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US-CHINA EV BATTERY COMPETITION AND THE ROLE OF SOUTH KOREA

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EXECUTIVE SUMMARY

The United States and China are competing for supremacy in manufacture of electric vehicles (EVs) and EV batteries, and they have approached battery technology development and factory expansion as a 21st-century arms race. To compete with China, US officials are seeking to expand cell manufacturing through cooperation with battery makers in South Korea. While automakers or battery firms can scale up cell manufacturing relatively quickly, securing battery raw materials remains the biggest obstacle to new supply chains.

Three countries currently dominate the global battery market: China, Japan, and South Korea. Six battery cell manufacturers in China, one in Japan, and three in South Korea account for over 90% of global production.[1] Firms in the three Asian nations also lead in manufacturing battery components and cells.[2] In no small part due to their limited market presence, US and European Union manufacturers are far behind in battery technology.

American officials appear to consider China's dominance of the battery supply chain and its battery technology advantages to be a serious threat to the US economy and to US national security. The US is working to accelerate the expansion of the US EV industry and to reorganize the battery supply network—now dependent on China—so that it relies more heavily on the US and its allies.

South Korea and its electric vehicle and battery industries can be a key economic security ally in the expansion of the US electric vehicle industry and the establishment of a US battery supply chain. But South Korean firms are also highly dependent on China for critical minerals and battery components. Success in this partnership—which involves South Korean firms' manufacturing in the United States as well as in Korea—will require close and effective cooperation between the two governments and among companies.

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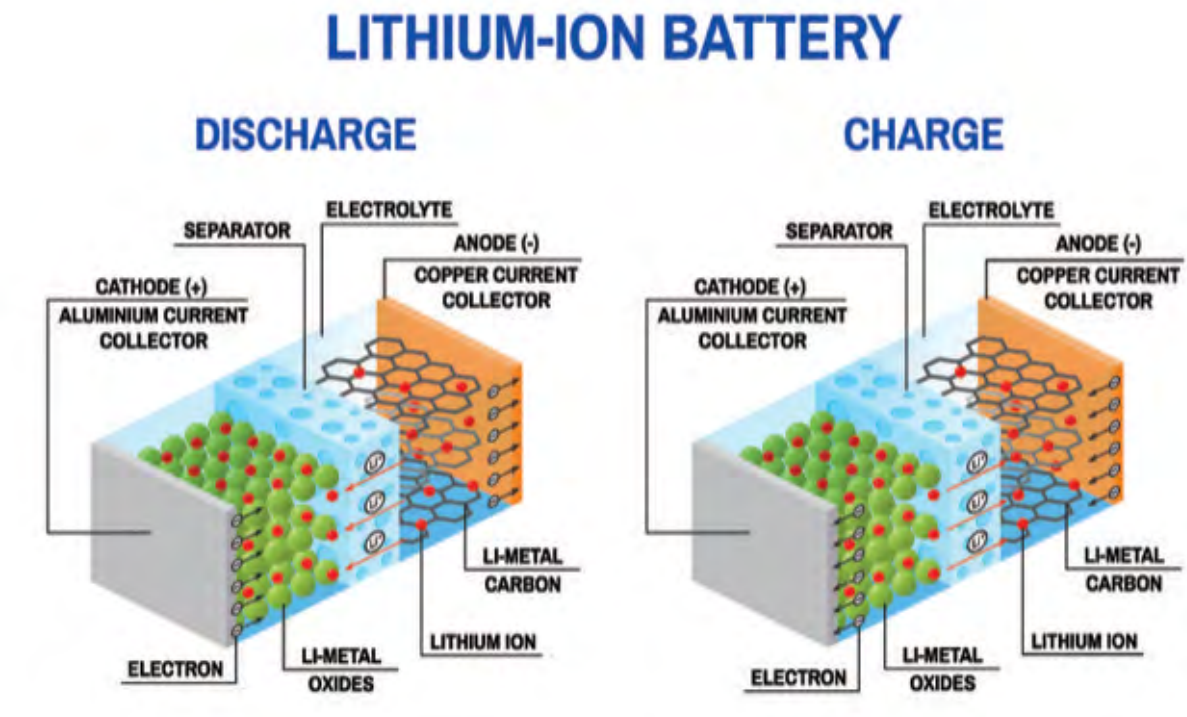
Battery Materials, Components, and Manufacturing

The battery supply chain begins with mining and processing battery minerals. Anodes, cathodes, electrolytes, and separators are then manufactured and assembled to create battery cells. Manufacturers make the large, powerful batteries required to move an EV by combining large numbers of cells.

Figure 1 illustrates a basic lithium-ion battery cell. When the battery is discharging, electrons move from the anode to the load (in an EV, this includes electric motors and other vehicle systems) to the cathode. At the same time, lithium ions move from the anode, through the separator, to the cathode. The lithium ions move within an electrolyte. When the battery is charging, the charger sends electrons from the cathode to the anode; at the same time, lithium ions move through the separator from the cathode to the anode.[3]

Critical mineral supply chains, including the supply chains for EV batteries, are a new front line in the global US-China rivalry. China exercises

Figure 1. Key components of a lithium-ion battery



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considerable control over each step of lithium-ion battery production, from mining raw materials to final assembly, and these advantages are likely to last. Indeed, Chinese companies control over 70% of lithium-ion battery manufacturing and nearly all stages of the EV battery supply chain.[4] They also have dominant positions in supply chains for key battery minerals, including lithium, cobalt, nickel, and manganese.[5] China's role in mineral processing, which follows mining and precedes component manufacturing, is especially strong.

The battery is the most important component of an electric vehicle and often contributes about 40% of the vehicle's cost.[6] China dominates most battery component manufacturing; Chinese firms make 74% of separators, 82% of electrolytes, 92% of anodes, and 77% of cathodes.[7] Of these, cathodes are perhaps most significant, in that their energy-intensive manufacturing contributes substantially to a battery's final cost. China's lithium iron phosphate (LFP) batteries have recently won half the world's cathode market.[8] US companies are responsible for only about 1% of global cathode production.[9]

Cathode costs are an important factor in EVs' ability to compete with internal combustion engine (ICE) vehicles on price. Many see $100/KWh in battery capacity as the threshold at which battery EVs achieve cost parity with ICE vehicles.[10] Some current forecasts predict that the industry could reach this point in 2025, in large part due to falling prices for key materials, including lithium, nickel, and cobalt. Oil prices will also affect when cost parity is reached—that is, lower oil prices will extend the time to reach parity.[11] However, because China is far ahead in EV production, non-Chinese markets might not reach this point until 2030.[12]

Battery manufacturers have worked to trim costs by assembling fewer larger-sized cylindrical battery cells into EV batteries. In the case of an electric car, 7,000 cells are required if an 1865 (diameter 18 mm, height 65 mm) battery is used;[13] 4,416 cells are required if a 2170 battery is used;[14] and from 828 to as few as 690 cells are required if a 4680 battery is used.[15] The cylindrical shape maximizes space efficiency and energy density.

Using LFP batteries also reduces manufacturing costs. Although LFP batteries are lower in energy density than nickel manganese cobalt (NMC) batteries, they are cheaper and safer from fire than NMC batteries, which have a lower flash point.[16] South Korean manufacturers have concentrated on producing NMC batteries because of their higher energy density, which both reduces weight and allows an EV to travel longer distances on a single charge.[17] LFP batteries do not contain nickel or cobalt, which are expensive raw materials, and are 30% cheaper than NMC batteries.

LFP batteries gained ground due to supply chain instability and raw material price increases associated with the COVID-19 pandemic and Russia's invasion of Ukraine,[18] though slumping EV demand has since reduced prices somewhat. China's large EV manufacturers adopted LFP batteries first; US and European carmakers have also moved in this direction.[19] LFP batteries are increasingly popular for stationary

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grid-scale energy storage systems, where their lower energy density and greater weight are less important.[20]

Growth of Chinese battery manufacturers like Contemporary Amperex Technology Co., Ltd. (CATL) and BYD has largely been at the expense of their competitors in South Korea and Japan. Officials in Beijing define batteries as a strategic technology and have invested time and money in developing the industry.[21] Today, Chinese firms can build new battery factories at a significantly lower cost than their US and other Western rivals.[22] In 2022, China's EV battery industry had 77% of global battery cell manufacturing capacity.[23]

South Korea's Dependence on China

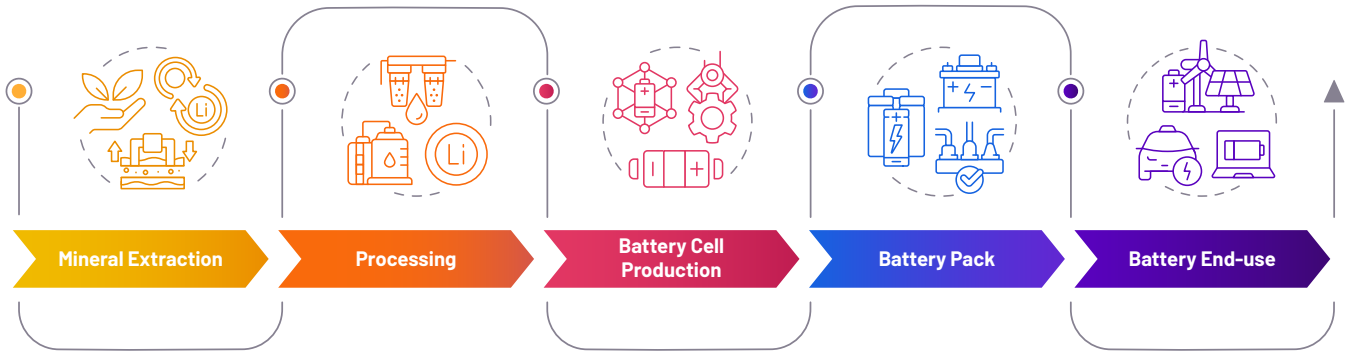
Three South Korean manufacturers were among the global top-five battery makers in 2023: LG Energy Solutions, with 16.4% market share; Samsung SDI, with 7.8%; and SK On, with 7.5%. All were behind China's CATL (35.6%). The Chinese EV company BYD was in third place. (15.6%).[24] South Korea's battery manufacturers rely heavily on China for battery materials. As of September 2023, Chinese imports supplied South Korea with over 96.6% of its precursor chemicals for cathodes,[25] 93.7% of its synthetic graphite for anodes, 80.4% of its lithium hydroxide, and 69.5% of its cobalt oxide.[26]

Figure 2 illustrates key steps in the lithium-ion battery manufacturing process, which yields not only EV batteries, but also grid-scale storage batteries and the batteries for myriad personal electronic devices.

In 2022, South Korea's overall trade balance with China turned into a deficit for the first time in over 20 years.[27] EV batteries, components, and materials along with other high-tech products contributed importantly to this situation. If South Korea's EV industry continues to grow without addressing its dependence on China, its trade balance could continue to deteriorate.

Indeed, trade statistics demonstrate ongoing deterioration. South Korea's trade deficit for lithium hydroxide grew from $3.2 billion in 2022 to $4.8 billion in 2023.[28] Deficits are also increasing for other battery materials. Moreover, many South Korean EV manufacturers rely on Chinese batteries and not just on Chinese components; Hyundai's Kona EV and the

Figure 2. Lithium-ion battery manufacturing process



Credit: Shutterstock/bsd studio

Kia Ray EV both use CATL LFP batteries.[29] As late as 2022, Hyundai was reportedly considering using CATL batteries in all its vehicles, and possibly even replacing the lead-acid batteries in ICE vehicles with lithium-ion batteries.[30]

Finally, South Korea's dependence on China is not strictly a matter of material or battery imports; South Korean companies also manufacture batteries in China. For example, of the 40 GWh/year in total production capacity that battery manufacturer SK On had in early 2022, 27 GWh was at three plants in China. The company's other plants were in South Korea, the United States, and Hungary.[31]

South Korea's dependence on China in its EV battery supply chain is especially problematic in view of China's past efforts to impose economic pressure on South Korea. After Seoul deployed the American-based Terminal High Altitude Area Defense (THAAD) missile defense system in 2017, China halted group tours to South Korea and shut down a South Korean grocery chain in China.[32] The diplomatic flare-up has motivated some Korean companies to reduce their dependence on China.[33]

Lesser reliance on Chinese imports is also a goal of South Korea's battery industry, which is reorganizing its supply chains and seeking the chemicals and materials needed to decrease its use of Chinese battery minerals. For example, in 2021, LG Energy Solutions announced plans to invest $5.2 billion (about ₩6.2 trillion) in battery material production through 2025.[34] LG Chem, one of South Korea's largest cathode material manufacturers, plans to produce 65% and 50% of its necessary lithium and nickel, respectively, by 2028.[35] LG Chem has invested $75 million in a US lithium company and will buy 50,000 tons/year from 2023 to 2027 from a Canadian source.[36]

Steelmaker POSCO is especially ambitious and has set a goal to become a global top-three lithium company

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by 2030.[37] In addition to sourcing lithium in Canada,[38] POSCO is building a domestic plant to extract lithium hydroxide.[39] Separately, POSCO has signed contracts to buy graphite (for anodes) from Tanzania.[40] POSCO hopes to obtain 750,000 tons of graphite from Tanzania over 25 years, an average of 30,000 tons/year. Considering that South Korea imported 48,000 tons of graphite from China in 2022, this could contribute importantly to diversifying graphite supplies.[41]

Both LG Energy Solutions and POSCO are seeking nickel supplies in Indonesia, which holds the world's largest reserves. By 2022, LG Energy Solutions was already planning nearly $10 billion in investments in Indonesia's EV battery supply chain, including $3.5 billion for a nickel smelter and $2.4 billion for a factory to make precursor chemicals and cathodes.[42]

Separately, POSCO is investing $441 million to build its own nickel smelting plant in Indonesia[43] on top of a smaller investment in a domestic nickel factory.[44] Many firms are pursuing battery recycling as an additional pathway to procuring needed materials.

Finally, South Korean firms are also building battery plants overseas, including in the United States, Hungary, and Poland.[45] Hyundai is working to develop its own LFP battery technology and is investing $7.3 billion in a wider EV battery program; the company aims to become one of the world's top-three EV manufacturers by 2030.[46] Of course, until the companies find new sources for key minerals, these plants will contend with material supply chains that are highly concentrated in China.

The US Inflation Reduction Act

The 2022 US Inflation Reduction Act (IRA) has complicated the challenges confronting South Korea's EV battery companies and others in the industry as they work to reduce dependence on China for battery materials.

The IRA's $7,500 EV tax credit provides a $3,750 credit for EVs that satisfy a battery component requirement and $3,750 for EVs that satisfy a critical minerals requirement.[47] South Korea was initially concerned about the battery component requirement, which requires an escalating share of battery components to be manufactured or assembled in North America. In distinction, the critical mineral requirement permits extraction or processing of critical minerals only in countries with free trade agreements with the United States, including South Korea.[48] America eventually addressed this issue through liberal interpretations of the IRA in Internal Revenue Service rules. Most immediately, this meant great flexibility in EV leasing, which is exempt from these two requirements.[49]

South Korea also has concerns about another aspect of the law: vehicles incorporating products of a "foreign entity of concern" (FEOC) are not eligible for the tax credit. A rule implementing this restriction defines FEOCs as being "incorporated in, headquartered in, or performing" their work in China, Iran, North Korea, or Russia. Under the rule, an entity is also considered an FEOC if these governments, their regional or local governments, or current or former senior officials hold at least 25% ownership or control.

If an FEOC's contracting arrangements establish de facto control over another entity, that organization also becomes an FEOC.[50]

After the US Department of the Treasury released this rule as a proposal in early December 2023, one-third of EV models that had been eligible for tax credits no longer qualified. Reports suggest that the pending rule was the principal cause.[51] South Korean trade officials have expressed several concerns about the proposed rule to the United States. Perhaps most notably, officials asserted that "no companies will be able to qualify for the tax credit in 2025 without an exemption for graphite."[52] South Korea was not alone in expressing concerns about graphite; several comments on the proposed rule focused on this problem.[53]

South Korean battery companies are diversifying their mineral supply chains to Argentina,[54] Australia,[55] and Indonesia,[56] among other places, though it will be extremely difficult to eliminate all dependence on China before the rule takes effect, despite exceptions that delay this through 2027.[57] The FEOC rule appears likely to undercut a $1 billion 2023 deal between SK On and two Chinese precursor chemical suppliers.[58]

Moreover, the FEOC rule poses its own challenges for the United States. Recent studies suggest that while the United States might be able to meet its EV battery demand with factories in North America by 2032, it will likely remain dependent on imported anodes (92% dependent, requiring graphite) and cathodes (82% dependent) at that time.[59] (This analysis assumes that annual EV battery demand reaches 800 GWh in 2032.)

The IRA's battery component and critical mineral requirements reflect a US effort to develop domestic EV battery supply chains and where necessary to source key components and materials elsewhere in North America (battery components) or in US free trade partners (critical minerals). The IRA encourages foreign EV manufacturers selling into the US market to do the same. As a result, the law is driving a South Korean search for battery minerals outside China; it is also driving substantial integration of the US and South Korean EV battery supply chains and considerable South Korean investment in the United States.

In searching for resources, South Korean battery manufacturers have focused significantly on Australia and Canada, which have free trade agreements with the United States as well as rich natural resources and developed mining industries. Canada holds 3.6% of the world's lithium reserves;[60] Australia is one of the top-two holders of reserves of lithium,[61] cobalt,[62] and nickel.[63]

SK On has been seeking to diversify its supply chain in Australia. In late 2022, the company signed a memorandum of understanding with Australia's Global Lithium Resources.[64] Established in 2018, Global Lithium holds significant lithium resources in Western Australia and is currently exploring at multiple sites. Notably, however, the Chinese firm Suzhou TA&A Ultra Clean Technology Co. is a "cornerstone investor" in Global Lithium and owns almost 10% of the company[65]—an arrangement that illustrates the challenges involved in untangling complex supply chains. SK On has a separate contract with Australia's

Lake Resources to supply lithium from sites in Argentina for its US battery plants.[66]

LG Energy Solutions has joined with three Canadian mineral companies to establish a North American battery mineral supply chain. In September 2022, the company signed agreements with Canada's Electra, Avalon, and Snowlake to secure cobalt sulfate, lithium hydroxide, and other key raw materials for batteries.[67] The *Global Lithium-Ion Battery Supply Chain Ranking*, issued annually by BloombergNEF (BNEF), placed Canada ahead of China for the first time in early 2024. This was in large part due to the IRA's stimulation of demand as well as China's weak environmental, sustainability, and governance conditions.[68] (The United States ranked third for similar reasons.)

Since the IRA's enactment, South Korean firms have announced six separate EV battery projects in the United States, each with investments of over $1 billion.[69] These include two LG Energy Solutions projects, specifically battery plants in Arizona and Michigan; an LG Energy Solutions battery project with Hyundai in Georgia; an LG Chem mineral and component plant in Tennessee; a Samsung/GM plant in Indiana; and an SK Innovation plant in Georgia. In addition, SK On and Ford are building a $5.8 billion complex including two battery plants in Kentucky.[70]

America's Big Three automakers—GM, Ford, and Stellantis—have each partnered with South Korean battery manufacturers to varying degrees. Tesla has largely relied on Japan's Panasonic (generally for providing nickel cobalt aluminum, or NCA, batteries) and more recently CATL (for LFP batteries).[71] The GM-LG Energy Solutions alliance, Ultium Cells LLC, is expected to produce about 160 GWh/year in batteries in a total of four factories.[72] Ford and SK will build 129 GWh;[73] and Stellantis will build one factory with LG Energy Solutions and one with Samsung at 40 GWh and 23 GWh.[74] POSCO Chemical is building a cathode material plant in Canada to supply materials for Ultium Cells.[75]

With these varied agreements, and others, US and South Korean companies are becoming deeply intertwined. Indeed, South Korean battery firms are well on their way to establishing a leading position in markets outside China, having secured 49% of relevant sales globally in the first quarter of 2023.[76]

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Looking Ahead

The IRA and ongoing interpretations and rulemaking will continue to shape the US-China competition for supremacy in electric vehicles and batteries as well as South Korea's role in this techno-economic clash. The global battery industry is still in its infancy; the United States, South Korea, and other partners are increasingly developing "de-risked" battery supply chains that maintain some dependence on China while expanding their own capabilities.

Given China's dominance in EV battery markets, contesting its role will require a dramatic expansion of manufacturing capacity. Announced battery plant projects in North America as of November 2022 could increase manufacturing capacity from 55 GWh/year in 2021 to 998 GWh/year in 2030, with the vast majority of this capacity in the United States.[77] Yet some forecast that by 2031, China's manufacturing capacity will reach 4,605 GWh/year—still far greater than America's, despite great effort.[78]

Moreover, some express concern that planned EV battery production capacity far outstrips expected demand, as China's capacity alone already exceeds current global needs.[79] Though this excess capacity could benefit consumers by driving down prices, it would also reduce profitability, especially for higher-cost producers. China's dominant market position is especially advantageous in such conditions. The United States and South Korea are making a big bet that cooperating to manufacture EVs and batteries will enable them to compete with China's massive EV industry. For the bet to pay off, a long-term commitment by both partners will be essential.

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Endnotes

1 Heejin Kim, "China's CATL Extends Lead as World's Top EV Battery Maker," *Bloomberg*, January 4, 2023, https://www.bloomberg.com/news/articles/2023-01-04/china-s-catl-extends-lead-as-world-s-top-ev-battery-maker.

2 BloombergNEF, "China's Battery Supply Chain Tops BNEF Ranking for Third Consecutive Time, with Canada a Close Second," November 12, 2022, https://about.bnef.com/blog/chinas-battery-supply-chain-tops-bnef-ranking-for-third-consecutive-time-with-canada-a-close-second/.

3 Inverted, "Learn about the Working of Lithium Ion Batteries," https://inverted.in/blog/learn-about-the-working-of-lithium-ion-batteries.

4 Agnes Chang and Keith Bradsher, "Can the World Make an Electric Car Battery without China?," *New York Times*, May 16, 2023, https://www.nytimes.com/interactive/2023/05/16/business/china-ev-battery.html.

5 Ibid.

6 Adrian Konig et al., "An Overview of Parameter and Cost for Battery Electric Vehicles," *World Electric Vehicle Journal 12*, no. 1 (2021), https://www.mdpi.com/2032-6653/12/1/21.

7 Chang and Bradsher, "Can the World Make an Electric Car Battery without China?"

8 Ibid.

9 Ibid.

10 Colin McKerracher, "Rising Battery Prices Threaten to Derail the Arrival of Affordable EVs," *Bloomberg*, December 6, 2022, https://www.bloomberg.com/news/articles/2022-12-06/rising-battery-prices-threaten-to-derail-the-arrival-of-affordable-evs.

11 Goldman Sachs, "Electric Vehicle Battery Prices Are Falling Faster than Expected," November 1, 2023, https://www.goldmansachs.com/intelligence/pages/electric-vehicle-battery-prices-falling.html.

12 International Energy Agency, "Global EV Outlook 2024: Executive Summary," April 2024, https://www.iea.org/reports/global-ev-outlook-2024/executive-summary.

13 Interplex, "Lithium-Ion Electric Vehicle Batteries: Everything You Need to Know," November 15, 2022, https://interplex.com/lithium-ion-electric-vehicle-batteries-everything-you-need-to-know/#:~:text=This%20EV's%20battery%20pack%20contains,module%20containing%201%2C584%20cells%20each.

14 Jordan Mulach, "Tesla Model Y Price to Fall with Next-Generation 4680 Battery—Report," Drive.com, September 12, 2022, https://www.drive.com.au/news/tesla-model-y-cost-to-reduce-4680-battery/.

15 Mark Kane, "Tesla's 4680-Type Battery Cell Teardown: Specs Revealed," *Inside EVs*, July 17, 2022, https://insideevs.com/news/598656/tesla-4680-battery-cell-specs/.

16 Modern Materials Handling, "New Tests Prove: LFP Lithium Batteries Live Longer than NMC," October 19, 2021, https://www.mmh.com/article/new_tests_prove_lfp_lithium_batteries_live_longer_than_nmc.

17 Cristian Agatie, "Korean Battery Producers Set to Lose Big to China as U.S. Carmakers Switch to LFP Cells," Auto Evolution, February 11, 2023, https://www.autoevolution.com/news/korean-battery-producers-set-to-lose-big-to-china-as-us-carmakers-switch-to-lfp-cells-210191.html.

18 "Russia-Ukraine Conflict Exposes Risks in EV Supply Chains," *Electronics Technology News*, May 10, 2022, https://etn.news/e-mobility-blogs/russia-ukraine-conflict-exposes-risks-in-ev-supply-chains.

19 Jackie Northam, "Ford Plans to Make EV Batteries in U.S. with Chinese Company That Developed the Tech," NPR, August 8, 2023, https://www.npr.org/2023/08/08/1192557960/ford-plans-to-make-ev-batteries-in-u-s-with-chinese-company-that-developed-the-t.

20 Grace Donnelly, "Batteries beyond EVs—Everything You Need to Know about Stationary Storage," *Tech Brew*, April 19, 2022, https://www.emergingtechbrew.com/stories/2022/04/19/batteries-beyond-evs-everything-you-need-to-know-about-stationary-storage.

21 Keith Bradsher and Michael Forsythe, "Why a Chinese Company Dominates Electric Car Batteries," *New York Times*, December 22, 2021, https://www.nytimes.com/2021/12/22/business/china-catl-electric-car-batteries.html.

22 Chang and Bradsher, "Can the World Make an Electric Car Battery without China?"

23 Govind Bhutada, "Visualizing China's Dominance in Battery Manufacturing (2022–2027P)," *Visual Capitalist*, January 19, 2023, https://www.visualcapitalist.com/chinas-dominance-in-battery-manufacturing/.

24 Jonghyun Kim, "China's CATL Widening the Gap . . . K Battery Aims for a Turnaround with Production in North America" [in Korean], *eNews Today*, April 17, 2024, https://www.enewstoday.co.kr/news/articleView.html?idxno=2115915.

25 Precursor chemicals are specialized compounds of battery minerals that are processed and mixed in specified ratios.

26 Kyung-Min Kang, "Korea's Heavy Dependence on China for Raw Materials Deepens," *Korea Economic Daily*, September 12, 2023, https://www.kedglobal.com/supply-chain/newsView/ked202309120009.

27 Joshua Park, "South Korea's First Trade Deficit with China: Stirrings in the Global Tech Sector," Center for Strategic and International Studies, August 3, 2022, https://www.csis.org/blogs/new-perspectives-asia/south-koreas-first-trade-deficit-china-stirrings-global-tech-sector.

28 See statistics at Korea International Trade Association, https://www.kita.org/kStatistics/commodity/countriesSpecific/countriesSpecific.do. The HSK (Harmonized System of Korea) code for lithium hydroxide is 2825202000.

29 Peter Johnson, "Hyundai Has a Plan to Lower EV Prices by Making Its Own Cheaper LFP Batteries," *Electrek*, November 8, 2023, https://electrek.co/2023/11/08/hyundai-plans-cheaper-ev-prices-lfp-batteries/.

30 Stan Lee, "Hyundai Considered Using CATL's Batteries for All Its Models," *The Elec*, July 21, 2022, https://www.thelec.net/news/articleView.html?idxno=4124.

31 "SK On to Build Fourth Battery Factory Plant in China," *Electrive*, April 11, 2021, https://www.electrive.com/2021/11/04/sk-on-to-build-fourth-battery-plant-in-china/#:~:text=SK%20On%20has%20three%20factories,production%20capacity%20of%2027%20GWh.

32 Kim Tong-Hyung, "China, South Korea, Clash over THAAD Anti-Missile System," *Defense News*, August 10, 2022, https://www.defensenews.com/global/asia-pacific/2022/08/10/china-south-korea-clash-over-thaad-anti-missile-system/.

33 Victoria Kim, "When China and U.S. Spar, It's South Korea That Gets Punched," *Los Angeles Times*, November 20, 2020, https://www.latimes.com/world-nation/story/2020-11-19/south-korea-china-beijing-economy-thaad-missile-interceptor.

34 Aria Alamalhodaei, "LG Chem Will Invest $5.2 Billion in Battery Materials through 2025," *Tech Crunch*, July 14, 2021, https://techcrunch.com/2021/07/14/lg-chem-will-invest-5-2b-in-battery-materials-through-2025/#:~:text=South%20Korea's%20LG%20Chem%20has,out%20its%20battery%20materials%20business.

35 Hyeon-gil Oh, "'50% Lithium Internalization in 5 Years' . . . LG Chem Battery Mineral Expansion" [in Korean], *Asia Business Daily*, June 7, 2023, https://www.asiae.co.kr/article/2023060708500232213.

36 "Piedmont Lithium and LG Chem Sign Equity Investment and Binding Offtake Agreements," *Businesswire*, February 16, 2023, https://www.businesswire.com/news/home/20230216005283/en/Piedmont-Lithium-and-LG-Chem-Sign-Equity-Investment-and-Binding-Offtake-Agreements.

37 POSCO, "POSCO HOLDINGS Secures Lithium from Oil-field Brine in Canada," November 21, 2023, https://newsroom.posco.com/en/posco-holdings-secures-lithium-from-oil-field-brine-in-canada/.

38 Ibid.

39 Mi-Sun Kang, "POSCO Breaks Ground on Lithium Hydroxide Plant in South Korea," *Korea Economic Daily*, June 13, 2023, https://www.kedglobal.com/batteries/newsView/ked202306130018.

40 Lee Ki-woo, "Establishment of a Chinese-Free Supply Chain for Key Battery Materials" [in Korean], *Chosun Daily*, June 29, 2023, https://www.chosun.com/economy/industry-company/2023/06/05/Y47TIIN3SFGPVHHXGG5GJBZ4YE/.

41 Ibid.

42 Bernadette Christina, "South Korea's LG Energy Solution Launches Nickel Processing Plants in Indonesia," *Reuters*, June 8, 2022, https://www.reuters.com/breakingviews/skoreas-lg-energy-solution-launches-nickel-processing-plants-indonesia-2022-06-08/.

43 Hyung-Kyu Kim, "POSCO Holdings to Produce Nickel in Indonesia," *Korea Economic Daily*, May 3, 2023, https://www.kedglobal.com/batteries/newsView/ked202305030002#:~:text=According%20to%20the%20company%2C%20the,produce%20one%20million%20electric%20vehicles.

44 Jung Min-hee, "POSCO to Build Nickel Plant in Gwangyang by 2023," *Business Korea*, July 30, 2021, https://www.businesskorea.co.kr/news/articleView.html?idxno=72956.

45 "GM and POSCO Future M to Expand EV Battery Supply Chain in North America with New Integrated CAM and Precursor Processing Complex," *PR Newswire*, June 2, 2023, https://www.prnewswire.com/news-releases/gm-and-posco-future-m-to-expand-ev-battery-supply-chain-in-north-america-with-new-integrated-cam-and-precursor-processing-complex-301840868.html; Stan Lee, "EcoPro BM and POSCO to Build New Factories in Europe," *The Elec*, April 20, 2021, https://www.thelec.net/news/articleView.html?idxno=2675.

46 Johnson, "Hyundai Has a Plan to Lower EV Prices."

47 US Department of the Treasury, "Treasury Releases Proposed Guidance on New Clean Vehicle Credit to Lower Costs for Consumers, Build U.S. Industrial Base, Strengthen Supply Chains," March 31, 2023, https://home.treasury.gov/news/press-releases/jy1379.

48 Ibid.

49 Chad P. Brown, "How the United States Solved South Korea's Problems with Electric Vehicle Subsidies under the Inflation Reduction Act," Working Paper 23-6, Peterson Institute for International Economics, July 2023, https://www.piie.com/sites/default/files/2023-07/wp23-6.pdf.

50 US Department of the Treasury, "Treasury Releases Proposed Guidance on New Clean Vehicle Credit." The Department of the Treasury released the final rule on May 3, 2024.

51 Nicholas E. Buffie, "Foreign Entity of Concern Requirements in the Section 30D Clean Vehicle Credit," Congressional Research Service, IN12322, February 28, 2024, https://crsreports.congress.gov/product/pdf/IN/IN12322#:~:text=This%20Insight%20describes%20both%20the,regulatory%20enforcement%20of%20those%20requirements.&text=The%20term%20"foreign%20entity%20of,threats%20to%20the%20United%20States.

52 US Department of Energy, "Memorandum for the Record," January 11, 2024, https://www.regulations.gov/document?D=DOE-HQ-2023-0067-0081.

53 Department of the Treasury, "Clean Vehicle Credits under Sections 25E and 30D; Transfer of Credits; Critical Minerals and Battery Components; Foreign Entities of Concern," May 3, 2024, https://subscriber.politicopro.com/eenews/f/eenews/?id=0000018f-3b8d-d759-a9ff-fbcf97660000.

54 Lee Haye-ah, "South Korean, Argentine Leaders Agree to Explore Joint Lithium Battery Production," *Yonhap News Agency*, September 9, 2023, https://en.yna.co.kr/view/AEN20230909001700315.

55 "Australian Battery Metal Players Key to South Korea's EV Ambition," *Reuters*, November 30, 2022, https://www.reuters.com/business/autos-transportation/australian-battery-metal-players-key-south-koreas-ev-ambition-2022-11-30/.

56 Kan Hyeong-woo, "Korea, Indonesia Join Forces to Build EV Ecosystem," *Korea Hearld*, March 23, 2023, https://www.koreaherald.com/view.php?ud=20230324000559.

57 Kat Lucero, "Final EV Tax Credit Regs Add New Battery Tracing Test," Law360, May 3, 2024, https://www.law360.com/articles/1832119/final-ev-tax-credit-regs-add-new-battery-tracing-test.

58 Kim Jaewon, "U.S. Rules Force South Korea's EV Battery Makers to Rethink China Deals," *Nikkei Asia*, December 8, 2023, https://asia.nikkei.com/Business/Business-Spotlight/U.S.-rules-force-South-Korea-s-EV-battery-makers-to-rethink-China-deals.

59 Ahmed Mehdi and Tom Moerenhout, "IRA and the US Battery Supply Chain: Background and Key Drivers," Columbia University Center on Global Energy Policy, June 8, 2023, https://www.energypolicy.columbia.edu/publications/the-ira-and-the-us-battery-supply-chain-background-and-key-drivers/.

60 US Geological Survey, "Lithium," Mineral Commodities Summaries, January 2023, https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-lithium.pdf.

61 Ibid.

62 US Geological Survey, "Cobalt," Mineral Commodities Summaries, January 2023, https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-cobalt.pdf.

63 US Geological Survey, "Nickel," Mineral Commodities Summaries, January 2023, https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-nickel.pdf.

64 SK On, "SK On Signs MOU with Global Lithium Resources to Bolster Key Battery Materials Supply Chain," September 29, 2022, https://eng.sk.com/news/sk-on-signs-mou-with-global-lithium-resources-to-bolster-key-battery-materials-supply-chain#:~:text=The%20representatives%20from%20SK%20On,raw%20material%20for%20EV%20battery.

65 Global Lithium Resources, "Annual Report 2022: People Power Planet,"https://wcsecure.weblink.com.au/pdf/GL1/02586050.pdf.

66 "SK On Inks Lithium Supply Deal with Australia's Lake Resources," *PR Newswire*, October 12, 2022, https://www.prnewswire.com/news-releases/sk-on-inks-lithium-supply-deal-with-australias-lake-resources-301647038.html.

67 Joyce Lee, "LG Energy Inks Cobalt, Lithium Supply Deals with Three Canadian Miners," *Reuters*, September 22, 2023, https://www.reuters.com/technology/lg-energy-inks-cobalt-lithium-supply-deals-with-three-canadian-miners-2022-09-23/.

68 BloombergNEF, "China Drops to Second in BloombergNEF's Global Lithium-Ion Battery Supply Chain Ranking as Canada Comes Out on Top," February 5, 2024, https://about.bnef.com/blog/china-drops-to-second-in-bloombergnefs-global-lithium-ion-battery-supply-chain-ranking-as-canada-comes-out-on-top/.

69 US Department of Energy, "Building America's Clean Energy Future," April 19, 2024, https://www.energy.gov/invest#:~:text=New%20U.S.%20battery%20manufacturing%20and,Over%2080%2C000%20potential%20new%20jobs.

70 SK On, "News and Reports about SK On," December 6, 2022, http://eng.sk-on.com/company/press_view.asp?idx=50&page=1&schtxt=battery&CompanyCode=011.

71 Find My Electric, "Tesla Batteries: What Kind of Battery Does My Tesla Have?" February 15, 2024, https://www.findmyelectric.com/blog/what-kind-of-battery-does-my-tesla-have/.

72 Shannon Cuthrell, "GM, LG Energy Solution Add $275M to Tennessee Battery Cell Plant Investment," *EE Power*, December 15, 2022, https://eepower.com/news/gm-lg-energy-solution-add-275m-to-tennessee-battery-cell-plant-investment/#.

73 "SK On–Ford Joint Venture Breaks Ground on EV Battery Mega Campus in Kentucky," SK On, press release, December 5, 2022, https://eng.sk.com/news/sk-on-ford-jv-holds-first-groundbreaking-ceremony-for-ev-battery-mega-campus.

74 Lee Sang Won, "Samsung SDI to Form EV Battery Joint Venture with Stellantis," *The Elec*, October 22, 2021, https://www.thelec.net/news/articleView.html?idxno=3495.

75 POSCO Chemical, "POSCO Chemical and GM Finalize Ultium CAM Joint Venture," May 7, 2022, https://www.poscochemical.com/en/pr/view.do?num=601.

76 Jung Min-hee, "Major Korean Battery Makers Post Combined 49% Market Share in Non-China Markets in Q1," *Business Korea*, May 9, 2023, https://www.businesskorea.co.kr/news/articleView.html?idxno=114266.

77 David Gohlke et al., "Assessment of Light-Duty Plug-in Electric Vehicles in the United States, 2010–2021," Argonne National Laboratory, ANL-22/71, November 2022, p. 27, https://publications.anl.gov/anlpubs/2022/11/178584.pdf.

78 Michael D. Plante and Jessica Rindels, "Automakers' Bold Plans for Electric Vehicles Spur U.S. Battery Boom," Federal Reserve Bank of Dallas, October 11, 2022, https://www.dallasfed.org/research/economics/2022/1011.

79 Colin McKerracher, "China Already Makes as Many Batteries as the Entire World Wants," *Bloomberg*, April 12, 2024, https://www.bloomberg.com/news/newsletters/2024-04-12/china-already-makes-as-many-batteries-as-the-entire-world-wants.