INDUSTRIES OF INDIA

THE LITHIUM-ION BATTERY

Source Companion

Every citation tag in the book resolves to an entry here, with the source, what it supports, and an honest record of how it was read.

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About this companion

This companion is the source ledger for *The Lithium-ion Battery: Ion, Cell, Charge*. Each bracketed tag in the book's text, such as [17.1], resolves here to a source, a link, the claims it supports, and a read-status: **read** (full or substantial passages read), **surveyed** (official summaries, abstracts, press pages or search highlights), or **inferred** (this book's own synthesis, flagged as such). Figures in the book carry the same provenance. Forecasts in the book are labelled as forecasts in the text itself.

Chapter 1 — A Stone That Burns Crimson

[1.1] Royal Society of Chemistry, 'Lithium — element information, properties and uses'. Read: substantial excerpts (discovery, naming, Brande 1821, Bunsen & Matthiessen 1855 bulk isolation). Backs: 1817 discovery by Arfvedson in Berzelius's laboratory; petalite from Uto; crimson flame; the name from Greek lithos. Limits: tertiary reference. URL: https://periodic-table.rsc.org/element/3/lithium

[1.2] U.S. Geological Survey, Mineral Commodity Summaries 2025 — Lithium. Read: extended excerpts (end-use split, production/consumption, prices, mine census). Backs: 2024 end uses (batteries 87%); world production ~240,000 t Li content 2024, +18%; consumption ~220,000 t; annual average battery-grade carbonate price $14,000/t (2024) vs $71,100 (2022). Limits: two-page summary. URL: https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-lithium.pdf

[1.3] J. Aronson, 'When I use a word… Discovering lithium,' The BMJ blog, 20 Jan 2017. Read: excerpt. Backs: petalite/Uto/Arfvedson/Berzelius narrative detail; etymology. Limits: commentary essay. URL: https://blogs.bmj.com/bmj/2017/01/20/jeffrey-aronson-when-i-use-a-word-discovering-lithium/

[1.4] G. S. Malhi, C. Davey, E. Bell, 'John Cade's lithium: A granular look at his achievement,' Australian & New Zealand Journal of Psychiatry, 2024. Read: abstract. Backs: Cade's 1949 MJA paper, guinea-pig experiments, self-experimentation, prior 19th-century gout use (Garrod). Limits: full text paywalled. URL: https://doi.org/10.1177/00048674241276700

Chapter 2 — The Lightest Metal's Problem

[2.1] J. B. Goodenough, 'How we made the Li-ion rechargeable battery,' Nature Electronics 1, 204 (2018). Read: substantial excerpt. Backs: Exxon program, TiS2 cell, dendrite growth causing internal shorts that 'would ignite the flammable electrolyte'; program abandonment. URL: https://doi.org/10.1038/s41928-018-0048-6

[2.2] Nobel Prize, 'Scientific Background on the Nobel Prize in Chemistry 2019 — Lithium-ion batteries'. Read: extended excerpts (intercalation criteria, Whittingham cell details, Yoshino section). Backs: electrode-potential framework; host-material requirements; early cell chemistries. The ~3,860 mAh/g theoretical specific capacity of lithium metal is the value given in this Nobel background document; not re-derived here. Limits: excerpts, not full document. URL: https://www.nobelprize.org/uploads/2019/10/advanced-chemistryprize2019-2.pdf

[2.3] W. Greatbatch et al., 'The Solid-State Lithium Battery: A New Improved Chemical Power Source for Implantable Cardiac Pacemakers,' IEEE Trans. Biomed. Eng. (1971). Read: abstract. Backs: Li/I2 cell, 2.8 V, lithium-iodide solid electrolyte, hermetic sealing, pacemaker use. URL: https://doi.org/10.1109/TBME.1971.4502862

Chapter 3 — Two Centuries of Stored Lightning

[3.1] Wikipedia, 'History of the battery.' Read: extended excerpts (Volta 1800 pile; Plante 1859 lead-acid and Faure 1881 pasted plates; Jungner NiCd 1899; Edison NiFe). Backs: pre-1900 chronology and cell constructions. Limits: tertiary; used only for uncontroversial chronology. URL: https://en.wikipedia.org/wiki/History_of_the_battery

[3.2] Federal Reserve History, 'Oil Shock of 1973-74' - surveyed (essay). Backs: 1973 and 1979 oil shocks and their effect on energy research funding; common-knowledge framing, no specific figure

taken. URL: https://www.federalreservehistory.org/essays/oil-shock-of-1973-74

Chapter 4 — An Oil Company's Battery

[4.1] Goodenough, Nature Electronics (2018) — as [2.1]. Backs: Exxon hiring Whittingham to build a rechargeable battery with TiS2; 1976 performance; dendrite fires; program abandonment.

[4.2] Nobel Prize scientific background 2019 — as [2.2]. Backs: Rüdorff 1965 TiS2 intercalation (Li0.6TiS2 via lithium in ammonia); Rouxel; Whittingham & Gamble full-range LixTiS2 with small lattice expansion; 1973 electrode proposal at Exxon; 1976 working cell (2.5 V emf, 10 mA/cm2, LiPF6 in propylene carbonate; LiClO4 variant cycled 1100 times).

[4.3] 'The epic story of Moli Energy, pioneer of the rechargeable lithium battery,' Electric Autonomy Canada, 18 Sep 2020. Read: substantial excerpts. Backs: Moli's founding; 1984 Molicel 2.2 V cell; August 10, 1989 Japanese phone fire; recall of 10,000 phones; internal short findings. Limits: single long-form journalistic history. URL: https://electricautonomy.ca/ev-supply-chain/batteries/2020-09-18/moli-energy-lithium-battery-technology/

Chapter 5 — The Oxide That Held the Ions

[5.1] UT Austin News, 'UT Mourns Lithium-Ion Battery Inventor and Nobel Prize Recipient John Goodenough,' 26 Jun 2023. Read: excerpt. Backs: biography arc; died 25 Jun 2023 aged 100. URL: https://news.utexas.edu/2023/06/26/ut-mourns-lithium-ion-battery-inventor-and-nobel-prize-recipient-john-goodenough/

[5.2] Nobel Prize scientific background 2019 — as [2.2]; plus Goodenough, Nature Electronics 2018 — as [2.1]. Backs: 1979/80 LixCoO2 cathode at ~4-5 V vs Li; >half the lithium reversibly extracted; Mizushima collaboration; charged/discharged-state reasoning.

[5.3] IDTechEx, 'Iron and Phosphate to Unlock the Mass-Market EV at Last,' 2025. Read: excerpt. Backs: LFP ~170 Wh/kg cell-level vs NMC811 ~260 Wh/kg; LFP ~40% of global car market 2024; Padhi et al. 1997 attribution standard (Nobel background [2.2] agrees). Limits: vendor analysis. URL: https://www.idtechex.com/en/research-article/iron-and-phosphate-to-unlock-the-mass-market-ev-at-last/32411

[5.4] NobelPrize.org, 'Akira Yoshino — Facts' and 2019 prize pages. Read: excerpts. Backs: 2019 Chemistry prize motivation, one-third shares; Yoshino biography (Asahi Kasei, b. 1948 Suita). Goodenough's status as oldest laureate at 97 consistent with the prize record. URLs: https://www.nobelprize.org/prizes/chemistry/2019/yoshino/facts/ and https://www.nobelprize.org/prizes/chemistry/2019/summary/

Chapter 6 — The Coke, the Cathode, and the Camera Company

[6.1] NobelPrize.org, 'Akira Yoshino — Facts.' Read: excerpt. Backs: Yoshino biography (b. 1948, Suita; joined Asahi Kasei 1972); 1985 petroleum-coke-anode battery as 'the first commercially viable lithium-ion battery.' URL: https://www.nobelprize.org/prizes/chemistry/2019/yoshino/facts/

[6.2] Nobel Prize scientific background 2019 (as [2.2]). Read: extended excerpts. Backs: Yoshino's path from polyacetylene to vapour-grown carbon fibre to heat-treated petroleum coke; mixed crystalline/disordered domains; ~0.5 V anode potential; LixCoO2 (tin-doped) cathode; PE/PP separators; LiClO4/propylene carbonate electrolyte. Yazami's early-1980s reversible lithium intercalation into graphite (CNRS/Grenoble) is standard recorded history consistent with the same document's anode-development section.

[6.3] Nobel Prize scientific background 2019 (as [2.2]). Backs: the drop-weight safety test Yoshino devised and its result.

[6.4] Asahi Kasei, 'Akira Yoshino — Honorary Fellow'. Read: excerpt. Backs: Asahi Kasei's identification of Yoshino as LIB inventor; company context. Sony's 1991 commercialisation and camcorder adoption: consistent with Sony corporate history materials and the Nobel background [2.2]; exact first-product detail recorded as industry-standard account. URL: https://www.asahi-kasei.com/asahikasei-brands/yoshino/

[6.5] M. S. Ziegler & J. E. Trancik, 'Re-examining rates of lithium-ion battery technology improvement and cost decline,' Energy & Environmental Science (2021). Read: extended excerpts. Backs: ~80 Wh/kg and ~200 Wh/L in 1991 rising to >250 Wh/kg and >700 Wh/L by 2018; 97% real price decline; ~13%/yr decline 1992-2016; learning rates 20-31%. URL: https://doi.org/10.1039/D0EE02681F

Chapter 7 — Stockholm, 2019

[7.1] NobelPrize.org, The Nobel Prize in Chemistry 2019 pages. Read: excerpts. Backs: prize date (9 Oct 2019), three one-third laureates, motivation wording. URL: https://www.nobelprize.org/prizes/chemistry/2019/summary/

[7.2] Nobel Prize scientific background 2019 (as [2.2]); "foundation of a wireless, fossil-fuel-free society" paraphrases the Academy's published popular background. Limits: lectures summarised from published materials, not viewed in full.

[7.3] UT Austin News obituary (as [5.1]). Backs: death 25 June 2023 at 100; 37 years on faculty; continued research into solid-state batteries.

Chapter 8 — The Rocking Chair

[8.1] Nobel Prize scientific background 2019 (as [2.2]). Backs: intercalation mechanism, topotactic hosting, host-material requirements (seven criteria quoted), cell construction.

[8.2] Nobel Prize scientific background 2019 (as [2.2]) plus standard battery literature. Backs: SEI concept (Peled 1979) and its ion-conducting/electron-blocking role; electrolyte window and ethylene-carbonate practice; voltage-climb narrative. Limits: SEI formation-consumption percentages (5-15%) are common industry figures, not tied here to one measurement; high-voltage LCO practice (4.35-4.4 V) is industry-standard product data.

Chapter 9 — The Cathode Families

[9.1] Goodenough, Nature Electronics 2018 (as [2.1]) and Nobel background 2019 (as [2.2]). Backs: LCO origins and character.

[9.2] IDTechEx, "Iron and Phosphate to Unlock the Mass-Market EV at Last" (as [5.3]). Backs: LFP ~170 Wh/kg vs NMC811 ~260 Wh/kg cell-level; LFP near 40% of global car market 2024; high-nickel trend. Table values assembled from these plus commonly published cell-level figures; flagged in-book as typical, not exhaustive.

[9.3] Orennia, 'Are LFPs Taking Over Batteries?' Read: excerpt. Backs: LFP patent landscape and expiry narrative. The 1997 Padhi/Goodenough olivine demonstration is standard recorded history (Nobel background [2.2] concurs). URL: https://orennia.com/insights/are-lfps-taking-over-batteries

[9.4] Benchmark Mineral Intelligence, 'What to expect for cathode markets in 2024?' Read: excerpt. Backs: LFP 45% of demand 2023, forecast 48% in 2024. URL:

https://source.benchmarkminerals.com/article/what-to-expect-for-cathode-markets-in-2024

Chapter 10 — The Other Electrode

[10.1] Nobel background 2019 (as [2.2], https://www.nobelprize.org/uploads/2019/10/advanced-chemistryprize2019-2.pdf) - read: extended excerpts. Lithium-metal theoretical capacity per the same document; graphite LiC6 / 372 mAh g-1 is the standard value given there.

[10.2] 'Issues impeding the commercialization of laboratory innovations for energy-dense Si-containing lithium-ion batteries,' Nature Energy (2023) - surveyed (abstract/highlights). Backs: silicon volume expansion ~3x, pulverisation, SEI growth. URL: https://www.nature.com/articles/s41560-023-01333-5

[10.3] Business Wire / Sila, 'Sila Raises $375M to Deliver Titan Silicon for Auto Series Production,' 27 Jun 2024. Read: excerpt. Backs: $375M raise, Moses Lake completion Q1 2025, auto deliveries from Q4 2025. URLs: https://www.businesswire.com/news/home/20240627486898/en/Sila-Raises-%24375M-to-Deliver-Titan-Silicon-for-Auto-Series-Production and https://www.silanano.com/press/press-releases/sila-raises-375m-to-deliver-titan-silicon-for-auto-series-production

[10.4] Amprius Technologies IR, 'The All-New Amprius 500 Wh/kg Battery Platform.' Read: excerpt. Backs: >450-500 Wh/kg silicon-anode cells, aviation/defence niches. Limits: company claims. URL: https://ir.amprius.com/news-events/press-releases/detail/42/the-all-new-amprius-500-whkg-battery-platform-is-here

[10.5] Benchmark Mineral Intelligence infographic, 'China controls three-quarters of graphite anode supply chain' - read: excerpt; with Fastmarkets, 'China's Jan-Feb graphite exports plunge amid export controls' - read: excerpt. Backs: China 74% of graphite-anode supply chain; <1% of uncoated spherical graphite outside China; Dec 2023 export controls context. URLs: https://source.benchmarkminerals.com/article/infographic-china-controls-three-quarters-of-graphite-anode-supply-chain and https://www.fastmarkets.com/insights/chinas-jan-feb-graphite-exports-plunge-amid-export-controls/

Chapter 11 — The Quiet Components

[11.1] EVTank / Yiwei Institute, 'China Lithium-ion Battery Electrolyte Industry Development White Paper (2025),' via Longbridge summary - read: excerpt. Backs: global electrolyte shipments 1.662 Mt in 2024 (+26.7%); China share above 90%; Tinci (Tianci) Materials nearly 500,000 t and 31.6% domestic share; price fall and falling concentration. URL: https://longbridge.com/news/223886299

[11.2] Asahi Kasei Separator Business Briefing (25 Apr 2024, IR PDF). Read: excerpt. Backs: Hipore wet-process separator's 40-year history tied to Yoshino's 1985 invention; Celgard dry-process lineage; shutdown behaviour is standard cell-design knowledge per [12.1]/[11.4]. URL: https://www.asahi-kasei.com/content/dam/asahi-kasei/us/en/ir/library/presentation/pdf/240425.pdf

[11.3] Asahi Kasei IR presentation (as [11.2]). Backs: ¥180 bn Ontario integrated separator plant, ¥160 bn Hipore sales target in year 5, 30% North American share target, DBJ/Honda co-investment. Celgard acquisition by Asahi Kasei (2015) is standard recorded corporate history.

Chapter 12 — When Batteries Burn

[12.1] Thermal-runaway staircase, step by step (the chapter cites one attributed value per step; separator SHUTDOWN and MELT are distinct processes and are not merged): SEI breakdown —

onset ~80°C (‘The SEI decomposition has an onset temperature of 80°C… at 100-120°C the electrolyte will decompose and/or the separator will begin to melt’), main exothermic decomposition in the 90-120°C band: ‘Advances in Prevention of Thermal Runaway in Lithium-Ion Batteries’, Advanced Energy & Sustainability Research (2021) - read (mechanism passages, full text). URL: https://advanced.onlinelibrary.wiley.com/doi/full/10.1002/aesr.202000059 Separator shutdown vs melt — PE pores collapse (shutdown fuse) at ~130°C, PP backbone melts ~165-170°C (‘PE and PP… melting points of approximately 130°C and 170°C’): Batteries 12(3):88, MDPI (2026) - surveyed (mechanisms section), URL: https://www.mdpi.com/2313-0105/12/3/88 ; trilayer design values per Celgard [11.4]. Cathode decomposition and oxygen release — the chapter cites the same aesr review’s value: ‘above 130°C the cathode begins to break down’ (read), with the review’s chemistry scope: onset is cathode-chemistry-dependent, layered oxides first, LFP hundreds of degrees later. NOTE: a second review (‘Mechanism and Control Strategies of Lithium-Ion Battery Safety’, Small Methods 2024, https://doi.org/10.1002/smtd.202400029 - surveyed abstract) places its modelled cathode step near ~200°C; the two sources differ by chemistry scope and the chapter deliberately does not average them.

[12.2] U.S. CPSC, ‘Dell Announces Recall of Notebook Computer Batteries Due To Fire Hazard’ (2006). Read: excerpt. Backs: Dell recall of Sony-made lithium-ion notebook batteries; figures of 4.1 M (Dell) and ~10 M total are the published record. URL: https://www.cpsc.gov/Recalls/2006/dell-announces-recall-of-notebook-computer-batteries-due-to-fire-hazard

[12.3] NTSB investigation DCA13IA037, Japan Airlines Boeing 787 battery fire, Boston, 7 Jan 2013 - surveyed (NTSB investigation page summary). Backs: JAL Boston fire, fleet grounding and containment redesign as public record; the ANA incident and 2013 grounding timeline are covered in the same NTSB/FAA record. Limits: investigation-page summary, not the full docket, in this edition. URL: https://www.ntsb.gov/investigations/Pages/DCA13IA037.aspx

[12.4] New York Times, ‘LG will pay G.M. $1.9 billion for a battery flaw that led to a Bolt recall,’ 12 Oct 2021; Reuters, ‘GM expands Chevy Bolt EV recall for fire risk,’ 20 Aug 2021. Read: excerpts. Backs: 141,000 recalled Bolts; $1.9 bn LG settlement; August 2021 expansion (+73,000 vehicles, $1 bn). URLs: https://www.nytimes.com/2021/10/12/business/lg-gm-bolt-battery-recall.html and https://www.reuters.com/business/autos-transportation/gm-recalling-73000-bolt-evs-cost-1-billion-halts-sales-2021-08-20/

[12.5] U.S. EPA, ‘Moss Landing Vistra Battery Fire Response: Frequently Asked Questions.’ Read: excerpt. Backs: 16 Jan 2025 fire; 300 MW system; ~100,000 batteries; EPA air monitoring Jan 17-20; EPA-supervised removal. URL: https://www.epa.gov/ca/moss-landing-vistra-battery-fire-faqs

Source Ledger — Chapters 13-18

Read-status key: **read** = full or substantial passages read via fetch; **surveyed** = search-result highlights, official summaries, abstract or press page read, full text not retrieved; **inferred** = background synthesis from multiple surveyed sources, flagged as such.

Chapter 13 — How a Cell Is Made

[13.1] Liu et al., “Pathways for practical high-energy long-cycling lithium metal batteries” (Nature Energy 2019) — surveyed. Supports: dry-room necessity, moisture sensitivity of practical cell chemistry; the full coating-to-formation sequence is documented by [13.2]. URL: https://www.nature.com/articles/s41560-019-0338-x **[13.2]** PEM of RWTH Aachen University / VDMA, ‘Production Process of a Lithium-Ion Battery Cell’ (brochure PDF) - surveyed (process steps). Supports: slurry mixing, coating, calendering, winding vs stacking sequence. URL:

https://www.pem.rwth-aachen.de/global/show_document.asp?id=aaaaaaaabwfmnyh **[13.3]** Cost model study (PMC11532491, "Cost modeling of lithium-ion battery manufacturing") — read (substantial passages). Supports: dry-room capital/energy share, moisture tolerance ppm levels, dew-point figures, formation and aging at 32.61% of manufacturing cost. URL: https://pmc.ncbi.nlm.nih.gov/articles/PMC11532491/ **[13.5]** Same as [13.3] — read. Supports: formation/aging as largest process-cost block (~32.61%), days-long aging for self-discharge screening. **[13.6]** Inferred — synthesis of the capacity-pipeline and ramp-difficulty reporting in [15.3], [15.6] and [16.4], with the cost model [13.3]; flagged in text as industry pattern, not a single measured figure.

Chapter 14 — The Shape of the Cell

[14.1] Tesla Battery Day 2020, official presentation deck (Tesla IR, 22 Sep 2020) - surveyed (deck). Supports: 4680 announcement, tabless claims, dry-electrode intent. URL: https://digitalassets.tesla.com/tesla-contents/image/upload/IR/2020-battery-day-presentation-deck **[14.2]** Cell Reports Physical Science, "Comparative teardown of Tesla 4680 and BYD Blade cells" (2025) — read (key results sections). Supports: 85.56 Wh (4680) vs 432 Wh (Blade) per-cell energies, construction differences, BYD LFP blade dimensions. URL: https://www.cell.com/cell-reports-physical-science/ **[14.3]** Inferred — standard prismatic/pouch construction descriptions synthesized from the teardown [14.2] and the Tesla deck [14.1]; flagged as generalised description. **[14.4]** Tesla patent application US2020/0144676A1, 'Cell with a tabless electrode' - surveyed (patent abstract/claims); construction results per the teardown [14.2]. Supports: tabless current-path physics, radial flow, welding difficulty. URL: https://patents.google.com/patent/US20200144676A1/en (NOTE: an earlier draft cited US2020/0067112 - that number resolves to an unrelated fuel-cell patent and was corrected.) **[14.5]** Inferred — chemistry/format affinity (LFP-prismatic, nickel-cylindrical) synthesized from the segment data in [22.2], [23.1] and [23.3] and the teardown [14.2]; flagged in text as pattern, not law. **[14.6]** Teardown [14.2] — read. Supports: packaging mass/volume fractions by format.

Chapter 15 — The Gigafactory

[15.1] Tesla-Panasonic joint gigafactory announcement, Tesla IR, 2014 — surveyed (release text). Supports: Nevada plant scope, 35 GWh ambition, $4-5B cost. URL: https://ir.tesla.com/press-release/tesla-gigafactory **[15.2]** Same as [15.1] plus Tesla 2013 shareholder letters — surveyed. Supports: "more than 2013 world output" arithmetic. **[15.3]** IEA, "Batteries and Secure Energy Transitions" (2024) — surveyed (executive materials). Supports: global announced capacity pipeline counts. URL: https://www.iea.org/reports/batteries-and-secure-energy-transitions **[15.5]** Inferred — scale-economics synthesis (utilisation, integration, learning) from [13.3] cost model and [15.3]. **[15.6]** IEA Global EV Outlook 2025, battery-manufacturing annex — surveyed. Supports: regional capacity distribution, IRA-driven North American wave, Europe's ramp difficulties. URL: https://www.iea.org/reports/global-ev-outlook-2025

Chapter 16 — Europe's Experiment

[16.1] Northvolt press release, 'Northvolt presents its plan to build Europe's largest battery factory' (2017, northvolt.com) + Reuters, 'Northvolt selects north Sweden site for mammoth battery plant' - surveyed (release/reporting). Supports: founding by ex-Tesla executives, Skelleftea siting, hydro power framing. URLs: https://northvolt.com/articles/northvolt-presents-its-plan-to-build-europes-largest-battery-factory/ and https://www.reuters.com/article/northvolt-gigafactory/northvolt-selects-north-sweden-site-for-mammoth-battery-plant-idUSL8N1MT4U5/ **[16.2]** Northvolt press release: '$1 billion equity capital raise led by Volkswagen Group and Goldman Sachs Merchant Banking, with

BMW Group, AMF, Folksam, IMAS' (northvolt.com) - surveyed (release headline and detail). Supports: capital raised, strategic investors, Northvolt Ett financing. URL: https://northvolt.com/articles/northvolt-completes-equity-capital-raise-to-enable-europes-first-homegrown-gigafactories-for-lithium-ion-batteries/ **[16.3]** Reuters, 'BMW cancels $2 bln battery cells contract with Northvolt', 2024-06-20 - surveyed (headline/deck). Supports: order cancellation timing and size; ramp delays per [16.2]/[16.4]. URL: https://www.reuters.com/business/autos-transportation/bmw-cancels-2-bln-contract-with-northvolt-says-handelsblatt-2024-06-20/ **[16.4]** Northvolt bankruptcy statement, 2025-03-12 — read (statement text). Supports: bankruptcy date, stated causes (capital, geopolitics), what remained standing. URL: https://northvolt.com/articles/bankruptcy/ **[16.5]** IEA Global EV Outlook 2025 (battery-manufacturing annex; same source as [15.6]) - surveyed. Supports: Asian incumbents operating European plants at volume; plant-level detail per company announcements cross-checked there. URL: https://www.iea.org/reports/global-ev-outlook-2025

Chapter 17 — Lithium Country

[17.1] USGS Mineral Commodity Summaries 2025, Lithium — read (PDF pages). Supports: world production ~240,000 t Li (2024), reserve figures by country, Australia/Chile/China ranking. URL: https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-lithium.pdf **[17.2]** IEA Global Critical Minerals Outlook 2025 — surveyed. Supports: demand growth, supply concentration, project pipeline. URL: https://www.iea.org/reports/global-critical-minerals-outlook-2025 **[17.3]** USGS Mineral Commodity Summaries 2025, Lithium (country resource/production table; same document as [17.1]) - read: extended excerpts. Supports: brine resource descriptions, Atacama/Argentina/Bolivia production contrasts. URL: https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-lithium.pdf **[17.4]** 'Water mining and extractivism of the Salar de Atacama, Chile' (WIT Transactions on Ecology and the Environment, doi.org/10.2495/eid200181) - surveyed (process passages). Supports: brine pumped from ~35 m; solar evaporation concentrates 0.18% Li to ~6%; salt precipitation sequence (halite, sylvinite, carnallite, bischofite); evaporation steps take 9-14 months from pump-out. NOTE: chapter text revised to match this range. URL: https://doi.org/10.2495/eid200181 ; company process description: SQM, 'Sustainability of lithium production' (sqm-ynv.com PDF), surveyed. **[17.5]** Columbia Center on Global Energy Policy, 'Assessing the Policy Ecosystems and Scaling Pathways of Direct Lithium Extraction' (June 2025) - surveyed (report highlights). Supports: DLE at pilot stage with several projects moving toward commercial demonstration; price-pressure challenges; flagged in text as early-stage. URL: https://www.energypolicy.columbia.edu/wp-content/uploads/2025/05/DLE-CGEP_Report_060325.pdf **[17.6]** Albemarle corporate page on Greenbushes/Talison (world's largest hard-rock lithium deposit, Talison ownership structure) - surveyed; conversion-chain concentration per IEA [17.2]. Supports: mine geography and ownership; ~6% Li2O concentrate grade is the industry-standard spec, flagged as approximate. URLs: https://www.albemarle.com/au/en/who-we-are/about-us-0 and https://www.iea.org/reports/global-critical-minerals-outlook-2025 **[17.7]** Price history: USGS mcs2025 annual averages 2020-24 [17.1] (read); 2022 spike peak: Caixin Global, 'Lithium Price Climbs to Record on Tight Supply', 2022-11-12 - surveyed (headline; Chinese spot carbonate at record highs, consistent with the chapter's 'above eighty thousand dollars at the extremes'). URL: https://www.caixinglobal.com/2022-11-12/lithium-price-climbs-to-record-on-tight-supply-101963906.html

Chapter 18 — The Cobalt Question

[18.1] USGS Mineral Commodity Summaries 2025, Cobalt — read (PDF pages). Supports: DRC ~226,000 t mine production 2024, >70% world share, reserve figures. URL: https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-cobalt.pdf **[18.2]** Cobalt Institute, Cobalt Market

Report 2024 — surveyed (highlights). Supports: CMOC ~41% of world mined supply, 2024 price trough, supply-glut framing. URL: https://www.cobaltinstitute.org/cobalt-market-report/ **[18.3]** Amnesty International, 'This is what we die for: Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt' (AFR 62/3183/2016, Jan 2016) - surveyed (report summary). Supports: artisanal-mining conditions; industrial vs artisanal share estimates flagged approximate. URL: https://www.amnesty.org/en/documents/afr62/3183/2016/en/ **[18.4]** Reuters, 'Congo to replace cobalt export ban with quotas from Oct 16' (2025-09-21) - surveyed (headline/deck). Supports: months-long suspension then quota system; stated market-management rationale. URL: https://www.reuters.com/world/africa/congo-replace-cobalt-export-ban-with-quotas-oct-16-2025-09-21/ **[18.5]** IEA Global Critical Minerals Outlook 2025 (same source as [17.2]/[17.6]) - surveyed. Supports: by-product economics (Cu-Co in DRC, Ni-Co in Indonesia); supply inelasticity argument. URL: https://www.iea.org/reports/global-critical-minerals-outlook-2025

Source Ledger — Chapters 19-24

Chapter 19 — Nickel's Second Act

[19.1] USGS Mineral Commodity Summaries 2025, Nickel — read (PDF pages). Supports: Indonesia ~2.31 Mt mine production 2024, ~62% world share, reserve data. URL: https://pubs.usgs.gov/periodicals/mcs2025/mcs2025-nickel.pdf **[19.2]** Nickel Institute, 'About nickel' (nickelinstitute.org) - surveyed. Supports: stainless steel as nickel's dominant first use (~2/3+); nickel's battery-share growth documented by IEA [19.1]/BMI [19.5]. URLs: https://nickelinstitute.org/en/nickel-applications and https://nickelinstitute.org/media/j5mzl1uq/fs3_productionanduseofnickel_.pdf **[19.3]** Reuters, 'Chinese firms to invest nearly $7 bln in nickel in Indonesia', 2024-07-26 - surveyed (headline/deck). Supports: Chinese-firm-led Indonesian HPAL/smelter investment boom. URL: https://www.reuters.com/markets/commodities/chinese-firms-invest-nearly-7-bln-nickel-indonesia-2024-07-26/ **[19.4]** IUCN NL, 'The Nickel Trail: Nickel mining in Indonesia: rising profits, devastating destruction' (2025) - surveyed (report highlights; IUCN Netherlands Committee). Supports: Morowali ecosystem pressures; sulphide orebodies geologically constrained. URL: https://www.iucn.nl/files/2025-05/the-nickel-trail-iucn-nl-1-2.pdf **[19.5]** IEA Global Critical Minerals Outlook 2025 (same source as [17.2]) - surveyed. Supports: two-tier market framing, Western sulphide offtake interest, automaker contracting trend. URL: https://www.iea.org/reports/global-critical-minerals-outlook-2025

Chapter 20 — The Invisible Half

[20.1] Benchmark Mineral Intelligence anode-chain analysis — surveyed. Supports: ~74% China share of anode chain, <1% spherical graphite production outside China. URL: https://source.benchmarkminerals.com/ **[20.2]** MOFCOM/China Customs Announcement No. 39 of 2023, 'Export Control of Graphite Items', 2023-10-20 (effective 2023-12-01) - surveyed (announcement heading/date on mofcom.gov.cn; corroborated by Reuters 2023-10-20 and CSM coverage). URL: https://www.mofcom.gov.cn/zwgk/zcfb/art/2023/art_1ff40b9b64d345c4a02b059096c4f01b.html
[20.3] Surovtseva et al., 'Toward a Life Cycle Inventory for Graphite Production', J. Industrial Ecology (2022), doi.org/10.1111/jiec.13234 - surveyed (abstract). Supports: synthetic graphite production energy ~45.9 MJ/kg (~12.8 kWh/kg, within the chapter's 10-15 range); natural flake much lower; cost shares labelled approximate. URL: https://onlinelibrary.wiley.com/doi/10.1111/jiec.13234 **[20.4]** Same as [20.1] plus USGS graphite MCS — surveyed. Supports: China share of processed graphite and anode production. **[20.5]** Same as [20.2]. Supports: licensing-not-banning distinction as

statecraft instrument. **[20.6]** Sila press release, ‘Sila Unveils the Nation’s First Automotive-Scale Silicon Anode Plant’ (Moses Lake, WA), 2025-09-23 - surveyed (release headline). Supports: automotive-scale silicon anode production start; ‘added to the blend’ framing. URL: https://www.silanano.com/press/sila-unveils-the-nations-first-automotive-scale-silicon-anode-plant **[20.7]** Recycled-graphite literature - surveyed (abstracts): Wang et al. graphite-regeneration review (OSTI 2574996, osti.gov); regenerated spent graphite reaching 350.2 mAh/g at 0.1C after 100 cycles (PMC11355843). Supports: near-fresh recovery performance; flagged as laboratory-scale. URLs: https://www.osti.gov/biblio/2574996 and https://pmc.ncbi.nlm.nih.gov/articles/PMC11355843/

Chapter 21 — Iron and Phosphate

[21.1] Goodenough et al., LFP discovery papers (1996-97) + Nobel 2019 scientific background PDF — read (PDF sections). Supports: olivine structure, 3.4-3.5 V plateau, Padhi/Goodenough attribution. URL: https://www.nobelprize.org/uploads/2019/10/advanced-chemistryprize2019-2.pdf **[21.2]** IEA Global EV Outlook 2025 (chemistry-share data; same source as [15.6]) - surveyed. Supports: LFP’s rise to plurality/majority of EV installations, China-led then global. URL: https://www.iea.org/reports/global-ev-outlook-2025 **[21.3]** Reuters, ‘Tesla shifting to cheaper lithium iron batteries globally’, 2021-10-21 - surveyed (headline). Supports: Tesla standard-range global LFP shift. URL: https://www.reuters.com/business/autos-transportation/tesla-shifting-cheaper-lithium-iron-batteries-globally-2021-10-21/ **[21.4]** A123 Systems v. Hydro-Québec & UT Austin, 657 F. Supp. 2d 276 (D. Mass. 2009) - surveyed (case record via vLex; patent-defense and sublicense facts per SEC exhibit). China invalidation: Chinese IP-law coverage of the LFP patent invalidation case (iplawcn.com, 2012). Supports: 2006 US suit, sublicense to A123, Chinese makers shipping royalty-free after domestic invalidation proceedings. URLs: https://case-law.vlex.com/vid/a123-sys-v-hydro-896046530 and https://www.sec.gov/Archives/edgar/data/1342056/000095013409016863/f57045e10vk.htm and https://www.iplawcn.com/patent_judicial/2012/0409/630.html **[21.5]** Reuters, ‘CATL says mass production of M3P battery underway’, 2023-03-24 - surveyed (headline). Supports: manganese-doped LFP (M3P) commercialisation. URL: https://www.reuters.com/technology/chinas-catl-says-mass-production-m3p-battery-underway-2023-03-24/ **[21.6]** BNEF 2025 price survey chemistry detail — surveyed (highlights). Supports: LFP $81/kWh vs NCM $128/kWh pack averages; cathode-cost floor framing is this book’s synthesis, flagged as such. URL: https://about.bnef.com/

Chapter 22 — The Price Curve

[22.1] Ziegler & Trancik, Energy & Environmental Science (2021) — read (abstract and key figures). Supports: 1991-2019 ~97% real price decline, learning-rate framing. URL: https://doi.org/10.1039/D0EE02681F **[22.2]** BloombergNEF 2025 Lithium-Ion Battery Price Survey, BNEF release dated 2025-12-09 — read (full release text, fetched and quoted). Supports: $108/kWh average pack (−8% y/y, ‘despite rising metal prices’); stationary-storage PACKS $70/kWh (−45% y/y, lowest-priced segment for the first time); BEV packs $99 (second consecutive year sub-$100); LFP packs $81 / NMC packs $128; China packs $84 with North America 44% and Europe 56% higher; lowest observed CELL $36 and pack $50, for LFP batteries going into stationary storage (BNEF ‘New Record Lows for Battery Prices’ article, read). URLs: https://about.bnef.com/insights/clean-transport/lithium-ion-battery-pack-prices-fall-to-108-per-kilowatt-hour-despite-rising-metal-prices-bloombergnef/ and BNEF’s record-lows article. Prior editions verified from BNEF release passages: 2024 survey $115 (−20%, biggest drop since 2017); 2023 survey $139; 2020 survey $137 with 2010 above $1,100 (−89% real). **[22.3]** Ziegler & Trancik [22.1] + IEA commentary — read/surveyed. Supports: forecasts-consistently-too-pessimistic claim; mechanism-vs-destiny framing is this book’s own, unlabeled external source.

Chapter 23 — The Giants

[23.1] SNE Research 2024 full-year press release — read (release passages). Supports: 894.4 GWh global EV battery usage 2024 (+27.2% y/y); K-trio (LG Energy Solution, SK On, Samsung SDI) combined 18.4% (−4.7pp y/y); LG 3rd at 96.3 GWh, SK On 5th at 39.0 GWh, Samsung SDI 29.6 GWh (−10.6%). CATL 37.9% and BYD 17.2% via cnevpost summary of the same SNE release (headline and highlights). URLs: SNE Research press release (sneresearch.com) and https://cnevpost.com/2025/02/11/global-ev-battery-market-share-2024/ **[23.2]** CATL 2024 Annual Report — read (key financial pages). Supports: revenue ¥362.0B, net profit ¥50.7B, capacity/utilisation narrative. URL: https://www.catl.com/en/investor/ **[23.3]** Reuters, 'US energy storage boom may ride on LFP', 2025-05-21 - surveyed (headline). Supports: storage-sector LFP pivot under tariff pressure; India's LFP adoption trajectory per IEEFA [25.3]. URL: https://www.reuters.com/business/energy/us-energy-storage-boom-may-ride-lithium-iron-phosphate-battery-cells-2025-05-21/ **[23.4]** GM investor release, 'General Motors and LG Chem Team Up to Advance Toward an All-Electric Future' (Ultium Cells JV, Dec 2019) - surveyed (release). Other JVs (Ford-SK, Stellantis-Samsung, Toyota-Panasonic) per company announcements of record, flagged as surveyed. Supports: JV map and mixed ramp record (cross-referenced to [12.4] recall economics and [15.6] capacity data). URL: https://investor.gm.com/news-releases/news-release-details/general-motors-and-lg-chem-team-advance-toward-all-electric/ **[23.5]** BYD vertical-integration reporting (cells-to-ships) + SNE [23.1] — surveyed. Supports: 17.2% 2024 share, integration depth, price-war advantage framing.

Chapter 24 — The Machine Tool

[24.1] Lead Intelligent Equipment turnkey-solutions pages (leadintelligent.com: 'turnkey solutions for lithium-ion EV battery, energy storage battery, 3C battery'; company described as world's largest turnkey provider, 100+ production lines delivered) - surveyed (site copy). Supports: one-vendor turnkey line pattern. URL: https://www.leadintelligent.com/en/battery-solution/lithium-battery-turnkey-solutions/ **[24.2]** Same as [24.1] plus Western gigafactory equipment-procurement reporting — surveyed. Supports: Western plants buying Chinese turnkey lines. **[24.3]** Same as [24.1]. Supports: Wuxi concentration claim ("the coaters of Wuxi" is this book's phrasing, sourced to Lead Intelligent's home city — verified via company profile, surveyed). **[24.4]** Inferred — knowledge-migration-via-equipment synthesis across [6.4], [15.6], [16.4] and [24.1]; flagged as interpretation. **[24.5]** Reuters, 'Tesla 4680 battery's secret sauce: Dry electrode coating', 2023-03-10 - surveyed. Supports: dry-coating removes solvent/drying step; Maxwell lineage; deployment difficulty. Complemented by Tesla Battery Day deck [14.1]. URL: https://www.reuters.com/technology/tesla-4680-batterys-secret-sauce-dry-electrode-coating-2023-03-10/

Source Ledger — Chapters 25-32

Chapter 25 — Batteries as Statecraft

[25.1] Two named instruments, both read on mofcom.gov.cn: (1) MOFCOM/China Customs Announcement No. 39 of 2023, 'Export Control of Graphite Items' (2023-10-20, effective 2023-12-01) - read (announcement scope; same source as [20.2]). URL: https://www.mofcom.gov.cn/zwgk/zcfb/art/2023/art_1ff40b9b64d345c4a02b059096c4f01b.html (2) MOFCOM/MOST Announcement No. 28 of 2025 adjusting the Catalogue of Technologies Prohibited and Restricted from Export - read (catalogue entries): adds battery cathode-material preparation technology (item 252604X: LFP preparation, LMFP preparation, phosphate cathode raw-material processes) and spodumene lithium-extraction technology to the restricted list. URL: https://www.mofcom.gov.cn/zcfb/zgdwjjmywg/art/2025/art_67e2a41850ec428eb1b7be6ec2f2bded.htm

plus spokesperson Q&A 2025-07-15: https://www.mofcom.gov.cn/xwfb/xwfyrth/art/2025/art_2c9b4a1e22e74916a4962f1039b1c61d.html Supports: instrument dates, scope, licensing-not-embargo design. **[25.2]** US Inflation Reduction Act text/summaries (production tax credit 45X; FEOC content rules); EU Battery Regulation 2023/1542 (EUR-Lex summary) — surveyed/read (EUR-Lex summary read). Supports: per-kWh production credits, content rules, EU carbon-declaration and due-diligence duties. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R1542 **[25.3]** IEA Global Critical Minerals Outlook 2025 processing-share data (same source as [17.2]) - surveyed. Supports: two-thirds-to-nine-tenths China processing shares by stage. URL: https://www.iea.org/reports/global-critical-minerals-outlook-2025 **[25.4]** BNEF 2025 survey [22.2] + overcapacity reporting — read (release text). Supports: efficiency-objection framing (storage PACKS at $70 — scope corrected during verification), stated as this book's analytical balance.

Chapter 26 — The Car Remade

[26.1] Rho Motion 2025 full-year EV sales release, 2026-01-14 (carried on Benchmark Mineral Intelligence's site) — read (release passages). Supports: 20.7M global EV sales 2025 (+20%), China 12.9M (+17%), Europe 4.3M (+33%), North America 1.8M (−4%), RoW 1.7M (+48%); US +1% after federal tax-credit elimination on 2025-09-30. URL: https://source.benchmarkminerals.com/article/global-ev-sales-reach-20-7-million-units-in-2025-growing-by-20 **[26.2]** IEA Global EV Outlook 2025 — surveyed. Supports: EV share of new-car sales trajectory, policy drivers. URL: https://www.iea.org/reports/global-ev-outlook-2025 **[26.3]** Gasgoo Auto News, 'BYD launches CTB technology, starts presale of BYD Seal' - surveyed; Tesla structural-pack intent per the Battery Day deck [14.1]. Supports: floor-first design inversion, cell-to-body engineering. URL: https://autonews.gasgoo.com/articles/news/byd-launches-ctb-technology-starts-presale-of-byd-seal-70020398 **[26.4]** CATL news, 'CATL Launches Second-Generation Shenxing, Naxtra…' (2025-04-21, catl.com/en/news/6401.html): peak 12C charging; Reuters, 'BYD unveils new super-charging EV tech', 2025-03-17: megawatt-class flash charging. - surveyed (headlines). 350 kW highway stations are Ionity's public spec; 2C-3C consumer-pack typical, flagged as range. URLs: https://www.catl.com/en/news/6401.html and https://www.reuters.com/business/autos-transportation/chinas-byd-unveils-faster-charging-ev-platform-aims-build-over-4000-charging-2025-03-17/ **[26.5]** Shenzhen full electric-bus conversion documented by WRI, "How Did Shenzhen, China Build World's Largest Electric Bus Fleet?" (wri.org) — surveyed; two/three-wheeler volumes cross-checked with [31.4] PIB data for India. Supports: fleet-first electrification sequence. URL: https://www.wri.org/insights/how-did-shenzhen-china-build-worlds-largest-electric-bus-fleet **[26.6]** IEA Global EV Outlook editions (oil-displacement estimates; same source as [15.6]) - surveyed. Supports: >1 million barrels/day avoided by EVs (stated conservatively as 'well over' in text). URL: https://www.iea.org/reports/global-ev-outlook-2025 **[26.7]** Inferred — flow-to-stock substitution framing is this book's synthesis of [26.1], [26.2] and [27.1].

Chapter 27 — The Grid Learns to Store

[27.1] IEA, "Batteries and Secure Energy Transitions" (2024) — surveyed. Supports: storage's grid role, deployment trajectory framing. URL: https://www.iea.org/reports/batteries-and-secure-energy-transitions **[27.2]** Same as [27.1]. **[27.3]** BNEF 2025 survey release [22.2] — read (release text). Supports: $70/kWh stationary-storage PACKS (cell-vs-pack scope corrected during verification: BNEF's figure is packs). **[27.4]** Volta Foundation Battery Report 2024, p.138 — read (page passages). Supports: 69 GW / 169 GWh new BESS installed in 2024, cumulative 150 GW / 363 GWh, Li-ion >98% of installations. Corroborated by BNEF storage-outlook article (76% jump to 69 GW/169 GWh, read). URLs: https://annualbatteryreport.org/battery-report/2024/138 and

https://about.bnef.com/insights/clean-energy/headwinds-in-largest-energy-storage-markets-wont-deter-growth/ **[27.5]** NREL, 'Research Roadmap on Grid-Forming Inverters' - surveyed (roadmap summary). Supports: synthetic inertia, mid-2020s specification adoption. URL: https://research-hub.nrel.gov/en/publications/research-roadmap-on-grid-forming-inverters/ **[27.6]** CAISO '2025 Special Report on Battery Storage' (Oct 2026) + California Energy Commission release, 'California surpasses 21,000 megawatts of battery resources' - surveyed (report/release). Supports: >10 GW California fleet claim (well exceeded: 21 GW by 2026); Australia/China pairing mandates per policy reporting, flagged as surveyed. URLs: https://www.caiso.com/documents/2025-special-report-on-battery-storage-oct-28-2026.pdf and https://www.energy.ca.gov/news/2026-08/california-surpasses-21000-megawatts-battery-resources-supporting-states **[27.7]** LDES Council, 'Towards a more efficient and cost-effective electricity system: 2025 benchmarking update' (ldescouncil.com) - surveyed (report page). Supports: long-duration cost competitiveness benchmarks vs lithium-ion beyond ~8h. URL: https://www.ldescouncil.com/assets/pdf/241104_Final%20LDES%20Benchmarking%20Report%20Sum

Chapter 28 — Ten Billion Small Suns

[28.1] EVTank/China YiWei Institute, 'A Report on China Cylindrical Battery Industry Development (2025)' (via electrification-solutions.com coverage): 5.9 billion 18650 cells shipped in 2024 alone, 46% of cylindrical shipments - surveyed (report coverage). Supports: consumer cells 'ship by the billion'; tool/drone household penetration flagged approximate. URL: https://electrification-solutions.com/18650-cylindrical-batteries-dominate-46-market-share-chinese-firms-rise-in-global-rankings/ **[28.2]** Same as [28.1]. **[28.3]** GSMArena, 'Honor details Magic 6 Pro's second-generation silicon-carbon battery' - surveyed. Supports: consumer-first chemistry migration (silicon-carbon anodes, higher-voltage cathodes, stacked pouches in premium phones). URL: https://www.gsmarena.com/honor_details_its_secondgeneration_siliconcarbon_battery_with_standalon news-61437.php **[28.4]** Electronic Specifier, 'Further, higher, longer: how batteries are driving growth in the drone market' - surveyed. Supports: drone battery performance requirements; 'briefcase delivery drones' direction; lawn equipment electrification documented in consumer-press coverage, flagged approximate. URL: https://www.electronicspecifier.com/industries/aerospace-defence/further-higher-longer-how-batteries-are-driving-growth-in-the-drone-market/ **[28.5]** GOGLA/Lighting Global 'Off-Grid Solar Market Trends Report 2024' (via ESMAP/Sun-News coverage): 685 million without electricity access; off-grid solar kits now the plurality approach - surveyed (report coverage). Supports: pico-solar kits scale and role. URLs: https://www.gogla.org/reports/ and https://documents1.worldbank.org/curated/en/099052924182541245/pdf/P177382-5ae77034-4468-451e-9a74-bb7e9b6653f1.pdf

Chapter 29 — Second Life and the Grave

[29.1] EU Battery Regulation 2023/1542 (EUR-Lex summary) — read (summary text). Supports: recovery targets (lithium 50% by 2027/80% by 2031 per regulation's lithium-recovery trajectory — stated in text as targets with dates), recycled-content minimums from 2031, due-diligence/passport provisions. URL: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023R1542 **[29.2]** Benchmark Mineral Intelligence, 'Western battery recycling scrap pool to account for more than a third of global supply by 2035', 2024-07-24 - surveyed (article text). Supports: scrap-pool share rising toward a third by 2035 (labelled forecast in text). URL: https://source.benchmarkminerals.com/article/western-battery-recycling-scrap-pool-to-account-for-more-than-a-third-of-global-supply-by-2035 **[29.3]** Second-life economics analysis + BNEF storage-cell pricing [22.2] — surveyed. Supports: new-cell price pressure on second-life margins; stated as

industry assessment. **[29.4]** Hydrometallurgy/pyrometallurgy process reviews + EU regulation [29.1] — surveyed/read. Supports: black-mass chain, lithium-last recovery difficulty, EU recovery targets. Note: chapter text corrected during production to the regulation's actual lithium figures (50% by end-2027, 80% by end-2031); an earlier draft's 27% figure was wrong and has been replaced. **[29.5]** 'Toward Direct Regeneration of Spent Lithium-Ion Batteries: A Next-Generation Recycling Method,' Chemical Reviews (2024) - surveyed (abstract). Supports: direct-recycling pilot-to-industrial threshold status. URL: https://pubs.acs.org/doi/10.1021/acs.chemrev.3c00884 **[29.6]** Benchmark scrap-pool projection [29.2] + IEA Critical Minerals Outlook 2025 recycling annex - surveyed. Supports: 2030s retirement wave, mid-century majority-recovery framing (labelled projection). URLs: https://source.benchmarkminerals.com/article/western-battery-recycling-scrap-pool-to-account-for-more-than-a-third-of-global-supply-by-2035 and https://www.iea.org/reports/global-critical-minerals-outlook-2025 **[29.7]** Redwood Materials process page — read; Li-Cycle acquisition by Glencore (Aug 2025) via newswire.ca + glencore.com releases — surveyed. Supports: recycling-industry turbulence (Li-Cycle collapse/rescue) and Redwood's process description. URLs: https://www.redwoodmaterials.com/ ; https://www.glencore.com/

Chapter 30 — What Comes Next

[30.1] EVModelCompare, 'Solid-state batteries: where each programme really is' (status page) - surveyed. Supports: multi-manufacturer pilot-line stage map. URL: https://evmodelcompare.com/battery/solid-state/ **[30.2]** Toyota/Idemitsu joint release, 'Beginning of Cooperation toward Mass Production of All-Solid-State Batteries for BEVs' (global.toyota) - surveyed (release). Supports: sulphide-electrolyte programme lead; Samsung SDI's 2027 target per its public statements, flagged as surveyed. URL: https://global.toyota/en/newsroom/corporate/39865919.html **[30.3]** Same as [30.1]/[30.2]; electrolyte-family trade-offs synthesized, flagged as survey-level. **[30.4]** Honda news release, 'Honda Unveils Demonstration Production Line for All-Solid-State Batteries' (Nov 2024) + Nissan news release, 'Nissan shows in-construction all-solid-state battery pilot line in Japan' - surveyed (releases). Supports: stage migration lab-to-demo-to-pilot; Chinese semi-solid shipments per [30.1] status page. URLs: https://global.honda/en/newsroom/news/2024/c241121eng.html and https://global.nissannews.com/en/releases/nissan-shows-in-construction-all-solid-state-battery-pilot-line-in-japan **[30.5]** CATL Naxtra launch, Reuters 2025-04-21 — read (Reuters article). Supports: 175 Wh/kg, December 2025 mass production, starter-battery/commercial-vehicle first applications. URL: https://www.reuters.com/business/autos-transportation/ **[30.6]** 'Critically assessing sodium-ion technology roadmaps and scenarios for techno-economic competitiveness against lithium-ion batteries,' Nature Energy (2024) - surveyed (abstract). Supports: hedge-not-killer framing; lithium-price sensitivity of the sodium case. URL: https://www.nature.com/articles/s41560-024-01701-9 **[30.7]** 'Post-Li batteries: promises and challenges,' Phil. Trans. R. Soc. A (2019) - surveyed (review abstract). Supports: horizon-scan claims on Li-S, Li-air, Mg/Ca; explicitly hedged in text. URL: https://royalsocietypublishing.org/doi/10.1098/rsta.2018.0297

Chapter 31 — The Indian Hour

[31.1] PIB release, PLI-ACC scheme status (PRID 2202973) — read (release text). Supports: scheme structure, ₹18,100 crore, 50 GWh target, awarded-capacity status. URL: https://pib.gov.in/PressReleasePage.aspx?PRID=2202973 **[31.2]** Same as [31.1] plus commissioned-capacity reporting — read/surveyed. Supports: award-vs-commissioning gap; stated as status at time of writing. **[31.3]** PIB release, Reasi lithium find (PRID 1944302) — read. Supports: 5.9 Mt inferred lithium resources, Jammu & Kashmir, early-exploration caveat. URL: https://pib.gov.in/PressReleasePage.aspx?PRID=1944302 **[31.4]** PIB release, FY25 electric two-

wheeler sales (PRID 2117485) — read. Supports: 1,149,334 units, +21% YoY. URL: https://pib.gov.in/PressReleasePage.aspx?PRID=2117485 **[31.5]** KABIL-CAMYEN agreement, mines.gov.in + PIB (PRID 1996380), 2024-01-15 — read. Supports: Argentina lithium blocks, exploration + offtake structure; subsequent KABIL activity via ministry releases, surveyed. URL: https://www.mines.gov.in/ **[31.6]** Moneycontrol, 'India's critical mineral trade is up 10x in ten years: MC Analysis' - read (article figures). Supports: $4.93B critical-mineral imports FY24 (from $475M FY15); battery packs 68% of critical-mineral imports FY24; China 72.8% share of battery-pack imports FY24 (up from 56.3% FY20). URL: https://www.moneycontrol.com/news/business/economy/indias-critical-mineral-trade-is-up-10x-in-ten-years-mc-analysis-12846974.html **[31.7]** Ministry of Environment, Forest and Climate Change, Battery Waste Management Rules 2022 (notified 24 Aug 2022; PIB release PRID 1854433) — surveyed (PIB release "Government notifies Battery Waste Management Rules, 2022"). Supports: formalisation framing. URL: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1854433 **[31.8]** Inferred — "Indian hour" strategic synthesis is this book's own reading of [31.2]-[31.7].

Chapter 32 — The Hinge

Closing essay: no external claims beyond those sourced in Chapters 1-31; cross-references are internal. No separate ledger entries required.

Source Ledger — Supplement (Chapters 1-12, expansion tags)

Entries for tags introduced in the depth-expansion pass. Read-status key as in 13-18.md.

[2.4] Ziegler & Trancik EES 2021 [22.1] + cell-energy-density histories — read/surveyed. Supports: 1991 cell ~80 Wh/kg / 200 Wh/L, >250 Wh/kg / >700 Wh/L late-2010s best cells. **[2.5]** CATL news, 'CATL Launches Second-Generation Shenxing…' (2025-04-21): 'world's first LFP battery with 800 km range and peak 12C charging rate'; GaAs multi-junction 47.6% record per NREL chart [2.2] - surveyed (headline; full cell chemistry N/A). URL: https://www.catl.com/en/news/6401.html **[2.6]** 'Lithium Thionyl Chloride Primary Battery: Technology, Applications & Market Review' (SDLE/Tadiran technical review PDF) + Powerstream primary-lithium selection page - surveyed. Supports: primary-empire framing, Li-SOCl2 metering, Li-MnO2 coin cells, Li-FeS2 AA, shelf-life claims. URLs: https://www.sdle.co.il/wp-content/uploads/2019/12/35-Lithium-Thionyl-Chloride-Primary-Battery-Technology-Applications-_-Market-Review-version-3.pdf and https://www.powerstream.com/Pli.htm **[3.3]** GM Heritage Center, '1912 Cadillac Model 30' (gm.com heritage collection): electric self-starter debut - surveyed (collection page). Starter-motor lead-acid timeline consistent with standard automotive histories. URL: https://www.gm.com/heritage/collection/cadillac/1912-cadillac-model-30 **[3.4]** Green Car Reports, 'Lithium-ion vs. nickel-metal hydride: Toyota still likes both for its hybrids' - surveyed. Supports: NiMH's hybrid afterlife (Prius usage into the 2020s) and patent-encumbrance framing. URL: https://www.greencarreports.com/news/1120320_lithium-ion-vs-nickel-metal-hydride-toyota-still-likes-both-for-its-hybrids **[4.4]** M. S. Whittingham, 'Storylines in intercalation chemistry,' Dalton Transactions (2014) - surveyed (review abstract). Supports: graphite intercalation history (Rudorff 1965 lineage), pre-Exxon pedigree. URL: https://doi.org/10.1039/c4dt00203b **[7.5]** Barnhart & Benson, 'Hydrogen or batteries for grid storage? A net energy analysis,' Energy & Environmental Science (2015) - surveyed (abstract/results); DOE Energy Storage Handbook Ch. 11 (Hydrogen) - surveyed. Supports: battery round-trip ~90%+ vs hydrogen power-to-power ~30-40%; figures stated as approximate in text. URLs: https://pubs.rsc.org/en/content/articlehtml/2015/ee/c4ee04041d and https://www.sandia.gov/app/uploads/sites/163/2022/03/ESHB_Ch11_Hydrogen_Headley.pdf **[8.4]**

‘Designing Advanced Electrolytes for High-Voltage LiCoO2’, ACS Energy Letters 2024, 9(1), 262 - surveyed (abstract). Supports: high-voltage LCO electrolyte engineering as active research direction; carbonates’ ~4.3 V ceiling per [8.1]. URL: https://pubs.acs.org/doi/10.1021/acsenergylett.3c02145 **[9.4]** ‘Advances in single-crystal nickel-rich ternary cathode materials for lithium-ion batteries’, Frontiers in Batteries and Electrochemistry (2024) - surveyed (review abstract). Supports: single-crystal Ni-rich research direction and performance case. URL: https://www.frontiersin.org/journals/batteries-and-electrochemistry/articles/10.3389/fbael.2024.1338069/full **[9.5]** Silicon-blend anode reporting [20.6] — surveyed. Supports: single-digit silicon blends, roadmap framing. **[10.6]** Cost model PMC11532491 [13.3] — read. Supports: anode cost position and graphitisation electricity intensity framing. **[11.4]** Celgard base-films page: trilayer PP/PE/PP product family, membrane-shutdown feature; THERMOFILM tri-layer tape - surveyed (site copy). Supports: PP/PE/PP sandwich with shutdown PE core; shutdown ~130 C and melt ~165 C are published values for PE/PP, flagged as approximate ranges. URL: https://www.celgard.com/base-films/ **[11.6]** Cost model PMC11532491 [13.3] — read. Supports: quiet-components’ aggregate cost share (~a third of bill of materials, stated approximately). **[12.6]** NFPA 855, Standard for the Installation of Stationary Energy Storage Systems (2026 edition page) - surveyed. Supports: spacing rules and the fire-code response; containerisation/deflagration design trend and LFP grid preference per [23.3] and the Moss Landing record [12.5]. URL: https://www.nfpa.org/product/nfpa-855-standard/p0855code **[8.3]** ‘Degradation Processes in Current Commercialized Li-Ion Batteries and Strategies to Mitigate Them,’ Annual Review of Materials Research (2024) - surveyed (abstract). Supports: SEI growth, cathode surface reconstruction, particle cracking, graphite ~10% breathing, silicon ~300% swelling (also [10.2]). URL: https://www.annualreviews.org/content/journals/10.1146/annurev-matsci-080522-104112