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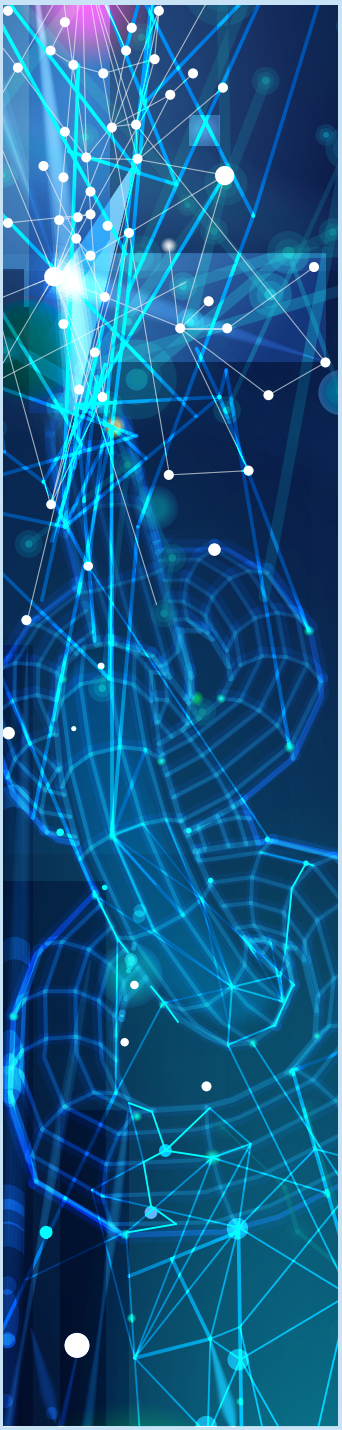

RE-IMAGINING BATTERY MINERALS SUPPLY CHAIN:

BLOCKCHAIN AND AI-DRIVEN TRACEABILITY FROM THE MINE TO MARKET

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Overview

The Mining and Metals Industry is undergoing a significant transformation due to technological advancements and the growing focus on transparency and sustainability. At the same time, demand for lithium, cobalt, nickel, and other minerals used in electric vehicle (EV) batteries and renewable energy storage systems is rising steadily. Conventional supply chain management systems do not ensure mine-to-market visibility for these battery minerals, leading to challenges in compliance with industry standards and global regulations for ethical sourcing of raw materials. Predictive analytics, Blockchain and artificial intelligence (AI) offer a robust framework for mining enterprises to boost supply chain operations and improve visibility across the value chain.

Market insights

Global demand for several metals and minerals is projected to spike over the next decade, particularly as sovereign states and enterprises accelerate effort to eliminate net carbon emissions by 2050. The demand for lithium and graphite is estimated to grow exponentially by 2040 with increased adoption of EVs and other renewable energy storage systems to achieve climate goals . Figure 1 depicts usage of Lithium-ion batteries[1].

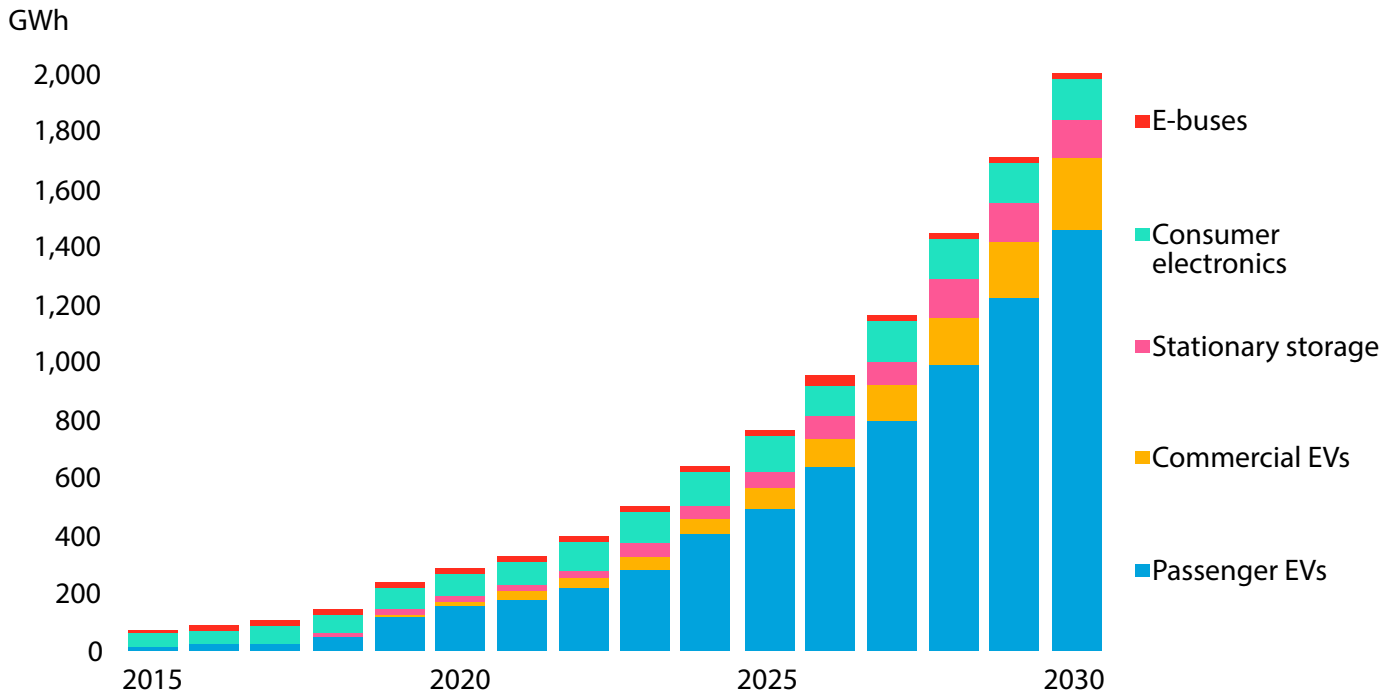


Figure 1: Anticipated global applications of Lithium-ion batteries.

The cost of Lithium-ion batteries has declined more than 80% over the last decade, which makes it a viable option in the electric vehicle and energy storage markets.

Material	Needed for 20% EV Sales (Tons)	Needed for 100% EV Sales (Tons)	Material Mined in 2019 (Tons)	Global Reserves (Tons)
Nickel	254,530	1,272,650	1,000,000	89,000,000
Lithium	37,750	188,700	77,000	17,000,000
Cobalt	31820	159,800	140,000	7,000,000

Table 1: Estimated amount of elements needed for EV batteries vis-à-vis mined and global reserves[2]

Table 1 shows the increase in demand for battery minerals as the sales of EVs increase globally. This acceleration underscores the need for efficient tracking of materials across the supply chain.

The Present Landscape

The Mining and Metals Industry, which supplies critical materials used in the manufacturing of EV batteries, faces several challenges:

Multiple stakeholders

Tracking the flow of materials from extraction to end-use, spanning diverse stakeholders including mining companies, smelters, manufacturers, distributers, retailers, and end-customers, is challenging[3].

Lack of transparency

The absence of a standard transparent mechanism to confirm the authenticity of raw materials, track child labor, and monitor environmental sustainability mars sourcing practices of metals and minerals[4].

Siloed operations

Various departments within a mining unit often use disparate information systems, leading to information silos. This hinders a comprehensive view of operations, which is essential for efficient decision making.

Addressing the challenges

A digital transformation enables mining enterprises to gain valuable insights from the vast amount of data generated by the supply chain to address operational challenges and improve the sustainability quotient.

Blockchain technology offers an immutable record of transactions, leading to data integrity, authenticity, and trust through the supply chain. Figure 2 illustrates important features of Blockchain. Blockchain can be combined with IoT devices such as RFID tags to ensure that materials are sourced ethically and sustainably from conflict-free regions, which mitigates cross-border compliance issues.

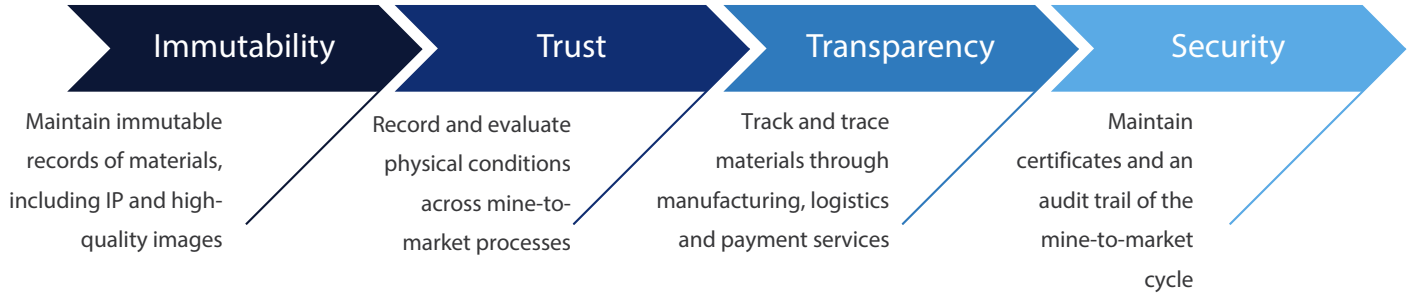


Figure 2: Features of Blockchain

Mining enterprises can use historical data to identify trends and patterns, predict supply chain performance issues, and find areas of improvement in the supply chain. This can be achieved by leveraging AI solutions. Moreover, AI-based analytical models derive valuable insights, enabling informed decisions to optimize supply chain operations.

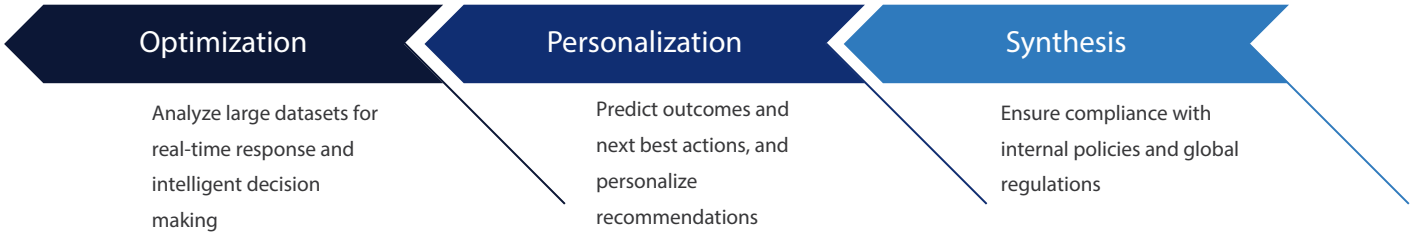


Figure 3: Features of Artificial Intelligence

Harnessing the Potential of Blockchain and AI

The transformative impact of Blockchain and AI in the battery minerals sector is evident in each stage of the supply chain – from mining to end-use and recycling of products for a second life

Traceability from the source:

Blockchain ensures traceability by securely recording and time-stamping every transaction from the initial stage of mining. It spans the extraction of minerals, quality assessment, transportation to processing facilities, and storage. This allows stakeholders to monitor and validate the journey of materials as well as the quality and quantity from the source to destination. Further, data integrity of Blockchain transactions simplifies auditing. The decentralized ledger verifies compliance with responsible mining practices, environmental regulations, and labor laws, and provides an indisputable record.

Smart contracts:

Blockchain automates compliance with predefined rules as materials move through the processing and manufacturing stages. Smart contracts embedded in the distributed ledger ensure that sustainable and responsible practices are adhered throughout the production process. Environmental impact assessment, fair labor conditions, and adherence to ethical standards are encoded into smart contracts, providing real-time assurance of compliance. The transparency provided by Blockchain enhances trust in the manufacturing processes for both regulators and consumers[5].

Real-time tracking:

Blockchain technology provides real-time visibility into the movement of materials, which is crucial for ensuring safety and reliability of the global supply chain and compliance with cross-border trade regulations. Further, Blockchain safeguards the reputation of enterprises and helps create a secure and reliable transportation network by providing a comprehensive view into each stage of logistics and distribution.

Real-time compliance:

Blockchain streamlines reporting. The immutable record enables companies to demonstrate adherence to regulatory standards in real time. Smart contracts automate tasks such as payment processing and quality assurance, enhancing efficiency and reducing administrative overheads. Notably, the decentralized nature of Blockchain reduces dependence on intermediaries, leading to cost savings.

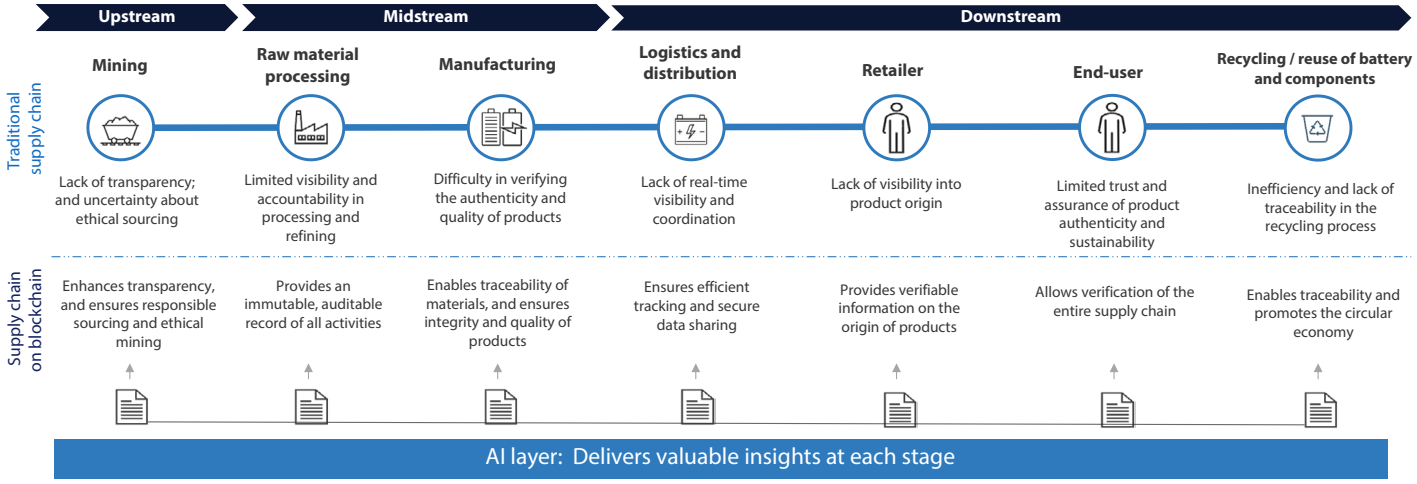


Figure 4: Benefits of Blockchain in Battery Minerals Mining – Traditional vs Blockchain powered Supply Chain

Blockchain and AI-powered supply chain for battery minerals

High-volume, low-value transactions are not ideal for Blockchain technology due to limitations such as transaction throughput, scalability, processing time, cost efficiency, and computational resources intensity. However, the value of battery minerals, such as cobalt, nickel, lithium, and tantalum, is high, and the transaction volume is increasing due to their increased use in end products such as smartphones, computers, energy storage systems, and electric vehicles, making Blockchain an ideal solution (Figure 4). Significantly, Blockchain addresses the traceability challenge as well as concerns about ethical sourcing by replacing paper-based systems in mining regions susceptible to sub-par operating conditions[6,7].

Data entered into Blockchain is validated by a consensus mechanism that is pre-programmed with a set of rules to ensure accuracy. Abnormalities and inconsistencies are flagged immediately in Blockchain system. AI models leverage data from Blockchain to predict potential risks or deviations in the supply chain. The recording of data in a series of blocks creates a 'digital fingerprint' of a product, allowing stakeholders to map materials in the end-product to a specific mine site. Companies can closely track the origin of materials to drive responsible sourcing and prevent unethically sourced minerals from entering their supply chain[8].

Figure 4 shows the supply chain for battery minerals and how Blockchain transactions ensure transparency and efficiency in each step - from mining and processing of materials to production of cell components and battery packs, and finally, recycling of end-products[9].

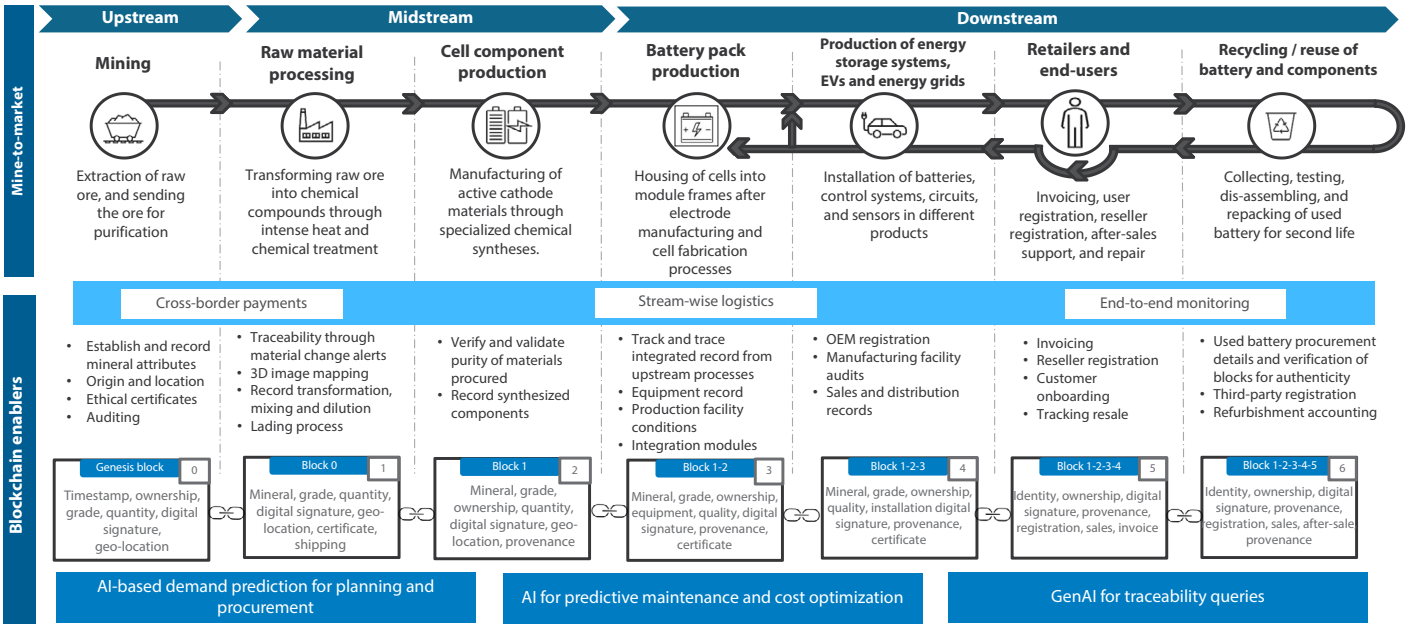
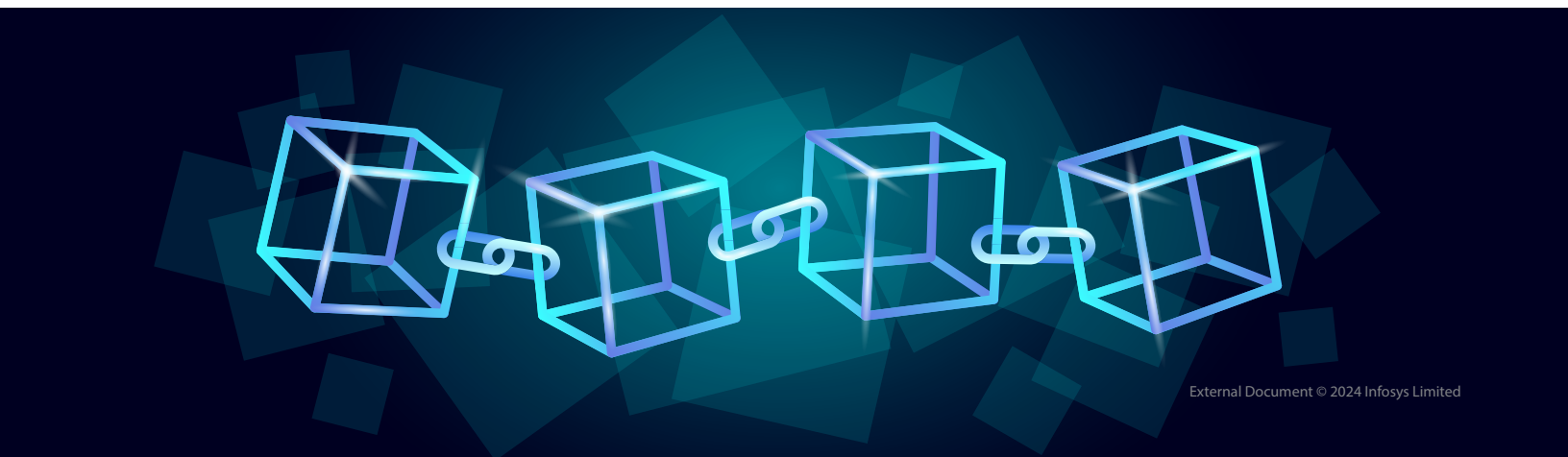


Figure 4: Blockchain and AI based tracking from Nickel Mine to Market in battery minerals supply chain.

Establishing the first block of Blockchain, also known as the genesis block, as the single source of truth is a crucial step. Enterprises should implement robust security measures powered by AI and adopt best practices for ensuring reliability and building trust in the genesis block. Further, regular auditing and compliance with regulations help enterprises realize global Sustainable Development Goals (SDG) of the United Nations[10].



How the Mining Blockchain aligns with UN SDG

Various features of Blockchain are inherently tied to the goals of the UN 2030 Agenda for sustainable development (Figure 5). Blockchain technology promotes responsible consumption, industry innovation, and climate action, and serves as a catalyst for positive change in the battery minerals sector.

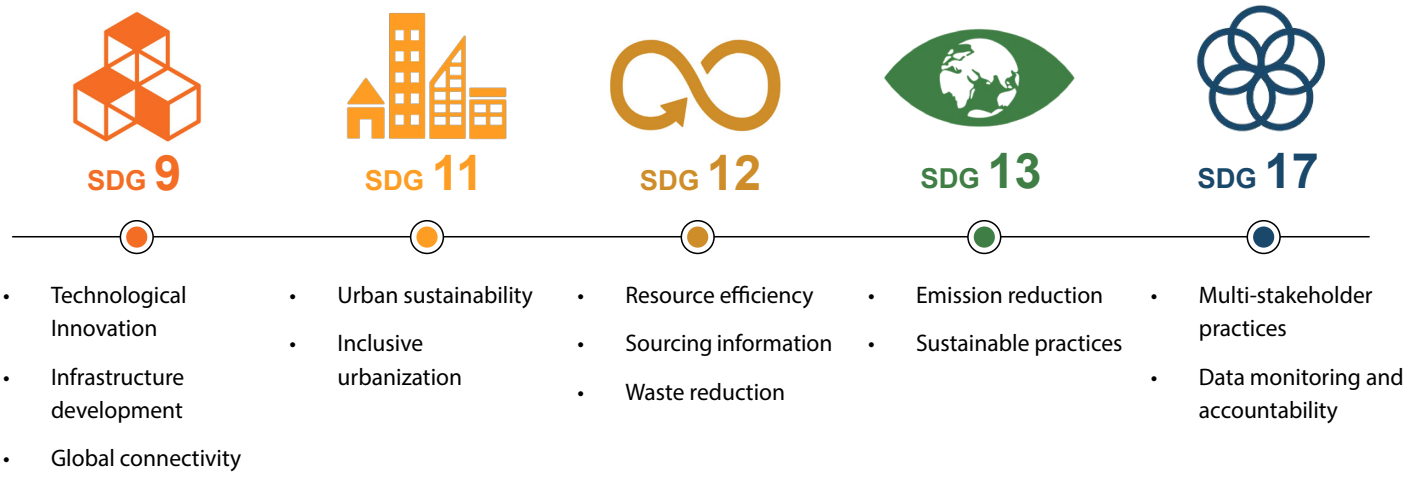


Figure 5: Using Blockchain to realize UN SDGs

Industry, innovation, and infrastructure

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Technological innovation: Implementation of Blockchain in supply chains facilitates innovation in tracking, verification, and data management.

Infrastructure development: Efficient and transparent supply chains help in building resilient infrastructure by ensuring reliable and sustainable delivery of raw materials for various industries.

Global connectivity: Blockchain solutions enhance global connectivity by bridging information gaps across borders.

Sustainable cities and communities

11 SUSTAINABLE CITIES AND COMMUNITIES

Urban sustainability: Efficient minerals supply chains support the development of sustainable urban infrastructure, especially in the context of EVs and renewable energy.

Inclusive urbanization: Transparent supply chains help in establishing equitable labor practices and sustainable community development in mining, contributing to the broader goal of sustainable urbanization.

Responsible consumption and production

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Resource efficiency: The use of resources through the supply chain can be optimized through real-time tracking. Better planning and waste reduction lead to sustainable production.

Sourcing information: Blockchain enables consumers and companies to access information on sourcing and processing of minerals, enabling responsible purchase decisions and adoption of sustainable practices.

Waste reduction: Improved traceability of the minerals supply chain facilitates efficient recycling and reuse, significantly reducing waste and promoting a circular economy.

Climate action

13 CLIMATE ACTION

Emission reduction: Enhanced efficiency and optimization of the supply chain reduce greenhouse gas emissions via sustainable practices in mining processes and transportation.

Sustainable operations: Blockchain technology enforces compliance with environmental standards, ensuring that industrial practices minimize the environmental impact of operations.

Partnerships for the goals

17 PARTNERSHIPS FORTHE GOALS

Multi-stakeholder partnerships: Blockchain solutions mandate collaboration between governments, NGOs, industry players, and technology providers. A platform for multi-stakeholder partnerships is essential for achieving UN SDGs.

Data monitoring and accountability: Blockchains promote data collection and monitoring. It provides reliable and verifiable data that can be used to track progress across sustainability goals[11].

Lessons from Blockchain Implementations

Proofs of concept, pilot projects and enterprise implementations in the mining sector indicate that Blockchain technology can be effectively used for supply chain tracking. However, the successful implementation of Blockchain-based solutions depends on some critical factors:

Digital trail of products

Blockchain should track all stages of the product lifecycle on a single platform and provide a comprehensive view and insights into the product.

Scalability

The implementation of Blockchain technology across a supply chain involves multiple stakeholders, ranging from producers to end-users. The diverse objectives and priorities of various stakeholders make it difficult to manage the system effectively. Enterprises should develop a standardized and scalable solution to address the requirements of stakeholders in a large consortium.

Incentives for supply chain actors

A transparent system is crucial for ensuring regulatory compliance, ethical sourcing, and quality of materials. Blockchain technology facilitates it by providing a platform for secure and transparent record keeping. To enhance participation by stakeholders, Blockchain solutions should offer incentives, such as better market access and premium pricing for verified ethical practices. In addition, it is important to design the system in a manner that allows producers to participate independently, without being part of a large consortium.

A five-step solution approach for smooth implementation

A five-step framework of best practices (Figure 6) enables seamless implementation of Blockchain technology in the mining industry[11],[12]. This approach not only enhances track-and-trace functionality, but also empowers the battery minerals sector to contribute to sustainable and responsible economic development.

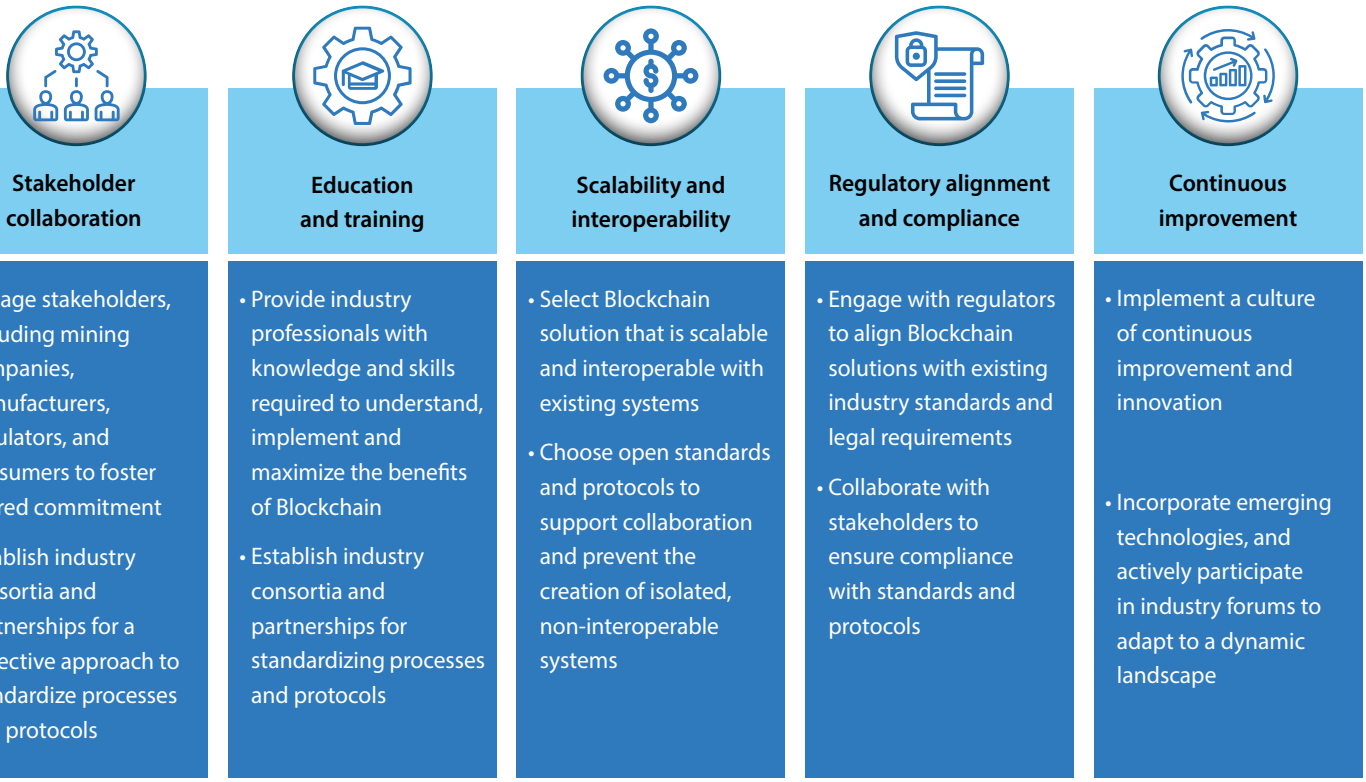


Figure 6: Five-step approach

Use cases for Blockchain and AI-based traceability

Figure 7 presents a user journey for tracking products and materials in a supply chain powered by Blockchain. For lithium used in an EV battery, the ledger includes data on the origin of raw materials, date of extraction, component manufacturer, assembly information, and fitment of the battery into the EV. Partners and stakeholders in the Blockchain may enter the unique identifier or serial number associated with their product in a dashboard for:

Customer-end traceability:

The comprehensive ledger of the battery lifecycle allows customers to retrieve information about each component and trace its original source. A clear and secure record of the battery's provenance not only ensures transparency, but also helps in holding the diverse supply chain players accountable for their value chains.

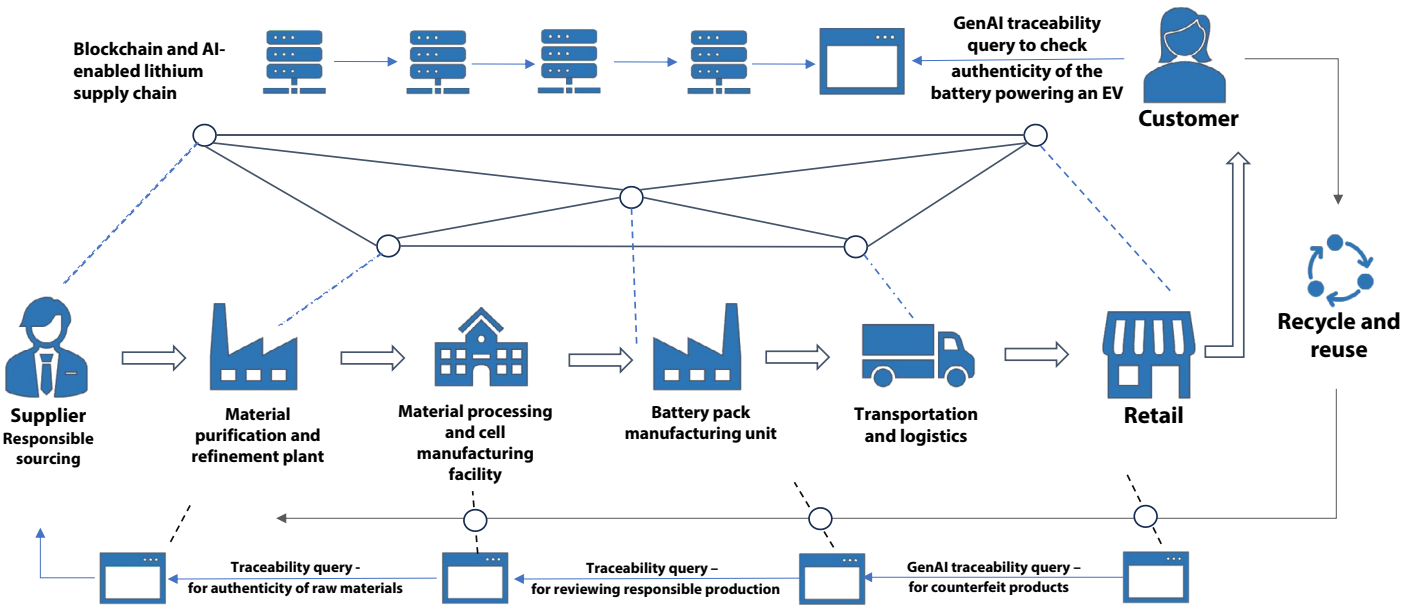
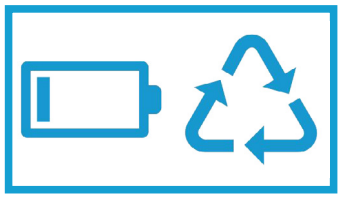


Figure 7: User journey for tracking battery minerals

Producer-end traceability:

Manufacturing facilities can track the origin of raw materials by entering the unique identifiers of received raw materials. The Blockchain portal provides a detailed history of the materials spanning the extraction, processing, and transportation stages. The dashboard allows manufacturers to verify the quality and sustainability of raw materials, ensuring responsible sourcing and enhancing credibility.



It is estimated that only 5% of Lithium-ion batteries are recycled.

More than 30% of global passenger vehicles will be electric by 2040, according to a Bloomberg report.

Second life traceability:

When a battery reaches the end of its life, it is sent to a recycling facility where valuable materials are extracted for reuse. Information about these materials can be entered into Blockchain system with a new unique identifier. This allows the next user or facility that receives these recycled materials to trace its origin, ensuring a circular economy that promotes sustainability and reduces waste.

Conclusion

Blockchain and AI technologies are revolutionizing the battery minerals supply chain, from mining and processing of ore to recycling used products. By providing a secure and transparent database for tracking and verifying transactions across the supply chain, Blockchain technology enables stakeholders to monitor the flow of materials and information and ensure adherence to standards for responsible production[13]. AI complements Blockchain by supporting auditing, identifying discrepancies, ensuring traceability, and facilitating informed decision making.

However, enterprises should address constraints while integrating Blockchain and AI into the supply chain, including implementation costs, technical expertise, data privacy, scalability, and interoperability issues. Notably, collaborative effort between governments, industries and research institutions can address these challenges and drive technological innovations to enable enhanced transparency, accountability and efficiency in supply chain operations.

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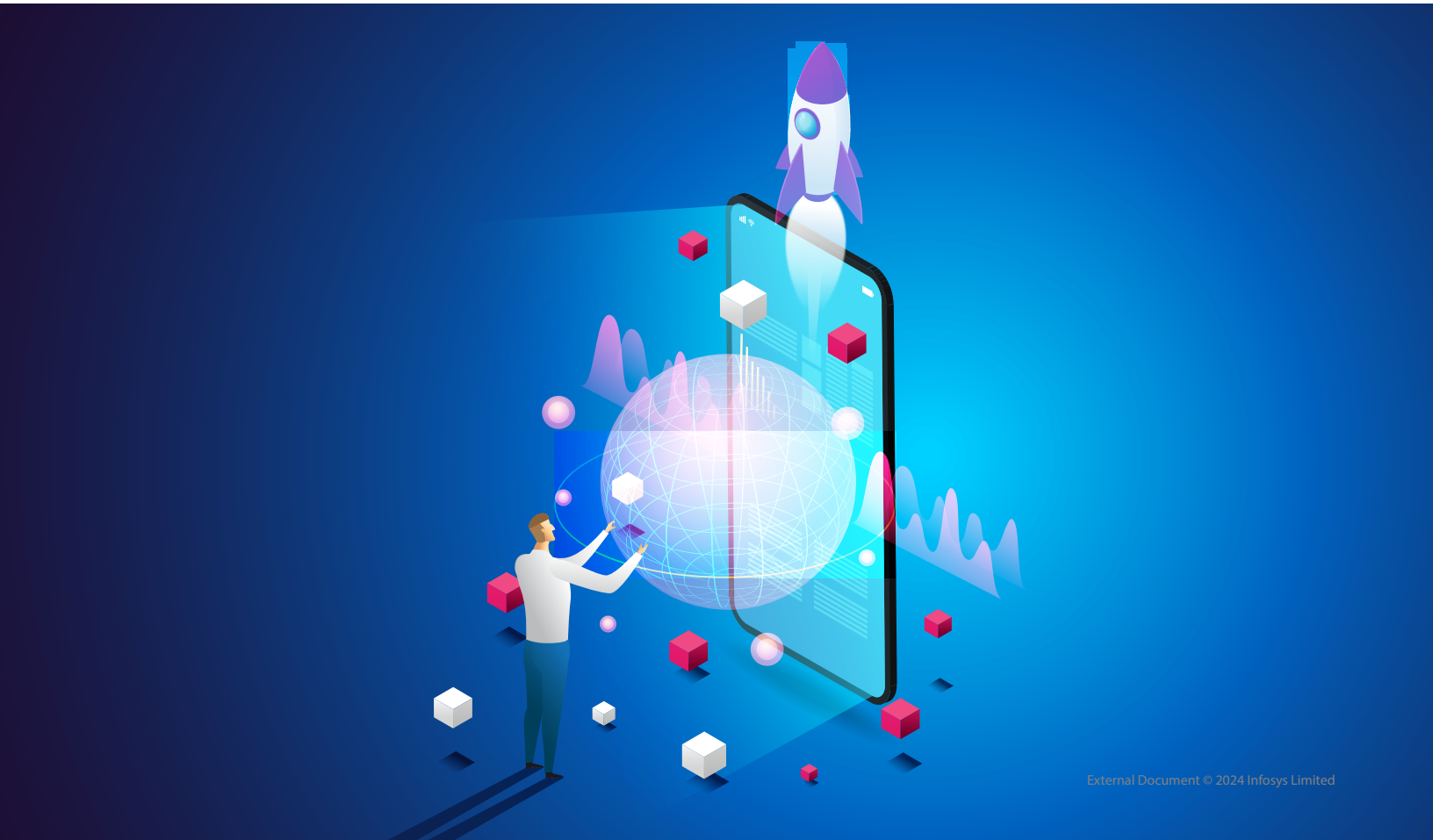

About the Authors

Amit Satish Bhat

Senior Associate Consultant, Process & Resources, Manufacturing Domain Consulting Group

Joseph Michael

Lead Consultant, Process & Resources, Manufacturing Domain Consulting Group

Amit Kumar

Lead Consultant, Process & Resources, Manufacturing Domain Consulting Group

Indresh Rathore

Principal Consultant, Process & Resources, Manufacturing Domain Consulting Group

For more information, contact askus@infosys.com

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