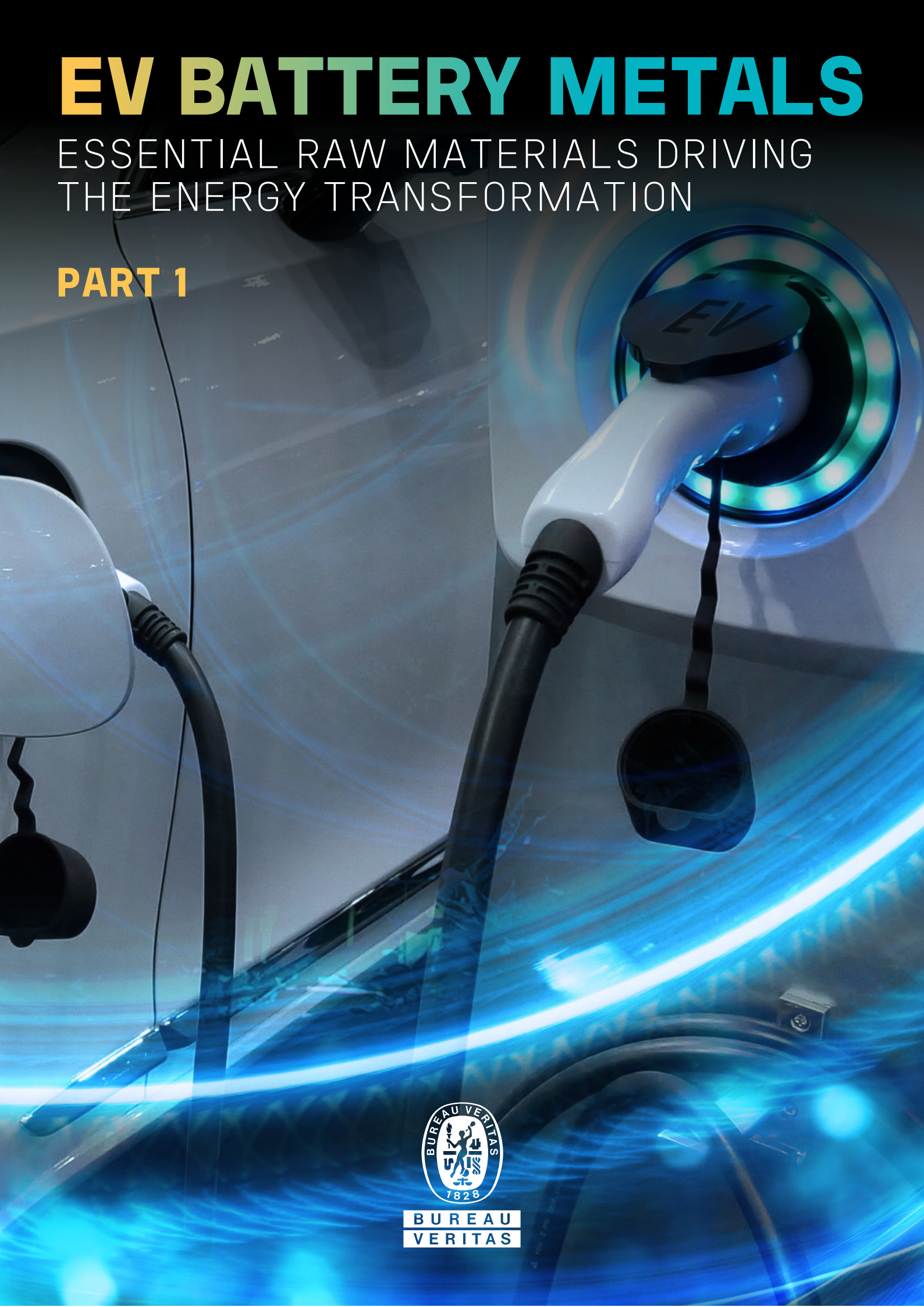
EV BATTERY METALS

ESSENTIAL RAW MATERIALS DRIVING THE ENERGY TRANSFORMATION

PART 1



BUREAU VERITAS

WHITE PAPER **OVERVIEW**

- The electric vehicle (EV) is expected to become the primary means of private transport, as the age of the internal combustion engine (ICE) draws to a close.
- EVs will help reduce emissions in the transport and power sectors by up to 30 per cent and thus become a key driver for decarbonization targets to be achieved by 2050 – the date that the European Union and other major economies have set as their ‘carbon neutral’ goal, under the terms of the Paris Climate Agreement.
- Global sales of EVs are expected to reach 12 million units by 2025 (comprising approximately 15 per cent of the global fleet).
- Research and development into new battery technology is accelerating.
- Essential raw materials for current EV battery technologies include lithium, varying concentrates of nickel, manganese and cobalt, copper (the battery cathode) and graphite (the anode).
- The forecast demand for EVs will necessitate a significant increase in production of these raw materials, there are concerns about whether this can be achieved ethically and sustainably.
- Lithium production is set to triple by 2025 , while lithium consumption may grow by as much as seven times by 2030 . Some components of the raw material supply chains are scalable (eg. mining of spodumene ore) but overall the supply chains are not yet mature. Downstream chemical and refining capacity will require substantial investment (particularly in the USA and Europe).
- The switch to EVs is an historic global change in transportation modality. The increase in demand for battery metals over the coming decade presents opportunities and challenges for all participants in the production, shipment, refining and manufacturing supply chains.
- Bureau Veritas is uniquely positioned to support the growth in this sector with a global footprint servicing the exploration, mining & trading sectors, including ESG and GHG traceability solutions across the raw material supply chains and engineering, procurement, cyber-security & certification solutions to the downstream industries.

INTRODUCTION

This paper aims to provide an overview of the EV battery market and its raw material supply and value chains. It examines how they are expected to develop and will explore how Bureau Veritas can support the sector with its existing services.

Since the Paris Climate Agreement of 2015, attention has focused on implementing strategies to reduce emissions from the burning of fossil fuels. These have included the adoption of renewable energy sources, such as wind turbines or solar energy.

APPROXIMATELY 20 MAJOR CITIES WORLDWIDE HAVE ANNOUNCED PLANS TO BAN GASOLINE AND DIESEL CARS BY 2030 OR SOONER, AND 17 COUNTRIES HAVE ANNOUNCED 100% ZERO-EMISSION VEHICLE TARGETS THROUGH TO 2050. BY 2040, IT IS EXPECTED OVER HALF OF ALL PASSENGER VEHICLES SOLD WILL BE ELECTRIC AND 31% OF ALL VEHICLES ON THE ROAD WILL BE EVS.

Research and development of new battery technology has also increased. Rechargeable energy storage batteries are now used to power electric vehicles, but they could also be used to store the surplus energy produced by intermittent renewables (wind and solar) for household use.

Most EVs are likely to be powered using **LITHIUM-ION BATTERIES (LIBS),** for which the expected life span is approximately 10 years. The composition of raw materials within EV batteries differs, depending on manufacturers, but six metals and minerals are considered critical - cobalt, graphite, lithium, manganese, nickel and copper.

Demand for these metals and minerals is expected to drive increased investment in exploration and mining.

BUREAU VERITAS IS A GLOBAL LEADER IN EXPLORATION & MINING TESTING AND INSPECTION SERVICES.

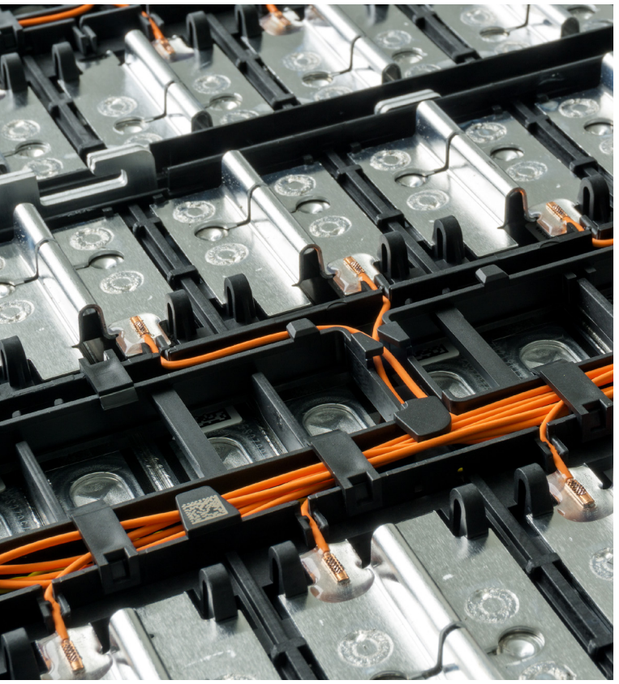
A core challenge presented by the extraction and use of these raw materials is ensuring an ethical and sustainable supply chain. As an example, mining of cobalt in some geographies can raise environmental and social concerns, including the potential use of child labour. There are also environment risks, such as pollution and overconsumption of water resources during mining, extraction and processing operations.

To protect brand reputation and demonstrate social and environmental responsibility, EV producers and their LIB suppliers will take steps to monitor and identify risks in their supply chains. For these reasons Bureau Veritas has identified important opportunities in **RESPONSIBLE SOURCING, TRACEABILITY AND CHAIN OF CUSTODY** in these supply chains.

SIX CRITICAL MATERIALS FOR EV BATTERIES

- **COBALT**
- **GRAPHITE**
- **LITHIUM**
- **MANGANESE**
- **NICKEL**
- **COPPER**

LITHIUM-ION BATTERIES (LIB) EXPLAINED



Several rechargeable battery technologies are available but lithium-ion batteries (LIBs) offer the EV manufacturer two important properties. They exhibit high energy and power density, and (compared to other batteries) they are small and relatively light. Lithium is the lightest solid material in the periodic table and one of the most energy dense, giving it low substitutability.

Since emerging as the preferred chemistry, EV battery research and development has focused on improving LIB performance. Most analysts expect LIB to remain the primary EV battery choice into the next decade. Beyond that, solid state lithium technology offers the prospect of batteries that are more stable, quicker to recharge and with increased longevity. Another technology is the lithium air battery; at half the weight of current LIBs, they promise higher energy density and – with no requirement for cobalt or nickel – they also present a lower environmental impact. But there is not yet any significant battery technology that does not rely on lithium.

LIBs comprise hundreds of individual cells connected together to deliver the necessary voltage and current requirements. Each cell typically has a nominal voltage of 3-4 volts.

Each LIB cell has four basic components: cathode, anode, electrolyte, and separator. Cathode chemical compositions in widespread use include lithium manganese oxide (LMO), lithium iron phosphate (LFP) and lithium nickel manganese cobalt oxide (NMC). Graphite is commonly used for the anode material.

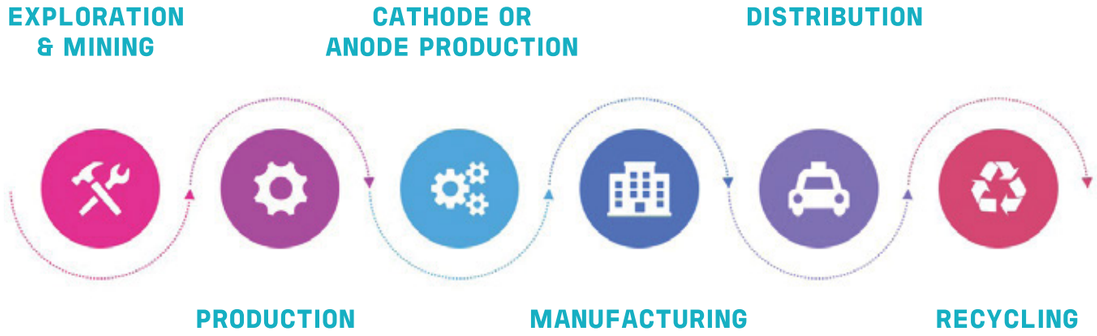
The electrolyte – usually lithium salts in an organic solvent such as ether – acts as a medium for the flow of ions between the cathode and the anode. A microporous membrane acts as a separator to provide a barrier between the cathode and the anode, enabling the flow of ions from one side to the other.

During charging of the battery cells, the lithium metal oxide cathode releases positively charged lithium ions - these move through the electrolyte to the anode. Electrons are also released from the cathode, but these cannot pass through the separator and flow through the external power circuit to reach the graphite anode. Once all the lithium ions reach the graphite layer, the cell is fully charged.

When a load is connected, i.e. an EV motor, the lithium ions and their electrons revert back to their stable state within the cathode. The Li ions flow back through the liquid electrolyte, and the electrons travel via the load, resulting in the discharge of an electrical current and the powering of the EV motor.

In a typical cell, the graphite layer is coated on to a copper foil to form the anode, and the metal oxide layer is coated on to an aluminium foil to form the cathode. These foils act as current collectors. All these layers are wound on to a cylinder around a central steel core.

SIMPLIFIED BATTERY SUPPLY CHAIN



RAW MATERIALS USED IN LIBS AND THEIR SUPPLY CHAINS

COBALT

Rechargeable batteries are the fastest growing driver for cobalt production. Cobalt is traded as ores, concentrates, oxides, hydroxides and chlorides.

China is the largest importer of cobalt ores and concentrates, the majority imported from the Democratic Republic of Congo – producer of 60 per cent of the world's cobalt. Chinese cobalt refineries produce cobalt oxides and hydroxides. These cobalt derivatives are combined with nickel and manganese to form the cathode in a LIB cell.

The biggest importer of cobalt oxides and hydroxides is South Korea, the majority from China, with the rechargeable battery market the prime driver.

UBS analysts predict demand for cobalt to increase by around 13 per cent per annum over the next decade, from 120K MT pa to 400K MT pa by 2030 , although this assumes manufacturers migrate to lower cobalt battery chemistries such as lithium-air and lithium ferrophosphate (see below).

GRAPHITE

Natural or artificial graphite can be used for anode production. Natural graphite provides better electrical conductivity, but synthetic graphite offers higher consistency. Recent improvements in the chemical purification of natural graphite have narrowed the gap.

Traded in the form of powder or flakes, the leading producers of refined natural graphite are China, Mexico and Canada. As per UBS forecasts, demand for natural graphite will grow by a factor of seven by 2030.

LITHIUM

Top producers of primary lithium are Australia (spodumene minerals mined from hard rock deposits) and the 'Lithium Triangle' of Chile-Argentina-Bolivia (extracted from salt lakes or underground brine pools) . Primary lithium is processed into lithium carbonate or lithium hydroxide, with more than 75% of processing occurring in China.

Most rechargeable batteries use high purity lithium carbonate, but demand for lithium hydroxide is increasing as technology advances. Mined or brine-extracted lithium can be purified and refined into either form. Most lithium producers are fully integrated, mining as well as refining.

The lithium compounds are combined with nickel or cobalt to produce the battery cathode, or with solvents to make electrolytes.

Japan is the largest importer of lithium oxides and hydroxides, the majority from China. South Korea is

the biggest importer of lithium carbonate, while Chile is by some way the largest exporter.

Analysts from UBS are bullishly predicting overall lithium demand to increase 11-fold by 2030, from approximately 400K MT in 2021. There is concern from others that this rise in demand could generate a lithium supply deficit if mining lags demand.

MANGANESE

Manganese is predominantly sourced from mines in South Africa (the largest producer), Australia and China, with further resources in Brazil, India and Ukraine. Trades cover ores, concentrates, oxides, and hydroxides, with China the largest importer of manganese ores and concentrates.

Steel-making accounts for around 85-90 per cent of total manganese consumption Commodity research firm Roskill suggests the steel market will continue to drive overall demand for manganese, but projects a doubling of manganese sulphate demand for LIB manufacturing over the next decade, with potentially significant effects on the manganese supply chain.

NICKEL

Nickel is the fifth most abundant element on earth: annual production in 2020 topped 2.5m MT, the largest producers being Indonesia, the Philippines, Russia, New Caledonia, Australia and Canada.

With nearly 70 per cent of world output used for stainless steel production, it's this industry that is the main driver for nickel demand. However, while steelmakers can tolerate impurities in the nickel they use, battery manufacturers can't. LIBs must use high purity nickel – termed 'class one' – if they are to realise their optimum performance and longevity. Any contaminants in the nickel can lead to rapid deterioration of the battery.

Class one nickel is ideally sourced from nickel sulphide ore, found in Russia, Canada, and Australia. This sulphide ore is processed into nickel sulphate, the majority of which is produced in China. UBS sees demand for nickel rising from approximately 2.6m MT per annum in 2021 to 5.8m MT pa by 2030. However, UBS warns that battery-led demand for nickel could be offset if alternative LIB chemistries – such as lithium ferrophosphate (LFP) or lithium-air – are more widely used. These chemistries require neither nickel nor cobalt.

In addition to these five core battery minerals, EVs have also contributed to a rise in demand for the rare-earth metals – a group of elements with applications across not just electronics but a range of industrial processes. China produces 81 per cent of the world's rare-earth supply.

Demand for neodymium (Nd), dysprosium (Dy) and praseodymium (Pr), used in EV motors, will grow from 30K MT pa in 2021 to 100K MT pa in 2030 according to UBS, with 80 per cent of that volume supplying the EV market.

BUREAU VERITAS SUPPORTING THE LIB SUPPLY CHAIN

Significant investment in new mine exploration or expansion of existing mines will likely be needed if the growing demand for all key EV battery raw materials is to be met.

Bureau Veritas is well-placed to provide solutions at all stages of the **EXPLORATION-MINING-MINERAL PROCESSING-EXPORT CYCLE**, thanks to our strong global network of mineral testing laboratories and commodity inspectors. In most locations Bureau Veritas laboratories already hold the equipment and expertise to perform qualitative and quantitative testing. In some cases new test methods have been developed to keep pace with the rapidly evolving nature of EV battery technologies.

Established metal & mineral traders are beginning to leverage their financial, commercial, and logistic expertise to enter these markets to create new supply chains and mechanisms for growth. Bureau Veritas is a leading provider of independent inspection & testing services to this industry.

Bureau Veritas is also providing **ENVIRONMENTAL-SUSTAINABILITY-GOVERNANCE (ESG)** services throughout the supply chain. These could form expert services to support clients to measure and improve their ESG performance or, auditing of compliance with existing certification schemes.

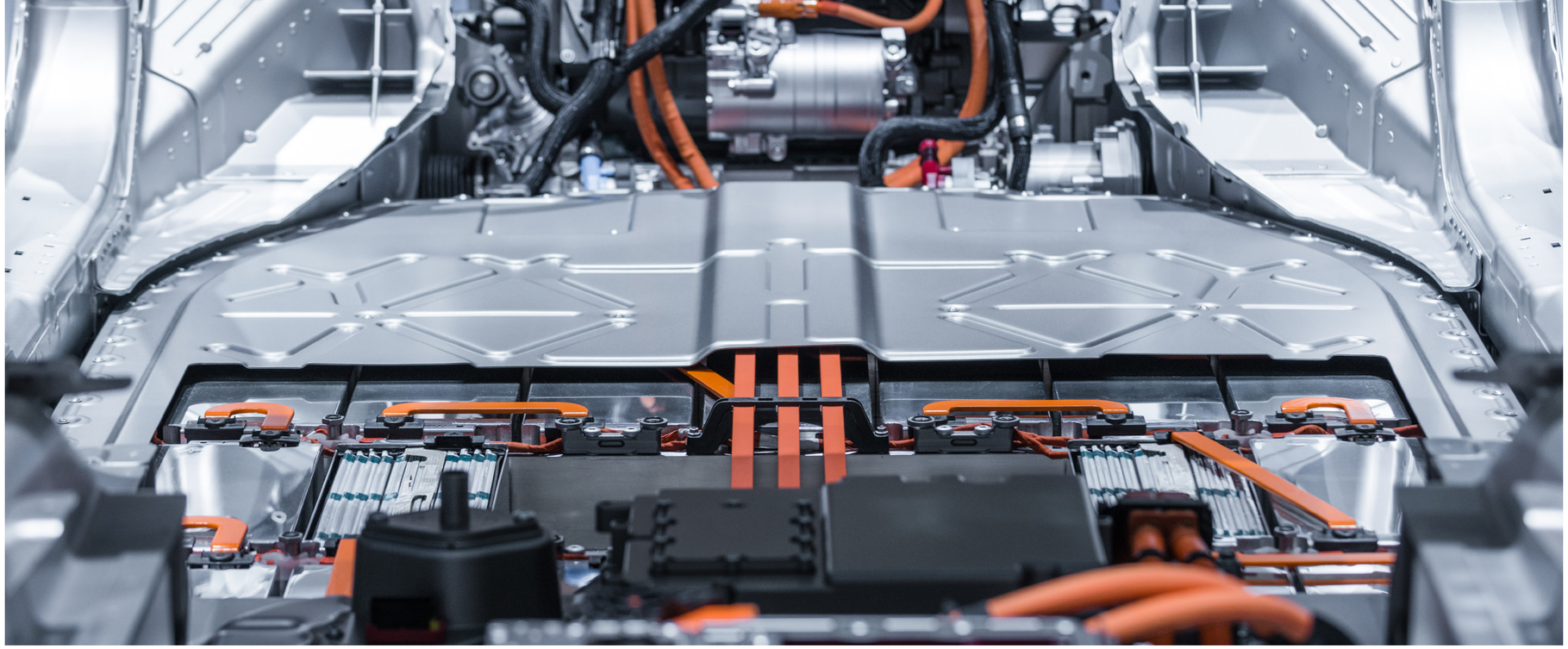
There are other opportunities to consider too… programs such as the **EU BATTERY PASSPORT** designed to ensure responsible and sustainable supply chains in the production of LIBs. This initiative will promote the collection and repurposing of spent batteries, and the harvesting and recycling of the valuable raw materials used in their production. Recycling companies can recover up to 95% of the nickel, cobalt and copper from LIBs and refine it for reselling in a developing **CIRCULAR ECONOMY.**

This process is comparable to the platinum group metals (PGM) market, where Bureau Veritas is already active.

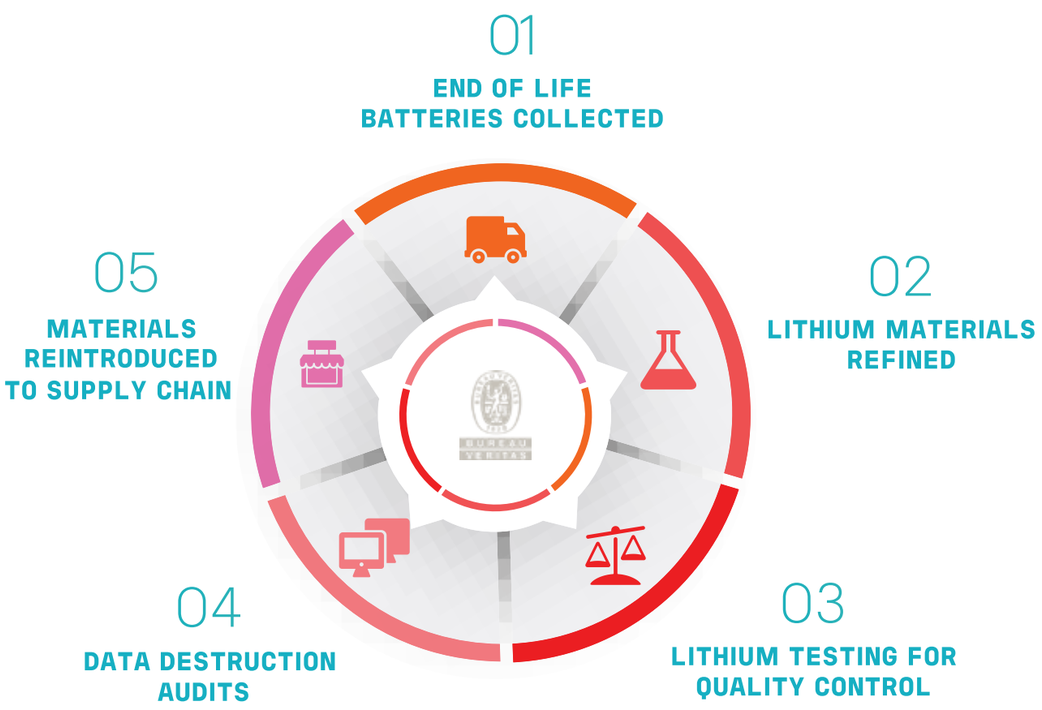
EV **BATTERY METALS**

While UBS study have placed conservative estimates of 80 thousand metric tonnes of recycled lithium by 2030, this tonnage must increase if the EV battery market is to keep its costs low and attain true sustainability. Bureau Veritas is well placed to service this developing Lithium circular economy with testing, inspection, traceability and chain of custody during collection-recovery-refining.

Looking further ahead, new and as-yet-untapped mineral resources may come on-stream. For example, cobalt-rich ferromanganese crusts are found on seamounts – underwater mountains – throughout the world's oceans. While research and development of deep-sea mining technology remains in its infancy, (as does legislation to regulate any future activity) any move to exploit these resources will require the expertise of Bureau Veritas **MARINE & OFFSHORE** division in the design, construction and inspection of deep-ocean mining installations.



USED EV BATTERY LIFE CYCLE



CONCLUSION

Electric vehicles powered by lithium-ion batteries will play a crucial role in delivering a decarbonised future. Six strategic metals & minerals (lithium-cobalt-nickel-manganese-graphite and copper) are required to produce these LIB.

Bureau Veritas is well placed to support the dramatic increase in demand for these raw materials as a global leader in:

- Exploration-mining-mineral processing geochemical and physical testing services
- Inspection and quantity / quality measurement in the traded supply chain
- ESG expertise for the mining-processing operations
- Certification of compliance with new and existing schemes
- Traceability and chain of custody throughout the developing LIB circular economy

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Bureau Veritas is a Business to Business to Society company, contributing to transforming the world we live in. A world leader in testing, inspection and certification, we help clients across all industries address challenges in quality, health & safety, environmental protection and social responsibility.

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