

Research Paper

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Profitability and Cost Structure in the Battery Cell Industry: A Comparative Analysis of CATL and Key Competitors

The battery market currently faces significant challenges for market participants. European and American EV sales stagnated during 2023 and 2024 (IEA, 2025). At the same time, dramatic overcapacities of Chinese companies increase pressure on prices and margins. Ultimately, several battery cell manufacturing companies face economic difficulties. Nevertheless, a few remain in a stronger economic position than the majority. This analysis compares Contemporary Amperex Technology Limited's (CATL) business performance based on publicly available data from the early 2023 through the first half of 2025 with three major competitors in the battery cell market China Aviation Lithium Battery (CALB), LG Energy Solution (LGES) and Samsung SDI (SDI). Besides location-based differences, CATL's efforts to establish own supply chains and potential economic benefits were also considered.

1. Introduction

Presently, the manufacturing of battery cells faces numerous challenges. Especially European companies are encountering difficulties in establishing local cell production. The insolvency of *Northvolt AB*, the postponement of *ACC's* battery cell plants in Italy and Germany, and recent decision of *Porsche AG* to cancel the *Cellforce GmbH* project to establish its own cell production illustrate the capital-intensity and challenge of maintaining an industrial-scale battery cell manufacturing successfully (batterienews.com, 2025; BatteryIndustry.net, 2024; Carla Westerheide, 2025; Julian Baumann, 2025; Porsche AG, 2025).

Moreover, intense price competition is ongoing due to a substantial mismatch between battery cell capacity expansion and current demand in China. As a result, battery cell market prices have declined by approximately 60% since 2022 (Fabrice Renard and Christophe Pillot, 2025). Additional overcapacities for cathode active material reinforced prices and margins pressure along the entire supply chain (Fabrice Renard and Christophe Pillot, 2025; Wu et al., 2025). Consequently,

battery cell manufacturers are forced to reduce sales prices, potentially eroding margins and earnings.

On the one hand, this development may have certain positive implications for customers and the automotive industry. In the context of intensifying competition, cell sales prices are decreasing, which reduces purchasing costs enabling automotive manufacturers and other customers to procure cells at lower prices.

On the other hand, to maintain economic viability, cell manufacturers need to decrease production costs. This price competition poses risks for market players that are unable to cut prices and maintain competitiveness simultaneously. Furthermore, the current situation is preventing new market participants from entering this challenging market. Nevertheless, some firms continue to perform strongly despite these adverse conditions.

An initial review of operating margins indicates that CATL and CALB were able to keep margins stable. Nevertheless, CATL exhibits significantly higher profitability (Figure 1).

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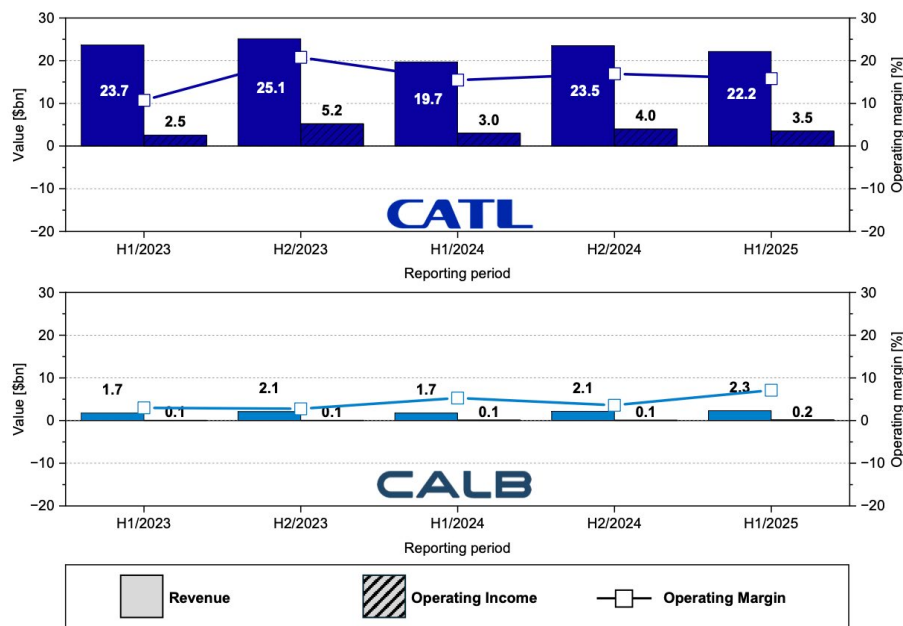


Figure 1: Revenue and operating income comparison of Chinese companies CATL and CALB between second half of 2023 to first half of 2025. The analysis considers only revenue and operating profit or loss associated with cell & battery manufacturing and its sales (CALB, 2024, 2025a, 2025b, 2025c; Contemporary Amperex Technology Co. Limited (CATL), 2023, 2024a, 2024b, 2025b, 2025d).

In comparison, the economic performance of two major Korean competitors, LGES and SDI, displays a significantly different picture. Both are facing operating loss since at least two reporting periods if subsidies granted through *Inflation-*

Reduction-Act are neglected (Figure 2).

The fundamental question arising from this observation is why Chinese manufacturers, especially CATL, are able to maintain high profitability despite global overcapacity and intense price competition, while other competitors

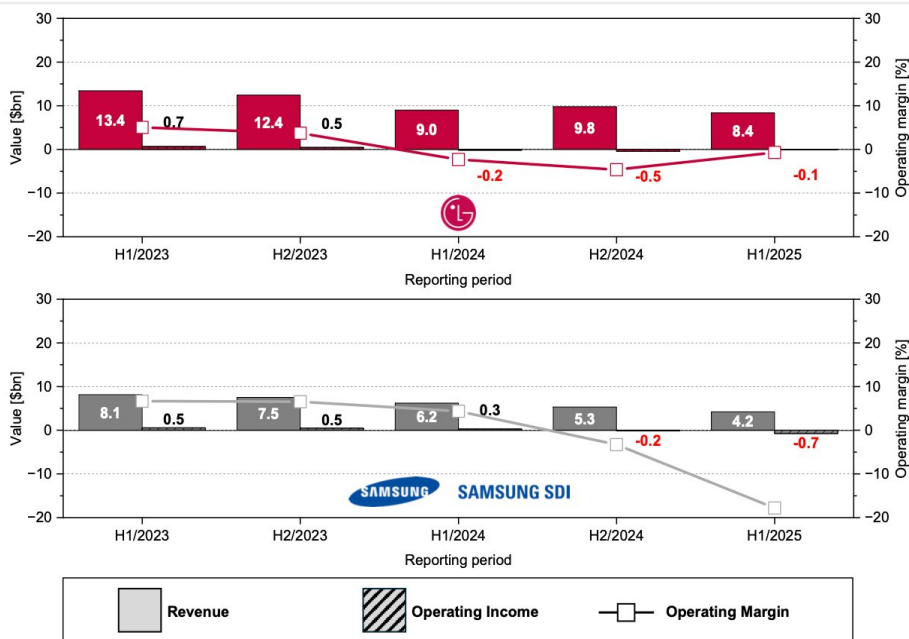


Figure 2: Revenue and operating income comparison of Korean companies Samsung SDI and LGES between second half of 2023 to first half of 2025. For LGES and SDI other operational income from *Inflation-Reduction-Act* of the U.S. government is excluded. The analysis considers revenue and operating profit or loss associated with cell & battery manufacturing and its sales (LG Energy Solution, 2023, 2024b, 2024c, 2025b, 2025c; Samsung SDI, 2023, 2024a, 2024b, 2025a, 2025b).

incur operating losses or achieve only low profitability. The existing literature provides limited insight into this question, although CATL has been examined in several studies:

Whitfield et al. examine the technological catch-up of BYD and CATL at the company level. The study assesses how BYD and CATL became leading firms in the EV and battery cell manufacturing sectors. The author ultimately identifies early corporate investments and technology efforts, as well as government policies, as key drivers of their success. (Whitfield and Wuttke, 2026) *Zhang et al.* conducted a study on CATL's profit model, including financial metrics. However, their analysis focuses primarily on customer and market perspectives. In addition, competitors are not assessed. (Zhang and Yang, 2023).

Fan et al. assessed the profitability of CATL's business, evaluating it from a variety of perspectives. This assessment also includes a brief evaluation of the major domestic competitor. Nevertheless, financial assessment is exclusively available for CATL. Nevertheless, the author arrived at the conclusion that the decline in the margin of CATL was substantial and was the result of increased domestic competition (Fan, 2022).

Therefore, the subsequent analysis evaluates CATL's business model and examines possible drivers for its resilience and profitability compared to key competitors. Within this analysis, the following hypotheses were assessed:

H1: In general, Chinese companies benefit from a significant cost advantage due to lower energy costs and wages associated with domestic production.

H2: As the global leading battery cell manufacturer, CATL benefits from economies of scale arising from its large manufacturing capacity.

H3: CATL benefits from vertical integration into the battery raw material supply chain and from significant acquisitions of related companies.

2. Method

For the data analysis, semi-annual and annual reports of the battery cell manufacturers CATL, CALB, LGES and SDI from 2023 to the first half of 2025 were analyzed and evaluated. The selection of these companies was based on three key criteria.

First, their business activities include battery cell

production which is globally relevant. Accordingly, all companies analyzed rank among the top ten in battery volumes sold in 2024. Second, required financial reporting data were accessible. Third, the companies' major business activity needed to be directly related to battery cell production.

It would also have been appropriate to include BYD, the world's second-largest battery cell manufacturer, in this comparison. However, from an external perspective, the battery business cannot be assessed independently of BYD's automotive business and other corporate activities.

To conduct this analysis, original Chinese and Korean reports were translated by using DeepL.com Pro-Version. The analysis focused on key financial indicators – as revenue, operating income and operating margin – consistent with prior studies (Fan, 2022). Additionally, raw material costs were encompassed to assess CATL's raw material strategy. Net income was excluded, due to varying tax rates and government incentives. Several key performance indicators were considered, including sales volume, production capacity and production output. All currencies were converted to USD using an average currency exchange rate for the respective year (ExchangeRates.org.uk).

Subsidies or government grants, such as *Inflation Reduction Act* (IRA) by U.S. government or Chinese governmental funding were subtracted wherever possible. In the *Statement of Profit or Loss* of both companies, the amount and type of funding become not immediately obvious. Therefore, it cannot be confirmed that government subsidies were fully excluded from the following analysis. (CALB, 2025a; 2025).

In addition to battery-related businesses, CATL and SDI generated revenues from other activities. For SDI, the production of semiconductors and displays contribute between 5% to 10% of total revenue. CATL generated approximately 10% to 15% of total revenue by businesses related to raw materials, battery materials, recycling and further businesses summarized under Others. For both companies, revenues and incomes from those activities were excluded to enable a more precise analysis of their battery-related businesses. Therefore, CATL's indirect expenses (Overhead, sales expenses, R&D expenses, etc.), which are not immediately attributable to the battery related business, were allocated based on the revenue share of the battery-related business units.

3. Results and discussion

3.1. Company profiles

CATL is a Chinese company headquartered in Ningde, Fujian. The company has extensive experience in battery cell manufacturing and in battery cell development for electric vehicle applications (xEVs), energy storage systems (ESS), and niche applications such as power tools and e-bikes. In addition, CATL actively acquires and invests in domestic and international projects to secure direct access to battery raw materials and to expand recycling activities for production scrap and end-of-life batteries. CATL operates lithium mining in China and has been identified as a stakeholder in a nickel mining project in Indonesia and a cobalt mining project in the Democratic Republic of Congo (BatteryIndustry.net, 2024; Contemporary Amperex Technology Co. Limited (CATL), 2021, 2022, 2025c; Tom Daly, 2022).

CATL supplies numerous well-known customers, nationally and internationally, including Volkswagen AG, Stellantis N.V. and Ford Motor Company. The company operates a total of 13 production facilities. Furthermore, several subsidiaries or equity investments in Joint Ventures are owned by to the company (Contemporary Amperex Technology Co. Limited (CATL), 2025a). One of the largest subsidiaries

is Guangdong Brunp Recycling Technology, which is involved in recycling and raw material sourcing activities (Guangdong Brunp Recycling Technology, 2023).

In 2024, CATL generated revenue of approximately \$50 billion while the annual production volume reached approximately 516 gigawatt-hours (GWh). Of this, 475 GWh were sold. CATL is undoubtedly the global leader in battery cell production for xEVs and ESS, its market share in these segments is approximately 37.9% respective 36.5%, while it surpasses the second-largest producer BYD by 20.7% and 23.3%, respectively (Contemporary Amperex Technology Co. Limited (CATL), 2025b). CATL supplies battery cells, modules and complete packs to its customers. However, a precise breakdown across specific markets and products is not disclosed. Nevertheless, due to the description in the semi-annual report in 2025 it is assumed that revenue and sales volumes are mainly attributable to xEV or heavy-truck applications rather than niche applications. Relevant chemistries are nickel-manganese-cobalt-oxide (NMC), lithium iron-phosphate (LFP) and sodium-ion (SIB).

CALB, the second company included in this analysis, is also a Chinese battery cell manufacturer. In contrast to CATL, CALB produces almost exclusively for the

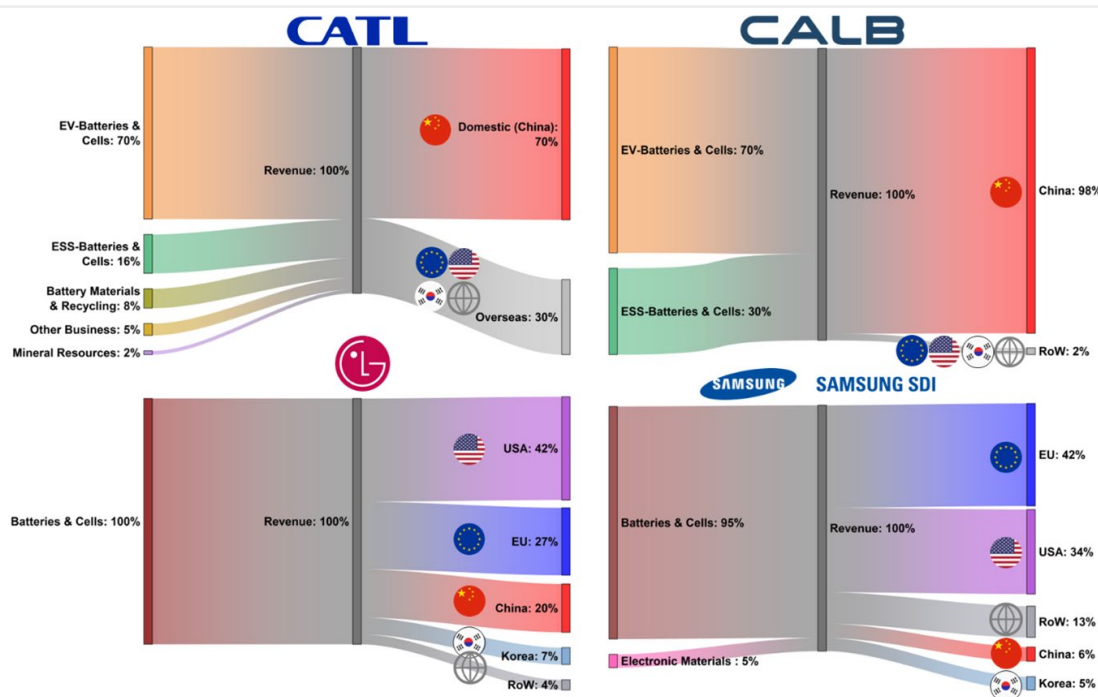


Figure 3: Revenues streams and revenue distribution of CATL, CALB, LGES and SDI for the year 2024 (CALB, 2025a; Contemporary Amperex Technology Co. Limited (CATL), 2025b; LG Energy Solution, 2025b; Samsung SDI, 2025a).

domestic market. Approximately 98% of CALB's revenue is generated in China (Figure 3) (CALB, 2025a; Contemporary Amperex Technology Co. Limited (CATL), 2025b). A production plant in the European Union is currently in planning stage (Reuters, 2025b). Compared with LGES, SDI and CATL, CALB's revenue is smaller, but its business growth rate is significantly larger (Figure 1). LGES and SDI are Korean companies operating production facilities in Asia and the European Union. In addition, both also manufacture in the United States. Currently, LGES maintains two joint ventures and one subsidiary, while two additional joint ventures are in the construction phase. SDI started its mass production at joint venture *Star Plus Energy* by the end of 2024 (Samsung SDI). Furthermore, SDI aims to start production at a second joint venture with *General Motors* as of 2027 with an annual capacity of 27 GWh (Samsung SDI). All companies produce cells for xEV and ESS applications. LGES, SDI and CATL, to some extent, provide cells for minor and niche applications (Contemporary Amperex Technology Co. Limited (CATL), 2025b; Fabrice Renard and Christophe Pillot, 2025; LG Energy Solution, 2025a; Samsung SDI). Additionally, SDI produces battery cells for portable electronic devices, such as smartphones, wearables and laptops.

Lastly, Figure 3 illustrates the revenue distribution across business segments and regions of all competitors. Comparing revenue streams and regions is important to understand location dependencies.

When comparing revenue streams, it becomes evident that the Chinese manufacturers CATL and CALB are primarily exposed to the Chinese market, with CALB being particularly dependent on it. By contrast, LGES and SDI have only a minor presence in China and therefore rely more heavily on the U.S. and European markets (Figure 3).

3.2. Production regions and capacity

In a comparative analysis of production costs, the location of production represents a crucial factor. Differences in location-related salaries and energy costs affect battery cell production cost significantly (Degen and Krätzig, 2024; Ruppert et al., 2025). Therefore, the subsequent overview illustrates companies' production capacities, their production regions and a qualitative estimation about the corresponding production share. Additionally, it shows where current capacity expansions or new production site developments accessing new regions are ongoing (Figure 4):

It is evident that the Chinese companies CALB and

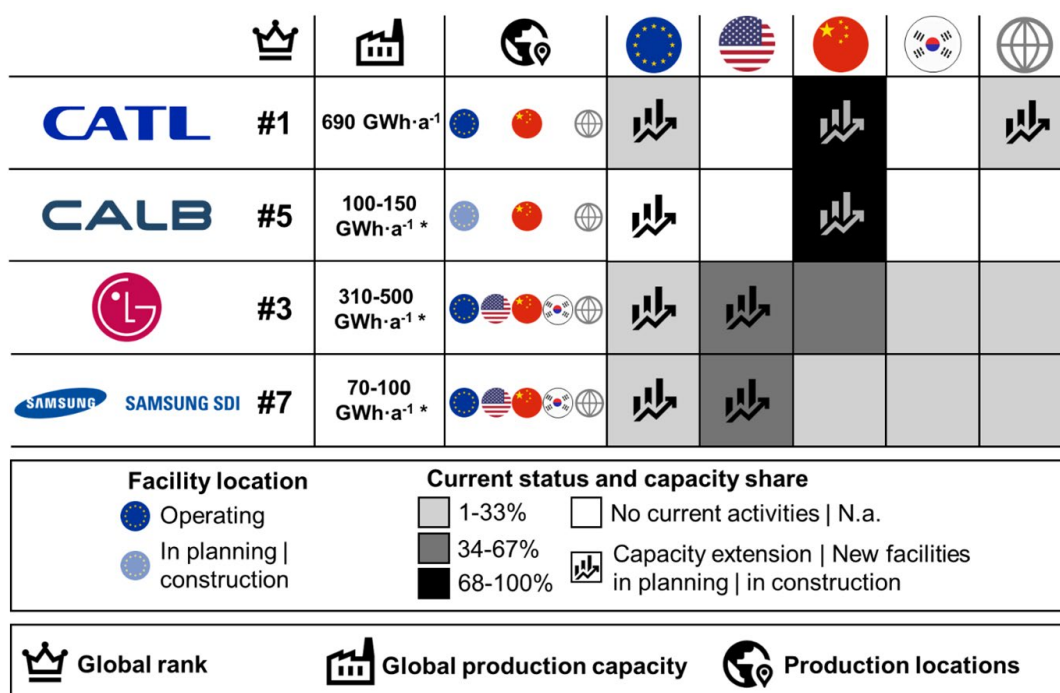


Figure 4: Production locations, capacity and capacity shares across various major regions (Contemporary Amperex Technology Co. Limited (CATL), 2025d). *Production capacities of LGES, CALB and SDI are estimated based on company information, news and announcements for (CALB, 2022; Florian Treiß, 2025; LG Energy Solution; LG Energy Solution, 2025a;

CATL mainly produce in China. Currently, neither CATL nor CALB has made official announcements regarding future production plants in the United States or Korea. CATL's production facility in Germany has a capacity of approximately 14 GWh·a⁻¹. The Hungarian factory aims to reach a capacity up to 100 GWh·a⁻¹. Consequently, the estimated production capacity share of CATL in Europe is below 34% of total capacity.

Currently, CALB does not maintain production facilities outside of China. However, a factory in Portugal is in the planning stage. The intended capacity is 15 GWh·a⁻¹ and start of production is planned in 2028 (Reuters, 2025b).

In contrast, LGES and SDI maintain a significant share of their production capacity in the European Union and the United States. Both companies also operate manufacturing facilities in China, but the capacity share in this region is below 25% of their total capacity. In addition, LGES has announced plans to increase annual production capacity in North America to up to 250 GWh·a⁻¹ and to raise the region's share up to 50% to 60% of its global production capacity. As noted above, LGES and SDI generate a larger share of their revenue from the U.S. and European markets than from China (Figure 3) (LG Energy Solution, 2024a).

Both LGES and SDI maintain large shares of their production capacity in the European Union and the United States, where average wages and energy costs are considerably higher, particularly in Europe. This leads to higher production costs. Consequently, LGES and SDI face a structural cost disadvantage associated with local manufacturing in the European Union and the United States. Their ability to reduce prices while remaining profitable is therefore more limited.

Additionally, transportation costs are a crucial factor that must be considered. Higher production costs in the European Union and the United States can be offset, by lower logistics costs resulting from shorter transport routes when supplying the European or American domestic market. However, these savings are generally limited and therefore only partially compensate higher production costs (Thomsen and Lux, 2025).

In conclusion, the geographic distribution of CATL's and CALB's production locations support hypothesis H1. However, CATL's manufacturing sites in Europe refute a purely location-based explanation. Otherwise, CALB would exhibit superior financial performance, due to exclusive domestic production. Hence, while production location confers a cost advantage for CATL

and for CALB, it is unlikely to be sufficient to explain the observed divergence in economic results.

This interpretation is further supported by the limited contribution of manufacturing costs to total battery costs, which is estimated at approximately 10% to 30% (Degen and Krätzig, 2024; Ruppert et al., 2025). A comparative assessment between China (low-cost case) and Germany (high-cost case) reports a cost differential of 5.8 \$·kWh⁻¹ for LFP pouch-cell production at a scale of 20 GWh·a⁻¹, corresponding to a 35% decrease in manufacturing costs and approximately 3% to 10% decrease of total battery cost (Ruppert et al., 2025). While LGES and SDI predominantly manufacture in the United States (comparable wages, lower energy cost compared to Germany) or other European countries (lower costs compared to Germany), a smaller location-driven cost differential appears plausible. Accordingly, the performance gap is likely explained by a combination of factors rather than by production location alone.

3.3. Capacity and production development

In general, producing larger volumes decreases manufacturing costs per kilowatt-hour through economies of scale (Mauler et al., 2021). However, capacity extensions are capital-intensive, which may also affect profitability. Moreover, if capacity utilization is low, higher production costs per unit occur in comparison to a smaller production facility operating at higher capacity utilization (Mauler et al., 2021).

For the analysis of production and sales volume, relevant data from all companies on a semi-annual basis were evaluated (Figure 5). On the one hand, the comparison of sales volumes reveals a substantial gap between CATL and the three competitors (Figure 6). This suggests that CATL may face lower manufacturing costs through economies of scale, thereby supporting thesis H2. On the other hand, LGES, as the second-largest producer by sales volumes exhibited the weakest income performance in 2024, which in turn contradicts thesis H2 (Figure 1).

Moreover, the cost reduction attributable to economies of scale appears quantitatively limited. For an illustrative LFP pouch-cell facility, increasing annual capacity from 20 GWh·a⁻¹ to 100 GWh·a⁻¹ reduces manufacturing costs by only 1.8 \$·kWh⁻¹ (fully utilization is assumed) corresponding to -16% of production cost or approximately -2% to -5% of total battery cost (Ruppert et al., 2025). Consequently, an in-depth assessment of

installed capacity and utilization is required.

From the second half of 2023 to the first of 2024, CATL's capacity utilization shrinks from 70% to 65%. In the subsequent reporting periods, both production volume and utilization increased significantly, while capacity extension – particularly in the first half of 2025 – slowed down (Contemporary Amperex Technology Co. Limited (CATL), 2024b, 2025b). Finally, CATL achieved the highest capacity utilization rate in comparison with LGES and SDI of approximately 90%. Between the second half of 2023 and first half of 2025, its annual production capacity increased by approximately 25%, while production volume rose by about 32% (Contemporary Amperex Technology Co. Limited (CATL), 2024a, 2024b, 2025b, 2025d).

LGES and SDI disclosed their production capacity in monetary terms or units rather than in gigawatt-hours. Consequently, a direct comparison to CATL is not feasible. The reported values indicate a substantial decline in capacity – for LGES from \$42.6 billion for 2023 to \$28.6 billion for 2025 and for SDI from 2.721 to 2.450 billion units during the same period (2025 capacities are estimated by doubling value received from semi annual reports). Reasons for the reported decline in production capacity are not disclosed. For LGES, it is unclear whether this reflects a real reduction in capacity or lower average battery prices, which would reduce the reported capacity value. A shift in product

mix toward lower-cost chemistries could have a similar effect. However, the capacity utilization rate is the more comparable and relevant metric. While CATL managed to increase utilization, LGES experienced a decline from 74.8% in first half of 2023 to 51.3% in the first half of 2025 (Figure 5). It remains unclear whether this trend reflects accelerated capacity expansion relative to production volumes or a contraction in demand. Due to the general ongoing market situation and overcapacities, a shrinking demand is more plausible than an accelerated capacity extension, which is also indicated during comparison of cell production capacities. In addition, there are announcements that LGES decided to reduce spending on investment for 2024 to address global overcapacities. Furthermore, sales volumes decreased between 2023 and 2024 (Figure 6) (Lee Min-Jo, 2024).

SDI's capacity utilizations rate draws a similar picture as LGES. Between the first half of 2023 and 2024, SDI maintained the highest capacity utilization rate of all companies in scope. Later in 2024 and first half of 2025 it shrinks to 44.2%. Surprisingly, this development is comparable to operating margin development. Between first half of 2023 and 2024, margin was stable, later it turned to an operative loss.

For CALB, no precise information about capacity utilization is disclosed. Due to the fast-growing sales and revenue of CALB in comparison to the other companies and even to CATL, a high utilization is assumed.

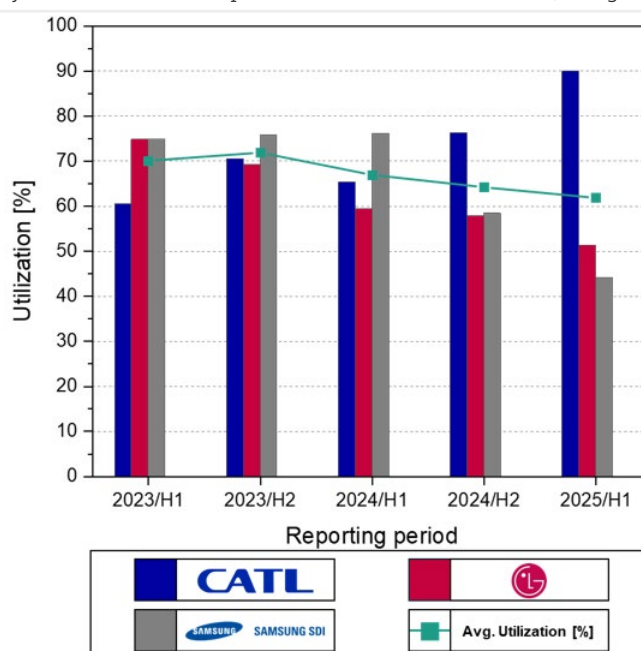


Figure 5: Production capacity utilization of CATL, LGES and SDI and average utilization across these companies. CALB does not disclose values related to capacity utilization.

If manufacturing continuously and the ability to shut down equipment is limited (e.g. dry room), the production cost measured per kilowatt-hour nearly doubles at a utilization rate of approximately 50%. Ultimately, relative to full utilization, this may increase total battery costs by approximately 10% to 30%.

Overall, production capacity and capacity utilization have a significant impact on production cost. Capacity expansions are cost-intensive and extent production capacities operating at lower utilization results in higher cost per unit. As shown in the reports, CATL maintains the largest production capacity operating at the highest utilization rate compared with its competitors. Therefore, CATL may benefit significantly from its high capacity utilization and large-scale production.

Nevertheless, a central question remains: How is CATL able to increase its utilization, while LGES and SDI face significant decline? A possible explanation could be a considerably lower sales price in comparison to LGES and SDI, offering CATL a significant advantage against its competitors. Furthermore, a demand shift in preferred cell chemistry is also a potential reason. According to *SNE Research*, the significant decline in sales volumes of the Korean companies LGES and SDI between 2023 and 2024 are attributable to a shift in demand from NMC to LFP cell chemistry. LFP is predominantly supplied by Chinese manufacturers such as CATL, BYD and CALB (Shanghai Metal Markets, 2025a; SNE Research, 2025).

3.4. Sales volumes and income development

Relevant information such as cell sales composition by type or chemistry were not disclosed. In particular, the cost of NMC, NCA or LCO battery cells is considerably higher than LFP battery cells due to more expensive raw materials (Fabrice Renard and Christophe Pillot, 2025; Ruppert et al., 2025).

The sales volumes comparison highlights CATL's dominance as the global market leader (Figure 6). LGES ranks third globally, with annual sales volumes equivalent to approximately 25% of CATL's value. CALB and SDI are positioned at 5. and 7. rank, respectively.

From 2023 to 2024, only Chinese companies CATL and CALB were able to increase sales volumes by approximately 20% respective 50%. Simultaneously, LGES and SDI experienced a sales volumes decline of 6% and 18%, respectively. As previously referenced, this development may be attributable to the accelerated distribution of LFP technology in ESS and xEV applications (Shanghai Metal Markets, 2025a; SNE Research, 2025). Recently, American automotive manufacturer *General Motors* has requested its suppliers, SDI and LGES, to produce LFP cells at its North American production facilities for its vehicle models (Sang-Hoon Sung, 2025).

Conversely, the average revenue per kilowatt-hour shows a divergent trend. In general, it declined

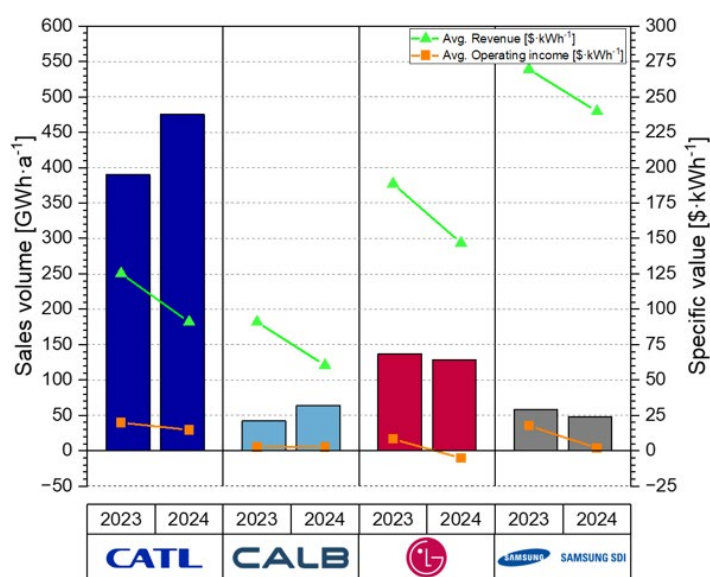


Figure 6: Sales volumes, average revenue and operating income per kilowatt-hour for 2023 and 2024. For LGES and SDI, IRA funds are excluded. (CALB, 2024, 2025a; Contemporary Amperex Technology Co. Limited (CATL), 2024a, 2025b; LG Energy Solution, 2024b, 2025b; Samsung SDI, 2024a, 2025a; SNE Research, 2025)

from 2023 to 2024 ranging from 20 \$·kWh⁻¹ to 40 \$·kWh⁻¹. Due to overcapacities and price competition in the battery cell market, companies decreased prices. It is noteworthy that SDI, with the highest revenue of approximately 269 \$·kWh⁻¹, exhibited the smallest decrease, amounting to approximately 29 \$·kWh⁻¹ to 240 \$·kWh⁻¹. However, it needs to be considered that SDI also produces a significant quantity of small-scale cells for smartphones and further portable electric devices, containing lithium cobalt oxide (LCO) which is more expensive. For those battery cells, the price per kilowatt-hour is considerably higher than for NMC or LFP chemistry due to higher cobalt share. Ultimately, this increases average revenue measured per kilowatt-hour. As the average revenue for both LGES and SDI decreases, the average operating income per kilowatt-hour for these entities also experiences a significant decline. It is noteworthy that LGES's ability to generate operating profit in previous reporting periods was primarily attributable to IRA subsidies from the U.S. government (Stan Lee, 2024c). In contrast, CALB and CATL face a smaller decline in income per kilowatt-hour compared to LGES and SDI. Consequently, both had the opportunity to compensate for shrinking revenue per kilowatt-hour by implementing cost optimization strategies.

Furthermore, it is important to note that Chinese government frequently provides significant subsidies to domestic companies. It subsidized the EV and battery industry with approximately \$231 billion between 2009 and 2023 (Scott Kennedy, 2024). Therefore, CATL as one of the largest recipients of governmental subsidies benefited significantly during the last years. Those fundings offer a boost to promote domestic companies and gain competitive advantages in an emerging market. According to public announcements, CATL received \$0.76 billion of subsidies in 2023 and approximately \$0.53 billion during the first half of 2024 (Kenji Kawase, 2025; Nikkei Asia, 2024).

For CATL and CALB, neither the type nor the amount of funding obtained was immediately disclosed. However it is important to note, that values may be subject to alteration if the amount of funding is precisely identified and deducted (Kenji Kawase, 2024, 2025; Nikkei Asia, 2024).

Nevertheless, summarizing results from previous analysis, the lower capacity utilization for LGES and SDI may be attributable to diminishing sales volumes

in 2023 and 2024. That may be caused due to weaker demand and intensified competition with companies such as CATL, which has demonstrated a significant cost advantage. Surprisingly, the lowest average revenue per kilowatt-hour was shown by CALB.

Assuming CATL and CALB benefit from a production cost advantage due to their domestic manufacturing in China and that both increased their sales volumes in response to higher demand for LFP cells, it remains unclear why CATL – despite operating production facilities in the European Union – achieves a considerably higher operating margin. Could CATL's endeavors to establish its own raw material supply chains provide a potential explanation for this competitive advantage?

3.5. Impact of raw material prices and vertical integration

Raw material accounts for the largest share of battery cell cost of 70% to 90% depending on the cell chemistry (Degen and Krätzig, 2024; Ruppert et al., 2025). Procuring or accessing raw material at the cost of production enables a potential advantage especially during periods of increasing material prices.

As demonstrated by preceding studies, supply chain of battery raw materials is predominantly controlled by Chinese companies (Greitemeier et al., 2025). Evidence suggests that CATL undertakes direct investments and strategic partnerships to secure raw material access. The company maintains activities in almost all steps along the supply chain. The present activities encompass the extraction and processing of raw materials, in addition to recycling end-of-life cells and production scrap by its subsidiary *Guangdong Brunp Recycling Technology* (Contemporary Amperex Technology Co. Limited (CATL), 2021, 2022, 2025c; Guangdong Brunp Recycling Technology, 2023; Reuters, 2025a).

LGES maintain also some projects with partners to secure raw material (Carrie Hampel, 2025). It is evident that only minor activities have been disclosed by SDI and CALB, at least in official announcements.

The subsequent illustration summarizes the present activities being undertaken by CATL, CALB, LGES and SDI along the battery cell supply chain: The categories encompass *Raw Material Mining and Processing, precursor CAM/CAM Production, Battery Cell Manufacturing and Recycling* (Figure 7). The figure refers to the three most expensive raw materials, namely lithium, cobalt and nickel.

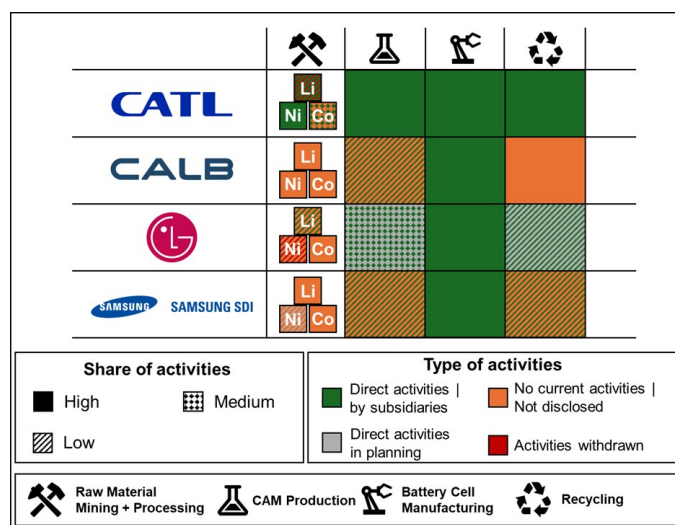


Figure 7: Overview of supply chain activities of CATL, LGES, CALB and SDI based on assumptions and public announcements of the companies (Carrie Hampel, 2025; Contemporary Amperex Technology Co. Limited (CATL), 2022, 2025c; Guangdong Brunp Recycling Technology, 2023; Jin-Won Kim, 2024; Matthias Bartmann, 2025; pandaily.com, 2023; Reuters, 2025a; Stan Lee, 2024a, 2024b; Tang Shihua, 2025).

As mentioned earlier, besides raw material security, financial benefits of self-sufficient raw material production become particularly evident during periods of elevated or rising material prices. A decline in the prices of relevant raw materials such as lithium, nickel and cobalt salts has been observed since 2023 (Fabrice Renard and Christophe Pillot, 2025). If the difference between the raw material market price and incurring cost of production is minimal, vertical integration might not offer a significant commercial benefit. Finally, a raw material cost analysis was conducted. Reported direct material costs from financial reports

were obtained and evaluated (Figure 8). In accordance with the diminishing market price for primary raw materials such as lithium, nickel and cobalt, all companies have exhibited a significant decrease in average raw material cost per kilowatt-hour from 2023 to 2024. It becomes evident that CATL reports a lower average raw material cost per kilowatt-hour than LGES and SDI. This difference may be attributable to CATL’s activities along the battery cell supply chain or, as noted earlier, to differences in product composition (Chapter 3.4). This initially supports thesis H3. However, the average

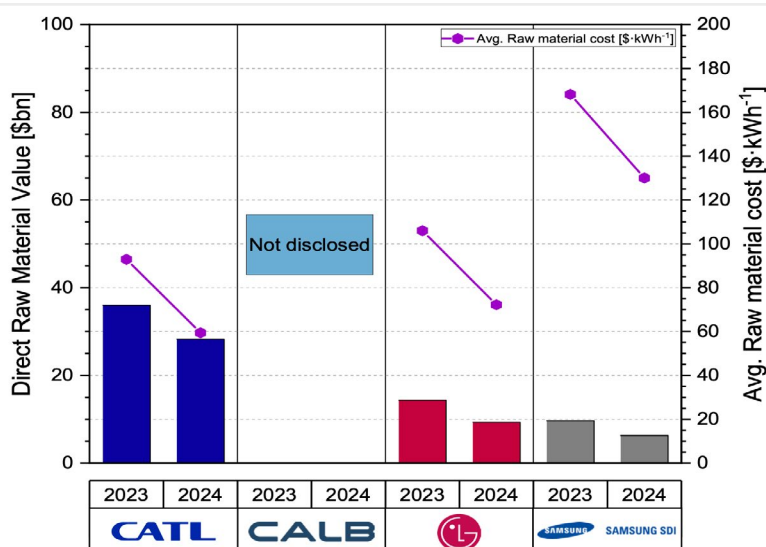


Figure 8: Total cost of raw material and cost per kilowatt-hour (For SDI, only battery cell related raw materials amount is considered | For CATL, encompassing raw material amount related to all business units) (Contemporary Amperex Technology Co. Limited (CATL), 2024a, 2025b; LG Energy Solution, 2024b, 2025b; Samsung SDI, 2024a, 2025a).

production cost of CALB as a difference of revenue and operating income (Figure 6) highlights an average cost encompassing production cost and material cost of $57 \text{ \$}\cdot\text{kWh}^{-1}$ which is lower than CATL average raw material cost of $59 \text{ \$}\cdot\text{kWh}^{-1}$ in 2024 (Figure 8). Accordingly, it is assumed that CALB incurred lower average raw material costs than CATL in 2024.

The magnitude of the commercial advantage derived from CATL's raw material access strategy remains unclear. CALB may have a higher share of LFP batteries, driven by its focus on the Chinese domestic market, partially explain observed cost differences (Figure 3). In contrast, CATL serves several international customers that continue to demand NMC batteries, particularly automotive manufacturers in mid-range and premium segments.

Lastly, CATL's reported direct raw material costs encompassed all business segments. Considering that around 15% of its revenue is obtained from at least non battery manufacturing activities, it is feasible that a minor share of raw material cost is related to other business units which are not attributable to CATL's manufacturing business. Therefore, the average raw material cost might be even lower than illustrated in Figure 8.

The current market prices of relevant raw materials may conceal the benefits of maintaining its own supply chains if the difference between cost of production and market prices is small. In the following, a calculation is conducted to evaluate the potential economic benefit between the cost of production and raw material spot prices:

Gallagher *et al.* conducted a scenario analysis to compare cost of production of battery grade lithium salt derived from brine or ore under different assumptions (Gallagher *et al.*, 2025). For production from ore, costs range from $7.1 \text{ \$}\cdot\text{kg}^{-1}$ (mining & refining in China) and $17.2 \text{ \$}\cdot\text{kg}^{-1}$ (mining & refining in Australia) (Gallagher *et al.*, 2025). In contrast, production from brine displays lower costs, ranging from $3.4 \text{ \$}\cdot\text{kg}^{-1}$ for extraction and refining in China to $6.6 \text{ \$}\cdot\text{kg}^{-1}$ for extraction in Chile followed by refining in China (Gallagher *et al.*, 2025). *Avicenne Energy* reported comparable conversion costs for lithium salts in the range of 5 to $15 \text{ \$}\cdot\text{kg}^{-1}$ (Fabrice Renard and Christophe Pillot, 2025). Compared with current market prices for battery grade lithium hydroxide or carbonate – ranging from 9.5 to $10.2 \text{ \$}\cdot\text{kg}^{-1}$ in November 2025 (Shanghai Metal

Markets, 2025b) – the immediate commercial benefit of CATL's vertically integrated supply chain appears limited, aside from improved raw material access and supply security (Shanghai Metal Markets, 2025b).

In 2024, average lithium salt prices were slightly higher at approximately $12.4 \text{ \$}\cdot\text{kg}^{-1}$ (Georgia Williams, 2024). The Jianxiawo mine, one of the world's largest lithium ore mines, is located in China and owned by CATL. Assuming the reported production cost of $7.1 \text{ \$}\cdot\text{kg}^{-1}$ for domestic mining and refining in China, a potential cost advantage of approximately $5.3 \text{ \$}\cdot\text{kg}^{-1}$ lithium carbonate or 42.7% could be derived in 2024.

Assuming a lithium salt demand of 0.6 to $0.7 \text{ kg}_{\text{LCE}}\cdot\text{kWh}^{-1}$ of cell capacity (Ruppert *et al.*, 2025), this corresponds to a total cost advantage of approximately 3.2 to $3.8 \text{ \$}\cdot\text{kWh}^{-1}$ or roughly 3% to 4% when compared with CATL's average revenue of $91 \text{ \$}\cdot\text{kWh}^{-1}$ in 2024 (Figure 6). In comparison, a theoretical calculation indicates that an LFP/graphite pouch cell (38 Ah) produced in China at a scale of $20 \text{ GWh}\cdot\text{a}^{-1}$ would cost approximately $59.0 \text{ \$}\cdot\text{kWh}^{-1}$ (Ruppert *et al.*, 2025). Raw materials account for $42.3 \text{ \$}\cdot\text{kWh}^{-1}$, which corresponds to roughly 72% of total costs (Ruppert *et al.*, 2025). In this case, the lithium cost advantage would translate into a total cost reduction of approximately -5% to -7%. This supports thesis H3, that CATL significant benefits from maintaining own supply chain activities.

Surprisingly, the calculated cost value aligns well with CALB's average revenue for 2024, for which exclusively domestic production in China and a high LFP share are assumed (Figure 6).

This raw material estimate assumes full self-sufficiency in lithium carbonate production within China. Consequently, the actual economic benefit for CATL is likely somewhat lower. For this initial comparison, focusing on lithium salts is sufficient, given their relevance across multiple lithium-ion cell chemistries. Nevertheless, if overcapacities decline and raw material prices rise due to supply shortages or a substantial demand increase in the future, CATL may achieve significantly higher cost advantages over its competitors (Wu *et al.*, 2025). Procuring raw materials at production cost rather than at market prices provides resilience against price volatility driven by market developments.

4. Conclusion

This study compared four battery cell manufacturers with differing production capacities, locations, and target markets. Overall, the results indicate several key drivers of CATL's superior profitability and resilience. Three hypotheses were analyzed and critically discussed.

First, the Korean competitors LGES and SDI face significantly higher location-based production costs due to their major manufacturing presence in Europe and the United States, which supports thesis H1. However, this factor alone does not explain the observed performance differences. Otherwise, CALB due to its exclusively domestic production in China would be expected to be in the strongest economic position. The potential reduction in total battery costs attributable to location effects is estimated at approximately -3% to -10%.

Economies of scale remain essential for reducing manufacturing costs. CATL has the largest production capacity, suggesting that it benefits most from economies of scale, which support H2 (Figure 4). However, economies of scale gains are most pronounced at smaller plant sizes, particularly below 10 GWh·a⁻¹. All companies in scope operate large-scale production facilities. Therefore, a limited contribution is expected. To illustrate this effect, a comparison between two large-scale plant sizes indicates a potential total cost reduction of approximately 2% to 6%, which is smaller than the estimated impact of production location.

Additionally, LGES and SDI companies have experienced declining utilization rates and shrinking sales volumes, which increase production costs per unit. Under continuous operation constraints with limited ability to temporarily shut down equipment, this can increase total battery costs by approximately 10% to 30% relative to full utilization. Consequently, economies of scale, as proposed in H2, remain relevant. In this case, however, the adverse cost impact of low utilization appears to outweigh the potential cost reductions associated with larger installed capacities. Under this interpretation, H2 is supported only when considering installed capacity alone. In this case, cell chemistry may play decisive role in competitiveness. LGES and SDI rely heavily on nickel-based technologies faced stagnating demand due to lower sales of EVs from European and American car manufactures since 2023. Over the same period, CATL and CALB have benefited from the growing

adoption of LFP chemistry across various applications such as entry- to mid-class EVs and ESS (Orangi et al., 2024). Their ability to produce LFP cells at lower cost while meeting market demand has reinforced their competitive advantage and strengthened their overall market position. However, a margin discrepancy remains evident when comparing CATL and CALB, both of which primarily operate in China.

Lastly, the supply chain strategies of all competitors were compared. Although CATL maintains its own supply chain activities, the entire benefits of these investments are not immediately evident. CATL shows a lower raw material cost per kilowatt-hour than LGES and SDI, while CALB appears to be in a similar cost range. However, it is not possible to clearly distinguish whether this advantage results from supply chain integration or from differences in product portfolio.

An estimate based on the gap between production costs and market prices suggests a total battery cost decreasing potential of -5% to -7% per kWh, assuming full self sufficiency in lithium salt production located from China, which supports thesis H3. Both CATL and CALB likely have a higher share of LFP chemistry, which further reduces the average raw material cost per kilowatt-hour. In addition, current lithium spot prices are close to production costs, assuming a Chinese raw material mining a refining. As a result, the near-term commercial benefits of proprietary supply chains appear limited, which contradicts thesis H3. In conclusion, CATL's supply chain activities represent a distinctive cost lever, even if their short-term impact is less pronounced than that of capacity utilization.

In summary, low capacity utilization of LGES and SDI has substantial potential to increase unit costs relative to CATL and CALB, assuming high utilization for CALB. Production location and supply chain integration of CATL provide an intermediate contribution to reducing total battery costs. By contrast, in this case the cost reduction potential from economies of scale is limited, particularly under the assumption of full capacity utilization.

Nevertheless, if raw material prices rise due to supply constraints or increasing demand, companies such as CATL that maintain vertically integrated supply chains could gain substantial additional cost advantages over their competitors. Procuring raw materials at production cost rather than at market prices provides resilience against price volatility and reinforces cost

leadership. At the same time, such developments would undermine the competitiveness of manufacturers that already face production-cost disadvantages and would additionally be exposed to rising raw material prices. This perspective underscores the strategic importance of raw material procurement and supply chain integration for battery cell manufacturers seeking to safeguard long-term competitiveness and ensure the viability of their business model.

Finally, it will be important to monitor how the current situation evolves. Recent announcements indicate that LGES improved its business performance in the third quarter of 2025 (LG Energy Solution, 2025d). Furthermore, SDI and LGES aim to start LFP cell production in the short term (LG Energy Solution). In addition, xEV demand in the European Union and U.S. markets increased compared with 2024 (Amir Orusov, 2025; European Environment Agency, 2025). However, several challenges for a European- or U.S.-localized battery cell production industry remain. These include substantial overcapacity in China and resulting in dumping prices, lack of supply chain activities, structural cost disadvantages, and uncertainty regarding future demand and cell chemistry.

5. Acknowledge

The author's utilized ChatGPT to enhance readability during the preparation of this work. After employing this tool, we thoroughly reviewed and edited the content as necessary, assuming full responsibility for the final publication.

6. Declaration of Internets

There are no conflicts of interest to declare

7. CRediT Authorship contribution statement

Jan-Hendrik Richter: Conceptualization, Methodology, Data Curation, Analysis, Visualization, Software, Writing – Original Draft. **Tim Niklas Franke:** Methodology, Data Curation, Analysis. **Simon Lux:** Conceptualization, Supervision.

8. Data availability

The authors declare that the data which were used for this analysis derived public available source. Further questions regarding the calculations and evaluation can be addressed directly to the corresponding author.

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