Global

Batteries: The Next Drivers of Transformation

Battery greenflation concerns have subsided with a substantial correction in battery metal prices. Moreover, with oversupply of some battery components emerging and new technology commercialization taking place in the 2020s, we now forecast a more rapid decline in battery prices to US$99/kWh by 2025. Accordingly, we see five key themes driving the industry transformation and highlight 21 Buy and Sell ideas to play these themes globally. Within, we update our proprietary battery pack price and cost curve model, improve our battery supply-demand model with new regional EV production historical data and outlook, and introduce total cost of ownership analysis for China BEVs. The five key themes are:

1. **Moving from a regulatory to consumer-led EV adoption phase:** We expect **battery prices to fall to US$99/kWh by 2025E – c.40% decline from 2022** and lower 2023E-30E battery pack prices by 11% on average (with 2030E now at US$72/kWh). We estimate that **cost parity of BEVs to ICEs without subsidies** in a broader part of the industry on a TCO basis **could be achieved around mid-decade.** Battery cost reduction could lead to more competitive EV pricing, more extensive consumer adoption, and further growth in EV battery TAM.
2. **Growing battery TAM opportunity from energy storage demand** in China/India: We earlier raised **2026-30E Chinese ESS battery demand by 50-150%** to c.140-400GWh, via re-assessing batteries' role in stabilizing China's green power.
3. **A tale of two battery markets and chemistries:** Regulations are regionalizing **the global cell market** into two belts **– a US-Korea market** focused on ternary batteries that is more insulated from the China surplus and positioned for margin expansion (link), and **a China-Europe market** that is well-supplied, fragmented and focused increasingly on LFP batteries.
4. **Leading technology could drive pockets of strength: Novel anode materials (silicon)** and **battery structures (large cylindrical, bipolar)** among the new technologies; **blade batteries** and **equipment constraints** for separators and wider copper foil rolls among existing technologies.
5. **Homogeneous competition in parts of the battery supply chain** – notably in cathodes, electrolytes and battery equipment – poses producer margin risks.

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PM summary: The Next Drivers of Transformation

As the previous concerns on battery raw material greenflation have subsided, the market focus is shifting to new dynamics in the battery industry leading to **four pertinent questions**: **(1)** Lithium prices have dropped meaningfully – **what are the implications for battery prices? (2)** Electric vehicle (EV) subsidies are being cut in Europe and China – **will consumers continue to purchase EVs? (3)** 2022-1H23 has seen EV policies globally gaining momentum – but looking ahead, **are there more catalysts to support the battery TAM? (4)** The recent round of intense capex investment globally has led to general oversupply in battery-related capacities – **how should investors position in the battery value chain?**

BEVs refer to battery electric vehicles that exclusively use energy stored in rechargeable battery packs, with no other source of propulsion.

We answer these questions with our updated **proprietary battery pack price and cost curve model**, revamped **battery supply-demand model** with newly introduced regional EV production historical data and outlook, and introduce the **total cost of ownership (TCO) analysis** for China BEVs.

In this regional collaboration report across the battery supply chain, **we identify 5 key themes for the current battery industry transformation:**

ICEs refer to internal combustion engine vehicles that typically use energy stored in gasoline or diesel.

#1. Moving from a regulatory to consumer-led EV adoption phase: As the regulatory-led EV adoption phase weakens with EV subsidy cuts in Europe and China at the start of 2023, the question arises as to when we might see consumer-led EV adoption. Compared with Europe and the US, China could be the closest to a consumer-led EV adoption phase, in our view, as EVs are competitively priced against ICEs in the local market. However, such competitive pricing has been subsidized by Chinese EV producers which are mostly loss-making. We expect this to eventually change **around mid-decade,** when battery price declines and sales volume scaling-up lead to a significant reduction in EV costs. Specifically, **we expect battery prices to fall to US$99/kWh by 2025E, a c.40% decrease from 2022**, almost half of which we expect to come from declining raw material prices (e.g. lithium). The reduction in battery costs could in turn lead to more competitive EV pricing, more extensive consumer adoption, and further growth in EV and battery TAM. With this update, we also **lower 2023E-30E battery pack prices by an average of 11%** (with 2030E now at US$72/kWh), mainly due to a reduced cell-to-pack premium.

#2. Accelerating battery TAM opportunity from energy storage demand: The growth in EV sales has historically been the main driver of global battery demand. However, room to further upgrade EV sales projections now appears limited from an emissions-control perspective – over 2022-23, new EV policies globally have already raised the policy-implied 2030E EV sales towards a level that is compatible with more sustainable growth. That said, new battery TAM opportunities are emerging from energy storage demand acceleration in China and India. For example, **we earlier raised 2026-30E Chinese battery demand estimates for energy storage by 50-150%** to c.140-400 GWh, as we re-assessed batteries' role in stabilizing China's green power. However, the upgrade so far in energy storage projections has not disrupted the oversupply outlook for batteries. Therefore, our preferred names to play the energy

An **inverter** turns the direct current output of a battery into alternating current for end use or feeding into the grid.

storage theme are **Envicool (Buy, on CL)** which is a major supplier of cooling equipment for energy storage, and **Goodwe (Buy, on CL)** a top-ranked inverter manufacturer globally.

#3. A tale of two battery markets and chemistries: As the world transitions to a low-carbon future, batteries are gaining critical importance from a national strategic perspective, given their pivotal role in energy supply. Meanwhile, battery supply chains remain geographically concentrated and susceptible to rising political tensions, with China dominating a large part of the supply chain. We see the passage of the Inflation Reduction Act (IRA) as a strong commitment from the US government to boost the self-sufficiency of batteries, which leads to **regionalization of the global cell market** – **a US-Korea market** which is more insulated from the China surplus and focused primarily on ternary batteries, and **a China-Europe market** which is well-supplied and focused increasingly on LFP batteries. Winners from this battery market regionalization in our view include the US battery self-sufficiency enablers like **LG Chem (Buy, on CL), LGES (Buy), Samsung SDI (Buy), Panasonic (Buy) and Tesla (Neutral);** whereas Chinese batteries producers like **CALB and Gotion (both Sell-rated)** could experience increased margin pressure, due to more difficulties in exporting the battery surplus.

#4. Leading technology could drive pockets of strength: Although the recent round of intense capex investment has led to general oversupply in battery-related capacities, technology that is new or relatively difficult to replicate could still drive pockets of **strength**:

1. **For technologies that could hit commercialization in the 2020s,** we focus on **novel anode materials (Si, Li metal)** and **battery structures (large cylindrical, bipolar):** Over 2023-25E, we expect producers to ramp up large cylindrical batteries, a new battery structure through which Tesla has reportedly achieved cost cuts of US$2,000-3,000 per pack; by 2024-25E, producers could start scaling-up capacity for Si-anode, a promising candidate to replace graphite and improve energy density; by 2026-27E, Toyota could start producing bipolar batteries, for which the company targets 40% cost reduction vs. its conventional batteries. For **solid-state batteries**, we see a relatively tough path towards scaling-up over the coming decade. We are **Buy-rated on EVE Energy, Daejoo, Toyota Motor** as the respective leaders in large cylindrical batteries, Si-anode, and bipolar batteries; we are **Sell-rated on QuantumScape**, as its FCF could be under pressure before and during ramping into volume production for solid-state batteries.
2. **For technologies that have already been commercialized,** we highlight that **blade batteries** are set to further empower BYD's EV competitiveness **(Buy BYD)**, and that **equipment constraints** for separators and wider copper foil rolls (1.4m width vs. standard 1.0m width) have led to disciplined supply and healthy margins of leading producers of separator **(Buy Yunnan Energy)** and wide-roll copper foils **(Buy SKC).**

#5. Homogeneous competition in parts of the battery supply chain: We observe an increase in homogenization of products in parts of the battery supply chain – notably in **cathodes, electrolytes** and **separators**. Such homogeneity in a competitive surplus environment – like in the cathode and electrolyte markets – poses challenges to producer margins. We believe the margin risks have not been fully reflected in the valuation of our **Sell-rated Posco Future M (NCM cathode), Ecopro BM (NCM cathode), Zhenhua (NCM cathode) and Tinci (electrolyte)**. Similar competition-induced downside risks can be seen in the **battery equipment market**, where demand is slowing due to decelerating EV demand growth and a global battery market heading into a surplus. We see stock valuations as stretched for our **Sell-rated Hymson** (laser filming equipment and battery cell assembly line) and **United Winners** (laser welding equipment).

How to Invest in the Global Battery Supply Chain

Driver			Stock ideas	
Bull	**New demand-driven**	Energy storage demand accelerating	BUY	**Envicool*** (cooling equipment), **Goodwe*** (inverter)
	Regulation-driven	The US IRA beneficiaries	BUY	**LG Chem*** (cell maker), **LGES** (cell maker), **Samsung SDI** (cell maker), **Panasonic** (cell maker)
	Technology-driven	Innovations to hit commercialization in 2020s	BUY	**EVE Energy** (large cylindrical battery), **Daejoo** (Si-anode), **Toyota Motor** (bipolar battery)
		Commercialized technologies that are leading	BUY	**BYD** (blade battery), **Yunnan Energy** (separator), **SKC** (wide-roll copper foil)
Bear	**Regulation-driven**	Difficulty for China to export capacity surplus	SELL	**CALB** (cell maker), **Gotion** (cell maker)
	Surplus-driven	Homogeneous competition in surplus	SELL	**Posco Future M** (NCM cathode), **Ecopro BM** (NCM cathode), **Zhenhua** (NCM cathode), **Tinci** (electrolyte)
		Intense competition amid slowing demand	SELL	**Hymson** (laser filming equipment and battery cell assembly line), **United Winners** (laser welding equipment).
	Technology-driven	FCF under pressure before and during ramping into volume production	SELL	**QuantumScape** (solid-state batteries)

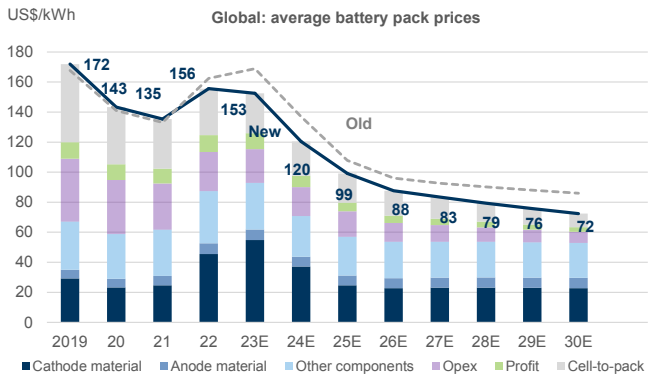
** For stocks on our conviction list.*

Source: Goldman Sachs Global Investment Research

The authors would like to thank Varuna Nangia and Eunice Ip, members of the Digital Content Strategy team for creating the interactive exhibits.

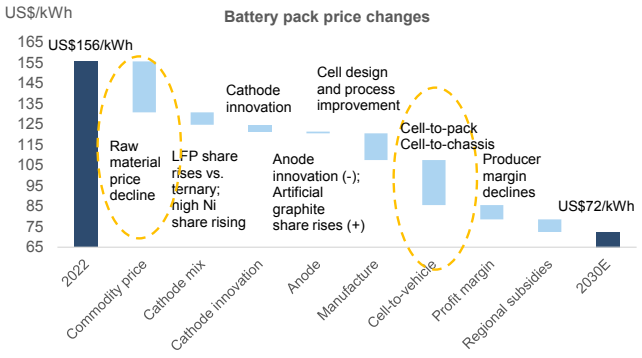
Thesis in key charts

Exhibit 1: Theme 1: We expect battery prices to fall to US$99/kWh by 2025E - c.40% decrease from 2022...



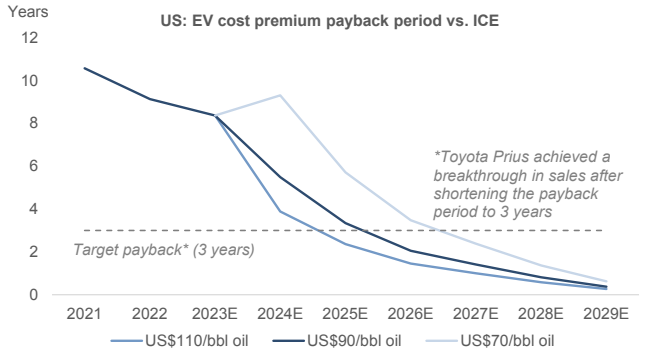
Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 2: ...and to reach US$72/kWh by 2030E, mainly driven by lower raw material costs and simpler cell-to-vehicle integration



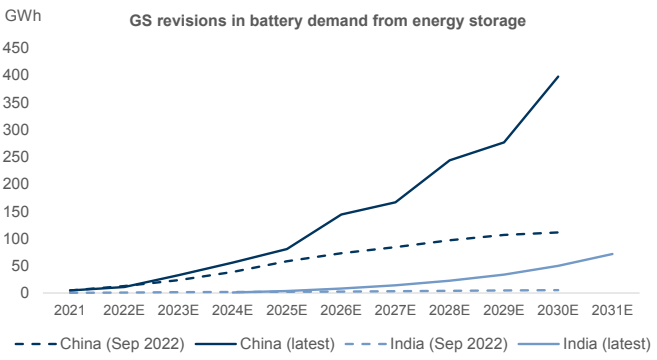
Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 3: The lower battery prices could contribute to the cost parity of BEVs to ICEs without subsidies by around mid-decade



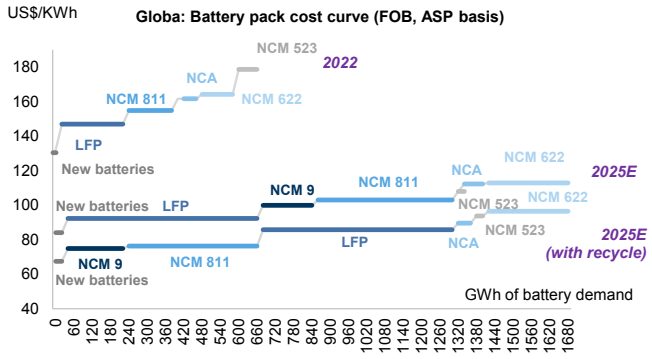
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 4: Theme 2: Battery TAM opportunity is accelerating from energy storage demand in China and India



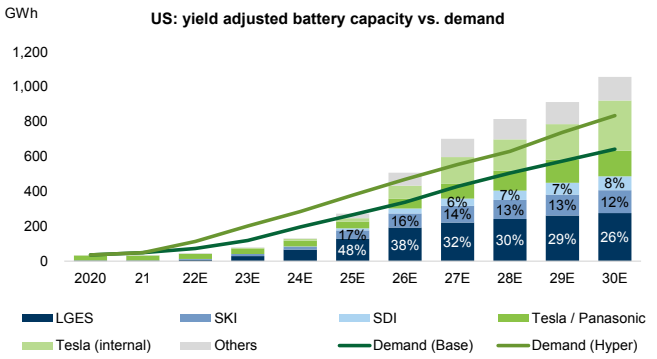
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 5: Theme 3: Supplier competitiveness is usually assessed by a global supply curve...



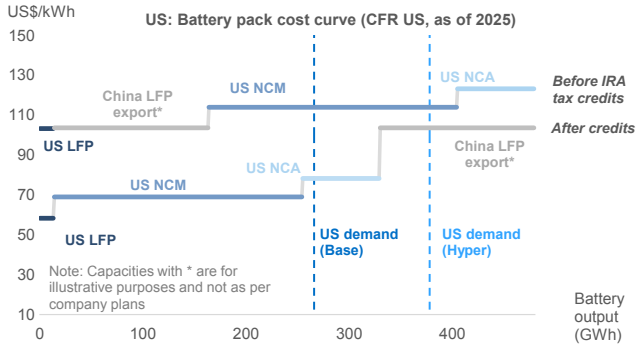
Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 6: ...but regulations are regionalizing the global cell market into two belts – a US-Korea market...



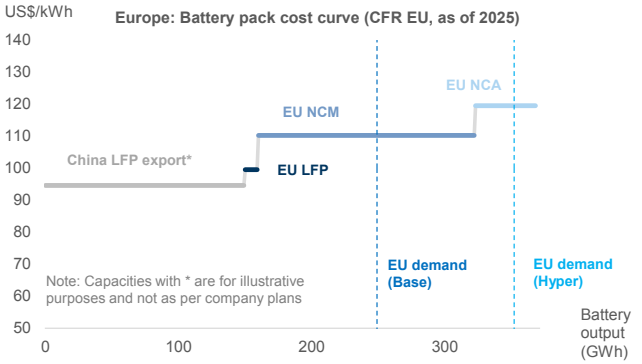
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 7: ...which is more insulated from the China surplus...



Source: Wood Mackenzie, SNE Research, Company data, Goldman Sachs Global Investment Research

Exhibit 8: ...and a China-Europe market that is well-supplied



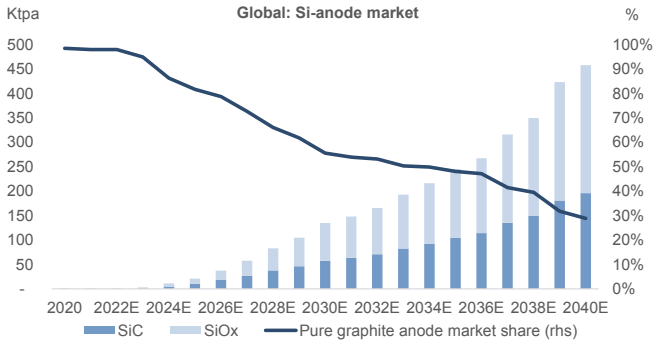
Source: Wood Mackenzie, SNE Research, Company data, Goldman Sachs Global Investment Research

Exhibit 9: Theme 4: For technologies that could hit commercialization in the 2020s, we focus on (1) large cylindrical batteries...

	Mass production	2025E capacity	2030E capacity	Partnership
		GWh	GWh	
Tesla	2023E	60	310	Tesla
EVE Energy	2023E	20	100	BMW, China local
LGES	2H24E	9	179	Tesla
Panasonic	2024E	40	120	Tesla, GM
CATL	2024E	40	110	BMW, Tesla, China local
Samsung SDI	2025E	1	141	BMW, GM
Subtotal		**170**	**960**	
% global EV battery demand		**12%**	**31%**	

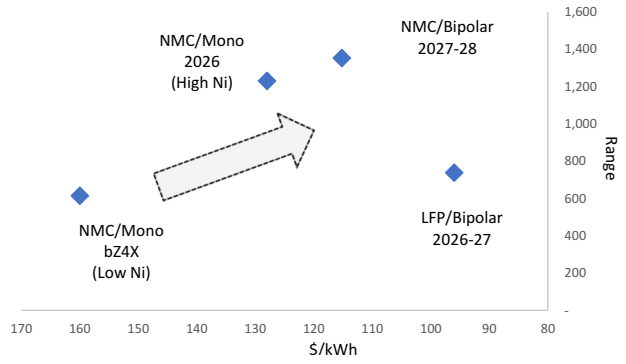
Source: SNE Research, Company data, Goldman Sachs Global Investment Research

Exhibit 10: ...(2) novel anode materials (silicon replacing graphite)...



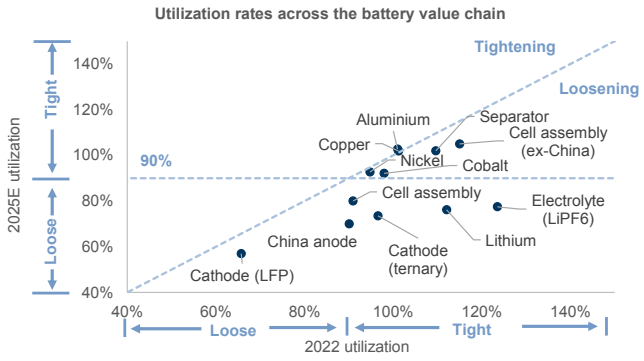
Source: Goldman Sachs Global Investment Research

Exhibit 11: ... and (3) bipolar batteries which we expect to achieve significant cost saving and range improvement



Source: Goldman Sachs Global Investment Research

Exhibit 12: Theme 5: Most battery materials and components are now seeing loosening supply/demand balance towards 2025E



Utilization = demand/supply for metals; demand/capacity for processed materials and components

Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

THE ECOSYSTEM OF EV BATTERIES

China | South Korea | Japan | Europe | US | Latam | Australia

Battery Makers

LG Energy Solution
Panasonic HD
SK Innovation
Samsung SDI
BYD
Tesla
General Motors
Ford Motor
Volkswagen
Toyota Motor
Hyundai Motor
Rivian Automotive
QuantumScape
Ganfeng Lithium
CALB
EVE Energy
Gotion High-Tech
Farasis Energy
VARTA AG
FREYR Battery

CATL, Automotive Energy Supply Corporation, Solid Power, SES AI, Northvolt, Kaipu Energy, Sunwoda Electronic, SVOLT

Cathode

Umicore
LG Chem
Shenzhen Dynanonic
Guizhou Zhenhua E-chem
Sumitomo Metal Mining
Huayou Cobalt
Ecopro BM
L&F
POSCO Future M

BASF SE
Ronbay
Beijing Easpring Material
Nichia

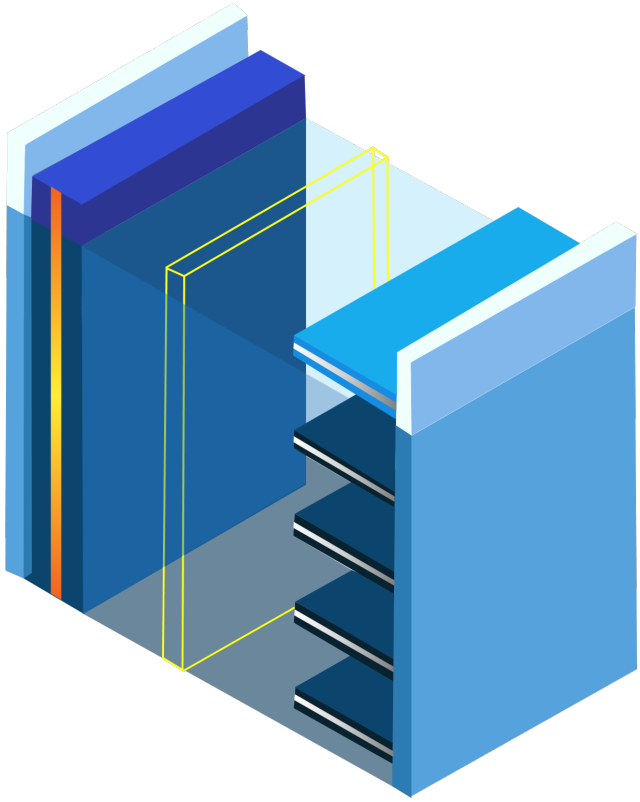
Anode

Shanghai Putailai New Energy
Daejoo Electronic Materials
Hansol Chemical
Shin-Etsu
POSCO Future M

Kaijin New Energy
Ningbo Shanshan
SGL Carbon
Resonac
Tokai Carbon

Battery Equipment Makers

Hymson
United Winners
HangKe Technology



Separator

Yunnan Energy
Shenzhen Senior Tech
Shanghai Putailai New Energy
Asahi Kasei
SK Innovation
Toray Industries

Semcorp
Cangzhou Mingzhu Plastic
W-Scope
Celgard
Entek

Electrolyte

Guangzhou Tinci Materials
3M
LG Chem
Mitsubishi Gas Chemical
Nippon Shokubai

Shenzhen Capchem Tech
Lanxess AG
UBE Corp.
Chunbo
Guotai Huarong

Raw Materials

SQM
Tianqi Lithium
Ganfeng Lithium
Qinghai Salt Lake Industry
YongXing Special Materials
Sichuan Yahua Industrial
CMOC Group
Huayou Cobalt
Zijin Mining
Mineral Resources
Rio Tinto
BHP
Iluka Resources
Lynas Rare Earths
South32
Allkem
Pilbara Minerals
IGO
Liontown Resources
Core Lithium

NEI Corporation
Xiamen Tungsten Co Ltd
Leading Edge Materials
First Quantum Minerals
Norilsk Nickel
Albemarle
Targray
Livent
Lithium Americas
NextSource Materials
Syrah Resources

Foils & Binders

LG Chem
Zeon
Hansol Chemical
SKC
Lotte Energy Materials

Arkema

Recycling

Ganfeng Lithium
Huayou Cobalt
GEM
Sumitomo Metal Mining

BASF SE

Not Rated, Not Covered or Coverage Suspended

We note that the list of companies across the EV batteries ecosystem we present above is not exhaustive, and the universe of companies involved in the global chain is likely to be larger than what is presented in this exhibit.

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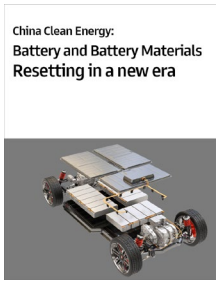
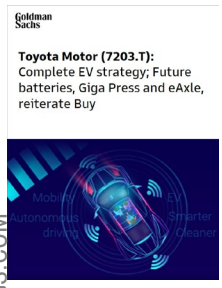
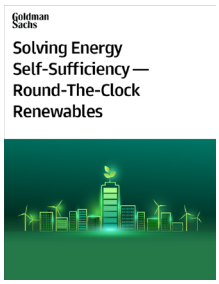
(Jun 2023)
We see limited room for volume expansion by Korean cathode producers, with expected surplus leading to significant margin compression risk.



[China Battery and Battery Materials: Resetting in a new era]
(Mar 2023)
Aggressive supply expansion, and heightened geopolitical risk presents rising industry overcapacity risk in our view.



[Toyota Motor (7203.T): Complete EV strategy; Future batteries, Giga Press and eAxle]
(Jun 2023)
We think strong EV products are the missing piece of Toyota's multi-pathway strategy, and we see this as a potential catalyst for share price re-rating.



[China: Solving Energy Self-Sufficiency — Round-The-Clock Renewables]
(Mar 2023)
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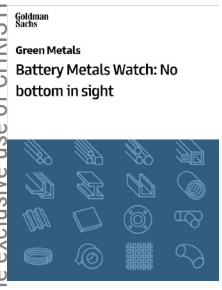
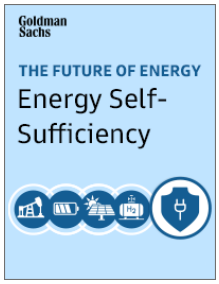


[Green Metals: Battery Metals Watch: No bottom in sight]
(Jun 2023)
We see structurally bearish fundamentals for lithium, nickel and cobalt.



[Global Batteries: The Self-Sufficiency Challenge]
(Nov 2022)
We leverage our battery and material supply demand models to assess the self-sufficiency gaps ahead.

[Metals & Mining: Direct Lithium Extraction: A potential game changing technology]
(Apr 2023)
Implementation of DLE technologies has the potential to significantly increase the supply of lithium from brine projects, nearly doubling lithium production.

[Batteries: The Greenflation Challenge II: Addressing six key investor debates]
(Jun 2022)
Battery innovations and more efficient manufacturing should continue to drive a long-term price decline.

[Batteries: Beginning of China oversupply, but IRA drives favorable cost curve in the US]
(Mar 2023)
We expect a global surplus in the coming decade on overbuilding of Chinese battery capacity and ex-China capacity expansions.

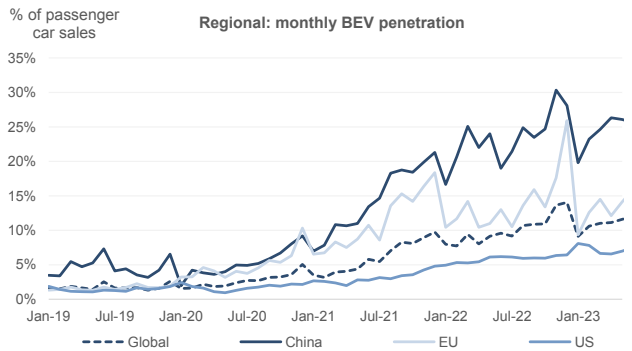
[Global Batteries: The Greenflation Challenge]
(Mar 2022)
To assess the impact of "Greenflation" and potential supply chain bottlenecks, we introduce our proprietary battery pack price and cost curve model.

#1 Moving from a regulatory to consumer-led EV adoption phase

As the regulatory-led EV adoption phase weakens with EV subsidy cuts in Europe and China at the start of 2023, the question arises as to when we might see consumer-led EV adoption. Compared with Europe and the US, China could be the closest to a consumer-led EV adoption phase, in our view, as EVs are competitively priced against ICEs in the local market. However, such competitive pricing has been subsidized by Chinese EV producers which are mostly loss-making. We expect this to eventually change around mid-decade, when battery price declines and sales volume scaling-up lead to a significant reduction in EV costs. Specifically, we expect battery prices to fall to US$99/kWh by 2025E, a c.40% decrease from 2022, almost half of which we expect to come from declining raw material prices (e.g. lithium). The reduction in battery costs could in turn lead to more competitive EV pricing, more extensive consumer adoption, and further growth in EV and battery TAM. With this update, we also lower 2023E-30E battery pack prices by an average of 11% (with 2030E now at US$72/kWh), mainly due to a reduced cell-to-pack premium.

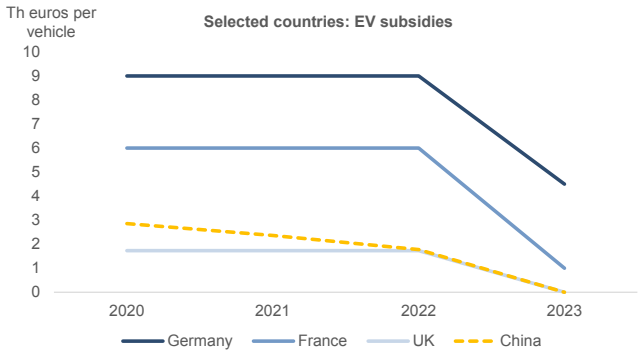
Global EV penetration retreated from the highs on the back of subsidy cuts. Although US EV sales continued its strength into 1H23 with strong support from the 2022 US IRA, global EV sales and penetration saw sequential declines in 1H23 vs. late 2022 (Exhibit 13). A few factors have contributed to this sequential decline, including reduced EV subsidies in a number of European countries and China, amid unstable economic conditions and cautious consumer spending (Exhibit 14). While a return of significant EV subsidies is not currently in sight for Europe and China, we note Chinese producers have been cutting EV prices following years of domestic competition, contributing to much cheaper EV prices in China (Exhibit 15). Compared with Europe and the US, where EVs are generally more expensive than ICEs, as carmakers have so far focused on larger and more luxurious EV models, we believe the EV market in China could be the closest to a consumer-led EV adoption phase (Exhibit 16).

Exhibit 13: Global EV penetration retreated from the highs in 1H23 vs. late 2022



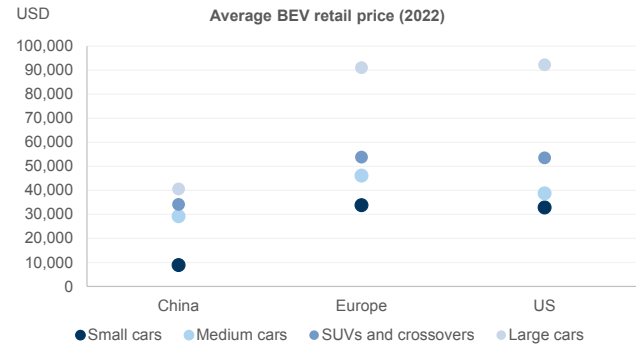
Source: CPCA, Autodata, SMMT, KBA, OFV/insideEVs, CCFA, UNRAE, EU-Evs, Wood Mackenzie, data compiled by Goldman Sachs Investment Research

Exhibit 14: The start of 2023 saw reduced EV subsidies in a number of European countries and China



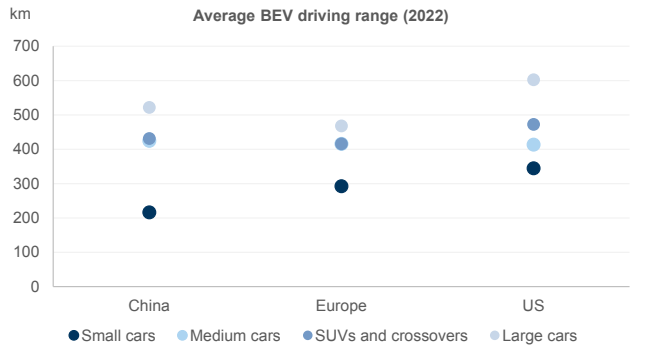
Source: SMMT, KBA, CCFA, data compiled by Goldman Sachs Global Investment Research

Exhibit 15: EVs are much cheaper in China than Europe and the US



Source: IEA

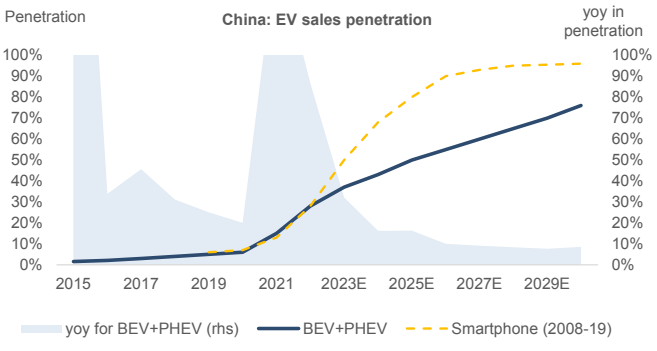
Exhibit 16: Europe and US carmakers have so far focused on larger and more luxurious EV models



Source: IEA

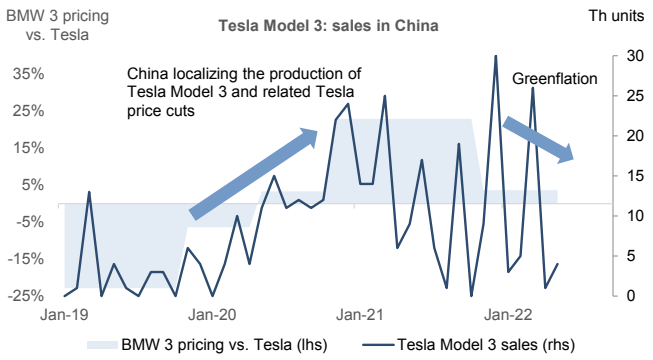
Chinese EVs are cheaper than gasoline cars. Despite national subsides being reduced to zero in 2023, EV penetration in China has remained at elevated levels (Exhibit 13). Notably, the strength in China EV sales started in 2020, when EV's share in passenger vehicle sales experienced a step change (Exhibit 17). Industry experts in China attribute such strength to the increased options of competitively-priced EVs – for example, Tesla's Model 3 underwent several price cuts over 2019-21 after production was localized in China, leading to its cheaper pricing vs. say, the BMW 3 series (Exhibit 18). Meanwhile, consumer preference for EVs is growing – in cities where people can freely choose between ICE and EV for the next car, the penetration of EV has also increased from minimal in 2019 to c.28% (Exhibit 19). Looking ahead, our China auto team expects EV penetration to further increase towards 80% by 2030E, though the path of this penetration increase could be slower than other novel products (e.g. smartphones in the 2010s, Exhibit 17). Compared with smartphones, which had a dominant advantage over conventional phones, current EV models do not have an absolute advantage over ICE, in our view, considering the less convenient recharging and the lower cruising range, especially in winter. We note headwinds to higher EV penetration have already emerged, including the spreading ICE price war in China.

Exhibit 17: EV's share in passenger vehicle sales experienced a step change in 2020



Source: The State Information Center, Wind, Goldman Sachs Global Investment Research

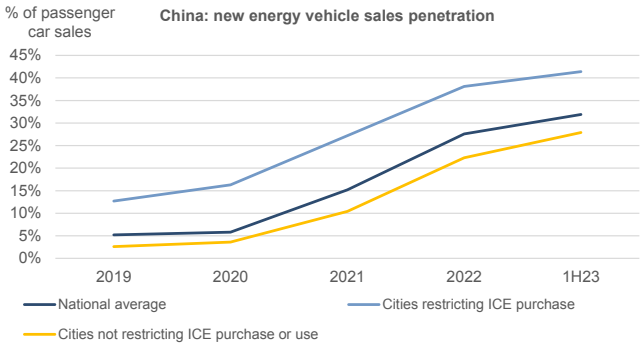
Exhibit 18: Tesla's Model 3 went through several price cuts over 2019-21, leading to its cheaper pricing vs. the BMW 3 series



Prices inclusive of a 10% sales tax which applies to ICEs but not to EVs

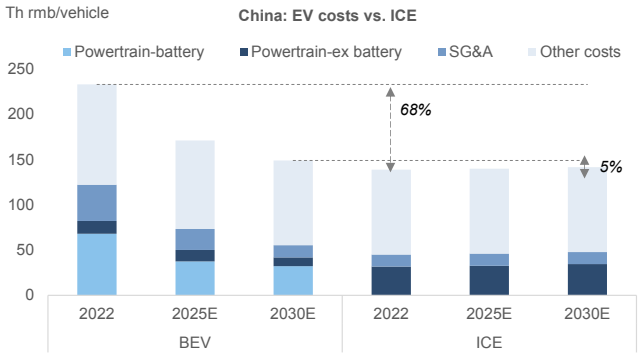
Source: CPCA

Exhibit 19: In cities where people can freely choose between ICE and EV, the penetration of EV has also approached c.28%



Source: CPCA

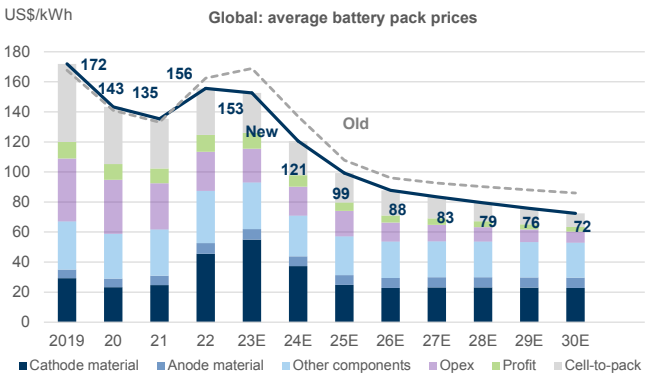
Exhibit 20: We assess that the producer cost of a typical EV in China is currently c.70% higher than an ICE



Source: Company data, Goldman Sachs Global Investment Research

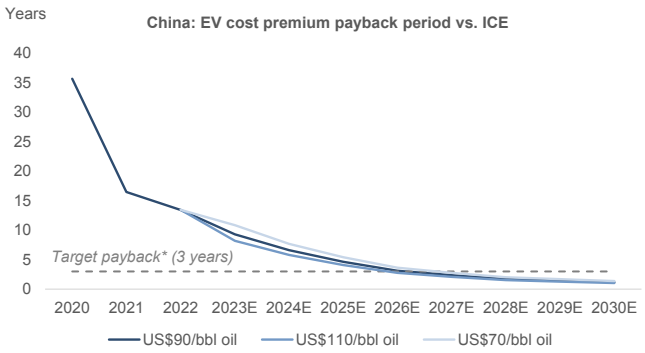
Battery cost deflation and EV economies of scale to drive down EV costs. So far, the competitive pricing of EVs in China has been subsidized by EV producers which are mostly loss-making, and the actual cost parity with ICE is yet to come. Taking cues from the profit margins of typical Chinese producers of BEV and ICE[1], we assess that the producer cost of a typical BEV is currently c.70% higher than an ICE, mainly due to higher powertrain and per unit SG&A costs (Exhibit 20). Looking ahead, we expect declining battery prices (Exhibit 21), as well as EV economies of scale to help narrow the cost gap between EVs and ICEs towards 2030E. As a rule of thumb, we see an EV premium payback period of around 3 years (i.e. the number of years needed for fuel savings from cheaper electricity vs. gasoline to cover the EV cost premium over an ICE) as a threshold for a new powertrain to be widely accepted by consumers, given the case of Toyota Prius. We expect this 3-year target could be reached around mid-decade for EV makers in China, as well as in ex-China markets like the US (Exhibit 22-Exhibit 23).

Exhibit 21: We expect battery prices to decline meaningfully from here



Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 22: The target payback of 3 years could be achieved around mid-decade for BEV makers in China...

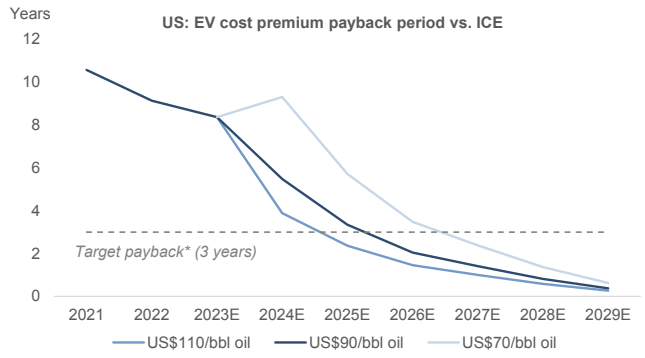


*Toyota Prius achieved a breakthrough in sales after shortening the payback period to 3 years.

Source: Company data, Goldman Sachs Global Investment Research

[1] For this study, we include Xpeng and NIO as samples for pure play BEV makers, and SAIC, GAC, Changan, Great Wall Motor, and Geely as samples for ICE makers

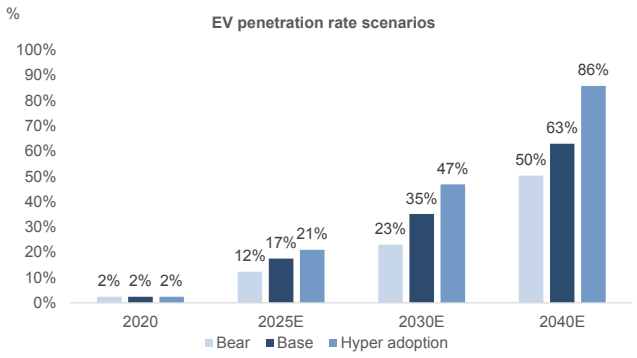
Exhibit 23: ...as well as in ex-China markets like the US



*Toyota Prius achieved a breakthrough in sales after shortening the payback period to 3 years.

Source: Company data, Goldman Sachs Global Investment Research

Exhibit 24: Lower EV battery prices and improved battery performance to drive a sustained shift to electric vehicles

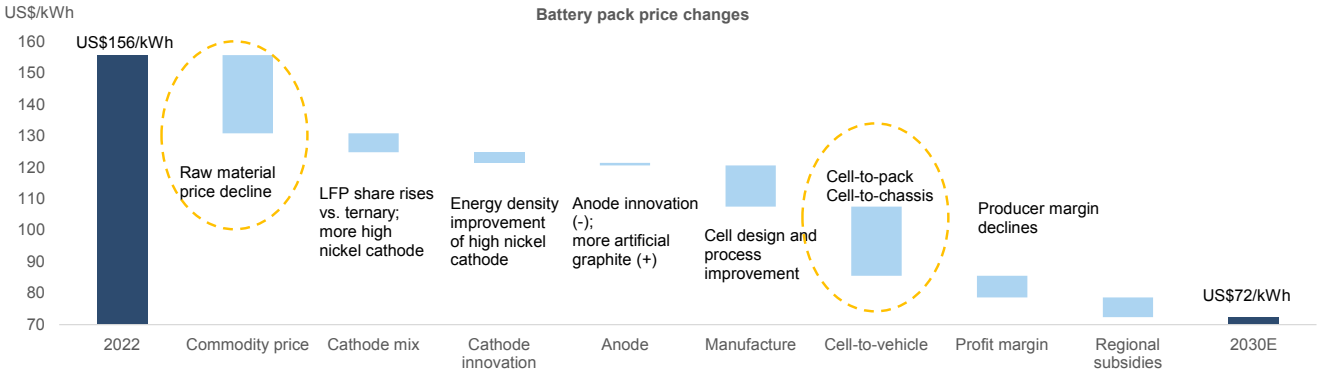


See 'Global Automobiles: Lowering our EV battery price forecasts; Kia up to Buy on improved EV margin outlook; reiterate Buy on Toyota', Kota Yuzawa

Source: Global Insight, MarkLines, Goldman Sachs Global Investment Research

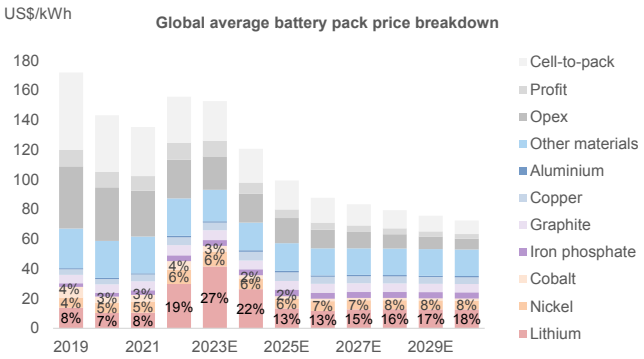
Increased visibility to lower battery costs. In our view, the main drivers for a decline in battery prices from here include lower lithium and other raw material costs (see ***Box: Further medium-term downside to remain for lithium***), and simpler cell-to-vehicle integration (e.g. cell-to-pack, cell-to-chassis, Exhibit 25-Exhibit 27). In this update, we lower 2030E battery pack prices from US$86/kWh to US$72/kWh (Exhibit 21), mainly due to a lowered cell-to-pack premium (2030E from US$19/kWh to US$9/kWh). The cell-to-pack premium in China has been dropping quickly in the past 3 years to US$15-20/kWh currently from c.US$30/kWh at 2021, with the industry estimate at US$10-15/kWh for 2025E (Exhibit 28). In our view, the low cell-to-pack premium in China reflects lower local opex, as well as the common use of cell-to-pack technology (a design that bonds cells directly into a pack, and skipping the intermediate step of bundling cells into "modules" which is then installed in a traditional pack, i.e. "cell-module-pack"). Since similar dynamics are playing out in ex-China (see the 4680 cell example in ***Section: #4 Leading technology could drive pockets of strength***), we now assume the 2018-22 annual decline rate in the global cell-to-pack premium extends into our forecast period, as manufacturing becomes simpler and more automated to save labor costs, and cell-to-chassis (a design that connects individual cells directly to the vehicle's chassis and skipping the step of bonding cells into a conventional pack which is then installed in a vehicle) could further reduce the cost for cell-to-vehicle integration. Meanwhile, looking at the supply situation across the battery value chain, we note most battery materials and components are now seeing a loosening supply/demand balance towards 2025E, alleviating previous concerns around greenflation (Exhibit 29).

Exhibit 25: The main drivers for declines in battery prices include lower raw material costs and simpler cell-to-vehicle integration



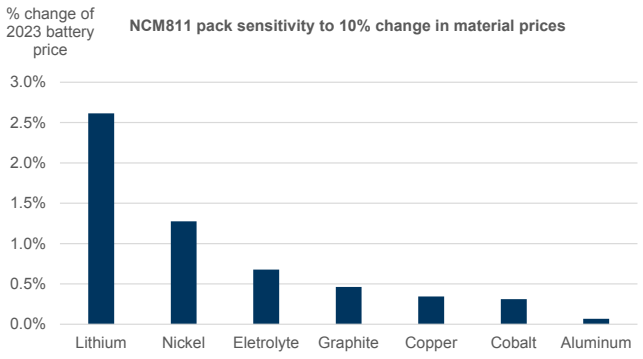
Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 26: Reduced raw material costs to contribute to lower battery prices



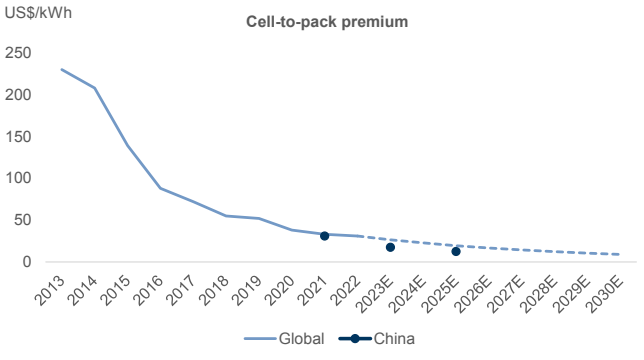
Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 27: Further medium-term downside for lithium prices to meaningfully reduce battery prices



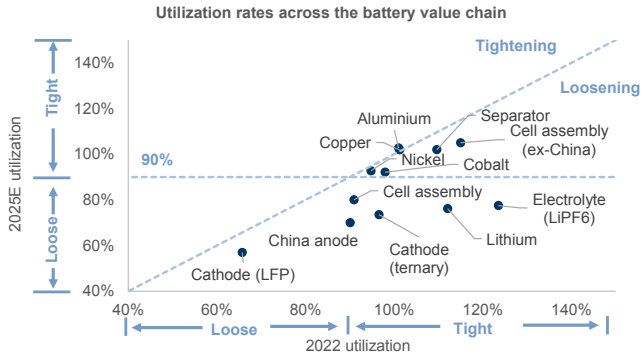
Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 28: The cell-to-pack premium in China has been dropping quickly in the past 3 years to US$15-20/kWh currently from c.US$30/kWh in 2021



Source: Company data, BNEF, Goldman Sachs Global Investment Research

Exhibit 29: Most battery materials and components are now seeing a loosening supply/demand balance towards 2025E



Utilization = demand/supply for metals; demand/capacity for processed materials and components

Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

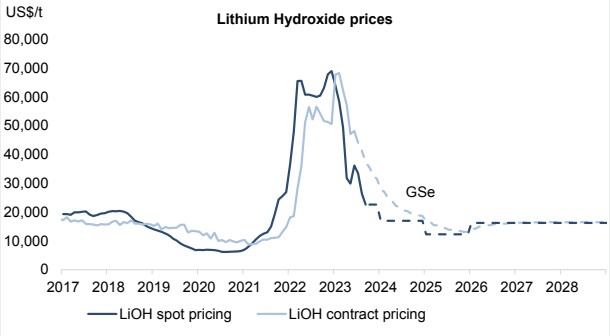
Box: Further medium-term downside to remain for lithium

Although lithium prices have been falling in recent months, our global commodity team continues to see a supply-led correction in the medium term (Exhibit 30). As global spodumene provides incremental raw material supply growth over 2023-24 (Exhibit 31), the team forecasts 2025 China battery grade lithium prices (ex-VAT) at US$11,000/12,500/t for carbonate/hydroxide respectively, before rebounding to our LT forecast of US$15,000/16,500/t (real $2027).

On price forecast setting, our LT lithium prices are based on selected unit cost and capex (lithium carbonate at US$15,000/t and spodumene (6% Li2O) at US$1,000/t), as we assume these prices would put the higher capex projects in our base case at returns that are mostly offset by cost of capital (15%-25% assumed). It is a price level at which we believe supply growth can be sustained to support the LT demand from the global EV market, yet not exaggerated to trigger aggressive expansions by all. We set our floor price for the industry at US$11,000/t for lithium carbonate, and US$800/t for spodumene (6% Li2O), based on the unit cost of marginal cost producers – mostly non-integrated refineries and the high-cost Chinese mica producers.

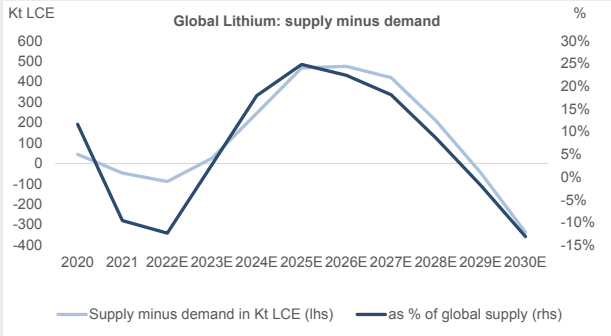
Emerging technologies like Direct Lithium Extraction (DLE) have the potential to be a game changer for lithium supply. By increasing supply from currently high-cost resources, we believe the eventual implementation of DLE could extend the size and duration of lithium market surpluses, or reduce deficits in a scenario where green demand is pulled forward. DLE could potentially increase the supply of lithium either via enabling low-grade existing conventional brine resources, or unlocking other potential lithium resources (such as typically low lithium concentration geothermal/oil field brines). While accelerated ramp-up of DLE-linked projects in the next five years is unlikely in our view, with nearly all projects remaining outside our base case supply estimates, our cost analysis suggests that DLE could widen, rather than steepen, the lithium brine cost curve. Notably, brine resources account for c.40% of global production today, despite accounting for nearly two-thirds of lithium resources, showing the significant potential that could be unlocked by DLE.

Exhibit 30: Further medium-term downside to remain for lithium



Source: Wind, KITA, Goldman Sachs Global Investment Research

Exhibit 31: The lithium market is going through a prolonged period of surplus



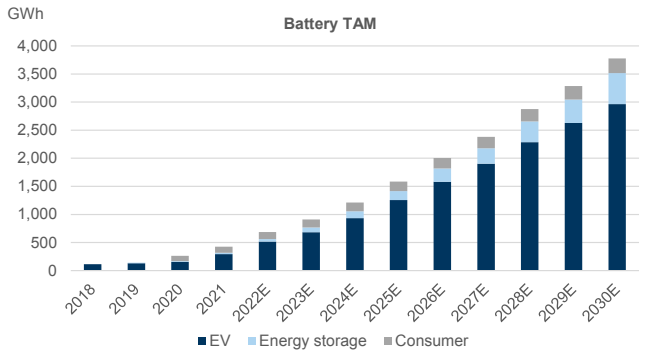
Source: BNEF, Woodmac, Company data, Goldman Sachs Global Investment Research

#2 Accelerating battery TAM opportunity from energy storage

The growth in EV sales has historically been the main driver of global battery demand. However, room to further upgrade EV sales projections now appears limited from an emission-control perspective – over 2022-23, new EV policies globally have already raised the policy-implied 2030E EV sales towards a level that is compatible with more sustainable growth. That said, new battery TAM opportunities are emerging from energy storage demand acceleration in China and India. For example, we earlier raised 2026-30E Chinese battery demand forecasts for energy storage by 50-150% to c.140-400 GWh, as we re-assessed batteries' role in stabilizing China's green power. However, the upgrade so far in energy storage projections has not disrupted the oversupply outlook for batteries. Therefore, our preferred names to play the energy storage theme are Envicool (Buy, on CL) which is a major supplier of cooling equipment for energy storage, and Goodwe (Buy, on CL) a top-ranked inverter manufacturer globally.

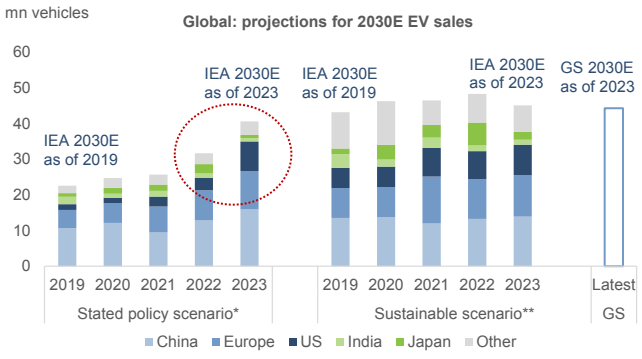
Room to further upgrade EV sales projections now appears more limited. EV sales growth has been the main driver of battery demand (Exhibit 32). Over 2022-23, EV policies globally have gained momentum and are catching up with countries' announced ambitions for emission reduction. Specifically, the US IRA and new EU CO2 standards for cars and vans[2] have led the IEA to significantly raise 2030E EV sales (in its "stated policy scenario"), narrowing the gap to a level that is considered compatible with more sustainable economic growth (Exhibit 33). The other side of the coin, however, is that room to further upgrade EV sales projections now appears limited, from an emission-control perspective.

Exhibit 32: EV sales growth has historically been the main driver of battery demand, followed by energy storage



Source: Wood Mackenzie, Goldman Sachs Global Investment Research

Exhibit 33: The circled increase partly reflects the US IRA and new EU CO2 standards, which contributed to higher 2030E policy-implied EV sales near a sustainable growth level

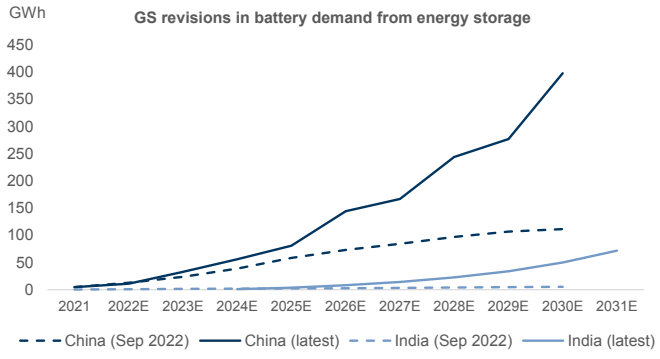


*Stated policy scenario - reflects existing policies and measures; **Sustainable scenario - reflects announced ambitions of countries to reduce emissions (Sustainable Development Scenario for 2020-21, Announced Pledges Scenario for 2022-23, due to data availability)

Source: IEA, Goldman Sachs Global Investment Research

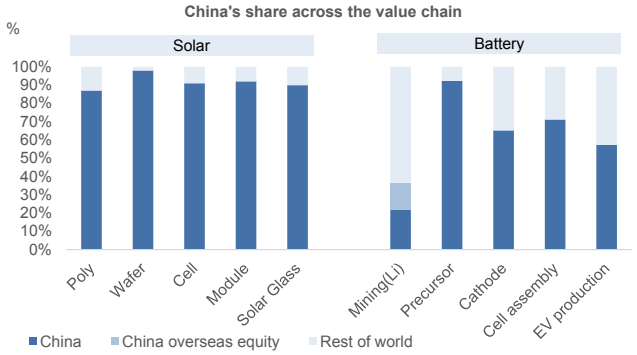
[2] In March 2023, the European Union adopted new CO2 standards for cars and vans requiring a 55% and 50% reduction in emissions of new cars and vans by 2030 (compared to 2021), and 100% for both by 2035.

Exhibit 34: New battery TAM opportunities are emerging from energy storage demand acceleration in China and India



Source: Company data, Goldman Sachs Global Investment Research

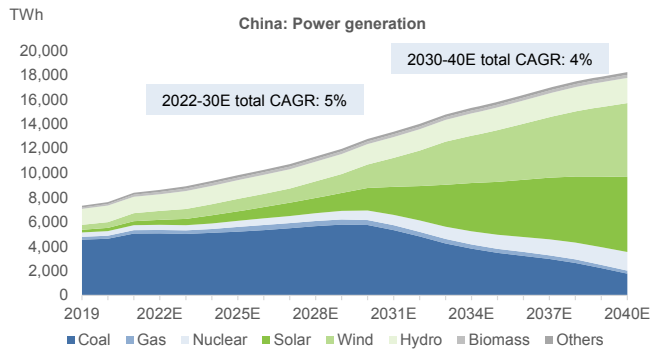
Exhibit 35: China is well-positioned to ramp up renewables, as it dominates a major part of the clean energy supply chain



Source: Company data, Wood Mackenzie, SNE Research, Goldman Sachs Global Investment Research

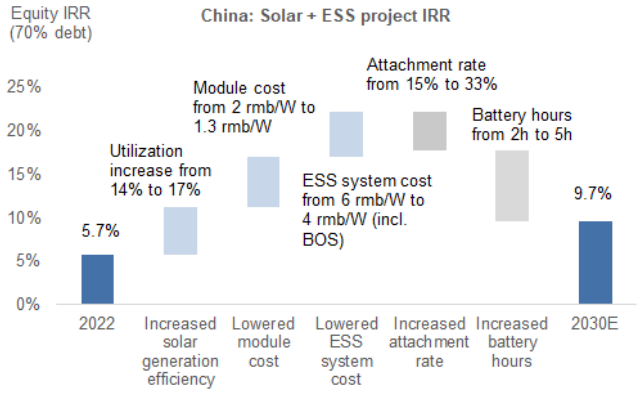
The focus is shifting to accelerating battery demand from energy storage in China... We earlier raised 2026-30E Chinese battery demand forecasts for energy storage by 50-150% to c.140-400 GWh (Exhibit 34, see more about **China's Energy Self-Sufficiency** here and here), as we re-assessed batteries' role in stabilizing China's power system, which relies increasingly on intermittent green power. As China focuses on the challenges to reduce imported fossil fuels, we view an affordable renewable energy system, equipped with sufficient energy storage and smart grid transmission, as China's long-term solution to achieving energy self-sufficiency (Exhibit 35). Amid regional protective policies like the US IRA and, as a result, growing difficulty for China to export the surplus in clean energy capacities, we expect China's installed renewable capacities to be almost triple that of government plans by 2030E (Exhibit 36). We expect solar and battery innovations and cost declines to make this faster green electrification economically-viable (Exhibit 37). To cope with the growing renewable intake, our hourly power balance model indicates that China's power system would require c.520 GW of energy storage by 2030E, of which we expect c.410 GW to come from batteries (70 times that of 2021, Exhibit 38); the power model also indicates that 3.5 hours of battery discharge per day will be required for the 2030E peak demand week, which in turn guides our assumption for battery discharge hours for new battery installation (Exhibit 39).

Exhibit 36: We expect China's renewable capacities to be almost triple that of government plans by 2030E and faster green electrification...



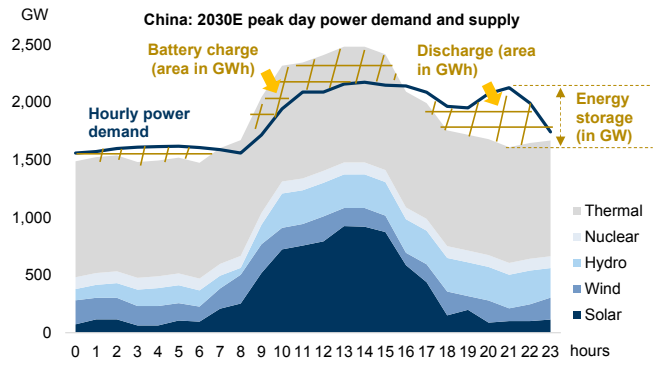
Source: Wind, CEC, Goldman Sachs Global Investment Research

Exhibit 37: ...facilitated by solar and battery innovations and cost declines which should allow enough increase in battery installation for stable power supply



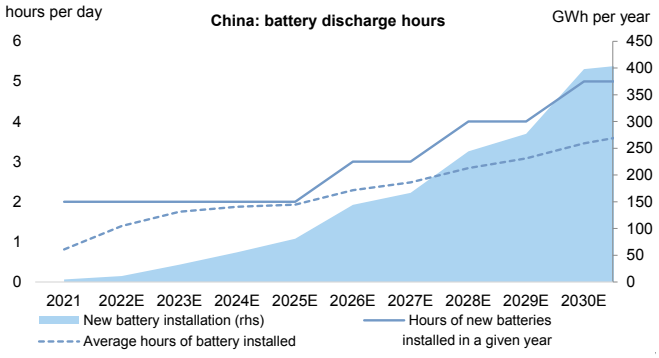
Source: Company data, Goldman Sachs Global Investment Research

Exhibit 38: Our hourly power balance model suggests that China would require c.520 GW of energy storage by 2030E



Source: Ren et al. (2022), Xin et al. (2022), Wind, Goldman Sachs Global Investment Research

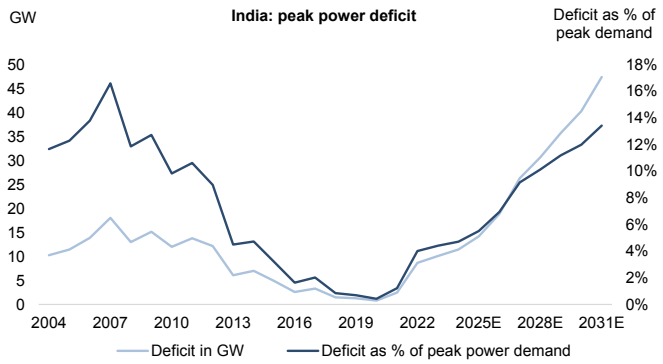
Exhibit 39: If hours of newly installed batteries reach 5h/d by 2030E, the average for installed batteries could reach 3.5 h/d as required for stable power supply in 2030E



Source: Company data, Wind, Goldman Sachs Global Investment Research

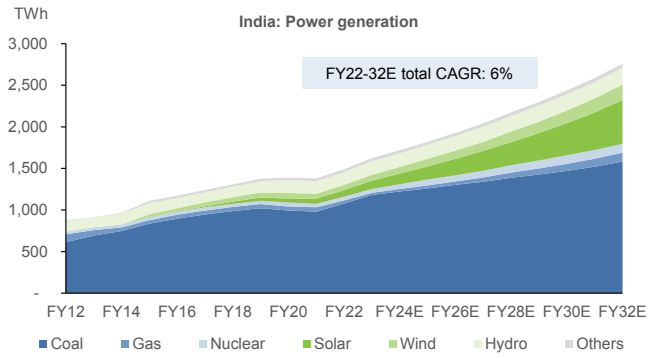
...as well as to energy storage in India. India's electricity sector is undergoing a generational shift in our view, as the country attempts to grow and decarbonize, simultaneously. Years of peak demand growth (rising electrification and appliances penetration) alongside less reliable capacity additions (renewables accounted for c.75% of new power capacity additions in the last 7 years) have absorbed the system's supply surplus. As such, we foresee the beginning of a peak power deficit cycle (Exhibit 40, see **India Clean Energy initiation** here and here). Our modeling estimates c.600 GWh storage demand by FY 2032E, of which we expect c.70 GWh to come from batteries, with the balance of demand being met by pumped hydro and incremental coal capacity addition.

Exhibit 40: For India, we foresee the beginning of a peak power deficit cycle



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 41: India's generation mix likely to be coal dominated over the next decade, even with significant planned renewable capacity addition



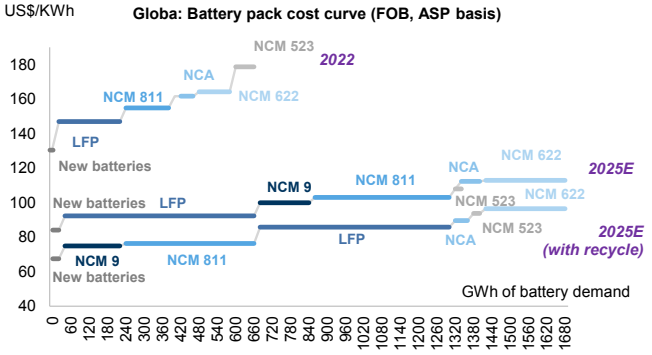
Source: CEA, Goldman Sachs Global Investment Research

#3 A tale of two battery markets and chemistries

As the world transitions to a low-carbon future, batteries are gaining critical importance from a national strategic perspective, given their pivotal role in energy supply. Meanwhile, battery supply chains remain geographically concentrated and susceptible to rising political tensions, with China dominating a large part of the supply chain. We see the passage of the Inflation Reduction Act (IRA) as a strong commitment from the US government to boost the self-sufficiency of batteries, which leads to regionalization of the global cell market – a US-Korea market which is more insulated from the China surplus and focused primarily on ternary batteries, and a China-Europe market which is well-supplied and focused increasingly on LFP batteries. Winners from this battery market regionalization in our view include the US battery self-sufficiency enablers like LG Chem (Buy, on CL), LGES (Buy), Samsung SDI (Buy), Panasonic (Buy) and Tesla (Neutral); whereas Chinese batteries producers like CALB and Gotion (both Sell-rated) could experience increased margin pressure, due to more difficulties in exporting the battery surplus.

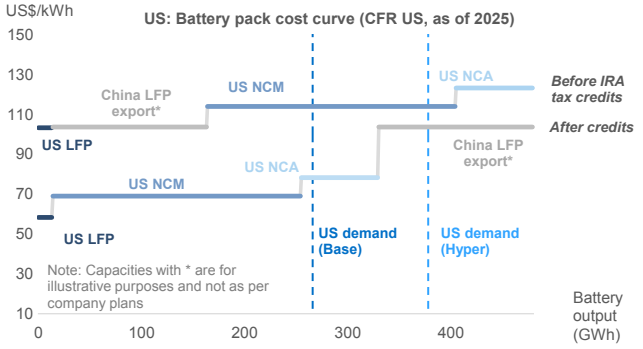
The US is strengthening the local battery supply chain. In response to China's dominance of the global battery supply chain and the country's competitive cost positioning in the global supply curves (Exhibit 35-Exhibit 42), the US government passed the 2022 IRA which offers significant tax credits to incentivize the local EV supply chain to phase out battery materials, components and cells from China (Exhibit 44). For example, Section 45X of the IRA has reshaped the battery cost curve in the US domestic market, by lowering costs of domestically manufactured batteries by US$45/kWh (US$35/kWh for cell and US$10/kWh for modules) against potential exports from China (Exhibit 43). We see the average eligible EV in the US receiving c.US$10,700 in IRA benefits from both Section 45X and 30D –which already covers the battery cost of a vehicle (Exhibit 45). As a result of such policies which strengthen local battery supply, we expect ex-China capacity expansion to accelerate and catch up with local demand growth by 2026E (Exhibit 46).

Exhibit 42: China's LFP batteries are competitively positioned in the global battery cost curve



Source: Company data, Wood Mackenzie, SNE Research, BNEF, Goldman Sachs Global Investment Research

Exhibit 43: The IRA effectively lowers the US domestic battery cost curve by US$45/kWh



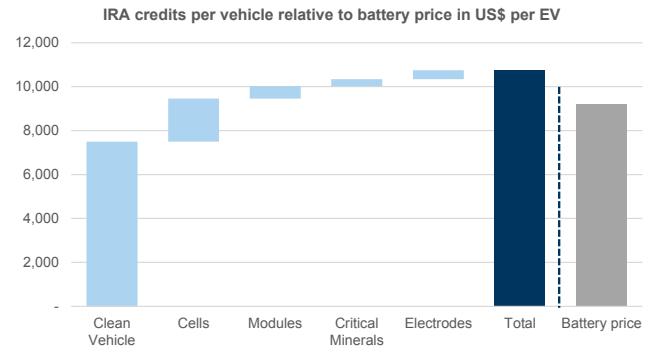
Source: Wood Mackenzie, SNE Research, Company data, Goldman Sachs Global Investment Research

Exhibit 44: The US IRA has encouraged the local EV supply chain to phase out battery components and cells from China, by offering tax credits for companies that manufacture cells in the US

Tax credits	Component	Location requirement	Max Credit	Unit	Direct Beneficiary
Clean vehicle credit (30D)	EV (meets critical minerals requirement)	Critical minerals were extracted or processed in a country that has a free trade agreement with the US, or recycled in North America.	3,750	USD per vehicle	Consumer
	EV (meets battery component requirement)	The battery's components were manufactured or assembled in North America.	3,750	USD per vehicle	Consumer
Advanced manufacturing production credit (45X)	Electrode active material	US domestic production and sale	10%	of production cost	Cathode/anode producer
	Battery cells	US domestic production and sale	35	USD per kWh	Cell makers
	Battery modules	US domestic production and sale	10	USD per kWh	OEM (e.g. Tesla)
	Critical minerals	US domestic production and sale	10%	of production cost	Critical minerals producer

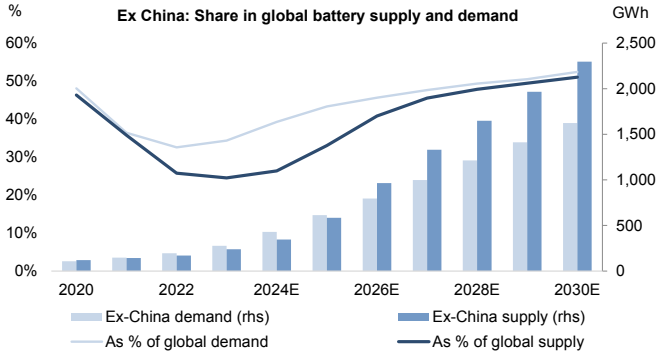
Source: Congressional Research Service, Goldman Sachs Global Investment Research

Exhibit 45: Overall IRA tax credits available for an average EV is higher than its corresponding battery price



Source: Company data, Goldman Sachs Global Investment Research

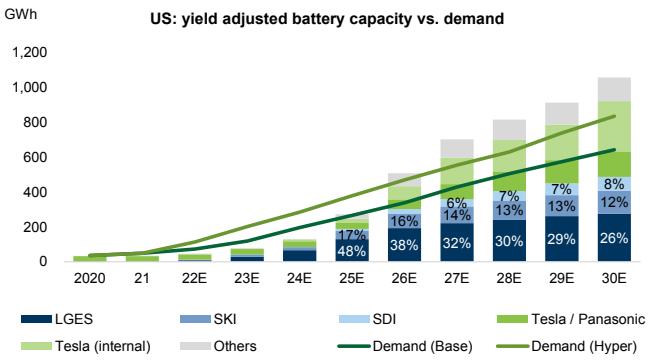
Exhibit 46: We expect ex-China capacity expansion to accelerate and catch up with local demand growth by 2026E



Source: Company data, Goldman Sachs Global Investment Research

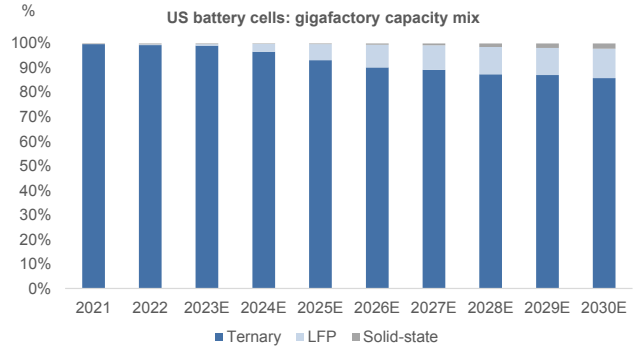
Korean cell producers are well positioned to leverage existing know-how and ramp up in the US. Based on projects already announced, we forecast Korean battery makers' market share in the US to grow from 12% in 2021 to 69% in 2025 (including stakes of JV partners, Exhibit 47). We see limited competition risks for Korean battery makers in the US in the near term, as the local ecosystem is still evolving while Chinese battery makers' expansion plans in the US have been limited. As such, we expect a relatively concentrated battery market in the US, with top cell manufacturers maintaining leadership over the longer term. Based on project announcements so far, most battery capacities ramping up in the US will be producing ternary lithium batteries (Exhibit 48).

Exhibit 47: We expect a relatively concentrated battery market in the US



Source: Company data, Goldman Sachs Global Investment Research

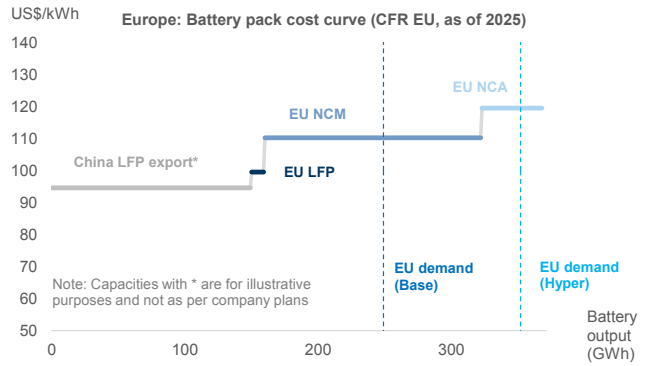
Exhibit 48: Most of the projects ramping up in the US will be producing ternary lithium batteries



Source: Wood Mackenzie

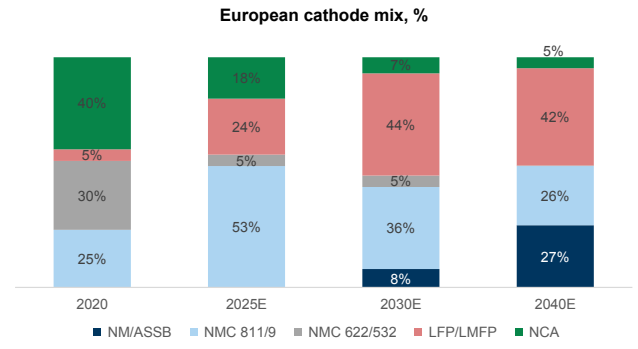
Europe still likely an end market for excess Chinese battery supply. Our EU team see 3 main reasons for this: (1) limited trade barriers to discourage Chinese imports, (2) rising demand for LFP batteries from the European mass market and (3) strong relationships between European OEMs and Chinese T1 battery makers. LFP battery exports from China remain the most cost-effective solution in Europe (Exhibit 49-Exhibit 50). We estimate additional costs of only US$2-3/kWh for selling Chinese-made batteries in Europe, factoring in freight costs and import duties, compared with c.US$12/kWh in additional costs to enter the US market; further, so far Europe has not constituted local content requirements for EV subsidies, whereas the US IRA credits of US$45/kWh is subsidizing locally manufactured batteries. Meanwhile, European OEMs are more open to LFP batteries (featuring shorter range), as European drivers typically travel shorter distances than those in the US (Exhibit 51). Lastly, despite LFP-based BEVs only starting to be deployed in Europe, Chinese cell makers have been long-time partners of European OEMs, especially for the German companies that generate large shares of their profits in the Chinese market (Exhibit 53). Therefore, China may be able to clear part of its battery surplus in Europe, leading to more aggressive competition and a more fragmented local market than the US (Exhibit 52).

Exhibit 49: LFP imports from China are the most cost-effective solution in Europe



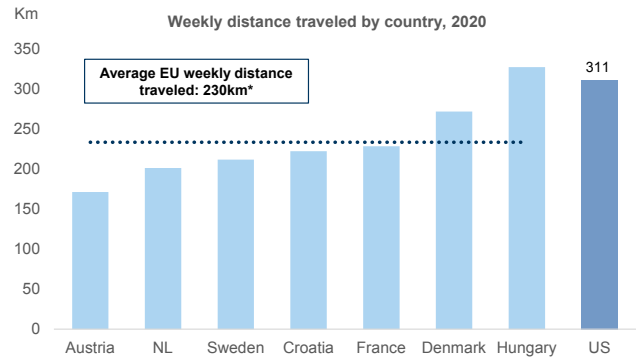
Source: Wood Mackenzie, SNE Research, Company data, Goldman Sachs Global Investment Research

Exhibit 50: Our Europe team expect 44% of European EVs in 2030E to come with LFP/LMFP batteries



Source: Goldman Sachs Global Investment Research

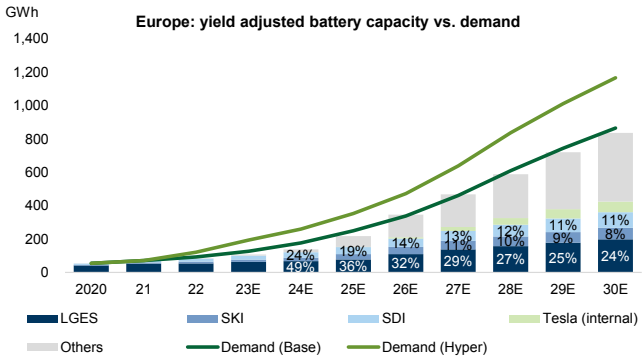
Exhibit 51: European drivers typically travel shorter distances than their US counterparts



*Average of major European countries listed in the chart; NL = Netherlands

Source: Acea, US Department of Transport

Exhibit 52: The European market may see more aggressive competition and a more fragmented market than the US



Source: Company data, Goldman Sachs Global Investment Research

Exhibit 53: Chinese Tier 1 battery makers have existing relationships and long-term contracts with Europe
OEM battery sourcing matrix as of 2Q23

	Volkswagen	Stellantis	Renault	Mercedes	BMW	Volvo Cars
Chinese battery producer						
CATL		Direct supply		Direct supply	Direct supply	Direct supply
Envision AESC			Direct supply	Direct supply		
Farasis				Direct supply		
Gotion	Direct supply					
SVOLT		Direct supply				
Ex-China battery producer						
ACC		JV		JV		
LGES	Direct supply	JV	Direct supply			Direct supply
Northvolt	Direct supply				Direct supply	JV
Samsung SDI		JV			Direct supply	
SK On	Direct supply					
Verkor			JV			
In-house	In-house					

Exhibit reflects principal sourcing strategies but may not be conclusive.

Source: Company data, data compiled by Goldman Sachs Global Investment Research

#4 Leading technology could drive pockets of strength

Although the recent round of intense capex investment globally has led to general oversupply in battery-related capacities, technology that is new or relatively difficult to replicate could still drive pockets of strength:

1. For technologies that could hit commercialization in the 2020s, we focus on novel anode materials (Si, Li metal) and battery structures (large cylindrical, bipolar) – Over 2023-25E, we expect producers to ramp up large cylindrical batteries, a new battery structure through which Tesla has reportedly achieved cost cuts of US$2,000-3,000 per pack; by 2024-25E, producers could start scaling-up capacity for Si-anode, a promising candidate to replace graphite and improve energy density; by 2026-27E, Toyota could start producing bipolar batteries, for which the company targets a 40% cost reduction vs. its conventional batteries. We are Buy-rated on EVE Energy, Daejoo, Toyota Motor as the respective leaders in large cylindrical batteries, Si-anode, and bipolar batteries; we are Sell-rated on QuantumScape, as its FCF could be under pressure before and during ramping into volume production for solid-state batteries.

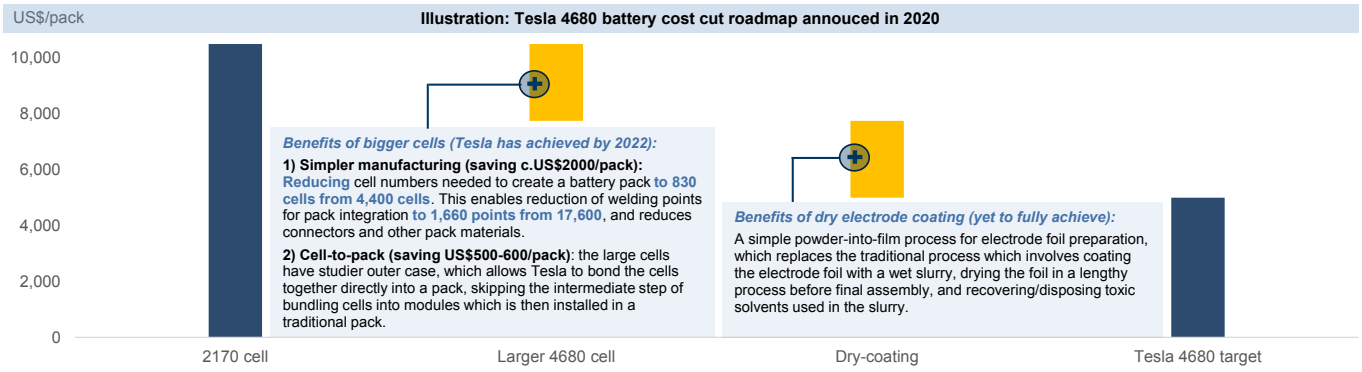
2. For technologies that have already been commercialized, we highlight that blade batteries are set to further empower BYD's EV competitiveness (Buy BYD), and that equipment constraints for separators and wider copper foil rolls (1.4m width vs. standard 1.0m width) have led to disciplined supply and healthy margins of leading producers of separators (Buy Yunnan Energy) and wide-roll copper foils (Buy SKC).

I. Multiple innovations could hit commercialization in the 2020s

Large cylindrical batteries – poised for mass production. Tesla's 2020 battery day highlighted its battery cost-saving strategies with potential cost-cuts of up to 56% – in 2022, the company has reportedly achieved around half of its target savings via switching to new 4680 cells (Exhibit 54). The 4680 cells, which are 46mm in diameter and 80mm in height, are 5.5 times the size of the current 2170 cells by volume. As the energy contained in each cell increases, a 4680 battery pack for Tesla Model Y would only need 830 cells, significantly less than the c.4400 cells required by a 2170 battery pack. Although the cell size increase alone may not significantly lift the energy density of a battery pack or the amount of energy the pack carries, the 80% reduction in the cell number per pack helps simplify the pack manufacturing process, leading to a meaningful savings of labor and machine time; further, the sturdier outer case of large cells has allowed Tesla to bond the cells directly into a pack (cell-to-pack), skipping the intermediate step of bundling cells into "modules" which is then installed in a traditional pack (cell-module-pack). Currently, Tesla is in the process of ramping internal capacity of 4680 cells in Texas and has plans to add in-house 4680 battery capacity in Nevada. Besides Tesla, multiple cell makers have announced targets to mass produce large cylindrical batteries over 2023-25E, with combined capacity at 12%/31% of 2025/30E global battery demand (Exhibit 55). We believe **Buy-rated EVE Energy** is a leader in developing high-end big cylindrical batteries, and is well-positioned to penetrate into

China's high-end EV battery market.

Exhibit 54: Tesla has reportedly achieved cost cuts of US$2,000-3,000 per pack, mainly via switching to new 4680 cells



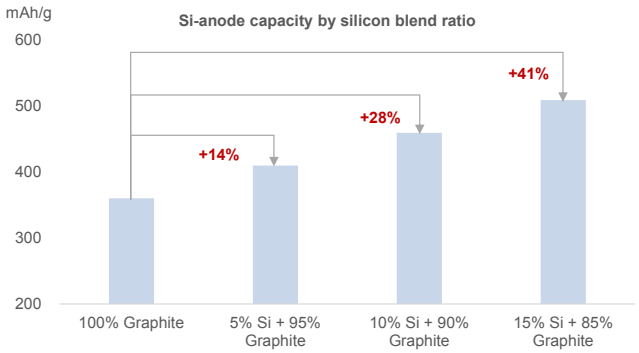
Source: Reuters, Tesla 2020 battery day

Exhibit 55: Producers have targeted to mass produce large cylindrical cells over 2023-25E

	Mass production	2025E capacity	2030E capacity	Partnership
		GWh	GWh	
Tesla	2023E	60	310	Tesla
EVE Energy	2023E	20	100	BMW, China local
LGES	2H24E	9	179	Tesla
Panasonic	2024E	40	120	Tesla, GM
CATL	2024E	40	110	BMW, Tesla, China local
Samsung SDI	2025E	1	141	BMW, GM
Subtotal		**170**	**960**	
% global EV battery demand		**12%**	**31%**	

Source: SNE Research, Company data, Goldman Sachs Global Investment Research

Exhibit 56: Blending silicon could significantly improve anode capacity

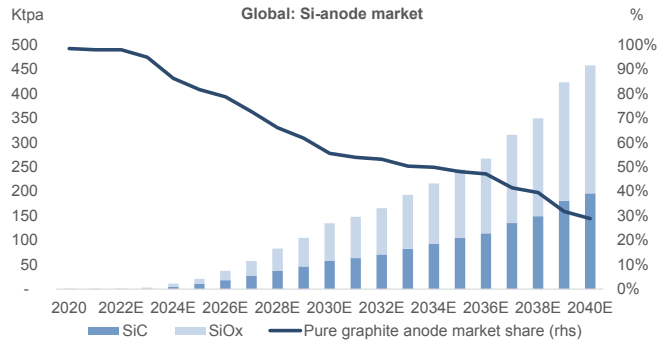


Source: Goldman Sachs Global Investment Research

Si-anode – becoming a necessity rather than an option. Graphite has been extensively used as an active anode material for lithium-ion batteries (LiBs) owing to its low cost and good cycle life. However, due to its low theoretical capacity of 372mAh/g, graphite cannot meet the increasing requirements for high energy density. Silicon (Si) is considered a promising candidate to replace graphite, due to its (1) high theoretical capacity of 4,200mAh/g, which means it can store up to 10X more lithium compared to graphite, (2) abundant reserves and low cost, and (3) relative environmental friendliness (link). Blending silicon with graphite can increase energy density and improve battery performance of LiB cells (Exhibit 56). The Si-anode industry is still at an early stage, with only a handful of commercialization cases. With battery cell makers and automakers announcing plans to adopt Si-anode technology for their next-generation batteries/vehicle models, multiple companies are developing Si-anode technology with plans to build mass production-level capacity by 2024-25E. Our auto team expects the Si-anode market to see steep growth at 220%/83% CAGR by 2025E/31E to US$1bn/US$5.5bn (Exhibit 57), with (1) the growing number of EVs, (2) higher Si-anode adoption rate, and (3) higher silicon blend ratio within anode as three multipliers driving growth. We believe **Daejoo (Buy-rated)** is well-positioned to capture a larger share of

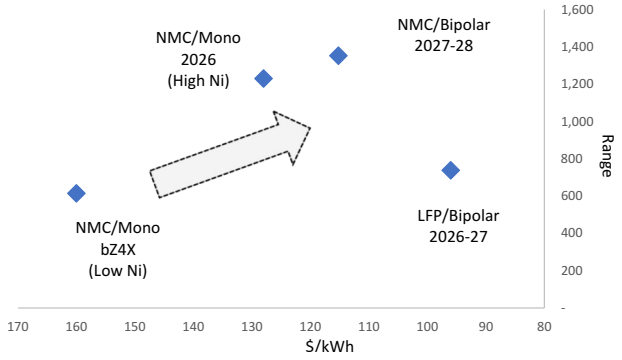
the Si-anode market, as the first company globally to commercialize high-efficiency Si-anode for LiBs.

Exhibit 57: We expect the global silicon anode market to grow at 220%/83% CAGRs until 2025E/31E



Source: Goldman Sachs Global Investment Research

Exhibit 58: Our auto team expects Toyota's bipolar batteries to achieve significant cost savings and range improvement



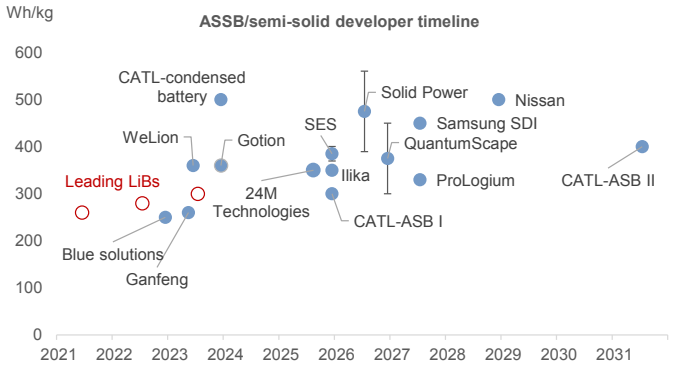
Source: Goldman Sachs Global Investment Research

Bipolar batteries – Toyota Motor in highlight. Our auto team expects mass production of Toyota's bipolar batteries, aimed at 2026-27 for LFP series and 2027-28 for NCM, to be a key enabler for Toyota to reach its 2030 EV sales target (3.5 mn EV sales vs. c.20,000 in 2022). Compared with Toyota's current batteries (batteries for Toyota BZ4X EV), our auto team expects Toyota's bipolar batteries to achieve significant cost savings and range improvement (Exhibit 58). The bipolar structure itself has been researched and developed for over 20 years, but no other manufacturer has embarked on commercial output due to the difficult production process (see below in ***Box: Bipolar batteries – benefits and challenges***). Toyota has already started commercial production of nickel-hydride bipolar batteries, developed together with Toyota Industries. As such, our auto team thinks the company has laid the groundwork to beat rivals to commercially produce bipolar batteries using LFP and NCM. We are **Buy-rated on Toyota Motor**, as we see the company as one of the few automakers globally capable of constructing a vertically integrated model for electric vehicles, including batteries and vehicle energy efficiency technology. We think strong EV products are the missing piece of Toyota's multi-pathway strategy (powertrain diversity), and we see this as a potential catalyst for a share price re-rating.

Solid-state & semi-solid batteries – a tough path towards scaling-up. In the past few months, more plans have been announced to mass produce semi-solid or solid-state batteries over the coming decade. For example, CATL announced in April that it is getting ready to mass produce CATL Condensed Battery before 2023-end, the cell energy density of which could reach 500 Wh/kg, much higher than the c.300 Wh/kg density of the leading LiBs; ProLogium announced in May a plan to invest €5.2 billion for a new solid-state gigafactory, which is set to reach mass production by 2027; Samsung SDI in 1H23 completed a fully automated pilot line for solid state batteries. Looking at the updated timeline, a number of Chinese cell makers are targeting ramp-up as early as 2023, while ex-China developers are mostly targeting mid/late 2020s (Exhibit 59-Exhibit 60). Despite the near-term ramp-up plan of the Chinese battery makers, we note the high costs of the new batteries could lead to limited adoption by OEMs in the next few

years, e.g. the volume remains low for WeLion's semi-solid battery sales to NIO, and that CATL is considering electric passenger aircraft as a likely end market for the condensed battery, and has formed a partnership with the Chinese aircraft manufacturer COMAC. As per Samsung SDI, while the cost for their solid state batteries may not exceed 2-3 times of their conventional batteries, the price could be expensive which it sees as more compatible with high-end EVs. We are **Sell-rated on QuantumScape** – we see its FCF under pressure before and during ramping into volume production for solid-state batteries in the latter part of the decade.

Exhibit 59: Multiple producers plan to mass produce semi-solid or solid-state batteries over the coming decade



Source: Company data, Wood Mackenzie, SNE Research, Goldman Sachs Global Investment Research

Exhibit 60: Companies are targeting to achieve commercialization using different technologies

	Anode	Electrolyte/separator	Cathode	Energy density		Commercialization	Partnership
Solid/Semi-solid state batteries potentially using Li metal/Si anode				Wh/kg	Wh/L		
Blue Solutions	Li metal	Solid electrolyte (polymer)	LFP	250	Not disclosed	Current	Mercedes
CATL	Si (estimated)	"Condensed battery"	Not disclosed	500	Not disclosed	2023	COMAC
	C-Si	Solid electrolyte (sulfide)	NCM	300	Not disclosed	2025	Not disclosed
	C-Si/Li metal	Solid electrolyte (sulfide)	NCM	400	Not disclosed	After 2030	Not disclosed
Ilika	Si	Solid electrolyte (oxide)	LCO	350	1000	2025	Toyota
SES	Li metal	Anode coating + proprietary liquid electrolyte + commercial separator	Commercial cathodes	370 (400+ projected)	700 (1000+ projected)	2025	GM, Hyundai
Solid Power	Li metal/Si	Solid electrolyte (sulfide) + solid catholyte/anolyte	NCM	390-560	785-930	2026	BMW, Ford, SK On
QuantumScape	Li metal	Solid electrolyte (ceramic) + gel catholyte	Nickel cathode	300-450	750-1100	Latter part of the decade	Volkswagen
Toyota	Not disclosed	Solid electrolyte (sulfide)	Not disclosed	Not disclosed	Not disclosed	2027-2028	Panasonic, PPES
Samsung SDI	Li metal	Solid electrolyte (sulfide) + Ag-C separator	NCA	450	900	2027	Many
ProLogium	Li metal/Si	Solid electrolyte (oxide) catholyte/anolyte	NCM	330	850-880	2027	Mercedes-Benz, NIO
Nissan	Li metal	Solid electrolyte (sulfide) + special protective films for anode + multilayer technologies to curb interface degradation	Cobalt-less cathode	c.500	c. 1000	2028	Renault, Mitsubishi
LGES	Li metal	Not disclosed	Sulfur-Carbon	Not disclosed	c.900	Beyond 2025	Many
	Not disclosed	Solid electrolyte (polymer)	Not disclosed	Not disclosed	600	2026	Many
	Not disclosed	Solid electrolyte (sulfide)	Not disclosed	Not disclosed	900	2030	Many
Honda	Not disclosed	Not disclosed	Not disclosed	Not disclosed	Not disclosed	2028	SES (& independent research)
SVOLT	Not disclosed	Solid electrolyte (sulfide)	Not disclosed	350-400	Not disclosed	Not disclosed	Not disclosed
Solid/semi-solid state batteries using other anodes							
WeLion	C-Si	Solid and liquid electrolyte + commericial separator	NCM (add LiTFSI, LLZTO)	360	Not disclosed	2023	NIO
Ganfeng	C-Si	Solid (oxide) and liquid electrolyte separator	NCM	260	Not disclosed	2023	Dongfeng
Gotion	Not disclosed	Not disclosed	LFP	360	Not disclosed	2023	Volkswagen
24M Technologies	Anolytes	Anolyte, catholyte + separator	LFP/NCM	350+	Not disclosed	2025	FREYR
	Li metal			450	Not disclosed	Not disclosed	Not disclosed

Source: Company data, Wood Mackenzie, Goldman Sachs Global Investment Research

II. Commercialized technologies that are still leading

Blade batteries empower BYD's EV competitiveness. Our auto team see vertical integration (especially battery cell) to be a key advantage for **BYD (Buy-rated)** to empower and strengthen the competitiveness of its EVs. BYD was established as a battery supplier to cell phone and laptops in 1995; in 2003, BYD started its auto business and integrated its battery technology into the world's first mass-produced PHEV model F3 DM. After 25 years of development in the battery field, BYD launched its LFP-based blade battery which utilizes the cell-to-pack approach. Although LFP batteries are generally cheaper than NCM batteries, they typically see energy density discounts of up to 30% vs. NCM batteries. However, BYD was able to narrow the gap by 10-15% using the blade battery cell-to-pack approach, enhancing the cost advantage of LFP batteries. Meanwhile, since LFP batteries operate at lower voltages than NCM batteries, the BYD blade batteries manage heat well in nail penetration tests and set new standards for EV battery safety. Facilitated by its blade batteries, our auto team expect BYD's power battery market share to expand, with installation volumes increasing from 72 GWh in 2022 to 204GWh in 2025E, implying 41% 3-year CAGR. With the company's deeply vertically integrated business model, its comprehensive product portfolio, and strong in-house capabilities enabling continued vehicle technology

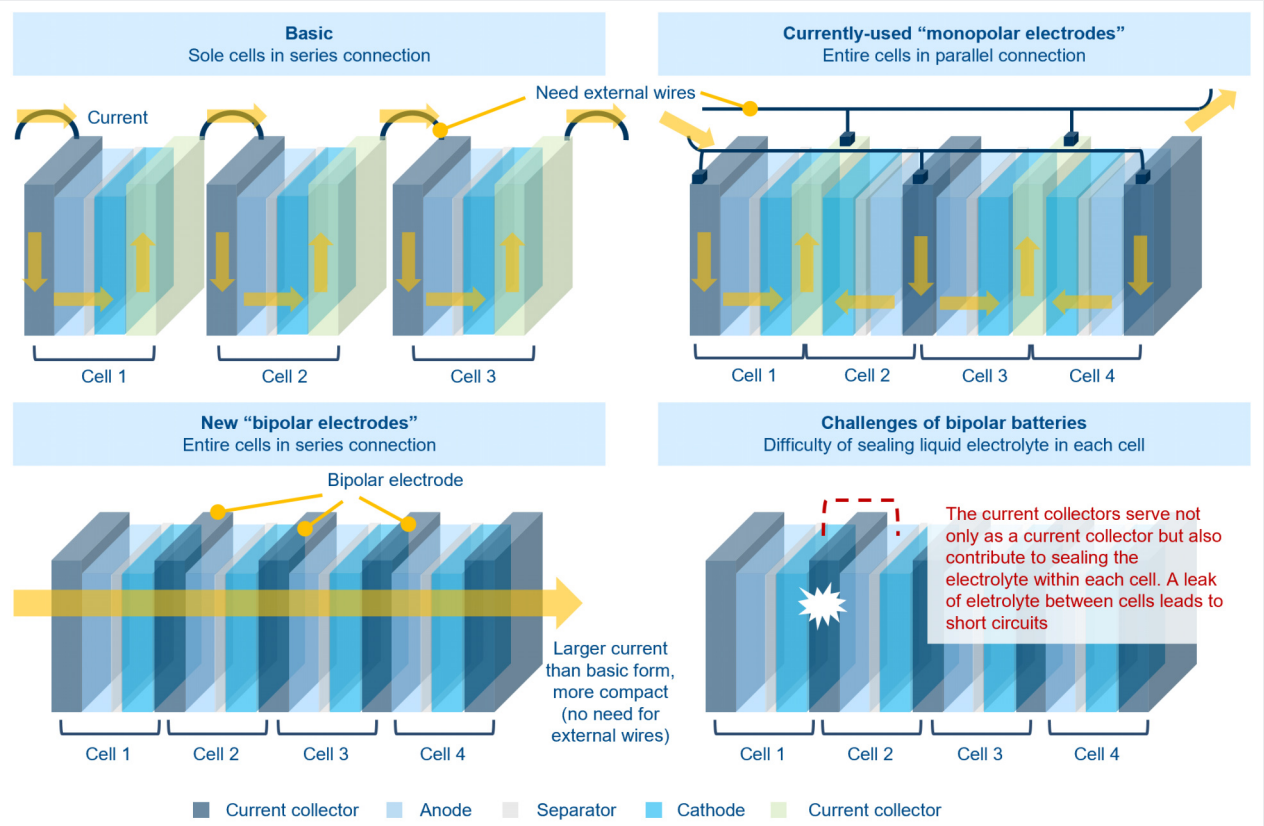
innovation, our auto team expect BYD to grow its total vehicle sales volume from 3.1mn in 2023E to 7.8mn in 2030E, capturing 1/3 of China's new energy vehicle wholesale demand.

Equipment constraints benefit top producers of separator and wide-roll copper foils. As per GGII, while China has localized c.90% of equipment for battery manufacturing, a few exceptions include equipment for separators and premium wide-roll copper foils. Currently, the equipment supply for these two types of products remains highly concentrated, with 2-3 Japanese and French manufacturers accounting for a major share of the market (see here and here). The leading producers of separators (Yunnan Energy) and wide-roll copper foils (SKC), via leveraging their industry positioning and scale, have both secured long-term equipment supply with the upstream manufacturers despite the industry equipment shortage. As such, we expect **Yunnan Energy (Buy-rated)** and **SKC (Buy-rated)** to be the few examples in the battery supply chain that enjoy both volume growth and healthy margins, thanks to upstream equipment shortages containing downstream competition. That said, new equipment suppliers are emerging in China. Hongtian Technology, acquired by Suzhou Douson in 2022, has announced breakthroughs in super-sized copper foil equipment, achieving an equipment diameter of 3 meters and a width of 1.82 meters; OK Technology, dedicated to localize separator equipment manufacturing in China, is ramping up its first production line in 2023. We are closely monitoring how their commercialization proceeds.

Box: Bipolar batteries – benefits and challenges

- **Benefits:** Bipolar is another step in the battery structure optimization (Exhibit 61) – the previous switch from the basic structure to the now commonly used "monopolar electrodes" (referring to the current collector being coated with the same active material on both sides) has led to higher efficiency, via reducing the use of current collector and electrolyte, as well as saving space for more active materials in the battery pack. "Bipolar electrode" (referring to the current collector being coated with cathode on one side and anode on the other side) further simplifies the battery structure, enabling electron transfers between the cathode and the anode to occur through the current collectors without external wires. The resultant shorter electron transfer leads to less energy wasted to tackle resistance. As a result, bipolar structures allow the battery to become more compact and stronger in power.
- **Challenges:** To date, the major hurdle to mass produce bipolar batteries is the difficulty of sealing liquid electrolyte in each cell, the failure of which could lead to ionic short circuits between cells (Exhibit 61). The sealing of electrolyte for bipolar batteries is different from conventional LiBs – for example, current collectors for bipolar batteries serve not only as current collectors but also contribute to sealing the electrolyte within each cell. We note Toyota has achieved mass production of nickel-metal hydride bipolar batteries, showcasing the producer's capability of adopting such sealing technology.

Exhibit 61: Bipolar structures allow the battery to become more compact and stronger in power



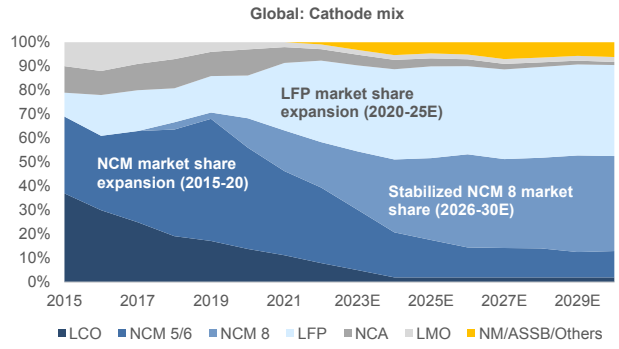
Source: Liu et al. (2020), Goldman Sachs Global Investment Research

#5 Homogeneous competition in parts of the battery supply chain

We observe an increase in homogenization of products in parts of the battery supply chain – notably in cathodes, electrolytes and separators. Such homogeneity in a competitive surplus environment – like in the cathode and electrolyte markets – poses challenges to producer margins. We believe the margin risks have not been fully reflected in the valuation of our Sell-rated Posco Future M (NCM cathode), Ecopro BM (NCM cathode), Zhenhua (NCM cathode) and Tinci (electrolyte). Similar competition-induced downside risks can be seen in the battery equipment market, where demand is slowing due to decelerating EV demand growth and a global battery market heading into a surplus. We see stock valuations as stretched for our Sell-rated Hymson (laser filming equipment and battery cell assembly line) and United Winners (laser welding equipment).

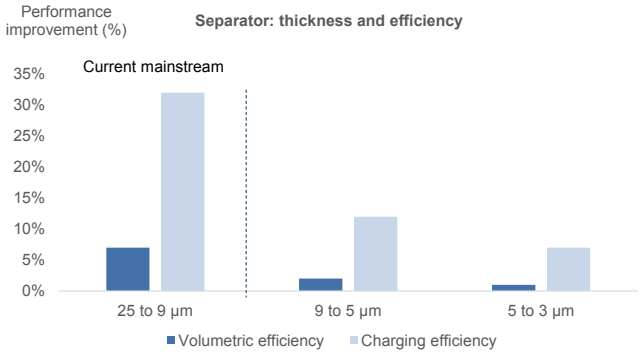
As innovation slows, product becomes homogenized. Over the past decade, the battery chemistry mix has undergone significant changes when the NCM and LFP cathodes took over the market share of LCO, and when NCM evolved from the lower nickel versions of NCM 5/6 to higher nickel versions of NCM 8/9 (Exhibit 62). As the chemistry changes slow down, the battery structure stabilizes, and the market expands for each type of battery & component, we observe an increase in homogenization of products in parts of the battery supply chain – notably in cathodes, electrolytes and separators. For cathodes, we see the NCM technology at risk of approaching maturity, with suppliers now having largely similar products and strategies (Exhibit 64); for electrolytes, "mainstream" products have emerged to serve the mass market demand, with extra profit from tailored recipes declining; for separators, technology is also maturing – the thickness of a mainstream separator has been reduced from c.20μm in 2018 to 7-9μm today, with limited performance upside to go thinner (Exhibit 63). Such homogeneity in a competitive surplus environment – like in the cathode and electrolyte markets – poses challenges to producer margins (Exhibit 65-Exhibit 67). We believe the downside margin risks have not been fully reflected in the valuation of our **Sell-rated Posco Future M** (NCM cathode)**, Ecopro BM** (NCM cathode)**, Zhenhua** (NCM cathode) and **Tinci** (electrolyte).

Exhibit 62: The battery chemistry mix has undergone significant changes over 2015-20 and is now stabilizing



Source: SNE Research, Company data, Goldman Sachs Global Investment Research

Exhibit 63: The upside potential for thinner separators is becoming limited



For charging efficiency, we refer to Dominik V. Horváth et al 2022 J. Electrochem. Soc. 169 030503

Source: Goldman Sachs Global Investment Research

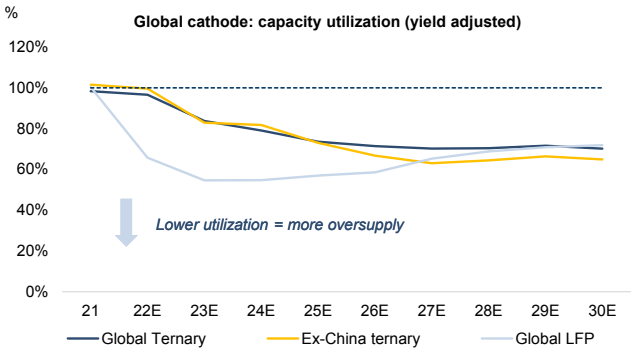
Exhibit 64: As a reflection of the NCM technology at risk of approaching maturity, suppliers now have largely similar products and strategies

Color code: same color for similar products

	Cathode makers			Integrated cathode-to-cell producer
	Ecopro BM	**L&F**	**Posco Future M**	**LG Chem**
Current	Mainly Ni>80% NC(M)A	Mainly Ni c.90% NCM(A)	Mainly Ni 60% NCM, Ni 80% NCM, NCMA	Mainly Ni 60% NCM, some Ni 80% NCM
2023	Commercialize **Ni 94% high nickel cathode**; pilot production of **single crystal cathode** and **LFP cathode**		Pilot production of **Ni 96% high nickel cathode** by year-end	
2024	Mass production of cobalt free (NMx) cathodes with 70-90% Ni & high voltage	Mass production of **single crystal cathode**; commercialize **Ni 95% high nickel NCMA**	Mass production of **Ni 96% NCM**	No specific timeline, but are developing: **Ni 95% high nickel cathode**, **single crystal cathode**, **high voltage NCM (Mid-Ni)**, **LFP**, and **Mn-rich cathodes.**
2025	Commercialize cathodes that are Li & **Mn rich**, Ni 30-45%, cobalt less or free	Commercialize **high voltage Ni 60% NCMA**; mass production of **LFP**		
2026	Mass production of sodium and **LFP cathodes**			

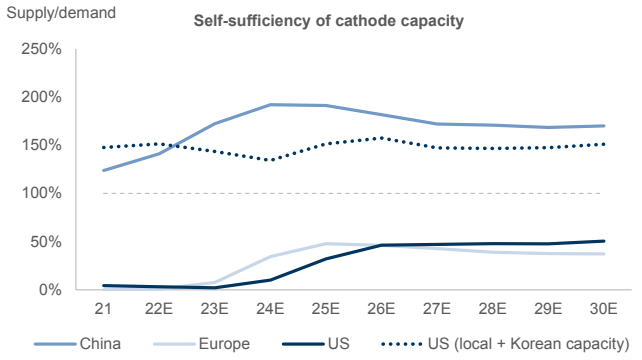
Source: Company data

Exhibit 65: From a global cathode market perspective, we expect a decade-long cathode surplus ahead...



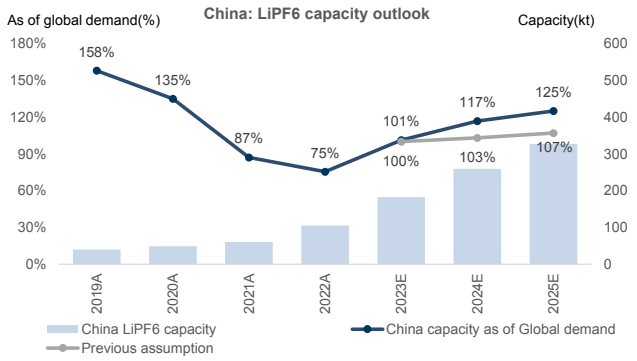
Source: Wood Mackenzie, Company data, Goldman Sachs Global Investment Research

Exhibit 66: ...from a regional cathode market perspective, we see no signs of a US market deficit even after cutting out China



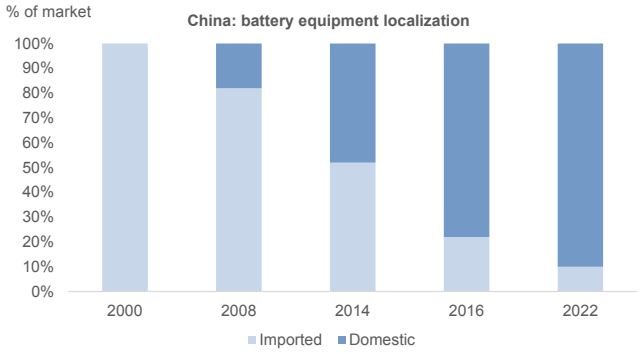
Source: Wood Mackenzie, Company data, Goldman Sachs Global Investment Research

Exhibit 67: China's LiPF6 supply addition has been faster than our expectation



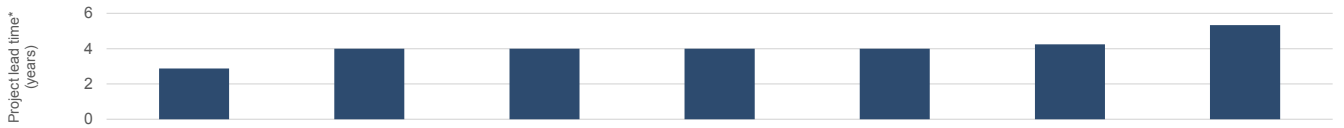
Source: Company data, Goldman Sachs Global Investment Research

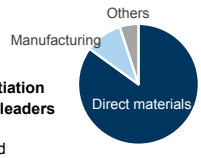
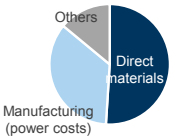
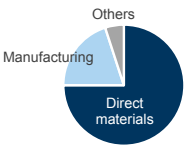
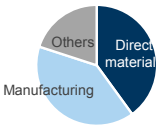
Exhibit 68: China scaled up domestic production of battery equipment over 2002-07



Source: Company data, GGII, Goldman Sachs Global Investment Research

Exhibit 69: Cell assembly requires longer preparation time for new entrants and a onger lead time to ramp up new projects



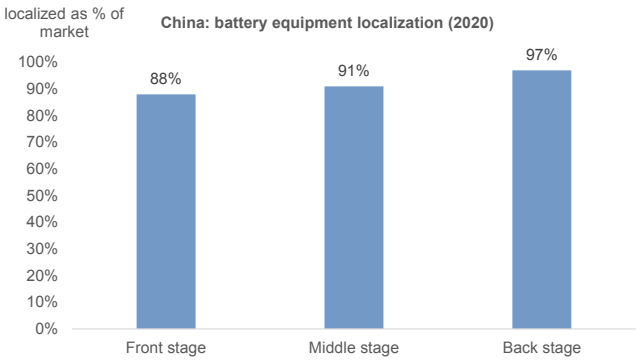
Hurdles	Eletrolyte (LiPF6)	Anode	Ternary cathode	LFP cathode	Ternary precursor	Separator	Cell assembly
Raw material /equipment access	China supplies c.2/3 of world's fluorine; large suppliers like Tinci has **integrated the full supply chain for LiPF6**	China accounts for c.80% of global graphite mining; suppliers mainly rely on **external raw material supply**	Some large producers have extended into precursor making, but still **need to buy from key precursor makers for precursor raw materials (Ni/Co)**; mainly rely on **external Li supply**	Suppliers mainly rely on **external Li supply**; some large suppliers have **internalized Fe precursor supply** (still rely on external precursor raw materials, e.g. Fe, but easier to source than Ni/Co)	Large suppliers like CNGR, GEM and Huayou have **either internalized or extended equity holdings** into raw materials (Ni/Co supply)	Separator capacity is constrained by high-profile separator equipment capacity. Large producers like Yunnan Energy have secured **dedicated equipment supply**	Some large suppliers (e.g. LG Chem/LGES) have **extended equity holdings** into metals, cathodes and other battery components
Technology know-how	Requires **3-5 years** of experience before ramping up	Requires **4-5 years** of experience before ramping up	Requires **2-5 years** of experience before ramping up; requires another 2-3 years to move on to high Ni - total **4-8 years for high Ni cathode**	Requires **3-6 years** of experience before ramping up	Requires **3-5 years** of experience before ramping up	Requires **3-5 years** of experience before ramping up	Requires **10+ years** of experience before ramping up
Dangerous materials	**Skills** to handle toxic Hydrofluoric Acid (HF) and PCl5 which could react with water to generate strong acid (HCl)	**Skills** to handle toxic Hydrofluoric Acid (HF)	**NA** (unless integrated with upstream precursor production which involves **skills** to handle dangerous materials)	The integration of upstream precursor requires **skills** to handle strong alkali (NaOH) and strong acid (H3PO4) to produce FePO4	**Skills** to handle strong alkali (NaOH) and strong acid (H2SO4)	**Skills** to handle toxic CH2Cl2	**Skills** to handle toxic N-methyl pyrrolidone (NMP)
Differentiation for cost leaders (from end product COGS breakdown perspective)	 Leaders have an advantage in the integrated supply chain during raw material shortages, but are less beneficial during material oversupply	 High share of power costs in COGS leads to **more obvious advantage for cost leaders** (Chinese producers enjoy lower power prices)	 High share of direct material cost which is linked to externally purchased raw metal materials leads to **less distinction in cost among producers**	 Cost leaders have an **advantage** in internalized precursors and other opex/capex (opex/capex costs lower in China)		 High share of manufacturing/other costs leads to **more obvious advantage for cost leaders** (opex/capex costs lower in China)	

*The project lead time includes time needed for feasibility study, construction and ramp-up

Source: Company data, Goldman Sachs Global Investment Research

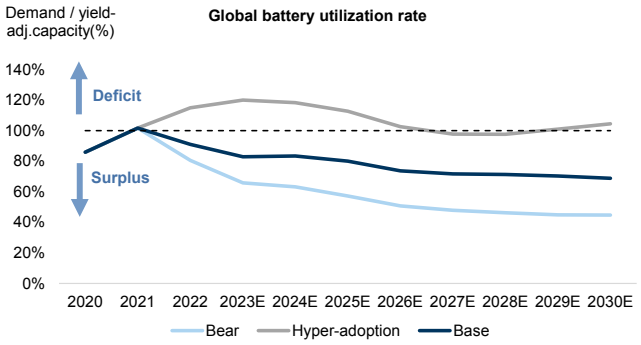
Intense battery equipment competition amid slowing demand. The localization of battery equipment production in China, pilot studies of which started in the late 1990s and ramped up over 2002-07, has been a core enabler for the country to produce cost-competitive battery products in scale (Exhibit 68). Currently, China has localized c.90% of equipment for battery manufacturing – for the front-stage equipment, where the entry barrier is relatively high, China's localization rate is below 90%, as manufacturers are still catching up with leading overseas producers for high-end equipment; for the middle and back-stage equipment, where the entry barrier is relatively low, China's domestically produced equipment has reached the international advanced level (Exhibit 70). Multiple Chinese producers participate in different segments of battery equipment manufacturing, with limited cases of a manufacturer exclusively owning a certain technology (Exhibit 72). Within such a competitive landscape, we believe equipment makers will see declining margins in 2023E-25E amid slowing demand. Specifically, we expect the growth in the global battery equipment TAM, the second derivative of growth in battery demand, to see a deceleration to +3% yoy in 2023E (from +97%/+29% in 2021/2022E). This is driven by our auto team's expectation of EV growth deceleration heading into 2023E, as well as the view that the global battery market is heading into a surplus after several years of aggressive capacity expansion (Exhibit 71). We see stock valuations as stretched for our **Sell-rated Hymson** (laser filming equipment and battery cell assembly line) and **United Winners** (laser welding equipment).

Exhibit 70: China has localized c.90% of equipment for battery manufacturing



Source: Huaon

Exhibit 71: The global battery market is heading into a surplus



Source: Wood Mackenzie, SNE Research, Company data, Goldman Sachs Global Investment Research

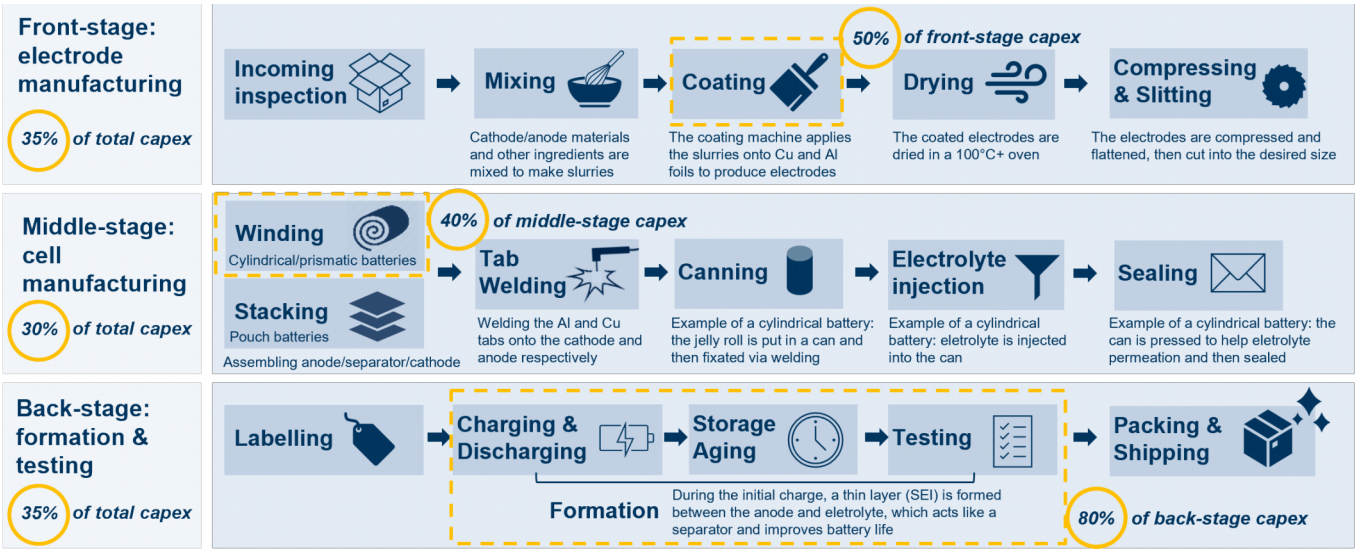
Exhibit 72: Multiple Chinese producers participate in different segments of battery equipment manufacturing (as of Sept 2023)

Company	Front stage: electrode manufacturing				Middle stage: cell manufacturing				Back stage: formation & testing		
	Mixing	Coating	Compressing	Slitting	Winding	Stacking	Welding	Sealing	Formation	Testing	Packing
Lead Intelligent	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Yinghe	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes
Kanhoo	Yes	Yes	Yes	Yes	Yes					Yes	Yes
Golden Milky Way	Yes	Yes	Yes	Yes	Yes						
Han's Laser		Yes					Yes				Yes
NAURA	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes
Putailai	Yes	Yes		Yes							
Hymson		Yes		Yes	Yes			Yes			
United Winners							Yes				
Nebula									Yes	Yes	
Hangke									Yes	Yes	Yes
Noblelift											Yes
New Trend											Yes

** Highlight for our Sell-rated companies*

Source: Company data, data compiled by Goldman Sachs Global Investment Research

Exhibit 73: Lithium battery manufacturing process



Source: Company data, Huaon, Goldman Sachs Global Investment Research

Stock highlights

Exhibit 74: Buy and Sell ideas to play the battery themes

Share price as of 27-Sep-23

Analyst	Ticker	Company	Rating	Share P.	Target P.	Upside (%)	Mkt Cap (US$bn)	2023E***		2023-25E	Description
								EV/EBITDA (X)	PE (X)	Net inc. CAGR	
Energy storage demand accelerating											
Jacqueline Du	002837.SZ	Envicool	Buy*	Rmb 26.3	Rmb 49.5	89%	2.1	31.2X	34.2X	43%	Specializes in precision cooling technology, helping data centers/ESS to operate in a highly controlled temperature environment; a major supplier of cooling equipment in ESS
Chao Ji	688390.SS	Goodwe	Buy*	Rmb 131.8	Rmb 290.0	120%	2.2	10.5X	14.0X	41%	A top-ranked inverter** manufacturer globally (solar inverter and ESS inverter)
The US IRA beneficiaries											
Nikhil Bhandari	051910.KS	LG Chem	Buy*	W 496,500	W 810,000	63%	28.7	7.6X	18.4X	90%	Leading chemical and battery company; its subsidiary LGES is one of the largest battery makers in the world
Nikhil Bhandari	373220.KS	LGES	Buy	W 476,500	W 620,000	30%	82.6	24.4X	54.0X	65%	LGES is the second-largest EV battery supplier globally and the largest outside China
Nikhil Bhandari	006400.KS	Samsung SDI	Buy	W 512,000	W 890,000	74%	25.4	10.6X	18.3X	30%	Leading battery and electronic materials manufacturer
Ryo Harada	6752.T	Panasonic	Buy	¥ 1,746	¥ 2,100	20%	26.2	5.4X	13.7X	12%	Offering a broad range of businesses with our key focus being its EV batteries
Innovations to hit commercialization in 2020s											
Eric Shen	300014.SZ	EVE Energy	Buy	Rmb 45.4	Rmb 60.8	34%	11.8	14.9X	18.1X	-9%	A leading producer of large cylindrical power batteries in China
Kee Ryung Kim	078600.KQ	Daejoo	Buy	W 83,700	W 110,000	31%	0.9	41.4X		227%	The first company globally to commercialize high-efficiency Si-anode for lithium-ion batteries
Kota Yuzawa	7203.T	Toyota Motor	Buy	¥ 2,748	¥ 3,200	16%	243.0	5.1X	9.9X	5%	Japan's largest global automaker introducing a series of battery/EV innovations including bipolar batteries
Commercialized technologies that are leading											
Tina Hou	1211.HK	BYD	Buy	HK$ 237.4	HK$ 321.0	35%	90.0	11.7X	23.8X	31%	A leading new energy vehicle maker both in China and globally.
	002594.SZ		Buy	Rmb 237.8	Rmb 336.0	41%		12.2X	25.0X		
Eric Shen	002812.SZ	Yunnan Energy	Buy	Rmb 60.6	Rmb 110.0	82%	7.3	10.1X	16.0X	35%	The largest battery separator supplier globally, with 1/3rd of global market share in 2022
Kee Ryung Kim	011790.KS	SKC	Buy	W 75,900	W 115,000	52%	2.1	26.2X		232%****	Leading copper foil maker which specializes in wide-roll copper foils
Difficulty for China to export capacity surplus											
Eric Shen	3931.HK	CALB	Sell	HK$ 19.9	HK$ 12.3	-38%	4.0	13.3X	36.9X	-73%	The 3rd-largest battery maker in China which has a low-margin-driven-growth business model
Eric Shen	002074.SZ	Gotion	Sell	Rmb 23.2	Rmb 22.6	-3%	5.5	16.5X	40.8X	-13%	Leading LFP battery producer in China, with a product mix mainly focusing on the price sensitive mini-van market
Homogeneous competition in surplus											
Nikhil Bhandari	003670.KS	Posco FM	Sell	W 359,500	W 240,000	-33%	20.6	79.5X	135.8X	52%	Leading Korean producer of cathode (NCM) and anode
Nikhil Bhandari	247540.KQ	Ecopro BM	Sell	W 253,000	W 120,000	-53%	18.3	52.0X	104.9X	43%	Leading Korean producer of cathode (NCM)
Eric Shen	688707.SS	Zhenhua	Sell	Rmb 23.4	Rmb 24.5	5%	1.4	12.9X	26.6X	70%	Chinese NCM cathode maker which is also ramping up sodium-ion cathode
Eric Shen	002709.SZ	Tinci	Sell	Rmb 27.2	Rmb 24.8	-9%	7.1	12.8X	20.8X	21%	Global leader in electrolyte and solvent materials in terms of sales volume
Jacqueline Du	688559.SS	Hymson	Sell	Rmb 44.5	Rmb 42.6	-4%	1.2	24.0X	19.4X	1%	Equipment supplier of high-speed laser filming equipment and battery cell assembly line
Jacqueline Du	688518.SS	United Winners	Sell	Rmb 23.9	Rmb 24.1	1%	1.1	16.5X	19.7X	5%	Leading supplier of laser welding equipment, focusing on battery applications
FCF under pressure before and during ramping into volume production											
Mark Delaney	QS	QuantumScape	Sell	Rmb 6.4	Rmb 5.0	-21%	2.9			Loss-making	One of the leaders in next-generation solid-state battery technology

* For stocks on our conviction list.
** An inverter turns the direct current output of a battery or solar panel into alternating current for end use or feeding into the grid.
*** For Japan-listed companies refers to 3/24E.
**** For 2025E vs. 2024E due to 2023 being loss-making.

TPs are on a 12-month time frame

Source: Refinitiv, Company data, Goldman Sachs Global Investment Research

Price target risks and methodologies

Exhibit 75: Price target methodologies and risks for our 21 highlighted Buys/Sells

Company	Price target methodology and risks
Envicool	Our 12-month target price of Rmb49.5 for Envicool is based on a 2024E P/E of 35x and discounted to 2024E with a CoE of 10.5%. Risks: (1) Tougher cooling technology competition; (2) Slower-than-expected liquid cooling penetration; and (3) Slower-than-expected end-market capex growth.
Goodwe	Our 12-month target price of Rmb290 for Goodwe is based on 15x 2025E EV/EBITDA and then discounted back to 2024E at an 8.5% CoE. Risks: Lower-than-expected market demand; lower-than-expected ASP; and slower-than-expected capacity expansion.
LG Chem	We are Buy-rated on LG Chem (on CL) with a 12-m 2024E SOTP-based (LGES: DCF-based with 8.4% WACC and 3.3% terminal growth rate; Petchem: 6.5x 24E EV/EBITDA; Advanced Materials: 17x 24E EV/EBITDA; Life Science: 14x 24E EV/EBITDA; other assets: 5.5x 24E EV/EBITDA) target price of W810,000. Key risks: (1) Lower earnings growth from the EV battery business due to slower capacity growth, weaker industry demand or higher raw material inflation, (2) larger fall in 2023 petchem margins, (3) slower growth in advanced materials capacity expansion, especially cathodes, (4) CROCI dilutive M&A (note LG Chem has expressed interest in M&A of various battery materials companies, per press reports).
LG ES	We are Buy-rated on LGES with a 12-m DCF-based (8.4% WACC, 3.3% terminal growth rate) target price of W620,000. Key risks: (1) higher-than-expected competition from OEMs and battery start-up companies, (2) higher-than-expected raw material cost, (3) further provision from potential EV/ESS battery recalls, (4) slower-than-expected ramp-up of new EV battery plants, and (5) lower-than-expected IRA credit capture rate.
Samsung SDI	We are Buy rated on Samsung SDI with a 2024E SOTP-based (xEV: DCF-based with 8.4% WACC and 3.3% terminal growth rate; Small-size Battery: 9x 24E EV/EBITDA; Energy Storage Battery: 14x 24E EV/EBITDA; Electronic Materials: 6x 24E EV/EBITDA; market/book value of listed/unlisted subsidiaries respectively), 12-month TP of W890,000. Key risks: Lower-than-expected global EV penetration rate growth, slower-than-expected shipment and market share growth in battery-related business, lower-than-expected battery business margins, lower EM business margins and a stronger-than-expected KRW:USD.
Panasonic	Our 12-month target price of ¥2,100 for Panasonic is based on EV/EBITDA of 5.5X (FY3/25E) based on the correlation between EV/EBITDA and CROCI. Risks: Lifestyle Updates Business: Decrease in demand for home and commercial air conditioning equipment. Panasonic Connect: Slow recovery in aircraft services, lower-than-expected sales growth at Blue Yonder, large impairment loss for Blue Yonder, changes in mounting system demand. Panasonic Energy: Loss of share to competitors in batteries for Tesla, slowdown in the EV market, increased price pressure on automotive batteries. Panasonic Automotive Systems: Lower-than-expected auto production volume. Panasonic Industry: Decrease in factory automation-related demand. Company-wide: Higher-than-expected investment and depreciation related to mass production of new automotive batteries, and inability to manage business portfolio based on clear KPIs over the medium/long term. FX fluctuations.
EVE Energy	Our 12-month P/E based target price of Rmb60.8 for Eve Energy is derived from an average of near-term and long-term valuation. We use the past 3-month average P/E of 20.2x for 2023E to arrive at a near-term valuation, while employing a 20.0x long-term P/E for 2030E and discounting back to 2023E at a COE of 10.8% to derive a long-term valuation (this includes a 1.3x premium to the 15x LT/ P/E we apply to the sector as we forecast it will deliver 1.3x volume growth vs the industry). Downside risks: 1) Unsuccessful mass production of big cylindrical battery; 2) Investment income risk; and 3) lower- than-expected consumer battery profit.
Daejoo	Our 12-month target price of W110,000 for Daejoo Electronic Materials is based 85:15 on a DCF:M&A methodology. Our M&A rank of 2 implies a 15% probability of Daejoo becoming an acquisition target and hence, we add a 15% weighting to our target price. For our M&A valuation of W150,000, we apply a target EV/EBITDA of 20.2x (20% premium to 16.8x global peer average) to our 2025E EBITDA and discount back to 2023E at an industry WACC of 8.4%. For our DCF assumptions, we use an industry WACC of 8.4%, derived from a risk free rate of 3.0%, Beta of 1.2X, equity risk premium of 6.25%, and terminal growth rate of 3.3%. Risks include: 1) delayed vehicle launch of key OEM clients; 2) slower-than-expected Si-anode market growth; 3) delay in capacity addition or failure to increase silicon blend ratio; and 4) failure in customer diversification.
Toyota Motor	Our 12-month target price of ¥3,200 for Toyota Motor is based on P/B-ROE correlation using our FY3/25 estimates. Risks include yen appreciation, delays in EV development, battery sourcing issues amid rapid growth in the EV market, disappointment in the company's shareholder return policy, protracted semiconductor shortages, and low capacity utilization in the China business.
BYD	Our 12-month DCF-based (WACC 10.8%, TGR 2.0%) target price for BYD A/H is Rmb336/HK$321 (applying a 14% discount to the H share). Risks: (1) Intensifying electric vehicle competition; (2) Slower-than-expected overseas expansion progress; (3) Lower-than-expected external battery sales.
Yunnan	Our 12-month P/E-based target price for Yunnan Energy of Rmb110.0 is derived from an average of a near-term and a long-term P/E valuation. We use the company's past 3-month average P/E of 16.3x for 2023E to arrive at a near-term valuation, and employ a 15.0x long-term P/E for 2030E and discount back to 2023E at 10.8% COE to derive a long-term valuation. Key downside risks: 1) Localization of base separator equipment driving higher-than-expected capacity addition; and 2) Lower-than-expected sales growth and 3) All solid state battery penetration.
SKC	Our 12-month, SoTP-based target price for SKC is W115,000. We use a target EV/EBITDA multiple in our methodology as we believe it best explains the valuations of relevant peer groups with similar business models and growth profiles. For the Mobility Materials business (copper foil), we apply a target EV/EBITDA of 16.8x to our 2025E EBITDA and discount it back to 2023E at an industry WACC of 8.4%, giving us W191,500. For Chemicals, we apply a 6.9x target EV/EBITDA (historical global chemical industry average with similar product categories) to our 2023E EBITDA. We then apportion the value for SKC's 51% stake in the chemicals business, SK PIC Global, which gives us W9,800. For Semiconductor materials, we apply a 2023E 10.3x target EV/EBITDA (reflecting the 10-year historical average for this industry), resulting in W15,700. Finally, for the other remaining businesses, we apply an 8.6x 2023E EV/EBITDA, the average of legacy businesses (chemical and semiconductor material) which gives us -W16,900. Key risks: High gearing, capital raise risk on high CAPEX, SK group risk, and all-solid-state battery launch.
CALB	Our 12-month P/E-based target price of HK$12.3 for CALB is derived from an average of near- and long-term valuation. We use the past 3-month average P/E of 15.5x for 2023E to arrive at a near-term valuation, while employing a 15.0x long-term P/E for 2030E, discounting back to 2023E at a 10.8% COE to derive a long-term valuation. Key risks: 1) signs of slower-than-expected industry capacity expansion; 2) new long-term contracts with major OEMs; 3) launch of advanced battery products to support margins; 4) acquisitions of minority shareholdings to capture attributable net profit.
Gotion High-Tech	Our 12-month P/E-based target price of Rmb22.6 for Giotion High-Tech is derived from an average of near- and long-term valuation. We use the past 3-month average P/E of 35.0x for 2023-24E to arrive at a near-term valuation, while employing a 15.0x long-term P/E for 2030E, discounted back to 2023E at a 10.8% COE to derive long-term valuation. Risks: 1) A higher share from Volkswagen; 2) breakthroughs with major OEMs; 3) product upgrading; 4) geopolitical tensions relief.
POSCO Future M	Our 12-month target price of W240,000 for Posco Future M is based on SOTP. We value: 1) the cathode and anode business using DCF (consistent with the valuation methodology for coverage companies in the Korean EV sector) and 2) the refractories/furnace business on 6.5x 2024E EV/EBITDA multiple (consistent with average of Posco FM during 2013-17 when it was a more pure-play on the refractories/furnace business). Risks: Faster than expected growth in EV penetration growth; stronger-than-expected NCM market share in the global cathode mix; higher-than-expected market share in cathodes and anodes; higher-than-expected cathode and anode margins; a weaker-than-expected KRW:USD.
Ecopro BM	Our 12-month target price of W120,000 for Ecopro BM is derived using a DCF framework through to 2040E (discounted to 2024E at a WACC of 8.3% and COE at 10.5%) which is consistent with the valuation methodology of coverage companies in the Korea EV sector. Risks: A meaningful upward revision of capacity plans; higher-than-expected demand and/or a slower-than-expected production ramp-up due to lower yields; further technological innovation from Ecopro BM in NCM based cathode; a weaker-than-expected KRW:USD.
Guizhou Zhenhua E	Our 12-month P/E based target price of Rmb24.5 for Zhenhua E-chem is derived from an average of near- and long-term valuations. We use the company's past 3-month average P/E of 14.7x for 2023E to arrive at a near-term valuation, while employing a 15.0x long-term P/E for 2030E and discounting to 2023E at a 10.8% COE to derive long-term valuation. Key upside risks: 1) Develop more advanced cathode products or secure significant supply contracts; 2) Stronger-than-expected sodium-ion demand; 3) An increase in the number of contracts from battery makers; and 4) Slower-than-expected industry capacity addition.
Guangzhou Tinci M	Our 12-month P/E based target price of Rmb24.8 for Tinci Materials is derived from an average of near-term and long-term valuation. We use the company's past 3-month average P/E of 16.0x on 2023E-2024E to arrive at a near-term valuation, while employing 15.0x long-term P/E on 2030E and discounting back to 2023E at a 10.8% COE to derive long-term valuation. Key upside risks: 1) Innovation in the electrolyte chemistry. We assume gross profit contribution from recipes to narrow over time. Solid innovation in electrolyte chemistry system led by Tinci could materially support unit gross profit. 2) Sustained price premium from the overseas market on the back of long term contracts. 3) Massive delay or cancellation of electrolyte capacity expansion from peers that tightens the market.
Hymson	Our 12-month target price of Rmb42.6 for Hymson is based on a 2025E P/E of 20x discounted back to 2024E with a CoE of 10.5%. Upside risks are higher-tha-expected battery capex, better-than-expected R&D progress, higher-than-expected GPM.
United Winners	Our 12-month target price of Rmb24.1 for United Winners is based on a 2025E P/E of 20x discounted back to 2024E with a CoE of 11.5%. Key upside risks: battery capex hight than our expectations; key customers resuming a high order pace and winning orders from new customers; new product categories R&D exceeding expectation.
Quantumscape	Our 12-month price target of US$5 for Quantumscape is based on 2X EV/the QS 2028 revenue target discounted back. Key upside risks to our view include: 1) QuantumScape's ability to hit/exceed its targeted battery specs; ability to ramp production; technological breakthroughs in today's lithium-ion batteries.
Tesla	Our 12-month price target of US$265 for Tesla is based on 50X Q5-Q8 EPS including SBC. Key risks to our thesis relate to the rate of EV adoption, auto demand and the auto cycle, market share, FSD, key person risk, margins, and operational risks and opportunities associated with Tesla's high degree of vertical integration.

Source: Goldman Sachs Global Investment Research

Disclosure Appendix

Reg AC

We, Nikhil Bhandari, Amber Cai, Kota Yuzawa, Eric Shen, Tina Hou, Jacqueline Du, Apoorva Bahadur, Mark Delaney, CFA, George Galliers, Philipp Konig, Kee Ryung Kim, Hugo Nicolaci, Trina Chen, John Tsang, Ryo Harada, Chao Ji and Ryan Park, hereby certify that all of the views expressed in this report accurately reflect our personal views about the subject company or companies and its or their securities. We also certify that no part of our compensation was, is or will be, directly or indirectly, related to the specific recommendations or views expressed in this report.

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Target price history table(s)

Daejoo Electronic Materials (078600.KQ)

Date of report	Target price (W)
19-May-23	110,000
05-Feb-23	125,000
01-Aug-22	110,000

Ecopro BM (247540.KQ)

Date of report	Target price (W)
03-Aug-23	120,000
12-Jun-23	125,000

L&F (066970.KQ)

Date of report	Target price (W)
03-Aug-23	250,000
12-Jun-23	255,000

Samsung SDI Co. (006400.KS)

Date of report	Target price (W)
12-Jun-23	930,000
13-Jan-23	850,000
14-Nov-22	900,000
26-Oct-22	880,000
29-Jul-22	800,000
19-Apr-22	890,000
30-Jan-22	900,000
19-Jan-22	920,000
14-Oct-21	970,000

LG Chem (051910.KS)

Date of report	Target price (W)
27-Jul-23	850,000
20-Jul-23	880,000
06-Jun-23	870,000
09-Apr-23	880,000
31-Jan-23	820,000
16-Jan-23	830,000
14-Nov-22	860,000
09-Oct-22	790,000
31-May-22	760,000
06-Apr-22	710,000
08-Mar-22	720,000

Posco Future M (003670.KS)

Date of report	Target price (W)
24-Jul-23	240,000
12-Jun-23	220,000

LG Energy Solution (373220.KS)

Date of report	Target price (W)
27-Jul-23	605,000
09-Jul-23	610,000
26-Apr-23	590,000

SKC (011790.KS)

Date of report	Target price (W)
04-May-23	115,000
07-Feb-23	130,000
10-Nov-22	183,100

LG Energy Solution (373220.KS)

Date of report	Target price (W)
09-Apr-23	585,000
29-Jan-23	540,000
16-Jan-23	550,000
14-Nov-22	570,000
09-Oct-22	530,000
27-Jul-22	465,000
31-May-22	475,000
27-Apr-22	450,000
08-Mar-22	455,000

SKC (011790.KS)

Date of report	Target price (W)
25-Oct-22	188,600

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