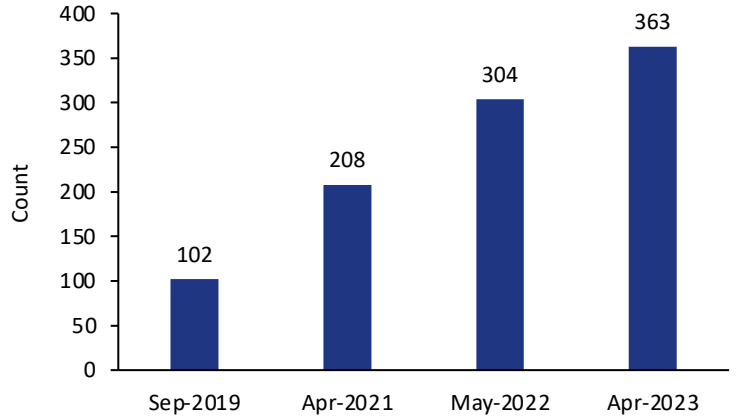
Electric Vehicle Battery Producers' Market Share (2022)



Source: SNE Research

- Over 6,000GWh of battery capacity could be commissioned, based solely on the announcements made till April 2023. The existing Gigafactory pipeline is centered around EV demand
- The largest battery manufacturer CATL is scaling up its Gigafactory in Germany beyond its first phase. Panasonic has been a dedicated supplier for Tesla and reported about 45% rise in sales during 2022. Besides pursuing existing battery sale contracts, Sk On and LG Chem are involved in upcoming Gigafactory projects
- Notable among the existing globally leading battery manufacturers with high vertical integration are BYD and Great Wall for presence across the value chain

Number of Global Gigafactory Projects Announced and Under Development

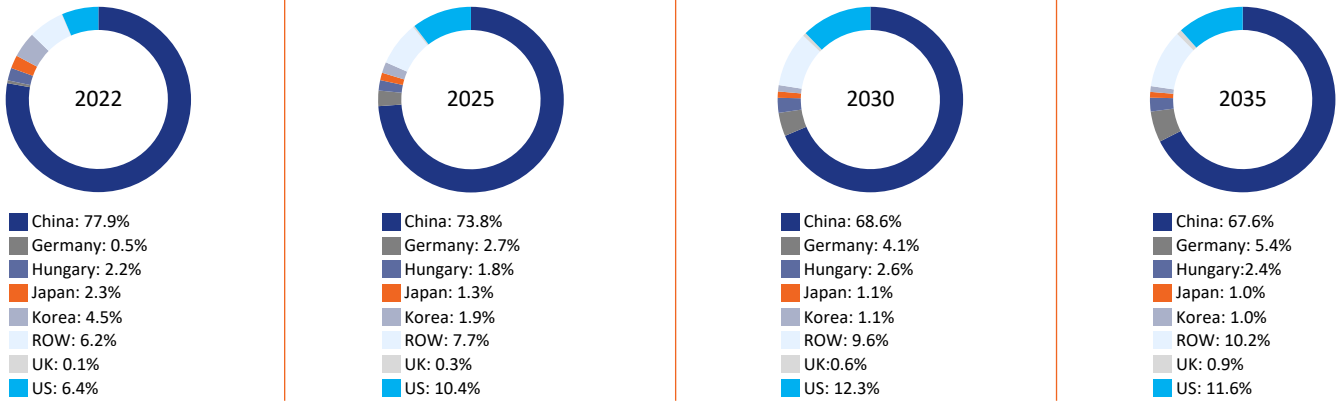


Source: Benchmark Minerals
Note: Data comprises tracked projects announced, planned or in development stages

- In 2015, only three Gigafactory projects were in development. By 2019 the Gigafactory pipeline rose to 102 projects which has further tripled to date, now encompassing 363 projects
- The driving force behind this expansion is the exponential growth of the electric vehicle (EV) industry, which demands localized and cost-effective battery production
- Further policy-driven incentives such as the United States Inflation Reduction Act (IRA) in August 2022 not only incentivized domestic production in the US but also incited a European policy race to attract competitive investments

Capacity Under Development

Relative Share of Countries in Upcoming Battery Production



Source: Benchmark Minerals

Gigafactory Investments in Canada (Indicative)

Company/Venture	Capacity (GWh)	Location	Scheduled
Stellantis and LG Energy Solution	50	Ontario	2024
Volkswagen (Powerco)	20	Ontario	2027
Stromvolt	35	Ontario	2030
Northvolt*	40	Quebec	-

**The company has reportedly shortlisted the production site*
Source: News reports, press releases

- In Canada, the Gigafactory pipeline has indirectly benefited from the IRA, which spurred increased battery demand from North America and influenced changes in local policy
- The Canadian government has adjusted its policies to stay competitive with the US IRA subsidy support. As a result, in April 2023, Volkswagen-led PowerCo committed to investing 7 billion CAD in a 90 GWh Gigafactory to be based in Ontario

Capacity Under Development - NAMER

Major Upcoming Gigafactories in the US

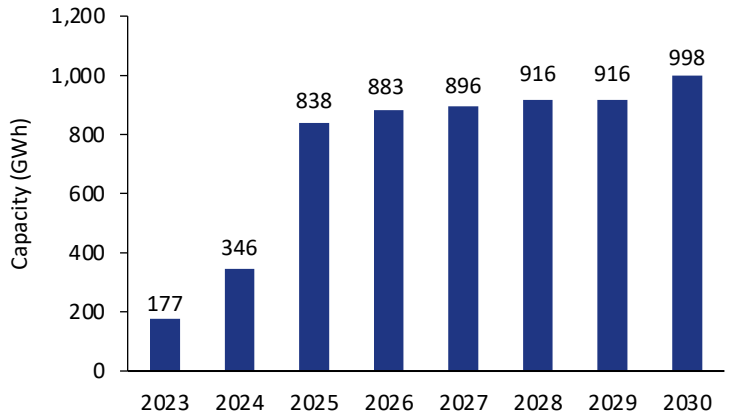
Company/Venture	Capacity (GWh)	Location	Scheduled
Ultium Cells	50	Lansing, Michigan	2025
LG Energy	20	Holland, Michigan	2025
Ford Motors	35	Marshall, Michigan	2026
Our Next Energy	20	Ven Buren, Michigan	2027
Ultium cells	50	Spring Hill, Tennessee	2023
Ford Motors	43	Stanton, Tennessee	2026
Ford Motors	86	Glendale, Kentucky	2026/30
Volkswagen	-	Chattanooga, Tennessee	-
Freyr	34	Coweta, Georgia	2029
Hyundai and SK On	-	Bartow, Georgia	2025
Hyundai and LG	30	Bryan, Georgia	2025
Panasonic	30	De Soto, Kansas	2025
Tesla*	100	Nevada	-
Envision AESC	30	Florence, South Carolina	2030
Stellantis	23	Kokomo, Indiana	2025
Statevolt	54	Imperial Valley, California	-
Kore Power	12	Buckeye, Arizona	2024
Honda	40	Ohio	2024

**Capacity expansion project*
Source: News reports, press releases

- Looking ahead to 2030, it is anticipated that Gigafactories in North America will boast a combined pipeline capacity of 1,000GWh spanning across the United States, Canada, and Mexico
- Major corporations such as Ford Motors, Ultium, and Hyundai are making considerable investments to boost capacity in the US
- The emergence of “battery belt” clusters in selected US states, including Tennessee, Michigan, Georgia, Arizona, and South Carolina, has been driven by attractive incentives and support measures. Interestingly, these locations often coincide with existing conventional vehicle assembly units, facilitating synergies for developers

Capacity Under Development - NAMER

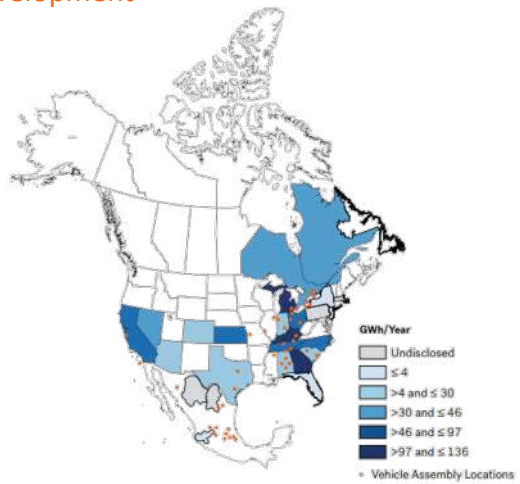
Announced Capacity for Gigafactory in North America



Source: Argonne National Laboratory (report as of November 2022)

- Collectively, about 1,000GWh of capacity could be traced in terms of announcements for North American region. The number expanded consistently over the years
- The North American pipeline also includes investment prospects in Mexico – progressively an important location for the US automakers' electric vehicle manufacturing

Clustering of the North American Gigafactory Capacity under Development



Source: Argonne National Laboratory

- The pipeline of North American gigafactories is clustered around some states and locations. It has been dubbed the 'battery belt' because factories have been centered in states with attractive incentives and support
- Tennessee, Michigan, Georgia, Arizona, and South Carolina are among the US states that are important in this regard
- Such facilities also overlap existing conventional vehicle assembly plant locations, which illustrates the synergies developers intend to exploit

Capacity Under Development - EU

Europe's Major Tracked Gigafactory Projects under Development

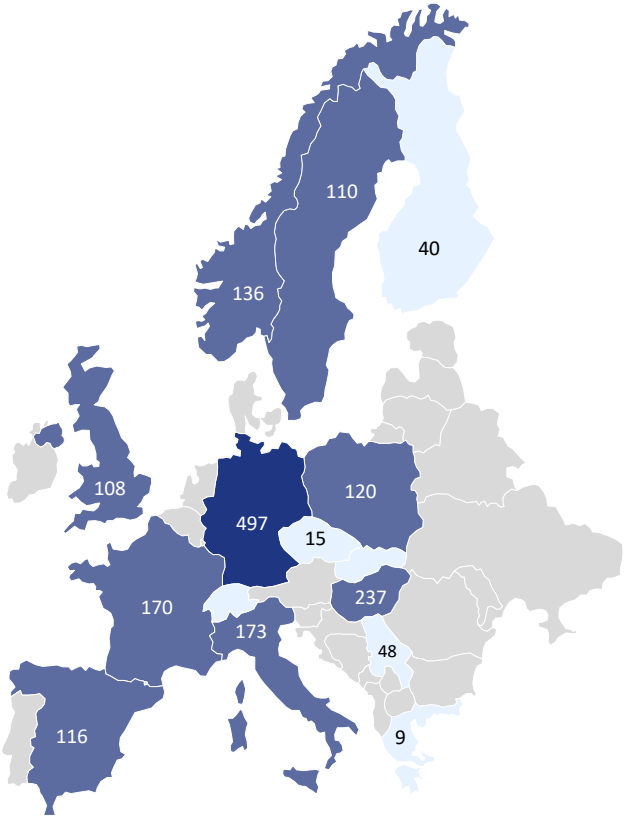
Country	City	Company	Capacity (GWh)
Germany	Berlin	Tesla	125
Italy	Termoli	ACC	120
Poland	Wroclaw	LG Chem	115
Germany	Erfurt	CATL	100
Hungary	Debrecen	CATL	100
Germany	Schleswig-Holstein	Northvolt	60
UK	Coventry	West Midlands	60
Sweden	Skellefteå	Northvolt	60
France	Dunkirk	Verkor	50
Sweden	Gothenburg	Volvo	50
Hungary	Iváncsa	SK on	50
France	Dunkirk	ProLogium	48
Portugal	Portugal	CALB	45
Italy	Scarmagno	Italvolt	45
Norway	Kristiansand	Morrow	43
Norway	Mo i Rana	FREYR Battery	43
Germany	Salzgitter	VW	40
Germany	Kaiserslautern	ACC	40
France	Douvrin	ACC	40
Spain	Sagunt	VW	40
France	Douai	Envision AESC	24
Spain	Navalmoral de la Mata	Envision Group	30

Source: Transport and Environment (report as of February 2023)
Note: Data above accounts for two-thirds of the total European capacity tracked

- A bigger momentum in the Gigafactory space lies in the European region, possessing a pipeline capacity of 1,300GWh
- Germany leads the European Gigafactory project pipeline with an estimated capacity of approximately 365 GWh, followed by Italy and France with roughly 160 GWh each
- The profile of companies making up the pipeline, while led by the legacy automakers, is made interesting by the entry of startups and technology providers
- The IRA's generous incentives have further persuaded European policymakers to become more motivated towards generating Gigafactory investments
- Policymakers are reaching out to the investors to support their cause. France secured the recent Gigafactory investments after high-level government intervention and assurances of support for planned investments

Capacity Under Development

A Regional View of the Planned European Gigafactory Capacity (GWh)

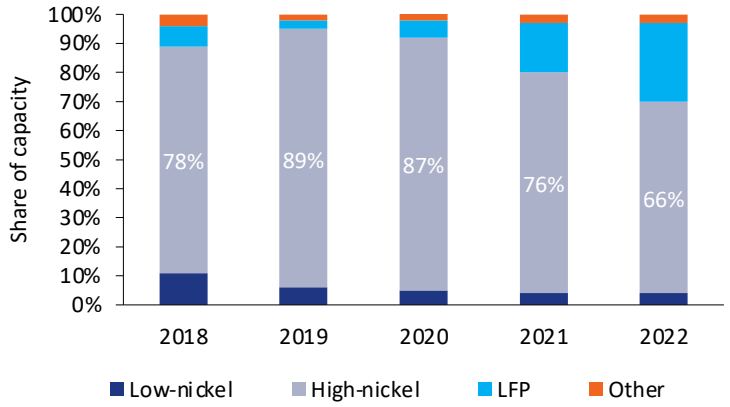


- The materialization of the European Gigafactory project pipeline faces significant barriers due to the issues of policy support (in terms of explicit subsidies or fiscal incentives) and raw material supply security
- Leading entities such as Northvolt, Polestar and Iberdrola already indicated considering relocation of their planned facilities
- Transport and Environment (February 2023) estimated one-fifth of the announced capacity at a high risk of delay, scaling down or cancellation
- In conclusion, the Gigafactory pipeline has experienced rapid expansion due to the surging global demand for EVs and supportive policy changes in Europe and the US

Source: Transport and Environment (report as of February 2023)

Evolving Technology Choices

Trend in Electric Vehicle Battery Chemistry Distribution



Source: IEA

- The long-term trend of shifting battery chemistry is informative of the evolving landscape for the upcoming Gigafactories
- By end of 2022, the Lithium Nickel Manganese Cobalt Oxide (NMC) stood as the dominant choice of battery chemistry, followed by Lithium Iron Phosphate (LFP) and Nickel Cobalt Aluminium Oxide (NCA)

Major Instances of Sodium-Ion Battery Production and Commercialization

Country		Development
HiNA Battery	China	Launched the first sodium-ion battery in 2017 when it was founded. As of February 2023, a test electric vehicle equipped with this battery was launched
Reliance Group	India	With acquisition of UK startup Faradion (pioneer in sodium ion with patented technology), the company marked its entry in sodium-ion battery market
AMTE Power	UK	Production of sodium-ion batteries based on technology licensed from Faradion (acquired by Reliance in 2022).
Natron Energy	US	Established production line in 2020, based on the Prussian-blue cathodes in sodium-ion battery. It has signed major partnerships since then
CATL	China	Company announced that its production lines will release sodium-ion battery-fitted vehicles within 2023

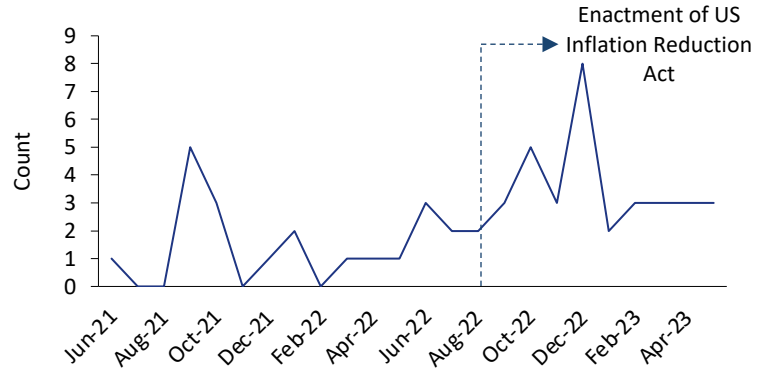
Source: News reports, press releases

- The predominant technology choice of Lithium-Ion also motivates the thrust to seek its alternative
- Sodium's abundant availability and cost-effectiveness, together with its similarity in chemical properties makes for an attractive proposition
- Globally, about 20 sodium-ion battery factories are in planning/development stages (as of April 2023). Chinese companies, with 16 such factories in process, have a head start in commercializing sodium-ion for electric vehicle deployment

3. KEY ENTERPRISES AND VENTURES

OEM Partnerships & Joint Ventures

Battery Production Partnership Announcements since mid-2021



Source: Reuters News (Refinitiv Eikon database)
Note: The data includes partnership announcements related to battery recycling and material sourcing

- Roughly three-quarters of the existing global Gigafactory pipeline is based on joint ventures and related partnership structures between the automobile and battery OEMs
- The pattern in announcements of battery production partnerships is indicative of the rising interest in the field. However, the underlying business conditions continue to evolve
- For automobile OEMs, the joint ventures constitute a critical step to acquire and integrate the technology in the shifting vehicle powertrains
- The US and European companies, especially those in the automotive sector, currently lead the way due to the competition and demand pressure

Automakers' Direct Deals/Partnerships with Miners

	Mining company	Metal	Type	Location	Detail
Ford	Liontown Resources	Lithium	Binding off-take and debt financing	Australia	150,000 tonnes per year of spodumene concentrate; A$300 million debt facility
General Motors	Livent	Lithium	Off-take and prepayment	South America	Lithium hydroxide supply from 2025; pre-payment of $198mn
Stellantis	Vulcan Energy Resources	Lithium	Equity investment and binding off-take	Germany	€50mn investment
Renault	Terraframe	Cobalt	MoU	Finland	Annual supply for 15GWh of battery capacity
Volkswagen	Huayou	Cobalt, Nickel	MoU for joint venture	Indonesia	Annual output of 120,000 tonnes of nickel and 15,000 tonnes of cobalt
Daimler	Rock Tech Lithium	Lithium	MoU	Canada, Germany	10,000 tonnes of lithium per year from 2026
BMW	European Lithium	Lithium	MoU	Austria	$15mn pre-payment if binding contract agreed
Toyota	BHP	Nickel	MoU	Australia	Nickel sulphate supply
Hyundai	Arafura Resources	Rare earths	Binding off-take	Australia	1,500 tonnes of neodymium praseodymium oxide per year

Source: Financial Times (as of November 2022)
Note: Data represented above excludes Tesla's as they are mostly existing supplier relationships

Technology Providers and Developers & Startups

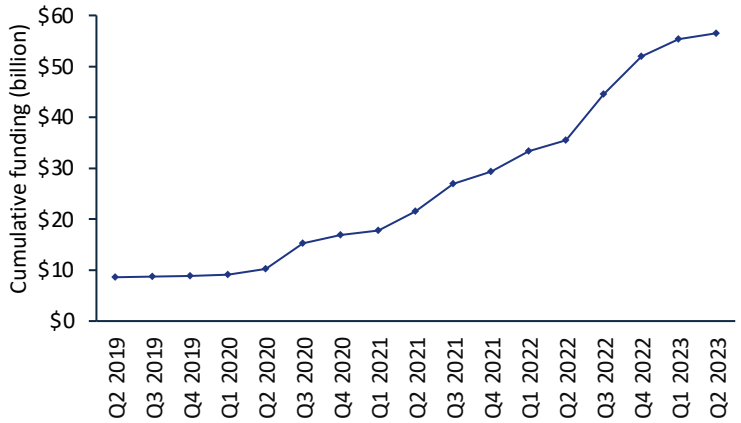
Technology Providers Setting up Battery Manufacturing Capacities (illustrative)

	Country	Development
GUS Technology	Taiwan	Though focused on Lithium Titanate and NCM materials, the company entered the battery manufacturing space for potentially Taiwan's first Gigafactory unit
Recharge Industries	UK	The Australia-based battery technology company acquired the bankrupt Gigafactory enterprise Britishvolt
Kontrolmatik Technologies	US	Turkish engineering and system integration enterprise, planning LFP-based Gigafactory
Kore Power	US	Developer of Lithium cells and battery storage solutions, the planned Gigafactory will cater to both electric vehicles and energy storage sectors
ProLogium	France	The Taiwan-based company plans to use its proprietary solid-state battery technology for the Gigafactory project

Source: News reports, Press releases

- The manufacturing pipeline for electric vehicle batteries is not limited to the OEM partnerships
- Part of the upcoming capacities is led by technology providers, or those entities engaged in the development chain of battery cell components
- The competitive edge of such enterprises would lie within technology, considering that the scale and profitability are two key known entry barriers

Trend in Cumulative Funding in Battery Tech/Startup Segment



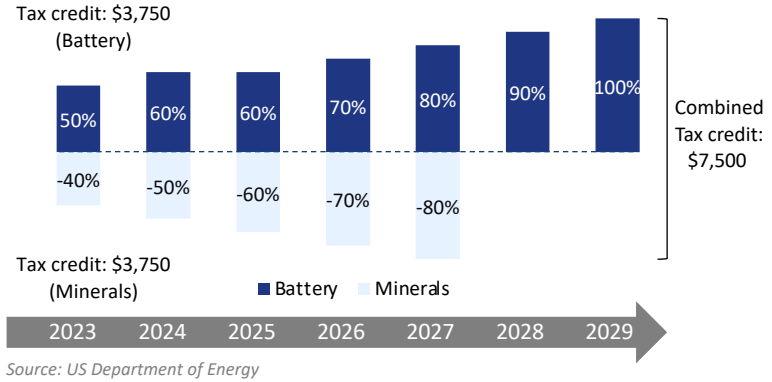
Source: Crunchbase

- Startups are leading some of the major Gigafactory projects under development. Venture capital (VC) funding enabled the enterprises to succeed
- PitchBook's February 2023 estimate held the Swedish Gigafactory manufacturer Northvolt as the highest-funded European startup for the $5.5 billion raised till that date
- Market entry of well-funded startups in the Gigafactory space is an encouraging factor for market depth. Business profitability will be tested regardless of legacy resources or supply chain arrangements

4. POLICY SUPPORT

Policy Backdrop Impacting Gigafactory Pipeline (USA)

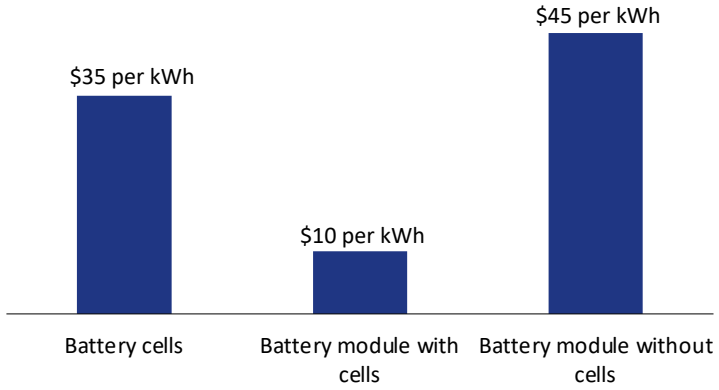
Minimum Local Sourcing Requirement for US Electric Vehicle Tax Credits



Source: US Department of Energy
Notes: (a) Battery requirements refer to minimum share of manufacturing/assembly in North America
(b) For minerals, the requirement refers to minimum share of sourcing within US, or trade partners of US, or recycled in North America(c) Tax credit refers to the tax benefit available to each electric vehicle, based on fulfilment of criteria

- The $370 billion US IRA is notable for the incentives for local manufacturing. The tax credits offered for locally sourced and produced electric vehicles constitute the major draw for investors
- For most part, the regulation has effectively tipped the balance, with the clear tax credit offer of $3,750 for those electric vehicles meeting either battery or critical mineral sourcing norms
- For meeting both, the tax credit is worth $7,500 per vehicle. In this regard, manufacturers are assured of tax credits on the production side

Production Tax Credits for Battery Manufacturing



Source: US Department of Energy

- A tax credit, equivalent to 10% of production cost, is available for the enterprise using the applicable critical minerals and for active electrode materials used in production
- The tax credit follows a slab on per kWh basis. For plants configured for battery modules without cells, the incentive is proportionately a bigger sum
- Other federal initiatives and support measures are running concurrently to promote investments in the battery ecosystem (such as capacity building measures, etc.)

Policy Backdrop Impacting Gigafactory Pipeline (Global)

US States Policy Support for Battery Manufacturing Investments (illustrative)

States	Support / incentives
Michigan	$1 billion in approved incentives for Ford Motors' battery manufacturing project
Kansas	$829 million incentives for the Panasonic battery manufacturing plant
Georgia	$358 million in incentives (grants/tax breaks) for FREYR Gigafactory project
Tennessee	$40 million sanctioned for the LG Chem's battery cathode plant

Source: Source: News reports, press releases

EU's Approved Member States' Aid for Battery Manufacturing Investment

Country	Aid for battery manufacturing investment
Sweden	$350 million EIB loan for Northvolt Gigafactory project.
Hungary	$89 million government support for Samsung's Gigafactory project
Spain	$837 million aid for Volkswagen and other Gigafactory projects

Source: Source: News reports, press releases

Countries Promoting Investments in Local Battery Production Facilities

Country	Policy support / initiative
Japan	Subsidy allocation worth $2.6 billion for domestic battery manufacturing facilities of at least 3GWh capacity.
South Korea	$5.32 billion worth of financial support for domestic firms seeking to invest in North America. The policy aid will help firms cope with the US legislation's norms.
Thailand	$0.74 billion subsidy budget for domestic production of electric vehicle batteries
Australia	$1.2 billion allocation (as of 2021) under manufacturing strategy roadmap, in which battery production enterprises are included for aid.

Source: News reports, press releases

- State-level support is complementing the federal side to attract manufacturing investments
- The US states of Georgia, Kentucky and Michigan could play a dominant role in unlocking upcoming capacities. Other states include Kansas, North Carolina, and Tennessee
- State-level authorities are actively offering incentives to competitively secure the projects

- Major investment areas are categorized under 'Important Projects of Common European Interest' (IPCEI), which streamlines the resources across the region to assist commercial viability
- In March 2023, the European Commission proposed the Net Zero Industry Act (NZIA) to encourage investments in specific technologies. NZIA has identified battery technology as one of its strategic technologies

- A handful of countries globally have announced concrete measures to attract the typical Gigafactory-scale of battery manufacturing
- China's state-led industrial policy ensured a dominant position of domestic enterprises. Other countries are exploring battery-led electrification and energy storage prospects
- Multiple global locations have come to the fore as a result of the need for diversification beyond China

5. COSTS AND FINANCING

Capital Cost

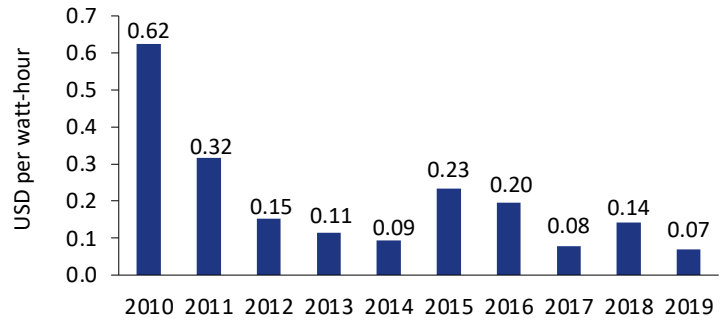
Indicative Capital Costs of Major Projects under Development

Company	Location	Capacity (GWh)	Cost per GWh
FREYR	Georgia, US	34	$50 million
CATL	Debrecen, Hungary	100	$74 million
ACC	Termoli, Italy	40	$50 million
Tesla	Berlin, Germany	100	$55 million
LG Energy	Arizona, US	43	$128 million
ONE	Michigan, US	20	$80 million
Tesla	Nevada, US	100	$36 million
Honda & LG	Ohio, US	40	$110 million
Northvolt	Sweden	60	$50 million
Volkswagen	Ontario, Canada	90	$58 million
CATL	Thuringia, Germany	14	$140 million
Italvolt	Piedmont, Italy	45	$84 million

Source: Press releases and news reports
Notes: (a) Volkswagen Canada project has a standing government commitment of C$13.2 billion in funding support. The cost indicated above refers to company's proposed investment
(b) Tesla's Nevada project is planned at the same location which houses the company's operational Gigafactory

- The emerging global manufacturing pipeline is unprecedented in scale and complexity. It provides some indications of the capital costs related to the Gigafactories
- The primary focus lies in vertical integration to maximize efficiencies and market share
- Local factors make the difference, as evident in the per GWh capital cost in North American projects versus those in the European region

Historical Trend in the Announced Capital Cost of Battery Manufacturing

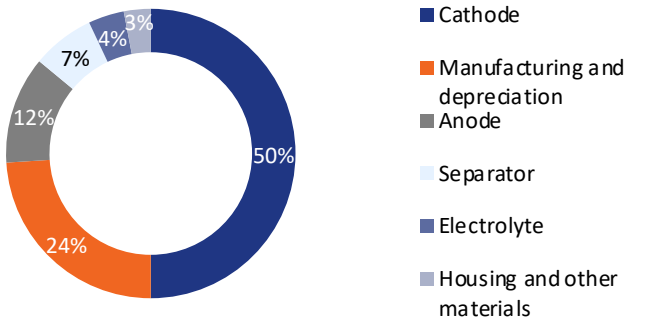


Source: IEA
Note: Data points include batteries for electric vehicles and energy storage, and reflect average costs in each year of commissioning

- At an aggregated level, the long-term trend appears to indicate a pattern of decline in the average capital cost of battery manufacturing facilities
- Active policy support, technology choice, easier financing, and development of efficient supply chain linkages will prove to be the cornerstones in the decline of average capital cost of battery manufacturing facilities

Capital Cost & Critical Inputs in Cost Structure

Distribution of a Typical Lithium-Ion Battery Cell Cost



Source: Visual Capitalist

- The vertically integrated structure of upcoming Gigafactories aims to reduce upfront investment cost through scale
- Cost of electrodes, cell assembly and finishing imposes a significant cost share in the dominant LFP battery chemistry
- Equipment supply also assumes a critical role in the current Gigafactory pipeline. Cost estimates and supply reliability could sharply change with progress in the Gigafactories' under development

Average Cost of Critical Battery Metals

Metal	Price per tonne (6-month average)	Application in batteries
Lithium Carbonate	$82,141	Cathode
Copper	$9,417	Current Collectors
Cobalt Sulfate	$8,767	Cathode
Nickel Sulfate	$6,488	Cathode
Manganese Sulfate	$947	Cathode

Source: Visual Capitalist

- Raw materials cost of the upcoming production facilities is largely centered on the critical minerals. The relative scarcity and competing demand will reflect in the prices as facilities are operationalized
- Critical inputs play a crucial role in cost structure because not every Gigafactory can fully vertically integrate with full control over back-end supply
- Additionally, long-term raw material contracts may be limited to a few pipeline companies. This will put a greater emphasis on commercial arrangements such as joint ventures and strategic partnerships

Critical Inputs in Cost Structure & Funding by Type

Illustration of Material Requirement for 20 million vehicles at Tesla

Commodity	Material required (tonnes)	Global production (tonnes, 2021)	Share of 2021 global production
Lithium	755.4K	532K	142%
Cobalt	61.4K	170K	36%
Aluminium (battery)	14.6K	68M	+0%
Aluminium (vehicle)	6.6M	68M	10%
Copper (vehicle)	1.8M	21M	9%
MagREO (NdPr, Dy, Tb)	18K	58K	31%
Manganese	19K	7.5M	+0%
Nickel	670.4K	2.7M	25%
Graphite	1.1M	1M	113%

Source: Mining.Com (as of August 2022)

- The arguable point is raw material supply lagging far behind the apparently accelerating demand. The pressure on the backward linkage is evident from the steps of existing OEMs
- Countering the issue, in May 2023, Tesla announced the setting up of a Texas-based lithium refining plant, making it the only North American auto OEM refining its own battery metal
- Other OEMs are also following suit. BYD, General Motors are making considerable effort and investment to secure critical minerals

Recent Major PE Funding in Gigafactory Projects

	Gigafactory project developer/promoter	Particulars
Greybull Capital	Britishvolt	As of February 2023, the PE investor was approached among other investors to take over the financially stressed venture
KKR	FREYR	As of December 2022, FREYR was in discussion for about $500 million funding from KKR
Fifth Wall and Franklin Templeton	ONE	$300 million Series B funding for the startup-led gigafactory project in Michigan

Source: Press releases and news reports

- The huge Gigafactory pipeline, despite its promise, faces challenges in securing funding
- Factors such as the complexity of projects, long-winded route of approvals, technology, and supply chain linkages together shape the investor perceptions
- As a result, the financing of such projects is from a mix of avenues including private equity, institutional funding, debt/bonds, etc

Funding by Type

Bond Issuance by Major Companies to Fund Battery Manufacturing Projects

Companies	Bond issuance
Northvolt	As of July 2022, the company announced issuance of $1.1 billion convertible notes, as part of fund raise for Gigafactory
LG Chem	$300 million worth of new 'green bonds' to fund project development
Sk On (Sk Innovation)	Green bond' offering worth $900 million in the US dollar bond market, with guarantees from Kookmin Bank
Honda	In March 2022, company announced issuance of $2.75 billion dollar-denominated green bonds. The proceeds will go towards battery production, among other electrification initiatives underway

Source: Press releases and news reports

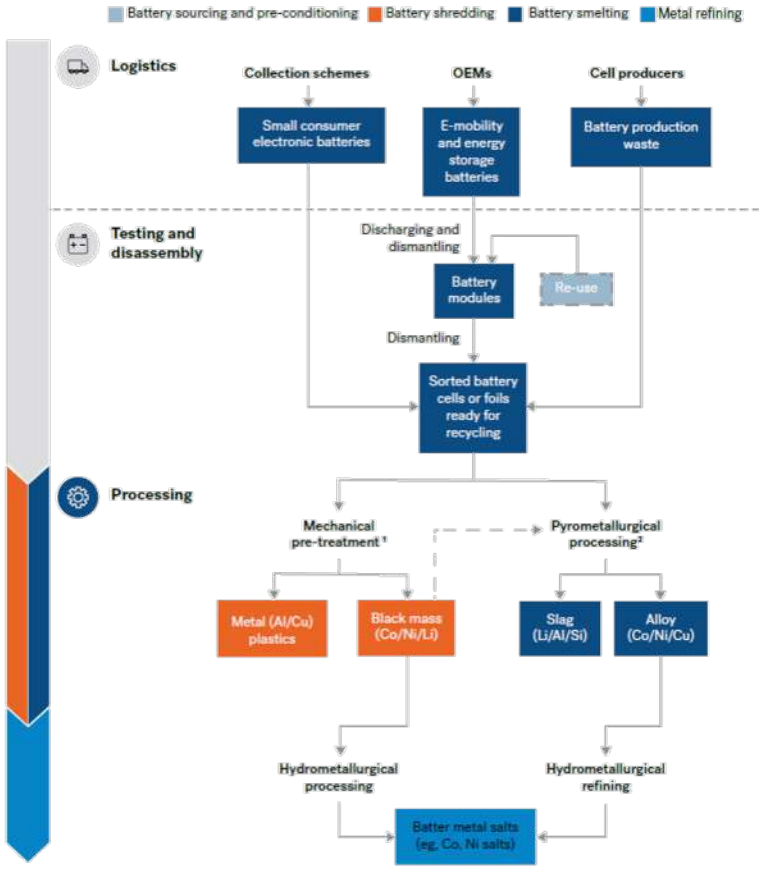
- Enterprises with strong and credible backing of equipment manufacturing, supply chain sourcing or joint ventures with major end-use customers have had access to the private equity and bond issuance routes of funding, among other avenues. Northvolt raised over $1 billion through bonds
- The dollar-denominated bond market has also been tapped into by the incumbent battery manufacturers for capacity expansion. A notable example is CATL's $1.5 billion bond issue in September 2020 to fund its planned capacity expansion
- With a dynamic phase of the Gigafactory industry landscape, a clearer picture of funding structure will be evident after a while. Some of the most important areas such as the business model, competitive strength in the supply chain, and geopolitical factors, together add to the flux

Source: Press releases and news reports

6. BATTERY RECYCLING

Major Battery Demand Segments

Battery Production Scraps are the Primary Global Supply for Battery Recycling Until 2030

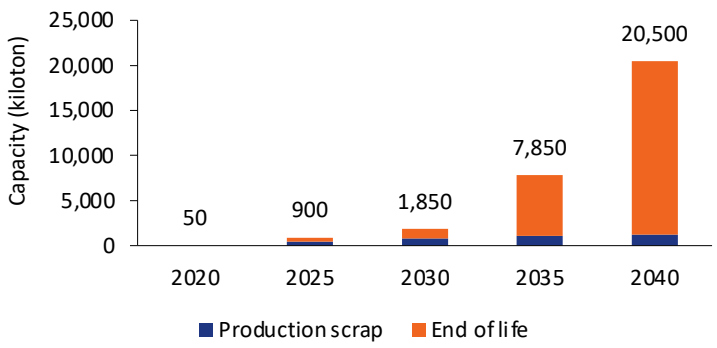


- The globally strong Gigafactory pipeline has brought to the fore the battery recycling segment of the chain that has otherwise been largely nascent till recently
- Multiple factors, ranging from sustainability concerns to localization and supply chain diversification, contribute to a heighted business interest and investment in recycling
- Predominant short-term demand arises from the Gigafactories' production scrap till electric vehicle fleet expands reasonably for end-of-life batteries
- The leading global markets in Gigafactory capacities are more likely to overlap with the upcoming demand hotspots in battery recycling

Source: McKinsey Battery Insights
Note: [1] Batteries are typically being thermally treated (80-600C) before and/or after crusing to remove the electrlyte (deactivation), optimize the sepration of electrode and current collector foil, minizize impurities that could disturb subsequent hydrometallurgical steps and reduce metals to their elemental form for optimized hydrometallurgical processing
[2] Smaller battery packs can be processed straight into smelter

Major Battery Demand Segments

Projected Global Supply of Electric Vehicle Battery for Recycling



Source: McKinsey

- The recycling demand for electric vehicle batteries is largely limited to production scrap. An expansion in the electric vehicle fleet will shift the recycling focus to end-of-life batteries
- Industry reports such as Mckinsey's concur that it will be only after 2030 when the end-of-life electric vehicle batteries can be available
- The Gigafactory pipeline is a major demand driver for battery recycling. Some of the major projects under development incorporate recycling in the design and plan

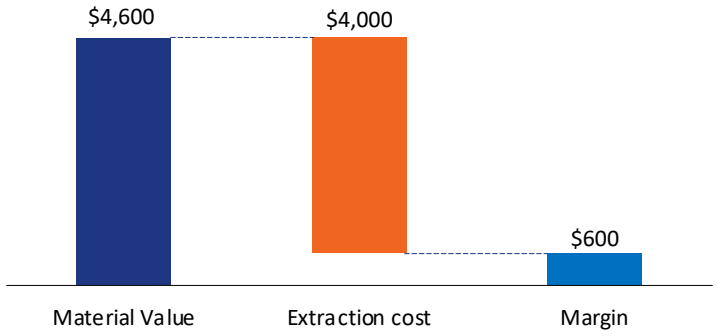
Gigafactories in Pipeline with Battery Recycling Facilities

Company/Group	Gigafactory in Plan/Development	Recycling plan
Northvolt	150GWh combined capacity across three European locations by 2030	By 2030, 50% of raw material requirement to be met through recycling. A joint venture with Hydro, named Hydro Volt, is part of the initiatives in this regard
Verkor	16GWh capacity planned at the Port of Dunkirk	Pilot project (operated by Startup Mecaware) to test using production-based carbon dioxide to recycle battery production rejects
Britishvolt	30GWh capacity planned by 2030 at Blyth, UK	Partnered with Glencore for recycling facility to process manufacturing scrap
Powerco (Volkswagen)	40GWh total capacity planned by 2025/2030 at the Saltzgitter plant, Germany	Plant being designed for closed-loop recycling, especially with over 90% for raw materials
Panasonic	30GWh capacity planned for 2025 commissioning at Kansas, US	Partnered with recycling company Redwood Materials for planned 30% recycled Lithium and 100% recycled Cobalt

Source: Press releases, respective companies

Major Battery Demand Segments

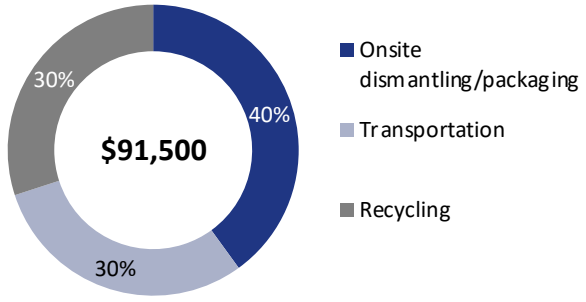
Estimated Monetary Value in Per Tonne of Electric Vehicle Battery Recycling



Source: McKinsey

- A Gigafactory has an estimated average scrap rate of 8% - 10%. But such average estimates are conditional to the assumptions of technology and plant-specific parameters
- Scale is an important factor in ensuring profitability. Other factors include recovered metals' price, battery cell chemistry, and battery supply chain localization
- With some assumptions in the battery closed loop recycling and extraction/processing costs, the ballpark estimate of the monetary value is $600 per tonne of battery material by 2025 (McKinsey, March 2023).

Cost Breakup of Decommissioning a 1-MWh NMC Lithium-Ion Battery Storage System

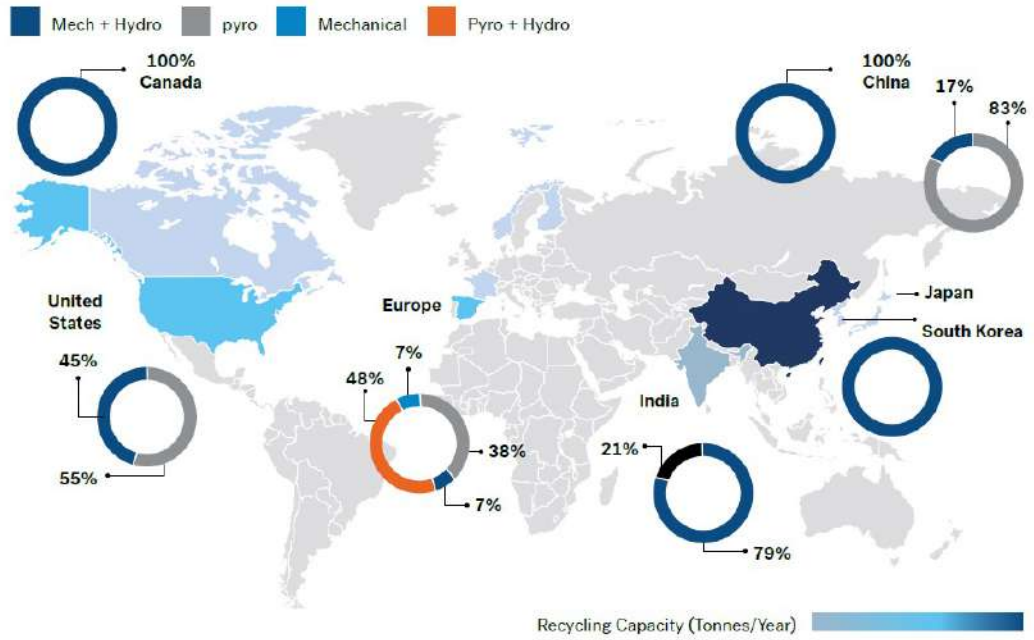


Source: Green Clean Solar

- The demand for recycling is not restricted to the Gigafactories under development. The existing battery manufacturing capacities are headed in the same direction
- After electric vehicles, grid-scale energy storage is the next major battery market. Recycled batteries, whether generated during manufacturing or at the end of the electric vehicle fleet's life cycle, are finding their way into battery storage units
- This is a nascent and emerging sub-segment of battery recycling with lack of defined policy and framework

Technology and Key Market Players

Global Recycling Capacity by Technology



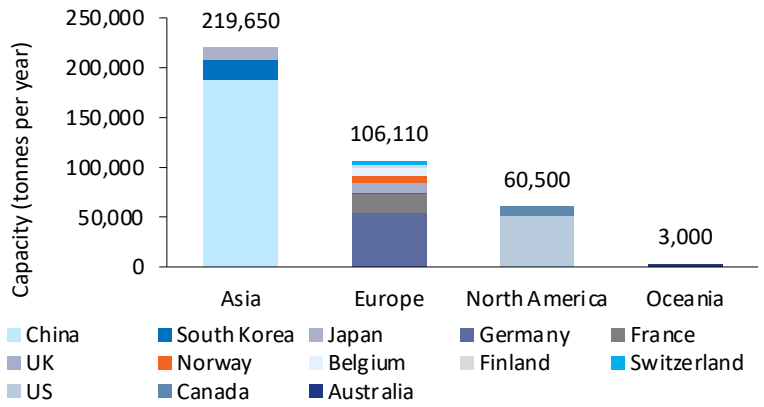
Source: Niti Aayog, Government of India

- There are established recycling technologies in place for the typical Lithium-Ion and other major battery chemistries in use
- To generalize though, there are four steps, namely preparation, pre-treatment (pyrolysis and mechanical), pyro-metallurgy and hydrometallurgy
- The combination of the steps varies across the recycling plants. In some cases, there are standalone recycling capacities, adopting either one of mechanical, pyrometallurgical or hydrometallurgical processes

Source: Canary Media

Technology and Key Market Players

Existing and Planned Lithium-Ion Battery Recycling Capacity by Region (2021)



Source: Canary Media

- The technology profile of battery recycling varies across countries and regions. This is in part a reflection of the existing industrial base in mineral processing and refining
- China's dominance is a given factor. The European and US based capacity is gradually coming to the fore, with incentives available for the domestic manufacturing units
- The prevalent recycling processes vary between Chinese hybrid modes of mechanical with hydro and European combination of mechanical, hydro and pyrometallurgy

Emerging Integrated Structure in Recycling Business

Vertically integrated	Cross-value chain partnerships	In-house OEM recyclers
Individual companies operate across the value chain for end-to-end offering. There is limited reliance on partnerships	Grouping of specialized companies to operate under a partnership agreement for recycling solutions	Tie-ups between automobile OEMs and cell manufacturers for closed-loop production and supply chain control. This is evident in major upcoming Gigafactories

umicore BASF SOLVAY VEOLIA Hydro northvolt

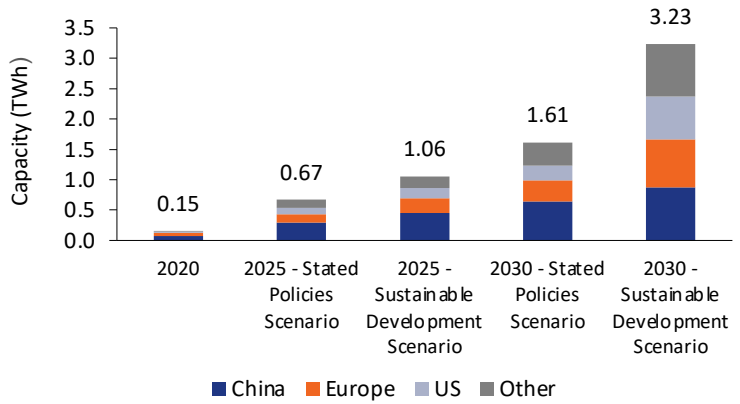
Source: McKinsey

- Some of the key global recyclers include Ecobat, Umicore, Accurec, SunEel, Kyoei Seiko, and Brunp, among others
- Recycling companies' existing production systems support multiple battery chemistries and production scraps. As Lithium-Ion batteries take on a greater share, there is increasingly a business case for redesigning
- Besides capacity expansion, upcoming investments will re-configure for a diverse input feedstock in Lithium-Ion and other leading battery formulations

7. OUTLOOK

Demand/Opportunity in the Global Battery Business

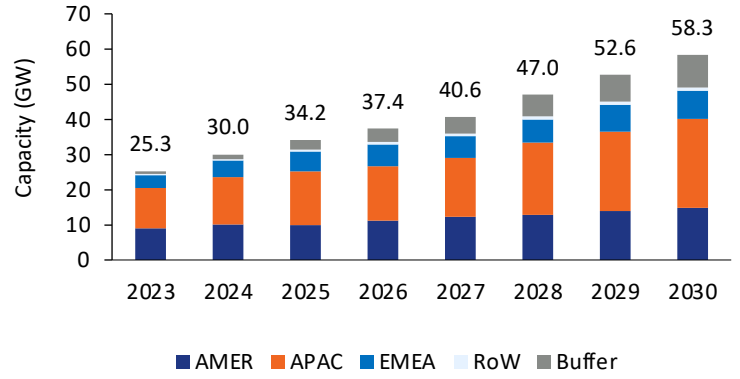
IEA's Projection of Electric Vehicle Battery Demand



Source: IEA (as of October 2022)
Note: Sustainability Development Scenario denotes the modelling scenario where all sustainability goals are met

- Electrification of transport is a major decarbonization initiative, with government-funded purchase subsidies having laid a solid foundation
- Policy frameworks focus most on passenger electric vehicles. Over a third of new vehicle sales will likely come from such vehicles by 2035, representing a rising share
- IEA's projection of 3.2TWh might be an under-estimate considering the latent demand in emerging markets

Projected Global Annual Battery Storage Installation

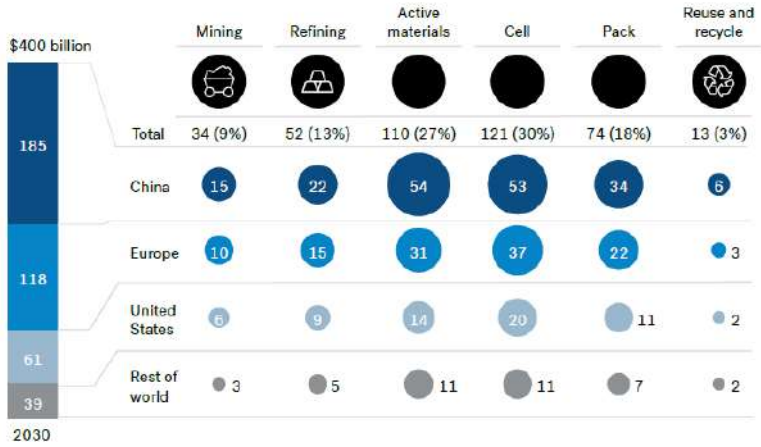


Source: BNEF
Note: Buffer is an estimate/headroom that is not explicitly allocated to any specific application

- Electric vehicles remain the dominant market for planned battery capacity. The use of battery storage in the grid is increasing as intermittent renewable energy penetration increases
- Rapid decline in the battery cost and favorable regulatory changes in the power markets enabled viable business cases for the storage developers
- BNEF projections indicate a five-fold rise in the annual battery storage installations by 2030. US and China to drive the bulk of storage capacity growth during the forecasted period

Battery Supply Chain Factors Influencing Investment

Revenue Projection Scenario for 2030 across the Lithium-Ion Battery Supply Chain



Source: McKinsey

- The predominant technology choice of Lithium-Ion batteries will have opportunities across the supply chain in varied measures
- Certain parts of the supply chain, such as recycling, emerge from recent developments and emphasis in sustainability and could grow with wider penetration of batteries in end-use sectors
- By 2030, McKinsey predicts $400 billion in supply chain revenue. Cell manufacturing and active materials account for a significant portion of revenue

Emerging Alternatives in Commercial Deployment of Batteries

Battery technology	Adoption by manufacturers
Sodium-Ion	Globally leading battery producers CATL and BYD will be deploying sodium-ion batteries in the EV production lines within 2023
Lithium Metal (solid-state batteries)	Battery technology provider QuantumScape has a joint venture with Volkswagen for testing deployment of its Lithium Metal prototypes
Lithium Iron Phosphate (cathode)	Tesla is using LFP-based batteries in some of its vehicle production lines. Ford and Volkswagen announced plans to include LFP in their product offerings

Source: MIT Technology Review; Electrek; Electrive and IEA

- Some of the recent major advancements are in the areas of active battery material chemistry, cell energy density and cell-to-pack design, among others
- Variants of Lithium metal anodes are being considered for potential improvements in energy density
- While EV-based batteries occupy the maximum attention, stationary use batteries (energy storage) are in the midst of similar transitory phase for alternatives

Battery Supply Chain Factors Influencing Investment

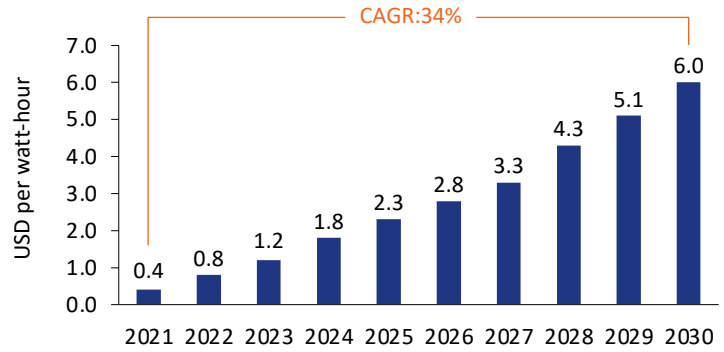
Innovations Impacting Battery Cell Components

	2010s		2020s		2030s	
Cathode	LCO	LMO LFP NMC/NCA	LFP NMC/NCA	LFP NMC/NCA LMFP/LMNO	NMC/NCA LMFP/LMNO Sulphur	LMFP/LMNO Sulphur
Separator/ electrolyte	Polymer/ liquid	Polymer/ liquid	Polymer/ liquid	Polymer/ liquid	Polymer/liquid/ advanced liquid/ semi-solid	Advanced liquid Semi-solid Solid
Anode	Graphite	Graphite	Graphite	Graphite Graphite+ Silicon	Graphite and Silicon Lithium metal Silicon anode	Lithium metal Silicon anode
Casing	Cylindrical	Cylindrical Pouch	Prismatic Cylindrical Pouch	Prismatic Cylindrical Pouch	Cylindrical Pouch Prismatic	Cylindrical Pouch

Source: McKinsey

LCO: Lithium Cobalt; LMO: Lithium Manganese Oxide; LFP: Lithium, Iron, Phosphate; NMC: Lithium, Manganese Cobalt; NCA: Lithium, Nickel, Cobalt, Aluminum Oxide; LMFP: Lithium, Manganese Iron Phosphate; LMNO: Lithium, Manganese Nickel Oxide

Projected Active Material Demand Globally



Source: PwC (Strategy&)

- Most of the emerging technologies in batteries will have to be introduced without the benefit of testing them in largescale deployment
- For Gigafactories, the Cathode and Anode active materials (about 70% of battery cell weight) are the most important in consideration
- The relevant minerals in the active battery materials include Graphite, Lithium, Nickel, Manganese and Cobalt where the projected requirement is critical in supply chain

Investment outlook

OEMs' Capex Commitments Toward Battery Capacity by 2030

Company	Partnerships	Battery investment
BMW	Battery: Envision AESC, Northvolt, CATL, EVE Energy, Samsung SDI, Solid Power, ONE Materials: European Lithium, Glencore, Ganfeng Lithium, Green Lithium, Lilac Solutions, Livent, Managem, Mangrove Lithium, Umicore OEM: Great Wall, Brilliance, Stellantis	$10.0B
Ford	Battery: LGES, SK On, Panasonic, Samsung SDI, Solid Power Materials: BHP, Huayou Cobalt, Ioneer, Lake Resources, Lilac Solutions, Liontown Resources, Rio Tinto, Syrah Resources, Vale OEM: Volkswagen, Changan, JAC, Jiangling	$7.0B
General Motors	Battery: LGES Materials: Controlled Thermal Resources, Glencore, Livent, Posco Chemical OEM: Honda, SAIC, Wuling, FAW	$7.5B
Mercedes-Benz	Battery: LGES, SK On, CATL, Farasis, Envision AESC, Factorial Energy, StoreDot Materials: Rock Tech Lithium, Sila Nano OEM: Geely, BYD, BAIC, Nissan, Rivian	$30.0B
Nissan	Battery: Envision AESC, LGES, CATL, Sunwoda OEM: DFM, Renault, Mitsubishi	$5.0B
Volvo	Battery: LGES, SK On, Northvolt, CATL, Samsung SDI, Guoxuan (Gotion), QuantumScape Materials: Ganfeng Lithium, Huayou Cobalt, Tsingshan, Nano One, Umicore, Vulcan Energy, CBMM OEM: FAW, SAIC, JAC	$3.3B
VW Group	Battery: LGES, SK On, Northvolt, CATL, Samsung SDI, Guoxuan (Gotion), QuantumScape Materials: Ganfeng Lithium, Huayou Cobalt, Tsingshan, Nano One, Umicore, Vulcan Energy, CBMM OEM: FAW, SAIC, JAC	$57.0B

Source: Reuters

- The capex requirement of the ongoing battery production ramp-up is subject to multitude of factors such as location, policy support/incentives and technology choice
- The investments will not be limited to the battery segment alone, as other upstream/midstream segments such as mining, refining, and processing will undergo a similar scale up to accommodate demand
- The Chinese influence on the global battery value chain could be moderated with the sustained spendings together with the protectionist policies evident in the US and Europe
- Multiple structures will together contribute to future investment spending – including state funding, joint ventures/strategic partnerships, public SPACs and private equity, among others

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