

China's Massive Investment into Cleantech R&D and Manufacturing is Catalysing the Global Energy Transition

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10 years ago, President Xi Jinping delivered a speech outlining that developing a New Energy Vehicle (NEV) industry was the only way for China to become a global automobile manufacturing powerhouse.¹ This speech marked the pivotal moment of China's trajectory in developing its new energy industry. Fast forward a decade, through strategic industry and energy policy, and a core focus on research and development (R&D), China has become the largest NEV manufacturer in the world, and in 2023, overtook Japan as the world's largest auto exporter.²

In 2023, energy transition investment reached a new record of ~ US\$1.8 trillion (A\$2.7 trillion) globally, surging 17% from the year prior. 2023 marked the 10th consecutive year of positive clean energy investment growth, with a compound annual growth rate of 24% since 2013.³ China's energy transition investment is world-leading, with US\$676bn (A\$1.0 trillion), or ~38%, of all global investment directed into cleantech manufacturing, renewable energy generation capacity, batteries and EVs.

Over the last decade, solar manufacturing globally has increased 10-fold to meet the increasing demand for clean energy. Investment into new solar manufacturing is set to raise global module manufacturing capacity from 640 GW in 2022, to over 1,200 GW by 2025.⁴ Despite falling factory utilisation rates across China, investment into solar and cleantech manufacturing continued to grow more than 70% in 2023 to US\$200bn (A\$301bn), accounting for ~ 4% of global GDP growth.⁵

With China leading the world across all cleantech supply chains, Chinese solar manufacturers have shifted to exporting a significant volume of market-leading modules, resulting in incredible price deflation across the value chain, catalysing the green energy transition and uptake of renewables globally in developed and emerging economies. Across the Chinese solar industry in 2023, polysilicon prices fell 66% to 65 RMB/kg (A\$13/kg), alongside a 50% drop in

¹ 新华网, [习近平:发展新能源汽车是迈向汽车强国的必由之路](#), 24 April 2014

² Reuters, [China's EV Export Boom Fuels Surge in Demand for New Car-Carrying Ships](#), 10 April 2024

³ BNEF, [Global Clean Energy Investment Jumps 17%, Hits \\$1.8 Trillion in 2023](#), 30 January 2024

⁴ IEA, [World Energy Outlook 2023](#), 24 October 2023

⁵ IEA, [Surging Investment in Manufacturing of Clean Energy Technologies is Supporting Economic Growth](#), 06 May 2024

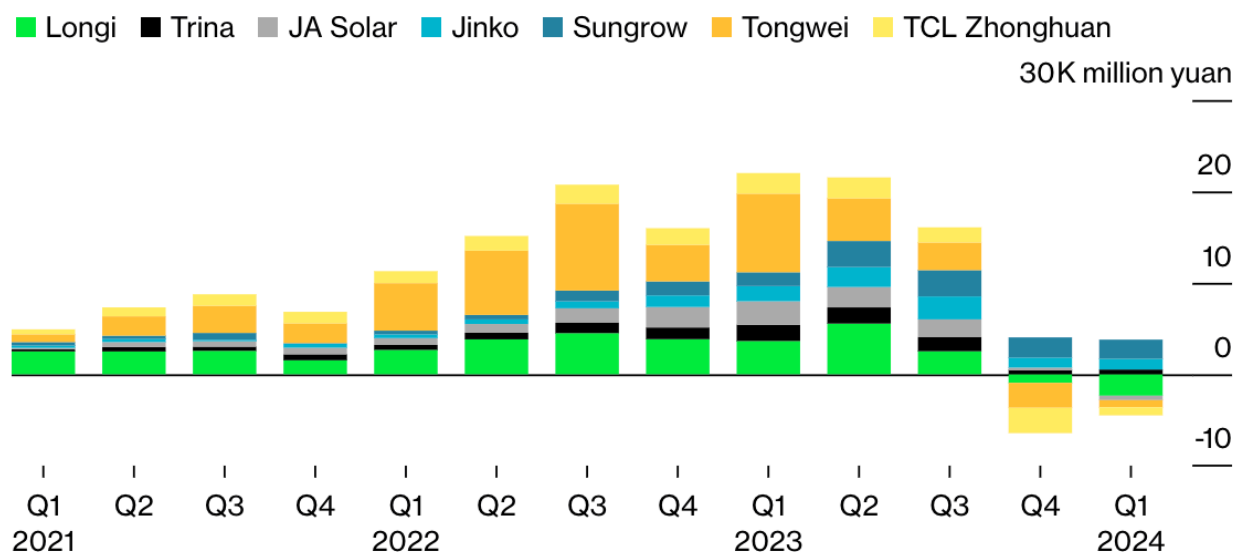
mono-wafers, 55% in mono-cell prices, and mono-module prices down 50% to under 1 RMB/W (A\$0.21/W) for P-PERC bifacial modules.⁶

Coupled with China’s massive capital allocation is continued innovation and R&D, which has led to incredible advancements in solar cell and module efficiencies, the economics of global deployment of rooftop and utility-scale solar PV have improved dramatically in recent years.

Since 2016, Perovskite/silicon Hybrid Tandem solar cells have improved from 23.6% efficiency to LONGi’s 33.9% record cell efficiency reached in November 2023. Thin-film CIGS cells have improved from a 5.9% efficiency in 1976 to 23.6% in 2023 from Sweden’s Evolar, which was acquired by First Solar in May 2023. HIT crystalline silicon cell efficiency reached 27.1% in 2023, led by LONGi, up from 21.2% in 2001.⁷

As prices continue to fall into 2024 across the solar value chain, Chinese, and thus, the world leaders, are continuing to invest into new capacity and R&D to further improve the quality and efficiency of solar cells and modules. Despite profitability reducing significantly over the last 12 months, as highlighted in Figure 1, capex and research spending is continuing to grow at a world-leading pace, and Prof Martin Green and Prof Renata Egan of UNSW are confident solar cell efficiencies can be improved another 20-30% over the coming decade, or more.

Figure 1: Shrinking Solar Profits as Manufacturers Slash Margins



Source: Bloomberg⁸

GoldWind Science & Technology (Goldwind)

GoldWind is the world’s largest wind turbine original equipment manufacturer (OEM), with a record 16.3 GW of capacity installed in 2023, maintaining its leading position for the second

⁶ LONGi, [LONGi Green Energy 2023 and 2024Q1 Results Investor Presentation](#), 30 April 2024

⁷ NREL, [Photovoltaic Research: Interactive Best Research-Cell Efficiency Chart](#)

⁸ Bloomberg, [China’s Solar Panel Giants Say Prices are Near the Bottom](#), 07 May 2024

consecutive year.⁹ GoldWind now has 8 R&D centers across China, Germany and Denmark, employing more than 3,000 R&D staff globally.

In 2023, Goldwind generated RMB 50.2bn (A\$10.4bn) in revenue across its consolidated operations, up 8.6% from 2022, with wind turbine generator manufacturing accounting for RMB 40.2bn (A\$8.4bn) of the group's revenue, up 10.3%. Goldwind invested RMB 1.9bn (A\$395m) into R&D over 2023, growing 19% from the year prior, reflecting a 3.8% share of revenue. Goldwind expanded its capital allocation to R&D in 2023, with 2022 R&D representing 3.4% of revenue.¹⁰

In 2023, GoldWind realised a NPAT of RMB 1.5bn (A\$312m) down 37.5% from 2022. Goldwind's R&D to net profit ratio was 1.24:1 in 2023. Goldwind is yet another example of a new energy industry global leader that has demonstrated its priority to long-term development over short-term financial gain, investing more capital in R&D than its net profit in 2023.

LONGi Green Energy Technology (Longi)

Longi is a global leader in cleantech manufacturing, with capabilities across supply chains of solar PV, batteries, and hydrogen energy equipment. In 2023, Longi achieved shipments of 125.4 GW of monocrystalline silicon wafers, external sales of 5.9 GW of monocrystalline cells, and shipments of 67.5 GW of monocrystalline modules.¹¹

As of the beginning of 2024, Longi's R&D division employed 5,157 R&D personnel, making up 6.9% of its total workforce. In 2023, Longi invested RMB 2.3bn (A\$478m) in R&D,¹² representing 1.8% of Longi's total revenue of RMB 129.5bn (A\$26.9bn). Longi realised a NPAT of RMB 10.8bn (A\$2.2bn) in 2023, translating to a R&D to net profit ratio of 0.21:1.

Longi's investment into R&D has resulted in several world records in cell efficiencies across multiple solar PV technologies. In December 2023, Longi's crystalline silicon heterojunction back-contact (HBC) solar cells achieved a new record of 27.09% efficiency, beating the previous record of 26.81% in November 2023, also developed by Longi.¹³ In November 2023, Longi's crystalline silicon-perovskite tandem cells achieved a new record of 33.9% efficiency, beating the previous record of 33.7% achieved in May 2023.¹⁴

In addition to being one of the largest solar manufacturers in the world, Longi's subsidiary, LONGi Hydrogen Technology (Xi'an) Co., Ltd. (LONGi Hydrogen), is a leader in developing green hydrogen technologies. As of the beginning of 2024, LONGi Hydrogen has installed a total 2.5 GW of alkaline electrolyser capacity.

⁹ Wood Mackenzie, [China Leads Global Wind Turbine Manufacturers' Market Share in 2023](#), 01 May 2024

¹⁰ Goldwind, [Annual Report 2023](#), 25 April 2024

¹¹ Longi, [2023 Annual Report: LONGi Maintains Robust Financial Condition and Strong Risk Resistance Capabilities](#), 30 April 2024

¹² 隆基绿能, [隆基绿能科技股份有限公司2023 年年度报告](#), 30 April 2024

¹³ Longi, [LONGi Sets a New World Record of 27.09% for the Efficiency of Silicon Heterojunction Back-Contact \(HBC\) Solar Cells](#), 19 December 2023

¹⁴ Longi, [LONGi Sets a New World Record of 33.9% for the Efficiency of Crystalline Silicon-Perovskite Tandem Solar Cells](#), 03 November 2023

LONGi Hydrogen played a critical role in China's first 10,000-tonne green hydrogen demonstration project, now in full production.¹⁵ The project can produce 20,000 tonnes of green hydrogen annually, supplied to Sinopec Refining and Chemical Company to replace the methane gas used in oil refining and processing, reducing the emissions associated with the firm's energy demand.

Sungrow Power Supply (Sungrow)

Sungrow is an internationally recognized cleantech manufacturer, specialising in the R&D, production, and service of new energy power equipment, including solar PV, wind, energy storage, and EVs. In 2023, Sungrow's global shipments of solar PV inverters reached 130 GW, and battery storage shipments of 10.5 GWh.¹⁶

As at the beginning of 2024, Sungrow employs a total of 5,327 R&D personnel, expanding 47% from the year prior, representing a significant 39.2% of its total workforce. In 2023, Sungrow demonstrated its commitment to innovation by investing RMB 2.4bn (A\$499m) in R&D, equivalent to 3.4% of its total revenue of RMB 72.3bn (A\$15.2bn). Sungrow realised a NPAT of RMB 9.4bn (A\$2.0bn) in 2023, achieving an R&D to net profit ratio of 0.26:1.

Sungrow's dedication to advancing technology is evident in its allocation of resources, with 25.9% of its NPAT being channeled into R&D activities during FY2023. This strategic investment underscores Sungrow's commitment to driving innovation and maintaining its position as a world leading manufacturer and developer of solar PV inverters and solar storage technologies.

Jinko Solar (Jinko)

Jinko is one of the world's largest solar PV module manufacturers, shipping 78.5 GW in 2023, up 68% from the year prior, generating RMB 118.7bn (A\$24.7bn) in revenue (+44%).¹⁷ In 2023, Jinko invested RMB 6.9bn (A\$1.4bn) into R&D, up 23% from 2022, and representing 5.8% of revenue. Although R&D spending increased, capital allocation was down from 6.79% in 2022.¹⁸

Jinko realised a NPAT of RMB 7.4bn (A\$1.5bn) in 2023, translating to an R&D to net profit ratio of 0.93:1, investing 93 cents on every dollar of net earnings into expanding its R&D capabilities.¹⁹ Jinko's R&D division now employs over 2,300 researchers, and now has more than 2,000 authorised patents across a range of high-efficiency solar cell and module technologies.

¹⁵ 隆基绿能, [隆基氢能助力我国首个万吨级绿氢示范项目全面投产](#), 30 August 2024

¹⁶ 阳光电源, [阳光电源股份有限公司2023年年度报告](#), 23 April 2024

¹⁷ Jinko, [4Q2023 Earnings Call Presentation](#), 20 March 2024

¹⁸ 晶科能源, [晶科能源股份有限公司2023年年度报告](#), 23 April 2024

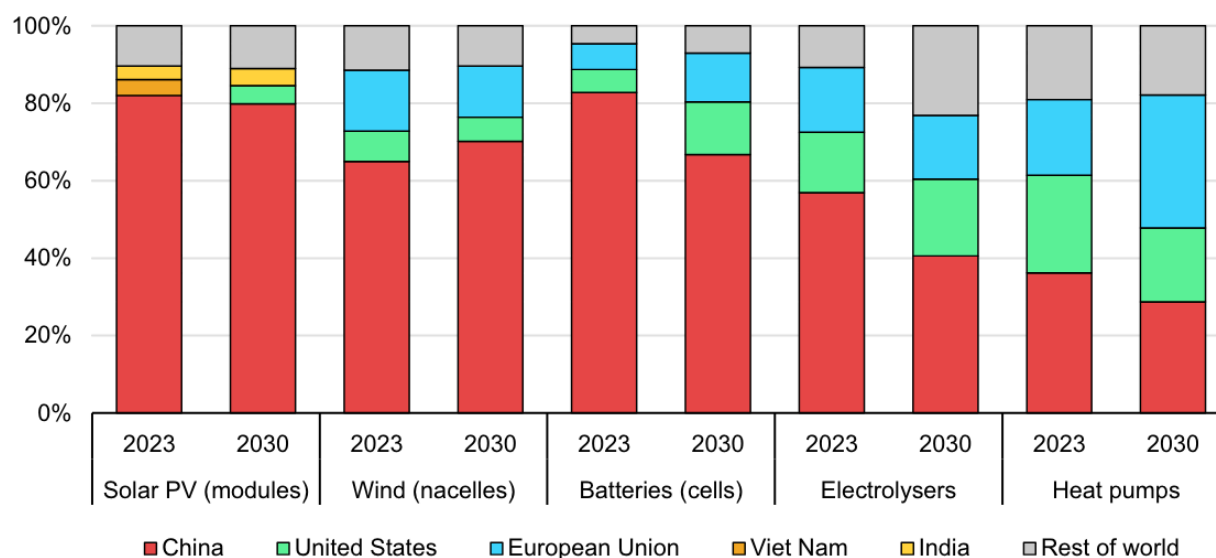
¹⁹ 晶科能源, [晶科能源股份有限公司2023年年度报告](#), 23 April 2024

EVs and Stationary Battery Storage

The case for batteries is equally impressive. As with most modular technologies, the greater manufacturing capacity that comes online, the cheaper they become, fuelling more demand, which in turn spurs further investment into manufacturing and innovation, creating a domino effect that has led to astonishing results in price deflation and energy density. Over the past 3 decades, battery prices have fallen 99%, falling over 82% in the last 10 years alone. In the same time, battery densities have risen 5-fold. Battery prices have fallen 19%, and energy density has improved 7%, for every doubling of capacity.²⁰

Clean energy manufacturing investment is dominated by solar and batteries, accounting for 95% of total capital expenditure (capex) in 2023, with China accounting for 75% of global investment. China is investing to maintain its position as a dominant world leader in clean energy manufacturing, with only a small shift in the IEA's forecast of market share in key technologies of solar, wind and batteries by 2030, as highlighted in Figure 2.

Figure 2: Current and Announced Manufacturing Capacity Concentration



Source: International Energy Agency ²¹

2024 has shown China's corporate leaders are continuing the incredible growth that we witnessed in 2023, and maintaining their market dominance. Over 2023, CATL, the world's largest manufacturer which was founded only 12 years ago, produced 259.7 GWh (+41%). BYD produced 111.4 GWh (+58%), for a combined market share of 53% globally for EV batteries.

Of the top 10 largest global battery manufacturers for EVs, 6 are Chinese firms. In 1QCY24, CATL produced 60.1 GWh of batteries for EVs, up 32% from 1QCY23. BYD produced 22.7 GWh over the same quarter, up 12% from the year prior. Combined, China's leaders of CATL

²⁰ RMI, [The Rise of Batteries in Six Charts and Not Too Many Numbers](#), 25 January 2024

²¹ IEA, [Advancing Clean Technology Manufacturing](#), 06 May 2024

and BYD produced 82.8 GWh in the first quarter of 2024, with a combined global market share of 52%²².

Contemporary Ampere Technology Ltd (CATL)

In 2023, CATL produced a total of 389 GWh across EVs and stationary storage, with 552 GWh of installed annual capacity, translating to a utilization rate of 70.5%. Despite being the no.1 producer of lithium-ion batteries globally, CATL is not slowing its development and expansion investments. In 2023, CATL had a further 100 GWh of capacity under construction.²³

CATL has maintained its market leadership through an impressive history of high capital allocation to R&D. In 2023, CATL invested RMB 18.4bn (A\$3.8bn), up 18% from 2022. R&D spend was 4.6% of total consolidated revenue in 2023. In 2022, CATL more than doubled its investment into R&D, exceeding RMB 15.5bn (A\$3.2bn), driven by incredible revenue growth from a rapidly expanding global production footprint and record EV sales in China, and globally.²⁴

Over 2023, CATL realised a NPAT of RMB 44.1bn (A\$9.2bn), which translated to an R&D to net profit ratio of 0.42:1. In 1QCY24, CATL invested RMB 4.3bn into R&D, or 5.4% of revenue over the quarter, an 18.7% higher ratio than in 2023.

In 2023, CATL's R&D personnel expanded by 26% to 20,604, accounting for a record 17.8% of employees. CATL employs over 360 Ph.D's, as well as over 3,900 employees with master's degrees. Higher-education employees were the largest growing group of CATL's employee network, expanding by ~ 37% in 2023. CATL has 6 R&D centres globally, one in Germany that operates alongside CATL's production bases in Germany and Hungary, and 5 R&D centres across China, operating with 11 production facilities.

On 25 April 2024, CATL unveiled its Shenxing PLUS battery, a LFP (lithium ferro-phosphate) battery with a range exceeding 1,000km. Through CATL's market leading investments into innovation and research, the Shenxing battery's energy density reached 205 Wh/kg, the first LFP battery to surpass 200 Wh/kg.²⁵

In stationary storage, CATL is also advancing battery capabilities to world-firsts, introducing the TENER in April 2024, a 6.25 MWh battery with zero degradation in the first 5 years of operation.²⁶ CATL has reduced the failure rate for its cells to a parts per billion (PPB) occurrence, significantly improving the reliability and longevity of its batteries used in large-scale grid firming, and EVs.

Even with rapidly scaling production capacity and expanding its technology portfolio, CATL is showcasing its world leadership through its roadmap to decarbonisation. On 18 April 2023,

²² SNE Research, [Jan to Mar 2024 Global EV Battery Usage](#), 07 May 2024

²³ CATL, [2023 Annual Report](#)

²⁴ CATL, [2023 Annual Report](#)

²⁵ CATL, [CATL Unveils Shenxing PLUS, Enabling 1,000-km Range and 4C Superfast Charging](#), 25 April 2024

²⁶ CATL, [CATL Unveils TENER, the World's First Five-Year Zero Degradation Energy Storage System](#), 04 April 2024

CATL announced its target to achieve carbon neutrality in its core operations by 2025 (Scope 1 and 2), and achieve net zero across its entire battery value chain by 2035.²⁷

Build Your Dreams (BYD)

BYD is the world's largest manufacturer of New Energy Vehicles (NEVs) globally, which encompass full battery electric vehicles (BEV) and plug-in hybrid vehicles (PHEVs). In 4QCY2023, BYD overtook Tesla to become the world's largest producer of BEVs. In 2023, BYD produced over 3 million NEVs and 1.57 million BEVs, growing its sales by 62% and 73% respectively. In 1QCY24, BYD sold over 624,000 NEVs, 300,000 of which were pure electric passenger vehicles.

In 2023, BYD invested RMB 39.5bn (A\$8.2bn) into R&D, +112% yoy, and was 6.6% of revenue of the year, a ratio 49% higher than recorded in 2022. BYD recorded a NPAT of RMB 31.3bn in 2023, achieving a 77% growth yoy. Incredibly, BYD recorded an R&D to net profit ratio of 1.26:1 in 2023, up from a ratio of 1.05:1 in 2022. Unlike BYD's global competitors, BYD invests more into innovation, research and long-term development in battery and electric mobility each year than the company receives in net earnings.

In 1QCY24, BYD invested RMB 10.6bn (A\$2.2bn) into R&D, up 70% from 1QCY23.²⁸ BYD recorded RMB 124.9bn (A\$26.0bn) in revenue over the quarter, translating to an incredible R&D share of revenue of 8.5%, a ratio 64% higher than 1QCY23. In the first quarter, BYD recorded an R&D to net profit ratio of 2.32:1.

In May 2024, BYD announced a new hybrid powertrain capable of travelling more than 2,000km without the need for refueling or recharging in its PHEV lineup, pushing the company well ahead of its rivals, with Geely's hybrid Galaxy L6 capable of 1,370km, and Zeekr's all-electric 001 model capable of 1,000km - powered by CATL batteries.²⁹

Building China's Circular Economies

The incredible expansion of production and deployment of new energy technologies will mean 100s of GW's of solar panels, wind turbines, grid firming batteries and EV batteries will retire in the next 20 years, and the annual requirements for decommissioning will continue to grow.

More than a third of all new vehicles sold in China are now electric, far ahead of the second largest EV market globally, Europe, of which only 1/8 new sales were electric. It is forecast China will reach its targets of 50% of new sales in 2026, 10 years ahead of schedule.³⁰ The rapid growth in China's battery market will translate to a need for significant recycling capacity and supply chains in the coming decades. Circular Energy Storage estimates China will have ~ 4 times as many batteries to recycle in 2030 than it did in 2021.

Not only does China have more than 50% of the world's available battery and production scrap suitable for recycling today, but China leads the world in chemical pre-processing and material

²⁷ CATL, [CATL Unveiled Its Carbon Neutrality Plan](#), 18 April 2023

²⁸ BYD, [2024 First Quarterly Report](#), 29 April 2024

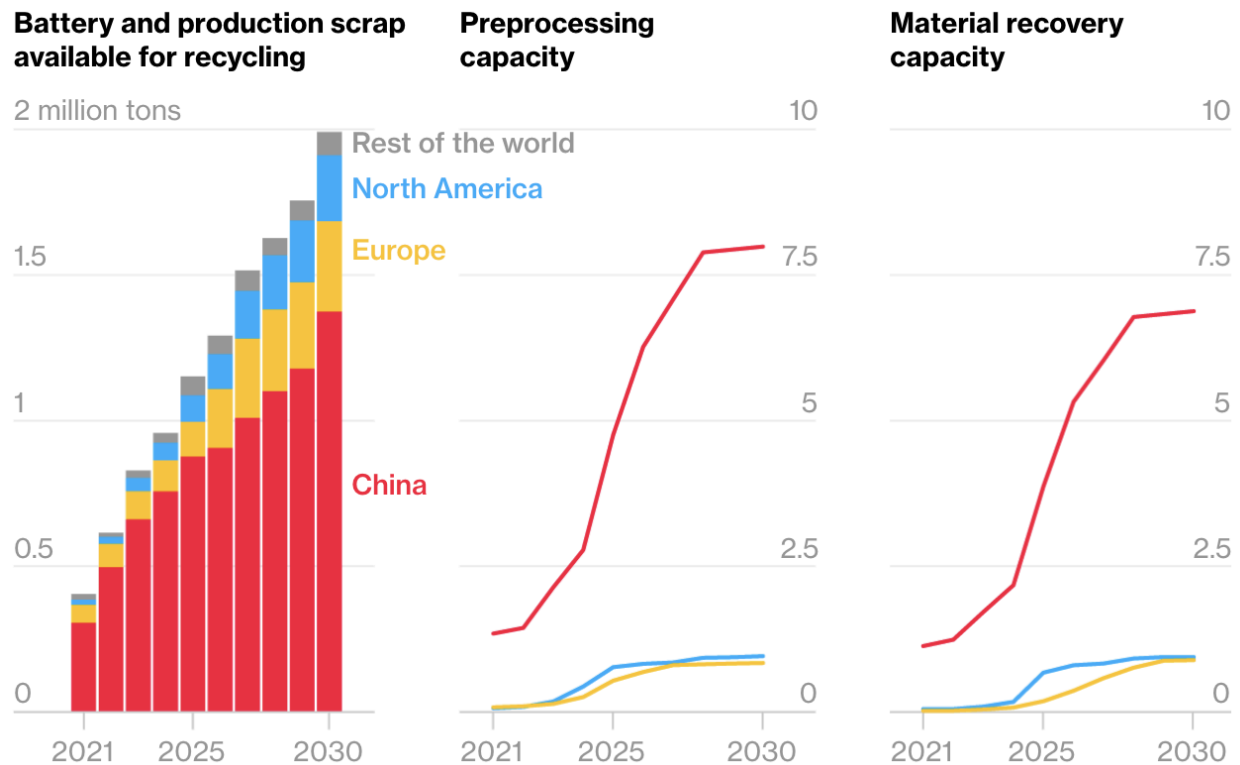
²⁹ Bloomberg, [BYD Unveils Hybrid Powertrain Capable of Ultra-Long Drive](#), 28 May 2024

³⁰ Bloomberg, [Flood of Used Batteries Could Supercharge China's Electric Car Market](#), 21 December 2023

recovery globally, as shown in Figure 3. China's battery recycling capacity is forecast to continue its rapid growth through to 2030.

CATL's battery recycling subsidiary, Brunp Recycling, recycled more than 100,000 tonnes of used batteries in 2023, and regenerated 13,000 tonnes of recycled lithium carbonate that can be fed back into the company's battery value chain.³¹ Brunp's recycling processes have achieved a recovery rate of 99.6% for nickel, cobalt, and manganese, and a 91% recovery rate for lithium. As of 2023, Brunp has seven recycling bases across China and Indonesia.

Figure 3: China's Dominance in Global Battery Recycling



Source: Bloomberg, Circular Energy Storage ³²

In 2018, the Chinese government announced requirements for Chinese auto manufacturers to establish collection and recycling facilities for end-of-life batteries, holding the OEMs responsible for the recovery of batteries used in their vehicles.³³ This recycling point is lost on many uniformed commentators saying the world is going to run out of critical minerals. China treats battery recycling as a national security option to diversify away from its overreliance on Australian virgin material supply.

³¹ CATL, [Environmental, Social and Governance \(ESG\) Report 2023](#)

³² Bloomberg, [Flood of Used Batteries Could Supercharge China's Electric Car Market](#), 21 December 2023

³³ Reuters, [China Puts Responsibility for Battery Recycling on Makers of EVs](#), 26 February 2018

As China continues its push into export markets, Chinese firms have recognised the importance of developing recycling supply chains as more jurisdictions place an emphasis on embedding circularity. In August 2023, the European Union announced a new battery regulation as part of the European Green Deal, in which targets for recycling efficiency, metal recovery and recycled content will be introduced and restricted from 2025.³⁴ This has seen [Glencore](#) invest in the critically important circular economy concept, with an EU leading [Sardinia investment](#). Like [Redwood Materials](#) is doing in the US.

By 2040, China is estimated to retire ~ 250 GW of solar panels and 280 GW of wind turbines. In August 2023, China's National Development and Reform Commission (NDRC), alongside five other state agencies, announced plans to establish a national recycling ecosystem for retiring wind turbines and solar panels, with industry standards and guidelines to decommission, dismantle and recycle components for re-use within their respective value chains.³⁵

Another example of China driving and leading the global energy system transformation.

Note: Climate Energy Finance uses the foreign exchange rates of AUD/CNY = 0.208, AUD/USD = 1.507.

³⁴ EU, [Circular Economy: New Law on More Sustainable, Circular and Safe Batteries Enters into Force](#), 17 August 2023

³⁵ PV Magazine, [China Plans Recycling System for Wind Turbines and Solar Panels](#), 18 August 2023