The battery paradox

How the electric vehicle boom is draining communities and the planet

Alejandro González & Esther de Haan

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The Centre for Research on Multinational Corporations (SOMO) is an independent, not-for-profit research and network organisation working on social, ecological and economic issues related to sustainable development. Since 1973, the organisation investigates multinational corporations and the consequences of their activities for people and the environment around the world.

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SOMO

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Amsterdam, December 2020

Contents

Acronyms

CO_2	Carbon dioxide
DRC	Democratic Republic of Congo
EBA	European Battery Alliance
EC	European Commission
EESC	European Economic and Social Committee
EIB	European Investment Bank
EU	European Union
EV	Electric vehicle
FPIC	Free, prior and informed consent
GBA	Global Battery Alliance
GWh	Gigawatt hours
NGO	Non-governmental organisation
ICE	Internal combustion engine
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRP	International Resource Panel
kWh	Kilowatt-hour
Li-ion battery	Lithium-ion battery
LCO	Lithium-cobalt oxide
LED Scenario	Low Energy Demand Scenario
LFP	Lithium iron phosphate
LMO	Lithium manganese oxide
LTO	Lithium titanate
NCA	Lithium nickel cobalt aluminium
NGO	Non-governmental organization
NMC	Lithium nickel manganese cobalt
SOMO	Centre for Research on Multinational Corporations
USGS	United States Geological Survey

Executive summary

The transport sector accounted for roughly a quarter of global CO_2 emissions in 2019, with over 70 per cent coming from road transport. It is clear that these emissions need to be curbed if the targets of the Paris Climate Agreement are to be reached and catastrophic climate change is to be avoided. But phasing out fossil fuel-powered cars in favour of electric vehicles may come at an unacceptably high social and environmental cost.

Electric vehicles are often presented as the ultimate solution to help reduce emissions from road transport. After all, they run on batteries instead of oil, eliminating the CO_2 exhaust emissions of traditional engines. This is why governments across the world are adopting policies to phase out petrol and diesel cars and stimulate massive uptake of electric vehicles. This has already led to a worldwide boom in the production and sales of electric cars, which will only pick up speed in the coming years.

At the core of this transition is the production of lithium-ion batteries. The minerals required to produce these batteries – lithium, cobalt, nickel, graphite, manganese– are extracted from the earth, just like fossil fuels, and demand for them is skyrocketing. A recent report by the World Bank estimates that demand for lithium, cobalt and graphite could grow by nearly 500 per cent by 2050.

While electric vehicles are widely embraced, the pressure of the great battery boom is increasingly being felt by communities around the world, including in Argentina, Chile and Bolivia – the so-called 'Lithium Triangle' countries that host three-quarters of the world's lithium resources – and the Democratic Republic of Congo, which produces about two-thirds of the world's cobalt. Issues reported include heavy pollution, water scarcity, exposure to toxics, non-disclosure of suficient information, lack of consultation and community consent, community conflicts and abuses, impact on indigenous rights, dangerous mining conditions and child labour. The unprecedented increase in demand for these and other raw materials thus poses serious human rights and environmental risks and begs the question how sustainable and fair a mobility transition based on the mass uptake of electric vehicles really is.

To answer this question, this report analyses the composition of the most common Li-ion batteries and reviews the whole battery value chain, from mining to production, and recycling. It looks at the composition of the batteries, the biggest players in the industry and the (expected) consequences on the ground. Apart from critically assessing the current and future social and environmental impacts of the soaring demand for minerals needed to produce batteries for electric vehicles, the report also looks at alternative, less mineral-dependent strategies to reduce emissions in the transport sector.

Key findings

- Extensive documentation shows that the social and environmental impacts associated with mining of key minerals (lithium, cobalt, nickel, graphite and manganese) for producing Li-ion batteries are destructive and widespread. The mass uptake of electric cars would result in more mining and energy consumption, increasing these impacts, which raises serious social and environmental concerns about transitioning from a dependency on oil to a dependency on minerals for mobility.

- As electric vehicles gain market share, an enormous number of the batteries that power them will reach end-of-life in the decades to come. An important concern is that battery manufacturers are currently not designing Li-ion batteries to optimise recycling. Differences in design of battery cells, modules and packs hinder recycling efficiency. Packs are not easy to disassemble and cells are not easy to separate for recycling.

- Key players pushing for the mass adoption of electric vehicles are primarily businesses, governments in the US, Europe and China, the European Commission as well as partnerships (battery alliances) with a strong corporate presence. The expected market value and potential profits of the Li-ion battery value chain is a key motivator of their efforts to scale up Li-ion battery production and the mass uptake of electric vehicles. Predictions clearly show that the expected economic benefits would be unequally distributed among the different segments of the value chain, predominantly favouring those businesses that are engaged with cell and car manufacturing.

- Corporate players and battery alliances are already heavily invested in the development of a Li-ion battery value chain, leading to a vested interest in the mass uptake of batteries. These companies are likely to support a system that locks society in a transport system where individual car ownership is central.

- Policy measures in different countries and at the EU level are playing a decisive role in incentivising the electric vehicle boom, often accompanied with public spending. In Europe, the declaration of the battery as a strategic priority by the European Commission is accompanied by an important change in industrial policy, which shifts away from open market and free competition towards a government supported Li-ion battery industry, allowing for the easing of market and state-aid rules.

- While mass adoption of electric vehicles is being promoted by industry and governments (particularly in the global north), it is not the only solution to address the impacts of passenger road transport. Scientists, civil society and communities across the world are calling for a different approach based on environmental justice and the need to reduce the demand for minerals and energy in absolute terms. Strategies proposed include ride-sharing, car-sharing and smaller vehicles. These strategies based on scientific studies have the biggest potential to reduce the impact of passenger road transport. Material efficiency strategies such as recycling and extended lifespan are also important. The effects of these combined strategies are discussed in the report.

Recommendations

The following are key recommendations based on the information provided in this report. For additional recommendations, we refer to the (forthcoming) *Principles for Businesses and Governments in the Battery Value Chain* drafted by Amnesty International and allies.

To governments

- States and the EU should prioritise reducing the mineral and energy demand of passenger road transport in absolute terms. To do so, States and the EU should support and promote strategies towards car-sharing, ride-sharing and public transport.
- States should introduce policy action and regulations that promote material efficiency strategies for the use of less materials and energy, including design of smaller Li-ion batteries and electric vehicles, reuse and recycling.
- States and the EU should require manufacturers to standardise the design of Li-ion cells, modules and packs, and include proper labelling, in order to optimise recycling.
- States and the EU should introduce rules mandating Li-ion battery producers and/or EV manufacturers to take back end-of-life Li-ion batteries, through an extended producer responsibility scheme.
- States and the EU should introduce binding regulation requiring companies to conduct mandatory human rights and environmental due diligence, including the obligation of businesses to publish their due diligence practices and findings. Due diligence requirements should cover the entire battery value chain and involve communities, workers, civil society and trade unions in its design, monitoring and implementation.
- States and the EU should facilitate a democratic public debate to discuss alternative strategies to address the impacts of passenger road transport that includes the participation and meaningful engagement of mining-affected communities, workers, environmentalists, scientists, civil society and that is based on environmental justice and respect for human rights.

To companies along the battery value chain

- All companies along the Li-ion battery value chain should map and disclose their supply chain and use their leverage with business relationships to request respect for human rights, decent working conditions and environmental protection through contractual obligations.
- All companies along the Li-ion battery value chain should carry out human rights and environmental due diligence, disclosing their findings on risks and abuses and outcomes; and prevent, address and mitigate their negative impacts.
- All companies should respect human rights and environmental laws, including the right to information, water, health; a healthy environment; communities' right to withhold consent; occupational health and safety standards; and the right of freedom of association and collective bargaining.
- All companies should provide victims of abuses occurring at any stage of the value chain with access to an effective remedy and have in place an effective grievance mechanism to receive workers' and external complaints.
- Companies should prioritise reducing mineral and energy demand in absolute terms, standardise design of Li-ion batteries and their components, which facilitate reuse and recycling. Manufacturers should ensure that Li-ion batteries and components include proper labels including battery health and safety guidelines for disassembling and recycling.

Introduction

Context and point of departure

Urgent action is needed to address the climate crisis. Phasing out fossil fuels and shifting towards more sustainable sources of energy is essential to curb global warming. Reaching the targets of the Paris Agreement and limiting global warming requires urgent and 'far-reaching transitions in energy, land, urban and infrastructure (including transport and buildings), and industrial systems', according to the Intergovernmental Panel on Climate Change (IPCC).[1] In 2019, the transport sector (land, air, sea and water) was responsible for 24 per cent of energy-related global CO_2 emissions.[2] Roughly, road transport accounts for more than 70 per cent of all transport emissions. Within road transport, passenger road transport accounts for roughly two thirds of emissions while commercial road transport accounts for the remaining one third.[3]

Almost all energy for transport (95 per cent) comes from burning diesel and gasoline.[4] In 2019, passenger cars burned more than 40 million barrels of oil per day, representing over 20 per cent of total global demand.[5] Therefore, reducing the environmental impacts of passenger road transport is imperative and poses a major challenge in terms of addressing the climate crisis.

Increasingly, mass uptake of electric vehicles (EVs) is presented as the solution to reduce emissions of passenger road transport. After all, EVs run on batteries instead of oil, which eliminate the CO_2 exhaust emissions of traditional internal combustion engines. Electric mobility is booming, especially in China and in the global north. The global EV fleet has gone from 17,000 units in 2010 to 7.2 million by 2019, with more than 2.1 million EV sales in 2019 alone.[6] Industry analysts estimate that global sales of EVs will reach 26 million in 2030 and 54 million in 2040.[7] Despite electrification, the global fleet of passenger cars is expected to grow from 1.2 billion in 2020 to 1.4 billion in 2030, and EVs will only account for 8 per cent of the total fleet in 2030, far from replacing internal combustion engines.[8]

Countries around the world are introducing regulations, incentives and legislation to phase out petrol and diesel cars. By 2025, in Norway only 100% electric or plug-in hybrid EVs will be sold.[9] By 2030, all new cars in the Netherlands should be emission free.[10] In the UK and France, as of 2030 and 2040, respectively, sales of petrol and diesel cars will not be allowed.[11] Policy-makers in Canada, Chile, Costa Rica, India and New Zealand are also supporting the uptake of EVs.[12]

China's objectives are ambitious. China has set a target of 7 million EV sales annually by 2025.[13] China is the world's biggest EV market, followed by the European Union (EU) and the United States (US). By 2025, China is projected to account to 54 per cent of the global passenger EV sales.[14]

Policy measures have played an important role in promoting the EV boom, including emissions regulations, fuel economy standards (EU), zero-emissions mandates (Quebec and California), subsidies (Korea, China), public procurement (EU Clean Vehicles Directive), restrictions on investment in combustion engine manufacturing (China) and reduction of purchase price for EVs (India).[15]

The Battery

Batteries are at the core of this momentous transition in passenger road transport. Batteries, as stated by the European Commission's Vice President, are 'at the heart of the on-going industrial revolution. Their development and production play a strategic role in the on-going transition to clean mobility and clean energy systems'.[16] Battery manufacturing has become a priority and a strategic goal for many regions, notably China and the EU. The latter recently adopted the Strategic Action Plan for Batteries to accelerate the building of a battery value chain in Europe (see Chapter 2.1).

While there are different types of batteries, lithium-ion batteries (Li-ion batteries) are expected to dominate the EV market at least for the next decade.[17]

But what's inside a Li-ion battery? The minerals required to produce the Li-ion batteries (i.e. lithium, cobalt, nickel, graphite, manganese) come from the earth, just like fossil fuels. Minerals are the ingredients for batteries' energy storage. And demand for them is skyrocketing. A recent report by the World Bank estimates that demand for lithium, cobalt and graphite could grow by nearly 500 per cent by 2050, driven almost entirely by demand for batteries used for EVs.[18] While governments and citizens in the global north are embracing and incentivising electric vehicles, the pressure of the great battery boom is being felt by communities in places like Argentina, Chile and Bolivia – the so-called 'Lithium Triangle' countries, which host 75 per cent of the world's lithium resources – and the Democratic Republic of Congo (DRC), which produces about two-thirds of the world's cobalt. Furthermore, energy-intensive mega-factories are rapidly being built to supply the surging need for batteries. As well as requiring soaring amounts of minerals, the manufacture of Li-ion batteries also requires energy and generates carbon emissions and waste.

The unprecedented increase in demand for raw materials to make Li-ion batteries poses serious human rights and environmental risks and calls into question how clean, sustainable and fair a mobility transition based on mass uptake of EVs and increased production of batteries really is. Furthermore, passenger EVs are predicted to become the main driver for global Li-ion battery demand, far exceeding demand resulting from commercial transport, energy storage and consumer electronics.

Mass adoption of EVs is, however, not the only solution to address the impacts of passenger road transport. Scientists, civil society and communities across the world are calling for a different approach based on environmental justice and on the need to absolutely reduce the demand for minerals and energy.

Aim and research questions

The aim of this paper is to discuss and critically assess the social and environmental implications resulting from a mass uptake of EVs as a solution to address the climate impacts of passenger road transport. In particular the aim is to assess the implications resulting from a soaring mineral demand to produce Li-ion batteries to propel EVs. Furthermore, the aim is to identify other existing strategies to address the social and environmental impacts of passenger road transport in order to broaden the debate, particularly strategies based on environmental justice and towards reducing resource and energy use.

By reviewing the Li-ion battery value chain, we also aim to support existing efforts of different groups (communities, workers, trade unions, environmentalists, activists) with increased knowledge of the key players, dynamics, latest developments and leverage points of the Li-ion battery value chain in order to support their efforts towards transparency, corporate accountability and demands to respecting human rights and environmental protection.

The objectives of this report are to:

- Provide an overview of the Li-ion battery, including its mineral composition, main components and type.
- Offer an analysis of the global Li-ion battery supply chain, including its stages, main stakeholders and location of main activities.
- Identify who are the key players pushing towards (and investing in) a transition towards the mass uptake of EVs. In particular, we will focus on Europe, where the Li-ion battery value chain is changing rapidly due to increased incentives and investments.
- Analyse the main predictions of mineral demand resulting from the mass production of Li-ion batteries for EVs.
- Identify some of the main social and environmental impacts associated with mining of minerals used to produce Li-ion batteries.
- Carry out an initial non-exhaustive identification of other strategies to address the social and environmental impacts of passenger road transport and the battery value chain.

Research methodology

This report focuses on Li-ion batteries used for passenger road EVs. We focus on passenger road transport, as it is the biggest sub-segment within the road transport sector, and is responsible for two thirds of emissions. As mentioned above, passenger EVs are also the main driver for the mass production of Li-ion batteries.

The main research method used for this report is desk-based research, further complemented by empirical information gathering. Desk research was based on primary and secondary sources. Primary sources included statistical data, company's publications, reports on the social and environmental impacts of mining and the transport sector and scientific journals. Secondary sources included media articles, books, non-governmental organisation (NGO) reports and company and industry reports. Some parts of Chapter 2, particularly on the social and environmental impacts of mining, relied on previous work by the Centre for Research on Multinational Corporations (SOMO) and other NGOs. Empirical information gathering included conversations and email exchanges with different experts as well as participation in workshops, panel discussions and seminars.

Structure of this report

Chapter 1 provides an overview of the battery, including its components and different chemical compositions, focussing on the lithium rechargeable battery. The entire battery value chain is analysed, including the main players involved and key location of activities for each stage.

In Chapter 2, we identify the key players and initiatives that are promoting the mass adoption of EVs, such as the European Battery Alliance and the Global Battery Alliance. We also review major industry players that are investing in the battery value chain as well as recent alliances and consolidation of business interests. We further zoom in on the corporations investing in developing a battery value chain in Europe, as well as the governmental support that they are receiving through public spending and incentives.

Chapter 3 focuses on analysing the soaring rise in demand for minerals resulting from mass uptake of EVs and battery production. We focus on key minerals for batteries (lithium, cobalt, manganese, graphite and nickel) including the associated social and environmental impacts resulting from mining for such minerals.

Chapter 4 focuses on carrying out a non-exhaustive identification of other strategies to address the social and environmental impacts of passenger road transport. We focus on strategies based on environmental justice, reduction of private passenger cars (in order to reduce mineral and energy demand) as well as material efficiency and recycling.

We conclude with recommendations for governments and companies along the battery value chain.

1 The Li-ion battery

1.1 Li-ion battery composition

A Li-ion battery is a group of inter-connected cells capable of charging and discharging. Common end-uses of Li-ion batteries include consumer electronics, electric vehicles and energy storage.

A Li-ion battery cell is made up of several components: a negative electrode or anode (usually made of graphite with a copper collector), a positive electrode or cathode (made from a transition metal oxide that can vary in chemical composition with an aluminium collector), a separator and an electrolyte.

The chemical composition of the cathode defines the specific Li-ion battery type. The most common Li-ion battery types used for EVs, according to their cathode composition, are:

- **Lithium nickel cobalt aluminum (NCA)**, (used by Tesla).
- **Lithium nickel manganese cobalt (NMC)**, which has a higher energy density (used by BMW, Hyundai, Volkswagen, Nissan, and Mercedes-Benz).
- **Lithium manganese oxide (LMO)** (used by Nissan first generation and BMW).
- **Lithium iron phosphate (LFP)**, (commonly used in public transportation as they are more stable).
- **Lithium titanate (LTO)**, (used in public transportation for its fast-charging properties).

Another type of battery, **Lithium-cobalt oxide (LCO)**, is mostly used by consumer electronics but is deemed unsuitable for cars because of safety reasons.

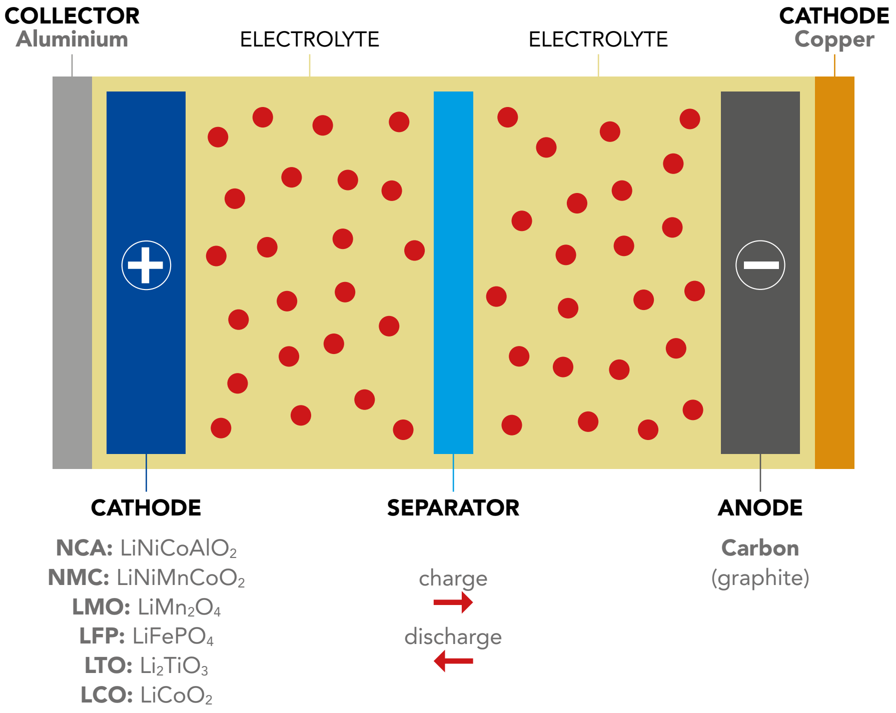
The key mineral constituents in most types of Li-ion batteries used for EVs are cobalt, lithium, graphite, manganese and nickel. Figure 1 shows a battery model, including the key materials used in the its different components.

The Li-ion battery type or composition determines its mineral demand. As an illustration, Figure 2 shows the mineral ratios for LMO, NMC 111, NMC 811 and NCA battery types.

The size of the battery (measured in power output) determines the amount of materials needed per unit. Currently the Li-ion battery size, measured in power output, ranges from 15 to100 kilowatt-hour (kWh). Compact EVs use a Li-ion battery size of 12-18 kWh, mid-size sedans use a 22-32 kWh pack, and high-end models (like Tesla) use a battery size of 60-100 kWh.[19] The bigger the size of the battery, the more minerals are required to produce them. Size plays a key role in the range of the battery. For instance, a Mitsubishi MiEV with a battery pack of 16 kWh has a range of 85 km while a Tesla S85 with a battery pack of 90 kWh reaches up to 360 km.[20]

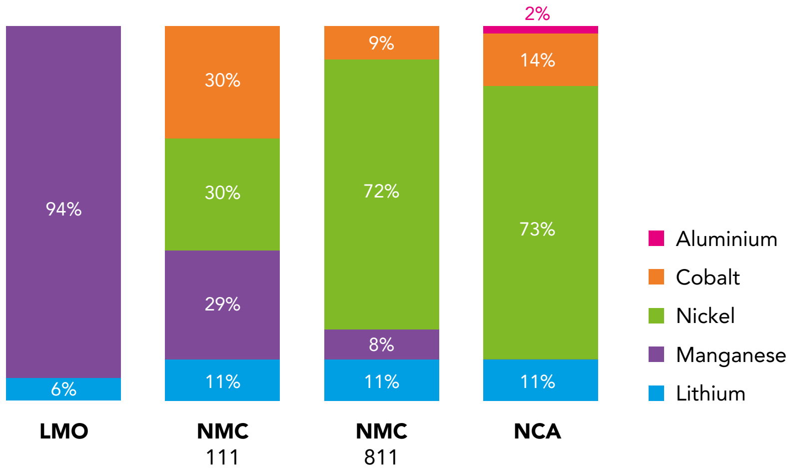
While Li-ion batteries will dominate the EV market in the next decade, according to analysts, there are other battery technologies currently being developed and tested that may become commercially viable in the near future. For instance, solid-state Li-ion batteries or zinc-air batteries could become

Figure 1 A Li-ion battery model



Source: Elaborated by SOMO.

Figure 2 Mineral ratios for the main EV Li-ion battery types



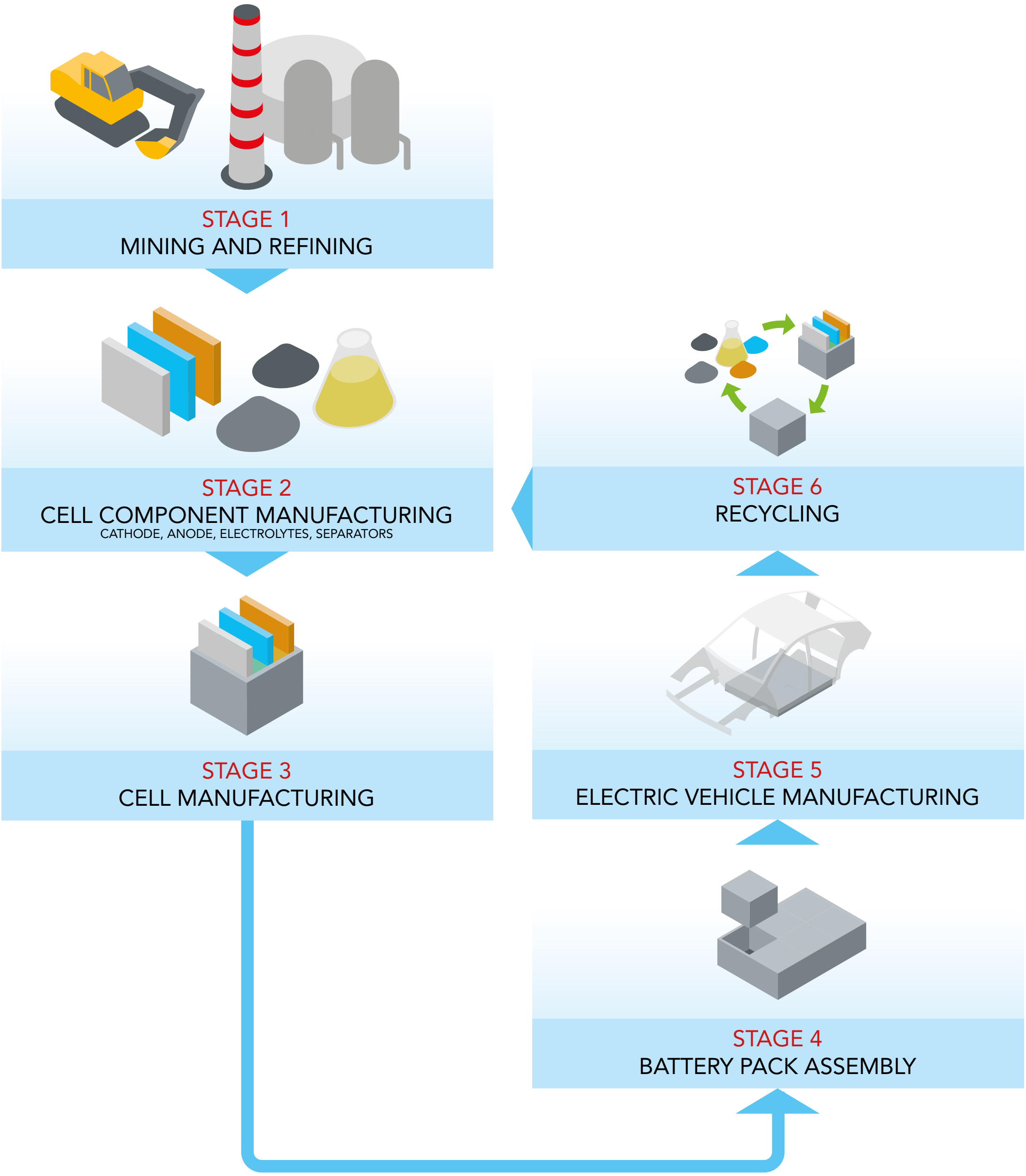
Source: BloombergNEF.

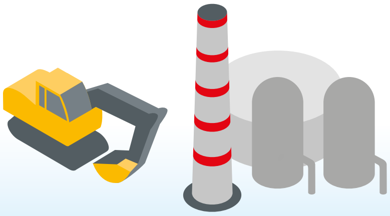
the next generation batteries for EV batteries. Solid-state Li-ion batteries use a solid electrolyte (i.e. polymer or ceramic) rather than a liquid one as used in current Li-ion batteries.
There are several options of additional minerals that could be used for the solid electrolyte (including aluminium, tin, silver and boron). Another important difference between technologies is that solid-state batteries use an anode made of lithium rather than graphite. According to some analysts and business roadmaps (e.g. Volkswagen), solid-state Li-ion batteries could be used commercially by EVs within 5 to 10 years.[21]

1.2 The Li-ion battery value chain

The Li-ion battery value chain has six key stages: mining and refining, cell component manufacturing (cathode, anode, electrolytes, separators), cell manufacturing, battery pack assembly, electric vehicle manufacturing and recycling.[22]

Figure 3 The lithium-ion battery value chain





STAGE 1 MINING AND REFINING

Sourcing of raw materials is the first stage of the battery supply chain.

The world's mine production of several key minerals for Li-ion batteries tends to be concentrated in a few countries as observed in Table 1. In 2018, DRC produced 70 per cent of the world's cobalt; Australia produced 62 per cent of lithium (followed by Chile with 18 per cent and Argentina and China both with 7 per cent); South Africa produced 30 per cent of manganese; China produced 68 per cent of graphite.[23] Table 2 illustrates the production share, total production, location of reserves, location of resources and total estimated resources for the key minerals used to manufacture batteries.[i]

Table 1 Production, reserves and resources of key minerals

Mineral	Production share 2018	Total Production 2018	Reserves	Resources	Total estimated world resources
Lithium	Australia 62%, Chile 18%, China 7% Argentina 7%, Canada 3%, Zimbabwe 2%, Portugal 1%	95,000 tonnes	Chile 52%, Australia 17%, Argentina 10%, China 6%, Canada 2%, Zimbabwe 1%	Bolivia 26%, Argentina 21%, Chile 11%, Australia 8%, China 6%	80 million tonnes
Cobalt	DRC 70%, Russia, 4%, Australia 3%, Philippines 3%, Canada 2%, Cuba 2%	148,000 tonnes	DRC 51%, Australia 17%, Cuba 7%, Russia 4%, Philippines 4%,	Vast majority in DRC and Zambia.	25 million tonnes (terrestrial) and 120 million (oceans floor)
Manganese	South Africa 31%, Australia 18%, Gabon 12%, Ghana 7%, Brazil 7%, China 6%	18,900 tonnes	South Africa 32%, Ukraine 17%, Brazil 17%, Australia 12%	South Africa 74%, Ukraine 10%	Large and irregularly distributed.
Nickel	Indonesia 25%, Philippines 14%, Russia 14 %, New Caledonia 9%, Canada 7%	2,400,000 tonnes	Indonesia 24%, Australia 22%, Brazil 12%, Russia 8%		>117 million tonnes
Graphite (natural)	China 62%, Mozambique 9%, Brazil 8%, Madagascar 4%, Canada 3%,	1,120,000 tonnes	Turkey 30%, China 24%, Brazil 24%, Mozambique 8%		>725 million tonnes (inferred)

Source: Compiled by SOMO with data from USGS Minerals Commodity Summaries 2020.[24]

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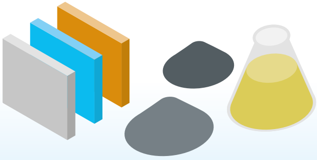
[i] Resources refer to the amount of the mineral in the earth's crust, while reserves refer to the amount of resources that could be economically extracted at a particular moment. 'Mineral Commodity Summaries 2020,' USGS Unnumbered Series, *Mineral Commodity Summaries 2020*, Mineral Commodity Summaries (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/mcs2020.



STAGE 2 CELL COMPONENT MANUFACTURING
CATHODE, ANODE, ELECTROLYTES, SEPARATORS

In stage 2 of the value chain, each of the different components of the Li-ion battery is manufactured, namely the cathode, anode, electrolytes and separators.

Asian companies dominate the manufacturing of cathode active materials and anodes. By 2019, 61 per cent of the cathode materials for EVs were produced by Chinese companies as well as 83 per cent of the anodes.[25]

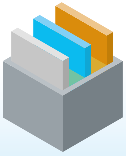
Table 2 details the revenues and the regional production distribution of the different cell components for the Li-ion battery market in 2015 and 2019 evidencing a growing concentration by China.

Table 2 Revenues and production distribution of the different cell components

Cell components	**Market Demand for Lithium batteries** 2018	**Revenues in US$** 2018	**Production Distribution** 2015	**Production Distribution** 2019
Cathode materials	313,000 tonnes	B$7.2	China 39%, Japan 19%, EU 13%, South Korea 7%, other 22%	China 61%
Anode materials	200,000 tonnes	B$1.8	No information	China 83%
Electrolyte	1,972,000 tonnes	B$2	China 60%, Japan 18%, Korea 7%, US 7%	No information
Separators	2500 mm^2	B$1.8	Japan 48%, China 17%, Korea 10%	No information

Source: SOMO taken from various sources.[26]

According to industry analysts the market value of cathode materials will grow significantly from US$7 billion in 2018 to $58.8 billion in 2024.[27]



STAGE 3 CELL MANUFACTURING

A Li-ion battery cell is a single electrochemical unit composed of the electrodes, a separator and the electrolyte. In stage 3, the different cell components are assembled into a single battery cell.

Chinese companies are the undisputed leaders of Li-ion battery cell manufacturing. In 2019, Chinese players concentrated 73 per cent of cell manufacturing, followed by North Americans (10 per cent) and Europeans (6 per cent).[28]

By the end of 2020, the world's top 5 Li-ion battery cell manufacturers in terms of capacity are CATL, LG Chem, Samsung, Panasonic and BYD as shown in Table 4 (including main factories and clients).[29]

Table 3 The world's biggest cell battery manufacturers by production capacity

Company	Forecast capacity in GWh end of 2020	Key factories	Key clients
LG CHEM (Republic of Korea) including joint ventures	93	Wroclaw, Poland Holland, Michigan, US Nanjing, China Ochang, Korea	Volkswagen, General Motors, Ford, Geely (Volvo), Renault, Nissan, Hyundai, Kia, Tesla and others
CATL (China) including joint ventures	110,1	Ningde, China Thuringia, Germany (announced) Guangzhou (announced) Jiansu, China	Geely (Volvo), BMW, Daimler, Volkswagen, Toyota, Honda, Nissan, other Chinese manufacturers
BYD (China)	60	Qinghai, China Shaanxi, China (announced) Chongqing, China (announced) Shenzhen, China Huizhou, China	BYD, Toyota
Panasonic (Japan)[ii]	69	Nevada, US Various locations, Japan Dalian, China	Tesla, BMW, Toyota
Samsung (South Korea)	62	Xian, China Ulsan, South Korea Göd, Hungary	BMW

Source: SOMO based on various sources.[30]

[ii] Includes Tesla's Gigafactory Nevada (@37 GWh), which is operated by Panasonic, however all of the production goes to Tesla. Tesla is currently operating an 10 GWh pilot plant in Fremont, California.

Four out of five of the largest Li-ion battery factories are located in China. The biggest factory is Tesla Gigafactory 1 in Nevada. Table 4 shows the world's biggest battery factories by production.

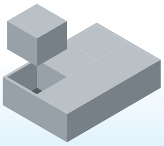
Table 4 The world's biggest battery factories by production capacity, 2019

Owner	Location	Country	Capacity in GWh
Tesla	Gigafactory 1, Nevada	US	37
LG Chem	Nanjing 1	China	28
CATL	Ningde	China	24
CATL-SAIC	Liyang	China	20
CATL	Liyang	China	15

Source: SOMO based on information from the Benchmark Minerals Intelligence.[31]

The number of factories that are planned to be constructed in the next 10 years has increased enormously spurred by the EV boom. At the end of 2019, 115 new lithium battery megafactories were planned around the world compared to 63 in December 2018.[iii][32] While China, with 88 out of the 115 factories in the pipeline, is expected to continue to be the leader in terms of capacity for the next 10 years, Europe has the highest growth rate with 14 megafactories in the pipeline and an estimated capacity of 348 Gwh by 2029. The EU is investing significantly in developing a whole Li-ion battery value chain within its territory (see Chapter 2.2).

[iii] Battery megafactories is a term coined by Benchmark Mineral Intelligence and refers to factories with an annual capacity of more than 1 GWH. It is equivalent to the term gigafactory used by Tesla.



STAGE 4 BATTERY PACK ASSEMBLY

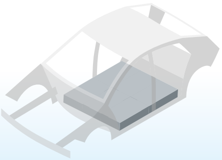
A battery pack is a set of interconnected cells. The battery pack includes wirings, sensors and the housing. The battery of an EV is expected to reach 40 to 50 per cent of the total cost of an EV.[33] Almost all car manufacturers (a notable exemption is General Motors) keep the design and assembly of the battery pack in-house. In some cases, the assembly of battery pack is done by a joint venture or a company whereby the car manufacturer has a stake. Table 5 shows the type of battery pack assembly (i.e. in-house, outsourced or joint venture) for different car manufacturers, as well as some of their key suppliers of cells.

Table 5 Battery pack manufacturing

Car manufacturer	Battery pack manufacturing	Supplier of cells
Tesla	In-house	Panasonic
GM	Outsourcing	LG Chem
BYD	In-house	BYD
BMW	In-house	Samsung SDI
Mitsubishi	In-house (through a joint venture named Lithium Energy Japan)	Not available
Nissan	In-house	Envision AESC
Renault	In-house (in collaboration with LG Chem)	LG Chem
Daimler AG	In-house	Buys cells in the global market
Volkswagen	In-house and joint venture with Northvolt AB (production planned for 2023)	LG Chem, Samsung SDI, CATL
Hyundai	Outsourcing	LG Chem and SK Innovation
Toyota	In-house for hybrids Joint ventures with CATL, BYD and Panasonic	CATL, BYD, Panasonic

Source: compiled by SOMO from various sources.[34]

Other battery pack manufacturers based in Europe include: Kriesel Electric GmbH (AT), Johnson Matthey Battery systems (UK), Continental (DE), BMZ (DE), Dow Kokam (FR) and Samsung SDI.[35]



STAGE 5 ELECTRIC VEHICLE MANUFACTURING

In this stage, the Li-ion battery pack is mounted into the vehicle. Major auto manufacturers are significantly increasing their investments to develop their EV portfolio and increase EV market penetration. By early 2019, automakers had announced more than $300 billion in investments in the EV environment. These investments were led by Volkswagen ($91 billion) followed by Daimler ($42 billion).[36] The main car manufacturers in terms of EV (unit) sales are shown in Table 6.

Table 6 Top 10 EV Car manufacturers' sales

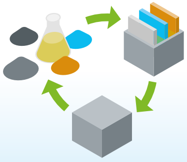
Car manufacturer	Sales in units, Jan-Nov 2019
Tesla (US)	304,841
BYD (China)	208,526
BAIC (China)	124,011
SAIC (China)	122,812
BMW (Germany)	117,932
Nissan (Japan)	74,940
Geely (China)	73,699
Volkswagen (Germany)	71,002
Hyundai (South Korea)	65,193
Toyota (Japan)	51,259
Total	**1,162,956**

Source: InsideEVs[37]

EV production and sales have boomed in the last few years. In 2019, more than 2.1 million electric vehicles were sold.[38] [iv] This is a small fraction of the total 92.8 million vehicles produced in the same year.[39] However, EV sales grew 40 per cent in 2019 alone. EV sales are predicted to reach 26 million units in 2030 and 54 million by 2040.[40]

With 1.06 million units sold in 2019, China remains the biggest EV market, followed by Europe (561,000 units) and the US (327,000 units).[41]

[iv] Sales data is used as a proxy of production as no publicly available data of the latter could be found.



STAGE 6 RECYCLING

Recycling of batteries is still limited due to a series of factors including recycling costs, limited volumes of batteries, recycling efficiency limitations, differences in battery design, types and chemistries, low collection rates and lack of recycling infrastructure. Furthermore, some recycling techniques do not recover all of the metals and the recycling itself may present social and environmental impacts such as chemical hazards, intense energy use and greenhouse emissions.

Until recently recycling of lithium batteries has focused on recovering cobalt due to its high value and favouring recycling techniques that fail to recover aluminium, lithium and manganese. There are no official statistics of global recycling volumes of lithium batteries. However, studies indicate that currently fewer than 5 per cent of end-of-life batteries are recycled.[42]

2 Key developments in the battery value chain

In this chapter we identify the key players and initiatives that are pushing for the mass adoption of EVs. We begin by examining the European Battery Alliance and the Global Battery Alliance, two of the most important public-private partnerships at European and global level, respectively. After that, we identify the key corporate players investing in the European battery value chain as well as the type of projects in which they are investing. We also highlight examples of public funding being used to support the development of the European value chain. Finally, we discuss recent trends in the battery value chain whereby corporate players from different segments of the value chain are strengthening ties among themselves, for instance in the form of long-term supply agreements, joint ventures or alliances between mining companies and car manufacturers or battery manufacturers.

2.1 Public-private initiatives supporting the development of the battery value chain

European Battery Alliance

The European Commission (EC) has identified the battery value chain as strategic due to its market value potential, its importance for a competitive industry and its role in the clean energy transition.[43] Since batteries account for a high proportion of cost of an EV (40 to 50 per cent), Europe aims to retain as much as possible of such added-value within its territory and protect its manufacturers from shortages and dependency on battery cell imports.[44]

The European Battery Alliance is an industry-led cooperative platform launched in October 2017 by the EC. The platform brings together the EC, EU countries, the European Investment Bank (EIB) and industrial and innovation actors with the goal of creating 'a competitive manufacturing value chain in Europe with sustainable battery cells at its core'.[45]

This is an ambitious project, considering that currently Europe has no industrial capacity to mass produce battery cells nor sufficient access to the essential raw materials.[46] In 2019, the European share of global battery cell manufacturing was only 6 per cent, which reflects the extent to which European car manufacturers are outsourcing their battery cell manufacturing to Asian battery powers in China, Japan and South Korea.[47]

In 2018, within the framework of the European Battery Alliance, the EC (working closely with industry and Member States) developed a Strategic Action Plan on Batteries.[48] The Strategic Action Plan states that the 'EU should therefore secure access to raw materials from resource-rich countries outside the EU, while boosting primary and secondary production from European source'.[49] According to the plan, the EU will use trade policy instruments to guarantee 'access to raw materials in third countries and promote socially responsible mining'.[50]

The support that the EC (including through the European Battery Alliance) is giving to the developing of a Li-ion battery value chain in Europe signals at least two important changes in European industrial policy. First, a change from open market to direct government support to industry or state targeted industrial policies.[51] Second, a change from a 'sectoral approach of industry' to a 'value chain focus'.[52]

Declaring the Li-ion battery as 'strategic' opens the door to justify exceptions to existing market rules, for instance permitting exemption for state-aid (see, for example, the Important Projects of Common European Interest Framework in section 2.2). A more permissive approach to state aid for businesses in the battery value chain is precisely what the European Economic and Social Committee (EESC) is recommending to the EC in the 2019 progress report of the Strategic Action Plan. In this progress report, the EESC calls the EC to 'adopt a flexible and supple approach to the investment aid that Member States grant to businesses in these chains'.[53] Such changes in policy can also be understood as a reaction to 'America First' protectionist policies (or its European equivalent) and to counteract Chinese geopolitical rivalry.

European policies toward Li-ion battery self-sufficiency have already succeeded in attracting public and private investments for the expansion of production in the region. EBA 250 was created as the industrial development programme of the EBA and it is led by EIT InnoEnergy. More than 260 industrial and innovator actors have joined EBA250 from all segments of the battery value chain, announcing consolidated private investments of up to €100 billion.[54]

Global Battery Alliance

In 2017, the Global Battery Alliance (GBA) was launched under the auspices of the World Economic Forum.[55] The Global Battery Alliance is a public-private partnership composed mostly of businesses (from the mining, chemical, battery and car industries) and to a much lower extent of public and international organisations and civil society groups.

The Global Battery Alliance has done research and modelling on the economic value that could be created by scaling up the development of the Li-ion battery value chain.[56] According to their base case scenario (described as a 'scenario of unguided value chain growth'), the Li-ion battery value chain is estimated to generate more than US$300 billion of revenues by 2030, compared to US$39 billion in 2018.[57] Interestingly, the lion's share of such revenues are captured by cell manufacturing ($137 billion or 46 per cent), followed by refining (25 per cent), battery pack manufacturers (16 per cent), cell component manufacturing (active materials) (8 per cent), reuse and recycling (4 per cent) and finally mining (3 per cent). The amount of revenues that would go to workers, local governments and communities is not mentioned.

The Global Battery Alliance also presents a target case, which – through a series of interventions – aims to increase the demand of Li-ion batteries by 35 per cent (as compared to the base case), driven by further reducing Li-ion battery costs by 20 per cent. According to their predictions, the target case would represent an increase of economic value of the Li-ion battery value chain of $130-185 billion.[58] Under the target case, $110-130 billion (representing 70-84 per cent of the total Li-ion battery value chain economic value) would be captured by only one segment of the value chain: application use and service.

Table 7 shows the estimated earnings (in billion US) per value chain stage for both the GBA base case and target case.

Table 7 Battery Value chain economic value in 2030 (Global Battery Alliance)

	Stage of the value chain	Base Case US$ billion earnings	Target case US$ billion earnings
Mining	Stage 1	2-3	3-4
Refining	Stage 1	5-8	6-11
Cell component manufacturing (active materials)	Stage 2	1-2	2-3
Cell manufacturing	Stage 3	9-16	12-20
Battery pack assembly	Stage 4	3-5	4-7
Application use and service	(Equivalent in part to) Stage 5	50-65	110-130
Recycling	Stage 6	~1	~1

Source: Developed by SOMO based on the Global Battery Alliance report A Vision for a Sustainable Battery Value Chain in 2030.[59]

In both cases, clearly the main recipients of the economic benefits are upstream multinational companies focused on mass producing Li-ion battery cells and EVs. In contrast, the earnings of recycling companies would be less than US$1 billion. Such scenarios also show that there would be an unequal distribution of economic benefits along the Li-ion battery value chain. Finally, the economic benefits for workers, communities or resource-rich countries are not even estimated.

The Global Battery Alliance is also developing a Battery Passport, which they propose will serve as a quality seal of batteries which will share relevant information about its sustainability including 'all applicable environmental, social, governance and lifecycle requirements based on a comprehensive definition of a "sustainable" battery'.[60]

2.2 Increased investments in the European battery value chain

To compete with China's grip on the value chain and to reduce dependency, Europe wants to move fast and invest hard in developing a European battery value chain. Supported by the EC and by industry players, major projects are currently underway, including plants for producing cell components and battery cells. European, Asian and North American players are investing in Europe, including giants such as LG Chem, Samsung, BASF, CATL, Daimler, VW and Tesla, among others. For this section, we will focus on cell component manufacturing and battery cell manufacturing, segments with the largest investments in Europe along the battery supply chain.

Cell component manufacturing

Within the European battery value chain, it is relevant to highlight two companies for the production of cathodes: German company BASF and Belgian company Umicore. Given the expanding market, both companies are investing in production capacity: BASF in Finland and Germany, and Umicore in Finland and Poland.[61]

Umicore's cathode materials are primarily developed for NMC batteries, but are also used in NCA batteries.[62] Umicore has signed long-term supply agreement with LG Chem and Samsung SDI to supply NMC cathodes materials.[63]

BASF produces both NMC and NCA cathode active materials.[64]

Battery cell manufacturers

In the EV value chain, the distance between the production of battery cells and packs, and battery and car assembly plants, is important due to transportation costs and greater certainty of the supply chain. For this reason, and the size and growth of the battery market, top international battery manufacturers are committing big investments in Europe. Forecasts estimate that Europe will reach a battery capacity of 207 Gwh by 2023, which will likely be insufficient to cover regional EVs' batteries demand, expected to be around 400 Ghw by 2028.[65]

CATL is building one of Europe's largest battery cell production plant in Germany with an initial capacity of 14 GWh by 2020 and with possibility to expand to 24 GwH in the future.[66]

BYD is already producing batteries for electric buses in Hungary and France.

South Korean companies are also investing in Europe. **LG Chem** plans to increase their battery cell production in Poland from 15 GWh to 65 GWh by 2022.[67] **Samsung SDI** has been investing in increasing its battery production in Hungary since 2017. **SK Innovation** has announced significant investments to expand its battery production capacity for the EV market. It supplies Volkswagen (VW) with Li-ion battery cells in the US and it is constructing two factories in Hungary to compete in the European battery market.[68] SK Group controls SK Innovation Co., Ltd., which in turn is the second largest shareholder of Lingbao Wason, a top Chinese copper producer. Lingbao Wason also has a long-term supply contract with global EV manufacturers, including CATL.[69]

Tesla is currently building a gigafactory in Berlin calling it 'the most advanced high-volume electric vehicle production plant in the world' and with production expected for 2021.[70]

SAFT (owned by Total) and PSA Group are planning to construct two battery factories in Germany and France. Each factory would have an initial production capacity of 8 GWh, expandable to 24 GWh.[71]

In focus: Northvolt

Swedish company Northvolt, has declared two ambitious goals: 'develop the world's greenest battery cell and establish one of Europe's largest battery factories'.[72]

Northvolt is currently constructing a big plant named Northvolt Ett (meaning 'one' in Swedish) in Skellefteå close to the Arctic Circle whereby active materials will be produced, cells assembled and recycling will take place. The plant aims to be operational by 2021 producing 8 GWh per year and expanding to 32 GWh by 2024.[73] Northvolt already has a battery assembly facility located in Gdansk, Poland.

In 2019, Northvolt and Volkswagen entered a joint venture to construct a second battery factory in Germany with a capacity of 16 GwH and expected start of operation by end of 2023.[74]

By mid-2019, Northvolt had obtained $1 billion in equity capital to construct the plant including investments by Volkswagen and BMW.[75] Northvolt has already sold a substantial part of their expected production to car manufacturers.

Northvolt's production strategy is vertically integrated by bringing most of the value chain in-house including production of active materials, electrode manufacturing, cell assembly, module assembly (pack) and recycling. Procurement of raw materials remains to be outsourced.[76]

Summary of key players along the battery value chain investing in Europe

Confidence in the expansion of the European battery value chain has attracted manufacturers from across the globe, as summarised in Table 8 on the next page.

EIB loans, EU budget and state aid supporting the development of the European battery value chain

The European Investment Bank (EIB) is playing an important role in financing the development of the European battery industry through loans. From 2010 to 2020, the EIB financed battery projects worth €950 million and offered support of €4.7 billion of overall project costs. In 2020 alone, the EIB committed to further finance more than €1 billion euros for battery projects. Considering all the projects that have been approved or are currently being appraised, the EIB is financing a total battery production capacity of approximately 51 GWh.[77] Table 9 on page 29 shows some examples of key projects financed by the EIB.

Table 8 Summary of Investments in the European EV Battery value chain

Company	Location	Plant type	Production start	(Planned) Annual capacity. Different units used.
BASF	Finland	NMC precursors for cathodes	2022	For 300,000 EVs
	Germany	Cathode active materials	2022	(For 400,000 EVs)
Umicore	Finland	NMC precursors for cathodes	2020	Not available
	Poland	Cathodes	2020	
Guotai-Huarong Poland	Poland	Li-ion Electrolyte	2020	For 1 million EVs
Terrafame	Finland	NMC precursors for cathodes	2021	Not available
LG Chem	Poland	Battery cells	2018	15 GWh (expandable to 65 GWh by 2022)
Samsung SDI	Hungary	Battery cells	2018	1.2 to 4.8 million cells
		Battery cells	2030	(216 million cells)
SK Innovation	Hungary	Battery cells	2019	7.5 GWh
		Battery cells	2022	(9.8 - 16 GWh)
CATL	Germany	Battery cells	2022	14 Gwh (expandable to 24 GWh)
SAFT	France	Battery cells	2023	8 GWh (expandable to 24 GWh)
	Germany	Battery cells	2024	8 GWh (expandable to 24 GWh)
Northvolt (Ett Factory)	Sweden	Battery cells, including cathodes, electrodes, plus battery packs assembly	2021	8 GWh
			2024	(32 GWh)
Northvolt (Zwei factory) and VW joint venture	Germany	Battery cells	2024	(16 GWh)
Blackstone Resources AG	Germany	Battery cells, refinery and R&D for 3D-printing battery manufacturing.	2025	(3 GwH)
Daimler	Germany	Battery pack assembly (2 operational)	2012 - 2020	500,000 packs
		3 Battery pack assembly (3 planned)		Not available
	Poland	Battery pack assembly		Not available
Jaguar / Land Rover	United Kingdom	Battery pack assembly	2020	150,000 packs
Tesla	Germany	Battery cells, battery pack assembly and EV production	2021	(500,000 EVs)

Source: SOMO, compiled from various sources.[78]

Figure 4 Companies (planning) investing in the European EV Li-ion Battery value chain

Table 9 **Key battery projects financed by the European Investment Bank**

Date	Grantee	Amount	Project description
November 2017	Northvolt AB	€52.5 million	Construction and operation of a facility producing battery cells in Sweden
June 2020	Umicore	€125 million	Construction of facility producing cathodes in Poland
March 2020	LG Chem	€480 million	Construction of facility producing cells and batteries in Poland
July 2020	Northvolt	€350 million	Construction of a battery gigafactory in Sweden

Source: SOMO based on data from the European Investment Bank.[79]

EU budget is also being used to fund research and innovation battery projects. For example, the EU Research and Innovation programme Horizon 2020 granted €1.34 billion to projects related to energy storage and for low-carbon mobility from 2014 to 2020. In 2019, Horizon 2020 launched a further call of €114 million to fund research and innovation battery projects, which was followed by an additional call in 2020 of €132 millions.[80]

Finally, state aid is also being used to support battery-related projects in Europe. In a recent example, the EC approved €3.2 billion of state aid in seven countries to support battery projects along the entire battery value chain based on the Important Projects of Common European Interest (IPCEI) framework. Large corporations will be the recipients of such state aid, including BASF, Umicore, BMW, Varta and Enel, among others.[81] In another example, in 2020 SAFT (owned by Total) and PSA requested €1.3 billion in public funding from France, Germany and the European Union.[82]

As mentioned in Section 2.1, when it comes to supporting the battery value chain (for instance through the European Battery Alliance, EIB loans, allocation of EU budget for R&D and State-aid), the EC (and some members such as France and Germany) are shifting from an industrial policy based on open market and direct competition to a policy allowing for much greater intervention of government in supporting business investments. As state aid involves taxpayers' money, it is important that the general public is not only aware but also supportive of the allocation of these funds. In order to make an informed decision, the general public requires transparency and enough information about the incumbent projects and their implications for human rights and the environment across the entire value chain.

2.3 Strengthening of corporate alliances in the battery value chain

Increasingly, the players along the Li-ion battery value chain are forming alliances and business partnerships to guarantee long-term supply and to collaborate on research, production and sales of batteries and EVs. Car and battery manufacturers are signing long-term contracts among them and with mining companies. The following are a few key examples:

The Renault Nissan Mitsubishi alliance, dating back to 1999, collaborates in many areas including electrification and mobility services. While this alliance doesn't include battery manufacturers, they have invested jointly in emerging companies developing battery technologies.[83]

In 2018, **Geely formed a joint venture with CATL** (CATL Geely Power Battery) for 'research and development, production, and sales of batteries, battery modules, and battery packs'.[84] The following year Geely partnered with LG Chem to produce and sell batteries in China.[85]

In June 2019, **Volkswagen partnered with Northvolt** in a 50/50 joint venture in order to build a lithium battery factory in Germany with planned production for the end of 2023. In return for its investment, VW acquired 20 per cent of the shares of Northvolt and secured a spot in the Supervisory Board, evidencing the tightening of power relations among the battery value chain players.[86]

In July 2019, **Toyota and CATL** announced a 'comprehensive partnership' to collaborate beyond the supply of lithium batteries and into development of new battery technologies in addition to reuse and recycling.[87] In February 2020, Toyota and Panasonic announced a joint venture (Prime Planet Energy & Solutions, Inc.) to further develop and sell prismatic batteries for cars (not only for Toyota).[88] A month later, Toyota and BYD formed a joint venture (BYD Toyota EV Technology) to focus on research and development of EVs.[89]

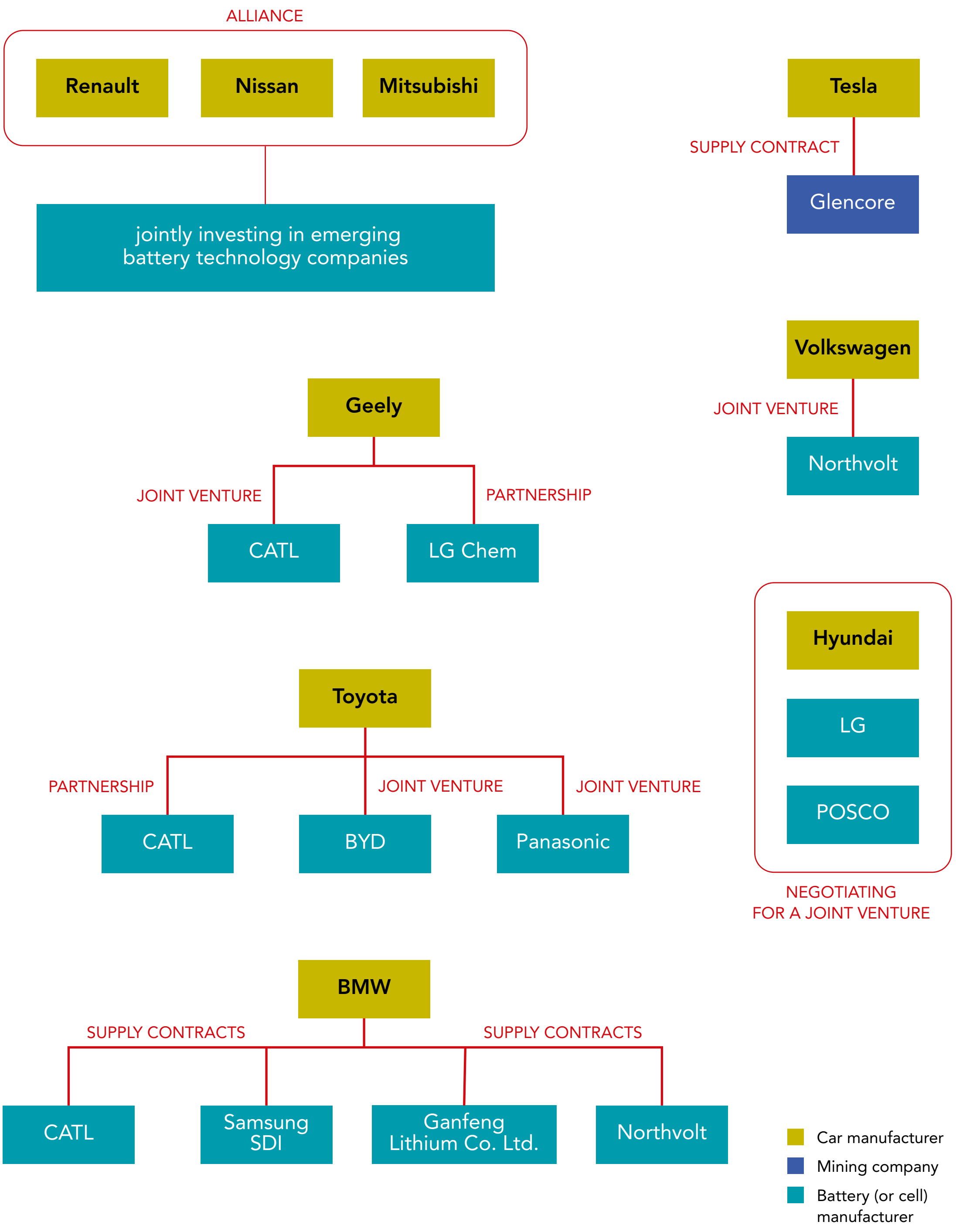
In November 2019, **BMW signed long-term supply contracts with both CATL and Samsung SDI.** BMW also announced that it will source cobalt and lithium directly from mining companies in Australia and Morocco and provide it to CATL and Samsung SDI.[90] Connected with this, BMW signed a long-term supply agreement with Ganfeng Lithium Co., Ltd. for the supply of lithium from Australia.[91] Finally, in June 2020, BMW and Northvolt signed a €2 billion long-term supply contract.[92]

In June 2020, **Tesla signed a deal with Glencore** to source cobalt for its batteries.[93] According to recent media reports, **Hyundai, LG and chemical producer POSCO** are negotiating an EV manufacturing joint venture.[94]

In early 2020, recycling company **Fortum**, **chemical producer BASF**, and the mining and refining company **Nornickel** have signed in a letter of intent to collaborate in developing a recycling facilities in Finland.[95]

Such partnerships signal that downstream companies (such as Lithium-ion battery and EV manufacturers) could set up human rights and environmental standards for suppliers in binding contractual agreements or even make their sourcing conditional on complying with such standards.

Figure 5 Corporate alliances in the battery value chain



3 Soaring mineral demand increases social and environmental impacts

3.1 Mineral demand predictions

There are many different predictions calculating mineral demand resulting from mass production of EV batteries. Below and in Table 11 we include predictions by the International Energy Agency, the Battery Alliance and Benchmark Mineral Intelligence that focus on forecasted mineral demand driven exclusively by batteries (and not by other technologies such as solar and wind) and within the next 10 years (which is important due to rapid technology developments).[v]

The International Energy Agency (IEA) has analysed two scenarios of predicted mineral demand for EV batteries. The IEA's *Stated Policies Scenario* is based on existing and announced policies and regulations and the IEA's *Stated Policies Scenario* is based on campaign goals whereby EV sales reach 30 per cent by 2030.[96]

According to the IEA's *Stated Policies Scenario*, demand for minerals for EVs batteries will grow as follows (2018 vs 2030): 19,000 tonnes to 180,000 tonnes for cobalt; 17,000 tonnes to 185,000 tonnes for lithium; 22,000 tonnes to 177,000 tonnes for manganese and 65,000 tonnes to 925,000 tonnes for class 1 nickel.[97]

The Global Battery Alliance also analyses two scenarios of mineral demand for EV batteries: a *base case*, based on 'unguided value chain growth', and a *target case* which aims to scale up battery production even more.[vi] Under the *base case,* from 2018 to 2030 demand for cobalt grows 2.1-fold reaching 274,000 tonnes; demand for lithium grows 6.4-fold reaching 275,972 tonnes;[vii] demand for nickel Class 1 demand grows 24-fold reaching 1,061,000 tonnes and demand for manganese grows 1.2-fold reaching 22,600 tonnes.[98]

Under the Global Battery Alliance *target case,* the demand for minerals grows 5 to 40 times more than in the base case. For the Battery Alliance, the target case represents an 'opportunity' whereby 'the mining industry needs to extract a volume equivalent to >300 Great Pyramids of Giza per year in 2030' and 'a weight equivalent to >110K Boeing 787s (Dreamliners) is refined per year'.[99]

According to Benchmark Minerals Intelligence, demand for minerals for the production of Li-ion batteries (for all applications and assuming operations at full capacity) will reach the following

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[v] The World Bank takes a different approach and calculates mineral demand for a cluster of low-carbon technologies (solar panels, wind turbines and batteries) for 2050. However, when it comes to lithium and graphite, battery storage accounts for the entire demand in the World Bank's report. The World Bank further notes that these projections may be conservative. Kirsten Hund et al., 'Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition,' The World Bank, 2020, 112.

[vi] By a factor of 19 as compared to the base case.

[vii] 1,469,000 tonnes of lithium carbonate equivalent (LCE) equals 275,972 tonnes of lithium metal equivalent. Conversion formula: 1 kg lithium metal equivalent (LME) = 5.323 kg lithium carbonate equivalent (LCE).

quantities by 2029: 466,000 tonnes of cobalt; 484,313 tonnes of lithium[viii]; 1,849,000 tonnes of nickel and 3,591,000 tonnes of graphite.[100]

Table 10 shows a summary of the mineral demand predictions discussed above as well as the latest available production data.

Table 10 Mineral demand predictions and recent production (in tonnes)

Mineral	**Production** 2018	**IEA Stated Policies Scenario** EV batteries demand in 2030	**Global Battery Alliance** Demand for batteries in transport, energy storage and consumer electronics in 2030	**Benchmark Minerals** Demand for Li-ion batteries for all applications in 2029
Lithium	95,000	185,000	275,972	484,313
Cobalt	148,000	180,000	274,000	466,000
Manganese	18,900	177,000	22,600	379,000
Nickel	2,400,000 (all nickel)	925,000 (class I)	1,061,000 (class 1 nickel)	1,849,000
Graphite	1,120,000	–	–	3,591,000

Source: SOMO, compiled from various sources.[101]

While the above predictions differ, they all show that the mass production of EV batteries would result in a staggering rise in demand for lithium, cobalt, manganese, nickel and graphite far exceeding current production levels. This also confirms analysts' views that, over the next decade, mineral production shortages are likely to arise meaning there is not enough mineral production to satisfy forecast demand of the Li-ion battery value chain.[102] Furthermore, the price of these minerals will have a significant impact on the production costs of Li-ion cells and thus on businesses and policy ambitions pushing for mass uptake of EVs. This is particularly the case considering that the production costs of Li-ion battery cells have dropped significantly in the last decades, reaching a point whereby the price of the raw materials constitute a significant portion of its production costs.[103]

It is also important to mention that other minerals are also required to produce Li-ion batteries, such as aluminium and copper. BloombergNEF estimates that Li-ion battery demand in 2030 will result in a 10-fold increase in demand for copper and a 14-fold increase for aluminium as compared to 2019.[104]

The manufacturing of the rest of the EV, as well as the networks of charging infrastructure, will also require vast amounts of minerals. While such minerals are out of the scope of this report, copper offers an interesting example. While an internal combustion engine vehicle contains an average of 23 kg of copper, a plug-in hybrid electric vehicle contains 60 kg, a battery electric vehicle contains 83 kg, and an electric bus contains up to 369 kgs. A fast battery charger can contain up to 8 kg of copper. The Copper Alliance estimated that the EV market will increase copper demand from 185,000 tonnnes in 2017 to almost 1.74 million tonnes in 2027. [105]

[viii] 2,578,000 tonnes of lithium carbonate equivalent (LCE) equals 484,313 tonnes of lithium metal.

These predictions exclude the amount of water and energy that is required for this tremendous amount of mining or the waste and emissions that will be generated. In the next section we will focus on the social and environmental impacts that are associated with mining of key battery minerals.

3.2 Social and environmental impacts

As discussed in the previous section, the surge of battery production leads to a substantial increase in demand for minerals. Predictions vary but they all anticipate a soaring rise in demand, which would inevitably require more mining.

It is widely documented, that mining goes hand in hand with severe and widespread social and environmental impacts.[106]

For example, the Business and Human Rights Resource Centre's Minerals tracker reports 167 allegations against 37 companies mining lithium, cobalt, copper, manganese and nickel for the transition to low-carbon technologies.[ix] The main number of allegations refer to (in descending order): environmental impacts, access to water, health impacts, indigenous peoples' rights, tax avoidance, labour rights, deaths, free, prior and informed consent (FPIC), land rights and corruption.[107]

Photo: Calma cine

[ix] Of those allegations, 12 are related to lithium, 50 to cobalt, 26 to nickel and six to manganese

In addition, the Environmental Justice Atlas documents hundreds of conflicts related to environmental issues of extractive projects, including cases related to lithium (14), cobalt (22), manganese (29) and nickel (54), among other minerals.[108]

The mining sector is also linked to the highest number of attacks to human rights defenders. In 2019, 25 per cent of the attacks on human rights defenders documented by the Business & Human Rights Resource Centre were related to mining.[109] From 2002 to 2019, Global Witness documented 1,939 killings of land and environmental defenders. Of the total number of killings, 367 were related to mining projects, making this sector the deadliest.[110] According to Global Witness, the root cause of such killings is often 'the imposition of damaging projects on communities without their free, prior and informed consent' and such violence is being fuelled by development banks and other investors that are 'financing abusive projects and sectors, and failing to support threatened activists.'[111]

Such extensive documentation of human rights abuses and environmental impacts related to mining raises serious concerns signalling that a mineral boom due to the mass uptake of EVs will drive an increase of such violations. Furthermore, such impacts are often being overlooked or ignored by proponents of the mass uptake of EVs. A recent systematic review of 88 peer-reviewed journal articles analysing the future demand of critical minerals found that 'little attention has been given to the social and environmental consequences that would almost certainly accompany a growth in metal demand. Most of the studies focus solely on predicting long-term demand, resulting in a lack of knowledge regarding the question, 'What are the socio-environmental implications of demand growth?' This leads to a neglect of the various risk factors that are likely to be worsened in parallel with rising metal demand.'[112]

Below we present a non-exhaustive overview of social and environmental impacts related to the key minerals needed to produce Li-ion batteries. This section relies on previous research by SOMO and other civil society organisations and experts.

Lithium

Li-ion batteries are the key driver for lithium demand, accounting for an estimated 65 per cent of the global end-use market.[113] Currently lithium is being extracted either from hard-rock minerals or from salt brines. Salt brine mining has lower costs but takes a longer time to process (8 to 18 months) compared to hard-rock mining (less than a month).[114]

Salt brine deposits are bodies of saline groundwater rich in dissolved lithium and other minerals. Brine is pumped out to the surface and then evaporated in a series of ponds resulting in lithium carbonate. Only highly concentrated brines are economically viable for mining, such as the ones in Chile and Argentina, which are the world's major producers of lithium from salt brines.

Spodumene is a mineral that contains lithium and is formed as crystals hosted by igneous rocks (pegmatites). The hard-rock ore containing lithium is extracted from underground or open-pit mines through conventional mining operations and then crushed and separated to produce a lithium concentrate. Such lithium concentrate is then converted into lithium-based chemicals through a process that involves acid leaching. Australia is the world's major producer of lithium concentrates from spodumene.

Since 2017, hard-rock production exceeded brine production as Australia tripled its production. Australia became the world's biggest producer, displacing Chile and Argentina to second and third place respectively.[115]

Chemical processing companies convert lithium carbonate, either from salt brines or from spodumene, into lithium hydroxide, which is used to produce cathodes for batteries.[x] Lithium production is highly concentrated by a few companies, the biggest of which (by market capitalisation) are Jianxi Ganfeng Lithium, Tianqi Lithium, Allbemarle, SQM and Livent.[116]

In 2018, most of world's lithium production came from six hard-rock mines in Australia; four brine operations in the lithium triangle (two in Argentina and two in Chile) and one hard rock and one mineral mine in China (see Table 2).[117]

Impacts

Lithium extraction in South America has been linked to negative impacts on water, indigenous rights and local communities' traditional livelihoods. While salt brines are located in water-scarce areas, lithium mining requires vast amounts of water being pumped out. Impacts to the water balance of the basin and salinisation of freshwater are major concerns.

In Argentina, research by **Fundación Ambiente y Recursos Naturales** (FARN) showed that communities were poorly informed about the potential impacts and haven't been meaningfully engaged during consultations. Furthermore, according to the study, the State has been absent during company-led consultations and has failed to provide sufficient information to local communities. Often the only information available is that produced by the mining companies, which have a vested interest in obtaining the social licence to operate. There is also a lack of understanding of cumulative impacts, a serious concern considering the large number of projects under development.[118]

In Chile, lithium mining operations have affected the rights and livelihoods of indigenous communities (including the Lickanantay people) with violations to self-determination, FPIC, land and water rights. The high intensity of water use has affected the water basins and the availability of the resource for human consumption.

According to a recent report, for the production of lithium in Chile, Albemarle extracts brine at a rate of 442 liters per second and freshwater at 23 liters per second. While SQM extracts brine at 1700 litres per second and freshwater at 450 litres per second. Those two lithium mining companies together with 2 copper mining companies (Minera Escondida owned by BHP Billiton and Compañía Minera Zaldívar) extract together 4,230 litres of fresh water per second, resulting in a hydrological stress for the Atacama salt flats. The report also highlights that, in 2016, Chilean authorities warned that 70 per cent of the country's water was used for mining operations and 17 per cent for the agricultural sector, leaving only 13 per cent for human consumption.[119]

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[x] Both lithium carbonate and lithium hydroxide are used for batteries.

In the spotlight: Olaroz – Cauchari, Argentina (Research conducted by FARN)
Lithium: Argentina – Right to Water, Community rights violations

Context: 21 per cent of the world's lithium resources are located in Argentina, which accounted for 7 per cent of global production in 2018.[120] In Argentina there are more than 40 projects in different phases. Government officials have welcomed the lithium boom with little attention to the social and environmental impacts.

In 2019, FARN published a study on two of the most advanced lithium projects in Argentina located in Olaroz-Caucharí salt flat (4,300 metres above sea level) – a fragile ecosystem, home to 10 indigenous Atacama communities since ancestral times. It is a place with a lack of fresh water resources to meet local demand. The study found serious concerns of local communities with regard to lithium mining in connection with FPIC rights, water and environmental risks, and power asymmetries.

FPIC and meaningful engagement: The study found that community members did not know the mining project details or their implications, and that communications from the company tend to be one-sided and difficult to understand. The good faith of companies is questioned by respondents as company representatives only present positive impacts and deny any risks to water or the environment. Information about risk factors and environmental impacts is not disclosed. Information has not been presented in a suitable timeframe and in a way that is understandable to the local communities. In contrast, it tends to be lengthy and technical.

According to the interviews conducted in the study:

- 83 per cent expressed that the information provided by the companies was too technical or too lengthy.
- 85 per cent were not consulted about how they wanted to receive information.
- 30 per cent did not received information from the mining companies.

Water and environmental concerns: Communities are highly concerned about the impact of mining on water resources and the lack of feasible risk studies. Some community members have reported lower water levels. Experts agree that there are crucial information gaps to properly assess the impacts of lithium mining in the area. Experts warn of the potential salinisation of fresh water of the aquifers. There is a total lack of cumulative impact assessments analysing the different mining operations, a serious concern considering that water basins may have subterranean links. The study found a serious lack of available hydrological studies for authorities to assess the environmental impacts of lithium mining in Argentina.

FARN cites a member of the National Ombudsman's Office who stated that 'neither provincial nor national authorities have conducted hydrological studies, or carried out superficial or underground water monitoring. In addition, they have not identified areas in which salt and fresh water co-exist, nor have they calculated the hydrological balance of the watersheds in the area. The only information available is that provided by companies and there is no baseline that can be used as a reference to identify eventual modifications in the environment.'[121]

Power asymmetries: While it is a State responsibility to implement the FPIC process and protect communities' participation rights, both the provincial and the national authorities have been absent during the whole engagement process. This has generated power asymmetries whereby the companies can negotiate directly with communities using their economic power and their privately generated information.

Source: FARN, 2019, 'Lithium extraction in Argentina: a case study on the social and environmental impacts.'[122]

Cobalt

Cobalt is used to manufacture many different products. However, more than 60 per cent of cobalt is used for producing lithium batteries.[123] Even though some manufacturers are exploring battery chemistries with less cobalt content, demand is still predicted to rise sharply in the upcoming years. See the projections in Chapter 3.1.

Approximately 70 per cent of the global cobalt production is now mined in DRC, where half of the world's resources are located. The largest cobalt producers in terms of both market capitalisation and production volume are: Glencore, China Molybdenum, Vale and Gecamines.[124]

Impacts

Both large-scale mining and artisanal mining of cobalt in DRC has been extensively linked to widespread, grave and systematic human rights violations and environmental impacts. Large-scale mining leads to recurrent violations including pollution, exposure of workers and communities to toxics, sub-standard health and safety conditions, contributing to community conflicts and abuses by security personnel. Artisanal mining in turn, which accounts for 20 to 30 per cent of production, often involves working under dangerous and unhealthy conditions, child labour and unfair compensation.[125]

Miners and local communities face exposure to toxic metals and pollution derived from cobalt mining. Research has documented the pollution of rivers due to mine discharges as well as community exposure to noise, water and air pollution.[126] In a forthcoming report of African Resources Watch (Afrewatch) and PremiCongo, information is provided on soil and water contamination caused by cobalt mining, on the basis of analyses of water and soil samples.[127] Exposure to dust containing cobalt particles is a cause of a severe lung disease (hard metal lung disease). Although cobalt is a normal part of a person's intake (vitamin B12) and occurs naturally in the environment, too much intake may affect the heart and the thyroid, cause asthma and skin issues. A recent medical study published in the *Lancet* has linked birth defects to toxic pollution in Southern Katanga.[128]

Child labour in cobalt mining has been extensively documented. When mining is carried out by children, it is considered one of the worst forms of child labour. Amnesty International and Afrewatch documented children as young as seven working up to 12 hours, with no protective equipment at all and carrying heavy loads in a research report in 2016.[129] Children are further exploited financially and physically abused, including beatings and other forms of violence. A recent class action by International Rights Advocates claims that children mining cobalt have died and been maimed while multinationals (Apple, Google, Dell, Microsoft and Tesla) have allegedly aided, abetted and benefitted from the situation.[130]

Eviction of communities and loss of livelihoods have been documented as a consequence of the vast amounts of land and water used by mining operations. In some cases, communities are resettled to areas without arable land or without water.[131]

Communities and artisanal miners report cases of excessive use of force by the DRC army and by public and private security guards. For example, in June 2019 armed groups evicted artisanal miners from the Tenke Fungurume Mine, property of China Molybdenum Company Limited (CMOC). Amnesty's press release on the issue state that 'According to African Resources Watch (Afrewatch) and media reports, local residents said that soldiers destroyed housing and shelters in two villages, which could amount to forced evictions contrary to international law. Afrewatch also reported that soldiers had fired shots to disperse artisanal miners, and said it had received reports of casualties.' [132]

Poor health and safety conditions is a serious issue in cobalt mining and includes a lack of basic protective equipment (facemasks, gloves, clothes), poor ventilation at mines and dangerous structures that lead to health incidents and accidents. Local media has reported many fatal accidents at unregulated artisanal mines resulting from poor construction or dangerous mining practices.[133] For instance, in June 2019 in Kolwezi at least 47 miners were killed due to the collapse of a tunnel at a mine operated by Glencore.[134] Furthermore, with no real bargaining power and a lack of sufficient information, miners receive unfair compensation for their work and are not able to negotiate for proper pay with traders.

As the government and large-scale operators have failed to create enough safe and regulated Artisanal Mining Zones, some artisanal miners are compelled to trespass on industrial sites or work on unsafe and unregulated areas with no safety measures.[135]

More than two thirds of the population in DRC earns less than US$1.90 a day, making it one of the poorest countries in the world – in stark contrast with the multinationals producing batteries, electronics and automobiles.[136] In 2017, Amnesty International concluded that such companies have failed to take adequate steps to mitigate human rights abuses and remediate harm in their cobalt supply chain.[137]

Nickel

Nickel is a key metal for two of the most popular EV battery chemistries: NCA and NMC. Nickel is likely to become even more important in the future as chemistries move away from cobalt.

Nickel 'is a naturally occurring, lustrous, silvery-white metallic element. It is the fifth most common element on earth and occurs extensively in the earth's crust, although most nickel is inaccessible in the core of the earth. Nickel does not occur in nature by itself but it is associated with cobalt or as an alloy with copper, zinc, iron or arsenic. It occurs in nature principally as oxides (laterites), sulphides and silicates.'[138] Nickel is predominantly mined in Indonesia (25 per cent), Philippines (14 per cent), Russia (14 per cent), New Caledonia (9 per cent), Canada (7 per cent), (see Table 2).[139]

The top nickel producers in 2019 were Tsingshan Group, Norilsk Nickel (Nornickel), Vale, Glencore, Delong and Jinchuan.[140]

Impacts

Nickel mining is having enormous social and environmental impacts. The impacts of open-pit nickel mining include: water pollution, damage to forests, land erosion (which further increases the risk of floods) and biodiversity loss.

Nickel mining is also affecting the health of workers and communities around the world. According to Greenpeace Research Laboratories, 'the mining of nickel-rich ores themselves, combined with their crushing and transportation by conveyor belt, truck or train, can generate high loadings of dust in the air, dust that itself contains high concentrations of potentially toxic metals, including nickel itself, copper, cobalt and chromium.'[141]

Nickel 'at high concentrations poses a respiratory health hazard likely to cause cancer and is also known to cause asthma, lung diseases, dermatitis and sensitivity in some people.'[142] Nickel sub-sulphide and oxidic nickel are the particular compounds related to respiratory cancer.

Indonesia has become the global leader in nickel production, including high grade nickel for EV batteries. The boom of nickel mining in Indonesia is exacerbating conflict and violence. The root of such conflict is related, in many cases, to concerns from local fisherfolk and farmers about environmental impacts affecting their life, health and livelihoods.[143]

A recent ban on exports of raw ores by the Indonesian government has resulted in a further concentration of economic power on a few mining companies with enough capital to either own or invest in local smelters as well as in an increase in foreign direct investment (mainly Chinese).[144] The Indonesia Morowali Industrial Park (IMIP) in Sulawesi has become the central hub of nickel processing and smelting. However, nickel is also mined in other locations and provinces. The IMIP project is owned by a Chinese-Indonesia joint venture between Shangai Decent Investment Group Co, Ltd. (part of the Tsingshan Group) and Indonesia PT Bintangdelapan Group and received financing from the China Development Bank and the Export Import Bank.[145] A recent report reviewing working conditions at the IMIP industrial complex identified serious labour issues including a lack of collective labour agreements, coerced resignations, insufficient wages to satisfy basic needs and serious health and safety concerns and accidents that have resulted in deaths, fatigue and anxiety.[146]

In Wawonii, Sulawesi farmers and fisherfolk are protesting due to the impacts of nickel mining on the forest and the sea affecting their daily subsistence and traditional livelihoods. In Obi, Makalu fisherfolk and farmers claim that the coastal waters have been polluted by nickel mining.[147]

It is also important to note that production of Nickel is energy intensive, generates high greenhouse gas emissions and produces large amounts of toxic waste.[148] The smelting of nickel in Indonesia, powered by coal plants, causes air pollution, which increase the risks of respiratory infections and pulmonary tuberculosis, among other diseases.[149]

Recently, mining companies in Indonesia asked for permission to dump their waste into the sea, in one of the most biodiverse areas of the world.[150] Such practices of dumping nickel mining waste into the sea is done in neighbouring Papua New Guinea. In 2019, a spill by Metallurgical Corporation of China turned a bay red, affecting marine life.[151]

The devastating impacts of nickel pollution can be seen in other countries as well. Norilsk, in northern Siberia, has been rated as one of the world's most polluted cities.[152] Norilsk's locals have been exposed to air pollution containing heavy metals, sulphur dioxide and other particles due to nickel and copper mining. This exposure has caused respiratory diseases as well as lung and digestive system cancers. The soil too has been heavily polluted with copper and nickel.

The company Norilsk Mining has been heavily criticised for damaging the Artic by its mining, oil and gas operations. In May 2020, the company was responsible for a major environmental disaster whereby 21,000 tonnes of diesel spilled into a river in Siberia, threatening the Artic environment.[153] Despite Norilsk Nickel's operations in the Arctic and causing a serious environmental disaster, major investors such as ING and ABP have continued investing in the company. As a result, they have been subjected to a campaign by Fair Finance Guide Netherlands 'calling for an end to all investments in companies that exploit raw materials in the Arctic, especially mining, oil and gas companies, and for Norilsk Nickel to repair all the environmental damage caused by the oil spill'.[154]

In the Philippines, in the province of Zambales, nickel mining operations have resulted in water pollution. Nickel laterite – a nickel oxide – has contaminated water sources and spilled up to 30-nautical miles offshore. Land, river channels and coastal waters have been polluted by nickel laterite, affecting rice paddies, rivers and fishponds.[155] The commune has been losing millions of dollars in income due to the impact of nickel mining on agriculture (i.e. mango and rice) and fishing. Large areas of land have become infertile.

In another region, on the island of Palawan, acid drainage has polluted soil and water, resulting in biodiversity loss, including a reduction of fish consumed by the communities. Nickel mining there has also affected the health of workers and communities and led to displacement of communities.[156]

Graphite

Graphite is used for producing the negative electrodes in Li-ion batteries. According to analysts, lithium batteries account for around 25 per cent of global demand for natural flake graphite.[157] Significant quantities of graphite are required in EV batteries, much more than any of the other minerals. According to several sources, an EV lithium battery uses between 1 and 1.2 kg of graphite per GWH.[158] Both natural and artificial graphite can be used to produce batteries. However, manufacturers natural graphite has been preferred by manufacturers due to lower costs.[159]

Natural graphite production is dominated by China, with more than 60 per cent, followed by Mozambique with 9 per cent and Brazil with 8 per cent (see also Table 2).[160] In the past, the low cost of Chinese graphite has discouraged mining elsewhere. However, with demand soaring, new graphite mining projects are being developed in countries including Mozambique, Madagascar and Namibia.

In Cabo Delgado province in Mozambique, which hosts high-grade deposits, Australian mining companies Triton Minerals, Mustang Resources, Battery Minerals and Syrah Resources all have investment plans or ongoing projects.[161] As an example, Triton Minerals has formed a strategic partnership with the Chinese state-owned enterprise Jinan Hi-Tech group to begin construction of the Ancuabe Graphite Project in 2020.[162]

Impacts
There is little information available on the impact of graphite mining in different parts of the world. In 2016, the *Washington Post* visited mining sites at five towns in China. Graphite mining in China has led to severe pollution affecting air, water and the crops of local communities. Polluted air affects workers and communities who are suffering an increase in respiratory problems and their water has become undrinkable.[163] Exposure to graphite dust can cause serious diseases such as lung fibrosis, occupational pneumoconiosis and heart failure.[164]

Manganese

The primary use of manganese is in steel production (which accounts for about 90 per cent of annual manganese demand), aluminium production and copper production.[165]

In the field of rechargeable Li-ion batteries, the use of manganese is increasing due to its high-energy capacity, low costs and increasing stability. In rechargeable lithium batteries. manganese can be used either as an oxide or as a sulphate, depending on the battery's chemistry.

For batteries, manganese is increasingly used in the form of manganese sulphate monohydrate (MSM). High purity MSM (HPMSM) can be made from manganese ore or from high-purity electrolytic manganese metal (EMM).

As NMC batteries dominate the market of EVs, demand for high-purity manganese metal and high-purity manganese sulphate is expected to increase substantially.[166]

Most of the world's manganese is produced by just a few countries: South Africa (31 per cent), Australia (18 per cent), Gabon (12 per cent) (see also Table 2)[167]

Impacts

Manganese is the 12th most abundant element on earth and occurs naturally in rocks, soil, water and foods. Exposure to manganese, an essential nutrient in small doses, occurs via water, air, soil and food.

Mining activities and production of steel are the main sources of anthropogenic manganese pollution. Mining and processing manganese ores pose occupational risks, such as chronic manganese poisoning.[168] 'The high toxicity of manganese has been well documented from numerous studies performed on workers in the mining, welding, and ferroalloy industries, and in other occupational settings with a high level of manganese exposure'.[169]

The most common occupational illnesses due to manganese exposure 'involve the nervous system. These health effects include behavioral changes and other nervous system effects, which include movements that may become slow and clumsy. This combination of symptoms when sufficiently severe is referred to as "manganism".'[170]

Other health impacts resulting from chronic manganese exposure include impaired motor skills (such as slowed hand movements), deficient cognitive performance, lung irritation (leading to pneumonia in some cases) and loss of sex drive.[171]

Studies focused on children living in areas with high manganese exposure have found impacts on brain development, behavioural change and cognitive deficits.[172] A study conducted in Ukraine found significantly higher levels of impaired growth and skeletal deformities in children living in manganese mining regions.[173]

In South Africa, mining-affected communities have associated manganese mining with air pollution, environmental damage and health issues. Furthermore, women in South Africa reported experiencing gender-based violence in connection with the development of mines as well as not benefiting from the projects.[174] One of the main concerns of the Maremane community in South Africa was the dust resulting from mining operations, which in turn results in health impacts. Other claims by the local communities included the lack of consultation, environmental damage, access to safe water, pollution of water, noise and health issues.[175]

Manganese toxicity can also significantly affect the growth of crops on certain types of soils.
It is clear from the above examples that mining for all of the key minerals required for batteries has been previously associated with serious and widespread social and environmental impacts.
A mobility transition based on increased mining raises serious concerns regarding the risk of increasing and exacerbating such impacts.

4 Strategies to address the social and environmental impacts of EVs and the battery value chain

In the previous chapters, it has become clear that – when it comes to passenger road transport – the main proposed solution addressing the climate emergency focuses on mass adoption of EVs powered by batteries. This solution is particularly supported by industry along the battery value chain as well as by governments from the global north. Initiatives such as the Global Battery Alliance are pushing to further scale up the production and consumption of EVs. Governments in the EU, the US and China are incentivising the mass adoption of EVs, often backed with public money in the form of subsidies, tax incentives and public loans. These initiatives portray EVs as a per se green technology that will contribute to saving us from environmental collapse.

However, and as discussed in Chapter 2, the mass uptake of EVs as currently forecast by the International Energy Agency (IEA), the Battery Alliance and expert analysts will result in an unprecedented and dramatic increase in raw material extraction. This raises serious concerns, particularly for mining-affected communities and the rural areas where mining often takes place. Concerns are based on copious evidence, such as that discussed in Chapter 3, documenting that mining is one of the deadliest and most polluting industries in the world and is often associated with severe and widespread social and environmental impacts.

Besides requiring soaring amounts of minerals, the Li-ion battery value chain (from mining to manufacturing to recycling) also requires vast amounts of water and energy and generates carbon emissions and waste. Existing life-cycle impact analysis of Li-ion battery production have a myopic focus on CO_2 emissions, neglecting impacts on other important factors such as water, land and biodiversity. A recent study by the International Resource Panel found that '90 per cent of biodiversity loss and water stress are caused by resource extraction and processing'.[176]

Furthermore, despite electrification, the total number of vehicles on the road is predicted to continue growing. BloombergNEF predicts that the total vehicle fleet will grow from 1.2 billion units in 2020 to 1.4 billion in 2030 and reach 1.6 billion in 2040. From the predicted fleet of 1.6 billion units in 2040, still around 1.1 billion units are internal combustion (ICE) passenger vehicles, which is the same number of ICE units as in 2015.[177] That would mean that, after more than 25 years, the total amount of polluting ICE cars will not be reduced.

Mass adoption of EVs is, however, not the only solution when it comes to addressing the climate emergency resulting from passenger road transport. A growing body of scientific evidence shows that mitigating environmental impacts and reaching sustainability goals cannot be achieved without reducing the total amount of raw materials and energy (throughput) that go into production and consumption.[178]

In this chapter we focus on identifying other existing strategies to address the social and environmental impacts of passenger road transport besides the mass uptake of EVs. The identification of alternative strategies and perspectives is not exhaustive but rather exploratory with the aim of informing public debate about the existence of different views and interests that needs to be considered in policy and political discussions.

The strategies discussed pertain to reduction of private passenger cars, material efficiency (including design, recycling and product lifetime extension) and environmental justice.

4.1 Reducing mineral and energy demand by having fewer cars on the road

The production of Li-ion batteries requires minerals, water and energy and generates greenhouse gas emissions. The more the material and energy throughput (driven by the amount and size of Li-ion batteries), the larger the generated waste and emissions. Hence the importance of reducing the amount (and size) of Li-ion batteries and cars on the road.

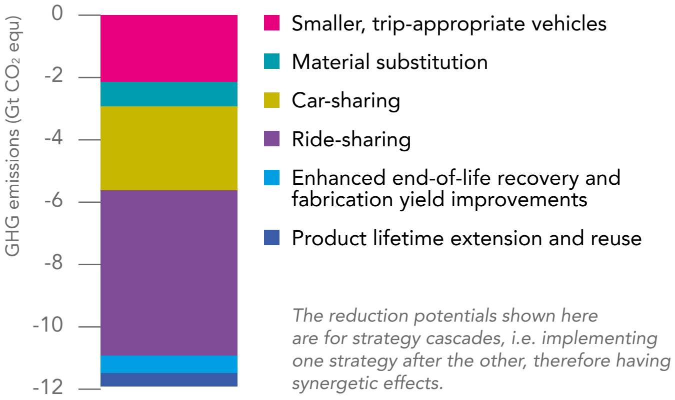
In 2018, IPCC scientists released the report *A Low Energy Demand Scenario for Meeting the 1.5°C Target and Sustainable Development Goals without Negative Emission Technologies*. The Low Energy Demand Scenario (LED scenario), besides looking at increasing the use of goods and material efficiency in general, specifically analyses the mobility sector, proposing a move from private ownership towards 'usership' and car sharing. According to the LED scenario analysis, 'Increasing vehicle occupancy by 25% and vehicle usage per day by 75% delivers the same intra-urban mobility with 50% of the vehicle fleet.'[179] This would allow the halving of the total number of light duty vehicles by 2050 to approximately 850 million. Furthermore, under the LED scenario, end-use energy demand is reduced by 40 per cent by 2050 through a series of measures including industry reducing its material outputs by 20 per cent.[xi]

Using fewer cars to provide the same service would require fewer batteries and thus reduce the minerals and energy demand and their related negative environmental impacts such as carbon emissions and mining-related pollution.

Furthermore, in a recent report, the International Resource Panel (IRP) concluded that ride-sharing, car-sharing and using smaller vehicles contribute the most to reducing life-cycle emissions of passenger cars, as can be seen in Figure 3.[180] Importantly, such strategies reduce both material and energy demand for passenger cars.

[xi] The scenario aptly differentiates between the global north, which would need to reduce the production of material goods by 42 per cent, and the south, by 12 per cent. A novelty of the LED scenario is that it shows that the ambitious 1.5°C target could be achieved by reducing the material throughput that goes into the economy without assuming future 'negative emissions technologies', which are controversial and speculative in terms of viability, scale and CO_2 storage capacity.

Figure 3 Material efficiency strategies to reduce GHG emissions



The reduction potentials shown here are for strategy cascades, i.e. implementing one strategy after the other, therefore having synergetic effects.

Source: IRP (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future.

Finally, degrowth theory that calls for a profound transformation of society and the economy puts emphasis on a planned scaling down of the energy and material throughput of the economy (production and consumption), especially of especially of high-income countries and consumers, with the goal of increasing well-being and enhancing ecological conditions.[181]

4.2 Material efficiency strategies (design, recycling and product lifetime extension)

In the above-mentioned report on resource efficiency and climate, the IRP assess the potential of material efficiency strategies to reduce the greenhouse gas emissions of passenger cars. As used by the IRP, material efficiency refers to using fewer materials to obtain the same level of well-being for society. Material efficiency is measured by the 'amount of service obtained per unit of material use'.[182]

The IRP analysed the following material efficiency strategies: using less material by design (designing smaller vehicles), material substitution, fabrication yield improvements and more intensive use of material (including ride-sharing and car-sharing), enhanced end-of life recovery and recycling and product lifetime extension.

Designing smaller vehicles and batteries results in a straightforward strategy to reduce minerals and energy consumption. In this vein, the IRP report concluded that, besides a shift from private ownership to ride- and car- share, the design of vehicles is a 'key point of leverage' because it ‘determines how much material they use, the energy used in their manufacturing and operations, their durability, and their ease of reuse and recycling’.[183]

The design of the Li-ion battery is very important for recycling. In particular the design of the cells and the battery pack can influence the ease of recycling as well as determining the most suitable recycling strategy. For example, if a battery module is difficult to disassemble and open then the cells can’t be easily accessed and the only option is to use a pyrometallurgy recycling process, which requires high energy and is expensive and not efficient in recovering all active materials.[184]

Therefore, it is important that Li-ion batteries’ design is adapted towards easy dismantling as ‘the design of current battery packs is not optimized for easy disassembly… Many of the challenges this presents to remanufacture, re-use and recycling could be addressed if considered early in the design process.’[185]

Manufacturers use different technical specifications to produce their batteries. The current wide array of cathode chemistries (i.e. NCA, LFO, NMC), forms of battery cells (i.e. cylindrical, prismatic, pouch), fixings and the ways cells are clustered in modules makes it very difficult to standardise recycling processes and improve recycling efficiency.[186]

Another constraint limiting recycling is the lack of proper labelling of the different chemistries of all battery components, including the anode, cathode and electrolyte. Without proper labelling recyclers are unable to determine the battery health, its components and the safety guidelines for disassembling and recycling.

From the above, it follows that the standardisation of cells, modules and packs would facilitate and increase recycling rates and efficiency. For example, the standardisation of lead-acid batteries has resulted in simple recycling and disassembling processes, which reduces cost and increases recycling rates and recovery.[187] Rules mandating manufacturers to take back end-of-life Li-ion batteries, through an extended producer responsibility scheme, could also incentivise them to standardise battery design.[188]

In addition, more attention is required for improving collection and recycling rates as well as the recovery rates of minerals. According to an IISD report ‘less than 5 per cent of Li-ion end-of-life batteries are recycled today’ while ‘approximately 99 per cent of lead-based car batteries are collected and recycled in North America and Europe, making them the most recycled of any major consumer product’.[189]

Recycling of minerals is a strategy with important potential to reduce primary demand for the production of batteries. A report prepared by the Institute for Sustainable Futures analysed the role of material efficiency, substitution and recycling in reducing primary demand for EVs and battery storage. The report concluded that ‘Recycling of metals from end-of-life batteries was found to have the greatest opportunity to reduce primary demand for battery metals, including cobalt, lithium, nickel and manganese.’[190]

It is important to notice, however, that while recycling can reduce primary demand of minerals, it will not be enough to satisfy predicted demand and there will be a delay in recycled minerals becoming available.

Finally, developing more efficient recycling processes is essential to reduce the impacts of recycling itself. According to life-cycle studies, 'the application of current recycling processes to the present generation of electric-vehicle LIBs may not in all cases result in reductions in greenhouse gas emissions compared to primary production.'[191] Another scientific peer-reviewed study found that the recycling of lithium from batteries with the current technology could result in up to 45 per cent more energy consumption and 16-20 per cent higher emissions than primary production.[192]

Also longer battery life results in less battery consumption and thus less energy and mineral demand. It is important that policy-makers introduce binding rules mandating extended producer responsibility for battery and car manufacturers. Such rules need to be clear in assigning financial and material responsibility to the producers, including for cases of repurposing of batteries for second use and that regulate for cases of future bankruptcy of producers. Legal requirements, establishing high collection rates for batteries as well as high recovery rates, are important to accelerate recycling. In the EU, the Battery Directive only requires the recycling of 50 per cent of the weight of a Li-ion battery without distinguishing which raw materials are recovered or the resulting implications of recycling on the environment.[193] An improvement to the EU Battery Directive could set up higher recycling rates and introduce material-specific targets.[194]

4.3 Environmental justice perspectives

There is a different vision around how to address the social and environmental impacts of passenger road transportation from organisations in both the south and north. Communities, activists, civil society, researchers and environmental organisations offer different views on the impacts that would result from mass uptake of EVs and present alternative solutions to address the climate emergency. Such visions are based on different conceptual frameworks such as environmental justice, the right to say no to mining, democratic decision-making and democratic-owned energy systems, human rights, buen vivir.[xii]

In the lithium triangle, the Plurinational Observatory of Andean Salt Flats brings together indigenous communities, environmental experts, academics and civil society organisations from Argentina, Chile and Bolivia with the goal of protecting the salt flats, and its ecosystems and local communities, from the lithium mining that is rocketing due to battery demand.[195] They are very critical about the EV 'green transition', which in their view is having profound negative impacts on local communities and peasants and is creating environmental 'sacrifice zones'. The Observatory calls for a public debate to discuss alternatives to tackling the climate crisis based on principles of environmental justice, democratic decision-making, buen vivir and human rights.[196] In the words of one of the Observatory's

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[wxii] There is no single definition for buen vivir. The term offers a platform for alternative visions of development having its roots in indigenous traditions in Latin America. Buen vivir focuses on achieving a good life in community, including nature. Eduardo Gudynas, 'Buen Vivir: Today's Tomorrow,' *Development* 54 (December 1, 2011), https://doi.org/10.1057/dev.2011.86.

founders, 'this vision would allow us to value communities and ecosystems, not as sources of mineral resources, but rather for the wealth of their communal knowledge and biodiversity, thinking of the regeneration of our relationship with water and nature as the starting point for a different transition.'[197]

The Eco Social Pact, which has been signed by more than 60 organisations from different Latin American countries and many individuals, is calling for a socio-ecological transition to an orderly phase out not only of oil and gas but also of mining and supports a shift to 'energy systems that are decentralized, de-commodified and democratic, as well as collective, safe and good quality transportation models'.[198]

In the US, the Climate Justice Alliance encompassing more than 70 rural and community based organisations from the climate movement, including a few international organisations, have developed a set of just transition principles to 'shift from an extractive economy to a regenerative economy'.[199] According to the Climate Justice Alliance, a just transition involves a 'set of principles, processes, and practices that build economic and political power to shift from an extractive economy to a regenerative economy. This means approaching production and consumption cycles holistically and waste-free. The transition itself must be just and equitable; redressing past harms and creating new relationships of power for the future through reparations.'[200] Their principles are based on environmental justice perspectives such as buen vivir, regenerative ecological economics, self-determination, equitable redistribution of resources and power, to name a few.

Also in Europe, where more mining is also being promoted as part of the continent's strategy on raw materials, environmentalist groups and affected communities are opposing and raising concerns.[201] The European Environmental Bureau (EEB), a network of European environmental organisations, has warned that the EC's raw material strategy is a 'double-edged sword' and calls for properly assessing its social and environmental impacts. The EEB argues that Europe's raw materials strategy should rather focus on 'reducing the use of limited resources and avoiding environmental disasters often linked to mining such as deadly pollution, water shortages and the displacement of people'.[202]

Recently, in reaction to the EC Critical Raw Materials strategy, more than 230 civil society organisations and academics expressed their deep concern to the EC raw materials strategy and called to 'make absolute EU Resource use reduction a priority', 'Respect EU communities' Right to Say No to mining projects' and 'End exploitation of third countries, particularly in the Global South, and effectively protect human rights' and 'Protection of "new frontiers"' (such as deep sea mining).[203]

The previous examples were discussed in order to show that different groups and movements are uniting across borders and calling for profound transformations to address the climate emergency – transformations that go beyond a mere change of vehicle technology. Such proposals call for a profound social and ecological transformation involving consumption, production, business models and people's relationship with natural resources. Such examples are by no means comprehensive but rather are mentioned to highlight the need for a more inclusive and profound debate on the available solutions to address the impacts of passenger road transportation, which includes the perspectives of those most affected by mining. Further research and debate is needed to assess the impacts, influence, potential and viability of such proposals.

5 Conclusions and recommendations

The aim of this paper was to discuss the social and environmental implications resulting from a mass uptake of EVs. Extensive documentation shows that the social and environmental impacts associated with the mining of key minerals (lithium, cobalt, nickel, graphite and manganese) for producing Li-ion batteries are severe and widespread. The mass uptake of EVs would result in more mining and would thus increase such impacts, which raises serious social and environmental concerns of transitioning from a dependency on oil to a dependency on minerals for mobility.

These impacts are already affecting regions and communities where mining is increasing. It is important to note that mining for such key minerals tends to be concentrated in a few countries and regions. For instance, DRC, Australia and China each produce more than 60 per cent of cobalt, lithium and graphite, respectively. A third of manganese is produced in South Africa while a quarter of nickel comes from Indonesia.

In reviewing the battery value chain, we found that Asian players dominate the manufacturing of both cell components and battery cells, whereby Chinese companies in particular are the undisputed leaders. Chinese companies produce more than 60 per cent of the cathodes, more than 80 per cent of the anodes and more than 70 per cent of battery cells. Furthermore, four of the five largest Li-ion battery factories are located in China. Looking into the future, more than 110 new battery mega factories are planned around the world, mostly in China but also a considerable number in Europe.

At the final stage of the value chain, recycling of batteries remains severely limited due to several factors such as costs, differences in battery types, Li-ion battery design, lack of stock of end-of-life EV Li-ion batteries and limited recycling infrastructure, among other reasons.

As EVs gain market penetration, a significant number of Li-ion batteries will reach end-of-life in the decades to come. An important concern is that battery manufacturers are currently not designing Li-ion batteries to optimise recycling. Current differences in the design of Li-ion battery's cells, modules and packs hinder recycling efficiency. Packs are not easy to disassemble, and cells are not easy to separate for recycling. Standardisation of cell design and chemistry would facilitate recycling and also enable a more efficient, ample and higher purity recovery of raw materials. Proper labelling of Li-ion battery components and improvements towards easy module disassembly and cell separation are also beneficial towards improving recycling.

Policy and regulations aiming to reduce the social and environmental impacts of mining, and fostering a circular economy, should put greater emphasis on mandating the standardisation and proper labelling of Li-ion batteries and their components. Regulations requiring manufacturers to take back end-of-life Li-ion batteries could incentivise manufacturers towards standardising and push them to design Li-ion batteries with recycling as a priority and thus relieve pressure for primary demand of minerals.

The review of the Li-ion battery value chain shows that the key players pushing for the mass adoption of EVs are primarily businesses, governments in the US, Europe and China, the ECs as well as partnerships with a strong corporate presence. The European Battery Alliance and the Global Battery Alliance are the two most important public-private partnerships at European and global level, respectively, striving towards an EV boom. For both alliances, the expected market value (and potential profits) of the Li-ion battery value chain is a key motivator of their efforts to scale up Li-ion battery production and the mass uptake of EVs. The GBA predictions of the Li-ion value chain economic value shows clearly that the expected economic benefits would be unequally distributed among the different segments of the value chain favouring upstream companies, predominantly favouring those businesses engaged with application use (i.e. EV manufacturers) and cell manufacturing.

Corporate players pushing for mass uptake of EVs, as well as the battery alliances, omit to explore other solutions to address the impacts of passenger road transport that reduce the total number of vehicles on the roads and thus require less minerals and energy. Multinationals are investing heavily in Europe to develop a Li-ion battery value chain, which leads to a now vested interest in the mass uptake of EV passenger cars These companies are likely to support a system that locks society in a transport system where individual car ownership is central.

Policy measures in different countries and at the EU level are playing a decisive role in incentivising the EV boom, often accompanied with public spending. In Europe, the declaration of the battery as strategic by the EC is accompanied by an important change in industrial policy, which shifts away from open market and free competition towards a government supported Li-ion battery industry that allows the easing of market and state-aid rules.

To answer the **main research question**: to critically assess if mass adoption of EVs is a solution to significantly reduce the environmental impacts of passenger road transport, Chapter 4 looked at different strategies besides the mass uptake of EVs.

All forecasts predict an unprecedented and soaring growth on mineral demand with all predictions based on the assumption of a growing number of vehicles on the road. For example, industry analysts estimate 1.6 billion vehicles will be on the road by 2040 (compared with 1.2 billion in 2020).[204] Of the predicted 1.6 billion fleet in 2040, still 1.1 billion units would be ICE cars, just as in 2015. Therefore, despite the enormous investments in developing a global Li-ion battery value chain and the resulting soaring mineral production, battery and EV manufacturing (and related social and environmental impacts), we would not be really reducing the absolute amount of carbon emitting ICE vehicles, as compared to present levels.

While mass adoption of EVs is being promoted by industry and governments (particularly in the global north) it is not the only solution in terms of addressing the impacts of passenger road transport. Scientists, civil society and communities across the world are calling for a different approach based on environmental justice and on the need to absolutely reduce the demand of minerals and energy. Strategies proposed include ride-sharing, car-sharing and smaller vehicles, which have the greatest potential to reduce the life-cycle impacts of passenger road transport. Material efficiency strategies such as recycling, smaller design and extended end of life is also important.

For instance, the Low Energy Demand Scenario developed by scientists from the IPCC shows that, by increasing vehicle occupancy and usage (for instance by car sharing), the same amount of intra-urban mobility could be achieved with half of the car fleet. According to such a scenario, the fleet of light duty vehicles could be reduced to 850 million by 2050. The IRP also recently concluded that car-sharing, ride sharing and smaller vehicles are the strategies that contribute the most to reducing life-cycle emissions of passenger cars. These solutions would also significantly reduce the amount of required energy, water and minerals.

Different organisations, including environmentalist groups, activists, affected communities and citizens from around the world, propose a different mobility transition. A transition based on communities' rights to say no to mining, an absolute need to reduce resource use, democratic decision-making, human rights, recognising and addressing past abuses and buen vivir, among other conceptual frameworks.

Furthermore, in SOMO's view, mandatory human rights due diligence should be an essential element of the mobility transition. All businesses along the Li-ion battery value chain should be required to conduct comprehensive mandatory human rights and environmental due diligence, should be transparent about their findings and should prevent, address and avoid negative impacts. Workers, communities and their representatives need to be part of the design and implementation of such due diligence processes. When violations occur, an effective remedy mechanism needs to be available for victims and to hold companies into account. Without mandatory human rights and environmental due diligence, there is no guarantee of a just mobility transition.

The following are key recommendations based on the information provided in this report. For additional recommendations, we refer to the (forthcoming) *Principles for Businesses and Governments in the Battery Value Chain* drafted by Amnesty International and allies.

To governments:

- States and the EU should prioritise reducing the mineral and energy demand of passenger road transport in absolute terms. To do so, States and the EU should support and promote strategies towards car-sharing, ride-sharing and public transport.

- States should introduce policy action and regulations that promote material efficiency strategies for the use of less materials and energy, including design of smaller Li-ion batteries and EVs, reuse and recycling.

- States and the EU should require manufacturers to standardise the design of Li-ion cells, modules and packs, and include proper labelling, in order to optimise recycling.

- States and the EU should introduce rules mandating Li-ion battery producers and/or EV manufacturers to take back end-of-life Li-ion batteries, through an extended producer responsibility scheme.

- States and the EU should introduce binding regulation requiring companies to conduct mandatory human rights and environmental due diligence, including the obligation of businesses to publish their due diligence practices and findings. Due diligence requirements should cover the entire battery value chain and involve communities, workers, civil society and trade unions in its design, monitoring and implementation.

- States and the EU should facilitate a democratic public debate to discuss alternative strategies to address the impacts of passenger road transport that includes the participation and meaningful engagement of mining-affected communities, workers, environmentalists, scientists, civil society and that is based on environmental justice and respect for human rights.

To companies along the battery value chain:

- All companies along the Li-ion battery value chain should map and disclose their supply chain and use their leverage with business relationships to request respect for human rights, decent working conditions and environmental protection through contractual obligations.

- All companies along the Li-ion battery value chain should carry out human rights and environmental due diligence, disclosing their findings on risks and abuses and outcomes; and prevent, address and mitigate their negative impacts.

- All companies should respect human rights and environmental laws, including the right to information, water, health; a healthy environment; communities' right to withhold consent; occupational health and safety standards; and the right of freedom of association and collective bargaining.

- All companies should provide victims of abuses occurring at any stage of the value chain with access to an effective remedy and have in place an effective grievance mechanism to receive workers' and external complaints.

- Companies should prioritise reducing mineral and energy demand in absolute terms, standardise design of Li-ion batteries and their components, which facilitate reuse and recycling. Manufacturers should ensure that Li-ion batteries and components include proper labels including battery health and safety guidelines for disassembling and recycling.

Endnotes

1 ‘Headline Statements – Global Warming of 1.5 °C,’ accessed October 15, 2020, https://www.ipcc.ch/sr15/resources/headline-statements/.

2 ‘Energy Technology Perspectives 2020 – Analysis,’ IEA, accessed October 15, 2020, https://www.iea.org/reports/energy-technology-perspectives-2020.

3 ‘A Vision for a Sustainable Battery Value Chain in 2030,’ World Economic Forum, accessed October 15, 2020, https://www.weforum.org/reports/a-vision-for-a- sustainable-battery-value-chain-in-2030/.

4 OAR US EPA, ‘Global Greenhouse Gas Emissions Data,’ Overviews and Factsheets, US EPA, January 12, 2016, https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

5 ‘Oil Demand From Road Transport: Covid-19 and Beyond,’ *BloombergNEF* (blog), June 11, 2020, https://about.bnef.com/blog/oil-demand-from-road-transport-covid-19-and-beyond/.

6 ‘Global EV Outlook 2020 – Analysis,’ IEA, accessed October 15, 2020, https://www.iea.org/reports/global-ev-outlook-2020.

7 ‘BNEF EVO Report 2020 | BloombergNEF | Bloomberg Finance LP,’ *BloombergNEF* (blog), accessed October 15, 2020, https://about.bnef.com/electric-vehicle-outlook/.

8 ‘BNEF EVO Report 2020 | BloombergNEF | Bloomberg Finance LP’.

9 ‘Norwegian EV policy,’ accessed October 15, 2020, https://elbil.no/english/norwegian-ev-policy/.

10 Bureau Woordvoering Kabinetsformatie, ‘Regeerakkoord ‘Vertrouwen in de toekomst’ – Publicatie – Kabinetsformatie,’ publicatie (Bureau Woordvoering Kabinetsformatie, October 10, 2017), https://www.kabinetsformatie2017.nl/documenten/publicaties/2017/10/10/regeerakkoord-vertrouwen-in-de-toekomst.

11 ‘Britain to Ban New Petrol Cars and Vans by 2030,’ *MINING.COM* (blog), accessed November 19, 2020, https://www.mining.com/web/britain-to-ban-new-petrol-cars-and-vans-by-2030/; Angelique Chrisafis and Adam Vaughan, ‘France to Ban Sales of Petrol and Diesel Cars by 2040,’ *The Guardian*, July 6, 2017, sec. Business, https://www.theguardian.com/business/2017/jul/06/france-ban-petrol-diesel-cars-2040-emmanuel-macron-volvo.

12 ‘Global EV Outlook 2020 – Analysis.’

13 ‘China Targets 7 Million EV Sales Annually By 2025, More Global Offerings,’ *InsideEVs*, accessed October 15, 2020, https://insideevs.com/news/334106/china-targets-7-million-ev-sales-annually-by-2025-more-global-offerings/.

14 ‘BNEF EVO Report 2020 | BloombergNEF | Bloomberg Finance LP.’

15 ‘Global EV Outlook 2019 – Analysis,’ IEA, accessed October 15, 2020, https://www.iea.org/reports/global-ev-outlook-2019; ‘Global EV Outlook 2020 – Analysis.’

16 ‘Statement by Vice-President for Energy Union Maroš Šefšovic Following the High-Level Meeting on Battery Development and Production in Europe,’ Text, European Commission – European Commission, accessed October 16, 2020, https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_17_3861.

17 ‘Global EV Outlook 2020 – Analysis.’

18 Kirsten Hund et al., ‘Minerals for Climate Action: The Mineral Intensity of the Clean Energy Transition,’ *The World Bank*, 2020, 112.

19 ‘A Novel Hybrid Thermal Management for Li-Ion Batteries Using Phase Change Materials Embedded in Copper Foams Combined with Forced-Air Convection,’ *International Journal of Thermal Sciences* 141 (July 1, 2019): 47–61, https://www.sciencedirect.com/science/article/pii/S1290072918305052.

20 ‘BU-1003: Electric Vehicle (EV) – Battery University,’ accessed October 21, 2020, https://batteryuniversity.com/learn/article/electric_vehicle_ev.

21 ‘Climate-Smart Mining: Minerals for Climate Action,’ Text/HTML, World Bank, accessed October 21, 2020, https://www.worldbank.org/en/topic/extractiveindustries/brief/climate-smart-mining-minerals-for-climate-action; ‘The ID. Battery from Volkswagen,’ accessed October 21, 2020, https://www.volkswagenag.com/en/news/stories/2018/10/powerful-and-scalable-the-new-id-battery-system.html.

22 N. Lebedeva, F. Di Persio, and L. Boon-brett, ‘Lithium Ion Battery Value Chain and Related Opportunities for Europe,’ 2017, https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/lithium-ion-battery-value-chain-and-related-opportunities-europe.

23 ‘Mineral Commodity Summaries 2020,’ USGS Unnumbered Series, *Mineral Commodity Summaries 2020*, Mineral Commodity Summaries (Reston, VA: US Geological Survey, 2020), http://pubs.er.usgs.gov/publication/mcs2020.

24 ‘Mineral Commodity Summaries 2020.’

25 ‘CHART: China’s Stranglehold on Electric Car Battery Supply Chain,’ *MINING.COM* (blog), April 17, 2020, https://www.mining.com/chart-chinas-stranglehold-on-electric-car-battery-supply-chain/.

26 Christophe Pillot, ‘The Rechargeable Battery Market and Main Trends 2018-2030,’ May 28, 2018, 24; ‘CHART.’; N. Lebedeva, F. Di Persio, and L. Boon-brett, ‘Lithium Ion Battery Value Chain and Related Opportunities for Europe,’ 2017, https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/lithium-ion-battery-value-chain-and-related-opportunities-europe.

27 Research and Markets, ‘Worldwide Lithium Ion Battery Cathodes Market Report 2019: Market Is a $7 Billion Market in 2018, and Is Expected to Reach $58.8 Billion by 2024,’ GlobeNewswire News Room, March 14, 2019, http://www.globenewswire.com/news-release/2019/03/14/1752966/0/en/Worldwide-Lithium-Ion-Battery-Cathodes-Market-Report-2019-Market-is-a-7-Billion-Market-in-2018-and-is-Expected-to-Reach-58-8-Billion-by-2024.html.

28 ‘CHART.’

29 Caspar Rawles (Head of Price Assessments, Benchmark Mineral Intelligence), email exchange December 11, 2020.

30 Intelligence; Matt Bohlsen, 'A Look At The Top 5 Lithium-Ion Battery Manufacturers In 2019,' Seeking Alpha, September 4, 2019, https://seekingalpha.com/article/4289626-look-top-5-lithium-ion-battery-manufacturers-in-2019; Email exchange with Caspar Rawles from benchmark Minerals (17 October 2019).

31 Benchmark Mineral Intelligence, 'EV Battery Arms Race Enters New Gear with 115 Megafactories, Europe Sees Most Rapid Growth,' *Benchmark Mineral Intelligence* (blog), December 31, 2019, https://www.benchmarkminerals.com/ev-battery-arms-race-enters-new-gear-with-115-megafactories-europe-sees-most-rapid-growth/.

32 Benchmark Mineral Intelligence.

33 'Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank on the Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe [COM(2019) 176 Final]' (European Economic and Social Committee, March 22, 2019), https://www.eesc.europa.eu/en/our-work/opinions-information-reports/opinions/strategic-action-plan-batteries-report.

34 'Volkswagen and Northvolt Form Joint Venture for Battery Production,' Volkswagen Newsroom, accessed October 22, 2020, https://www.volkswagen-newsroom.com:443/en/press-releases/volkswagen-and-northvolt-form-joint-venture-for-battery-production-5316; 'In China Hyundai Kona Electric To Be Equipped With CATL Batteries,' *InsideEVs*, accessed October 21, 2020, https://insideevs.com/news/351687/china-hyundai-kona-electric-catl-batteries/; 'SK Innovation to Supply Hyundai Electric Cars,' electrive.com, December 23, 2019, https://www.electrive.com/2019/12/23/sk-innovation-to-exclusively-supply-hyundai-electric-cars/; Reuters Staff, 'Toyota-Panasonic Venture to Start EV Battery Development in April,' *Reuters*, February 3, 2020, https://www.reuters.com/article/us-toyota-panasonic-battery-idUSKBN1ZX0LW; 'Toyota Strikes Battery Deal with China's CATL,' *Automotive News Europe*, July 17, 2019, https://europe.autonews.com/suppliers/toyota-strikes-battery-deal-chinas-catl; Desk Editor Insider, 'Hyundai, LG Chemical to Set Up EV Factory in Indonesia,' *The Insiders Stories* (blog), June 23, 2020, https://theinsiderstories.com/hyundai-lg-chemical-to-set-up-ev-battery-plant-in-indonesia/.

35 Lebedeva, Di Persio, and Boon-brett, 'Lithium Ion Battery Value Chain and Related Opportunities.'; Reuters Staff, 'BMW, Samsung SDI sign battery supply deal worth about $3.2 bln,' *Reuters*, November 21, 2019, https://br.reuters.com/article/bmw-samsung-sdi-idINS6N25P03G; Paul Lienert, 'GM, LG Chem to Build $2.3 Billion Electric Vehicle Battery Plant in Ohio,' *Reuters*, December 6, 2019, https://www.reuters.com/article/us-gm-lg-chem-jv-exclusive-idUSKBN1Y90C6; 'Lithium Energy Japan,' Mitsubishi Corporation, accessed October 21, 2020, http://www.mitsubishicorp.com/jp/en/bg/power-solution-group/project/lithium-energy-japan/.

36 Paul Lienert Taylor Norihiko Shirouzu, Edward, 'Exclusive: VW, China Spearhead $300 Billion Global Drive to Electrify Cars,' *Reuters*, January 10, 2019, https://www.reuters.com/article/us-autoshow-detroit-electric-exclusive-idUSKCN1P40G6.

37 'Global EV Sales In November 2019: Down 26% Year-Over-Year,' *InsideEVs*, accessed October 21, 2020, https://insideevs.com/news/389990/global-ev-sales-in-november-2019/.

38 'Global EV Outlook 2020 – Analysis,' IEA, accessed October 15, 2020, https://www.iea.org/reports/global-ev-outlook-2020.

39 'World Motor Vehicle Production | ACEA – European Automobile Manufacturers' Association,' accessed October 21, 2020, https://www.acea.be/statistics/tag/category/world-production.

40 'BNEF EVO Report 2020 | BloombergNEF | Bloomberg Finance LP,' *BloombergNEF* (blog), accessed October 15, 2020, https://about.bnef.com/electric-vehicle-outlook/.

41 'Global EV Outlook 2020 – Analysis.'

42 Clare Church and Larin Wuennenberg, 'Sustainability and Second Life: The Case for Cobalt and Lithium Recycling,' March 2019, 68; 'It's Time to Get Serious about Recycling Li-ion Batteries,' Chemical & Engineering News, accessed November 5, 2020, https://cen.acs.org/materials/energy-storage/time-serious-recycling-lithium/97/i28.

43 'Com(2018) 293 Annex 2 – Strategic Action Plan on Batteries' (European Commission, May 17, 2018), https://ec.europa.eu/transport/sites/transport/files/3rd-mobility-pack/com20180293-annex2_en.pdf.

44 'European Battery Alliance Q&A,' Text, European Commission – European Commission, accessed October 22, 2020, https://ec.europa.eu/commission/presscorner/detail/en/MEMO_18_6113.

45 'European Battery Alliance,' Text, Internal Market, Industry, Entrepreneurship and SMEs – European Commission, May 8, 2018, https://ec.europa.eu/growth/industry/policy/european-battery-alliance_en.

46 'European Battery Alliance Q&A.'

47 'CHART.'

48 'Strategic Action Plan on Batteries.'

49 'Strategic Action Plan on Batteries.'

50 'Strategic Action Plan on Batteries.'

51 Ben Hall and Richard Milne, 'Europe First: How Brussels Is Retooling Industrial Policy,' December 2, 2019, https://www.ft.com/content/140e560e-0ba0-11ea-bb52-34c8d9dc6d84.

52 'Strategic Action Plan on Batteries (Report).'

53 'Strategic Action Plan on Batteries (Report).'

54 'COM(2019) 176. Report from the Commission to the European Parliament, the Council, the European Economic Social Committee, the Committee of the Regions and the European Investment Bank on the Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe' (European Commission, September 4, 2019), https://ec.europa.eu/commission/sites/beta-political/files/report-building-strategic-battery-value-chain-april2019_en.pdf.

55 'Global Battery Alliance – Home,' World Economic Forum, accessed October 22, 2020, https://www.weforum.org/global-battery-alliance/home/.

56 'A Vision for a Sustainable Battery Value Chain in 2030,' World Economic Forum, accessed October 15, 2020, https://www.weforum.org/reports/a-vision-for-a- sustainable-battery-value-chain-in-2030/.

57 'A Vision for a Sustainable Battery Value Chain in 2030,' 17.

58 'A Vision for a Sustainable Battery Value Chain in 2030,' 24.

59 'A Vision for a Sustainable Battery Value Chain in 2030.'

60 'The Global Battery Alliance Action,' World Economic Forum, accessed October 22, 2020, https://www.weforum.org/global-battery-alliance/action/.

61 'BASF Further Invests in Europe to Strengthen Global Leadership Position for Battery Materials for Electric Vehicles,' accessed October 22, 2020, https://www.basf.com/global/en/media/news-releases/2020/02/p-20-127.html.

62 'Umicore Automotive,' accessed October 22, 2020, https://rbm.umicore.com/en/automotive-industries/.

63 'Umicore Announces Strategic Supply Agreement with Samsung SDI for NMC Cathode Materials,' accessed October 23, 2020, https://www.umicore.com/en/newsroom/newsroom/news/umicore-announces-strategic-supply-agreement-with-samsung-sdi-for-nmc-cathode-materials/; 'Umicore Announces Partnership with LG Chem for the Supply of NMC Cathode Materials,' accessed October 22, 2020, https://www.umicore.com/en/media/press/umicore-announces-partnership-with-lg-chem-for-the-supply-of-nmc-cathode-materials.

64 'Cathode Active Materials,' BASF Catalysts, accessed October 22, 2020, https://catalysts.basf.com/products-and-industries/battery-materials/cathode-active-materials.

65 'Report on the Implementation of the Strategic Action Plan on Batteries.'

66 Dan, 'CATL Starts Building Battery Plant in Germany,' electrive.com, October 19, 2019, https://www.electrive.com/2019/10/19/catl-starts-building-battery-plant-in-germany/.

67 'LG Chem Secures €500M for Polish Factory Expansion,' electrive.com, April 24, 2020, https://www.electrive.com/2020/04/24/lg-chem-secures-ehalf-a-billion-for-polish-factory-expansion/.

68 Joseph White Yang Hyunjoo Jin, Heekyong, 'Exclusive: SK Innovation in Talks to Set up EV Battery JVs with Volkswagen, China Partners,' *Reuters*, April 10, 2019, https://www.reuters.com/article/us-sk-innovation-batteries-exclusive-idUSKCN1RM0FR.

69 Yang.

70 'Tesla Gigafactory | Tesla,' accessed October 21, 2020, https://www.tesla.com/gigafactory.

71 'Launch of a Pilot Plant to Manufacture European Batteries for Electric Vehicles,' Saft Batteries | We energize the world., January 29, 2020, https://www.saftbatteries.com/media-resources/press-releases/launch-pilot-plant-manufacture-european-batteries-electric-vehicles.

72 'Northvolt Chronicles,' Northvolt Chronicles, accessed October 22, 2020, https://chronicles.northvolt.com.

73 'Northvolt | Enabling the Future of Energy,' accessed October 22, 2020, https://northvolt.com/production.

74 'Volkswagen and Northvolt Form Joint Venture for Battery Production,' Volkswagen Newsroom, accessed October 21, 2020, https://www.volkswagen-newsroom.com:443/en/press-releases/volkswagen-and-northvolt-form-joint-venture-for-battery-production-5316.

75 Niklas Pollard Hellstrom Johannes, 'Sweden's Northvolt Raises $1 Billion to Complete Funding for Mammoth Battery Plant,' *Reuters*, June 12, 2019, https://www.reuters.com/article/us-northvolt-funding-electric-idUSKCN1TD1WG.

76 'Northvolt Chronicles.'

77 'EIB Reaffirms Commitment to a European Battery Industry to Boost Green Recovery,' European Investment Bank, accessed October 28, 2020, https://www.eib.org/en/press/all/2020-121-eib-reaffirms-commitment-to-a-european-battery-industry-to-boost-green-recovery.

78 'BASF Further Invests in Europe to Strengthen Global Leadership Position for Battery Materials for Electric Vehicles,' accessed November 18, 2020, https://www.basf.com/global/en/media/news-releases/2020/02/p-20-127.html;
'Finnish Battery Industry Intensifies Cooperation: Forum, BASF, and Nornickel Sign Cooperation Agreement on Battery Recycling,' accessed November 18, 2020, https://www.basf.com/global/en/media/news-releases/2020/03/p-20-135.html;
Henry Sanderson, 'BASF Takes Aim at Asia's Dominance with Finnish Battery Materials Plant,' October 22, 2018, https://www.ft.com/content/9632f33a-d620-11e8-a854-33d6f82e62f8;
'Umicore to Acquire Cobalt Refinery and Cathode Precursor Operations in Finland,' accessed November 18, 2020, https://www.umicore.com/en/media/press/umicore-to-acquire-cobalt-refinery-and-cathode-precursor-operations-in-finland/;
'Umicore's New Plant in Nysa Is Moving Forward Fast despite the Pandemic,' accessed November 18, 2020, https://www.umicore.com/storage/regiopl/nysanews-tile01.gif;
'FAQ – Frequently Asked Questions,' GTHR, accessed November 18, 2020, http://gthr.pl/en/about-us/faq-frequently-asked-questions/;
'Terrafame's Nickel Sulphate Production Offers the Lowest Carbon Footprint in the Industry – Altogether 60% Lower than in Existing Conventional Processes,' accessed November 18, 2020, https://www.terrafame.com/news-from-the-mine/news/2020/09/terrafames-nickel-sulphate-production-offers-the-lowest-carbon-footprint-in-the-industry-altogether-60-lower-than-in-existing-conventional-processes.html;
'State Aid: In-Depth Investigation into LG Chem – Poland,' Text, European Commission – European Commission, accessed November 18, 2020, https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1470;

'LG Chem Secures €500M for Polish Factory Expansion,' electrive.com, April 24, 2020, https://www.electrive.com/2020/04/24/lg-chem-secures-ehalf-a-billion-for-polish-factory-expansion/;

'EUR-Lex – 52020AS48556 – EN – EUR-Lex,' accessed November 18, 2020, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020AS48556;

'Samsung SDI begins expanding Hungary battery plant,' THE ELEC, Korea Electronics Industry Media, February 21, 2020, http://thelec.net/news/articleView.html?idxno=738;

'SK Innovation Plans Second EV Battery Plant in U.S., Expansion in Hungary,' *Reuters*, January 10, 2020, https://www.reuters.com/article/us-tech-ces-sk-innovation-idUSKBN1Z82QB;

'SK Innovation Pushes for 3rd EV Battery Plant in Hungary,' accessed November 18, 2020, http://www.koreaherald.com/view.php?ud=20200907000834;

'Launch of a Pilot Plant to Manufacture European Batteries for Electric Vehicles,' Saft Batteries | We energize the world, January 29, 2020, https://www.saftbatteries.com/media-resources/press-releases/launch-pilot-plant-manufacture-european-batteries-electric-vehicles;

'Northvolt | Enabling the Future of Energy,' accessed November 18, 2020, https://northvolt.com/production;

'Blackstone Resources – Battery Technology R&D,' Blackstone Resources, accessed November 18, 2020;

Daimler, 'Global Battery Production Network: Mercedes-Benz Cars to Build Battery Factory in Jawor, Poland,' Daimler, January 22, 2019, https://www.daimler.com/company/locations/battery-factory-jawor.html;

'Jaguar Plans In-House Battery Pack Production Capacity Of 150K / Year,' InsideEVs, accessed November 18, 2020, https://insideevs.com/news/358407/jaguar-battery-pack-150000-annually/;

Reuters Staff, 'Tesla's German Plant to Produce 500,000 Cars a Year: Bild,' *Reuters*, December 11, 2019, https://www.reuters.com/article/us-tesla-berlin-idUSKBN1YF0QV.

79 'NORTHVOLT COMMERCIAL DEMONSTRATION LINE (EDP),' accessed October 28, 2020, https://www.eib.org/en/projects/pipelines/all/20170637;

'EIB and Umicore Conclude €125 Million Loan for Battery Materials Production in Poland,' European Investment Bank, accessed October 28, 2020, https://www.eib.org/en/press/all/2020-148-eib-and-umicore-conclude-eur125-million-loan-for-battery-materials-production-in-poland;

'Electric Vehicle Battery Production in Europe Gets Boost Thanks to EIB Loan of €480 Million to LG Chem Wroclaw Energy in Poland,' European Investment Bank, accessed October 28, 2020, https://www.eib.org/en/press/all/2020-088-electric-vehicle-battery-production-in-europe-gets-boost-thanks-to-eib-loan-of-eur480-million-to-lg-chem-wroclaw-energy-in-poland;

'European Backing for Northvolt's Battery Gigafactory in Sweden,' European Investment Bank, accessed October 28, 2020, https://www.eib.org/en/press/all/2020-208-european-backing-for-northvolt-s-battery-gigafactory-in-sweden.

80 'Report on the Implementation of the Strategic Action Plan on Batteries.'

81 'State Aid: €3.2 Billion Public Support Battery Value Chain,' Text, European Commission – European Commission, accessed October 28, 2020, https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6705.

82 'Launch of a Pilot Plant to Manufacture European Batteries for Electric Vehicles,' January 29, 2020.

83 'Renault Nissan Mitsubishi,' The Alliance – Renault Nissan Mitsubishi, accessed October 28, 2020, https://www.alliance-2022.com/about-us/.

84 'Geely Auto and Contemporary Amperex Technology Form JV for New Energy Vehicle Batteries : Geely Global Media Center,' accessed October 28, 2020, http://global.geely.com/media-center/news/geely-auto-and-contemporary-amperex-technology-form-jv-for-new-energy-vehicle-batteries/.

85 'Geely Auto and LG Chem to Establish Joint Venture Company to Produce Batteries in China : Geely Global Media Center,' accessed October 28, 2020, http://global.geely.com/media-center/news/geely-auto-and-lg-chem-to-establish-joint-venture-company-to-produce-batteries-in-china/.

86 'Volkswagen and Northvolt Form Joint Venture for Battery Production.'

87 TOYOTA MOTOR CORPORATION, 'CATL and Toyota Form Comprehensive Partnership for New Energy Vehicle Batteries | Corporate | Global Newsroom,' Toyota Motor Corporation Official Global Website, accessed October 28, 2020, https://global.toyota/en/newsroom/corporate/28913488.html.

88 'Toyota and Panasonic Decide to Establish Joint Venture Specializing in Automotive Prismatic Batteries | Headquarters News,' Panasonic Newsroom Global, accessed October 28, 2020, http://news.panasonic.com/global/press/data/2020/02/en200203-4/en200203-4.html.

89 'BYD, Toyota Launch BYD TOYOTA EV TECHNOLOGY Joint Venture to Conduct Battery Electric Vehicle R&D | Corporate | Global Newsroom | Toyota Motor Corporation Official Global Website,' accessed October 21, 2020, https://global.toyota/en/newsroom/corporate/32126024.html.

90 'BMW Group Forges Ahead with E-Mobility and Secures Long-Term Battery Cell Needs – Total Order Volume of More than 10 Billion Euros Awarded,' accessed October 28, 2020, https://www.press.bmwgroup.com/global/article/detail/T0302864EN/bmw-group-forges-ahead-with-e-mobility-and-secures-long-term-battery-cell-needs-—-total-order-volume-of-more-than-10-billion-euros-awarded?language=en.

91 'Securing Raw Material Supplies for Battery Cells: BMW Group Signs Supply Contract with Ganfeng for Sustainable Lithium from Mines in Australia,' accessed October 28, 2020, https://www.press.bmwgroup.com/global/article/detail/T0303684EN/securing-raw-material-supplies-for-battery-cells:-bmw-group-signs-supply-contract-with-ganfeng-for-sustainable-lithium-from-mines-in-australia?language=en.

92 'BMW and Northvolt Sign a Supply Contract Worth 2 Billion Euros,' *European Battery Alliance* (blog), July 17, 2020, https://www.eba250.com/bmw-and-northvolt-sign-a-supply-contract-worth-2-billion-euros/.

93 Henry Sanderson, 'Tesla to Buy Cobalt from Glencore for New Car Plants,' June 16, 2020, https://www.ft.com/content/aa09dbcb-37ed-4010-a0ee-ab6cfab4d4b5.

94 'Hyundai Motor, LG and POSCO Groups May Launch an EV Battery Joint Venture – Businesskorea,' accessed October 28, 2020, http://www.businesskorea.co.kr/news/articleView.html?idxno=40586.

95 'Finnish Battery Industry Intensifies Cooperation: Fortum, BASF and Nornickel Sign Cooperation Agreement on Battery Recycling,' accessed November 25, 2020, https://www.basf.com/global/en/media/news-releases/2020/03/p-20-135.html.

96 'Global EV Outlook 2020' (International Energy Agency, June 2020).

97 'Global EV Outlook 2020,' 179.

98 'A Vision for a Sustainable Battery Value Chain in 2030: Unlocking the Full Potential to Power Sustainable Development and Climate Change Mitigation' (World Economic Forum, September 2019), 21.

99 'A Vision for a Sustainable Battery Value Chain in 2030,' 25.

100 Caspar Rawles (Head of Price Assessments, Benchmark Mineral Intelligence), email exchange December 11, 2020.

101 'Mineral Commodity Summaries 2020,' USGS Unnumbered Series, *Mineral Commodity Summaries 2020*, Mineral Commodity Summaries (Reston, VA: U.S. Geological Survey, 2020), https://doi.org/10.3133/mcs2020; 'Global EV Outlook 2020';
'A Vision for a Sustainable Battery Value Chain in 2030,' September 2019;
'Battery Megafactory Raw Material Demand,' *Benchmark Mineral Intelligence* (blog), accessed November 5, 2020, https://www.benchmarkminerals.com/lithiums-price-paradox/battery-megafactory-raw-material-demand/.

102 Ariel Cohen, 'Manufacturers Are Struggling To Supply Electric Vehicles With Batteries,' *Forbes*, accessed November 25, 2020, https://www.forbes.com/sites/arielcohen/2020/03/25/manufacturers-are-struggling-to-supply-electric-vehicles-with-batteries/; 'UK Calls Last Orders on Combustion Engine, but Needs to Spend $20bn on Four EV Battery Gigafactories by 2027 – Benchmark Comment,' *Benchmark Mineral Intelligence* (blog), accessed November 25, 2020, https://www.benchmarkminerals.com/membership/uk-calls-last-orders-on-combustion-engine-but-needs-to-spend-20bn-on-four-ev-battery-gigafactories-by-2027-benchmark-comment/.

103 Presentation by Andrew Leyland, Head of Strategic Advisory at Benchmark Mineral Intelligence, 11 November 2020, https://www.facebook.com/IndustriALLGlobalUnion/videos/358170408611620

104 BloombergNEF, email with James Frith (22 September 2020).

105 IDTechEx, 'The Electric Vehicle Market and Copper Demand – Copper Alliance,' June 2017, https://copperalliance.org/wp-content/uploads/2017/06/2017.06-E-Mobility-Factsheet-1.pdf.

106 'EJOLT | Environmental Justice Organisations, Liabilities and Trade,' accessed October 29, 2020, http://www.ejolt.org/; Marta Conde, 'Resistance to Mining. A Review,' *Ecological Economics* 132 (February 1, 2017): 80-90, https://doi.org/10.1016/j.ecolecon.2016.08.025;
Antistatique, 'Home | RMI Report 2020,' accessed October 29, 2020, https://2020.responsibleminingindex.org/en/results/thematic/318.

107 'Transition Minerals | Business & Human Rights Investment Trackers,' accessed October 29, 2020, https://trackers.business-humanrights.org/transition-minerals/.

108 'EJOLT | Environmental Justice Organisations, Liabilities and Trade', accessed December 12, 2020.

109 'Human Rights Defenders & Business – 2020 Snapshot,' accessed October 29, 2020, http://dispatches.business-humanrights.org/hrd-january-2020/.

110 'Land and Environmental Defenders: Annual Report Archive,' Global Witness, accessed October 29, 2020, https://copperalliance.org/wp-content/uploads/2017/06/2017.06-E-Mobility-Factsheet-1.pdf. Email exchange with Laura Furones (November 4,2020).

111 'Enemies of the State?,' Global Witness, accessed October 29, 2020, https://www.globalwitness.org/en/campaigns/environmental-activists/enemies-state/.

112 Takuma Watari, Keisuke Nansai, and Kenichi Nakajima, 'Review of Critical Metal Dynamics to 2050 for 48 Elements,' *Resources, Conservation and Recycling* 155 (April 1, 2020): 104669, https://doi.org/10.1016/j.resconrec.2019.104669.

113 'Mineral Commodity Summaries 2020.'

114 'This Metal Is Powering Today's Technology – at What Price?,' *Magazine*, January 15, 2019, https://www.nationalgeographic.com/magazine/2019/02/lithium-is-fueling-technology-today-at-what-cost/.

115 This Metal Is Powering Today's Technology – at What Price?,' *Magazine*, January 15, 2019, https://www.nationalgeographic.com/magazine/2019/02/lithium-is-fueling-technology-today-at-what-cost/.

116 'Market Cap Leading Lithium Mining Companies 2020,' Statista, accessed October 29, 2020, https://www.statista.com/statistics/799740/global-market-cap-of-lithium-mining-companies/.

117 'Mineral Commodity Summaries 2020.'

118 Pía Marchegiani, Jasmin Höglund Hellgren, and Leandro Gómez, 'Lithium Extraction in Argentina: A Case Study on the Social and Environmental Impacts' (FARN, 2019).

119 Amanda Romero and José Aylwin, 'Globalización de las empresas de energía renovable,' December 2019, 58.

120 'Mineral Commodity Summaries 2020.'

121 Marchegiani, Hellgren, and Gómez, 'Lithium Extraction in Argentina: A Case Study on the Social and Environmental Impacts'; Virginia De Francesco, 'La Imperiosa Necesidad de Contar Con Información Confiable,' *Revista Pulso Ambiental*, no. 10 (August 2018).

122 Marchegiani, Hellgren, and Gómez, 'Lithium Extraction in Argentina: A Case Study on the Social and Environmental Impacts.'

123 'Cobalt Demand Forecast Global Distribution by Industry 2020,' Statista, accessed October 30, 2020, https://www.statista.com/statistics/808206/forecasted-global-cobalt-demand-distribution-by-industry/.

124 'Cobalt Production Volume by Company Worldwide,' Statista, accessed October 30, 2020, https://www.statista.com/statistics/1172194/global-leading-cobalt-producing-companies-production-volume/; 'Century Cobalt | Cobalt Leaders,' accessed October 30, 2020, http://www.centurycobalt.com/cobalt.

125 SOMO, 'Time to start caring about cobalt. Evaluating the due diligence conducted by nine insurers active in the Dutch insurance market to address human rights abuses in the cobalt supply chain' (Fair insurance Guide, July 2020).

126 Fleur Scheele et al., 'Cobalt Blues. Environmental Pollution and Human Rights Violations in Katanga's Copper and Cobalt Mines.' (SOMO, April 2016).

127 Forthcoming publication of AFREWATCH and PremiCongo within the 'Mind the Gap' project coordinated by SOMO.

128 Daan Van Brusselen et al., 'Metal Mining and Birth Defects: A Case-Control Study in Lubumbashi, Democratic Republic of the Congo,' *The Lancet Planetary Health* 4, no. 4 (April 1, 2020): e158-67, https://doi.org/10.1016/S2542-5196(20)30059-0.

129 ''This Is What We Die for' Human Rights Abuses in the Democratic Republic of Congo Power the Global Trade in Cobalt.' (Amnesty International and Afrewatch, 2016), https://www.amnesty.org/download/Documents/AFR6231832016ENGLISH.PDF.

130 'IRAdvocates Files Forced Child Labor Case Against Tech Giants Apple, Alphabet, Dell, Microsoft and Tesla for Aiding and Abetting Extreme Abuse of Children Mining Cobalt in DRC.,' International Rights Advocates, accessed October 30, 2020, http://www.iradvocates.org/press-release/iradvocates-files-forced-child-labor-case-against-tech-giants-apple-alphabet-dell.

131 Scheele et al., 'Cobalt Blues. Environmental Pollution and Human Rights Violations in Katanga's Copper and Cobalt Mines.'

132 'DRC: Crisis in Mines Requires Sustainable Solutions' (Amnesty International, July 25, 2019), https://www.amnesty.org/en/documents/afr62/0772/2019/en/.

133 'This Is What We Die for' Human Rights Abuses in the Democratic Republic of Congo Power the Global Trade in Cobalt.'

134 'DRC: Crisis in Mines Requires Sustainable Solutions.'

135 'DRC: Crisis in Mines Requires Sustainable Solutions.'

136 'The World Bank in DRC,' Text/HTML, World Bank, accessed October 30, 2020, https://www.worldbank.org/en/country/drc/overview.

137 'Time to Recharge. Corporate Action and Inaction to Tackle Abuses in the Cobalt Supply Chain.' (Amnesty International, 2017).

138 AIOH Exposure Standards Committee, 'Nickel and Its Compounds – Potential for Occupational Health Issues (2016),' May 2016, https://www.aioh.org.au/static/uploads/files/nickel-and-its-compounds-wfthftxcirqz.pdf.

139 'Mineral Commodity Summaries 2020.'

140 'Nickel Production Global Distribution by Company 2019,' Statista, accessed November 4, 2020, https://www.statista.com/statistics/692900/distribution-of-global-nickel-production-by-producer/.

141 Max Opray, 'Nickel Mining: The Hidden Environmental Cost of Electric Cars,' *The Guardian*, August 24, 2017, sec. Guardian Sustainable Business, https://www.theguardian.com/sustainable-business/2017/aug/24/nickel-mining-hidden-environmental-cost-electric-cars-batteries.

142 AIOH Exposure Standards Committee, 'Nickel and Its Compounds – Potential for Occupational Health Issues (2016).'

143 'On an Island Coveted by Miners, Villagers Prepare to Raise a Ruckus,' Mongabay Environmental News, September 13, 2019, https://news.mongabay.com/2019/09/on-an-island-coveted-by-miners-villagers-prepare-to-raise-a-ruckus/;
Ian Morse, 'Mining Turned Indonesian Seas Red. The Drive for Greener Cars Could Herald a New Toxic Tide.,' *Washington Post*, accessed November 3, 2020, https://www.washingtonpost.com/world/asia-pacific/mining-turned-indonesian-seas-red-the-drive-for-greener-cars-could-herald-a-new-toxic-tide/2019/11/19/39c76a84-01ff-11ea-8341-cc3dce52e7de_story.html.

144 Arianto Sangadji, Muh Fardan Ngoyo, and Pius Ginting, 'Road to Ruin: Challenging the Sustainability of Nickel-Based Production for Electric Vehicle Batteries' (Rosa Luxemburg Stiftung, November 2019), https://www.rosalux.de/en/publication/id/41300/road-to-ruin.

145 'Tsingshan's Indonesia Morowali Industrial Park: Build, and They Will Come | HSBC China,' accessed November 3, 2020, https://www.business.hsbc.com.cn/en-gb/belt-and-road/story-5.

146 Sangadji, Fardan Ngoyo, and Ginting, 'Road to Ruin: Challenging the Sustainability of Nickel-Based Production for Electric Vehicle Batteries.'

147 'On an Island Coveted by Miners, Villagers Prepare to Raise a Ruckus.'

148 Ester van der Voet et al., 'Environmental Implications of Future Demand Scenarios for Metals: Methodology and Application to the Case of Seven Major Metals,' SSRN Scholarly Paper (Rochester, NY: Social Science Research Network, February 1, 2019), https://papers.ssrn.com/abstract=3344670.

149 Sangadji, Fardan Ngoyo, and Ginting, ‘Road to Ruin: Challenging the Sustainability of Nickel-Based Production for Electric Vehicle Batteries.’

150 ‘Indonesian Miners Eyeing EV Nickel Boom Seek to Dump Waste into the Sea,’ Mongabay Environmental News, May 18, 2020, https://news.mongabay.com/2020/05/indonesian-miners-eyeing-ev-nickel-boom-seek-to-dump-waste-into-the-sea/.

151 Melanie Burton Daly Tom, ‘Chinese-Owned Nickel Plant Spills Waste into Papua New Guinea Bay,’ *Reuters*, August 29, 2019, https://www.reuters.com/article/us-papua-mining-spill-idUSKCN1VI0VW.

152 Ben Barber et al., ‘The Top 10 Toxic List,’ *HuffPost*, 07:33 500, https://www.huffpost.com/entry/most-polluted-places_b_4213940.

153 ‘Russian Arctic Oil Spill Pollutes Big Lake near Norilsk,’ *BBC News*, June 9, 2020, sec. Europe, https://www.bbc.com/news/world-europe-52977740.

154 ‘Dutch ING & ABP Also Invest in Arctic Spill’s Norilsk Nickel | Fair Finance Guide International,’ accessed November 3, 2020, https://fairfinanceguide.org/ff-international/news/2020/dutch-ing-abp-also-invest-in-arctic-spills-norilsk-nickel/.

155 EJOLT, ‘Santa Cruz, Zambales Nickel Mining Impacts Sustainable Agriculture and Fisheries, Philippines | EJAtlas,’ Environmental Justice Atlas, accessed November 3, 2020, https://ejatlas.org/conflict/sta-cruz-zambales-nickel-mining-impacts-sustainable-agriculture-and-fisheries.

156 Melanie Müller and Michael Reckordt, ‘Without Responsibility and Transparency. Human Rights Risks along the Nickel Supply Chain,’ October 2017, 12.

157 Benchmark Mineral Intelligence, ‘Graphite + Anodes 2019: Key Talking Points,’ *Benchmark Mineral Intelligence* (blog), November 15, 2019, https://www.benchmarkminerals.com/graphite-anodes-2019-key-talking-points/.

158 ‘Graphite – Syrah Resources,’ accessed November 3, 2020, http://www.syrahresources.com.au/markets;
‘UNIQUE TECHNOLOGY,’ OneD Material, accessed November 3, 2020, https://www.onedmaterial.com/technology;
‘Doing the Math on Tesla’s Potential New Demand for Flake Graphite,’ *InvestorIntel*, July 19, 2017, https://investorintel.com/market-analysis/market-analysis-intel/analyst-math-teslas-potential-new-demand-flake-graphite/.

159 ‘The Batteries in Your Favorite Devices Are Literally Covering Chinese Villages in Black Soot,’ *Washington Post*, accessed November 3, 2020, https://www.washingtonpost.com/graphics/business/batteries/graphite-mining-pollution-in-china/.

160 ‘Mineral Commodity Summaries 2020.’

161 ‘Mozambique’s Glittering Graphite Mining Boom,’ *The Africa Report.com*, January 22, 2019, https://www.theafricareport.com/412/mining-mozambique-glittering-graphite/.

162 ‘Ancuabe Graphite Project,’ *Triton Minerals Ltd* (blog), accessed November 3, 2020, https://www.tritonminerals.com/projects/upulo-ancuabe-graphite-project/.

163 Peter Whoriskey, ‘In your Phone, in their air’ (Washington Post, October 2, 2016) accessed November 13, 2020.

164 S. Roodhouse Gloyne, Geoffrey Marshall, and Clifford Hoyle, ‘Pneumoconiosis Due to Graphite Dust,’ *Thorax* 4, no. 1 (March 1, 1949): 31-38, https://thorax.bmj.com/lookup/doi/10.1136/thx.4.1.31; ‘CDC – Pneumoconioses – NIOSH Workplace Safety and Health Topic,’ November 7, 2018, https://www.cdc.gov/niosh/topics/pneumoconioses/default.html.

165 ‘About Manganese,’ *International Manganese Institute* (blog), accessed November 6, 2020, https://www.manganese.org/about-manganese/;
‘Euro Manganese Inc. | Manganese,’ mn25, accessed November 6, 2020, https://www.mn25.ca/manganese.

166 ‘Euro Manganese Inc. | Manganese.’

167 ‘Mineral Commodity Summaries 2020.’

168 Ykateryna Duka et al., ‘Impact of Open Manganese Mines on the Health of Children Dwelling in the Surrounding Area,’ *Emerging Health Threats Journal* 4 (May 6, 2011): 7110, https://doi.org/10.3402/ehtj.v4i0.7110.

169 Halina Röllin and Claudina Nogueira, ‘Manganese: Environmental Pollution and Health Effects,’ *Encycl Environ Health*, December 31, 2011, 617-29, https://doi.org/10.1016/B978-0-444-52272-6.00540-7.

170 ‘ATSDR – Public Health Statement: Manganese,’ accessed November 3, 2020, https://www.atsdr.cdc.gov/phs/phs.asp?id=100&tid=23.

171 Duka et al., ‘Impact of Open Manganese Mines on the Health of Children Dwelling in the Surrounding Area.’

172 ‘ATSDR – Public Health Statement.’

173 Duka et al., ‘Impact of Open Manganese Mines on the Health of Children Dwelling in the Surrounding Area.’

174 David Ollivier de Leth, Joseph Wilde-Ramsing and Sophie Kwizera, ‘Human Rights in Wind Turbine Supply Chains Update 2019’ (Action Aid, November 2019), https://www.somo.nl/human-rights-in-wind-turbine-supply-chains-update-2019/.

175 ‘Mining in South Africa 2018. Whose Benefit and Whose Burden?’ (Action Aid South Africa, 2018).

176 Bruno Oberle et al., ‘Global Resources Outlook 2019: Natural Resources for the Future We Want.’ (International Resource Panel, 2019), https://www.resourcepanel.org/reports/global-resources-outlook.

177 ‘BNEF EVO Report 2020 | BloombergNEF | Bloomberg Finance LP,’ *BloombergNEF* (blog), accessed October 15, 2020, https://about.bnef.com/electric-vehicle-outlook/.

178 Edgar Hertwich et al., ‘Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. Hert’ (IRP, n.d.);
Arnulf Grubler et al., ‘A Low Energy Demand Scenario for Meeting the 1.5 °C Target and Sustainable Development Goals without Negative Emission Technologies,’ *Nature Energy* 3, no. 6 (June 2018): 515–27, https://doi.org/10.1038/s41560-018-0172-6;
Arjen Y. Hoekstra and Thomas O. Wiedmann, ‘Humanity’s Unsustainable Environmental Footprint,’ *Science* 344, no. 6188 (June 6, 2014): 1114–17, https://doi.org/10.1126/science.1248365.

179 Grubler et al., ‘A Low Energy Demand Scenario for Meeting the 1.5 °C Target and Sustainable Development Goals without Negative Emission Technologies.’

180 Hertwich et al., ‘Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. Hert.’

181 Federico Demaria, Giacomo D’Alisa, and Giorgos Kallis, *DEGROWTH: A Vocabulary for a New Era*, 2015; Jason Hickel, ‘Degrowth: A Theory of Radical Abundance,’ no. 87 (n.d.): 15.

182 Hertwich et al., ‘Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future. Hert.’

183 Hertwich et al.

184 Dana L. Thompson et al., ‘The Importance of Design in Lithium Ion Battery Recycling – a Critical Review,’ *Green Chemistry* 22, no. 22 (November 16, 2020): 7585–7603, https://doi.org/10.1039/D0GC02745F.

185 Gavin Harper et al., ‘Recycling Li-ion Batteries from Electric Vehicles,’ *Nature* 575, no. 7781 (November 2019): 75-86, https://doi.org/10.1038/s41586-019-1682-5.

186 Thompson et al., ‘The Importance of Design in Lithium Ion Battery Recycling – a Critical Review.’

187 Harper et al., ‘Recycling Li-ion Batteries from Electric Vehicles,’ November 2019.

188 Thompson et al., ‘The Importance of Design in Lithium Ion Battery Recycling – a Critical Review.’

189 Clare Church and Larin Wuennenberg, ‘Sustainability and Second Life: The Case for Cobalt and Lithium Recycling,’ March 2019, 68.

190 Elsa Dominish, Sven Teske and Nick Florin, ‘Responsible Minerals Sourcing for Renewable Energy.’ (Report prepared for Earthworks by the Institute for Sustainable Futures, University of Technology Sydney, 2019).

191 Gavin Harper et al., ‘Recycling Li-ion Batteries from Electric Vehicles,’ *Nature* 575, no. 7781 (November 2019): 75-86, https://doi.org/10.1038/s41586-019-1682-5; Rebecca E. Ciez and J. F. Whitacre, ‘Examining Different Recycling Processes for Li-ion Batteries,’ *Nature Sustainability* 2, no. 2 (February 2019): 148–56, https://doi.org/10.1038/s41893-019-0222-5.

192 Saeed Rahimpour Golroudbary, Daniel Calisaya-Azpilcueta and Andrzej Kraslawski, ‘The Life Cycle of Energy Consumption and Greenhouse Gas Emissions from Critical Minerals Recycling: Case of Li-ion Batteries,’ *Procedia CIRP*, 26th CIRP Conference on Life Cycle Engineering (LCE) Purdue University, West Lafayette, IN, USA May 7-9, 2019, 80 (January 1, 2019): 316-21, https://doi.org/10.1016/j.procir.2019.01.003.

193 ‘Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on Batteries and Accumulators and Waste Batteries and Accumulators and Repealing Directive 91/157/EEC (Text with EEA Relevance),’ Pub. L. No. 32006L0066, OJ L 266 (2006), http://data.europa.eu/eli/dir/2006/66/oj/eng.

194 Matthias Buchert, Stefanie Degreif and Peter Dolega, ‘Öko-Institut (2018): Ensuring a Sustainable Supply of Raw Materials for Electric Vehicles: A Synthesis Paper on Raw Material Needs for Batteries and Fuel Cells.,’ March 2018, 74.

195 ‘Observatorio Plurinacional de Salares Andinos,’ Observatorio Plurinacional de Salares Andinos, accessed November 4, 2020, https://observatoriosalares.wordpress.com/.

196 ‘El observatorio,’ *Observatorio Plurinacional de Salares Andinos* (blog), August 14, 2019, https://observatoriosalares.wordpress.com/blog/.

197 Observatorio de Salares, ‘Lithium and socio-environmental conflicts in times of crisis: An opportunity to (re)think the transition,’ *Observatorio Plurinacional de Salares Andinos* (blog), June 29, 2020, https://observatoriosalares.wordpress.com/2020/06/29/lithium-and-socio-environmental-conflicts-in-times-of-crisis-an-opportunity-to-rethink-the-transition/.

198 ‘Pacto Ecosocial del Sur. Por Pacto Social, Ecológico, Económico e Intercultural para América Latina.,’ Pacto Ecosocial Latinoamericano, accessed November 4, 2020, https://pactoecosocialdelsur.com/.

199 ‘Just Transition – Climate Justice Alliance,’ accessed November 4, 2020, https://climatejusticealliance.org/just-transition/.

200 ‘Just Transition – Climate Justice Alliance.’

201 ‘Cáceres Rejects Lithium Mine,’ accessed November 4, 2020, https://theecologist.org/2020/jun/10/caceres-rejects-lithium-mine.

202 Mauro Anastasio, ‘Europe’s Strategy for Critical Raw Materials ‘a Double-Edged Sword,’’ *EEB – The European Environmental Bureau* (blog), accessed November 4, 2020, https://eeb.org/europes-strategy-for-critical-raw-materials-a-double-edged-sword/.

203 ‘Civil Society Concerns on EU Critical Raw Materials Plan,’ Friends of the Earth Europe, accessed November 4, 2020, http://foeeurope.org/civil-society-concerns-eu-critical-raw-materials-plan-280920.

204 ‘BNEF EVO Report 2020 | BloombergNEF | Bloomberg Finance LP,’ BloombergNEF (blog), accessed October 15, 2020, https://about.bnef.com/electric-vehicle-outlook/.