Conflicting objectives in the green transition

An impact analysis of a scenario excluding the import of electric buses and batteries to the European market

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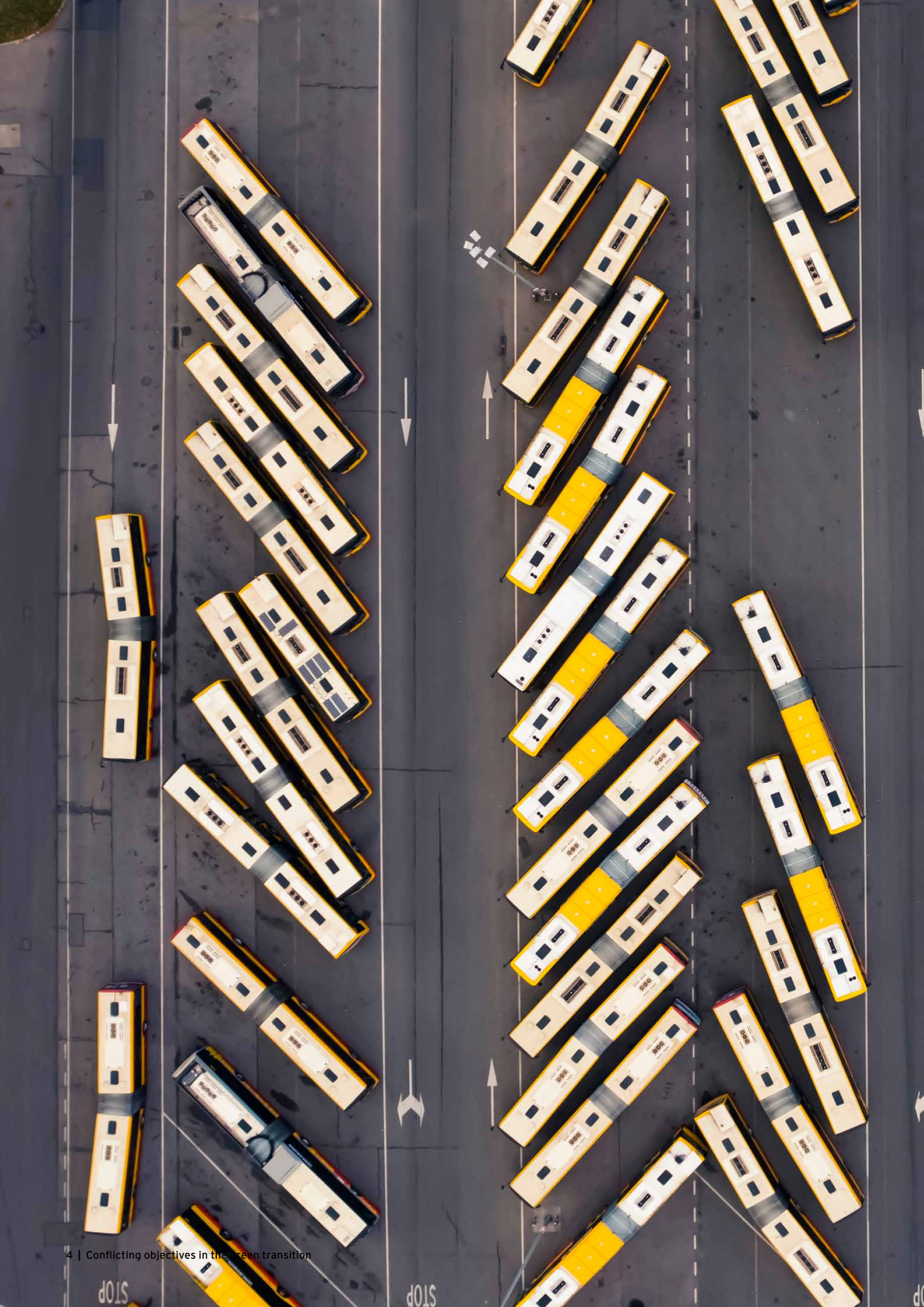
Content


STOP
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Executive summary

The climate transition is driving an accelerated electrification of Sweden's bus fleet, and in alignment with the EU's goal for zero emissions, all urban buses should be emission free by 2035. This increase in demand for electric buses comes as public tenders are also setting tougher criteria for social sustainability control. This situation could lead to a complex dilemma, pitting the green transition against social sustainability. This is because the production chains for electric buses and batteries are largely controlled by countries that, according to the purchasing center Adda of Sveriges Kommuner och Regioner (SKR) and the Global Rights Index 2023, are linked to sustainability risks concerning human rights.

The extensive criteria may compel bus operators, who compete for government contracts in services, to potentially disqualify electric buses and batteries sourced from countries deemed high risk. Barring these nations, wholly or in segments, from the supply chain could significantly disrupt the availability of electric buses for years to come. If China, responsible for the majority of global production, were to be excluded, the price of electric buses is projected to soar by more than 40%. Simultaneously, despite substantial investment, Europe's manufacturing of batteries is not keeping pace with demand, which might result in supply deficits and extended waiting periods for delivery.

As Sweden electrifies its bus fleets in the pursuit of a more sustainable future, this shift raises heightened concerns about human rights risks. The shift toward electric buses is happening most rapidly in the public transportation sector, where regional authorities, in collaboration with transport firms, are spearheading the move to electrify their bus fleets. By 2035, all city buses and over 75% of public transportation buses are expected to be electrified in Sweden, corresponding to more than 6,000 new electric buses compared to today. As an effect of the increasing demand for battery-electric vehicles, risks regarding working conditions and human rights linked to the manufacture of the vehicles, especially the batteries, have been highlighted. A large part of today's battery production takes place in China, which reportedly can experience these issues in certain component stages in the production of these products, such as mining of minerals and metals[5].

The report's sponsors assess that control cannot be guaranteed according to strict procurement requirements. Several Swedish regions have started imposing requirements in their procurement processes to guarantee that electric buses are manufactured without infringing on human rights. The requirements can take different forms, which in turn affect the tenderers. The strictest requirements place a great deal of responsibility on the bus companies and mean that vehicles produced in high-risk countries cannot be used unless the bus companies can guarantee that production is carried out correctly throughout all supply chains. Due to the high number of components and the complex value chain, it is currently very difficult to trace components through the supply chain. For requirements that demand full transparency in the value chain, the report's sponsors assess that they are unable to ensure control to the extent required by the regions.

In reality, bus operators might have to reject buses made completely or partially in countries considered high risk. The result of regional mandates could mean there are no market-available buses that satisfy procurement standards due to their complete or partial production in these high-risk areas. Even after excluding vehicles with known production in a high-risk country, the problem remains in ascertaining the origin of batteries and components due to the complex value chains with a lack of transparency.

This report aims to evaluate Europe's ability to meet domestic demand. This is to evaluate, in a simplified scenario, the consequences that an import ban would entail for Europe in terms of supply and price levels for vehicles and batteries. The report analyzes the possibility of meeting European needs through domestic production. Due to China's dominant position, the report highlights, in particular, China's role in the value chain.

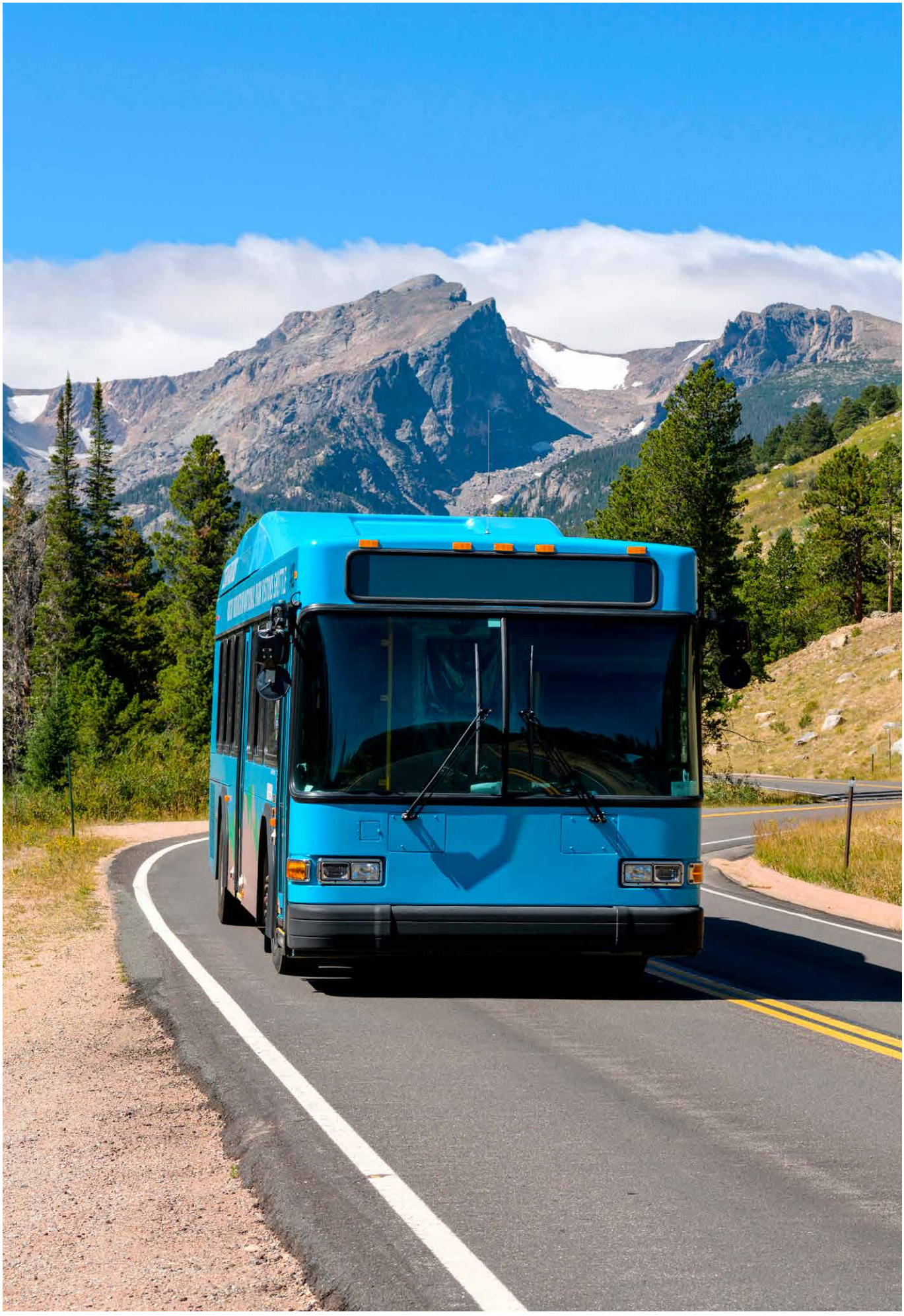
China accounts for most of the world's production. The analysis shows that China accounts for the majority of world's production through large parts of the value chain, with a particular focus on the production of electric buses, batteries and battery components, as well as the processing of battery materials and the extraction of graphite. For electric buses and batteries, China accounted for 77% and 82% of global production, respectively, in 2023.

European buses are 30% to 40% more expensive than Chinese buses, and the difference is expected to increase. Today, the demand for electric buses is greater than the production in Europe, although the production of electric buses is expected to catch up post 2027. Meeting the need for public transport buses from Europe comes at a cost. Electric buses from Europe have a cost that is 30% higher for regional buses and 40% higher for city buses compared to buses from China. This corresponds to SEK1.6 million and SEK1.7 million per bus, which would lead to an increased cost of SEK9.9 billion if the 6,000 electric buses expected to be procured by 2035 were to be purchased from Europe instead of China.

European production of LFP batteries does not meet demand, and dependence on China remains. The batteries mostly used for electric buses, lithium iron phosphate (LFP), are expected to become more common in the future and account for 30% to 40% of battery demand in Europe by 2030, corresponding to 320–420 GWh. Despite expansion, European production of LFP is estimated to only amount to 3% of the need in 2030. Europe will therefore continue to depend on China, which currently accounts for the majority of LFP battery production with 70% of the global market.

LFP batteries from Europe cost 20% to 30% more than Chinese ones. It is estimated that LFP batteries produced in Europe will result in an increased cost of 20% to 30% compared to Chinese batteries, which may increase further due to overproduction in China. For a medium-sized bus battery for a regional bus, this corresponds to between SEK100,000 and SEK150,000 per battery.

The consequences depend on how other countries act. How other European countries choose to manage risks in the value chain for electric buses and batteries will play a crucial role in shaping the market impact. If only Sweden were to set requirements in procurements in such a way that production in high-risk countries is effectively excluded, the consequences would probably be cost increases but a supply that can meet the need. If larger parts or all of Europe introduce similar requirements, the supply of European buses and batteries will greatly fall short of the demand and, for the foreseeable future, lead to long delivery times and, in the long run, a significant delay in the electrification of public transport.




Wünsche, Ideen, Visione

Introduction and purpose

Reducing emissions from the transport sector is a crucial part of achieving global and national climate goals, with Sweden aiming to reduce emissions from the transport sector by 70% by 2030, compared to 2010 levels[1]. Swedish regions have long been at the forefront of emission reductions and have already taken steps to switch to fossil-free fuels[2]. They are now taking further steps in the same direction by driving the electrification of bus fleets for public transport, in collaboration with Sweden's bus companies. However, with increased electrification, risks related to human rights and forced labor in the production of vehicles and batteries have emerged, creating a complex conflict of objectives, where the climate transition may conflict with the risk of substandard working conditions.

The growing demand for electric buses amid the green transition

The electrification of bus fleets is driving a growing demand for both electric buses and their batteries. While the transition is fastest in public transport, it also applies to tourist buses and other commercial traffic. Given the projected electrification rate, over 6,000 additional electric buses will be needed in Swedish public transport by 2035, in addition to the 1,200 electric buses already in service. Currently, some regions require all new city buses be fully electric. Of the projected need, the majority is estimated to be city buses. According to the EU's zero-emission target, 90% of city buses should be emission free by 2030, with the goal of reaching 100% by 2035[3].

Regional buses have longer routes than city buses, requiring batteries with a longer range. As a result, the electrification of regional buses is expected to progress more slowly. However, technological improvements in the coming years are expected to enable the production of batteries and buses better suited for regional traffic. Despite the slower technological development for regional buses, several electric regional buses are already in service in various parts of Sweden. It is estimated that 75% of all new regional buses will be electric by 2035.

The electrification of buses in Swedish public transport can lead to significant emission reductions. Forecasts show that continued electrification of the bus fleet will result in an annual emission reduction of about 70% by 2035 (76,000 tons of CO_2 annually), compared to buses running on biodiesel (HVO100). In urban transport, emissions are expected to be reduced by 90%, while in regional transport, the reduction is anticipated to be around 60%[4].

Sustainability risks linked to human rights in the production of electric vehicles and batteries

As electrification progresses and the share of battery-electric vehicles increases, it has been highlighted that a significant portion of production takes place in countries considered high risk for human rights violations[5]. High-risk countries are defined in this report according to SKR's central purchasing agency Adda's risk assessment of the world's countries. The risks associated with electric vehicles and batteries have received special attention, not because of the products themselves, but due to the countries where production and material extraction occur, including the mining of minerals. Minerals and metals are largely extracted in high-risk countries, where mining is characterized by a hazardous work environment, low wages, a lack of trade union rights, and the presence of child labor. Human rights violations in the mining industry have been reported in the Democratic Republic of Congo, China, Brazil and Egypt, among others[5].

China is a world leader in the production of electric vehicles, including electric buses, batteries and related components, accounting for a large part of global production. In a report commissioned by Stockholms Lokaltrafik (SL), Västtrafik, Skånetrafiken and Luleå Lokaltrafik AB (LLT), the risks linked to electric buses and their batteries were analyzed. The report analyzed seven battery manufacturers in China, which together account for 80% of global battery production, as well as one bus manufacturer that also produces electric buses.

The analysis concluded that there are inherit production risks associated with electrified buses, batteries and battery components, as most manufacturers have links to businesses in areas with a high risk of forced labor[6].

Several European vehicle manufacturers have also chosen to locate parts of their production in high-risk countries. For example, in 2023, Volvo Buses announced a collaboration with Egyptian MCV for the production of bodies for electric buses in the European market[7]. According to the Global Rights Index 2023, Egypt is one of the world's 10 worst countries for workers.

The report's sponsors assess that control cannot be guaranteed in accordance with stricter procurement requirements

A vehicle and its battery can contain over 30,000 components, produced and assembled in several stages by an extensive and complex supplier network. In addition, there can often be up to four parallel suppliers for each component. The intricacy of the supply chain, coupled with restricted access to data, often results in manufacturers being unaware of the origins of their components. This poses difficulties in creating and maintaining the level of control necessary to ensure full transparency and traceability in the value chain[8].

To minimize the risks that buses used in public transport could be linked to manufacturing that violates human rights, several regions in Sweden have chosen to include procurement requirements mandating that bus companies ensure the buses are produced under acceptable conditions. In cases where production takes place in a high-risk country, bus companies must, according to certain procurement requirements, prove that human rights violations did not occur during production, for example, through third-party audits[9].

According to the Ethical Trading Initiative (ETI), Sweden's three largest transport authorities and procurers of bus traffic are currently collaborating on requirements for buses, including batteries, to be manufactured sustainably, environmentally and socially. Bus companies are required to comply with UN human rights rules, apply the OECD Guidelines for Multinational Enterprises on Responsible Business Conduct, and continuously work to improve reporting on traceability[10]. The goal is to create an industry-wide standard for the procurement of public transport services.

The report's sponsors welcome this development and support the application of UN human rights rules and the OECD guidelines in procurement requirements[11]. However, they have noticed that some regions, in individual procurements, have chosen to further tighten the requirements, which introduces a level of control that the commissioners do not believe they can guarantee. In many cases, these stricter requirements involve ensuring traceability further back in the supply chain, including the production and final assembly of batteries, as well as the extraction of critical minerals. Some regions have even opted to require that the supplier of bus services does not use products produced in higher-risk countries at all.

Overall, these stricter procurement requirements lead the report's sponsors to fear that they will be compelled to exclude vehicles that have been wholly or partly produced in high-risk countries. They believe the requirements in several procurements impose responsibilities and risks that they are not equipped to bear.

The OECD Guidelines for Multinational Enterprises on Responsible Business Conduct are recommendations aimed at multinational companies. These guidelines promote companies' positive contributions to society and aim to reduce the negative impacts of their operations. They include broad recommendations and expectations for due diligence in areas such as human rights, labor law, the environment, corruption, consumer interests and taxation[12]. The guidelines aim to ensure that multinational companies act responsibly, regardless of where their operations are conducted.

Assessment of Europe's ability to meet domestic demand

This report analyzes Europe's capacity to satisfy its need for electric buses through domestic production. The goal is to examine the dependence on production in high-risk countries, and to stimulate, in a simplified scenario limited to the European market, the consequences that restricted imports would have on Europe in terms of supply and price levels for vehicles and batteries. The analysis specifically focuses on China, given its dominant role in the global market.

The report's focus on production within the European market is due to the fact that the majority of electric buses and batteries imported to Europe come from China[13]. Therefore, the report does not consider potential future import opportunities from low-risk countries outside Europe.

Since electric buses produced in Europe often contain batteries made in China or other higher-risk countries, the analysis is divided into two sections: one addressing electric buses and the other focusing on batteries. The purpose of this approach is to determine whether Europe can meet the demand for electric buses and their batteries through domestic production.

The evaluation for bus fleets extends up to 2035, aligning with the regions' 10-year procurement plans, while the assessment for batteries projects until 2030 due to the rapidly changing market, where forecasts rarely extend beyond that year.

Additional considerations include:

- The analysis focuses on China's role in Europe's imports of electric buses and batteries, due to its dominance in the value chain. Other high-risk countries are implicitly considered, as the main focus is whether Europe's domestic production can meet market needs.
- The value chain analysis emphasizes the final production of electric buses, the manufacturing of battery cells and battery modules, and selected aspects of component manufacturing for batteries.
- The analysis only includes specifically buses used in publicly procured local and regional public transport.

The value chain for electric buses

A basic understanding of today's battery types, components and the electric bus value chain is essential for evaluating China's role in production and the potential impact of excluding Chinese capacity from different stages of the value chain.

Predominant use of LFP batteries in electric buses

Lithium-ion batteries are the most common type used in modern electric buses. This type of battery forms the basis of the battery value chain. This section describes lithium-ion batteries, their most common battery chemistries and their respective advantages and disadvantages.

Due to their high energy density and long service life, lithium-ion batteries are the most widely used in electric vehicles. These batteries consist of individual cells combined into modules, which are then grouped to create a battery pack that provides the high voltage required to power the electric motor in the vehicle[14,15].

Each battery cell comprises four main components: anode, cathode, electrolyte and separator:

- **Anode:** Typically made of graphite; it hosts lithium ions that move from the cathode as the battery discharges, providing power.
- **Cathode:** Composed of metal oxide, the cathode determines the battery's energy capacity and voltage, often using a combination of cobalt, nickel, manganese or iron.
- **Electrolyte:** A medium facilitating the movement of lithium ions between the cathode and anode.
- **Separator:** A critical safety component, the separator prevents direct contact between the cathode and anode, which could otherwise lead to a short circuit.

Lithium-ion batteries are classified based on the type of metal oxide used in the cathode, with lithium nickel manganese cobalt (NMC) and lithium iron phosphate (LFP) being the most common chemistries.

NMC batteries are mainly used in long-range vehicles due to their high energy density, which allows for extended travel distances. However, the cobalt used in these batteries makes them expensive, and the majority of cobalt mining takes place in the Democratic Republic of Congo (DRC), where human rights issues are prevalent[16].

LFP batteries, on the other hand, use iron and phosphate — raw materials that are commonly available and cheaper to manufacture compared to NMC batteries. The long lifespan of LFP batteries, combined with their lower raw material cost, makes them a cost-effective option for electric buses and commercial vehicles. Also, LFP batteries are safer due to their thermal and chemical stability. This combination of cost-effectiveness, longevity and safety has made LFP batteries the dominant choice in electric buses and commercial vehicles today[17]. However, LFP batteries have a lower energy density compared to NMC batteries, but since buses and commercial vehicles often operate on defined routes with charging opportunities, this limitation is less significant.

Both NMC and LFP batteries are used in today's electric buses, though LFP batteries are more common. Battery technology is evolving rapidly, with new advancements continually being made.

Five main steps in the electric bus value chain

The value chain for electric buses encompasses the entire process from the extraction of raw materials to the final production of the buses. It can be divided into five main stages, each involving different actors, from mining companies to vehicle manufacturers. The process begins with the extraction of raw materials for batteries, such as lithium, nickel, cobalt, manganese, iron ore and graphite. These materials are then processed into the anode, cathode, separators and electrolyte, which are critical components of batteries. In the next step, these materials are used to produce components needed for battery cells. The specific components vary depending on the type of battery chemistry – whether nickel manganese cobalt (NMC) or LFP batteries.

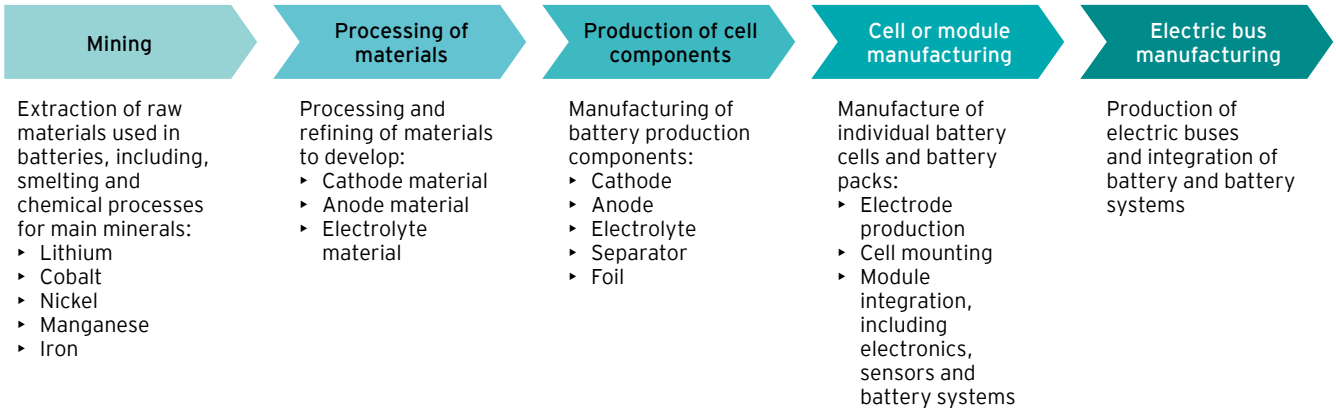
Once the battery components are manufactured, they are assembled into battery cells, which are then grouped into modules and battery packs. These packs are designed to achieve the necessary energy capacity for electric buses and are installed along with battery control systems.

China's dominance in the value chain

China currently dominates global production across various stages of the electric bus value chain. The country has a significant lead in the intermediate stages of the value chain, particularly in battery production and the manufacturing of electric buses. With a decade-long head start in battery production and electric vehicle manufacturing, China has successfully integrated itself into the entire value chain[18]. As of 2023, China accounted for 77% of global electric bus production and 82% of global battery production, far outpacing Europe.

For cell components, China dominates in all areas with at least 63% of the market share. In the production of LFP cathodes, a technology particularly suited for electric buses, China commands nearly the entire market, with a staggering 99% share.

Figure 1. The value chain of electric buses

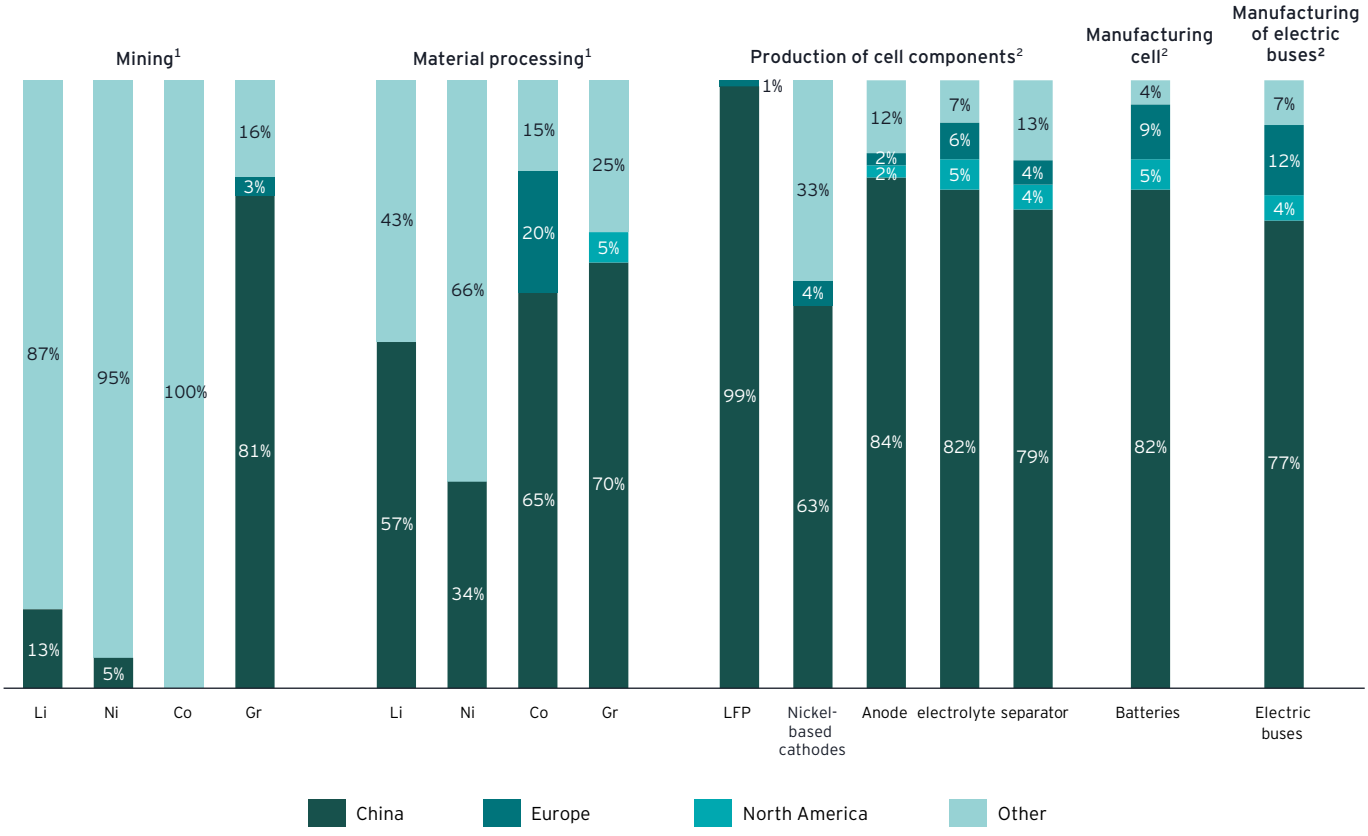


Source: *EY analysis*

In 2022, China also accounted for over half of the global capacity in the processing of lithium, cobalt and graphite. Specifically, China dominates the graphite-to-anode value chain, controlling over 80% of global graphite extraction. When it comes to the extraction of lithium, nickel and cobalt, China's role is somewhat less pronounced. However, other higher-risk countries hold significant market shares in these areas. For instance, the Democratic Republic of Congo is responsible for 70% of cobalt extraction, while Russia plays a key role in the extraction of nickel, cobalt and graphite. Given that mineral extraction is linked to local deposits, it is challenging for other regions to increase their production capacity. As a result, dependence on these countries is likely to persist as long as the current battery technologies continue to require these specific minerals.

It is thus clear that if China were excluded from the entire value chain, the production of electric buses and batteries would almost come to a complete halt. This is especially true for the batteries primarily used in electric buses, as excluding China from LFP cathode manufacturing alone would eliminate the entire global supply.

Figure 2. Regions' share of global production capacity at each stage of the electric bus value chain, percent

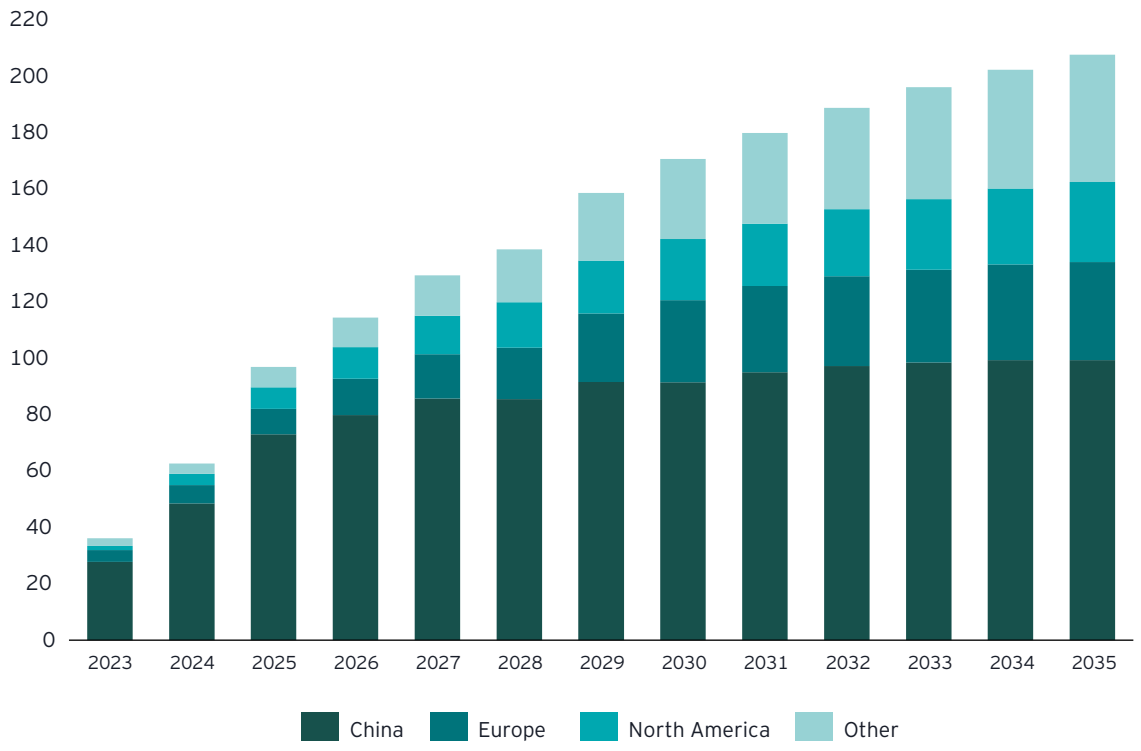


1 Share of mining and material processing processes in 2022
2 Share of cell component manufacturing and cell manufacturing in 2023

Source: *EY analysis based on data from EIA and Wood Mackenzie*

Electric buses

Figure 3. Global electric bus manufacturing by region, thousands of vehicles



Source: *EY analysis based on data from KGP*

The first part of the analysis examines China's position in global electric bus production, whether Europe can satisfy its needs through domestic production alone, and its implications. Since electric buses manufactured in Europe frequently include batteries sourced from China or other higher-risk countries, the following section provides an analysis of the batteries.

China's dominance in global production

The demand for electric buses is expected to increase in the coming years as transportation and public transit are electrified to reduce emissions from the transport sector.

Currently, electric buses account for 12% of global bus production, a figure expected to increase to 40% by 2030. By 2035, it is anticipated that nearly half of the buses manufactured worldwide will be electric, driven by rising demand. This translates to an increase in global annual production from the current figure of 36,000 electric buses to more than 200,000 in 2035.

China dominates the electric bus industry, producing 77% of the worldwide supply. Leading companies Yutong, BYD, King Long, and Zhongtong hold a combined 47% of the global market. Of these, Yutong alone accounted for 19% of 2023's total global production, which makes it the largest electric bus manufacturer in the world.

In the next 10 years, other regions are expected to ramp up production and gain market share. Despite this, China is projected to hold around half of the market by the beginning of the next decade, with the four Chinese companies

remaining the leading manufacturers, albeit with slightly lower market shares.

Europe's production of electric buses is on the rise, and it is projected to reach 29,000 units by 2030, up from the current 4,000 per year. This surge signifies an estimated annual growth rate of 32% and a boost in Europe's market share from 12% to 17%.

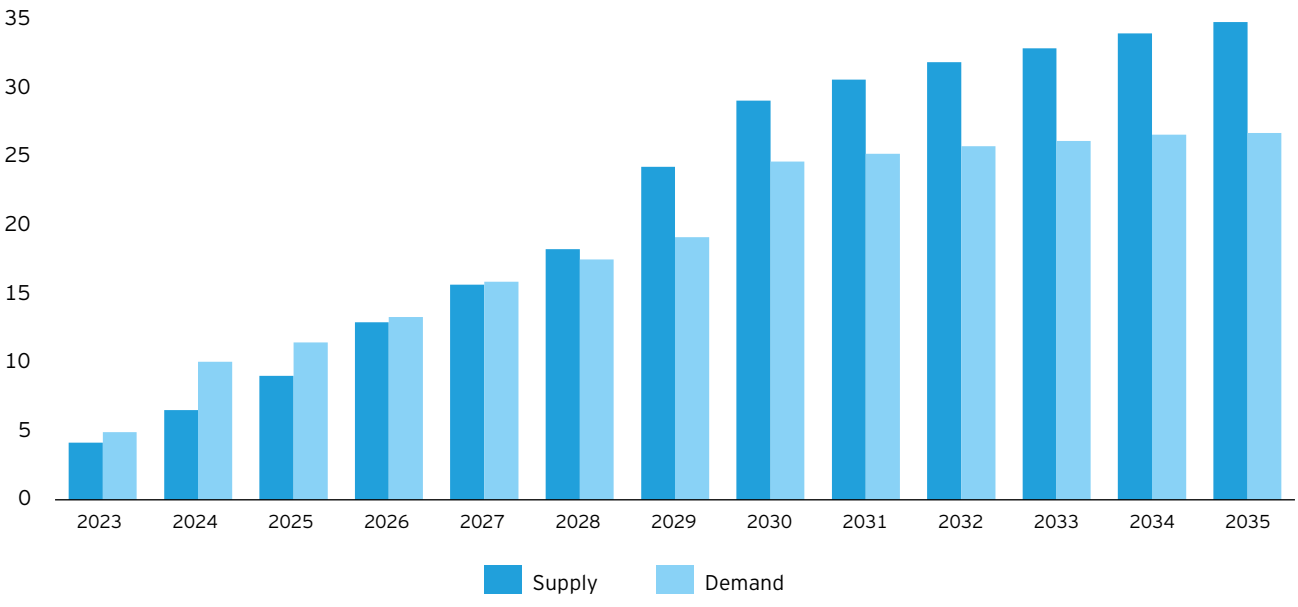
It is expected that European manufacturers like IVECO, Daimler Buses, Volvo Bus, and MAN will boost local production in Europe, collectively comprising more than half of the European market share by 2030. Simultaneously, numerous Chinese manufacturers have made their mark in the industry with BYD as the leading Chinese producer in Europe, operating a factory in Hungary. In 2023, they produced 380 electric buses, making them the fourth largest producer with a 7% share of the European market. BYD is projected to continue being the leading Chinese manufacturer in Europe by 2030, with an expected annual production of about 800 electric buses. However, with the expanding production capabilities of European manufacturers, BYD's output is expected to represent just under 3% of the total regional production by 2030.

European production capable of meeting local needs in a few years, though at a higher cost

Currently, European production is insufficient to meet the need for electric buses in Europe, which in 2023 was 50% higher than domestic capacity. Supply is projected to lag behind demand until 2027, at which point production is anticipated to surpass European demand for electric buses by 2028.

By 2030, production is expected to exceed demand by 15%. At this point, Europe could satisfy its own needs, assuming that most electric buses produced within Europe remain in the region. However, these vehicles rely on batteries, which carry the risk of human rights violations, an issue explored in the following section.

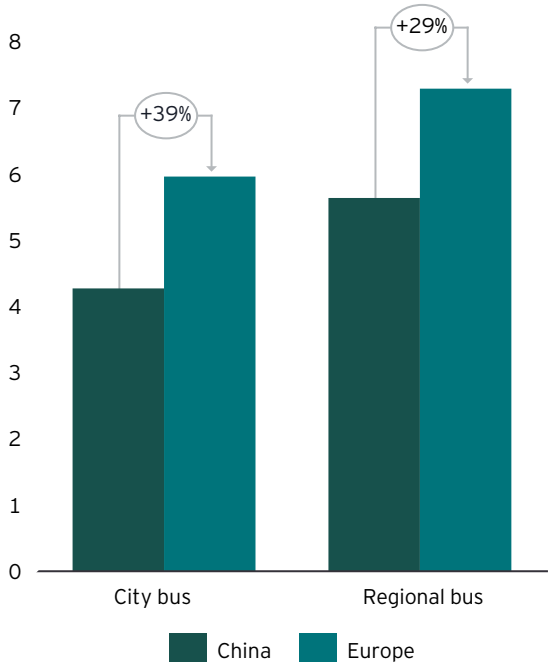
Figure 4. Europe's supply and demand for electric buses, thousands of vehicles



Source: *EY analysis based on data from KGP. Demand is calculated based on the IPCC's 2.0 scenario.*

Moving forward, Europe might offer more electric buses, albeit at a steeper price. A detailed evaluation indicates that the cost disparity for city buses made in Europe is growing, with prices in 2024 being around 40% higher than those of Chinese electric buses, amounting to roughly SEK1.7 million per bus. For regional buses, there is a 30% price difference, equating to approximately SEK1.6 million per bus in the same year. Considering the anticipated acquisition of 6,000 electric buses by 2035, it is estimated that European buses will cost SEK9.9 billion more than their Chinese counterparts.

Figure 5. Price comparison between city and regional buses produced in China and Europe, MSEK/bus



Source: *EY analysis based on interview with industry expert*

Assuming a scenario where more countries make the same assessments as Sweden regarding the issues of production in higher-risk countries, and China is thus excluded from all or large parts of the European electric bus market, several years will follow where demand exceeds supply. During this time frame, European manufacturers might benefit from a somewhat sheltered market. Globally, the demand for electric buses in 2030 is expected to exceed production by 20%, potentially boosting Europe's export chances. This suggests that prices for European-produced electric buses are likely to keep climbing under these circumstances.

Additionally, indicators suggest a rise in the price of Chinese batteries imported into Europe. For example, the EU is exploring increased import duties on electric buses and batteries produced in China, to counter price reductions that may be driven by Chinese government subsidies[19]. The introduction of the Carbon Border Adjustment Mechanism (CBAM) by the European Union may lead to an increase in costs for Chinese-manufactured buses. This would be due to the potential imposition of a carbon tax on steel and aluminum from China utilized in these vehicles, attributable to their greater environmental impact compared to materials sourced within Europe.

Batteries

Examining battery production for electric buses is vital to understand associations with higher-risk countries. Similar to the analysis of electric buses, this study focuses on China's position in global battery production, whether Europe can fulfill its regional demand, and the implications of these factors. This was achieved by examining the overall battery industry and conducting a detailed analysis of LFP batteries, which power most of today's electric buses.

Rising demand for electric vehicles drives increased need for batteries

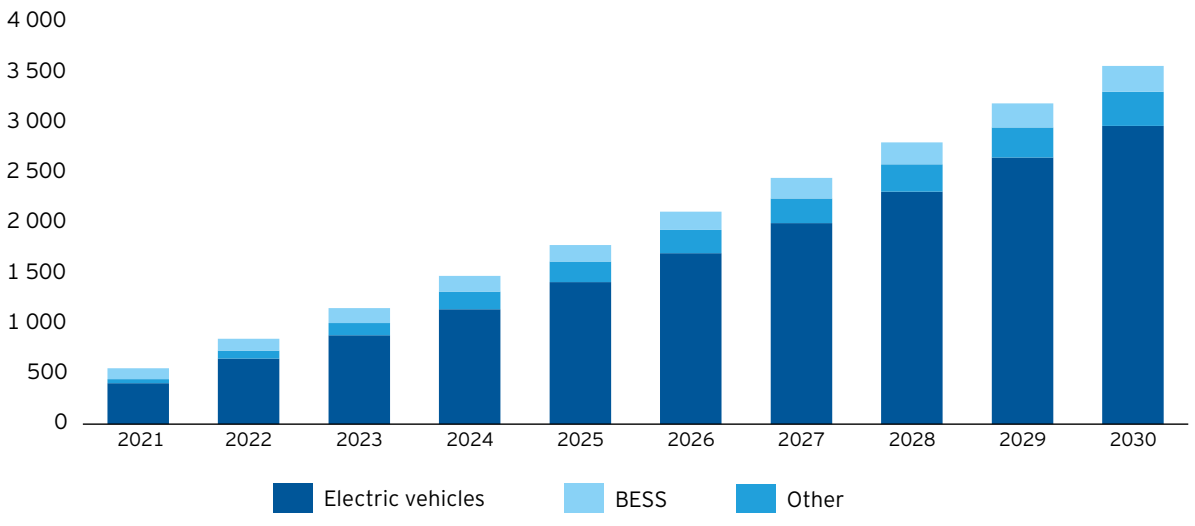
Lithium-ion batteries are mainly used in electric vehicles, battery energy storage solutions (BESS) and consumer electronics. In 2023, electric vehicles accounted for 77% of the demand and are anticipated to remain the leading segment driving global demand. Total demand is expected to increase from 1,160 GWh in 2023 to 3,600 GWh in 2030, marking an increase of more than 200%.

Battery demand is surging largely due to the electrification push in the auto industry, spurred by regulatory measures like the EU's "Fit for 55" climate plan, the US Inflation Reduction Act, and the EU's mandate for all new vehicles to be emission free by 2035[20]. By 2030, it's anticipated that electric vehicle batteries will make up more than 80% of the world's battery demand[21]. In 2022, the estimated battery demand for electric buses was around 10 GWh, which accounted for about 1.5% of global demand, making it a smaller sector compared to other uses.

In Europe, the phase-out of fossil cars is expected to drive demand for electric vehicles, and consequently, increase demand for batteries. The EU's ban on fossil fuel vehicles dictates that a minimum of 59% of cars sold by 2030 must be electric to achieve the eventual goal of a complete transition to electric cars by 2035.

Transport and environment estimates that the European demand for batteries will increase to over 1 TWh by 2030, with a low estimate of 860 GWh and a high estimate of 1,240 GWh. With technological advancements, a larger proportion of heavy commercial vehicles, such as buses and trucks, will be able to be electrified, leading to increased demand in that segment by 2030.

Figure 6. Global demand for lithium-ion batteries, GWh/year



Source: *EY analysis based on data from Wood Mackenzie*

Today, batteries for electric buses make up a smaller part of the total battery demand. Even with the projected increase in electric bus production in Europe, only 6 GWh in 2025 and 12 GWh in 2030 will be required to cover the demand.

Multiple factors drive the demand for LFP

Multiple factors are driving up demand for LFP batteries. NMC once dominated the battery market, claiming over 70% of it; however, in recent times, LFP batteries have seen a rise in market share, largely due to the preferences of Chinese producers[22].

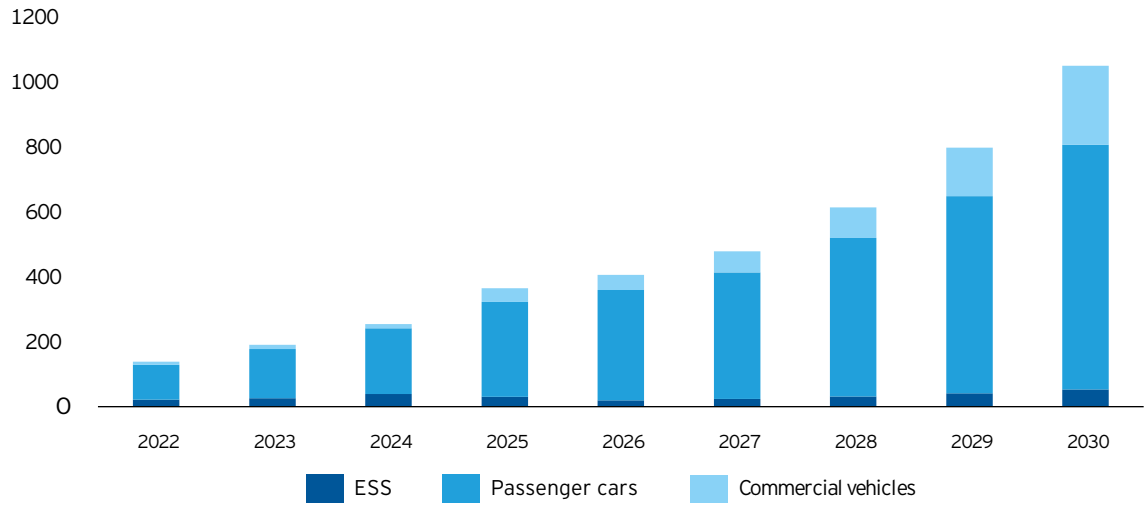
The increasing share of LFP batteries is mainly due to two factors:

- They offer distinct cost benefits over NMC batteries. As of 2023, they cost, on average, 32% less than NMC batteries[23]. These cost-saving advantages primarily come from their independence from pricier metals such as nickel and cobalt, in favor of more affordable materials like iron and phosphorus.
- China previously owned patents on LFP batteries, making manufacturing abroad more expensive. With the expiration of these patents in 2022, international production has been enabled. Furthermore, technological developments in LFP have broadened their use in electric vehicles. Car manufacturers like Volkswagen, Tesla, and Daimler plan to incorporate a greater share of LFP batteries into their vehicles.

The increased demand is driven not only by the need for electric vehicles but also by the fact that LFP is the preferred battery chemistry for the fast-growing BESS segment, which is less sensitive to battery size and weight. At present, the need for batteries in this sector surpasses that of electric buses.

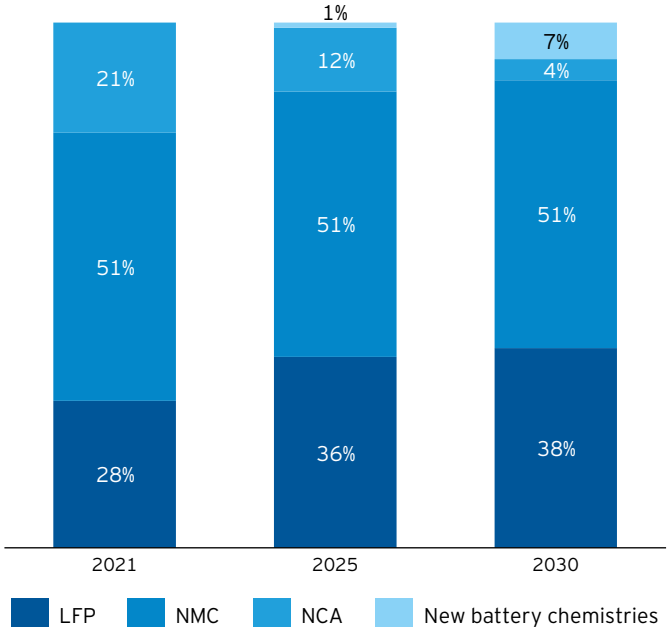
The market share of LFP batteries is expected to increase from 28% in 2021 to 38% by 2030. Some projections indicate a future market share of just over 40%, which would make LFP the single largest battery chemistry on the market.

Figure 7. European demand for lithium-ion batteries, GWh/year



Source: *EY analysis based on data from Transport and environment*

Figure 8. Forecasted market share for various battery chemistries, percent



Source: *Goldman Sachs*

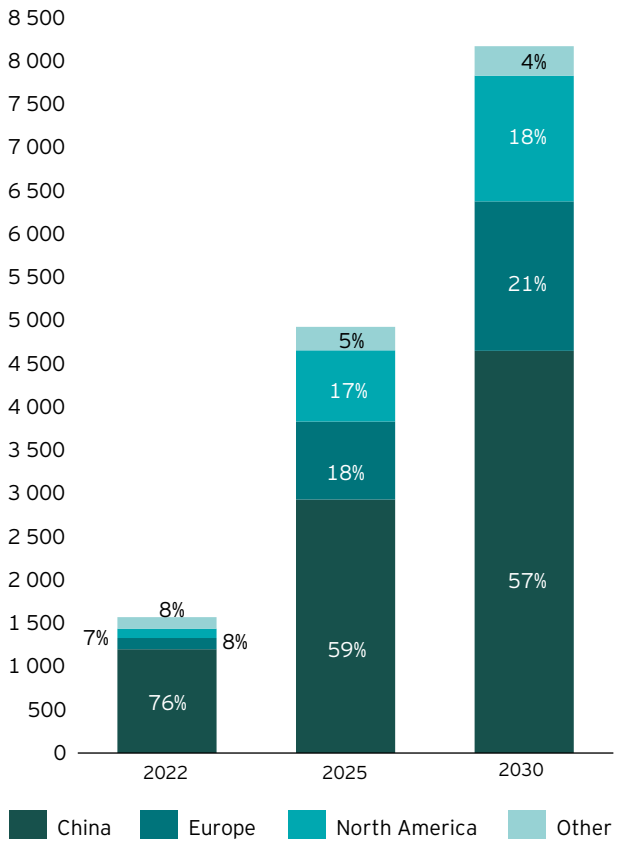
While the European and US markets have historically preferred NMC batteries, LFP has become the dominant battery chemistry in China[24]. In 2023, LFP battery production constituted around 70% of China's overall battery output. This is in stark contrast to Europe, where LFP battery production was virtually nonexistent[25]. In 2023, demand for LFP batteries in Europe was only 5%, although it is expected to increase to 30% to 40% by 2030[26].

China's near 80% share in global battery production

In 2022, the worldwide announced capacity for battery production reached 1,600 GWh, indicating a significant surplus relative to global demand. In the same year, China accounted for 76% of this capacity. By 2030, global capacity is expected to increase to 8,200 GWh, assuming all announced capacity is realized[27]. While China is anticipated to maintain its leading position in capacity, ramped-up production in Europe and the US may reduce China's market share to just under 60%, with Europe's share expected to increase to just over 20%, making the region the second-largest producer.

The growth in capacity within Europe and the US is partly driven by an increasing number of battery makers recognizing the benefits of proximity to vehicle manufacturers[28]. China's overproduction of batteries relative to domestic demand is expected to persist, making the country dependent on continued exports to other regions, including Europe.

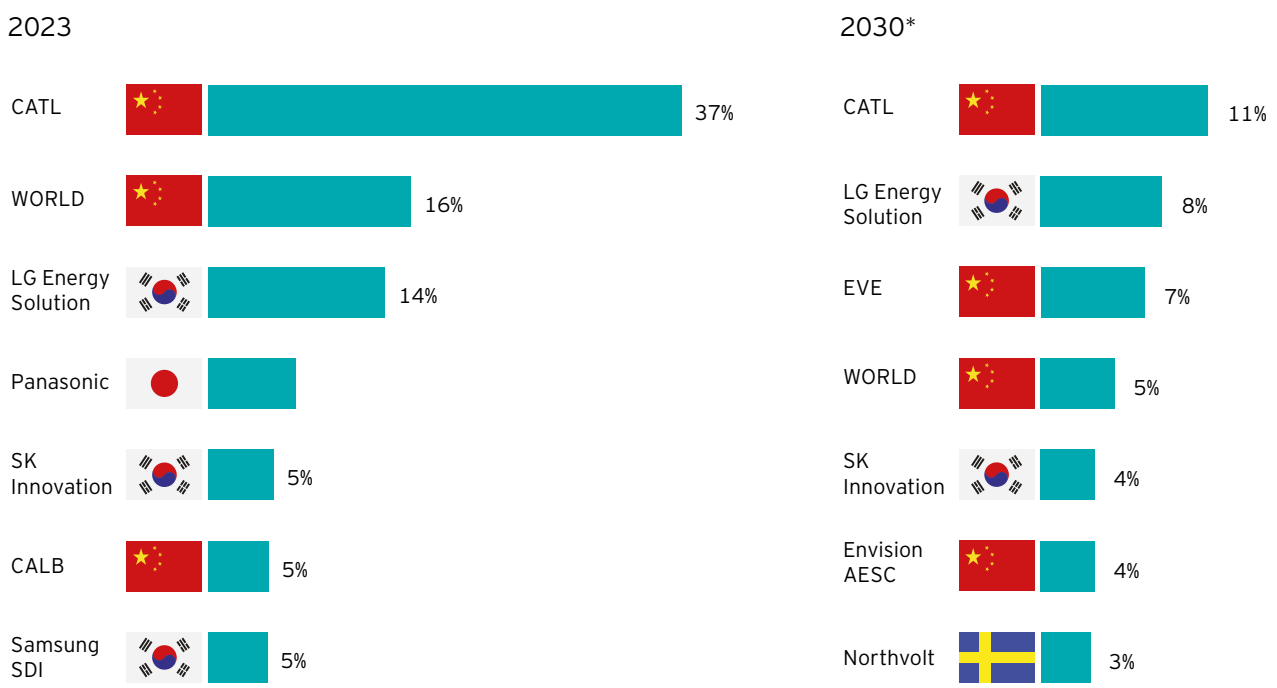
Figure 9. Global announced annual capacity for lithium-ion battery production, GWh/year



Source: *EY analysis based on IEA, Volta and Wood Mackenzie*

Based on announced capacity, battery production will continue to exceed global demand by a good margin, with China's capacity alone sufficient to cover global needs.

Figure 10. Leading producers in the global battery market in 2023 and 2030, percent



* Based on advertised capacity

Source: *EY analysis based on data from Volta and S&P*

Nevertheless, multiple factors could lead to actual output being lower than anticipated. It is probable that some of the advertised battery will not come to realization. Many projects are still in need of financing or haven't yet acquired the necessary permits for construction. Among those under construction, delays are expected, and it is unlikely that all plants will function at maximum capacity.

China's dominance goes beyond just mass-producing batteries. The nation has long invested in its battery sector, achieving significant progress in innovation and technology. This has placed the country at the forefront of battery patents today[29]. China has also succeeded in building up production and integrating the flow throughout the battery value chain.

The three largest Chinese battery manufacturers – CATL, BYD and CALB – currently account for 58% of the world's battery production. Based on announced future capacity, Chinese companies will remain leaders in 2030, although with smaller market shares due to increased competition as more players enter the market.

Several Chinese manufacturers are building production capacity in Europe and are expected to play an important role in boosting European production. Based on today's announced capacity, more than 20% of future European production will be driven by Chinese companies established in the European market. This implies that batteries produced in Europe could still be made by Chinese companies, which are expected to continue using Chinese subcontractors, thereby maintaining China's participation in the battery manufacturing.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Europe's output sufficient to fulfill demand under favorable conditions

China's dominance in the battery market is expected to persist, even as Europe experiences a large build-up of battery production capabilities within the region.

There is also a large build-up of battery production in Europe. In total, an annual capacity of over 1,700 GWh has been announced in Europe by 2030. The majority of this capacity will be produced by the 49 battery factories in Europe that are expected to achieve an annual capacity of over 2 GWh (gigafactories) by 2030.

Figure 11. Announced upcoming battery projects until 2030[1], GWh

UK, 200 GWh
AMTE Power, 10 GWh
Tata Motors, 2026, 40 GWh
West Midlands, 2029, 60 GWh
Envision AESC, 2030, 35 GWh[3]
Britishvolt, 2030, 30 GWh
Nissan, 2030, 25 GWh

France, 158 GWh
ACC, 2024, 40 GWh
Verkor, 2025, 46 GWh
Envision AESC, 2025, 24 GWh[3]
ProLogium, 2026, 48 GWh

Spain, 120 GWh
Envision AESC, 2025, 50 GWh[3]
Phi4Tech, 2025, 10 GWh
Volkswagen, 2026, 40 GWh
InoBat, 2026, 10 GWh
Basquevolt, 2027, 10 GWh

Portugal, 45 GWh
CALB, 2026, 45 GWh[3]

Italy, 93 GWh
FAAM, 2025, 8 GWh
Itavolt, 2026, 45 GWh
ACC, 2026, 40 GWh

Norway, 82 GWh
Freyr, 2024, 29 GWh
Beyonder, 2024, 10 GWh
Morrow, 2026, 43 GWh

Sweden, 110 GWh
Northvolt, 2025, 60 GWh
NOVO, 2026, 50 GWh

Finland, 27 GWh
Finish Minerals, 2027, 27 GWh

Germany, 378 GWh
Gotion, 18 GWh[3]
CATL, 14 GWh[3]
Tesla, 2024, 100 GWh
ACC, 2025, 40 GWh
PowerCo, 2025, 40 GWh
SVOLT, 2025, 16 GWh[3]
QuantumScape, 2026, 20 GWh
Northvolt, 2027, 60 GWh
SVOLT, 2029, 40 GWh[3]
CustomCells2, 43,5 GWh

Slovakia, 30 GWh
Inobat, 2025, 10 GWh
Inobat, 2026, 20 GWh

Switzerland, 7,6 GWh
SCB, 2029, 7,6 GWh

Poland, 115 GWh
LG Energy Solutions, 115 GWh

Czech Republic, 15 GWh
MES, 2025, 15 GWh

Hungary, 230 GWh
Samsung SDI, 50 GWh
SK Innovation, 18 GWh
CATL, 2025, 100 GWh[3]
SK Innovation, 2025, 30 GWh
Sunwoda, 2025, 5 GWh[3]
EVE Energy, 2026, 28 GWh[3]

Romania, 22 GWh
BEE, 2026, 22 GWh

Serbia, 60 GWh
ElevenEs, 2026, 48 GWh
InoBat, 2027, 32 GWh

1 Includes battery projects with a capacity of > 2 GWh
2 Year not announced
3 Chinese manufacturers shown in bold

Source: *EY analysis based on Wood Mackenzie, Volta, BatteryNews.com*

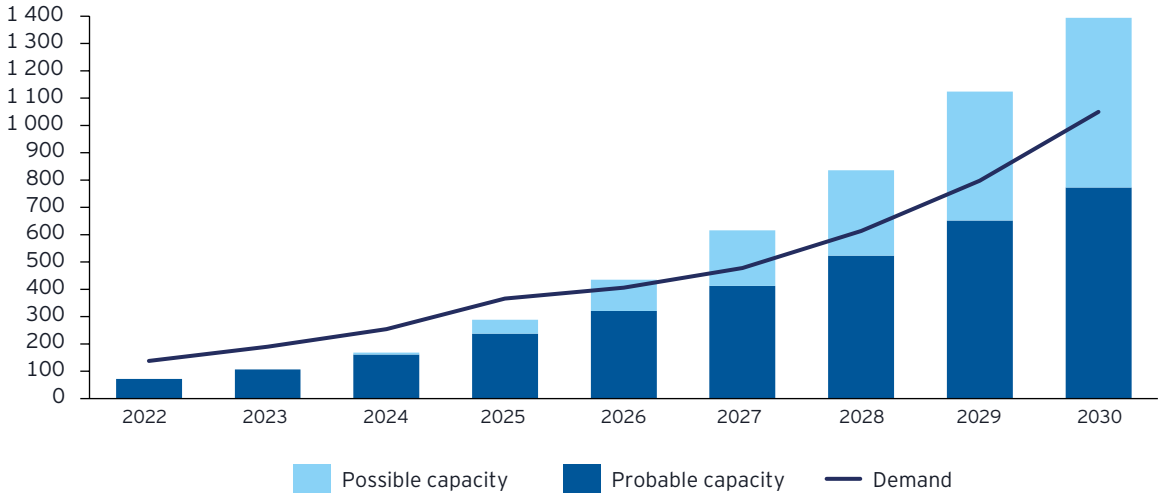
As previously stated, the proposed projects come with different levels of uncertainty. Transport and environment estimates likely production at 240 GWh by 2025 and 780 GWh by 2030. These estimates include projects with advanced processes for financing and permitting, assuming a gradual increase in production to reach 85% of the advertised maximum capacity. Other forecasts, including those from S&P, indicate annual production could exceed 1 TWh by 2030[30].

The strategies of the EU, US, and other regions, implemented through regulations and incentives, will significantly shape the European market's evolution and influence where battery producers choose to establish their manufacturing facilities.

Moreover, many electric vehicle producers have secured their future production by signing long-term agreements with battery makers, indicating that a portion of the projected supply will not be accessible on the open market[31].

In 2022, European production only met 50% of regional demand, with most of it manufactured by LG Chem in Poland and Samsung SDI in Hungary[28]. It is anticipated that by 2025, production will meet 65% of the demand, which is projected to grow to 70% by 2030 due to ongoing expansion. For Europe to be self-sufficient in meeting the full demand by 2030, over half the projected capacity — currently not guaranteed — would need to be deployed. However, if all the planned capacity comes to fruition, production might satisfy the demand by 2026.

Figure 12. European production capacity and demand for lithium-ion batteries, GWh/year



Includes only projects with a capacity of > 1 GWh

Source: *EY analysis based on T&E, Wood Mackenzie and Volta*

Europe has a long way ahead to meet domestic demand for LFP batteries

In terms of LFP battery production capacity, Europe is projected to fall short of meeting expected demand by 2030. Due to this shortage, customers with higher purchasing power are expected to be prioritized, with passenger cars likely taking precedence over buses because of their higher profit margins and greater capacity to pay a premium price.

Another sector vying for LFP battery production is battery energy storage systems (BESS), which is predicted to need 10 GWh by 2025 — nearly double the forecasted demand for bus batteries at 6 GWh. Implementing BESS aims to meet the EU's capacity requirements during peak energy periods and reduce reliance on Russian gas as part of a geopolitical decoupling strategy. BESS presents a solid commercial argument, and a growing number of European nations are expanding their BESS capabilities.

In response to the rising need for LFP batteries in Europe, ElevenEs is constructing the continent's first major battery factory in Serbia. The factory is projected to reach a capacity of 48 GWh by 2026[32], potentially fulfilling 10% to 15% of Europe's demand for LFP batteries.

The process of producing NMC can be readily adapted to produce LFP, potentially leading to a shift where current factories that manufacture NMC batteries might decide to start making LFP batteries due to the rising demand.

Production of cathode materials in Europe insufficient for local needs

To satisfy European demand for LFP batteries by 2030, over 330,000 tonnes of LFP cathode active material will be required. Currently, only Aleees and Norway's Freyr have declared intentions to produce LFP CAM in Europe by 2025, with a projected annual output of at least 30,000 tonnes. Therefore, the announced production capacity represents less than 10% of what will be needed to meet Europe's demands by 2030.

The total CAM capacity in Europe is estimated to reach 1,070 kT CAM by 2030. Although not officially announced, LFP CAM might partially contribute to this capacity figure.

LFP batteries produced in Europe estimated to be 20% to 30% more expensive than those made in China

Batteries represent the most significant cost portion of an electric vehicle, with a full battery accounting for as much as 50% of a heavy-duty vehicle's overall cost[33]. As of 2023, the average cost for battery packs stood at US$128 per kWh, while battery cells were priced at US$89 per kWh. This indicates that an average single cell accounts for approximately 78% of the entire battery pack's value[34]. For LFP batteries, this figure is slightly higher, representing 84% of the battery pack's value[35].

At the regional level, China had the lowest average cost for battery packs in 2023, at US$126 per kWh. In contrast, prices in the US and Europe were 11% and 20% higher, respectively. Battery manufacturing in the US and Europe incurs higher costs than in Asia, largely due to higher costs for energy, equipment, land and labor.

The average price of CATL's LFP cells produced in China was US$70 per kWh in 2023, with expectations to reduce this further to US$56 per kWh by 2024.

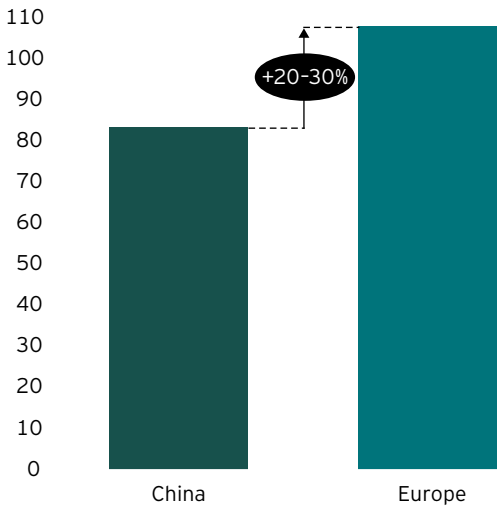
LFP packs produced in China had an average cost of US$84 per kWh in 2023. Given regional differences, the price gap between Chinese and European LFP batteries is estimated to be between 20% and 30%, resulting in a cost of US$100 to US$109 per kWh for European batteries. This price difference could add up to SEK130,000 for a 500 kWh bus battery[36].

Europe's strong position in future battery innovation

Europe is making significant investments in innovation and the development of novel battery technologies, positioning itself as a leader in the advancement of future battery generations for electric buses[37].

Future developments are expected to lead to more affordable batteries, including for a new type of phosphate-based technology called LMFP and advancements in NMC chemistries[38]. These new types of batteries may be well suited for certain types of buses, potentially reducing Europe's reliance on Chinese LFP batteries. However, these new battery technologies are expected to become available only after 2030.

Figure 13. Price per LFP battery pack in 2023, US$/kWh



Based on the assumption of an average size of a bus battery of 500 kWh.

Source: *EY analysis based on Bloomberg NEF*


emissions

Regulations and control affect future manufacturing

Regulatory oversight is crucial for fostering production and managing the value chain in the industry. The European Union is implementing measures to boost local production while imposing stricter requirements on the import of electric buses and batteries.

The EU's drive for increased domestic production

The EU is actively promoting battery production within the region to meet the growing demand for sustainably manufactured batteries. Through various initiatives and legislation, the EU aims to develop domestic battery production. This effort includes investment support for new battery factories and backing research and innovation in battery technology. Below are key regulations and initiatives within the EU that impact domestic battery production and importation.

EU Regulation 2023/1542 on batteries and waste batteries

As part of the EU Green Deal, the regulation aims to mitigate risks related to human rights violations and environmental standards throughout the battery manufacturing value chain. Due diligence requirements are central to ensuring compliance, while the regulation also sets standards for battery durability, performance, passports and recycling. All manufacturers, producers, importers and distributors of batteries within the EU market are subjected to this regulation, which was enacted in 2023, with its requirements being phased in gradually[39]. Chinese manufacturing expenses are expected to rise as battery and electric bus producers adjust to meet EU standards, necessitating environmental enhancements, technology improvements and the creation of recycling networks[40].

European Battery Alliance (EBA)

Launched by the European Commission in 2017, the EBA now consists of over 800 stakeholders across various sectors involved in the battery value chain. The EBA aims to ensure the availability of raw materials and to develop a complete and competitive value chain for battery production in the EU. This is primarily achieved by uniting stakeholders and encouraging investments in production infrastructure across Europe. The EBA aims to establish competitive battery cell production in Europe by 2025 and position the region as a global leader in battery cell production by 2030, encompassing the entire battery value chain, from raw materials to recycling[41].

The Critical Raw Materials Act (CRMA). The CRMA sets targets to secure a stable and long-term supply of raw materials necessary for EU industry, reducing dependence on imports from specific countries. The regulation includes key raw materials for battery production (nickel, cobalt, lithium, etc.). The targets are set based on Europe's expected battery demand by 2030, aiming for 10% of mineral extraction, 40% of material processing and 45% of battery recycling to occur within the EU[42].

The EU's measures and their impact on European production capacity

The EU's measures are likely to affect production capacity in Europe and may, in the long term, contribute to a reduced dependence on China.

Battery pass enables future traceability

Currently, there is no well-established or efficient method to track a battery, its components and raw materials throughout the entire value chain. The EU has integrated due diligence guidelines into the EU Battery Regulation to enhance transparency and traceability of batteries. These rules are designed to amplify corporate accountability for risk assessment and adherence within supply chains[43].

The EU is developing technological solutions to facilitate the tracking of batteries, known as battery passports. Battery passports are electronic systems designed to monitor each phase of a battery's lifecycle — from raw material extraction through manufacturing, usage and ultimate disposal. By 2027, these passports will be mandatory for all batteries used in electric vehicles within the European market.

By introducing battery passports, the EU aims to create a framework for comparing batteries based on different criteria, establishing common minimum requirements for sustainable and responsibly produced batteries[44]. The regulation requires manufacturers to use digital solutions, such as QR codes or radio frequency identification (RFID) tags, to collect and store data throughout the entire value chain. The economic operator placing the battery on the EU market is responsible for ensuring accurate and up-to-date information.[40]

However, while the system seeks to address the traceability's practical needs, there are still obstacles in deploying it effectively, as cooperation among stakeholders in the battery value chain is essential. Compounding the problem is the current situation in which information is compartmentalized and not shared among participants in the battery value chain. Also, there is a shortage of standards and compatibility for existing data. Therefore, establishing traceability through a battery passport requires robust data, enhanced teamwork, clearly defined roles and responsibilities, along with the complexity of validating such data[45].

Other factors influencing battery production in Europe

The development of battery production in Europe is also shaped by external factors elements and global initiatives. The US's Inflation Reduction Act (IRA), aimed at boosting competitiveness in sectors like electric vehicles and renewable energy, is one such example. The IRA introduced financial incentives, including tax breaks and subsidies, for companies that invest in domestic production of batteries and related components for electric vehicles. As a result, battery manufacturers may consider the establishment and location of their factories.

These global measures reflect a broader shift toward strengthening local production chains and reducing dependence on international imports. Since December 2022, nine planned gigafactories have been announced in the US, poised to deliver a combined capacity of 315 GWh by 2030. This would account for approximately one-third of the anticipated total US production, which is nearly 1 TWh[46].

While Europe might gain insights and inspiration from US strategies to boost its own capacities, the growing appeal of manufacturing in the US could limit capacity growth in Europe.

Designing sustainability requirements for complex supply chains

Procuring organizations can approach sustainability requirements in various ways. This may involve mandating that suppliers implement structured programs for environmental and social management, which include oversight and ongoing advancement of their supply networks. Companies might also insist that suppliers obtain accreditations from reputable external agencies or equivalents that confirm sustainable practices, such as ISO 14001 for environmental management or SA8000 for social accountability. These certifications ensure systematic and continuous work on sustainability issues and facilitate procurers' control.

In complex and globalized supply chains with many steps and sub-components, risks related to both social and environmental sustainability are not uncommon. To ensure compliance with human rights, among other things, it is important to analyze the exposure and segment the risks.

As part of the procurement process, organizations can allow suppliers to estimate their risk exposure. The most critical risks can be highlighted, and the procuring organization can require in-depth due diligence in these high-risk areas to verify the accuracy of the self-assessment.

To conclude, gaining a clear understanding of the intended outcomes for requirements within a specification is crucial. By employing process-oriented requirements, one gains insight into how the supplier manages risks, conducts follow-up activities, and promotes ongoing improvement. Furthermore, segmenting risks provides a more comprehensive view of the most significant risks, thereby providing the procurement organization with a stronger foundation for making informed decisions.

Following this, the supplier relationship can be enhanced by establishing transparent monitoring procedures and carrying out thorough due diligence to collaboratively implement suitable measures and consistently identify and address risks within the supply chain.

With stricter sustainability regulations, future procurements will increasingly depend on legal standards. This shift swill lead to greater consistency across procurements, providing clearer guidelines for buyers and suppliers to follow, innovate and meet established criteria.

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