Charging Toward Zero Emissions:

Evaluating Climate Progress by Top EV Battery Manufacturers

GREENPEACE

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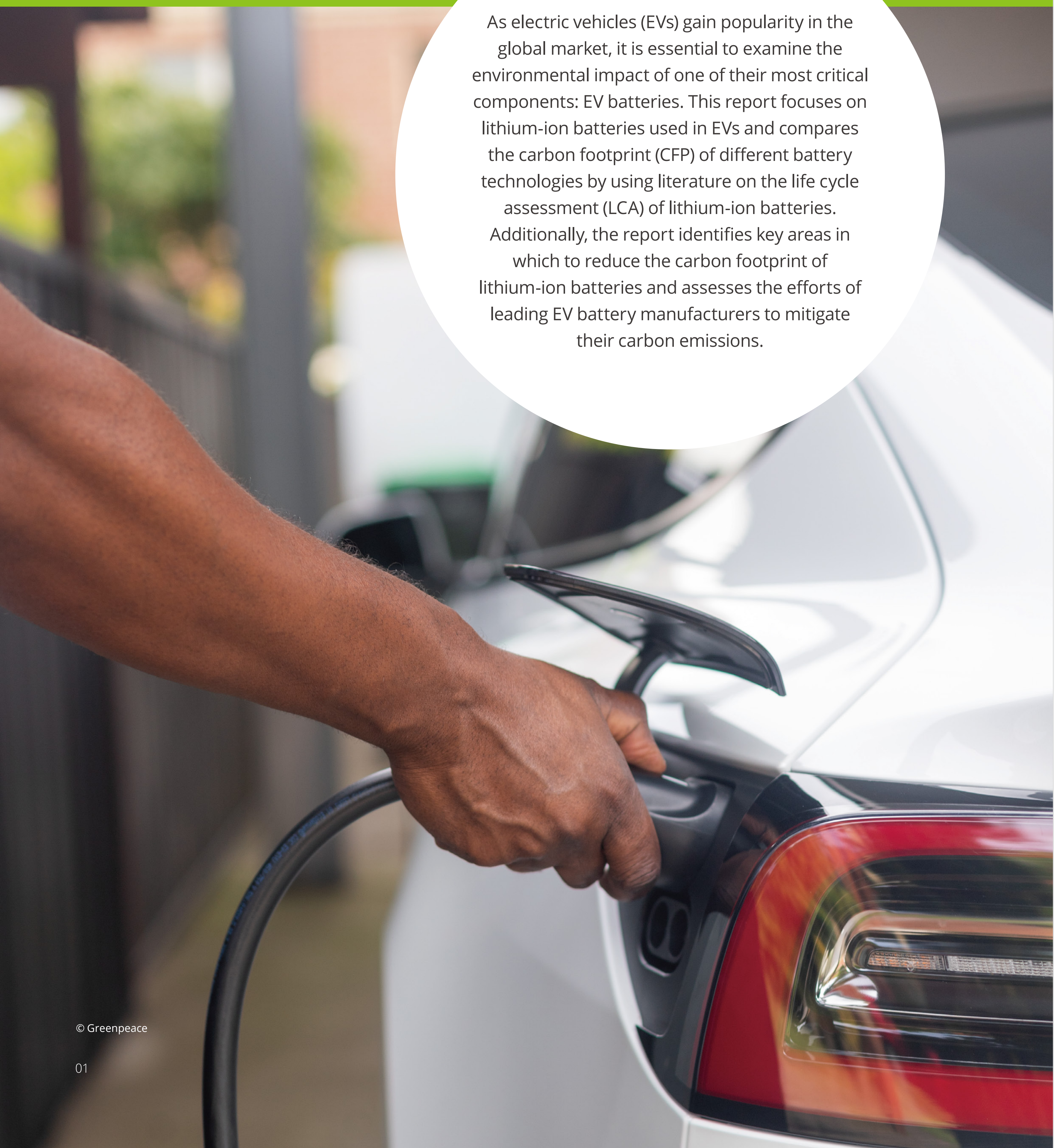
Executive summary

As electric vehicles (EVs) gain popularity in the global market, it is essential to examine the environmental impact of one of their most critical components: EV batteries. This report focuses on lithium-ion batteries used in EVs and compares the carbon footprint (CFP) of different battery technologies by using literature on the life cycle assessment (LCA) of lithium-ion batteries. Additionally, the report identifies key areas in which to reduce the carbon footprint of lithium-ion batteries and assesses the efforts of leading EV battery manufacturers to mitigate their carbon emissions.



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Key findings

- **The carbon footprint of lithium-ion batteries with different cathode chemistries**

The carbon footprint of lithium-ion batteries with different cathode chemistries varies based on the carbon intensity of the electricity used in manufacturing and the regions where cathode materials are produced. However, in our comparison under the same conditions and assumptions, we find that the carbon footprint of lithium iron phosphate (LFP) batteries is lower than that of lithium nickel manganese cobalt oxides (NMC) batteries. **The ranking of carbon footprint values (kg CO_2/kWh) for commonly used battery types is as follows: LFP < NMC811 < NMC622 < NMC111.**

- **Emission hotspots of manufacturing lithium-ion batteries**

This report identifies two major sources of emissions that significantly contribute to the carbon footprint of lithium-ion batteries: battery manufacturing and the production of cathode materials. For LFP batteries, manufacturing accounts for 35.83% and cathode production accounts for 29.41% of the total carbon footprint. In contrast, for NMC batteries, the contribution from cathode materials increases with higher nickel content: 38.28% for NMC 111, 44.56% for NMC 622, and 57.71% for NMC 811. The report findings suggest that to reduce carbon emissions, battery manufacturers will need to focus on accelerating the adoption of renewable electricity in battery manufacturing and sourcing low-carbon cathode materials.

- **The impact of energy sources**

This report suggests that the manufacturing stage of battery production—responsible for roughly one-third of cradle-to-gate carbon dioxide (CO_2) emissions—can be highly electricity-intensive and therefore overwhelmingly dependent on the carbon intensity of the local grid. Leading manufacturers such as CATL, BYD, and LGES operate hundreds of gigawatt-hours of capacity in China and Poland, where carbon intensity of electricity exceeds 500 g CO_2/kWh, resulting in manufacturing emissions two to four times higher than those of comparable European facilities. Given this dependency, securing green power is the most effective lever for battery makers to decouple production from dirty grids and change the upstream carbon curve into a downward trend for carbon emissions.

- **Assessment of the decarbonization efforts of battery manufacturers**

Electricity consumption during the manufacturing stage and the production of cathode materials are major sources of emissions that contribute significantly to the carbon footprint of EV batteries. This report examines the carbon reduction initiatives employed by the top ten battery manufacturers regarding renewable electricity commitments and supply chain. The assessment is as follows:

- Only three of the top ten battery manufacturers have committed to 100% renewable electricity for their operations and established carbon reduction targets for their supply chains, addressing key GHG emission sources in EV battery production—electricity use and supply chain emissions.The remaining seven lack one or both, highlighting a significant gap in the industry's decarbonization efforts for EV battery manufacturing.
- CATL, LGES, and Panasonic Energy address their emission hotspots through committing to achieve 100% renewable electricity at the company level and setting reduction targets for their suppliers or supply chain.
- CALB, Gotion, SK On, Sunwoda and Samsung SDI lack either reduction targets for suppliers or a commitment to 100% renewable electricity. Specifically, SK On, Sunwoda, and Samsung SDI do not have emissions reduction targets for their supply chains, which account for a significant portion of the GHG emissions associated with manufacturing EV batteries. CALB and Gotion have yet to commit to 100% renewable electricity.
- BYD and EVE lack commitments to 100% renewable electricity and reduction targets for their suppliers, which are crucial for decarbonization of EV battery production.

Table 1: An evaluation of plans to address greenhouse gas emissions hotspots in battery production by manufacturers.

Name	Market Share	Concrete Action Plan for Addressing GHG Emission Hotspots	
		100% Renewable Electricity Commitment at the Company Level	Setting Reduction Targets for Supply Chain
CATL	38.18%	√	√
LGES	12.02%	√	√
Panasonic Energy	4.01%	√	√
CALB	4.41%	No information	√
Gotion	3.21%	No information	√
Samsung SDI	3.81%	√	No information
SK On	3.11%	√	No information
Sunwoda	2.10%	√	No information
BYD	16.53%	No information	No information
EVE	2.81%	No information	No information

Recommendations

Based on the findings of this report, a series of measures are recommended to battery manufacturers and policymakers to achieve decarbonization.

- **Accelerate the adoption of renewable electricity with clear targets and timelines**

The recommendation to battery manufacturers is to strive for a 100% renewable electricity ratio as quickly as possible. Specifically, the report authors suggest that manufacturers commit to setting renewable electricity targets with deadlines no later than 2030. Additionally, manufacturers should regularly monitor and report their progress in adopting renewable electricity. By accelerating this transition, battery manufacturers can significantly reduce the carbon footprint of their products, meet the demands for low-carbon batteries, and contribute to the broader goal of achieving net-zero targets.

- **Decarbonize the supply chain**

Given that a significant portion of the carbon footprint in battery production is from the upstream supply chain, the recommended action to battery manufacturers is to establish numerical carbon reduction targets with specific timelines for carbon-intensive materials and their suppliers. Without decarbonizing their supply chains, battery manufacturers risk losing their competitive edge as the EU Batteries Regulation is implemented.

- **Advance the use of recycled raw materials**

Battery manufacturers are recommended to establish targets for using recycled raw materials in their products and regularly report on their progress. With the EU Batteries Regulation (adopted in July 2023) mandating minimum levels of recycled content for critical minerals including nickel, cobalt, and lithium, compliance with the requirements is imperative for battery manufacturers. However, setting ambitious targets for using recycled materials beyond regulatory minimum requirements and investing in recycled raw materials can provide additional benefits for manufacturers, such as reducing the carbon footprint of their products, minimizing the environmental and social impacts of raw material extraction, and mitigating risks associated with global supply chain disruption.

- **Enhance the transparency of emission data**

Battery manufacturers are recommended to provide comprehensive reports on the climate impacts of their operations and value chains. Specifically, the recommendation is that battery manufacturers are transparent about their Scope 1, 2, and 3 emissions, including a detailed breakdown of Scope 3 emissions. Additionally, manufacturers should report their progress on all sustainability targets they have committed to, including net-zero commitments and interim carbon reduction goals. They should also disclose the carbon footprint of their batteries, enabling consumers to make informed choices about sustainable products. Furthermore, the report authors urge policymakers around the world to collaborate in strengthening transparency requirements for climate information related to batteries.

Contents

Glossary/Acronym

Al	Aluminium
BEV	Battery Electric Vehicle
CFP	Carbon Footprint of a Product
CAM	Cathode Active Materials
CATL	Contemporary Amperex Technology Co. Limited
CALB	China Aviation Lithium Battery
EV	Electric Vehicle
EVE	EVE Energy Co., Ltd.
EU	European Union
GHG	Greenhouse gas
Gotion	Gotion High-tech Co., Ltd.
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Technology
GWh	Gigawatt hour, a unit of energy representing one billion watt hours
GWP	Global Warming Potential
ICE	Internal Combustion Engine
IEA	International Energy Agency
KWh	Kilowatt hours
LCA	Life Cycle Assessment
LFP	Lithium Iron Phosphate Battery
LGES	LG Energy Solution Ltd.
LIB	Lithium-ion Batteries
NCA	Nickel Cobalt Aluminum Oxide
NMC[1]	Lithium Nickel Manganese Cobalt Oxide
NMC 111	$LiNi_{0.33}Mn_{3.33}Co_{0.33}O_2$
NMC 532	$LiNi_{0.5}Mn_{0.3}Co_{0.2}O_2$
NMC 622	$LiNi_{0.6}Mn_{0.1}Co_{0.2}O_2$
NMC 811	$LiNi_{0.8}Mn_{0.1}Co_{0.1}O_2$
SBTi	Science Based Targets Initiative
SK On	SK On Co., Ltd.
Sunwoda	Sunwoda Electronic Co., Ltd.

[1] The NMC cathode chemistry comes in various commercial formulations, mainly NMC111, NMC622, and NMC811, where the numerical suffixes—111, 622, and 811—represent the molar proportions of nickel, manganese, and cobalt in the cells, respectively.

Chapter 1

Introduction and Methods

1.1

Research background

The transport sector is the third largest source of carbon emissions after electricity and industry, accounting for more than one-third of end-user emissions [1]. Due to the potential to reduce greenhouse gas (GHG) emissions in the transport sector, electric vehicles (EVs) were considered an alternative to internal combustion engine vehicles (ICEV). Governments around the world have enacted relevant laws and bills to promote EVs, such as the Net Zero Industry Act in the EU, the "14th Five-Year Plan" in China and the Production Linked Incentive (PLI) scheme in India. According to International Energy Agency (IEA) report data, EV markets are experiencing stable growth, with sales nearing 14 million in 2023. From 2020 to 2023, the share of EVs in total sales has increased from about 4% to 18%, and are expected to increase to 17 million by the end of 2024 [2].

EV batteries are an essential component of EVs and according to the IEA, under the stated policies scenario, EV battery demand is projected to grow **four-and-a-half times** by 2030 and almost seven times by 2035 compared to 2023 [3, p. 142]. With the IEA's announced pledges scenario and the net zero emissions by 2050 scenario, demands could be significantly higher [3, p. 142].

This report focuses on lithium-ion batteries used in EVs and compares the carbon footprint (CFP) of different battery technologies by using literature on the life cycle assessment (LCA) of lithium-ion batteries. Additionally, it identifies key areas for reducing the carbon footprint of lithium-ion batteries and assesses the efforts of leading EV battery manufacturers to mitigate their carbon emissions and reduce the environmental impact of EV batteries.

1.2

Research methods

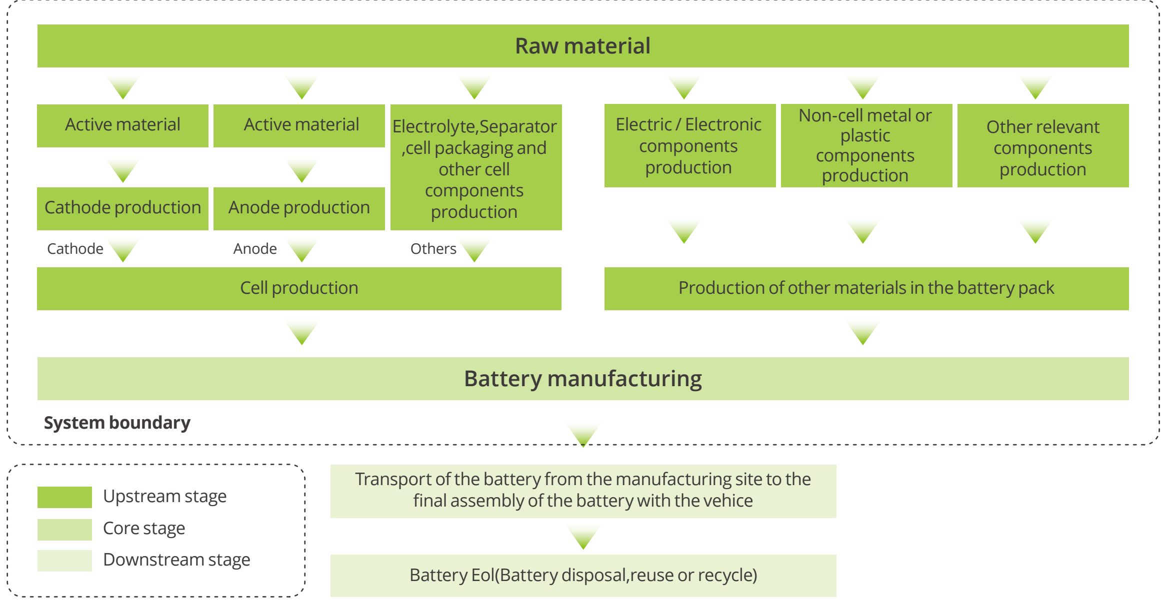
1.2.1 Research objectives

- Compare the carbon footprint (CFP) of different battery technologies.
- Identify the key emission reduction hotspots in the battery industry.
- Assess leading battery manufacturers' decarbonization efforts.

1.2.2 Scope and system boundaries

This analysis covers six battery chemistries—$LiFePO_4$ (LFP); four grades of nickel-manganese-cobalt (NMC 111, 532, 622, 811); and lithium-nickel-cobalt-aluminium oxide (NCA)—chosen for their market dominance and robust life cycle assessment data. Our system boundary extends from the extraction of raw materials to battery manufacturing (cradle-to-gate), with a functional unit of 1 kWh of usable capacity. The boundary of cradle-to-gate includes both the core and upstream stages, as shown in Figure 1.

Figure 1: System boundary of batteries from cradle to gate



Regarding the scope of battery manufacturers, this study selected ten EV battery manufacturers with the highest global market share in 2024: CATL (Contemporary Amperex Technology Co. Limited), BYD[2] , LGES (LG Energy Solution Ltd.), CALB (China Aviation Lithium Battery), Panasonic Energy (Panasonic Energy Co., Ltd.), Samsung SDI (Samsung SDI Co., Ltd.), Gotion (Gotion High-tech Co., Ltd.), SK On (SK On Co., Ltd.), EVE (EVE Energy Co., Ltd.), Sunwoda (Sunwoda Electronic Co., Ltd.). The combined global sales of the ten EV battery manufacturers in 2024 reached 900 GWh, accounting for 90.18% of the total global EV battery market share that same year[3] . The market share of each company is in Appendix II.

1.2.3 Data collection

All CFP figures are drawn from over 30 peer-reviewed life cycle assessment studies and publicly available research reports. To ensure comparability, we controlled for system boundaries and functional units and applied the following standards:

- Anode material: Graphite across all studies.
- Life cycle assessment databases: Restricted to GREET(Greenhouse gases,Regulated Emissions, and Energy use in Technologies), Ecoinvent, or Gabi.
- Life-cycle inventory data sources: Primary data or high-quality secondary data.

Results are disaggregated by region (China, Europe, the United States, Japan and South Korea), with further supply-chain details discussed in the report. All data are current through April 30, 2025.

Battery manufacturers' product portfolios, factory location, and capacity data were extracted from MarkLines and retrieved between January and May 2025. Information on EV battery manufacturers' climate targets and emission data was found in the companies' publicly released statements and sustainability and ESG reports. The latest versions of sustainability and ESG reports, as of May 9, 2025, were used. In addition, the team contacted ten battery manufacturers to verify the information relevant to each company and incorporated their feedback to update the data accordingly.

1.2.4 Analysis

For each battery chemistry and region, we calculated the mean, median, and range of CFP (kg CO_2 eq/kWh) and performed chemistry comparisons in each region. We also decomposed the cradle-to-gate CFP into key component contributions—cathode materials, anode, manufacturing energy, and others—to identify which stages drive the bulk of emissions. Finally, we drew on targeted literature reviews to explore critical factors—such as electricity-grid carbon intensity and raw-material sourcing—that warrant deeper discussion for future decarbonization strategies.

1.2.5 Limitation

This study depends on secondary data with varying vintages and geographic coverage, which may introduce uncertainty when comparing closely clustered CFP values. Please refer to the detailed data tables for precise figures and consider these potential discrepancies when interpreting the comparative results.

[2] In this report, BYD refers to FinDreams Battery Co., Ltd. The predecessor of FinDreams Battery Co., Ltd. was BYD Lithium Battery Co.,and FinDreams Battery produces consumer batteries, electronic batteries, electric vehicle batteries and energy storage batteries. Please see reference [4].

[3] The statistical scope is based on the 2024 shipment record by company published by SNE, market shares are calculated from its data. Source in reference [5].

Chapter 2

An analysis of the carbon footprint of electric vehicle batteries and emissions hotspots

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2.1

Overview of electric vehicle battery technologies

Lithium-ion batteries dominate the EV market due to their balance of performance, cost, and scalability. A lithium-ion battery cell consists of four main components: a cathode, an anode, an electrolyte, and a separator. Within the lithium-ion family, lithium-ion batteries comprise different chemistries, each with unique properties that affect performance, cost, and environmental impact. The most common types of cathode chemistries are: lithium nickel manganese cobalt oxide (NMC); lithium iron phosphate (LFP); and lithium nickel cobalt aluminum oxide (NCA).

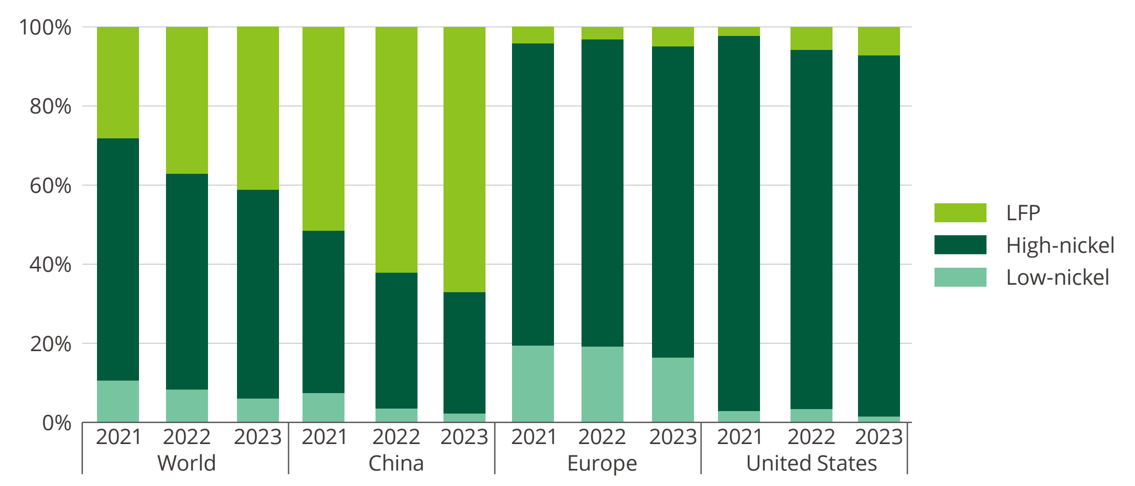
Each battery with different cathode chemistries has distinct features, as summarized in Table 1. NMC and NCA batteries offer high energy densities, enabling longer vehicle ranges. In contrast, LFP batteries have a lower energy density, resulting in shorter ranges. However, LFP excels in affordability and durability—it is cheaper than NMC and NCA and boasts a longer lifespan. Due to these differences, each technology suits specific applications: NMC and NCA are often preferred for mid- to long-range EVs despite higher costs, while LFP is more ideal for budget-friendly electric vehicles.

Table 1: Key characteristics of different battery types[4]

Battery	Energy density (Wh/kg)	Cycle life	Cost ($/kWh)
NMC	High	Medium	Medium
NCA	High	Medium	High
LFP	Low	High	Low

Regarding the battery capacity for electric vehicle sales categorized by chemistry, NMC and NCA have collectively outperformed LFP on a global scale, comprising 60% [7] of the market share in 2023. China serves as a pivotal hub for LFP production and adoption, with two-thirds [8] of electric vehicle sales in the country utilizing this chemistry during the same year. Conversely, NMC has established a dominant presence in both the European and US markets, accounting for over 90% [8] of sales in each region.

Figure 2: Share of battery capacity of electric vehicle sales by chemistry and region, 2021-2023[5] [3]



Despite the dominance of lithium-ion batteries, their limitations—such as high costs and reliance on critical minerals such as cobalt and lithium—have prompted interest in alternative solutions. For example, sodium-ion batteries have garnered significant attention due to their cost-effectiveness and sustainability. The widespread availability of sodium has the potential to reduce dependence on scarce resources and mitigate environmental and social concerns associated with cobalt and lithium mining. Additionally, sodium-ion batteries are more cost effective than the lithium-ion batteries due to the abundance of sodium [8]. However, ongoing research is necessary to address the challenges faced by sodium-ion batteries, including limited energy density and charge efficiency.

[4] Data adopted from [6].

[5] Low-nickel includes lithium nickel manganese cobalt oxide (NMC) 333, NMC442, and NMC532. High-nickel includes NMC622, NMC721, NMC811, lithium nickel cobalt aluminium oxide (NCA), and lithium nickel manganese cobalt aluminium oxide (NMCA)

Source: Adapted from IEA (2024), Global EV Outlook 2024. All rights reserved.

2.2

Comparison of the carbon footprints of different electric vehicle battery technologies

To ensure consistency and enhance the comparability of carbon footprint values across battery chemistries, we conducted a region-specific analysis focusing on China, Europe, the United States, Japan and South Korea.

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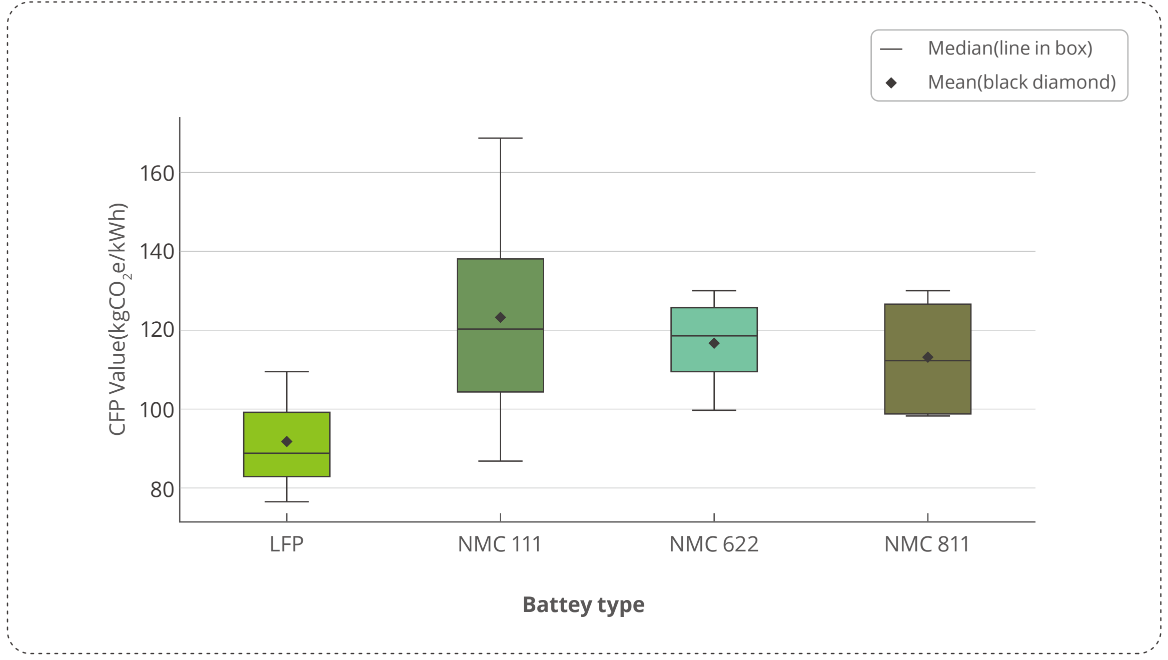
China

Given China's rapid advancements in EV battery technology and its commanding share of key production stages in the global supply chain, a substantial body of life-cycle assessment literature has adopted Chinese manufacturing conditions as its analytical backdrop. In this chapter, we compile and statistically summarize 17 cradle-to-gate carbon-footprint results drawn from seven peer-reviewed studies [9-15] of batteries produced in China—specifically LFP, NMC 111, NMC 622, and NMC 811 chemistries. All selected papers employ a consistent system boundary (cradle-to-gate) and use kilowatt-hour (kWh) as the functional unit, drawing their life-cycle inventory data from one of three authoritative databases: GREET, Ecoinvent, or GaBi. Nonetheless, variations in publication year and in the underlying life-cycle inventory sources introduce some divergence in the reported carbon footprint values across these studies.

The boxplot suggests that LFP batteries consistently have a lower carbon footprint compared to all NMC variants. Both the mean and median CFP values for LFP—91.7 and 89.2 kg CO_2/kWh, respectively—are lower than those of any NMC chemistry. In contrast, NMC 111 exhibits the greatest variability, ranging from 87.1 to 168.7 kg CO_2/kWh, and has the highest median CFP at 120.5 kg CO_2/kWh. NMC 622 and NMC 811 also maintain relatively high carbon footprints compared to LFP.

Both mean and median values (displayed on Figure 3) indicate that, under China's current energy mix and processing technologies, cradle-to-gate carbon footprints escalate in the order LFP < NMC 811 < NMC 622 < NMC 111.

Figure 3: Cradle-to-gate life-cycle assessment carbon footprint distribution of lithium-ion battery by cathode chemistries in China[6]



[6] Data compiled from [9-15].

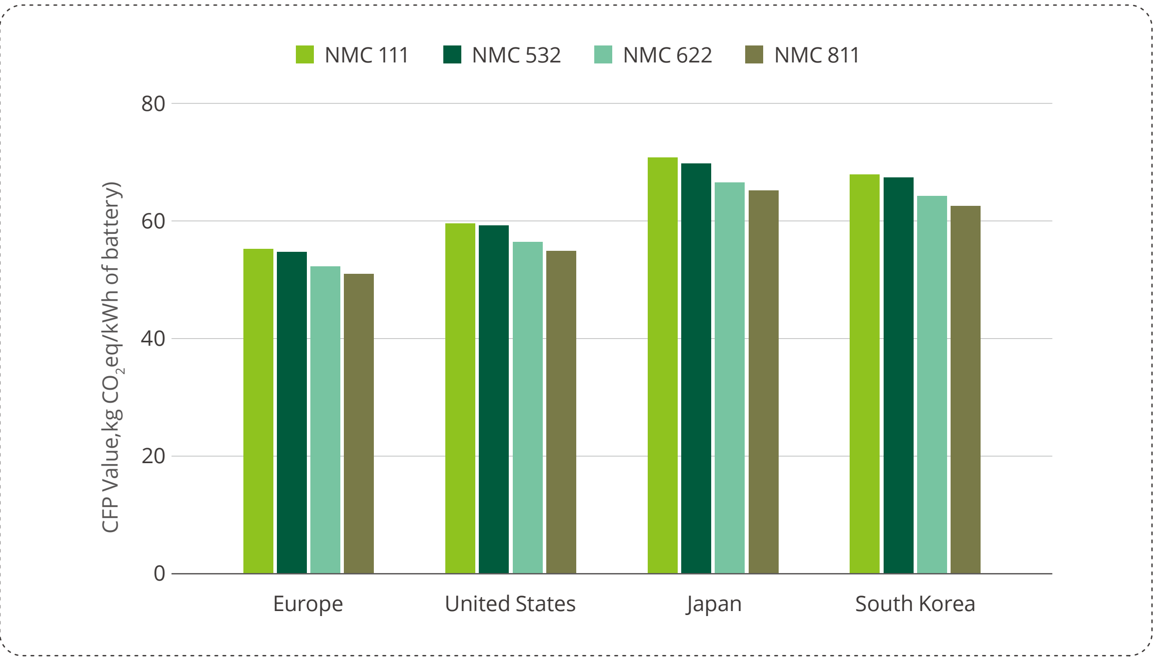
Europe, the United States, Japan and South Korea

Very little research has been published that compares the carbon footprints of common lithium-ion batteries (NMC 111, NMC 532, NMC 622, NMC 811, and LFP) manufactured in Europe, the US, Japan, and South Korea. This report has identified only two published studies that allow for a consistent comparison of carbon footprints of lithium-ion batteries with different cathode chemistries in those regions using the same methodology.

Winjobi et al. (2022) [16], compared four types of NMC lithium-ion batteries within each region: NMC 111, NMC 532, NMC 622, and NMC 811. The system boundary for the carbon footprint analysis extends from cradle to gate, encompassing the acquisition of raw materials, processing, cell production, assembly of cells into modules, and assembly of battery modules into battery packs. The researchers employed the GREET (greenhouse gases, regulated emissions, and energy use in technology) life-cycle assessment model for their analysis. For each individual country or region (Europe, the US, Japan, and South Korea), they assumed that the locations for NMC production, cell production, and battery management system production are all situated within each region.

The carbon footprint for NMC lithium-ion batteries presented in Winjobi et al. (2022) is summarized in Figure 4, with emissions measured from cradle to gate and expressed in kg CO_2-eq/kWh. In Europe, emissions for NMC 111, NMC 532, NMC 622, and NMC 811 are 55.1, 55.0, 52.3, and 51.0 kg CO_2-eq/kWh [16], respectively. In the US, the values are slightly higher at 59.5, 59.3, 56.4, and 55.1 kg CO_2-eq/kWh [16]. For Japan, emissions are notably higher, with 70.6, 70.0, 66.6, and 65.2 kg CO_2-eq/kWh [16], while South Korea shows emissions of 68.0, 67.5, 64.2, and 62.8 kg CO_2-eq/kWh [16] for the same battery types. A clear trend emerges: NMC batteries with higher nickel and lower cobalt content generally have a slightly smaller carbon footprint compared to those with lower nickel and higher cobalt content. However, the study by Winjobi et al (2022) did not include LFP batteries, so it is not possible to determine how the carbon footprints of NMC batteries compare to those of LFP batteries.

Figure 4: Carbon footprint comparison of NMC lithium-ion battery manufacturing across different cathode chemistries in Europe, the United States, Japan, and South Korea[7]

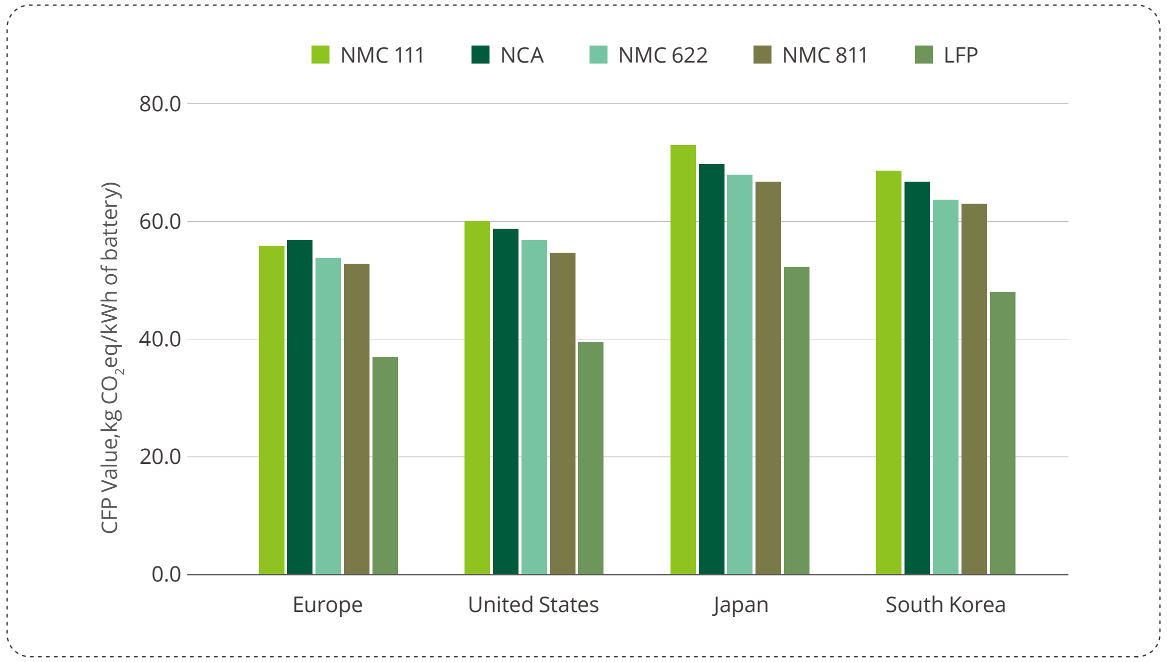


[7] Data adopted from [16].

A study by Bieker (2021) [17] from the International Council on Clean Transportation (ICCT) employed the GREET model to estimate the carbon footprint of lithium-ion batteries produced in Europe, the US, Japan and South Korea, including both LFP and NMC batteries. The LCA results are summarized in Figure 5. The carbon footprints of lithium-ion batteries with cathodes of NMC 111, NMC 622, NMC 811, NCA, and LFP produced in Europe are 56 kg CO_2-eq/kWh, 54 kg CO_2-eq/kWh, 53 kg CO_2-eq/kWh, 57 kg CO_2-eq/kWh, and 34-39 kg CO_2-eq/kWh [17], respectively. The carbon footprint for batteries with cathodes of NMC 111, NMC 622, and NMC 811 in the US, Japan and South Korea are similar to those reported in the first study (Winjobi et al., 2022) [16]. Bieker (2021) [17] also displayed the same pattern as the first study that NMC batteries with higher nickel and lower cobalt contents have a lower carbon footprint within the NMC family, and that the carbon footprint of LFP batteries is lower than that of NMC batteries.

Combining the studies by Winjobi et al (2022) and Bieker (2021), it can be observed that the carbon footprint values (kg CO_2/kWh) for manufacturing NMC lithium-ion batteries are generally higher than those for LFP batteries. Additionally, the ranking of carbon footprint values (kg CO_2/kWh) for lithium-ion batteries with different cathodes is as follows: NMC 111 (close to NCA) > NMC 622 > NMC 811 > LFP.

Figure 5: Carbon footprint comparison of NMC and LFP lithium-ion battery manufacturing across different cathode chemistries in Europe, the United States, Japan, and South Korea[8]



[8] Data adopted from [17].

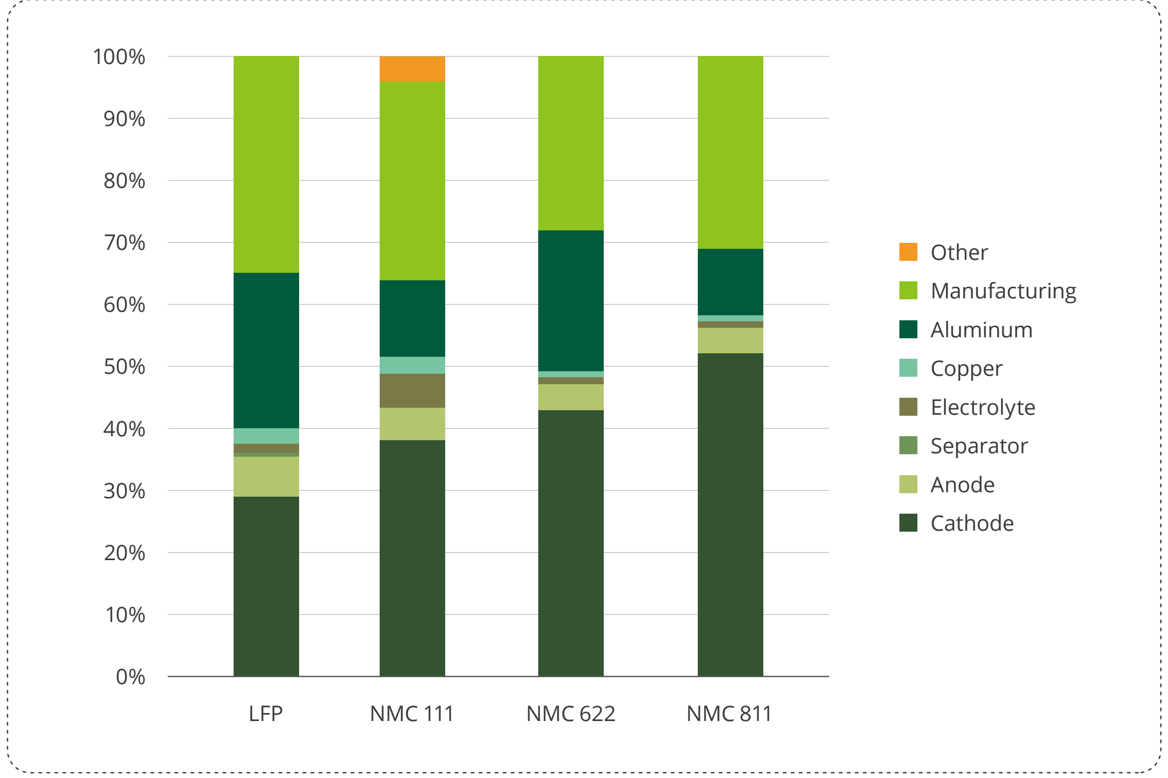
2.3

Analysis of emission hotspots in electric vehicle battery production

2.3.1 Analysis of the contributors to the carbon footprint of electric vehicle batteries

The average emissions profiles across different battery chemistries—specifically LFP and various NMC types (NMC 111, NMC 622, and NMC 811)—based on data from 15 studies [9,11,12,15,18-28] that analyse carbon emissions during the manufacture of EV batteries are summarized in Figure 6. For LFP batteries, manufacturing (35.83%) and cathode production (29.41%) are the dominant contributors to the overall carbon footprint. In contrast, NMC batteries exhibit a progressively higher cathode contribution with increasing nickel content: 38.28% for NMC 111, 44.56% for NMC 622, and 57.71% for NMC 811. These findings highlight the critical need to prioritize the decarbonization of cathode active material production. Across all chemistries, manufacturing processes consistently account for a substantial share of emissions, underscoring the importance of reducing energy-related impacts in battery production.

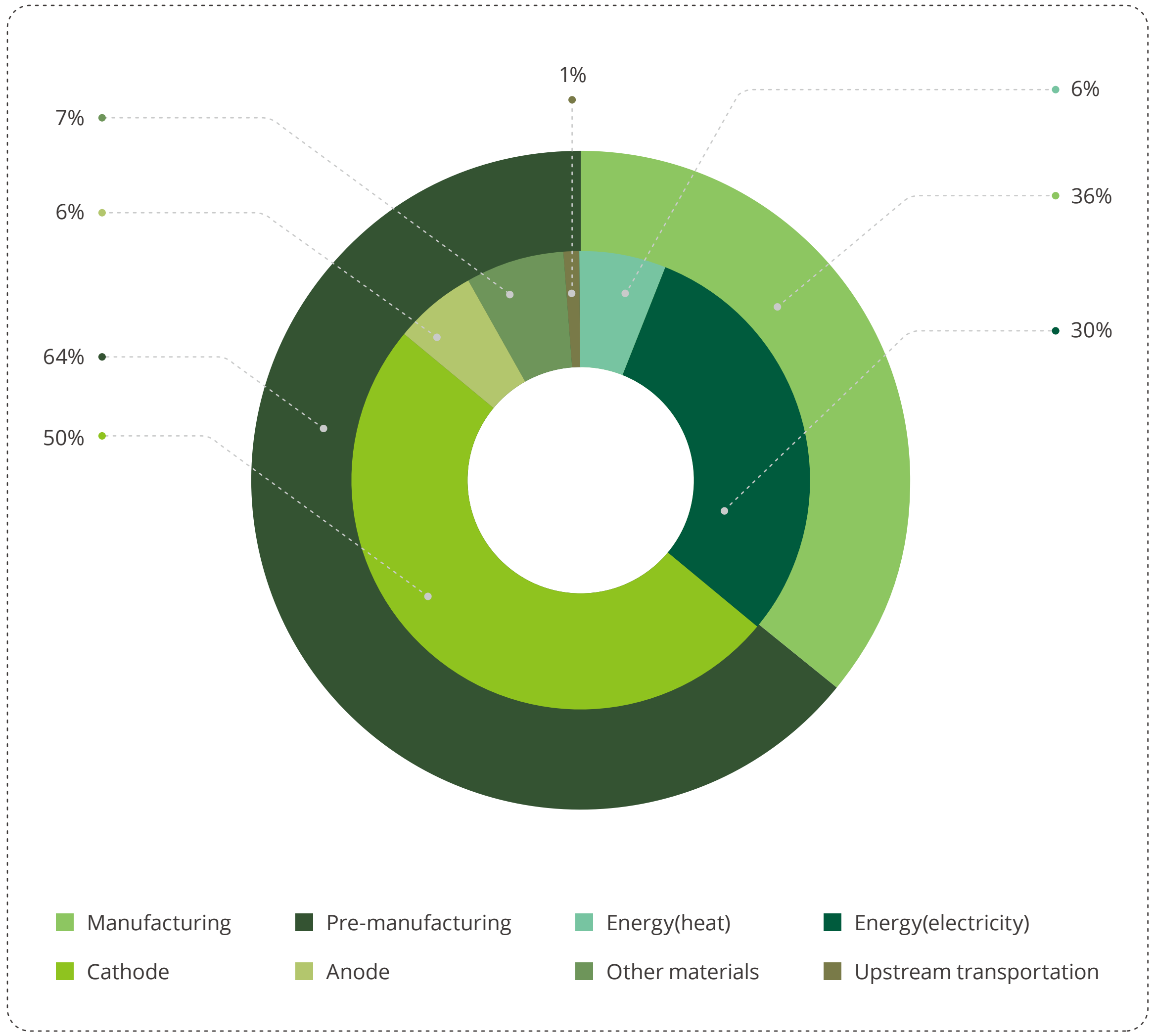
Figure 6: Cradle-to-gate life cycle analysis carbon footprint percentage breakdown of lithium-ion batteries – by literature[9]



[9] Data compiled from [9,11,12,15,18-28].

The LG Energy Solutions 2023 ESG report [29] offers a gigafactory-level breakdown that mirrors the academic findings presented above, and the report suggests that 36% of a battery's cradle-to-gate emissions occur during cell production, with electricity use alone responsible for 30% of the total footprint. On the upstream side, cathode active material production (encompassing cathode synthesis and aluminum foil processing) accounts for half of the total carbon footprint.

Figure 7: Cradle-to-gate life cycle analysis carbon footprint percentage breakdown of lithium-ion batteries – by LGES[10]



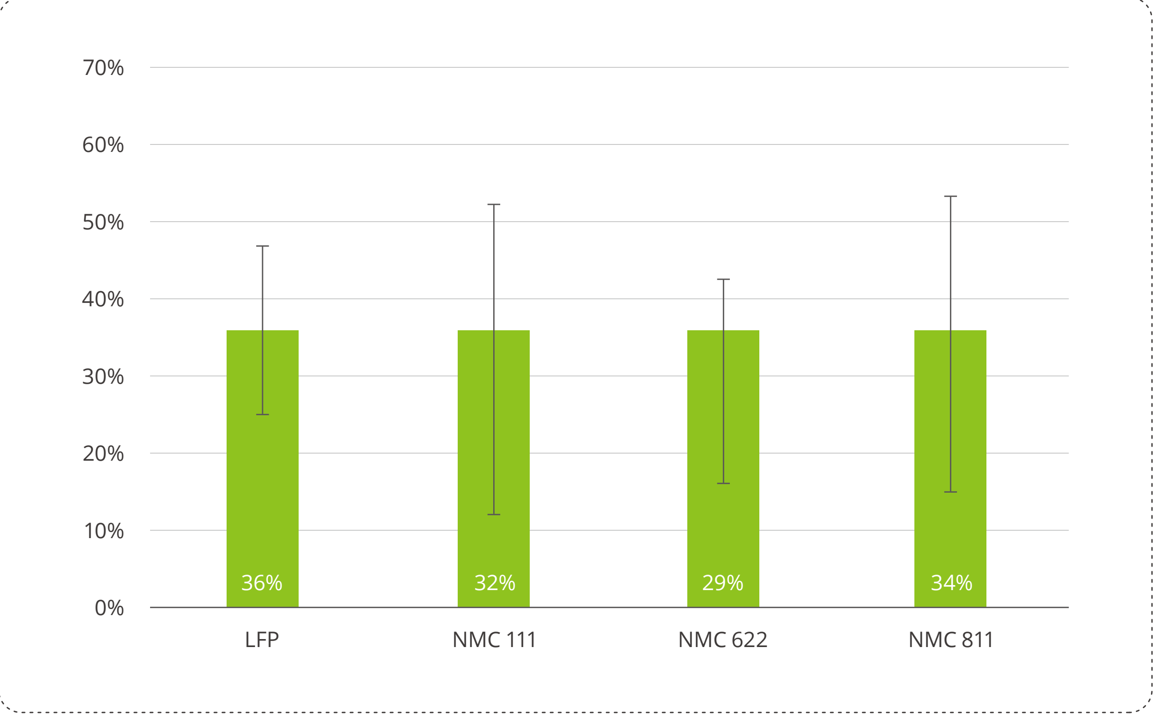
[10] Data adopted from [29].

2.3.2 Emission hotspots

- **Impact of energy**

Drawing on data synthesized from 15 peer-reviewed studies [9,11,12,15,18-28], the manufacturing stage alone accounts for roughly one-third of the cradle-to-gate carbon footprint across all examined battery chemistries, with mean contributions spanning 29% to 36%, as shown in Figure 8. Specifically, LFP cells exhibit the highest average manufacturing share at 36 % (±11 %), followed by NMC811 at 34 % (±19 %), NMC111 at 30 % (±19 %), and NMC622 at 29 % (±13 %). During the manufacturing stage, processes such as electrode fabrication (mixing active materials with binders and solvents, coating onto current collectors, drying, and calendaring), cell assembly (stacking or winding electrodes and separators), electrolyte filling, formation cycling, and module/pack integration require substantial electricity inputs, making it one of the most energy-intensive life-cycle stages.

Figure 8: The contribution of manufacturing to total electric vehicle battery carbon footprint (cradle-to-gate) [11]

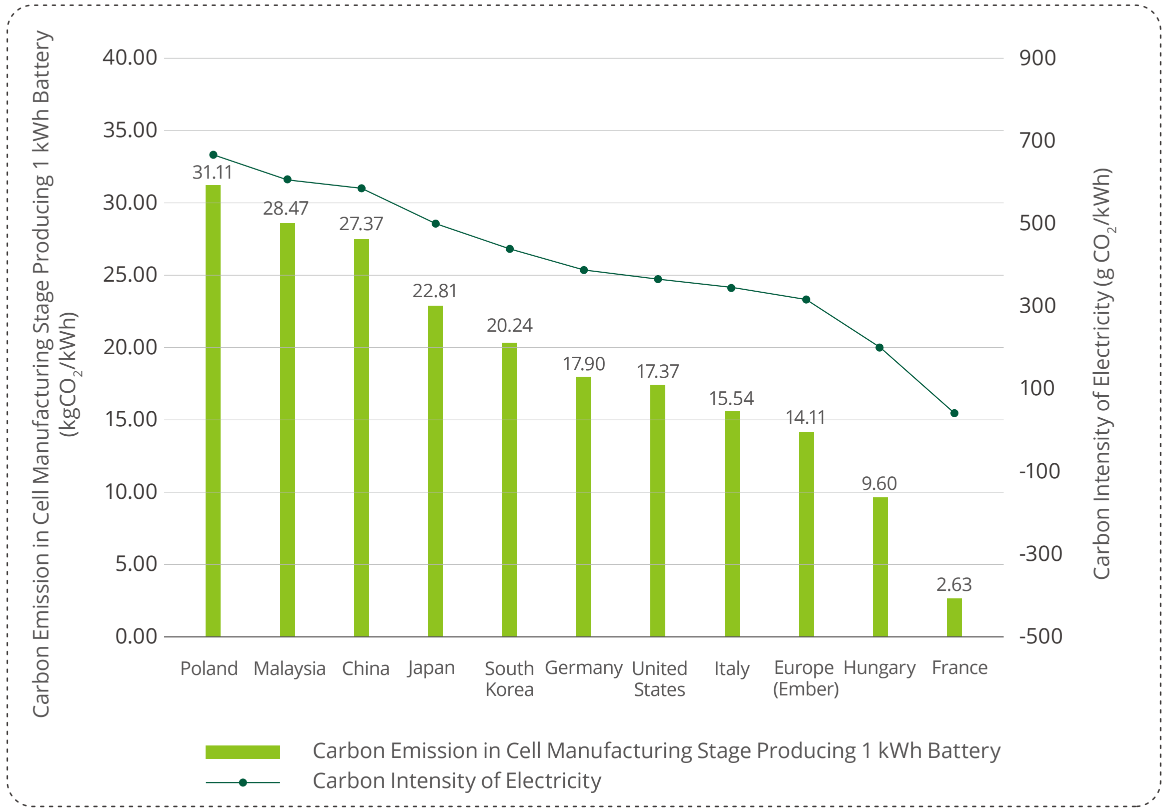


[11] Data compiled from [9,11,12,15,18-28].

Life cycle assessments of lithium-ion battery production consistently show that the carbon intensity of the electricity used in cell manufacturing is a key driver of overall greenhouse gas emissions. In the cradle-to-gate study by Kolahchian Tabrizi et al. [14], four production locations—France (0.085 kg CO_2/kWh), Italy (0.371 kg CO_2/kWh), Germany (0.409 kg CO_2/kWh), and China (0.797 kg CO_2/kWh)—were modeled using the GREET framework. When comparing overall lithium-ion battery production, electricity-related impacts translate directly into the cradle-to-gate carbon footprint per kWh of battery capacity. For example, NMC 811 cells produced entirely in France can achieve as low as 52kg CO_2 eq./kWh, whereas the same chemistry in Germany reaches up to 126.5kg CO_2 eq/kWh, and in China spans 99–136 kg CO_2 eq/kWh depending on supply-chain scenarios. Shifting production from China to Europe thus yields reductions of 32–60%, with France attaining the greatest benefit due to its low-carbon grid. Even within Europe, country-to-country differences bracket savings of 30–42% simply by operating in lower-intensity markets.

To isolate the carbon impact of grid electricity alone at the most energy-intensive stage, cell manufacturing, this report presents a direct comparison of cell-manufacturing CFP against national electricity carbon intensities—assuming 100% of process energy is drawn from grid electricity (Fig. 9).

Figure 9: Carbon emissions from cell manufacturing and from the carbon intensity of the electricity grid by countries/regions[12]



The findings of this report suggest that decarbonizing the electricity supply is as important as process improvements in efforts to reduce emissions from the manufacturing process for lithium ion batteries. Policymakers and industry should prioritize siting gigafactories in regions with cleaner grids or invest in dedicated renewables for on-site power. Without such measures, gains from advanced cell chemistries and scale economies will be largely offset by high-intensity electricity inputs.

[12] Data calculated from [30-32]

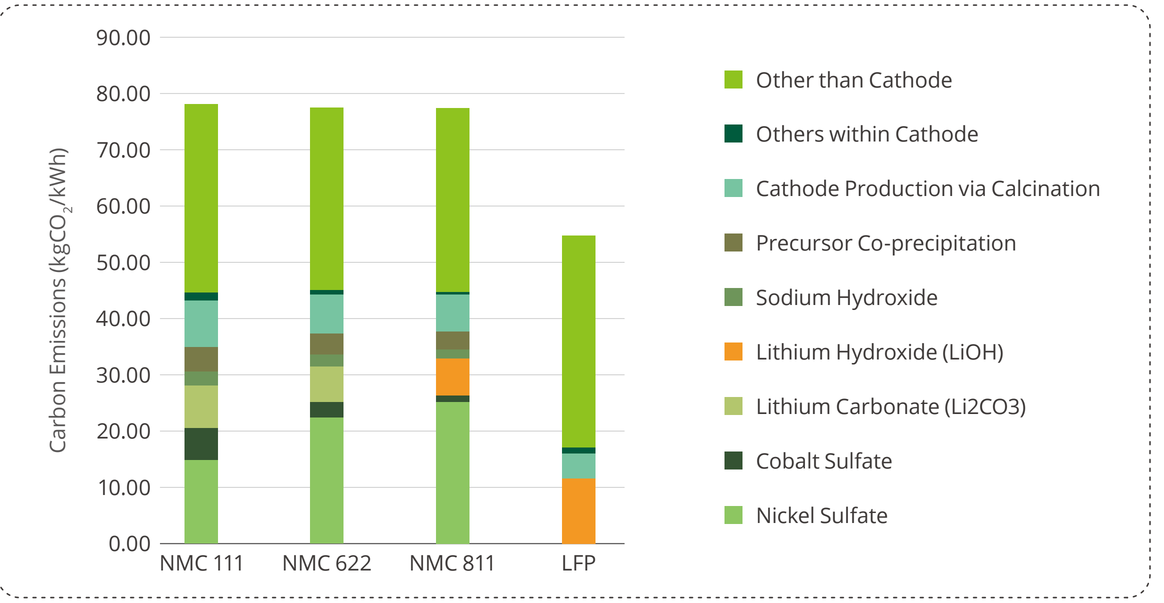
- **Cathode production**

NMC cathodes begin with co-precipitation of nickel sulfate, cobalt sulfate and either lithium carbonate (for NMC 111 and NMC 622) or lithium hydroxide (for NMC 811), followed by calcination to form the layered $LiNi_xCo_yMn_{1-x-y}O_2$ structure. In contrast, LFP cathodes are produced by reacting iron phosphate precursors with lithium hydroxide and heat-treating the resulting $LiFePO_4$ phase. This fundamental difference—NMC's reliance on nickel and cobalt salts versus LFP's iron- and phosphate-based chemistry—drives divergent carbon intensity profiles across the two cathode families.

A study by Llamas-Orozco et al. [22], shown in Figure 10, presents a cradle-to-gate life-cycle assessment of global lithium-ion battery production (including all mainstream chemistries), detailing the greenhouse-gas emissions attributable to cathode active materials. By weighting each region's carbon footprint according to its share of current manufacturing capacity, the study derives global average emission intensities for both cathode materials and overall battery production, which allows consistent comparisons as follows:

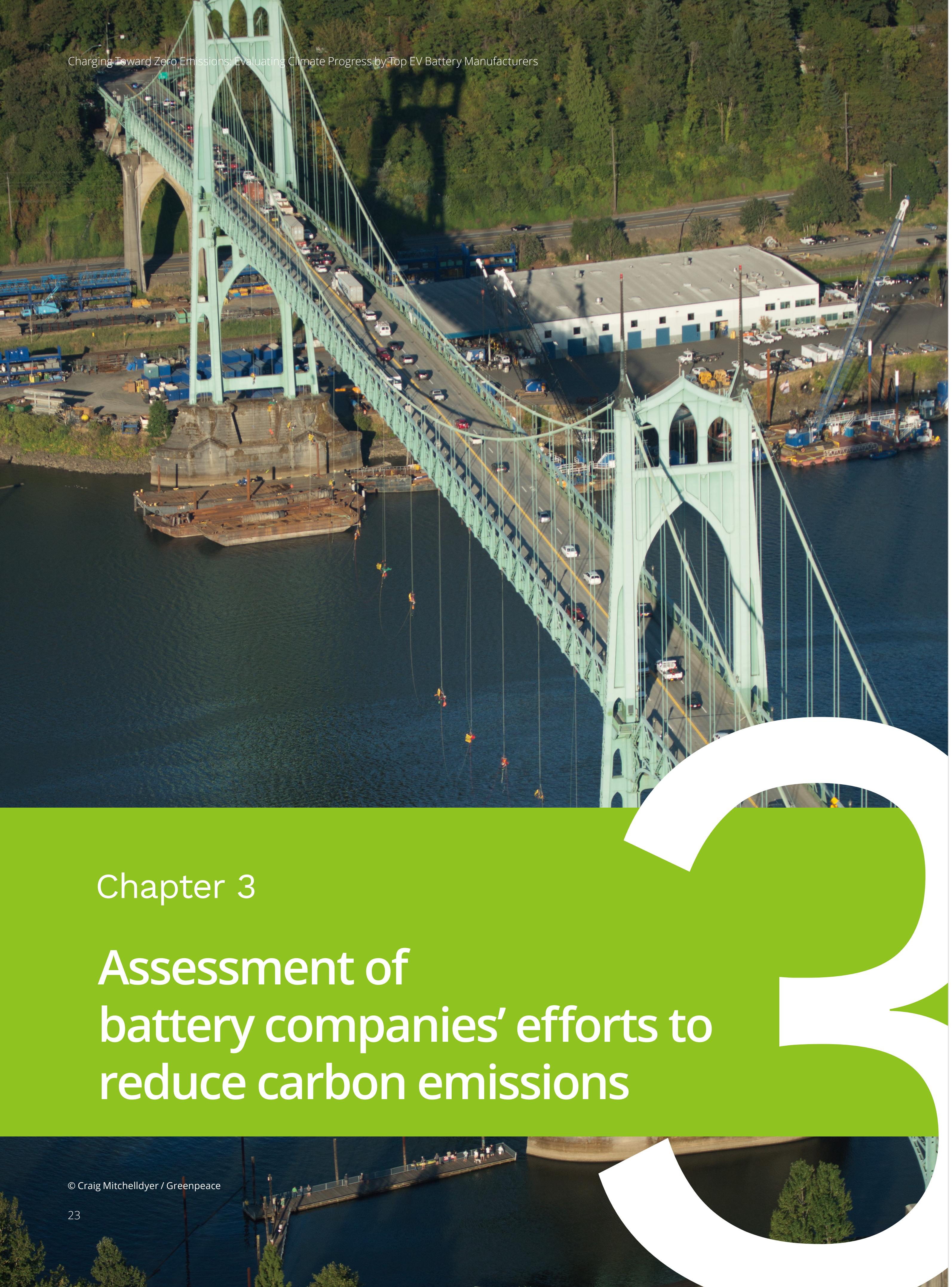
A quantitative comparison of individual precursor and process emissions suggests that **nickel sulfate is the single largest contributor** in NMC systems, rising from 14.73 kg CO_2/kWh in NMC 111 to 25.10 kg CO_2/kWh in NMC 811, while lithium source emissions modestly decrease from 7.45 kg CO_2/kWh (Li_2CO_3) to 6.47 kg CO_2/kWh (LiOH) as nickel content increases. Additional inputs—including cobalt sulfate (5.79-1.23 kg CO_2/kWh), sodium hydroxide, precursor co-precipitation and calcination (6.50–8.28 kg CO_2/kWh)—aggregate to a substantial footprint for NMC cathodes. By contrast, LFP eliminates nickel and cobalt entirely: its dominant emissions arise from lithium hydroxide (11.45 kg CO_2/kWh) and calcination (4.40 kg CO_2/kWh), with 'other' auxiliary materials contributing only 1.04 kg CO_2/kWh. The findings from Llamas-Orozco et al. [22] underscore that decarbonization efforts for NMC should target lower-carbon nickel extraction and reduced calcination energy. Overall, LFP cathodes exhibit a significantly lower overall carbon footprint than NMC chemistries.

Figure 10: A cradle-to-gate life cycle analysis carbon footprint breakdown of lithium-ion batteries – by literature[13]



A sensitivity analysis [14] of lithium sourcing for NMC cathodes demonstrates that brine-derived lithium offers a clear global warming potential advantage over ore-based and mixed sources. The decrease in carbon intensity is more pronounced for lower-nickel variants (e.g., NMC 111 and NMC 622), whereas the benefit is less marked for high-nickel formulations (NMC 811) because converting brine-sourced lithium carbonate into lithium hydroxide requires additional energy. However, this discussion on the topic of lithium only captures the global warming potential aspect of lithium sourcing. Battery manufacturers must also take into account the broader environmental and social impacts involved.

[13] Data adopted from [22].



Chapter 3

Assessment of battery companies' efforts to reduce carbon emissions

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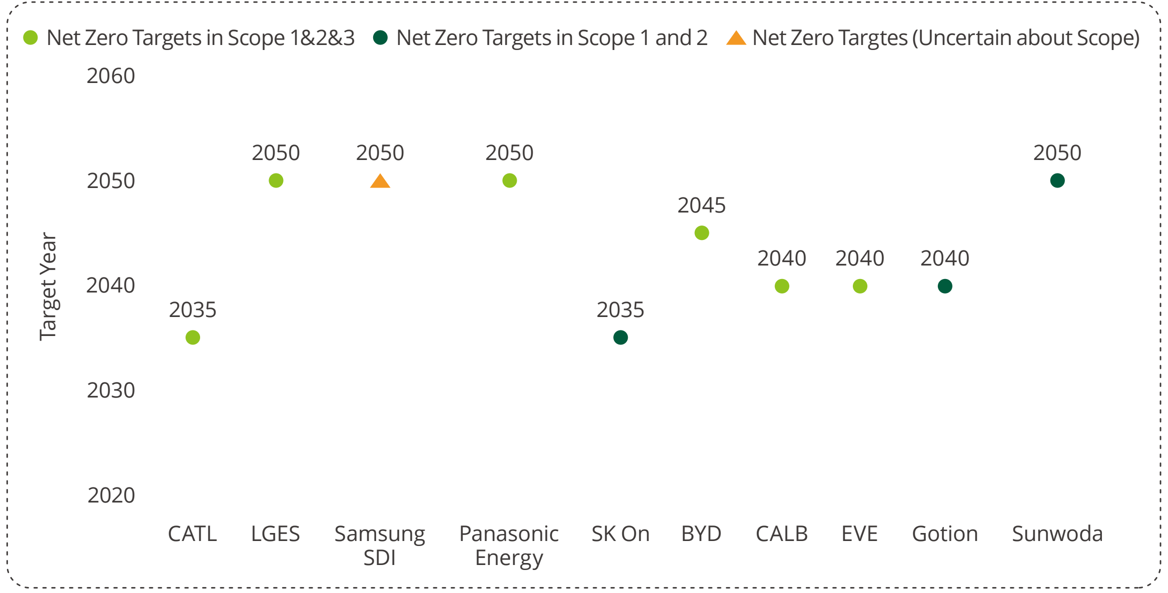
Building on the analysis presented in Chapter 2, it is evident that the primary contributors to carbon emissions in EV battery manufacture stem from energy sources and cathode materials. This chapter focuses on the top ten global EV battery manufacturers by market share (their total market share accounted for 90.18% in 2024), and provides a comprehensive overview of their efforts to reduce emissions. Within this chapter is a compilation of information regarding each company's climate initiatives and efforts aimed at mitigating emissions hotspots. Furthermore, this chapter evaluates the actions taken by the top battery manufacturers and gains valuable insights into the sector's progress toward sustainability.

Assessment of the climate ambitions of different battery manufacturers

The global top ten battery manufacturers included in this chapter have all established their net-zero targets (Figure 11). The net-zero targets for CATL, LGES, Panasonic Energy, BYD, CALB, and EVE encompass their entire value chain, while the targets for SK On, Gotion, and Sunwoda are limited to Scope 1 and 2 emissions, addressing only a small fraction of each company's greenhouse gas emissions and reflecting less ambition compared to those companies that aim for comprehensive coverage. Samsung SDI's net-zero target does not specify its scope.

Figure 11: Net-zero commitment status of the global top ten battery manufacturers[14]



There is a disparity in the timeframe regarding when the battery manufacturers are committed to achieving net zero across their entire value chain. For example, CATL has announced its intention to achieve net zero across the entire value chain by 2035, whereas most other companies have set net zero targets within the 2040–2050 timeframe.

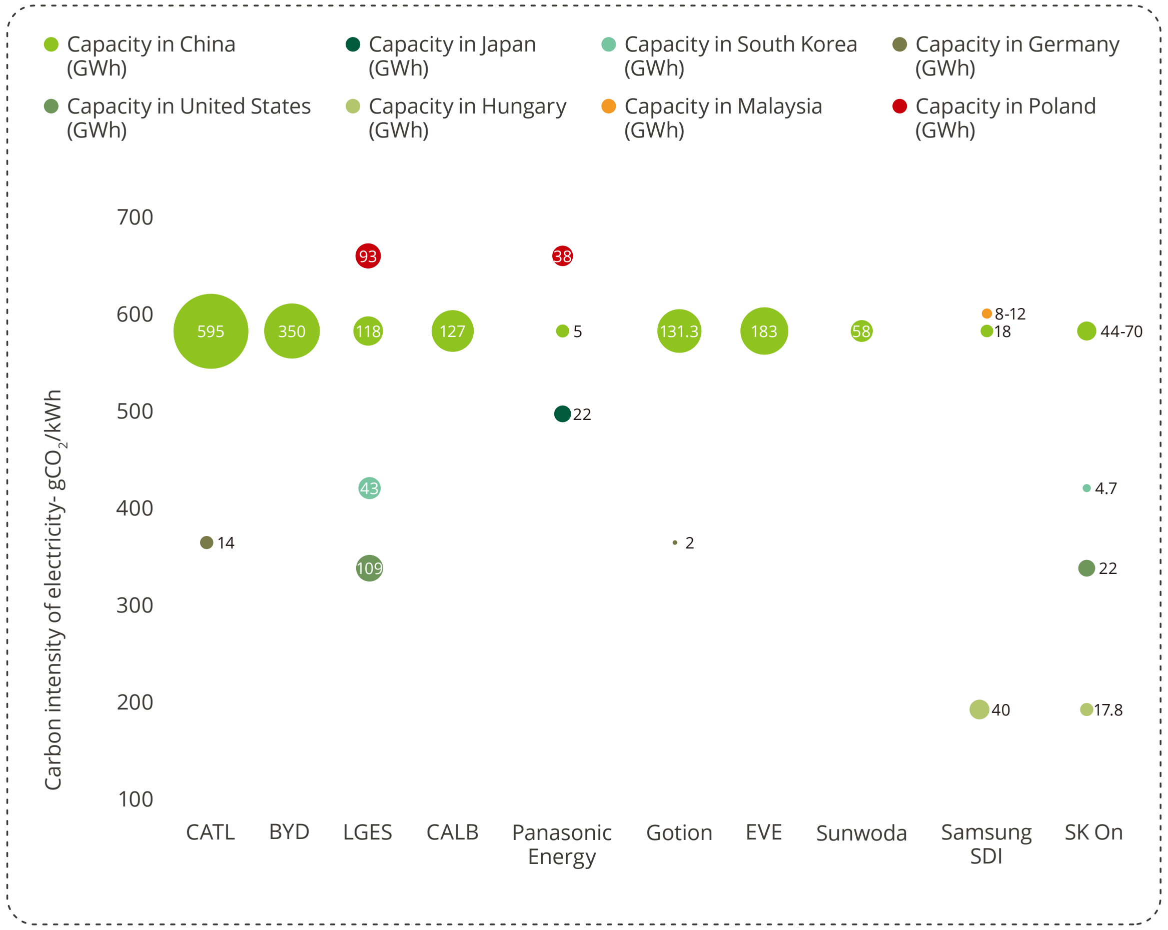
Establishing ambitious net zero targets is important to help guide a company's high-level strategies to address carbon emissions. However, it is even more important to examine how companies set specific targets and measures to achieve those goals, as these are essential for assessing the credibility of their net-zero commitments. The following sections will discuss the specific efforts and measures taken by battery manufacturers to address their carbon emissions.

[14] 1) Panasonic Holdings Corporation plans to achieve net-zero emissions by 2050 across Scope 1, 2, and 3. As an operating company of Panasonic Holdings Corporation, Panasonic Energy has also set this as a uniform target for all Panasonic Group operating companies, please see [33].
2) EVE's net zero commitment is the carbon neutrality across the core value chain by 2040.
3) Source: Please see Appendix I: Company Profiles

- **An assessment of the adoption of renewable electricity by battery manufacturers**

Chapter 2 analyzed emission hotspots, concluding that the battery manufacturing phase is energy-intensive, primarily due to high electricity consumption. The manufacturing stage alone accounts for roughly one-third of the cradle-to-gate carbon footprint of lithium-ion batteries. Without the adoption of renewable electricity, the carbon footprint of lithium-ion batteries will be heavily affected by the carbon intensity of electricity in the national electricity grid. Figure 12 illustrates the locations of battery company factories, their production capacities, and the carbon intensity of electricity in those areas. The majority of production capacity of the top ten battery manufacturers is concentrated in China, where the carbon intensity of electricity (more than 500 g CO_2/kWh) is higher than in other major producing countries such as the US, South Korea, Germany, and Hungary (Figure 12). To significantly reduce the carbon footprint of battery production, manufacturers will need to increase their use of renewable electricity.

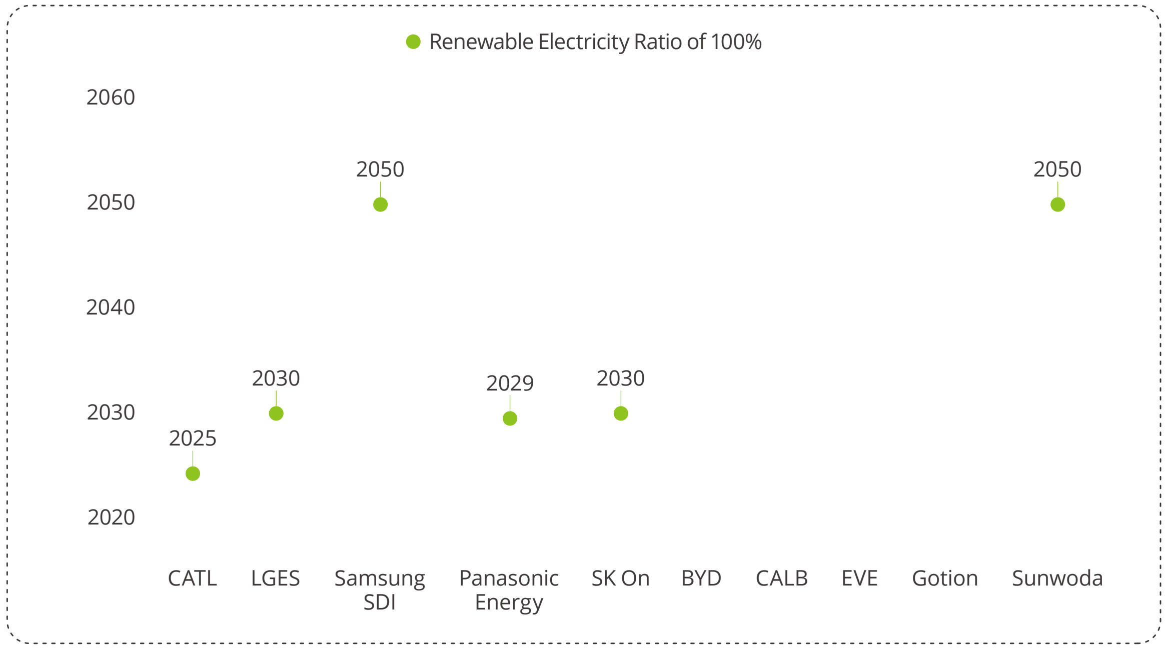
Figure 12: The production capacity of leading global battery companies by region and the carbon intensity of electricity in those regions[15]



[15] 1) Data compiled from [34-37], and calculated by Greenpeace.
2) The values of carbon intensity refer to 2023, except for Malaysia, where the most recent data is from 2022.
3) Data on EV battery production capacity are pertain to 2023. Additionally, the figures for Samsung SDI and SK On represent planned capacities.

Six of the ten major battery manufacturers—**CATL, LGES, Samsung SDI, SK On, Panasonic Energy, and Sunwoda**—have set 100% renewable electricity targets (Figure 13). CATL has set an ambitious goal, aiming for 100% zero-carbon electricity in its core operations by 2025. However, it remains unclear whether this target covers all its production facilities or only select sites. LGES and SK On follow closely, targeting 100% renewable electricity by 2030, while Panasonic Energy aims to achieve the same by fiscal year 2029, placing it between CATL and LGES in terms of timeline. Samsung SDI and Sunwoda aim to achieve 100% renewable electricity by 2050. In contrast, BYD, CALB, EVE, and Gotion lack a commitment to 100% renewable electricity.

Figure 13: The 100% renewable electricity targets of the top ten battery manufacturers[16]

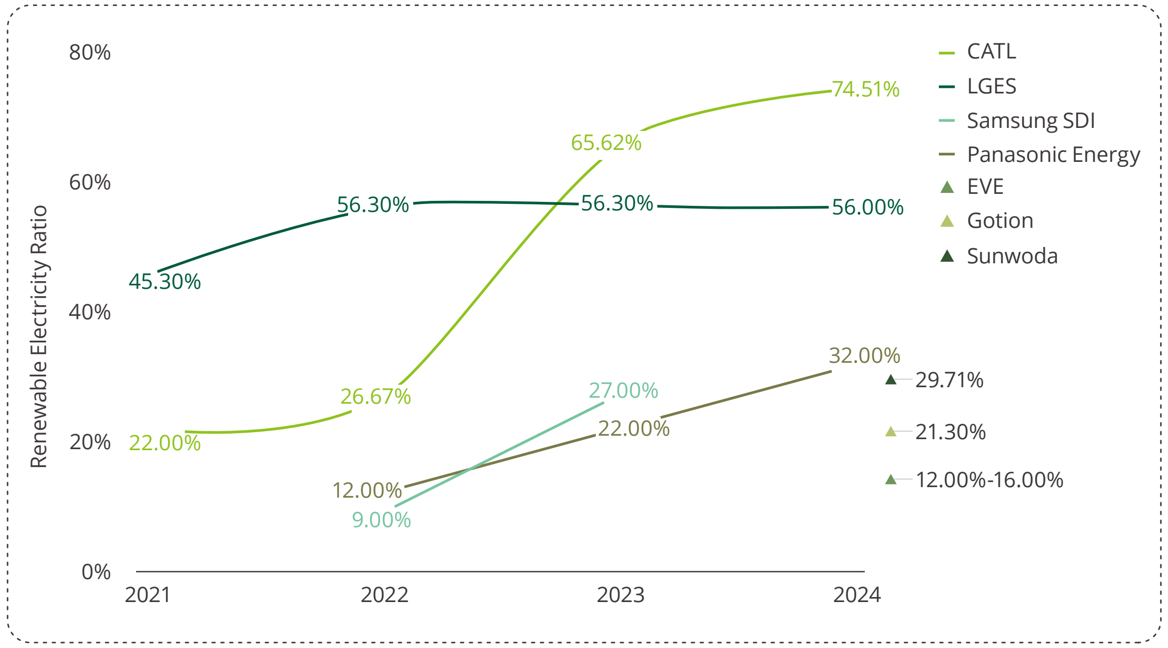


[16] 1) Regarding CATL's commitment, it was reported that by 2025, the company will achieve 100% zero-carbon electricity usage in its core operations;
2) Regarding Panasonic Energy's target, 2029 refers to FY 2029.
3) Source: Please see Appendix I: Company Profiles

CATL, LGES, Panasonic Energy, Samsung SDI, Sunwoda, Gotion and EVE have reported their progress on adoption of renewable electricity (Figure 14). CATL's adoption of zero-emission electricity jumped from 22.00% in 2021 to 74.51% in 2024, showcasing the firm's push towards the use of renewable electricity. In 2023, CATL's renewable electricity ratio reached 65.62%, surpassing LGES, which held a ratio of 56.30% that year and had previously led among battery manufacturers.

With a high proportion of renewable electricity usage, CATL is better positioned to mitigate the impacts of carbon intensity in electricity generation in China. LGES maintains a steady lead, starting at 45.30% in 2021 and plateauing around 56% by 2024. The move towards increased use of renewable electricity indicates a strong commitment to sustainability among the top battery manufacturers.

Figure 14: EV battery manufacturers' renewable electricity ratio at the company level [17]



Samsung SDI and Panasonic Energy both show a gradual increase in the adoption of renewable electricity. Samsung SDI increased its ratio of renewable electricity from 9.00% in 2022 to 27.00% in 2023, and Panasonic Energy increased its ratio of renewable electricity from 12.00% in 2022 to 32.00% in 2024. Sunwoda, Gotion and EVE each reported their renewable electricity ratios to be 29.71%, 21.30% and 12.00%–16.00% in 2024, respectively. Notably, BYD, CALB and SK On have not yet disclosed their renewable electricity consumption ratio figure at the company level.

[17] 1) For Panasonic Energy, the years 2022, 2023, and 2024 refer to the fiscal years.
2) Source: please see Appendix I: Company Profiles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Assessment of supply chain decarbonization efforts

As discussed in Chapter 2, the cathode production of lithium-ion batteries is highly energy intensive and contributes approximately 30% - 60% of the cradle-to-gate carbon footprint of a battery, depending on its specific cathode chemistry. To reduce the carbon footprint of batteries, manufacturers will need specific measures to decarbonize the supply chain, particularly in relation to reducing emissions from refining materials used. This section will discuss and assess efforts made by leading battery makers to decarbonize, including carbon reduction targets and renewable electricity targets for their supply chain and suppliers.

Table 2 illustrates the engagement of the top ten battery manufacturers in setting and reporting on carbon reduction targets covering supply chains, including renewable electricity targets for their suppliers. Only five out of the ten manufacturers covered in this assessment have reported setting carbon reduction targets for their suppliers or supply chain, indicating limited focus on supply chain decarbonization. Two manufacturers (CATL and LEGS) have set renewable electricity targets for their suppliers. LGES demonstrates a proactive stance by targeting 100% renewable electricity (RE100) for all Tier-1 suppliers (covering critical components like cathode, anode, and copper foil) by 2030, with an extended goal of RE100 for core value chains by 2040. CATL also set zero-carbon electricity usage targets for its core raw material suppliers, yet it has not unveiled the specific target number and year by which the target must be achieved. CATL reported that the overall zero-carbon electricity use rate of its cathode and anode suppliers reached 57%, and that of aluminum product suppliers reached 45%.

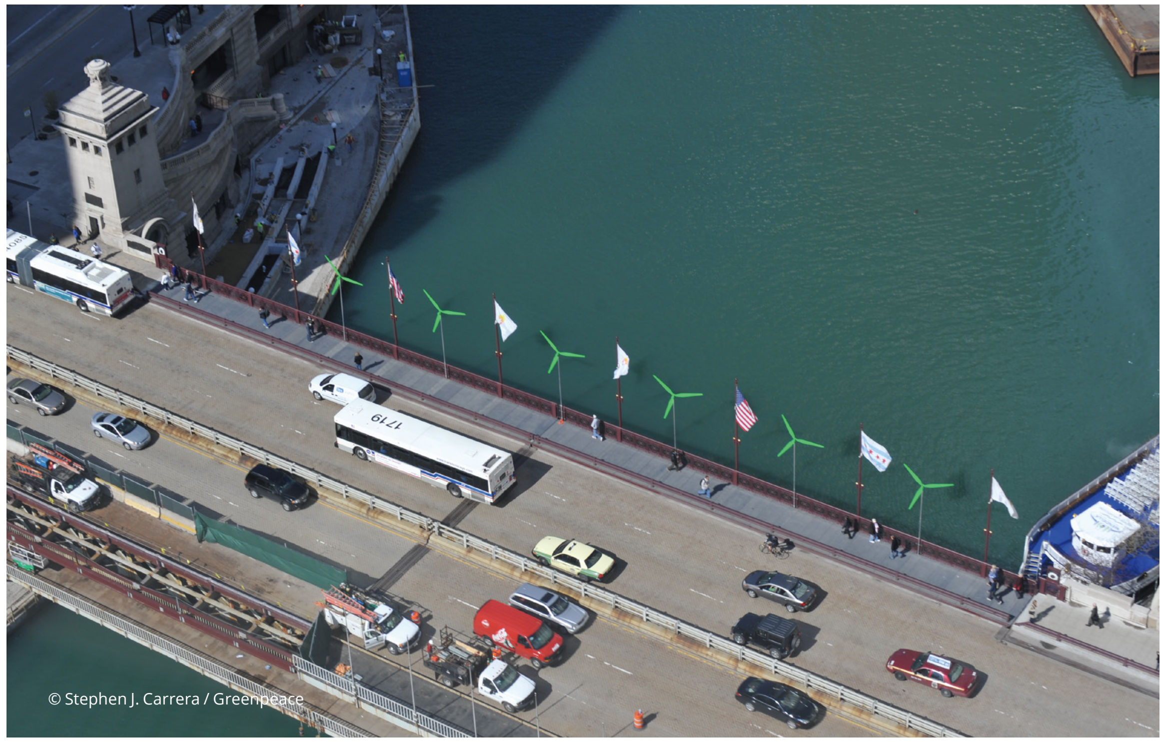
Table 2: Specific supply chain carbon reduction targets set by leading battery manufacturers[18]

Name	Carbon reduction targets covering supply chain	Target type	Report progress on targets
CATL	zero-carbon electricity ratio targets for core material suppliers [38, p. 82]	Renewable Energy	CATL reported that the overall ratio of zero-carbon electricity usage among anode and cathode suppliers reached 57%, while aluminum suppliers achieved a ratio of 45% [38, p. 82]
LGES	Achieve RE100 for all Tier-1 suppliers (Covering all materials such as cathode, anode, and copper foil) by 2030, and extend RE100 for core value chains by 2040 [29, p. 40]	Renewable Energy	No related information is being disclosed.
Panasonic Energy	Panasonic Energy has set the target of a 50% reduction in its carbon footprint by fiscal 2031 compared to fiscal 2022 and is promoting the reduction of CO_2 emissions throughout its entire supply chain [39]	Carbon Reduction	No related information is being disclosed.
CALB	Reduce carbon of the supply chain by 10% per year [40]	Carbon Reduction	No related information is being disclosed.
Gotion	Promote suppliers to meet a 5% annual carbon reduction target [41].	Carbon Reduction	No related information is being disclosed.
Samsung SDI	No related information is being disclosed.	NA	NA
SK On	No related information is being disclosed.	NA	NA
BYD	No related information is being disclosed.	NA	NA
EVE	No related information is being disclosed.	NA	NA
Sunwoda	No related information is being disclosed.	NA	NA

Panasonic Energy, CALB and Gotion have established carbon reduction targets covering their supply chains or targets for suppliers. Panasonic Energy has set the target of a 50% reduction in its carbon footprint by fiscal 2031 compared to fiscal 2022. Based on its 2031 target, Panasonic Energy reported that for fiscal 2024, it has set reduction targets for components and materials that significantly impact the carbon footprint per unit volume of batteries, and is currently discussing reduction initiatives with suppliers. CALB commits to reducing supply chain carbon emissions by 10% per year, and Gotion commits to promoting suppliers to meet a 5% annual carbon reduction target. However, Gotion and CALB have not clarified the scope of the suppliers covered by their targets, nor whether their reduction targets are based on absolute volume or intensity.

Samsung SDI, SK On, BYD, EVE, and Sunwoda did not disclose related information on the company's specific targets for reducing supply chain carbon emissions. The absence of goals is particularly striking for BYD and EVE, which, despite commitments to achieving net zero across the value chain by 2045 and 2040 respectively, have been silent about their specific targets for reducing emissions from their supply chains.

[18] Source: please see Appendix I: Company Profiles



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Assessment of targets for the use of recycled raw materials

Using recycled materials is a promising approach to significantly reduce the carbon footprint and avoid the negative environmental impacts of metal extraction. Research indicates that substituting primary raw materials with recycled materials can reduce the carbon footprint of lithium-ion battery manufacturing to varying degrees—3.5% with the pyrometallurgy method and 32.0% with the hydrometallurgy method—depending on the recycling techniques employed [42]. Meanwhile, from the regulatory side, the EU Batteries Regulation mandates minimum levels of recycled content for critical minerals: 16% by 2031 and 26% by 2036 for cobalt; 6% by 2031 and 12% by 2036 for lithium; and 6% by 2031 and 15% by 2036 for nickel [43].

Of the ten companies reviewed in this analysis, only Samsung SDI, LGES, Gotion and Panasonic Energy have reported setting targets for the use of recycled metals. Samsung SDI aims for 21% recycled metal usage by 2025 and 26% [44, p. 35] by 2030; LGES and Gotion target up to 20% [29, p. 47] recycled metals by 2030 and 14% [41, p. 11] recycled material usage in cell products by 2027, respectively. Panasonic Energy has set the target of achieving 20% recycled cathode material content in its automotive batteries by 2027 [45]. Notably, only Samsung SDI has published its progress, reporting a 12% [44, p. 95] ratio of recycled metal use in 2023.

As the compliance deadline approaches for the EU Batteries Regulation regarding minimum levels of recycled content, battery manufacturers will need to establish targets for the use of recycled materials, monitor progress, and periodically report on achievements.

- **Assessment of emissions data transparency**

Emissions data transparency is essential because it enables stakeholders—such as consumers, investors, and regulatory authorities—to accurately assess the environmental impact of a company. Furthermore, transparency in emissions reporting serves as a reflection of the industry's dedication to environmental responsibility and sustainability.

All of the top ten battery manufacturers disclosed Scope 1 and 2 emissions, which typically includes direct emissions from owned or controlled sources and indirect emissions associated with the purchase of electricity, steam, heating, or cooling (Table 3).

Table 3: Emissions data transparency from the top ten battery manufacturers[19]

Name	Scope 1 and 2	Scope 3	Breakdown of Scope 3	Scope 3 Category 1
CATL	Disclosed	Disclosed	Disclosed	Disclosed
Gotion	Disclosed	Disclosed	Disclosed	Disclosed
CALB	Disclosed	Disclosed	No related information is being disclosed.	No related information is being disclosed.
Sunwoda	Disclosed	No related information is being disclosed.	No related information is being disclosed.	No related information is being disclosed.
BYD	Disclosed	No related information is being disclosed.	No related information is being disclosed.	No related information is being disclosed.
EVE	Disclosed	No related information is being disclosed.	No related information is being disclosed.	No related information is being disclosed.
LGES	Disclosed	Disclosed	Disclosed	Disclosed
Samsung SDI	Disclosed	Disclosed	Disclosed	Disclosed
SK On	Disclosed	Disclosed	Disclosed	Disclosed
Panasonic Energy	Disclosed	Disclosed	Disclosed	Disclosed

Seven battery manufacturers—CATL, LGES, Samsung SDI, Panasonic Energy, SK On, CALB, and Gotion—are disclosing their Scope 3 emission data, which includes indirect emissions within the value chain of the reporting company. Of these seven manufacturers, CATL, LGES, Samsung SDI, Panasonic Energy, SK On, and Gotion provide a breakdown of Scope 3 emissions, including Scope 3 Category 1 emissions (from purchased goods and services), which represent a significant portion of the carbon footprint for battery companies. In contrast, three manufacturers—BYD, EVE, and Sunwoda—are not reporting their Scope 3 emission data.

[19] Source: please see Appendix I: Company Profiles

Electricity consumption during manufacturing and the production of cathode materials are major sources of emissions, which significantly contributes to the carbon footprint of EV batteries. This report examines the carbon reduction initiatives of the top ten battery manufacturers regarding renewable electricity commitments and supply chain. The assessment is as follows:

1) Only three of the top ten battery manufacturers have committed to 100% renewable electricity for their operations and established carbon reduction targets for their supply chains, addressing key GHG emission sources in EV battery production—electricity use and supply chain emissions.The remaining seven lack one or both, highlighting a significant gap in the industry's decarbonization efforts for EV battery manufacturing.

2) CATL, LGES, and Panasonic Energy address their emissions hotspots through committing to achieve 100% renewable electricity at the company level and setting reduction targets for their suppliers or supply chain.

3) CALB, Gotion, SK On, Sunwoda and Samsung SDI lack either reduction targets for suppliers or a commitment to 100% renewable electricity. Specifically, SK On, Sunwoda, and Samsung SDI do not have emissions reduction targets for their supply chains, which account for a significant portion of the GHG emissions associated with manufacturing EV batteries. CALB and Gotion have yet to commit to 100% renewable electricity.

4) BYD and EVE lack commitments to 100% renewable electricity and reduction targets for their suppliers, which are crucial for decarbonization of EV battery production.

Table 4: An evaluation of plans to address greenhouse gas emissions hotspots in battery production by manufacturers. [20]

Name	Market Share	Concrete Action Plan for Addressing GHG Emission Hotspots	
		100% Renewable Electricity Commitment at the Company Level	Setting Reduction Targets for Supply Chain
CATL	38.18%	√	√
LGES	12.02%	√	√
Panasonic Energy	4.01%	√	√
CALB	4.41%	No information	√
Gotion	3.21%	No information	√
Samsung SDI	3.81%	√	No information
SK On	3.11%	√	No information
Sunwoda	2.10%	√	No information
BYD	16.53%	No information	No information
EVE	2.81%	No information	No information

[20] Source: please see Appendix I: Company Profiles

Appendix I: Company Profiles

Company Name	CATL
Market Share	In 2024, CATL captured 38% of the global market share [5].
Product Portfolio	In 2023, CATL's global product portfolio was distributed as follows: NMC: 47%; LFP: 53% [35].
Net-zero commitment	In 2023, CATL announced its plan to achieve carbon neutrality **across the battery value chain** by 2035 [46]. According to its zero-carbon strategy, CATL carbon neutrality **in core operations** will be achieved by 2025 [38, p. 82].
Carbon Reduction Targets covering supply chain[21] and the Progress on Targets	CATL set zero-carbon electricity ratio targets for core material suppliers [38, p. 82], but it has not disclosed its numerical targets and the specific timeline. In its 2024 ESG report, CATL reported that the overall ratio of zero-carbon electricity usage among anode and cathode suppliers reached 57%, while aluminum suppliers achieved a ratio of 45% [38, p. 82].
Participated in the SBTi	No.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	RE target: By 2025, the company will achieve 100% zero-carbon electricity[22] usage in its core operations. RE Ratio: Zero-carbon electricity ratio in 2024: 74.51% Zero-carbon electricity ratio in 2023: 65.62% Zero-carbon electricity ratio in 2022: 26.67% [38, p. 82]. The ratio of green power consumption reached 22% in 2021 [47].
Recycled content targets for raw materials	No related information has been disclosed.
Emission Data Disclosure	In its latest Carbon Emission Accounting Report (2023), CATL disclosed its Scope 1 and 2 emissions, as well as Scope 3 emissions (including detailed Scope 3 Categories 1 [48] [23].

[21] Carbon Reduction Targets covering supply chain also include renewable electricity targets for suppliers

[22] CATL used "zero carbon electricity" without a clear definition.

[23] Except for Scope 3 Category 1, precise figures regarding each category of Scope 3 emissions are not provided.

Company Name	FinDreams Battery (BYD)
Market Share	In 2024, BYD captured 16.5% of the global market share [5].
Product Portfolio	In 2023, BYD's global product portfolio was dominated by LFP, with a distribution as follows: NMC:1%; LFP: 99% [35].
Net-zero commitment	According to its 2024 ESG Report, FinDreams Battery has committed to value chain carbon neutrality by 2045 and to achieving carbon neutrality in operations in 2031-2035 [49, p. 71-72].
Carbon Reduction Targets covering supply chain and the Progress on Targets	No related information has been disclosed.
Participated in the SBTi	Yes, FinDreams Battery[24] has committed to the SBTi.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	No related information about the renewable electricity targets of FinDreams has been disclosed, though FinDreams disclose the targets for some of their subsidiary companies. (During the reporting period, Shanghai BYD Company Limited committed to use 100% renewable energy by 2030. The SZB plant in Baolong Park of Shenzhen BYD Lithium Battery Co., Ltd. has committed to decarbonising electricity by using 60% renewable electricity by 2030, 90% by 2040 and 100% by 2050 [49, p. 68].) No related information about the renewable electricity ratio of FinDreams is being disclosed. FinDreams disclosed its zero-carbon electricity usage but did not disclose its total electricity usage in 2024, therefore the RE ratio remained unknown. Zero-carbon electricity use in 2024: 1,205,617 MWh [49, p. 194].
Recycled content targets for raw materials	No related information has been disclosed.
Emission Data Disclosure	In its latest ESG Report (2024), FinDream disclosed only its Scope 1 and 2 emissions [49, p. 194].

[24] In SBTi's website,BYD Lithium Battery Co., Ltd. is listed. See [50].

Company Name	LGES
Market Share	In 2024, LGES captured 12% of the global market share [5].
Product Portfolio	In 2023, LGES's product was 100% NMC [35].
Net-zero commitment	Achieve carbon neutrality throughout the value chain (Scope 1-3) in 2050 with a baseline of 2021; Achieve carbon neutrality within the scope of LG Energy Solution by 2040 [29, p. 39].
Carbon Reduction Targets covering supply chain and the Progress on Targets	LGES plans to transition all electricity used in raw material production and components supplied by all Tier-1 suppliers to 100% renewable electricity by 2030 [29, p. 40]. Achieve RE 100 (Renewable Electricity 100%) of its core value chain by 2040 [29, p. 39].
Participated in the SBTi	No.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	RE Target: Achieve RE100[25] at all business sites in 2030 [29, p. 39]. RE ratio in 2024: 56% [51, p. 77] RE ratio in 2023: 56.3%. RE ratio in 2022: 56.3%. RE ratio in 2021: 45.3% [29, p. 119].
Recycled content targets for raw materials	By 2030, LGES aims to use up to 20% recycled metals, thereby aligning with global regulations and advancing its commitment to sustainable management [29, p. 47].
Emission Data Disclosure	In its latest ESG Report (2024), LGES disclosed its Scope 1 and 2 emissions, as well as Scope 3 emissions (including detailed Scope 3 Categories 1-7) [51, p.152].

[25] RE100 (Renewable Electricity 100%), EV100 (Electric Vehicle 100%)

Company Name	CALB
Market Share	In 2024, CALB captured 4.4% of the global market share [5].
Product Portfolio	In 2023, CALB's global product portfolio was distributed as follows: NMC: 46%; LFP: 54% [35].
Net-zero commitment	2030, carbon neutrality in operations 2040, carbon neutrality in its value chain [52, p. 4].
Carbon Reduction Targets covering supply chain and the Progress on Targets	CALB has set a target of reducing carbon in the supply chain by 10% per year [40, p. 35].
Participated in the SBTi	No.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	Neither the RE Target nor the RE ratio has been disclosed. CALB disclosed its renewable energy consumption including fossil gas without specifying renewable electricity consumption.
Recycled content targets for raw materials	No related information has been disclosed.
Emission Data Disclosure	In its latest ESG Report (2024), CALB disclosed its Scope 1 and 2 emissions, as well as its scope 3 emissions (but it did not provide a breakdown of Scope 3 emissions) [52, p. 29].

Company Name	Panasonic Energy
Market Share	In 2024, Panasonic Energy captured 4% of the global market share [5].
Product Portfolio	In 2023 Panasonic Energy's product was 100% NMC [35].
Net-zero commitment	Panasonic Holdings Corporation commits to achieve net zero emissions by 2050 across Scope 1, 2, and 3 [53]. As an operating company of Panasonic Holdings Corporation, Panasonic Energy has also set this as a uniform target for all Panasonic Group operating companies [33].
Carbon Reduction Targets covering supply chain and the Progress on Targets	Panasonic Energy has set the target of a 50% reduction in its carbon footprint by fiscal 2031 compared to fiscal 2022 and is promoting the reduction of CO2 emissions throughout its entire supply chain [39].
Participated in the SBTi	Panasonic Energy's parent company, Panasonic Holdings, has joined the SBTi [53].
Renewable Electricity (RE) Target at the Company Level and RE Ratio	RE target: Electricity renewable energy[26] ratio 100% FY2029 [54, p. 39]. RE ratio in FY 2024: 32%. RE ratio in FY 2023: 22%. RE ratio in FY 2022: 12% [33].
Recycled content targets for raw materials	Panasonic Energy has set the target of achieving 20% recycled cathode material content in its automotive batteries by 2027 [45].
Emission Data Disclosure	In its latest Integrated Report (2024), Panasonic Energy disclosed its Scope 1 and 2 emissions, as well as Scope 3 emissions (including detailed Scope 3 Categories 1,5,6) [54, p. 71].

[26] Percentage of electricity, fuel, etc. used by Panasonic Energy that is derived from renewable energy sources , includes certificates, credits, and other externally procured items.

Company Name	Samsung SDI
Market Share	In 2024, Samsung SDI captured 3.8% of the global market share [5].
Product Portfolio	Available data indicates that Samsung SDI produces both NMC and LFP batteries, though the exact proportion remains unclear due to limited data accessibility [35].
Net-zero commitment	In 2022, Samsung SDI announced that its carbon neutrality goal would be by 2050 [55], but without specific scope.
Carbon Reduction Targets covering supply chain and the Progress on Targets	No related information has been disclosed.
Participated in the SBTi	No.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	RE target [56]: 94% RE Ratio for 2030. 97% RE Ratio for 2040. 100% RE Ratio for 2050. RE Ratio in 2023: 27%. RE Ration in 2022: 9% [44, p. 35].
Recycled content targets for raw materials	Samsung SDI set its target use of recycled metals to be 21% in 2025 and 26% in 2030 [44, p. 35].
Emission Data Disclosure	In its latest Sustainability Report (2024), Samsung SDI disclosed its Scope 1 and 2 emissions, as well as Scope 3 emissions (including detailed Scope 3 Categories 1, 2, 3, 4, 5, 6, 7, 8, 9, 12, 13 and 15) [44, p. 34].

Company Name	Gotion
Market Share	In 2024, Gotion captured 3.2% of the global market share [5].
Product Portfolio	In 2023, Gotion's global product portfolio was distributed as follows: NMC: 8%; LFP: 92% [35].
Net-zero commitment	Gotion announced in its 2024 ESG report that they "Planned to achieve carbon neutrality by 2040" in operations [41, p. 11].
Carbon Reduction Targets covering supply chain and the Progress on Targets	"Management of emissions reduction targets: the company will integrate 'dual-carbon' requirements into its supply chain management from 2022; and push suppliers to meet a 5 per cent annual carbon reduction target" [41, p. 49].
Participated in the SBTi	No.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	No related information about RE target has been disclosed. RE ratio in 2024 : 21.3% （376,674MWh/1,762,400.47MWh） [41, p. 70-72].
Recycled content targets for raw materials	By 2027,14 % recycled material use in cell products [41, p. 11].
Emission Data Disclosure	In its latest ESG report（2024）, Gotion disclosed only its Scope 1 and 2 emissions, as well as Scope 3 emissions including detailed Scope 3 Category 1 [41, p. 76] [27].

[27] Except for Scope 3 Category 1, precise figures regarding each category of Scope 3 emissions are not provided.

Company Name	SK On
Market Share	In 2024, SK captured 3.1% of the global market share [5].
Product Portfolio	Available data indicate that SK On mainly produces NMC622 and NMC811, though the exact proportion remains unclear due to limited data accessibility [35].
Net-zero commitment	SK On committed to achieve net zero early by 2035 in Scope 1 and 2 [57].
Carbon Reduction Targets covering supply chain and the Progress on Targets	No related information has been disclosed.
Participated in the SBTi	No.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	SK On committed to converting electricity use to 100% renewable energy by 2030 [58]. No related information about SK On's renewable electricity ratio has been disclosed.
Recycled content targets for raw materials	No related information has been disclosed.
Emission Data Disclosure	SK On disclosed Scope 1&2 emissions and Scope 3 emissions (including Scope 3 category 1,3,4,5,6,7,9,11,12) [59].

Company Name	EVE Energy
Market Share	In 2024, EVE captured 2.8% of the global market share [5].
Product Portfolio	In 2023, EVE's global product portfolio was distributed as follows: NMC: 18%; LFP: 82% [35].
Net-zero commitment	The company has made the following low-carbon development commitments: achieve carbon neutrality in operations by 2030 and carbon neutrality across the core value chain by 2040 [60, p. 26].
Carbon Reduction Targets covering supply chain and the Progress on Targets	No related information has been disclosed.
Participated in the SBTi	No.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	RE target in 2024: 4%-8% [60, p. 29]. Precise figures regarding the RE target in 2024 have not been disclosed. RE ratio in 2024: 12%-16% [60, p. 29]. Precise figures regarding the RE ratio in 2024 have not been disclosed.
Recycled content targets for raw materials	No related information about recycled content targets for raw materials has been disclosed. EVE disclosed its recycled materials (lithium, nickel and cobalt) usage for products in 2024. "Factory 11 and 12 at the Jingmen base have actively introduced recycled materials into production to manufacture greener products. 73 tons of recycled lithium, 722 tons of recycled nickel and 96 tons of recycled cobalt have been applied through the green supply chain" [60, p. 36].
Emission Data Disclosure	In its latest Sustainability Report (2024), EVE disclosed only its Scope 1 and 2 emissions [60, p. 60].

Company Name	Sunwoda
Market Share	In 2024, Sunwoda captured 2.1% of the global market share [5].
Product Portfolio	In 2023, Sunwoda's global product portfolio was distributed as follows: NMC: 58%; LFP: 42% [35].
Net-zero commitment	As of the data collection date (April 2025), Sunwoda plans to achieve carbon neutrality in operations by 2050 [61, p. 50].
Carbon Reduction Targets covering supply chain and the Progress on Targets	No related information has been disclosed.
Participated in the SBTi	Yes, Sunwoda has committed to the SBTi.
Renewable Electricity (RE) Target at the Company Level and RE Ratio	RE Ratio target in 2050: 100% [61, p. 23]. RE ratio in 2024: 29.71% [61, p. 56].
Recycled content targets for raw materials	No related information has been disclosed.
Emission Data Disclosure	In its latest ESG Report (2024), Sunwoda disclosed only its Scope 1 and 2 emissions [61, p. 130].

Appendix II: Market share of the global top ten battery manufacturers

Company Name	2024 Capacity [GWh]	2024 Market Share
CATL	381	38.18%
FinDreams Battery (BYD)	165	16.53%
LGES	120	12.02%
CALB	44	4.41%
Panasonic Energy	40	4.01%
Samsung SDI	38	3.81%
Gotion	32	3.21%
SK On	31	3.11%
EVE	28	2.81%
Sunwoda	21	2.10%
Others	98	9.82%
Total	998	

Appendix III: Battery companies' ESG or sustainability reports

Company/[GWh]	Reporting Period	Name	Link
CATL	January 1, 2024, to December 31, 2024	2024 ESG Report - CN	https://www.catl.com/uploads/1/file/public/202503/20250328110514_yhfqo19im4.pdf
	January 1, 2023 to December 31, 2023	2023 Carbon Accounting -EN	https://www.catl.com/en/uploads/1/file/public/202409/20240920152219_4mm2h2equv.pdf
FinDreams Battery (BYD)	January 1, 2024, to December 31, 2024	2024 ESG Report - CN	https://www.fdbatt.com/responsibility/%E5%BC%97%E8%BF%AA%E7%94%B5%E6%B1%A02024%E5%B9%B4%E5%BA%A6%E5%8F%AF%E6%8C%81%E7%BB%AD%E5%8F%91%E5%B1%95%E6%9A%A8ESG%E6%8A%A5%E5%91%8A.pdf
LGES	January 1, 2024 December 31, 2024	2024 ESG Report - KR	https://www.lgensol.com/upload/file/sustainability/LG_Energy_Solution_2024_ESG_Report_KR_FF.pdf
	January 1, 2023 December 31, 2023	2023 ESG Report - EN	https://www.lgensol.com/upload/file/sustainability/LG_Energy_Solution_2023_ESG_Report_ENG_FFF[0].pdf
CALB	January 1, 2023 December 31, 2023	2023 ESG Report - CN	https://invest.calb-tech.com/upload/file/20240430/20240430201844.pdf
	January 1, 2024, to December 31, 2024	2024 ESG Report - CN	https://invest.calb-tech.com/upload/file/20250430/20250430085523.pdf
Panasonic Energy	Fiscal year 2024 (April 1, 2023 to March 31, 2024)	Integrated Report 2024 - EN	https://www.panasonic.com/content/dam/panasonic/global/en/energy/sustainability/report/Integrated_report2024_en.pdf
	Fiscal year 2023 (April 1, 2022 to March 31, 2023)	Integrated Report 2023 - EN	https://www.panasonic.com/content/dam/panasonic/global/en/energy/sustainability/report/Integrated_report2023_en.pdf
Samsung SDI	2023 fiscal year (Jan. 1, 2023 ~ Dec. 31, 2023)	Sustainability Report 2024 - EN	https://www.samsungsdi.com/upload/download/sustainable-management/2024_Samsung_SDI_Sustainability_Report_English.pdf
Gotion	January 1, 2024, to December 31, 2024	2024 ESG Report - CN	https://static.cninfo.com.cn/finalpage/2025-04-25/1223284107.PDF
SK On	Year of 2023	ESG Data	https://esg.skinnovation.com/en/environmental/SKO
EVE	January 1, 2024, to December 31, 2024	2024 Sustainability Report - CN	https://pdf.dfcfw.com/pdf/H2_AN202504171657994665_1.pdf?1744920849000.pdf
Sunwoda	January 1, 2024, to December 31, 2024	2024 Sustainability Report - CN	https://www.sunwoda.com/upload/portal/20250422/b623437ed1ab436ccda1e0712fb70a6b.pdf

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