Global Battery Anode Materials Study

Prospectus

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Where are we now?

Lithium-ion batteries (LIBs) are currently being considered as the power sources of choice for applications involving large scale grid energy storage, electric vehicles and consumer electronics. The unprecedented demand for these batteries has propelled the growth of the LIB value chain worldwide, creating a complex ecosystem of suppliers, manufacturers, and end-users. Companies in the supply chain are grappling with several issues in this regard:

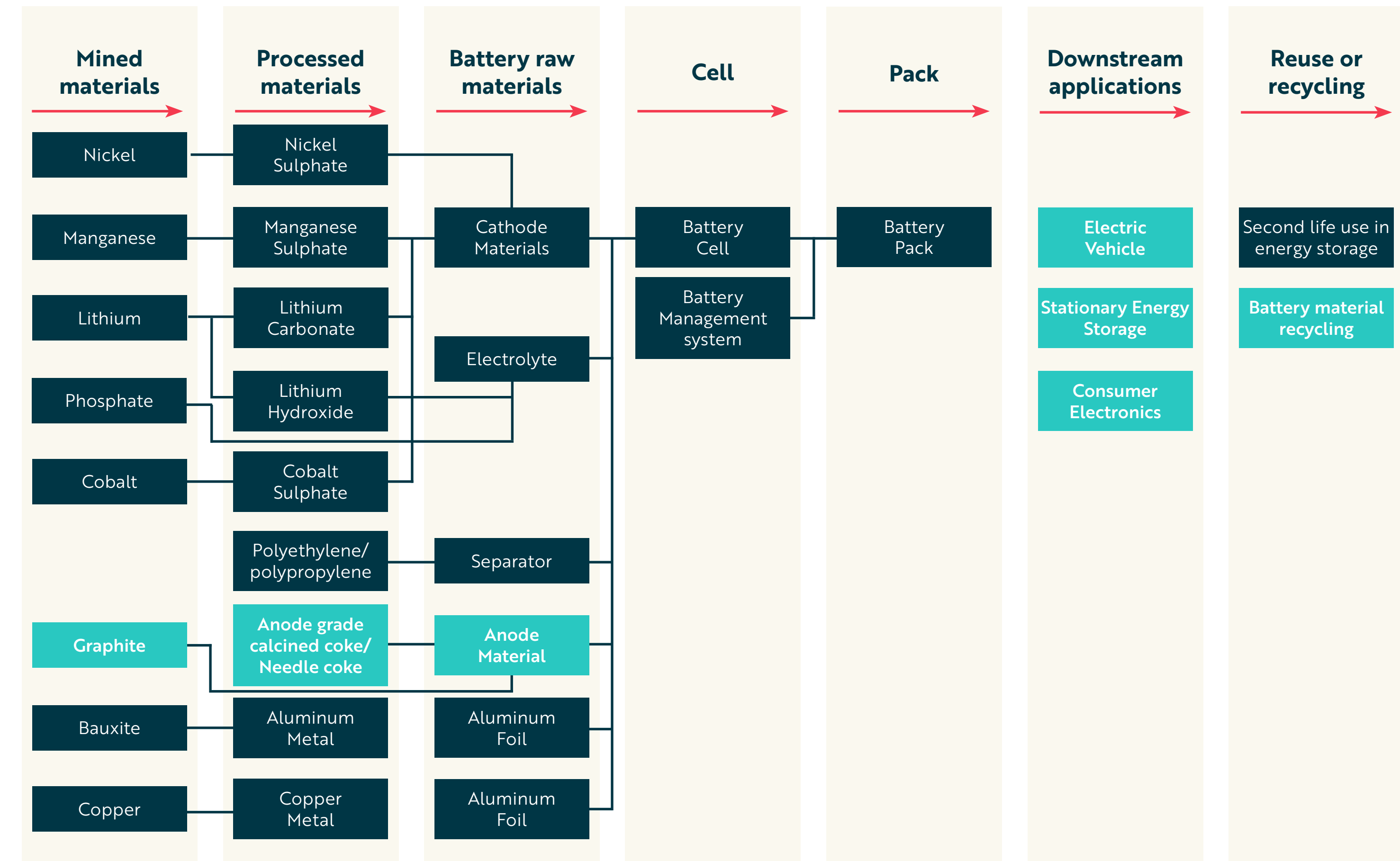
- What will be the market size of battery anode materials and their precursors five, ten and fifteen years' time?
- How will quality specifications change over time as new technologies develop? Will there be enough supplies within those parameters of calcined coke, needle coke natural graphite?
- Will reduced refining in the future impact supplies of needed petroleum coke within the right quality range?
- What will global supply chains look like? Which regions will be the most likely to expand capacity along the value chain?
- What new technologies are on the horizon that can impact the volumes and growth of currently favored materials?
- Is there enough feasibly attainable natural and synthetic graphite to meet future demand?
- Which companies and geographies are best positioned to grow in each step of the supply chain?
- What are the risks and rewards of investing in the supply chain?

The battery value chain encompasses multiple stages, each playing a crucial role in the production and distribution of batteries starting with the mining of raw materials followed by the refining of active materials and then the preparation of cells, modules, packs and other engineered product components in the battery system.

Battery value chain

Our comprehensive analysis delves into the intricacies of the lithium-ion battery anode value chain, exploring its markets, trends, and dynamics.

The lithium-ion battery value chain encompasses a diverse array of stakeholders, technologies, and market segments. From raw material extraction to end-use applications, each stage of the value chain contributes to the production, distribution, and utilization of lithium-ion batteries. As demand continues to surge across various sectors, industry players must navigate evolving market dynamics, technological advancements, and sustainability challenges to maintain competitiveness and foster innovation in the global battery market.



ELECTRIC VEHICLES

The transition towards electric vehicles is driving the demand for lithium-ion batteries. Government incentives, environmental regulations, and consumer preferences are further accelerating EV adoption globally. However, transition and adoption are still restricted primarily to developed countries because of infrastructure and high EV purchase prices. Battery manufacturers are now also investing in high-capacity cells, fast-changing technologies, and solid-state battery solutions to meet the performance requirements of EVs.

RECYCLING

Battery recycling continues to be a growing concern from a sustainability and economics perspective. The importance of recovering as much raw material as possible to help with resource depletion, as well as to help solve the supply gap, in time, cannot be underestimated. Recycling technologies enable the recovery of critical minerals, such as lithium, nickel, cobalt, manganese and graphite.

STATIONARY STORAGE

In stationary energy storage, lithium-ion batteries play a crucial role in enabling the integration of renewable energy sources, such as solar and wind power. Energy storage systems facilitate grid stability, peak shaving, and load balancing, thereby enhancing the reliability and efficiency of renewable energy installations. Falling battery costs and advancements in energy management systems are driving the deployment of utility-scale battery storage projects worldwide.

ROLE OF ANODE MATERIALS IN BATTERIES

Anode materials in LIBs represent approximately 10% of the total cell price. Graphite is the largest single mineral in a LIB anode and a supply deficit is expected. Therefore, recycling of anode materials is important to reduce waste, to lower costs and to secure supply. More than 99% of the graphite recovery from waste anode battery is possible with the right technology.

GEOGRAPHICAL STRUCTURE

Countries like Asia, Europe and North America are the primary manufacturers of lithium-ion battery cells, modules, and battery packs used in different applications. However, raw material production for these batteries is concentrated mostly in China due to their strength in processing and refining. Reliance on imports makes the battery industry susceptible to price fluctuations of raw materials and therefore large OEMs are trying to vertically integrate with their suppliers to secure material inputs. These players are also working towards making the battery value chain more sustainable and CO_2 neutral.

What will we focus on?

The battery anode is a vital element of a LIB, based on its properties and morphology. In this study we will focus on analyzing the growing demand of batteries and the requirement for battery anode material, including alternate/substitute materials. It will also cover recent advancements in anode technology for LIBs as shown below.

This study is designed to provide a quantitative and qualitative strategic market analysis of the global battery anode value chain, by major component.

It will provide industry stakeholders with a clear overview of demand volumes by major downstream market and anode material, as well as expected technologies, production capacities, investment needs, and other supply chain developments. A road map will be developed showing the advancements of anode material in high-energy LIBs and for promoting sustainable battery technologies. The study will inform users on present challenges and how to mitigate risks.

Significant investments are being made to enhance performance, sustainability, and cost-effectiveness within battery anodes, driven by ongoing climate change discussions, decarbonization trends, geopolitical tensions, and the push for technological independence. Moreover, a global shift towards creating circular battery ecosystems is emerging, focusing on sustainability through effective battery recycling and resource conservation.

	Graphite	Silicon	Lithium-Titanate (LTO)	Lithium Metal
Technology Readiness	Graphite and Synthetic Graphite are the most widely used and established anode material.	Most promising candidate to replace graphite. In research and development phase.	Commercially viable with Pilot Plants planned and large scale manufacturing to come.	Currently in the development phase.
Advantages	High conductivity, high specific surface area, low cost, and strong stability. It has been used in lithium-ion batteries for many years.	Higher lithium storage capacity which can increase energy density and cycle life. They are safer, lighter, and require less maintenance.	Temperature resilient and long life. Offers longer life cycle.	Highest theoretical capacity, low density, lowest electrochemical potential. Offers the highest energy density when compared to other anode options.
Disadvantages	Graphite can't meet increasing demand. Energy storage capacity is limited, susceptible to problems during long-term use which limits reliability and cycle life.	Silicon anodes expand when charged, and repeatedly swell and shrink during cycling reducing life cycles.	Lower energy density than graphite and silicon anode technology.	Dendrite formation during cycling poses safety risks and reduces life cycle.

What's on the mind of battery material leaders?

We have been having ongoing conversations with battery material companies. These topics and key questions will act as critical content for this study. They include:

- Regional battery anode capacities
- Subsidy requirements to make battery manufacturing cost-effective
- Battery anode demand; it's effect on the petroleum coke supply
- Forecasts, probabilities, and geographies of future manufacturing facilities
- Investment costs and investors' willingness to invest?
- Government policy on battery materials
- Who needs battery anodes; at what quantity and quality
- Customers for battery anodes
- Environmental rules and regulations for battery anode manufacturing
- Size of battery anode market (natural and synthetic graphite)
- Battery anode producer profiles
- Carbon footprint of the full life cycle of a battery anode manufacture
- Department of energy (DOE) future funding for batteries and EVs
- Net zero funding initiatives by region

We will answer their questions and yours.

In response, our market analysis study will provide an assessment of different battery chemistries along with anode material requirements. We will include what we assess to be feasible innovations and thus build up the supply-demand gap analysis over the forecast period (to 2040).

In the case of LIB anodes, our focus is on the gradual shift from the discovery of new materials to improving the efficacy of existing ones. The growing discussion on climate change and the need for sustainable energy solutions will be featured in our study. Present trends indicate that optimization efforts have moved beyond purely research-based activities to include industry-led initiatives.

Therefore, this LIB value chain study is specifically targeted to anodes and aims to keep an eye on the technological advancements fore casted by industry participants, rather than public announcements. The emphasis is now on scaling up LIB anode production to meet the surging demand of LIBs, reflecting a broader shift from basic technological development to mass production principles, including those of the circular economy. Consequently, a critical parameter will be outlined in this study, such as the availability and sourcing of materials.

PRELIMINARY

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KEY QUESTIONS ANSWERED

Investment guidance for the battery value chain based on parameters like current business line, raw material procurement and cost of the project.

Demand, imports, exports, production, and capacity for each demand sector. Historically from 2021 to 2024 and projected through to 2040.

Demand, imports, exports, production, and capacity for lithium-ion battery cells, broken down to relevant type/sizes historically from 2021 to 2024 and projected through to 2040.

The regional focus of the study will be as illustrated:
- North America
- China
- Europe
- Rest of World

Location analysis based on parameters like electricity, water, land and labor cost, distance from port or subsequent industries, incentives/subsidies offered (From section 7).

Demand, imports, exports, production, and capacity for green pet coke, calcined coke, anode grade needle coke, natural graphite broken down to relevant specifications/categories historically from 2021 to 2024 and projected through to 2040.

Overview of new technologies and an outlook on the impact of demand of natural and synthetic graphite.

How well individual directives are performing in each region in order to secure access to critical materials. This will include analysis on incentives/subsidies offered in different countries.

Forecasted recycling and reuse of spent graphite with analysis of policy measures that are in place to promote it.

Challenges and mitigation measures related to supply chain, operations, and geopolitical climate.

Section 5 and 6 will be based on the data fill in the following form

Material	Year	Year
Supply		
Capacity		
Company A, Site		
Company B, Site		
Total Capacity		
Production		
Capacity utilization, %		
Imports		
Total Supply		
Demand		
Consumption		
Use A		
Use B		
Total Consumption		
Exports		
Total Demand		
Net Trade Balance		

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Methodology

Our research methodology involves a mixture of primary and secondary data sourcing. Key steps involved in the research process are listed below.

DATA COLLECTION

- We will start gathering market data from primary and secondary sources.
- Worley Consulting Insights already has the worlds' leading historical information databases on green petcoke and calcined petcoke. This database will be expertly extended downstream for each step of the industry value chain.
- Secondary sources encompass market research reports, industry databases, trade publications, company websites, and government regulations etc.
- Primary sources may include interviews with industry experts, surveys, and interactions with key market stakeholders such as manufacturers, suppliers, and end-users.

COMPETITIVE ANALYSIS

- Analysis of the competitive landscape of the battery anode materials market, including the market share, product portfolio, pricing strategies, and distribution channels of key players.
- Examination of the battery anode materials supply chain, including raw material sourcing, manufacturing processes, and end-user industries.
- Identification of potential bottlenecks, risks, and opportunities for optimization.

MARKET SEGMENTATION AND ANALYSIS

- Segmentation of the battery anode material market based on various factors such as material end-use industry (e.g., automotive, consumer electronics, energy storage) and geographical region; this activity will be followed for each anode material application.
- Estimation of the market size and forecast of its future growth using models, analyzed trends, and the expert insights, considering factors such as historical data, demand-supply dynamics, technological advancements, regulatory policies and overall economic growth.
- Evaluation of the key drivers, restraints, opportunities, and challenges influencing the battery anode material market.
- Assessment of factors such as increasing demand for electric vehicles, growing adoption of renewable energy storage solutions, advancements in battery technology, and regulatory initiatives promoting energy efficiency and sustainability.

REPORT FORMULATION

- Structured supply/demand tables for each step of the value chain by region (above).
- Listing of recommendations for market entry or expansion strategies for companies operating in or planning to enter the battery anode material market.
- Commentary on factors such as market segmentation, competitive positioning, technological differentiation, and regulatory compliance.

VALIDATION & PUBLICATION

Validation is crucial in our process. Through an intricate process, we will validated and re-validated data points, then send our market estimates and forecasts to industry experts for validation. After their approval, the report will undergo scrutiny by our Quality Assurance team to ensure compliance with style guides, consistency, and design standards before publication.

Our experience

The world has entered a major energy transition. This will have a profound influence on humanity. Our brightest minds are drawing on our extensive experience to identify future sustainable pathways.

Worley is a leader in providing Energy Transition solutions. To date, we have successfully delivered 4,585+ projects worldwide. We provide our services across the full asset life cycle. Our unique approach to Energy Transition is through our tools and technology, enabling us to support our customers on their journey towards NetZero.

Worley fully recognizes that the energy transition is transforming the sectors in which we work. Global trends such as social pressure to decarbonize the industry, coupled with digitalization, and decentralization are impacting the global marketplace and all of our customers. These trends are bringing unprecedented challenges but also opportunities as companies seek to re-align themselves.

Expanding the supply of battery materials

We partner with our customers and other key stakeholders across the value chain to help build a sustainable supply chain at speed and scale as they work to meet the energy transition's increasing demand for batteries materials.

We consult, engineer, and construct solutions, from the mining of raw materials through to all the intermediate processing steps for active materials manufacturing and recycling.

With over 50,000 employees in more than 50 countries and having completed multiple projects and studies, we have an excellent understanding of the global impact of battery technology.

RAW MATERIALS

50+ years
of experience in critical materials for the Energy Transition, including lithium, cobalt, nickel, manganese, graphite, copper, aluminum, vanadium

Full service offering
- Mine Planning & Development
- Material handling & Mineral Processing
- Hydro metallurgy & Pyrometallurgy
- Tailings & Waste management
- Non-process infrastructure
- Transport & logistics

ACTIVE MATERIALS

Experience you can lean on
We have a deep resource pool with extensive experience in petroleum coke, calcined petroleum coke, and active material projects. Our Centers of Excellence are located in Argentina, Australia, Canada, Chile, United Kingdom, and the United States.

We have conducted numerous international consulting assignments involving feasibility reviews, market studies, price forecasts, and project finance support as independent technical or market consultant for various active material projects.

BATTERY MANUFACTURING

Big picture delivery
Decades of Tier 1 delivery expertise brings us the experience production facilities are planned, scoped and optimized through the design and build phases, integrating all necessary elements to ensure operating objectives are met.

Asset development
From pilot to production scale facilities, we plan, design and build active material production facilities for all battery components.

APPLICATION & INTEGRATION

World leader
We are recognized as best in class for the delivery and operation of large scale, complex energy generation, storage and distribution systems across a full range of applicable technologies:
- Stationary storage systems
- Distributed energy systems & microgrids
- EV charging Infrastructure
- Transport electrification
- Mining and heavy industry decarbonization

RECYCLING & 2ND LIFE

Asset development
From pilot to production scale facilities, we plan, design and build recycling, reuse & recovery facilities across a range of materials.

Technology partner
We work with emerging technologies to provide structured pathways and advice to commercialization through our unique partnership model. Worley is a bankable brand recognized across Tier 1 financial markets.

Project Experience

Electric vehicle demand is growing thanks to new government legislation. But this demand is putting pressure on the battery materials value chain. The pace and scale of production growth makes securing and sourcing battery-grade minerals and metals a high priority.

It traditionally takes decades to develop new mines from greenfield deposits. But we've developed new, standardized approaches to deliver battery materials infrastructure at scale.

We also support the commercialization of sustainable extraction technologies such as Direct Lithium Extraction through our technology partnership offerings. The search for socially responsible suppliers is underway, and successful projects depend on collaboration across the supply chain.

COMPANIES WE'VE WORKED WITH:

SQM, TINCI, Johnson Matthey, NMG Nouveau Monde Graphite, EVM, Millennial Lithium, Lithium Americas, talga, Ronin 8, Lithium One, BASF, Albemarle, TWIGG, umicore, Tesla, Advantage Lithium, Nikola, CarbonScape, Green Lithium, nanoOne, Syrah Resources, northvolt, Koch Project Solutions, Centaur Resources, Phillips 66, Sila, A1 Lithium, pluspetrol, Compass Minerals, SiFAB worley consulting

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