LEVIN SOURCES

Hybrid Electric, Plug-in Hybrid Electric and Battery Electric Vehicles

Part of the
GREEN ECONOMY SERIES

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About this paper

In Part One of our three-part series analysing the minerals behind the green economy, we look at the rise of Hybrid Electric Vehicles (HEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Battery Electric Vehicles (BEVs) and the minerals they require.

We consider how, as this sector grows, the demand for certain minerals will likely change, and for others stay the same, and what the greening of the automotive sector means for the responsible sourcing of minerals.

The paper is split into two sections:

1. ***What will change and stay the same, and the impacts changes will have on responsible sourcing and the mineral sector***

2. ***An in-depth look at how 13 individual metals are involved in the shift towards a green economy***

We welcome your feedback, comments and questions on the contents of this paper. Please do not hesitate to get in touch with our expert team:

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Introduction

The race for a greener automotive future is on. At the Paris COP21 Conference in August 2017, the UK Government pledged that almost all of its vehicles will be zero emission by 2050; Volvo declared it would only make electric and hybrid cars from 2019 onwards; and France declared an intention to ban all diesel/petrol only vehicles by 2040.

Battery Electric Vehicles (BEVs), Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electic Vehicles (PHEVs) have been embraced by governments and industry alike to a previously unforeseen degree. HEVs are powered by both an Internal Combustion Engine (ICE) and an electric motor; their batteries are charged by the operation of the ICE, or by the kinetic energy of the car. BEVs are powered only by batteries, and need to be recharged at a plug-in station.

PHEVs are similar to HEVs, however their batteries can be recharged at a plug-in station. While there are a wide variety of estimates on rates of dissemination of these vehicles, one position is that global BEV and PHEV sales could reach 17 million by 2030.
As demand for BEVs, HEVs and PHEVs increases, the mineral profile of the vehicles on our roads will change. These vehicles require new, and larger volumes of certain minerals that ICE powered vehicles do not. At the same time, certain minerals will be used at more or less the same amount in all vehicle groups.

> “We are taking bold action and want nearly every car and van on UK roads to be zero emission by 2050 which is why we've committed to investing more than £600m in the development, manufacture and use of ultra-low emission vehicles by 2020.”
>
> *- Chris Grayling, Secretary of State for Transport, British Department for Transport*

What will change, and what will stay the same?

The battery chemistry of BEVs, HEVs and PHEVs can vary; Lithium Cobalt Oxide (LCO), Lithium Nickel Manganese Cobalt Oxide (NMC), Lithium Nickel Cobalt Aluminium Oxide (NCA), and Lithium Iron Phosphate (LFP) currently dominate the market, with the expectation that batteries with greater nickel content, and thus superior energy density, will become industry leaders.

Other metals expected to increase in demand include copper, lead, titanium, and silicon, which are primarily used in the wiring and construction of batteries. However, this is all dependent upon which type of battery chemistry ultimately prevails.

China is currently developing its own battery technology that will likely differ from existing models, and will thus require different types and volumes of minerals. The determination of which battery chemistry will dominate the future market will be based on an assessment of overall cost and performance. The rates at which in-demand metals are recycled will also determine their demand.

Regardless, as the market for BEVs, HEVs and PHEVs grows, demand for minerals needed in ICE powered vehicles will decline, for example the platinum group metals used in catalytic converters (platinum, palladium, and rhodium).

Other minerals will likely remain essential to all vehicle groups, such as mica, tin and tantalum.

Mica is a key component of automotive paint; tin is commonly used in electroplating and soldering; and tantalum is essential to vehicle computer and audio systems.

Mica, a key component in automotive paint

What impacts will these changes have on the minerals sector?

The minerals sector will have to adjust to increasing demand for particular minerals. For example, current cobalt production stands at 100,000 tonnes a year, but an additional 260,000 tonnes per annum could be required to meet BEV, HEV and PHEV demand by 2030. Annual production of lithium, which is currently a very small industry, will need to increase from 182,000 tonnes to 3.1 million tonnes over 20 years. Meanwhile, the battery anode market for graphite has been forecast to more than triple in the next five years.

Mined-out tin area, Bangka, Indonesia.
Photo: Estelle Levin-Nally

This shift in demand will see greater dependence on the mineral resources of particular countries. The World Bank has recently highlighted many developing and emerging economies that have significant reserves of minerals vital to the (existing) BEV, HEV and PHEV sector, as follows:

- Bolivia has 9 million tons of lithium in reserves
- The Democratic Republic of the Congo (DRC) has substantial lithium (1 million tons) and cobalt (3.4 million tons) reserves
- Guinea holds up to 26% of global bauxite reserves (a necessary mineral for aluminium production)
- Argentina and Chile boast significant lithium reserves, and the latter also has important copper deposits yet to be tapped
- New Caledonia has enormous supplies of nickel, with an estimated 8.4 million metric tons still to be exploited
- Other important nickel countries with developing and emerging economies include Cuba (5.5 million), Indonesia (4.5 million), the Philippines (4.8 million), Guatemala (1.8 million), Madagascar (1.6 million) and Colombia (1.1 million)
- Developing countries produce 77% of the world's silicon;
- China is a dominant producer (featuring as top five producer nation for aluminium, steel, lithium, silicon, titanium) and consumer of all the BEV, HEV and PHEV metals
- China has a virtual monopoly on the world's rare earths elements—metals vital to the BEV, HEV and PHEV sector.

What does this mean for the responsible sourcing of minerals?

Companies are coming under increasing scrutiny as to whether they source minerals in a responsible way—whether they consider human rights, integrity and environmental performance factors when managing their supply chains.

Many of the minerals vital to BEVs, HEVs and PHEVs are mined in regions that are more high-risk when it comes to human rights and integrity risks, including child and forced labour, unsafe working conditions, unchecked environmental degradation, and corruption.

For example, child or forced labour have been identified in the mining industries of the DRC, Madagascar, Guinea, Bolivia, Colombia, the Philippines and Indonesia.

The 2016 Corruption Perceptions Index ranking of the majority of the above mentioned countries is also poor; out of 176 assessed countries, the results are as follows: DRC (156th); Madagascar (145th); Guatemala (136th); Argentina (95th); Guinea (142nd); Bolivia (113th); Colombia (90th); the Philippines (101st); and Indonesia (90th)*.

*The lower the ranking of a country, out of 176 assessed, the higher the perception of corruption.

The BEV, HEV and PHEV sector is not unique in the responsible sourcing challenges it will face—these are common across virtually every extractives-reliant industry. However, component and vehicle manufacturers in this sector can take proactive steps to manage risks in their supply chains and ensure that they are not contributing to human rights abuses, unmitigated environmental impacts, and corruption. Conducting supply chain due diligence is an important first step to assessing risk in a supply chain, after which a process can be initiated to mitigate and remediate identified risks.

Companies in the BEV, HEV and PHEV sector should prepare themselves to expand the scope of their due diligence which traditionally has been focused on conflict minerals—tin, tungsten, tantalum and gold—to include a broader selection of minerals, including those named above. This will help them to tackle these risks early and head-on, prevent any reputational or financial losses, and contribute to the stable development of these countries' mining industries.

Cobalt (Co)

New to electric vehicle supply chains

Where found in car	Battery
Where produced	The Democratic Republic of the Congo (DRC), China, Canada, Russia, Australia
Biggest market	China
Extraction method	Rarely extracted from ore alone; often a by-product of copper and nickel mining
ASM/LSM	ASM and LSM
Risks	Child labour; environmental degradation; smuggling; health and safety concerns, human rights abuses
Who is working on this?	Responsible Cobalt Initiative Responsible Raw Materials Initiative
Increase or decrease in demand	Increase

Additional information: Madagascar is also a significant producer of cobalt, co-produced with nickel.

Graphite (Allotrope of C)

New to electric vehicle supply chains

Where found in car	Battery
Where produced	China, India, Brazil, Turkey, North Korea
Biggest market	China
Extraction method	Open-pit (for lake and micro-crystalline graphite) and underground shaft mines (for lump graphite)
ASM/LSM	Mostly LSM, some Small-scale mines
Risks	Pollution, health concerns, poor labour conditions, environmental concerns
Who is working on this?	Institute of Public and Environmental Affairs
Increase or decrease in demand	Increase

Additional information: Benchmark Mineral Intelligence forecasts that the battery anode market for graphite will increase from 80,000 tonnes in 2015 to 250,000 tonnes by the end of 2020.

Madagascar also a minor producer, with significant reserves.

Lithium (Li)

New to electric vehicle supply chains

Where found in car	Battery
Where produced	Australia, Chile, China, Argentina, Zimbabwe
Biggest market	China
Extraction method	Hard rock mining; Pump out brine and leave to evaporate
ASM/LSM	LSM only
Risks	Water and energy intensive; pollution (water, air, land), violations of indigenous rights, high levels of waste (little to no recycling)
Who is working on this?	Australian Battery Recycling Initiative Responsible Battery Coalition
Increase or decrease in demand	Increase

Additional information: Estimated reserves for Bolivia is 9 million tonnes.

Aluminium (Al)

Increased demand

Where found in car	Body, battery, wheels
Where produced	Bauxite: Australia, China, Brazil, Guinea, India Alumina: China, Australia, Brazil, Jamaica, USA Aluminium: China, Russia, Canada, India, UAE
Biggest market	China
Extraction method	Bauxite is typically mined open-cast, ore is refined to alumina oxide, then smelted into aluminium
ASM/LSM	LSM only
Risks	Violations of indigenous rights, tensions over land use, processing water and energy intensive, pollution
Potential for positive impact	Increased used of environmentally friendly methods for production; land restoration; recycling
Who is working on this?	The Aluminium Stewardship Initiative
Increase or decrease in demand	Increase

Additional information: 26% of known global bauxite reserves are in Guinea.

Copper (Cu)

Increased demand

Where found in car	Battery, interior wiring, motor
Where produced	Chile, Peru, China, USA, Australia
Biggest market	China
Extraction method	Extraction of copper, followed by beneficiation, smelting, refining and fabrication
ASM/LSM	ASM and LSM
Risks	Dangerous working conditions, environmental damage and ecological impact, energy intensive, underpayment
Potential for positive impact	Recycling (copper is the most recycled material in the world)
Who is working on this?	Clean Copper™ Supply Chain Alliance
Increase or decrease in demand	Increase

Additional information: Zambia also produces a large amount of copper.

Lead (Pb)

Increased demand

Where found in car	Battery
Where produced	China, Australia, USA, Peru, Mexico
Biggest market	China
Extraction method	Extraction of lead ore, followed by concentration and conversion.
ASM/LSM	LSM only
Risks	Health risks, pollution, energy intensive, environmental damage
Potential for positive impact	Recycling
Who is working on this?	World Health Organization (WHO) International Lead and Zinc Study Group
Increase or decrease in demand	Increase

Additional information: In 2014, more lead was produced via recycling than mining.

Nickel (Ni)

Increased demand

Where found in car	Battery
Where produced	The Philippines, Russia, Canada, Australia, New Caledonia
Biggest market	China
Extraction method	Underground tunnelling for sulphide deposits. Open-pit mining for laterite deposits, following by leaching with acids at high temperatures
ASM/LSM	LSM only
Risks	Health risks, violation of indigenous rights, violence, human rights abuses, environmental damage
Potential for positive impact	Recycling
Who is working on this?	International Nickel Study Group
Increase or decrease in demand	Increase

Additional information: Madagascar is also a significant producer of nickel, co-produced with cobalt.

Steel (Alloy of Fe, C, others)

Increased demand

Where found in car	Body, motor, wheels, battery
Where produced	Iron ore: China, Australia, Brazil, India, Russia Steel production: China, Japan, USA, Russia, South Korea
Biggest market	China
Extraction method	Steel is an alloy of iron, carbon, and fluxes such as lime-stone, as well as scrap steel
ASM/LSM	ASM and LSM
Risks	Use of fossil fuels, soil erosion, pollution (water, noise, air), health and safety, loss of habitats and areas of natural importance, health issues, child labour
Potential for positive impact	Recycling
Who is working on this?	Australian Steel Stewardship Forum
Increase or decrease in demand	Increase

Additional information: 26% of known global bauxite reserves are in Guinea.

Titanium (Ti)

Increased demand

Where found in car	Batter reinforcement
Where produced	China, Russia, Japan, Kazakhstan, Ukraine
Biggest market	China
Extraction method	Extracted from rutile and ilmenite ore. Alluvial. Open-pit.
ASM/LSM	ASM and LSM
Risks	Environmental damage, energy intensive, waste
Potential for positive impact	Recycling
Increase or decrease in demand	Increase

Additional information: Madagascar and South Africa are also significant producers of titanium, with loss of coastal forest a major environmental risk in Madagascar.

Silicon (Si)

Increased demand

Where found in car	Window, battery
Where produced	China, Russia, USA, Norway, France
Biggest market	China
Extraction method	Large-scale dredging operations
ASM/LSM	LSM only
Risks	Environmental damage, health and safety concerns
Potential for positive impact	Some recycling
Who is working on this?	Earthworks
Increase or decrease in demand	Increase

Additional information: Silicon is the second-most abundant element in the earth's crust, occurring in sand as quartz grains, or as flint.

Mica (Group of phyllosilicate minerals)

Still in use

Where found in car	Paint
Where produced	China, Russia, Finland, USA, South Korea
Biggest market	Japan
Extraction method	Open-pit or shaft mining
ASM/LSM	ASM and LSM
Risks	Illegal exploitation, child labour, heath and safety concerns, environmental damage, poor labour conditions, human rights abuses, extortion, conflict financing, forced labour
Who is working on this?	SOMO and Terres des Hommes Bachpan Bachao Andolan (Save the Childhood Campaign) Responsible Mica Initiative
Increase or decrease in demand	Increase not determined by shift towards green economy

Additional information: Mica is the name given to a group of 37 minerals that are physically or chemically similar. They are formed as layers in the ground which can easily be split into sheets. The mica industry is split into two: those producing flake mica (open-pit mining) and those producing sheet mica (shaft or open-pit).

Madagascar is also a minor small-scale producer of mica.

Tin (Sn)

Still in use

Where found in car	LCDs, audio components, controls
Where produced	China, Indonesia, Peru, Bolivia, Brazil
Biggest market	China
Extraction method	Hard rock mining, alluvial mining
ASM/LSM	ASM and LSM
Risks	Illegal exploitation, environmental damage, loss of land, ecological impact, conflict financing, human rights abuses, health and safety concerns, child labour
Who is working on this?	ITRI - ITSCi IDH Indonesian Tin Working Group Conflict-Free Sourcing Initiative Electronic Industry Citizenship Coalition Enough Project Organisation for Economic Cooperation and Development Global Witness Responsible Raw Materials Initiative
Increase or decrease in demand	Increase not determined by shift towards green economy

Tantalum (Ta)

Still in use

Where found in car	LCDs, audio components, controls
Where produced	The Democratic Republic of the Congo (DRC), Rwanda, Brazil, China
Biggest market	China
Extraction method	Typically open-pit mining
ASM/LSM	ASM (especially in DRC) and LSM
Risks	Illegal exploitation, smuggling, conflict financing, human rights abuses, poor working conditions, forced labour, health and safety concerns, child labour
Who is working on this?	Conflict-Free Sourcing Initiative Electronic Industry Citizenship Coalition Enough Project Organisation for Economic Cooperation and Development Global Witness Responsible Raw Materials Initiative
Increase or decrease in demand	Increase not determined by shift towards green economy

Levin Sources

Levin Sources is a consultancy and social venture that moves more raw materials through systems where good governance and better business are the norm.

For more than seven years, we have been at the forefront of responsible mining and sourcing, with unique expertise in issues surrounding raw material sustainability and artisanal and small-scale mining.

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> “Our goal is to drive raw materials through systems where good governance and better business are the norm, building resilient futures for us all.”

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Find out more

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