The Key Minerals in an EV Battery

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Breaking Down the Key Minerals in an EV Battery

Inside practically every electric vehicle (EV) is a lithium-ion battery that depends on several key minerals that help power it.

Some minerals make up intricate parts within the cell to ensure the flow of electrical current. Others protect it from accidental damage on the outside.

This infographic uses data from the European Federation for Transport and Environment to break down the key minerals in an EV battery. The mineral content is based on the 'average 2020 battery', which refers to the weighted average of battery chemistries on the market in 2020.

The Battery Minerals Mix

The cells in the average battery with a 60 kilowatt-hour (kWh) capacity—the same size that's used in a Chevy Bolt—contained roughly **185 kilograms** of minerals. This figure excludes materials in the electrolyte, binder, separator, and battery pack casing.

Mineral	Cell Part	Amount Contained in the Avg. 2020 Battery (kg)	% of Total
Graphite	Anode	52kg	28.1%
Aluminum	Cathode, Casing, Current collectors	35kg	18.9%
Nickel	Cathode	29kg	15.7%
Copper	Current collectors	20kg	10.8%
Steel	Casing	20kg	10.8%
Manganese	Cathode	10kg	5.4%
Cobalt	Cathode	8kg	4.3%
Lithium	Cathode	6kg	3.2%
Iron	Cathode	5kg	2.7%
Total	**N/A**	**185kg**	**100%**

The cathode contains the widest variety of minerals and is arguably the most important and expensive component of the battery. The composition of the cathode is a major determinant in the performance of the battery, with each mineral offering a unique benefit.

For example, NMC batteries, which accounted for **72%** of batteries used in EVs in 2020 (excluding China), have a cathode composed of nickel, manganese, and cobalt along with lithium. The higher nickel content in these batteries tends to increase their energy density or the amount of energy stored per unit of volume, increasing the driving range of the EV. Cobalt and manganese often act as stabilizers in NMC batteries, improving their safety.

Altogether, materials in the cathode account for **31.3%** of the mineral weight in the average battery produced in 2020. This figure doesn't include aluminum, which is used in nickel-cobalt-aluminum (NCA) cathode chemistries, but is also used elsewhere in the battery for casing and current collectors.

Meanwhile, graphite has been the go-to material for anodes due to its relatively low cost, abundance, and long cycle life. Since the entire anode is made up of graphite, it's the single-largest mineral component of the battery. Other materials include steel in the casing that protects the cell from external damage, along with copper, used as the current collector for the anode.

Minerals Bonded by Chemistry

There are several types of lithium-ion batteries with different compositions of cathode minerals. Their names typically allude to their mineral breakdown.

For example:

- **NMC811 batteries cathode composition:**
  80% nickel
  10% manganese
  10% cobalt
- **NMC523 batteries cathode composition**:
  50% nickel
  20% manganese
  30% cobalt

Here's how the mineral contents differ for various battery chemistries with a 60kWh capacity:

HOW BATTERY CHEMISTRIES DIFFER, BY MINERAL CONTENT

FOR A 60KWH LITHIUM-ION BATTERY

The name of the battery chemistry typically indicates the composition of the cathode.

	NMC811 Nickel (80%) Manganese (10%) Cobalt (10%)	NMC523 Nickel (50%) Manganese (20%) Cobalt (30%)	NMC622 Nickel (60%) Manganese (20%) Cobalt (20%)	NCA+ Nickel Cobalt Aluminum Oxide	LFP Lithium iron phosphate
LITHIUM	5KG	7KG	6KG	6KG	6KG
COBALT	5KG	11KG	11KG	2KG	0KG
NICKEL	39KG	28KG	32KG	43KG	0KG
MANGANESE	5KG	16KG	10KG	0KG	0KG
GRAPHITE	45KG	53KG	50KG	44KG	66KG
ALUMINUM	30KG	35KG	33KG	30KG	44KG
COPPER	20KG	20KG	19KG	17KG	26KG
STEEL	20KG	20KG	19KG	17KG	26KG
IRON	0KG	0KG	0KG	0KG	41KG

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With consumers looking for higher-range EVs that do not need frequent recharging, nickel-rich cathodes have become commonplace. In fact, nickel-based chemistries accounted for **80%** of the battery capacity deployed in new plug-in EVs in 2021.

Lithium iron phosphate (LFP) batteries do not use any nickel and typically offer lower energy densities at better value. Unlike nickel-based batteries that use lithium hydroxide compounds in the cathode, LFP batteries use lithium carbonate, which is a cheaper alternative. Tesla recently joined several Chinese automakers in using LFP cathodes for standard-range cars, driving the price of lithium carbonate to record highs.

The EV battery market is still in its early hours, with plenty of growth on the horizon. Battery chemistries are constantly evolving, and as automakers come up with new models with different characteristics, it'll be interesting to see which new cathodes come around the block.

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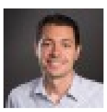
The cost of electric vehicle batteries can vary based on size and chemical composition. Here are the battery costs of six popular EV models.



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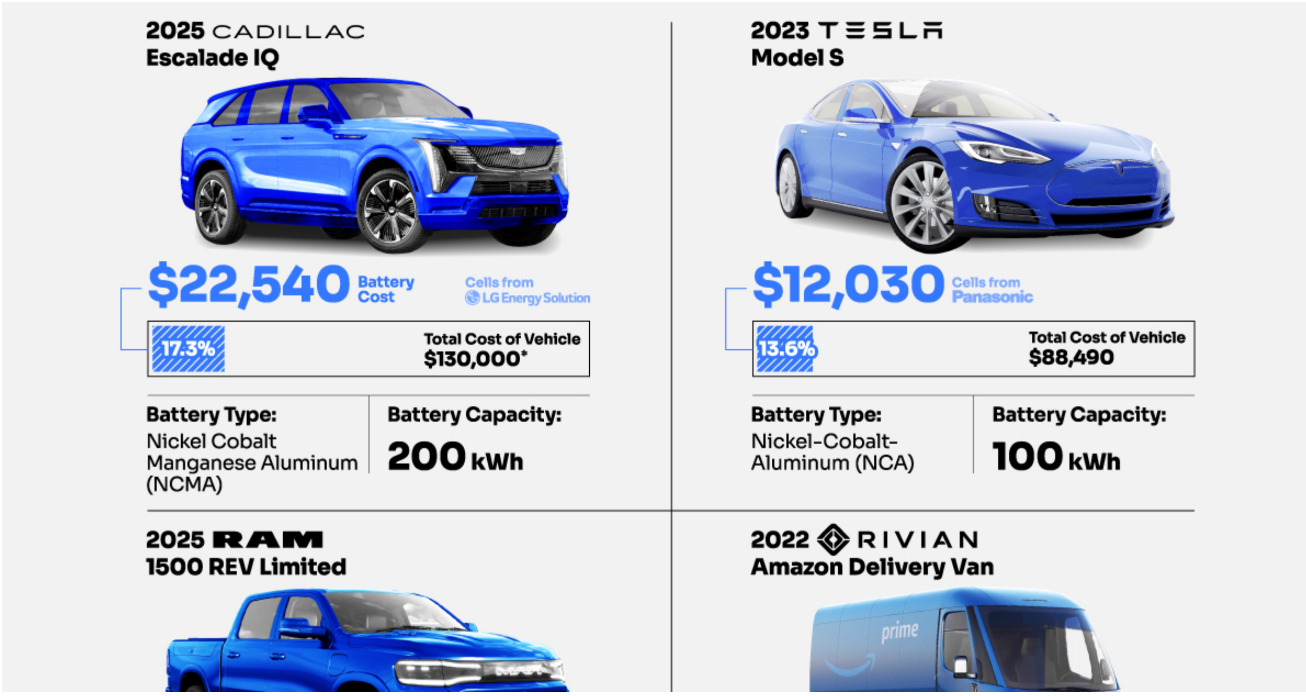

What is the Cost of Electric Vehicle Batteries?

The cost of an electric vehicle (EV) battery pack can vary depending on composition and chemistry.

In this graphic, we use data from Benchmark Minerals Intelligence to showcase the different costs of battery cells on popular electric vehicles.

Size Matters

Some EV owners are taken by surprise when they discover the cost of replacing their batteries.

Depending on the brand and model of the vehicle, the cost of a new lithium-ion battery pack might be as high as $25,000:

Vehicle	Battery Type	Battery Capacity	Battery Cost	Total Cost of EV
2025 Cadillac Escalade IQ	Nickel Cobalt Manganese Aluminum (NCMA)	200 kWh	$22,540	$130,000
2023 Tesla Model S	Nickel Cobalt Aluminum (NCA)	100 kWh	$12,030	$88,490
2025 RAM 1500 REV	Nickel Cobalt Manganese (NCM)	229 kWh	$25,853	$81,000

Vehicle	Battery Type	Battery Capacity	Battery Cost	Total Cost of EV
2022 Rivian Delivery Van	Lithium Iron phosphate (LFP)	135 kWh	$13,298	$52,690
2023 Ford Mustang	Lithium Iron Phosphate (LFP)	70 kWh	$6,895	$43,179
2023 VW ID.4	Nickel Cobalt Manganese (NCM622)	62 kWh	$8,730	$37,250

The price of an EV battery pack can be shaped by various factors such as raw material costs, production expenses, packaging complexities, and supply chain stability. One of the main factors is chemical composition.

Graphite is the standard material used for the anodes in most lithium-ion batteries.

However, it is the mineral composition of the cathode that usually changes. It includes lithium and other minerals such as nickel, manganese, cobalt, or iron. This specific composition is pivotal in establishing the battery's capacity, power, safety, lifespan, cost, and overall performance.

Lithium nickel cobalt aluminum oxide (NCA) battery cells have an average price of **$120.3** per kilowatt-hour (kWh), while lithium nickel cobalt manganese oxide (NCM) has a slightly lower price point at **$112.7 per kWh**. Both contain significant nickel proportions, increasing the battery's energy density and allowing for longer range.

At a lower cost are lithium iron phosphate (LFP) batteries, which are cheaper to make than cobalt and nickel-based variants. LFP battery cells have an average price of **$98.5 per kWh**. However, they offer less specific energy and are more suitable for standard- or short-range EVs.

Which Battery Dominates the EV Market?

In 2021, the battery market was dominated by NCM batteries, with 58% of the market share, followed by LFP and NCA, holding 21% each.

Looking ahead to 2026, the market share of LFP is predicted to nearly double, reaching 38%.

NCM is anticipated to constitute 45% of the market and NCA is expected to decline to 7%.

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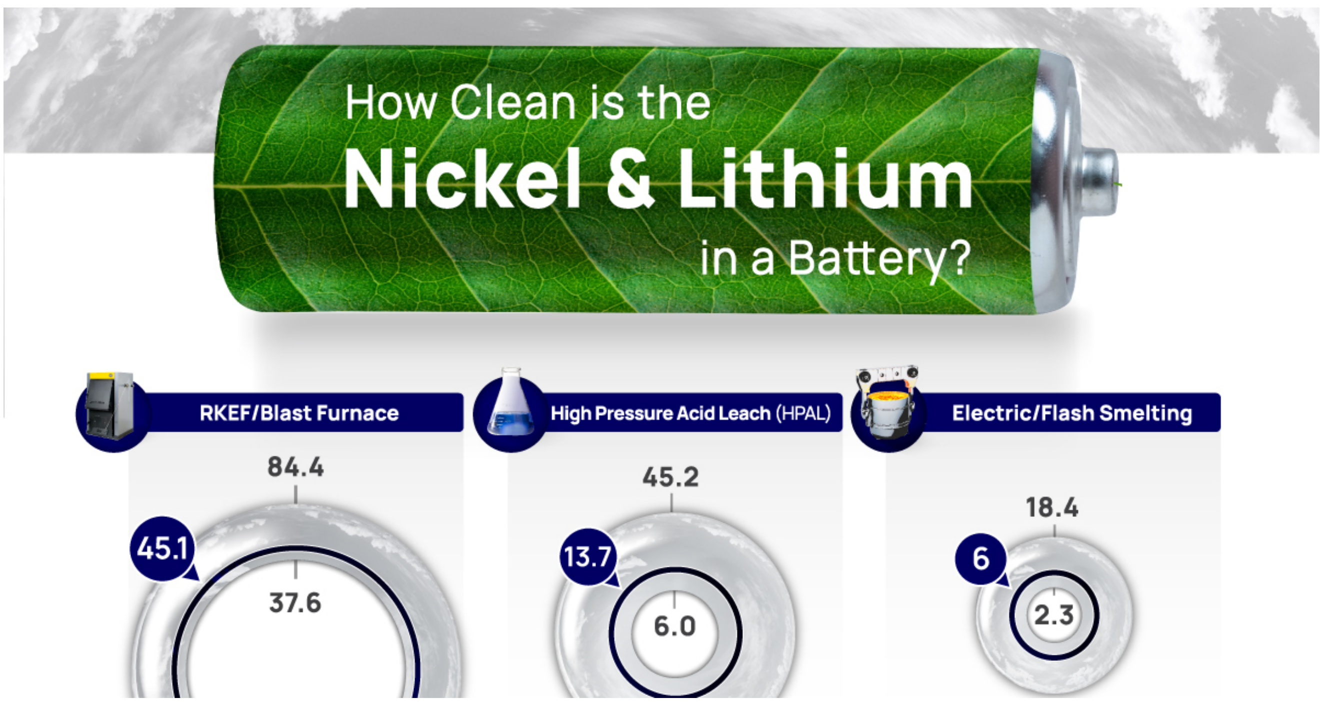

How Clean is the Nickel and Lithium in a Battery?

The production of lithium (Li) and nickel (Ni), two key raw materials for batteries, can produce vastly different emissions profiles.

This graphic from Wood Mackenzie shows how nickel and lithium mining can significantly impact the environment, depending on the processes used for extraction.

Nickel Emissions Per Extraction Process

Nickel is a crucial metal in modern infrastructure and technology, with major uses in stainless steel and alloys. Nickel's electrical conductivity also makes it ideal for facilitating current flow within battery cells.

Today, there are two major methods of nickel mining:

- From **laterite deposits**, which are predominantly found in tropical regions. This involves open-pit mining, where large amounts of soil and overburden need to be removed to access the nickel-rich ore.

- From **sulphide ores**, which involves underground or open-pit mining of ore deposits containing nickel sulphide minerals.

Although nickel laterites make up 70% of the world's nickel reserves, magmatic sulphide deposits produced 60% of the world's nickel over the last 60 years.

Compared to laterite extraction, sulphide mining typically emits fewer tonnes of CO2 per tonne of nickel equivalent as it involves less soil disturbance and has a smaller physical footprint:

Ore Type	Process	Product	Tonnes of CO2 per tonne of Ni equivalent
Sulphides	Electric / Flash Smelting	Refined Ni / Matte	6
Laterite	High Pressure Acid Leach (HPAL)	Refined Ni / Mixed Sulpide Precipitate / Mixed Hydroxide Precipitate	13.7
Laterite	Blast Furnace / RKEF	Nickel Pig Iron / Matte	45.1

Nickel extraction from laterites can impose significant environmental impacts, such as deforestation, habitat destruction, and soil erosion.

Additionally, laterite ores often contain high levels of moisture, requiring energy-intensive drying processes to prepare them for further extraction. After extraction, the smelting of laterites requires a significant amount of energy, which is largely sourced from fossil fuels.

Although sulphide mining is cleaner, it poses other environmental challenges. The extraction and processing of sulphide ores can release sulphur compounds and heavy metals into the environment, potentially leading to acid mine drainage and contamination of water sources if not managed properly.

In addition, nickel sulphides are typically more expensive to mine due to their hard rock nature.

Lithium Emissions Per Extraction Process

Lithium is the major ingredient in rechargeable batteries found in phones, hybrid cars, electric bikes, and grid-scale storage systems.

Today, there are two major methods of lithium extraction:

- From **brine**, pumping lithium-rich brine from underground aquifers into evaporation ponds, where solar energy evaporates the water and concentrates the lithium content. The concentrated brine is then further processed to extract lithium carbonate or hydroxide.
- **Hard rock** mining, or extracting lithium from mineral ores (primarily spodumene) found in pegmatite deposits. Australia, the world's leading producer of lithium (46.9%), extracts lithium directly from hard rock.

Brine extraction is typically employed in countries with salt flats, such as Chile, Argentina, and China. It is generally considered a lower-cost method, but it can have environmental impacts such as water usage, potential contamination of local water sources, and alteration of ecosystems.

The process, however, emits fewer tonnes of CO_2 per tonne of lithium-carbonate-equivalent (LCE) than mining:

Source	Ore Type	Process	Tonnes of CO_2 per tonne of LCE
Mineral	Spodumene	Mine	9
Mineral	Petalite, lepidolite and others	Mine	8
Brine	N/A	Extraction/Evaporation	3

Mining involves drilling, blasting, and crushing the ore, followed by flotation to separate lithium-bearing minerals from other minerals. This type of extraction can have environmental impacts such as land disturbance, energy consumption, and the generation of waste rock and tailings.

Sustainable Production of Lithium and Nickel

Environmentally responsible practices in the extraction and processing of nickel and lithium are essential to ensure the sustainability of the battery supply chain.

This includes implementing stringent environmental regulations, promoting energy efficiency, reducing water consumption, and exploring cleaner technologies. Continued research and development efforts focused on improving extraction methods and minimizing environmental impacts are crucial.

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