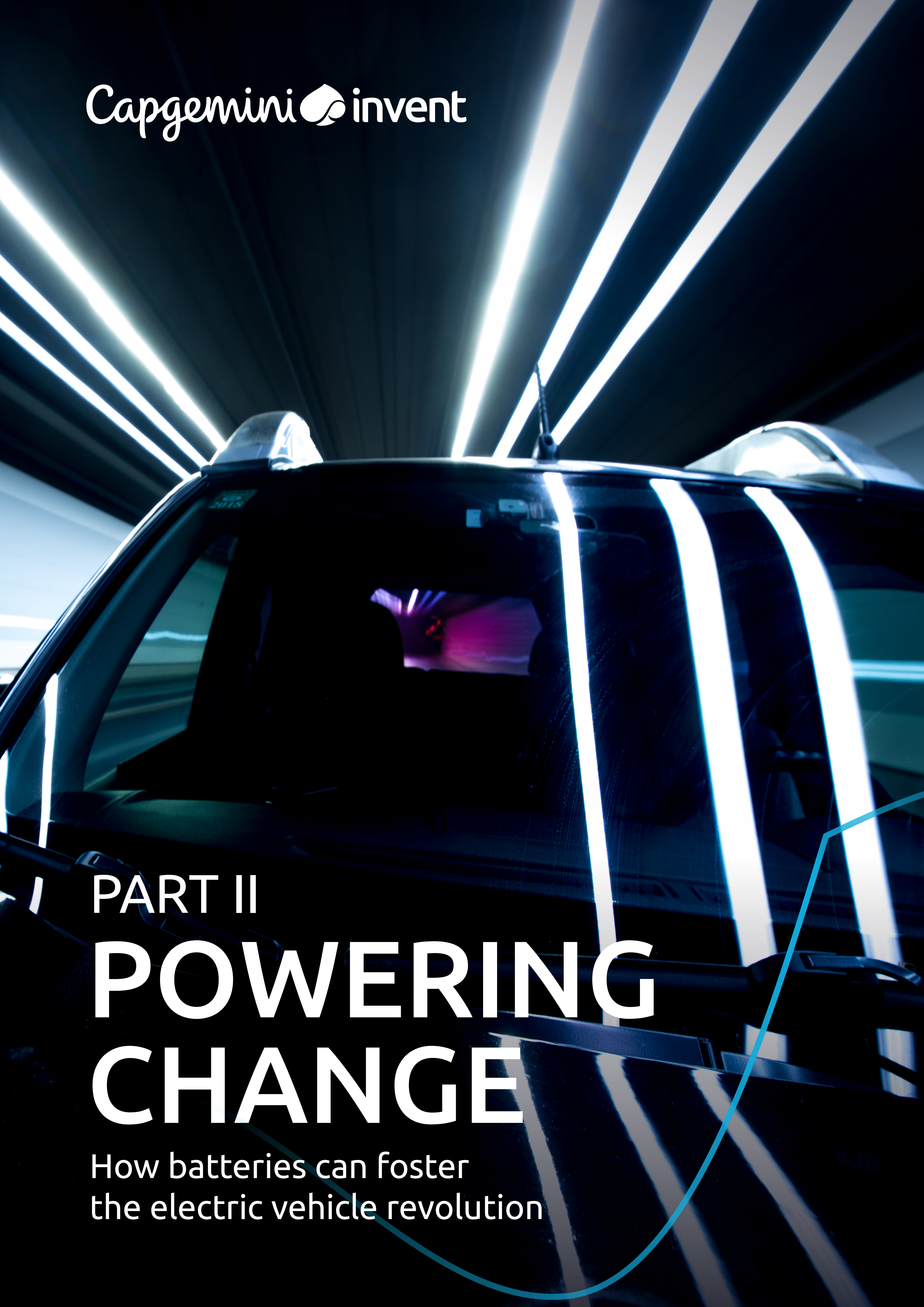


PART II

POWERING CHANGE

How batteries can foster
the electric vehicle revolution

2

RAW MATERIALS ARE CRUCIAL FOR BATTERY SUPPLY

Raw materials account for a major part of today's battery cost on both a cell and system level. Therefore, the current price increases of many materials (e.g., lithium, nickel, manganese, and cobalt) are leading to a slower price reduction on a battery system level in automotive. Most raw material costs are passed on at the supply chain, i.e., price increases in raw materials lead to higher end-product costs. This makes it more difficult to achieve the often cited $100/kWh cell price, which is needed to reach cost competitiveness with conventional ICE vehicles.

Raw materials account for more than 60% of total BEV battery cost.[22 23] Stricter regulation and rising customer awareness of ESG criteria in the raw materials supply chain is also playing a key role. However, the meeting of ESG criteria can be difficult because some battery materials can be sourced in only a handful of countries with worrisome political and socioeconomic challenges. To achieve an ethical, secure, and transparent supply chain, new automotive networks and partnerships within the value chain need to be built. Also, new technologies, such as blockchain, may be useful to validate ethical standards through the increased traceability they provide. Some companies, such as RCS Global, have already enhanced functionality to ensure the tracking of raw materials through blockchain supply-chain networks to enable clearer, wider, and more accurate data visibility.[24 25]

"Raw materials account for more than 60% of total BEV battery cost."

- Simon Schäfer, Manager, CX E-Mobility

[22]This figure assumes cell cost accounts for 82% of total pack cost in cell-to-pack designs and raw materials account for 75% of cell cost.
[23]BNEF (2021) [24]Capgemini (2021) [25]RCS (2021)

2.1 Raw power: the materials used in battery chemistry

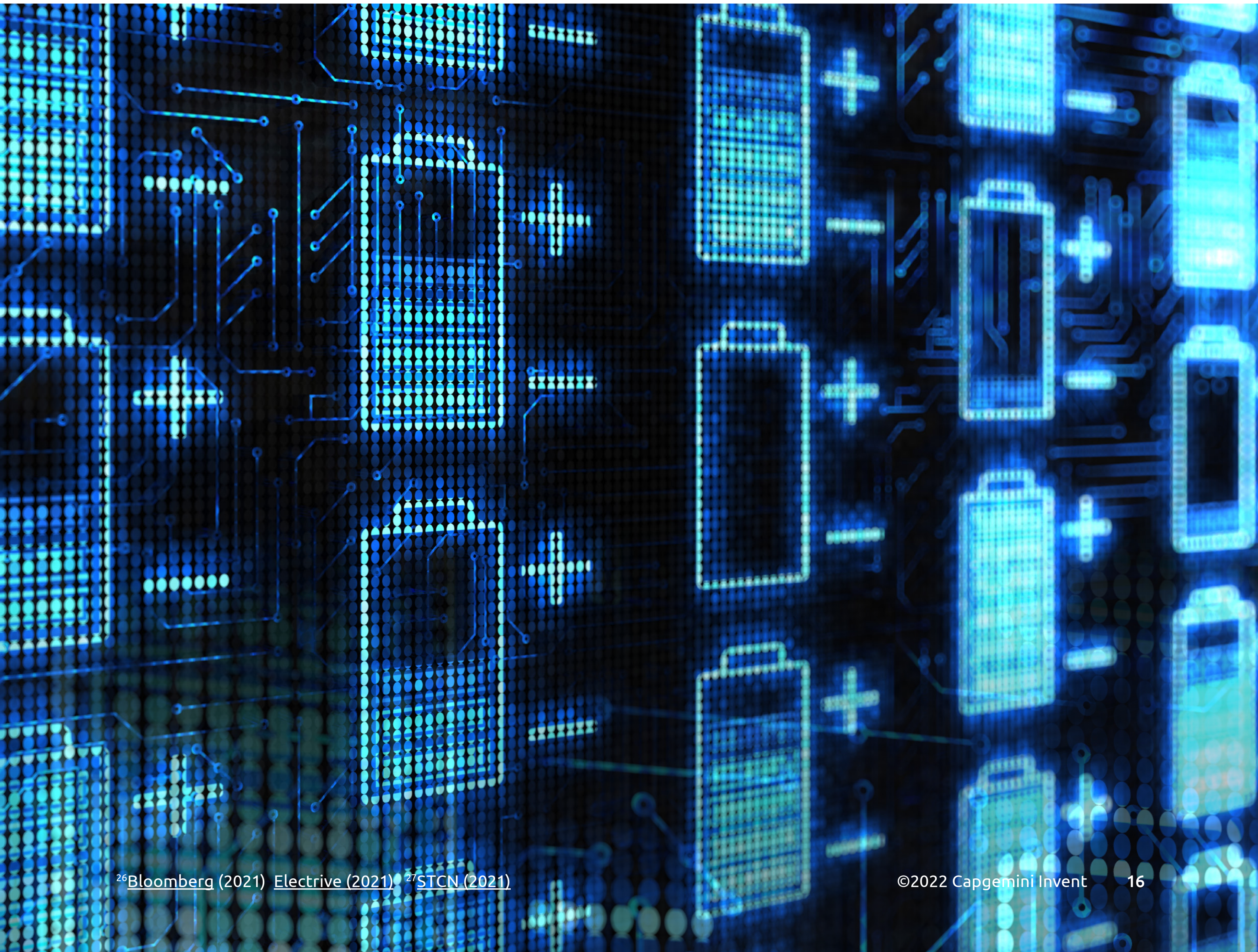
Electric vehicle lithium-ion batteries of the current generation use a wide range of different materials: On the cathode side, a range of materials – like copper, nickel, cobalt and manganese – is used as active material and an aluminum foil as a current collector. The anode consists of graphite, either natural or synthetic, and is based on petroleum coke. Sometimes silicon is added to further improve the overall energy density.

With each battery type there are trade-offs between power, energy, safety, lifespan, cost, and performance. Separator and electrolyte design also influence battery properties. Since the materials used are so important in terms of cost and in terms of vehicle properties such as range or vehicle design, we will have a deep dive in the raw materials market.

Li-Ion Chemistries: Cathode active materials differ between entry and high-end models

The relatively high financial and ESG costs of cobalt are leading to many recent initiatives to avoid or reduce the amount of cobalt used in batteries. From 2023 onwards, for example, Volkswagen plans to have a unified battery cell and will be deploying Lithium Iron Phosphate chemistries (LFP) in its entry models, nickel manganese in its volume models, and nickel-rich NMC in its high-end models. These cell chemistries use little or no cobalt.

Tesla, which presently uses a combination of nickel-cobalt-aluminum and nickel-manganese-cobalt cathodes in its standard range cars, started to shift to LFP worldwide. Although they are less energy dense, LFP-based lithium-ion batteries are lower in cost. Mercedes-Benz will also switch their EQA and EQB models to LFP chemistries to be able to offer price competitive offers in entry-level car segments.[26] While switching to LFP generally leads to price benefits, the higher volatility in the raw materials market led to a price increase for LFP BYD customers in 2021.[27]

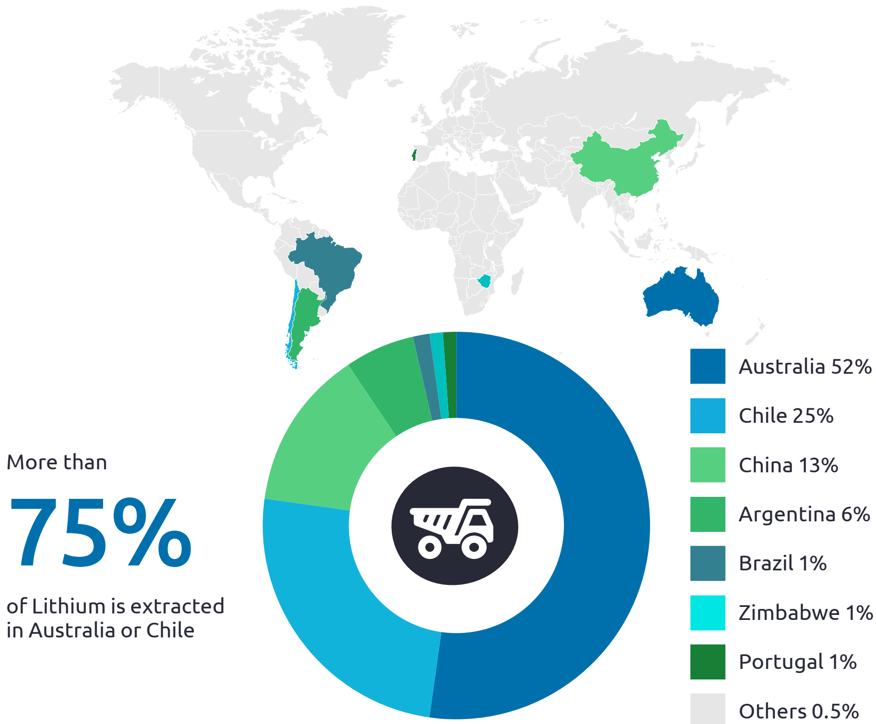


[26]Bloomberg (2021) Electrive (2021) [27]STCN (2021)

2.2 Raw materials sourcing: lithium

Lithium is a key component of automotive batteries, and even if there is a move to other cell chemistries, such as all solid state, lithium will remain a key component. As often cited by eMobility critics, lithium extraction, including the solvent and mining waste produced, presents environmental and health concerns, in addition to being volatile as a commodity.

Currently, lithium mine production is dominated by Australia and Chile, accounting for 75% of all lithium produced in 2021.[28]

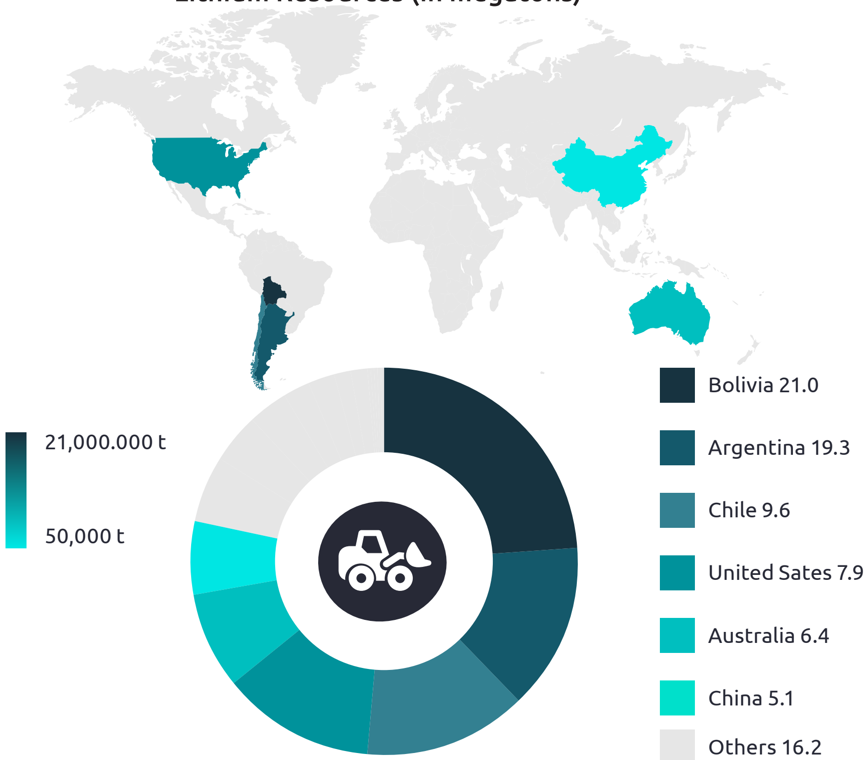


Raw Lithium is currently mostly mined in Australia and China, or extracted via evaporation ponds in Chile and Argentina

While lithium is currently mostly mined in South America, Australia, and China, there are identified resources available in North America and Europe, which could be used to implement a local supply chain.

Local supply chains can improve the security of supply, reduce CO2 transportation effects, and lead to better ESG ratings. Steps are being taken to infuse more responsibility into raw material mining and develop a more sustainable and ethical battery value chain.[29]

Lithium Resources (in megatons)



Identified raw lithium resources have increased to 86 megatons due to continuous exploration and rising lithium prices

[28]USGS (2022) [29]BASF (2021), Global Mining Review (2021)

A closer look at extraction

In Australia most lithium mining is of the hard rock spodumene variety, whereas in the South American countries, evaporation ponds are used to extract the lithium from saline brines. While hard rock spodumene mining has a higher CO2 footprint, there is less environmental risk due to less water consumption. Evaporation ponds are often criticized for their high levels of salt and sweet water consumption; however, the exact amount is still debated among scientists and much depends on the extraction method or if it is combined with direct lithium extraction (DLE).

DLE can be used, for example, in thermal water brines, where water contains a relatively high amount of lithium, as seen in Germany.
Deep sea mining is currently not in focus for many stakeholders in the battery value chain due to unforeseeable risks, such as noise or light pollution, destruction of marine life habitats, and chemical pollution, when extracting lithium from deep seabeds.

The following methods are used to extract lithium:

1. Hard rock mining and spodumene processing involves producing a lithium sulfate solution from mining and acid leaching the spodumene ores, which is then, using an electrochemical process, converted into lithium carbonate hydroxide.
Converting lithium carbonate into lithium metal requires an electrochemical process and leads to a high CO2 impact. This method dominates Australian production and accounted for the majority of lithium extracted in 2021.

2. Evaporation ponds use salt-rich waters pumped into evaporation ponds, and when the lithium chloride reaches the desired concentration, it is treated with sodium carbonate, precipitating lithium carbonate. These ponds are in areas in with high evaporation rates, such as the elevated deserts in South America, and the extraction and cleaning is often criticized for its high water consumption.

3. Direct lithium extraction (DLE) has recently gained in popularity and involves the absorption of lithium from saline water using a porous material that enables ion exchange, lithium bonding, and solvent extraction. Lithium is later released by washing it with hydrochloric acid. This method produces dilute lithium chloride, which has impurities. Alternative methods, such as thermal water extraction, are currently only being explored in small scale projects, for example, in Oberrheingraben, Germany.
If these projects can reach price competitiveness, they will become more attractive due to their more robust sustainability criteria.

4. Deep sea mining can liberate polymetallic nodules that contain minerals like cobalt or lithium. However, in 2021 the WWF and
a number of major companies, scientists, and political leaders pledged their support for a moratorium against deep sea mining due to the risks to ocean health.[30]

Looking at the different players in lithium mining, over the last years there has been a shift away from only a few larger players to a more diverse market, with many smaller initiatives emerging.

		Market Cap	2021 Revenue
GanfengLithium	Jiangxi Ganfeng Lithium Co. Ltd	38.6B	839M
ALBEMARLE	Albermarle	26.5B	3130M
TIANQI LITHIUM	Tianqi Lithium	11.8B	748M
SQM	Sociedad Química y Minera de Chile	24.1B	2868M
PILBARA MINERALS LIMITED	Pilbara Minerals	6.8B	176M

Vital statistics for mining companies

[30] WWF (2021)

2.3 A digital battery passport - possibly built on blockchain technology - could enable transparency across complex value chains

A digital product passport is already being evaluated in the EU, with numerous benefits and use cases for batteries.[31] Blockchain technology can provide irrefutable provenance of more ethically sourced raw materials and interest investors who may have otherwise been deterred. A supply chain infused with data from end to end also provides the flexibility to develop a more pluralistic network. It can respond as batteries evolve and react to geo-political impacts arising from conflict or trade tensions. It also enables strategies of securing raw materials supply, such as the investment in greenfield mining projects to bring new sources of raw materials directly into their supply chains. These strategies are already being implemented by some of the main EV suppliers in Europe or US.

To enable a transition to a circular economy, different actors in the value chain need to share information about products and materials - as well as the usage and charging behavior of the battery - all along the supply chain and to possible second life usage. Several start-ups use blockchain tech to help manufacturers, brands, and OEMs trace raw materials from their source to the end products. This is done by sharing data about their products while retaining information privacy.

Before the advent of blockchain tech, transparency of ethical and sustainable sourcing to interested parties was out of reach.
The sourcing of raw materials posed significant reputational, legal, and commercial risks.

A digital passport – possibly based on blockchain – can overcome this with:

- An incorruptible decentralized control that promotes trust
- An audit trail for irrefutable proof of ethical production of raw materials at every transfer step
- The secure storage of provenance information
- The sharing of data while protecting confidential information

Blockchain not only brings supply chain visibility, security, reduced risk, and flexibility to organizations it can also provide end-consumers with the reassurance that the products they are purchasing are ethically and sustainably sourced.[32 33]

[31]EU (2022) [32]Franks (2014) [33]Capgemini (2021)

2.4 The implications of volatile supply in the raw materials market

Currently, with EVs representing a minor stake of total car sales, supplies of nickel, cobalt, and lithium, are sufficient to meet demand. But with Electric vehicles projected to make up 31% of the global fleet by 2050,[34] we anticipate that there is a potential shortfall in the global mining capacity required to extract the minerals needed to manufacture the batteries to meet this projected demand.[35]

Such a shortfall in the raw materials essential for battery production, as EV demand rises, could result in OEMs struggling to fill orders and consumers being deterred from EV ownership by long waiting lists. This would, in turn, mean that the market for EVs is at risk of stalling at very moment it should be accelerating.

We see the following as the main factors that could contribute to a sub-optimal supply to meet demand:

Price volatility

A volatile market impacts everyone, not just the companies extracting raw materials and those considering starting such operations, the OEMs intending the ramp up EV production, and the potential end-users of EVs. For example, battery grade lithium is averaging $76,700 a ton, up 95% since the beginning of 2022. In 2021, the commodity was trading at $13,400 a ton.[36] It also presents significant challenges in financing. Concerns over price volatility, and the nascent character of the sector mean that funders are working out what sort of offtake commitments they are willing to accept from particular projects.

Uncertainty over future battery compositions

As discussed earlier, as the industry moves towards the optimal battery chemistry per use case, the precise make-up of raw materials needed is still indetermined and in flux. For example, the next generation of batteries may result in a decrease in nickel and cobalt demand.

The need for transparency and data and risk management

There is a growing need for transparency and risk management in the raw materials supply chain. With up to US$30-45 billion needing to be invested in mining capacity by 2025[37] in order to meet the demand for EVs and the batteries, it is imperative that as many roadblocks to such large-scale investment are removed as possible. We believe the recent digital advances of data can provide the foundation for more effective tracing and tracking of materials that can assuage the concerns of potential investors. As mentioned earlier, blockchain technology is opening all kinds of doors.

An increase in raw materials mining will need to be supported by an appropriate risk management program that covers such issues as child labor, human rights, and supply chain due diligence and management.

Key considerations

Although Europe and the US do not play a major role in battery raw material production today, theoretically, most of the resources needed are available in Europe and the US. But to build up the necessary mining and raw material industry, long lasting projects are necessary – the building and development of new mines can require over a decade.[38] Therefore, supply security is especially challenging, something that will increase in the near future as the demand for batteries quickly rises.

[34]Electrek (2021) [35]Linklaters (2019) [36]Benchmark Minerals (2022)
[37]Horizonte Minerals (2021) [38]CNN (2022)

How is R&D evolving to produce stronger batteries?
Find out next week in chapter III of Powering Change, or download the full report now on our website.

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