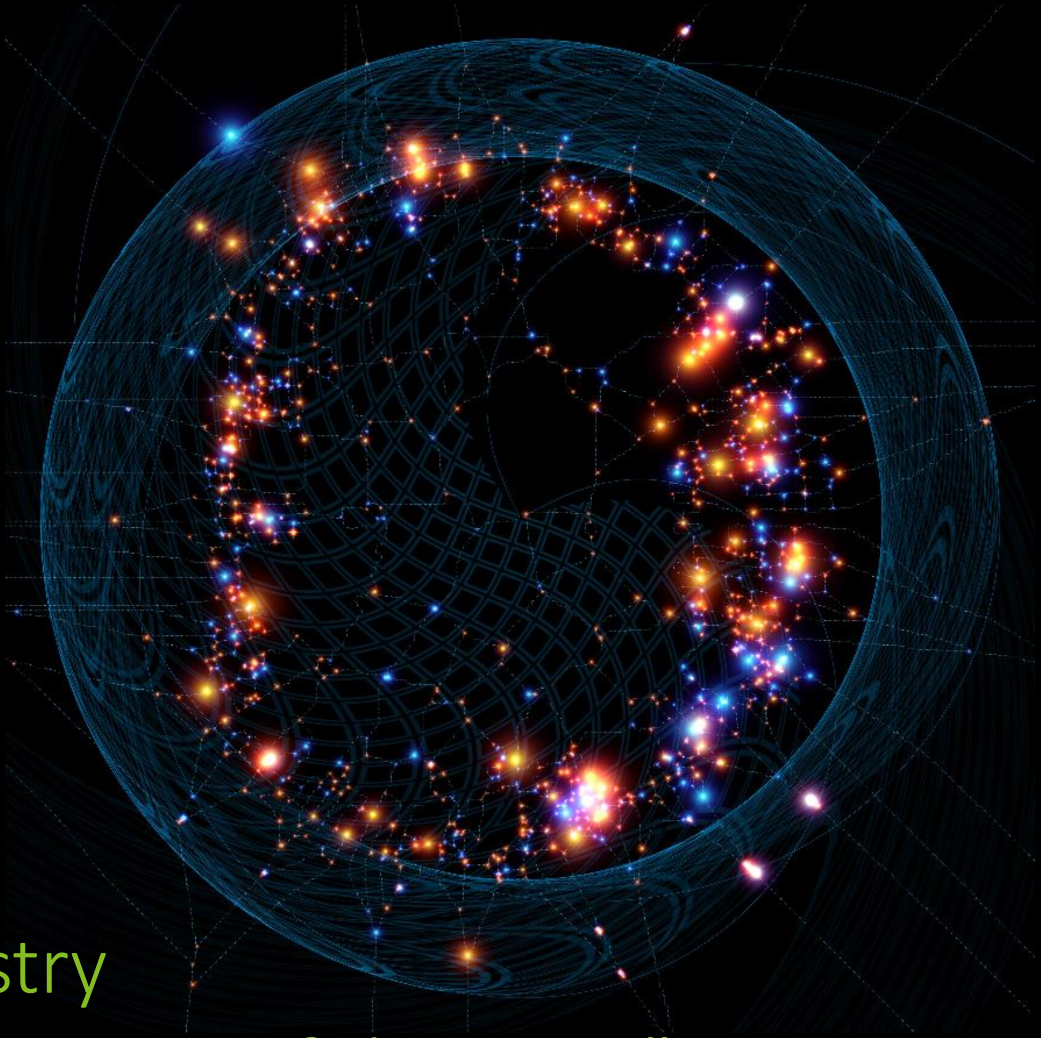


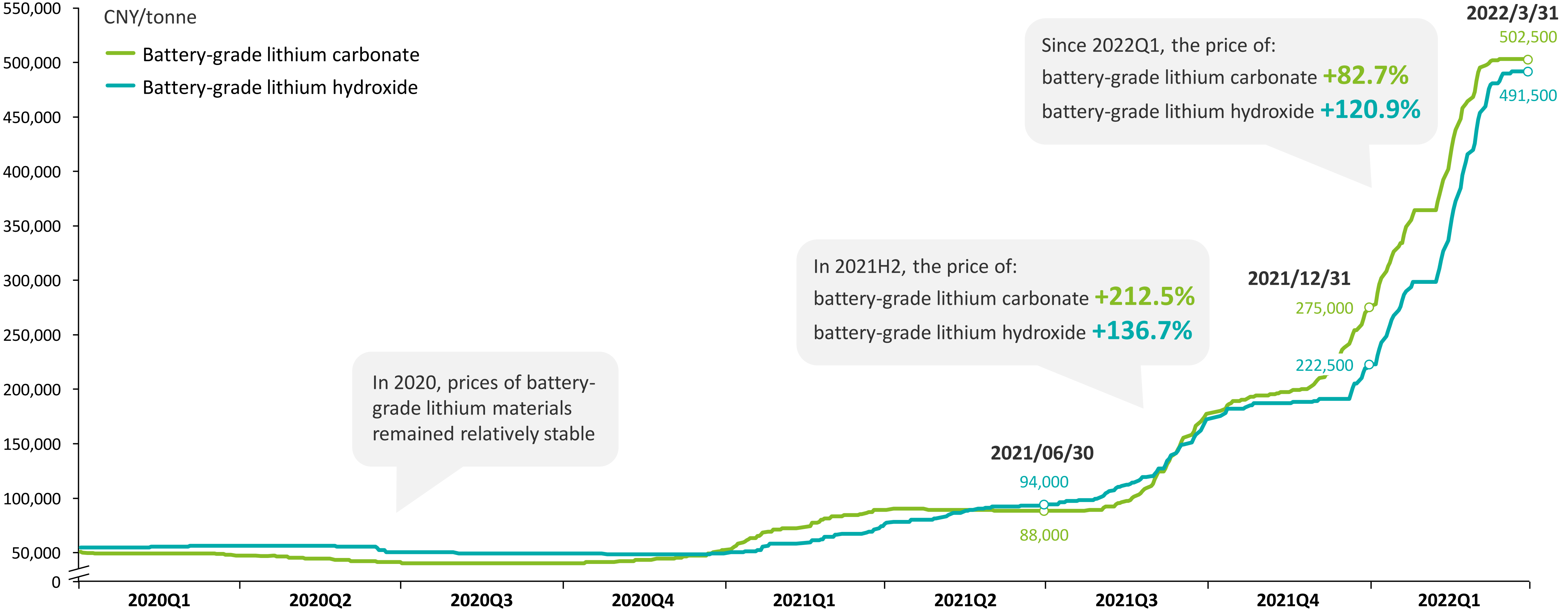
China Lithium Industry
Deloitte POV 2.0: “Battery of the Time”

Deloitte Consulting China | April, 2022

Battery-Grade Lithium Materials Price Trends

Since 2021 H2, the lithium batteries market has experienced tremendous growth, with more than five-fold price increases for battery-grade lithium specialty materials, far surpassing previous market expectations.

Price trends of battery-grade lithium materials in China



In 2020, prices of battery-grade lithium materials remained relatively stable

In 2021H2, the price of:
battery-grade lithium carbonate **+212.5%**
battery-grade lithium hydroxide **+136.7%**

Since 2022Q1, the price of:
battery-grade lithium carbonate **+82.7%**
battery-grade lithium hydroxide **+120.9%**

Source: Wind, Deloitte analysis

Key Takeaways

With the emergence of global carbon neutrality and surging penetration of new energy vehicles, the global lithium battery industry continues to flourish, mainly driven by **rising demands of EV lithium batteries.** As the industry matures, **technological innovation of EV lithium batteries has shifted from policy-oriented to market-oriented**, and suppliers proactively utilize different technologies to promote the medium to long-term growth of lithium batteries.

In the medium-term, cost reduction and efficiency improvement are mainly achieved through **material upgrades and structural renovations**.

- **Material upgrades**: cathode and anode materials are the core factors that determine the energy density of EV batteries. The **breakthrough of cathode material** is most likely to bring about a revolutionary increase in the energy density of EV batteries. In the short to medium term of cathodes materials landscape, **LFP will be developed in parallel with ternary materials**, and technical advancement will be carried out based on current chemical system; **high-nickel ternary materials** are still compatible during the development process from semi-solid to all-solid-state batteries, with great potentials.
- **Structural renovations:** based on mature lithium battery material systems, firms **innovate and simplify battery cells, modules and packaging types etc**., in order to improve batteries' systematic performance, e.g. BYD's blade batteries, CATL's CTP technology etc. Structural renovation is the other important technological development route besides material upgrades.

In the long-term, **R&D could continuously reduce liquid content in electrolytes**, but there remains critical technical challenges en-route to full-solid-state batteries.

- **Clear development trends for solid-state batteries**: Compared to conventional liquid batteries, solid-state batteries show superior performances regarding energy density and safety. Therefore, lithium companies, battery manufacturers and OEMs on the industry chain have been proactively investing in R&D for solid-state batteries. Currently, the industry is transiting **from semi-solid to all-solid-state**.
- **Critical challenges for all-solid-state batteries:** Although there is a general consensus in the industry on the trend of developing towards solid-state batteries, the critical technical problems, such as high interface resistance, of all-solid-state batteries are difficult to overcome, and there is still a long way to go for large-scale installation. As the liquid content continues to decrease and the energy density is significantly improved, **solid-liquid hybrid batteries with extremely low liquid electrolyte content may be a more commercially practical solution**.

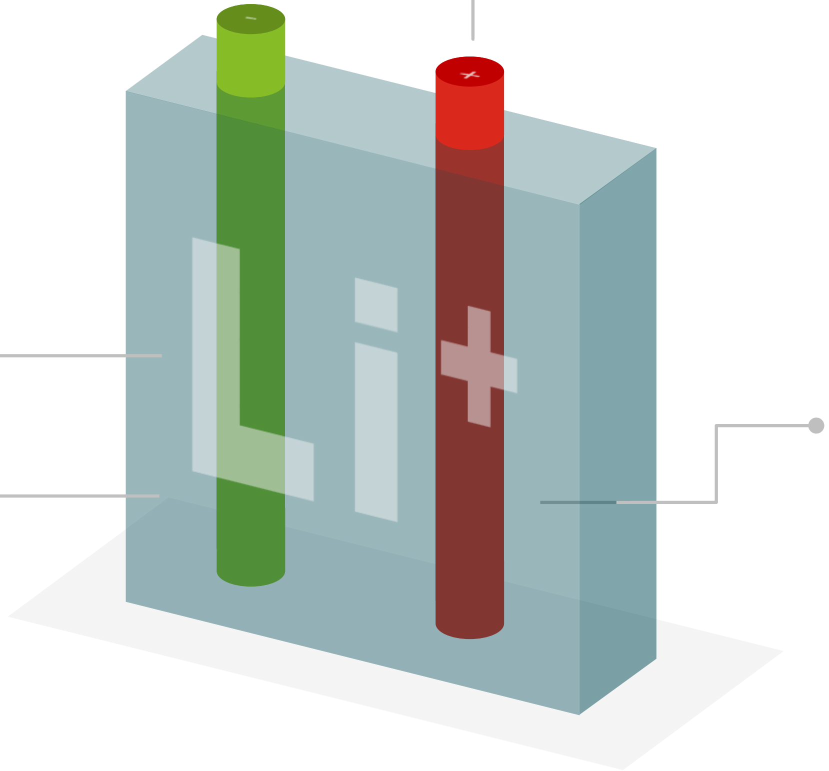
Looking ahead into the future, the development of lithium batteries could be restricted by the shortage of lithium resources, **sodium-ion batteries have shown potentials as an alternative**, which, once commercialized can complement lithium batteries in application.

- **Complementary relationship of Sodium and lithium batteries:** Despite the resource abundance and cost advantages of sodium-ion batteries, constrained by relatively low energy density, sodium batteries are difficult to replace lithium batteries in the field of passenger EV batteries. Sodium batteries may **substitute lithium batteries in low-energy density required or mid/low-end scenarios**, and it's expected to achieve large-scale commercial applications in scenarios of energy storage and low-speed vehicles etc.

Overview of Lithium Battery Structure

Currently, lithium batteries are mainly comprised of the key components of cathode, anode and electrolyte. Enterprises are actively seeking technological innovation and breakthroughs in various parts.

Lithium-ion battery structure and technological trends



Anode

Predominantly consists of graphite materials, but are upgrading towards silicon-based materials

Packaging:

- Prismatic
- Cylindrical
- Pouch

Structural Renovations

- Structural improvement of battery cell
- Simplification of battery structure

Cathode

Upgrades of key materials :

- High-nickel & cobalt-free materials
- Upgrades from LFP to LMFP[1]

Development of new materials :

- Li-rich Mn-based materials, etc.

Electrolyte

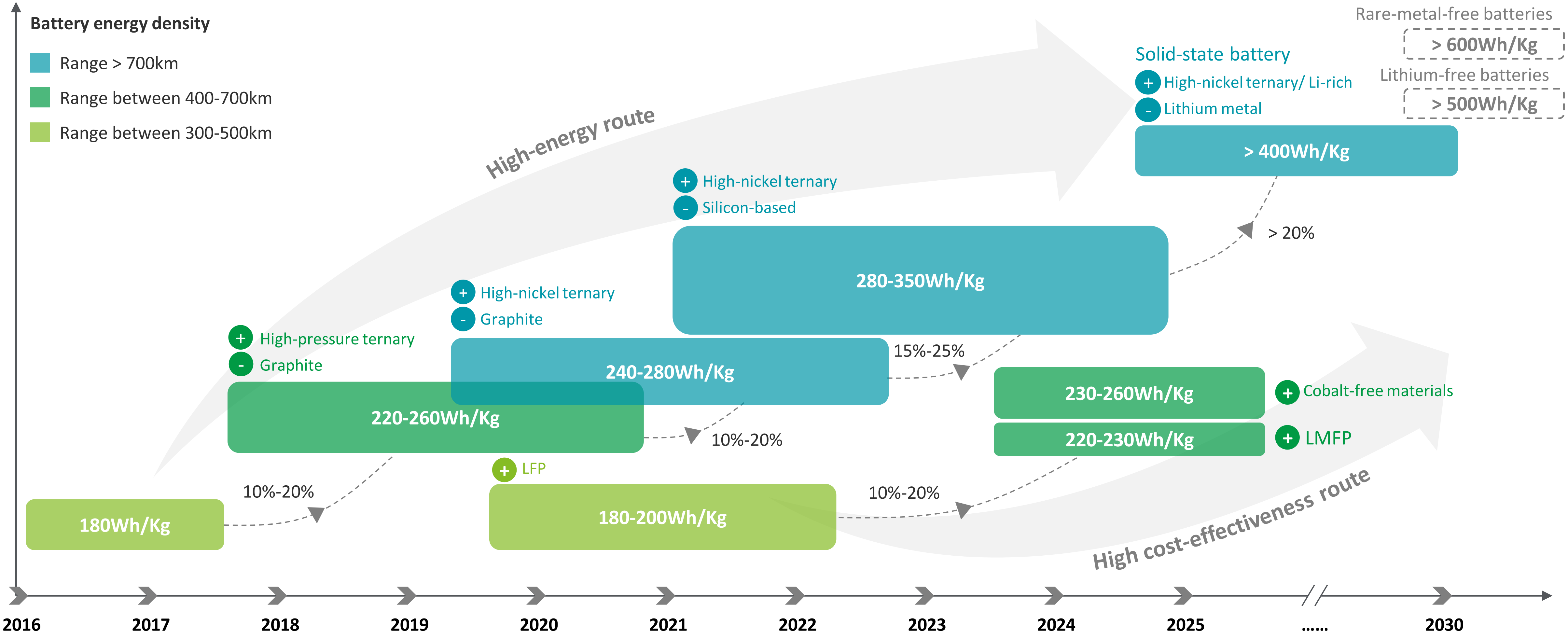
Gradual reduction in liquid content, moving towards solid electrolyte

Notes: 1. LFP= $LiFePo_4$; LMFP= $LiFe_xMn_1\text{-}xPO_4$

Source: public information, Deloitte analysis

Technical Route of EV Battery

High-energy and high cost-effectiveness are the two main routes in the development of EV battery technologies, with the key being the upgrade of the underlying battery chemical systems.



Source： Expert interview, public information, Deloitte analysis

Deloitte Observations and POV: Technological Development of EV Battery

- 01 Advancement of cathode & anode materials in lithium battery
- 02 Structural innovation & packaging development of lithium battery
- 03 Outlook of solid-state lithium battery
- 04 Sodium-ion battery & application prospects
- 05 EV battery development from automotive OEMs perspective
- 06 Business implications of EV battery trends

Advancement of Cathode & Anode Materials in Lithium Battery

Cathode Materials Development Trends: High-Nickel/Cobalt-Free Ternary Materials

High-nickel/cobalt-free ternary batteries, with their advantages in energy density, have been a popular development goal for battery companies and OEMs. However, whether cobalt-free batteries can substantially improve battery performance beyond the conceptual hype is still uncertain.

Trend of ternary materials: Increase nickel and reduce cobalt

High-nickel, cobalt-free

Energy density improvement

The main role cobalt plays in ternary batteries is to stabilize its structure, without participating in electrochemical reactions. Reducing the proportion of cobalt and increasing that of nickel can improve energy density.

Cost reduction

Cobalt is an expensive rare resource with volatile supply. Reducing cobalt content helps to control the material costs of ternary batteries.

N-C-M ratio trends: 1:1:1 → 5:2:3 → 6:2:2 → 8:1:1

- To reduce costs and enhance energy density, battery suppliers and OEMs around the world have been working to reduce cobalt and to exceed the minimum limit of cobalt content in ternary materials.
- Currently, NCM811 is the mass-produced NCM battery with the lowest nickel content.

Long-term obstacles in achieving actual cobalt-free ternary batteries

SVOLT's "cobalt-free" battery

- In August, 2021, the "cobalt-free" battery developed by SVOLT first came into mass production. Whilst attracting great industrial attention, its technical approach has also raised debates.

Cathode material

- The cathode material of SVOLT's cobalt-free battery is $LiNi_{0.5}Mn_{1.5}O_4$, which is not technically cobalt-free ternary material, but a direct application of a binary material without cobalt.

Energy density

- After meaningful de-cobaltizing, energy density should increase, but the energy density of SVOLT's cobalt-free battery, 240Wh/kg, is only similar to that in early NCM523, which is hardly comparable to the energy density of NCM811.

- Currently, most "cobalt-free" batteries advertised use cathode materials without cobalt or replace cobalt with other stabilizers, but the performance of which are much worse than cobalt.
- Safety and other characteristics, such as matching with electrolytes, of ternary batteries after real de-cobaltizing are technical challenges yet to resolve.

Source: Economics observations, public information, Deloitte analysis

Cathode Materials Development Trends: LMFP

Given the increasing focus on safety and cost-effectiveness for LFP batteries, LMFP ($\mathrm{LiFe_xMn_1\text{-}xPO_4}$), while not a new material, is seen as an upgrade from LFP and has regained popularity. Despite the increasing industrialization of LMFP, blended applications are primarily expected in the short term.

The advantages and developmental trends of LMFP

Good overall performance

- Compared with current mainstream cathode materials, LMFP has higher energy density than LFP, with competitive advantages in safety and costs.

	LMFP	LFP	Ternary（NCM）
Theoretical energy density	697 Wh/kg	578 Wh/kg	1204 Wh/kg
Safety	High	High	Medium
Theoretical life	Long	Long	Medium
Cost	Low	Low	High

Development pathways

Replacement of LFP

- The energy density in LMFP is 15% -20% greater than that in LFP, with price increases by only 5%-6%, indicated its potential replacement opportunity given its cost-effectiveness.

Blended applications with ternary materials

- LMFP can be used in combination with ternary materials. With advantages such as low costs, high safety, and high energy density, it can thus be implemented as a cost-control solution for OEMs.

Four-wheel applications expected to volume in 2022H2

Lithitech

- Owns an LMFP production line of 2,000 tonnes. From Sep, 2021 to Mar, 2022, the company sets to build new equipment with an annual LMFP production capacity of 3,000 tonnes.
- The purchase quantity of LMFP for two-wheel vehicles has already been huge by the end of 2021, demands from four-wheel vehicles are expected to massively volume up in 2022H2.

Tianneng Battery

- Tianneng Lithium-ion Battery, a subsidiary of the group, launched Heng-Tech Series battery products in 2021, which adopts its self-developed LMFP cell.

Dynanonic

- In 2021, the company announced to build a “production site with annual production capacity of 10 thousand tonnes of novel phosphate cathode materials” in Qujing Economic & Technology development area.
- Samples of novel LMFP have been sent for testing, expected to be produced at scale 1 or 2 years later.

CATL

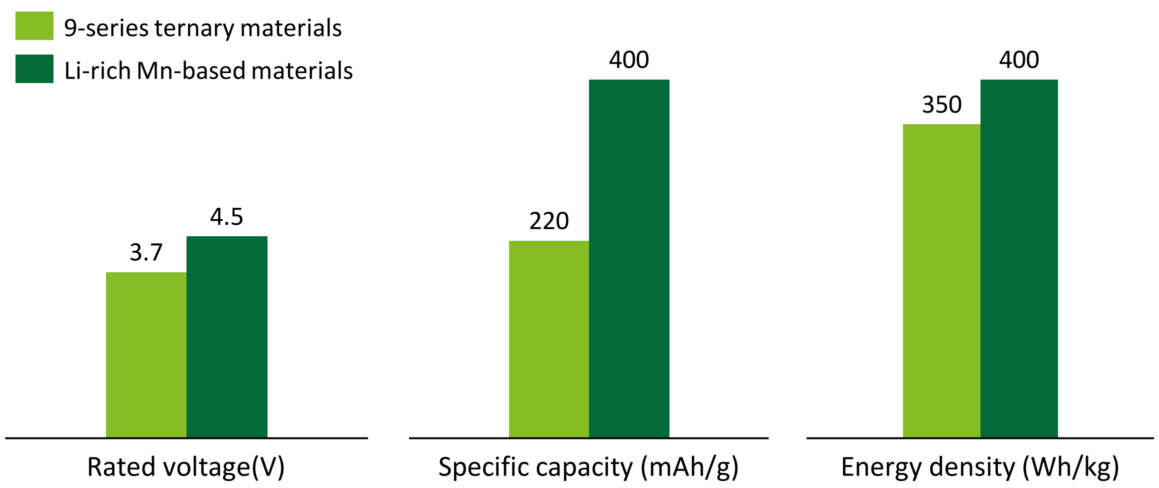
- In 2017, CATL applied for patents for the production methods of LMFP and graphene mixed cathode materials, and owned technical capacity for LMFP production.

Source: China Merchants Securities, Zhongtai Securities, expert interviews, public information, Deloitte analysis

Novel Cathode Materials: Li-Rich Mn-Based Materials

The characteristics of Li-rich Mn-based cathode materials are paradigm-shifting to some extent, regarded as a possible breakthrough for the next generation of batteries. However, the route to industrialization is young and still carries uncertainties.

Li-rich Mn-based materials might be the next-gen of cathode materials



- Li-rich Mn-based cathode materials can be considered as a layered oxide with Li_2MnO_3 & $LiMO_2$(M=Ni, Co, Mn).
- Compared with high-nickel ternary materials, Li-rich Mn-based materials, with the advantages of high voltage and larger specific discharge capacity, have the potential to raise the lithium batteries’ energy density from its current state to 400Wh/kg.
- In 2021, a project led by CAAM indicated that the costs of Li-rich Mn-based batteries can be reduced by 30% compared to ternary lithium batteries, implying great development potentials.

Industrialization of Li-rich Mn-based materials is still at its infancy

Limits to application

- Currently, the industrial application of Li-rich Mn-based materials is mainly constrained by its material disadvantages:

1. **Low initial coulombic efficiency (ICE)**, Li-rich Mn-base cathode materials experience relatively high irreversible loss of capacity during the initial discharge, which affects its performance and cycle life.
2. **Severe energy loss**, during the iteration process of Li-rich Mn-based cathode materials, the joint effect of surface chemical reaction and its internal expansion leads to severe loss of voltage, which affects battery life.

Current state of industrialization

- Ningbo Fuli company is the first to set foot on the industrialization process of Li-rich Mn-based cathode materials, while Beijing Easpring, Jiangxi Special Electric Motor Co, Ningbo Ronbay and Soundon etc. also have relevant R&D plans.

FuLi 富理

Ningbo Fuli Battery Material Technology CO., LTD is a startup founded in 2016 by the team of the lithium battery engineering lab in Ningbo Institute of Materials Technology and Engineering, CAS.

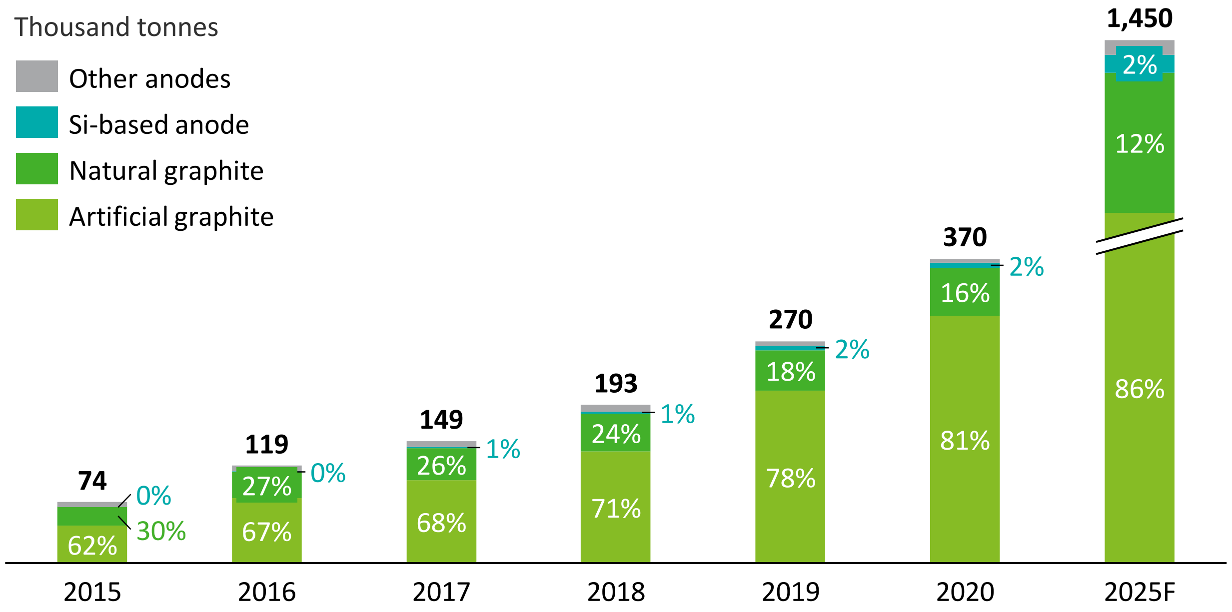
- Focuses on the development of cathode materials used in long-range EV Li-batteries: **Li-rich Mn-based cathode materials** and Si/C compound anode materials.
- Currently, a pilot-scale production line has been built, making Fuli the first supplier in the world with the ability to provide high-capacity Li-rich Mn-based cathode materials at scale.

Source: Expert interviews, Tebon securities, Chinese Academy of Science, public information, Deloitte analysis

Anode Materials Development Trends: Silicon-Based Anode Materials

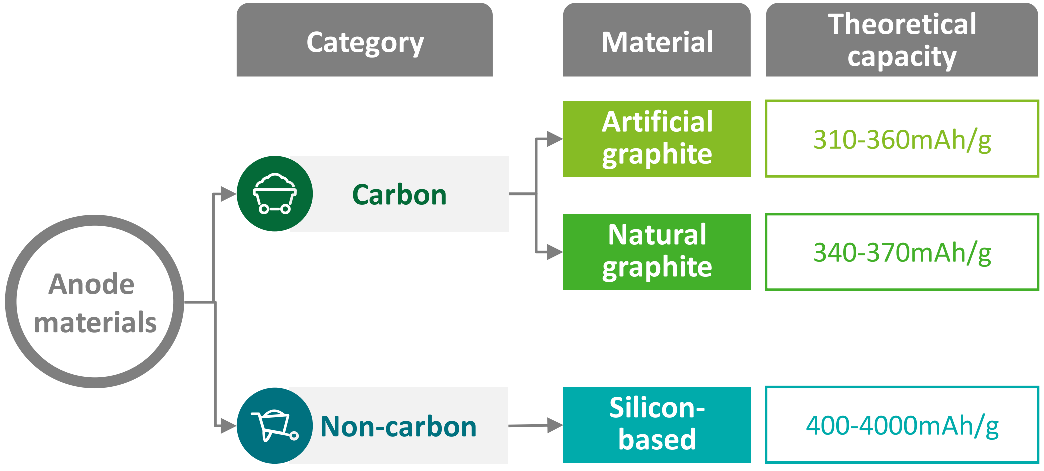
Artificial and natural graphite are the most-commonly adopted anode materials for lithium batteries, but in order to exceed the current energy density limit, silicon-based anode materials with higher theoretical capacity is an important direction for R&D.

2015-2025 China Li-battery anode materials delivery by types



- Artificial graphite performs better than natural graphite in areas such as cycling life, safety, charge/discharge ratio etc., with similar costs and capacity/g. It has thus become the mainstream choice for anodes in lithium batteries.
- Demands for natural graphite mainly come from foreign firms like Panasonic and SDI, while domestic firms are gradually switching towards artificial graphite.

Theoretical capacity of mainstream and Si-based anodes



Anode materials

Category	Material	Theoretical capacity
Carbon	Artificial graphite	310-360mAh/g
	Natural graphite	340-370mAh/g
Non-carbon	Silicon-based	400-4000mAh/g

- Currently, the capacity of high-end graphite materials in the market has reached 360~365 mAh/g, which implies limited improvement opportunities for energy density in lithium batteries. Therefore, silicon-based anode materials with higher theoretical capacity have the potential to be the next generation of anode materials for high-energy-density lithium batteries.

Source: GGII, Kaiyuan Securities, public information, Deloitte analysis

Technical Routes and Industrialization Progress of Silicon-Based Anode Materials

Both the development and applications of silicon-based anode materials face technical challenges, limiting the ability of mass production in China, though pioneers have started batch application.

Technical routes of silicon-based anode materials

- Although Si-based anode materials have absolute advantages over graphite materials in terms of capacity, but given that silicon materials are easily expandable with poor inductivity, there are technical difficulties to be addressed before application at scale. Two main technical routes of Si-based anode materials include:

SiO anode materials

- Japanese and Korean firms started much earlier down this route, and are currently in leading position with multiple relatively mature SiO_x products have been introduced.
- Although some Chinese firms have attempted to introduced SiO_x anode materials into the market, they are still catching up with foreign players.

SiC compound anode materials

- Some foreign firms have achieved mass production of Si/C anode materials, with Hitachi chemical being the biggest supplier. Hitachi Chemical supplies the Si/C products used by Tesla.
- Most of domestic firms in China are still in the process to industrialize Si/C application, with slow progress.

- The production concentration of Si-based anode materials has always been high, most domestic firms are in the development and testing phases.
- Technological challenges of material characteristics, material costs and immature production techniques are the three key barriers to the industrialization of Si-based anode materials.

Main Chinese players and their industrialization progress

BTR

- One of the first Chinese companies that achieved mass production of silicon-based anode materials; Industrialized the production of Si-based anode materials and enabled bulk sales in 2013.
- In 2022, the company announced that it plans to invest in the construction of a silicon-based anode material project with an annual capacity of 40,000 tones in Guangming District, Shenzhen.

Shanshan Co

- Built a pilot-scale production line for Si/C anode materials with growing production capacity, but current delivery rate remains low.
- High-capacity silicon alloy anode materials have been industrialized and supplied to CATL.

Gotion high-tech

- Invested in and commissioned a Si-based anode materials project with 5,000 tonnes production capacity n 2016.
- In January, 2021, officially introduced a 210Wh/kg LFP pouch battery, and announced the successful application of Si-based anode materials in LFP chemical system for the first time.

Putailai/ Jiangxi ZiChen

- Collaboratively built a pilot lab with the Institute of Physics, CAS; implied that the 2nd generation of Si-based products were ready for industrialization; pilot production line of SiO has been built in Liyang.
- Putailai's wholly-owned subsidiary ZiChen Techology developed a series of Si/C anode materials that can be used in 3C digital batteries, storage batteries and power batteries etc.

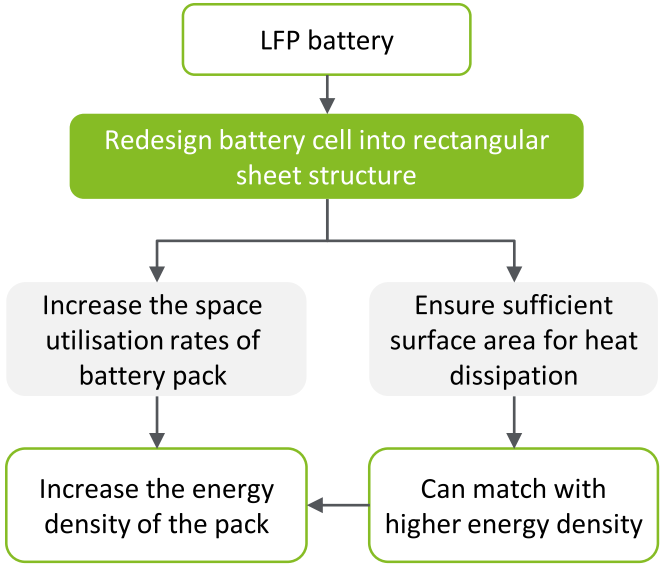
Source: Everbright securities， Kaiyuan securities, public information, Deloitte analysis

Structural Innovation & Packaging Development of Lithium Battery

Structural Improvement: BYD Blade Battery (1/2)

Through improving structure based on current battery materials, BYD's blade battery has effectively targeted and solved current developmental pain points in the industry, such as battery fire, inadequate mileage range, poor performance at low temperature etc.

Technical improvements of BYD blade battery


LFP battery

Redesign battery cell into rectangular sheet structure

Increase the space utilisation rates of battery pack

Ensure sufficient surface area for heat dissipation

Increase the energy density of the pack

Can match with higher energy density

Energy density

↑ 50%

- The blade battery developed by BYD is a new generation of LFP batteries. By amending the current design of cell unit and utilising space within battery pack, high energy density per volume can be achieved effectively.

BYD blade battery thrives in battery KPIs

Blade battery

Safety
- Heat safety performance exceeded national requirement
- Safety can still be ensured even with leak in the liquid coolant plate or defects in the packaging seal

Mileage range
- Can easily travel long distance, with maximum capacity surpassing 100KWh, C-grade vehicles can travel up to 700 km

Battery life
- Both storage and cycle life are much greater than requirements for vehicle operational life.

Strength
- When facing oscillations, modelled collapses, squashing and anti-pressure levels, blade batteries perform satisfactorily.

Power
- Instant maximum power of 363kW, approximately 500HP, allowing for acceleration of 3.9s/100 kms.

Low-temperature
- Able to sustain the best performance in-35℃~55℃, discharge capability in low temperature is around 90% of that in room temperature

Source: BYD press conference, Everbright securities, public information, Deloitte analysis

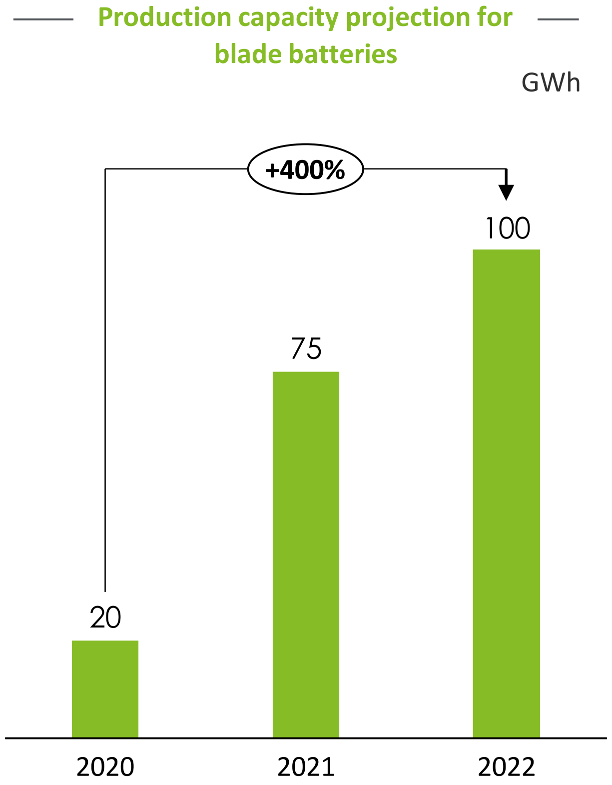
Structural Improvement: BYD Blade Battery（2/2）

Through acquisitions, new construction and technical upgrade of existing production lines, BYD proactively increases the production capacity of blade batteries; In addition to internal supply, blade batteries were also supplied externally, the performance of which is well-recognized in the market.

BYD: Chinese production plans of Fudi Battery[1]

Fudi battery site	Capacity planning
Guangdong Huizhou	20GWh
Guangdong Shenzhen	14GWh
Qinghai Xining	24GWh
Chongqing Bishan	45GWh
Shanxi Xi'an	30GWh
Hunan Changsha	20GWh
Guizhou Guiyang	15GWh
Anhui Bengbu	20GWh
Anhui Wuwei	40GWh
Jiangsu Yancheng	30GWh
Shandong Jinan	30GWh
Jiangxi Wuzhou	20GWh
Hubei Xiangyang	30GWh
Jilin Changchun	45GWh
Anhui Chuzhou	Phase 1: 5GWh
Zhejiang Shaoxing	Plans unannounced

🟩 Disclosed as production site for blade batteries

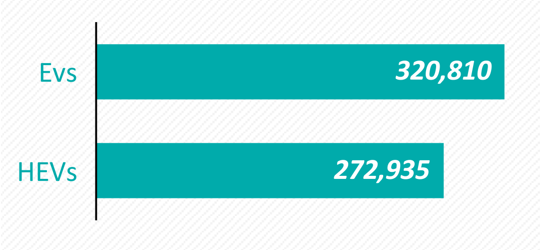


Note： 1. In 2019, BYD divested its battery business and founded a wholly-owned subsidiary Fudi Battery.
Source: BYD press conference, BYD annual report, CPCA, Everbright securities, TF securities, public information, Deloitte analysis

Business applications of BYD blade batteries

Internal supply

- In 2021, BYD became the annual sales champion for passenger EV in China, with annual sales over **590,000.**



- Besides the new models of entire EV series, DM-i hybrid models also installed blade

汉 唐 宋 秦
元 海豚 e2

External supply

> Almost every automotive brand one can imagine is negotiating with Fudi Battery. Blade batteries will gradually be installed on EV models of mainstream brands, both at home and abroad.
>
> —BYD CEO Chuanfu Wang

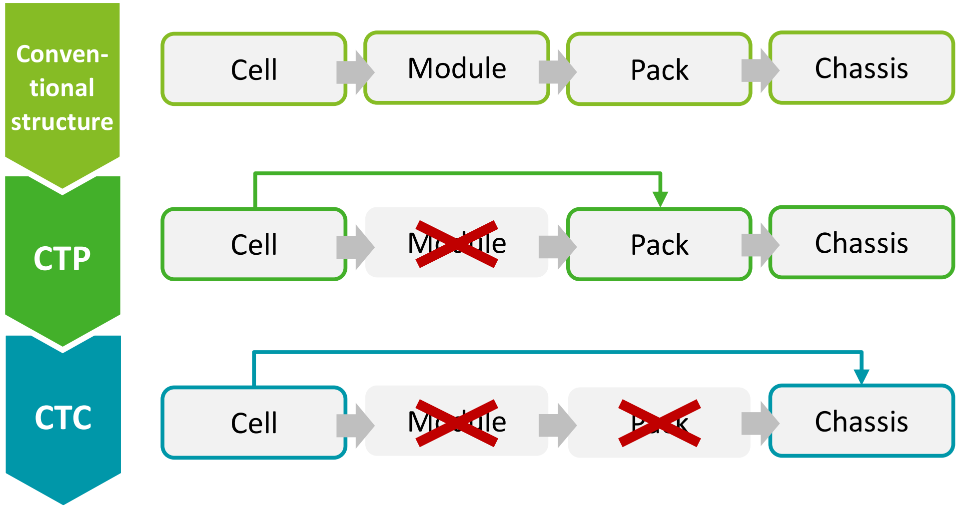
2021.06: Hongqi E-QM5 EV using blade batteries officially launched

2022: Toyota bZ SDN with blade batteries (mass prod. ver.) will arrive in 2022

Structural Simplification: CATL's Approach from CTP to CTC[1]

Ambitions beyond battery: to reduce costs and improve efficiency for OEMs, while increasing the organization's participation in the automotive model development cycle. In order to realize the concept of CTC, the battery system and the electric motor system require higher degree of integration

CATL's technical route of battery structure



- Following the introduction of CTP concept in 2019, CATL published its development route on battery structure in 2020. Besides the 2nd and 3rd CTP battery systems, they also proposed an integrated CTC system that went directly from battery cell to chassis.

Advantages and commercial application of CTP/CTC

Compared with conventional structure

Stage of commercialization

CTP

↑ **Space utilisation** **15%-20%**

↓ **Component quantity** **40%**

↑ **Energy density** **10%-15%**

↓ **Costs of battery pack[2]** **10%-15%**

Installed on multiple EV models

- **NCM battery + CTP solution**
  BJEV, Nio, WM Motor
- **LFP + CTP solution**
  Tesla Model 3

CTC

↓ **Cost reduction**
CTC technology can reduce the costs of EVs down the level that are competitive with fuel vehicles

↑ **Mileage range improvement**
CTC technology can reduce the weight and volume of battery packs to the largest extent, increasing the mileage range to at least 800km

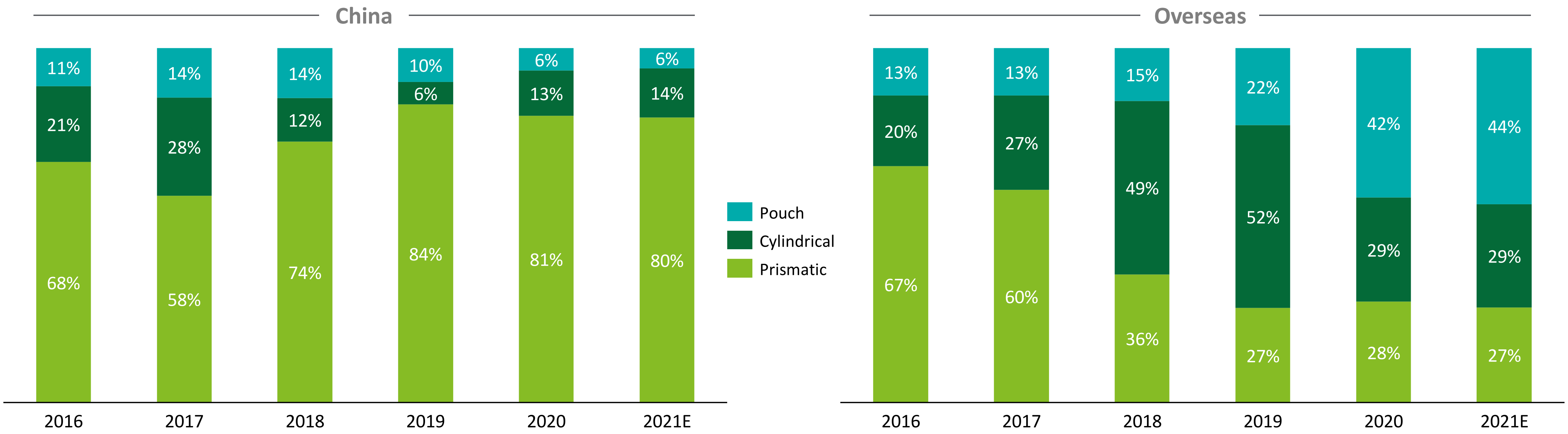
- Plans to introduce the 4th generation of highly-integrated CTC battery system in around 2025.
- In Sep, 2021, CATL announced it's plan to establish a JV focusing on the control technology of electric drive system for EV, aiming to accelerate the implementation of CTC.

Notes: 1. CTP-Cell to Pack, CTC-Cell to Chassis; 2. Estimated based on the cost model of battery from Everbright Securities
Source: CATL press conference, CATL corporate announcement, Everbright securities, public information, Deloitte analysis

Market Shares of Different Packaging Routes for EV Battery

EV batteries are most commonly seen in prismatic, cylindrical and pouch packaging. Prior to 2017, the packaging share and trends within and outside of China were relatively consistent. Due to the expansion and mass-production of top players on each route, different trends were seen in recent year.

Delivery shares of EV batteries by packaging types



- Recently, prismatic EV batteries dominate the China market, with CATL and BYD as the main players, market shares of prismatic batteries have been in a leading position.
- International market trends for the last 3 years have been quite different, by virtue of Tesla's and Panasonic's business growth, the market share of cylindrical batteries have significantly increased in 2018; In 2020, benefited from the deepening penetration of NEVs in Europe and expansion of LG Chemicals, the market share of cylindrical batteries doubled, while the market shares of prismatic batteries continued to shrink.

Source: GGII, Public information, Deloitte analysis

Comparisons of Three Packaging Routes and Development Implications

The future development of different packaging routes are primarily led by top players and technological advancement. The R&D movement towards solid-state batteries might affect market focus of battery packaging, allowing for a rise in the market shares of pouch format.

	Prismatic battery	Cylindrical battery	Pouch battery
Technical advantages	• High level of safety • High systematic energy efficiency, relatively high energy density • Relatively simple structure, good stability, convenient for capacity expansion	• High flexibility in grouping • Matured production techniques, highly standardized production lines • Relatively low costs	• High flexibility in size variations, relatively low weight • High energy density • Low internal resistance, high level of safety
Technical disadvantages	• Production techniques are highly variable, resulting in significant individual heterogeneity • In mass-application, system life is often much shorter than individual cell life	• Post-grouping heat dissipation remains a challenge for design • Low unit capacity, relatively low energy density	• Weak mechanical strength, complicated sealing technology • Complicated grouping structure, complex requirements for design • Relatively high costs
Top players	CATL 宁德时代 BYD SAMSUNG SAMSUNG SDI	Panasonic LG Energy Solution	LG Energy Solution SK innovation
Development prospects	• In medium term, to exceed the current energy density ceiling, players have sought innovation in battery structures. The key is to further utilize the supporting characteristics of the cell shell and to simplify modular components, in order to improve the energy density of battery packs. Lacking of shell support, pouch batteries are difficult to use when modules are simplified. Thus, in the medium term, prismatic and cylindrical batteries should be more flexible to structural innovation.		• In the long term, with trend of solid-state batteries, once liquid electrolyte is no longer required, the necessity of hard shell will decrease. Pouch packaging is thought to be the most suitable solution for SSB.

Long-term development trends

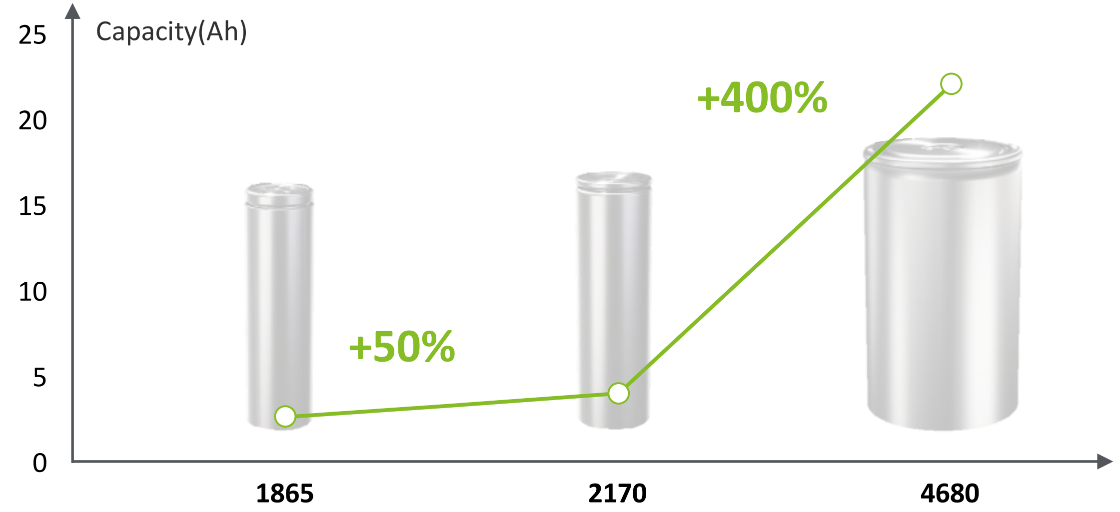
Source: IC Battery, Dongguan Large Battery, public information, Deloitte analysis

Case Analysis: Tesla’s 4680 Large Cylindrical Battery

Tesla’s plan for 4680 battery have led to an R&D boom for large cylinder batteries, attracting upstream battery manufacturers to adjust plans for production capacity. Chinese players have also proactively participated in the competition for 4680 contracts.

Development history of Tesla’s cylindrical batteries

- As the external diameter increases, cylinder batteries show significant improvement on energy and gradual reduction in costs.



	1865	2170	4680
Diameter	18 mm	21 mm	46 mm
Height	65 mm	70 mm	80 mm
Capacity	2.65 Ah	4 Ah	22 Ah
Usage	7000 units/vehicle	4000-5000 units/vehicle	900-1000 units/vehicle

Source: Tesla’s battery day, company official websites, Wallstreet insights, 36kr, public information, Deloitte analysis

Tesla’s 4680 application plans and impacts on battery manufacturers

- The application of cylindrical batteries are mainly driven by Tesla’s demands, and battery manufacturers accelerate the R&D of large cylindrical battery to accumulate relevant technologies.

Tesla

2020

In Sep. 2020, Tesla announced the plan for 4680 batteries on Battery Day. Annual production capacity is expected to be 100 GWh by 2022, and 3 TWh by 2030.

2021

In July 2021, Tesla announced significant progress of 4680 batteries production in the 2021 Q2 earnings call.

In Nov. 2021, Tesla announced to build a battery equipment factory in Canada to increase the mass-production of 4680 battery, which is expected to started loading vehicles in the US at the start of 2022. The mass-production site in Texas is expected to reach a production capacity of 100GWh by the end of 2022.

2022

In Feb. 2022, the one millionth 4680 battery was announced that had been completed production in January.

Battery manufactures

Panasonic

The financial report revealed that the company accelerated the R&D of 4680, and the prototype production equipment was planned to be installed within FY2022.

BAK Power

The company released the 4680 large cylindrical battery in March 2021, and it’s expected to achieve mass production in 2023.

EVE Energy

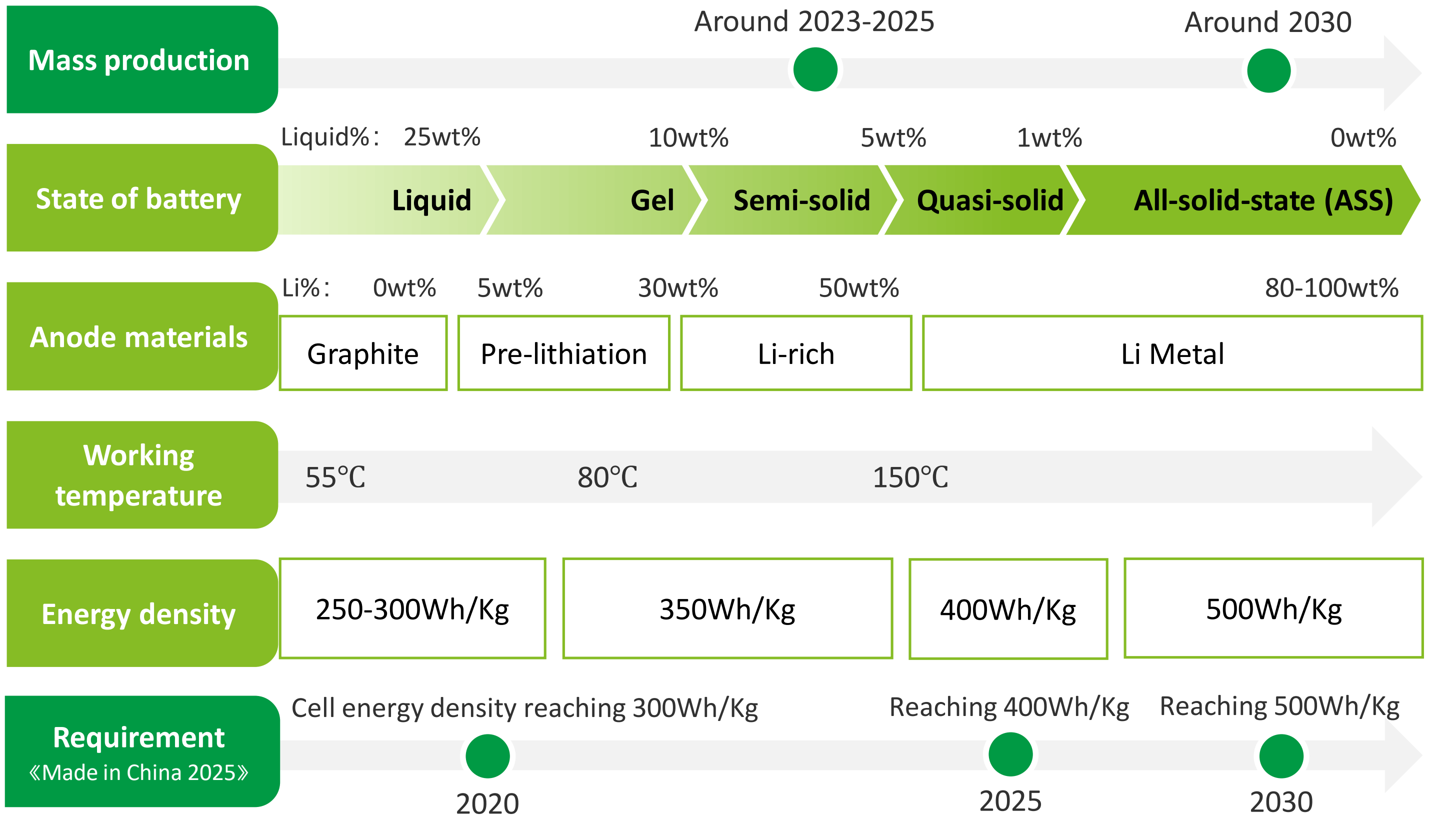
In 2021, the company indicated that their strategic planning for larger cylindrical battery has been completed with 46 series batteries technology on hand.

Outlook of
Solid-State Lithium Battery

Outlook of Solid-state Lithium Battery Development

Liquid-state Li-battery is difficult to catch up with the medium-to-long term energy density requirements for EV battery. Solid-state Li-battery shows significant advantages, but there are still major technical challenges ahead to tackle.

Development route of solid-state Li-battery and requirement for energy density



Mass production
Around 2023-2025
Around 2030

State of battery
Liquid%： 25wt% 10wt% 5wt% 1wt% 0wt%
Liquid | Gel | Semi-solid | Quasi-solid | All-solid-state (ASS)

Anode materials
Li%： 0wt% 5wt% 30wt% 50wt% 80-100wt%
Graphite | Pre-lithiation | Li-rich | Li Metal

Working temperature
55℃ 80℃ 150℃

Energy density
250-300Wh/Kg | 350Wh/Kg | 400Wh/Kg | 500Wh/Kg

Requirement
《Made in China 2025》
Cell energy density reaching 300Wh/Kg – 2020
Reaching 400Wh/Kg – 2025
Reaching 500Wh/Kg – 2030

Significant advantages of solid-state battery:

- **High energy density**： Compared with conventional liquid Li-battery, solid-state battery can work with high-energy cathode and Li-metal anode materials, which thus have higher theoretical energy density.
- **High safety**： The main safety concern of liquid battery lies within its liquid electrolyte. By replacing it with solid electrolyte, solid-state battery is more tolerant to heat, which greatly reduce the risks of ignition or explosion.
- **Low weight**： Without liquid electrolyte and separator, packaging and cooling systems can be simplified in solid-state battery pack, which reduce the total weight and size of the pack for battery range improvement.

Application of ASS battery faces major technical challenges

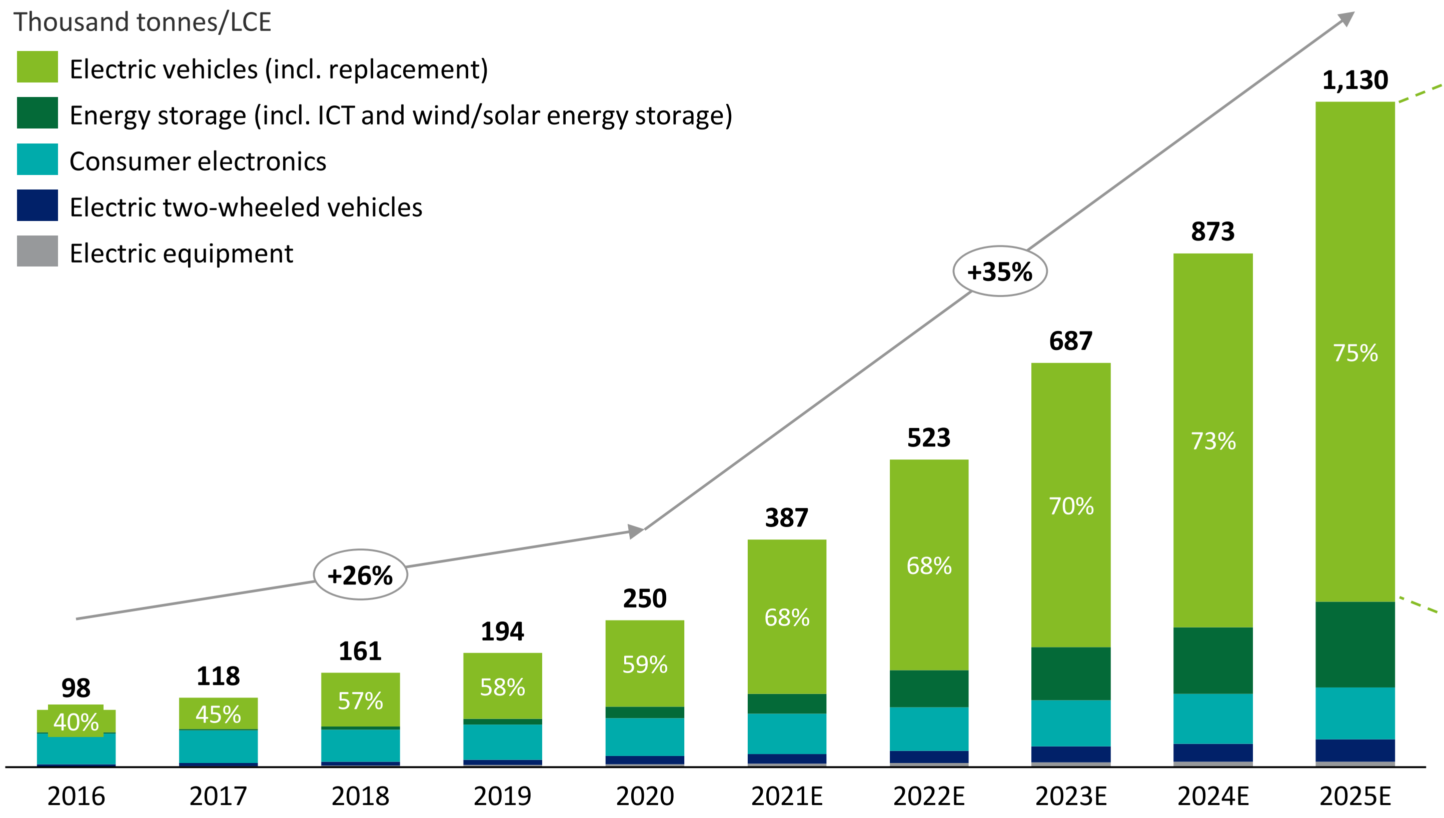
- **Interface problems affecting battery performance:** Large impedance of solid-solid interface causes poor performance of ASS Li-battery, and the interfaces will be continuously damaged during cycling due to poor interfacial behaviour leading to shorter battery life.
- **Solid electrolyte affecting fast-charging**： Li-ion mobility in solid electrolyte is relatively low, especially for polymer and oxide solid electrolyte, limiting the fast-charging capability.

Source: Everbright Securities, expert interviews, public information, Deloitte analysis

The Impact of Solid-state Battery Development on Lithium Demand

Increase in demand for EV batteries is the main driver of upstream lithium demands globally. The development of solid-state battery enriches the lithium application scenarios in anode materials. Pre-lithiation and Li metal anodes are examples of applications with significant growth prospects in the future.

Global battery-grade lithium demand estimation by application



	Liquid	Gel /Semi-solid	Quasi-solid /ASS
Li Application	Liquid batteries are the mainstream of EV batteries, with lithium mainly used in cathode and electrolyte	Gel/semi-solid batteries start to emerge, where lithium is mainly used in pre-lithiation anodes etc.	Following business pilot of quasi-solid/ASS batteries, lithium metal anode will be applied more widely

Lithium demand for EV (thousand tones/LCE)						’20-’25 CAGR
2020	2021E	2022E	2023E	2024E	2025E	
147	262	358	483	635	849	42%

- In the medium term, global lithium demand will grow steadily. The main driver is Li application in EVs, which results from rising EV penetration and increasing application scenarios with the development of solid-state batteries.

Source: Minmetal Securities, public information, Deloitte analysis

Technical Routes of Solid Electrolyte

Amongst the three major technical development routes of solid electrolyte, polymer route is the first to achieve commercialization but with critical weakness; oxide route is currently making significant progress; and the sulphide route shows huge potential despite being in early stage of development.

Three major technical routes of solid electrolyte

	Polymer solid electrolyte	Oxide solid electrolyte	Sulphide solid electrolyte
	Low electrical conductivity		High electrical conductivity
Performance	**Materials:** PEO, PAN etc. **Strengths:** Good performance under high temperature, ease of electrolyte membrane production at scale **Weaknesses:** Low conductivity at room temperature, narrow electrochemical window **Cost:** High	**Materials:** LiPON, NASICON etc. **Strengths:** Good cycling performance, high electrochemical stability **Weaknesses:** Relatively low conductivity of materials, poor interfacial performance **Cost:** Low	**Materials:** LiGPS, LiSnPS, LiSiPS etc. **Strengths:** High electrical conductivity, excellent working performance **Weaknesses:** ease of oxidation, relatively poor interface stability **Cost:** Relatively low
Players	• Polymer route is mainly chosen by **European and American Companies**, with high-energy polymer being a target for future R&D. Bolloré batScap ionic MATERIALS solid energy Solid Power SEEO	• **Chinese Companies** are more likely to choose oxide route, and LLZO products have been supplied to the consumer electronic market. ProLogium 清陶能源 SAKTI3 SONY 赣锋锂业 GanfengLithium	• The sulphide route preferred by **Japanese and Korean companies**, in light of its performance and adaptability to ASS batteries, but there are huge R&D challenges. TOYOTA CATL 宁德时代 SAMSUNG SAMSUNG SDI Panasonic

Because of the relatively low costs and R&D challenges, most new players and domestic companies went down oxide route, which is expected to apply in semi/quasi-solid batteries on EVs at scale. From a long-term perspective, although sulphide route is the most difficult one, its excellent performance and large potential attract players with sufficient funds to consistently invest in this route. Top players have been accumulating decades of technical experience, and will form high technical barriers once they have technology breakthrough.

Source: TF securities, Everbright securities, company website, public information, Deloitte analysis

Case Analysis: Oxide Route Practice—Prologium (1/2)

Prologium's R&D focus moves from wearable devices battery towards EV battery, and continuously upgrades its core technologies. The company remains in a leading position of industrialization in the solid-state battery industry.

Concentrating on solid batteries, Prologium's current R&D is mainly financed by fund-raising

Early start of solid-state technology

- Prologium was founded in 2016, with a founding objective to industrialize solid-state batteries.
- In 2012, Prologium introduced flexible printed circuit solid-state battery.
- In 2014, Prologium introduced pouch solid-state battery, and commercialized the product in consumer electronics area.
- Clients from consumer electronics and wearable devices brought in stable income for Prologium, as well as mass production experience of small-capacity solid batteries.

Switching focus to EV battery and start industrialization

- In 2017, a pilot-scale production line of 40MWh was built, which allowed automatic winding production, marking the start of mass production.
- In 2018, unveiled BiPolar+ technology, and WM announced a sample EV installed Prologium's solid-state batteries.
- In 2019, unveiled Multi Axis BiPolar+ (MAB) solid-state battery pack for cars, and signed strategic cooperation deals with OEMs including NIO, Aiways, and Enovate, as an attempt to scale-up installation. Enovate announced its sample EV installed Prologium's solid-state batteries.

Mass production capacity planning

- In 2020, Prologium has completed its D round fund raising, in which FAW industrial fund invested, taking the collaboration between Prologium and FAW to the next level.
- Established its mainland China headquarter and global industrial plant in Hangzhou, with production capacity set to reach 7Gwh by 2023.
- In 2021, officially introduced CIP (cell is pack) technology.
- Signed sample operation frameworks with multiple OEMs, each targeting to produce 3000-5000 EVs to enter the market.

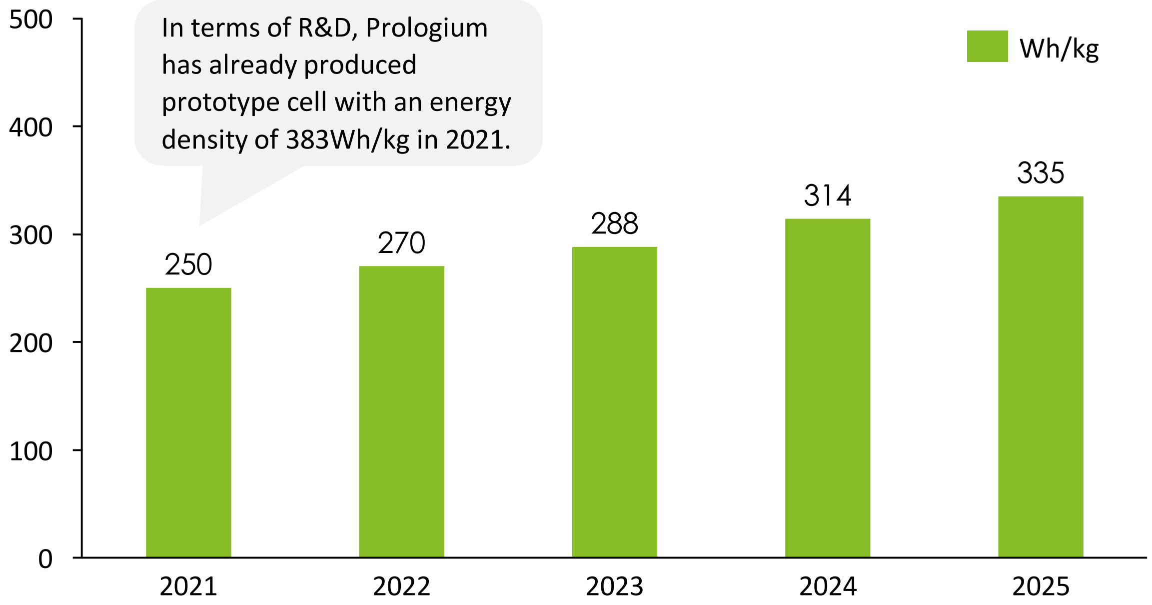
- Prologium focuses on developing **oxide solid-state batteries**, with three core technologies: Lithium Ceramic Battery, Multiaxial Bipolar Battery Pack and Active Safety Mechanism.
- Currently, gel materials only take up less than 10% of volume in Prologium's battery cell, and less than 4% of weight. Industrialized transition from quasi-solid to all-solid-state only requires fine 15% of adjustments, without significant technical challenges. ASS Li metal batteries **are expected to be produced for testing by 2023,** and to be mass-produced by 2024. Mass-produced ASS batteries will be first piloted in IT industry and then apply to EV batteries.

Source: Prologium's official website, public information, Deloitte analysis

Case Analysis: Oxide Route Practice—Prologium (2/2)

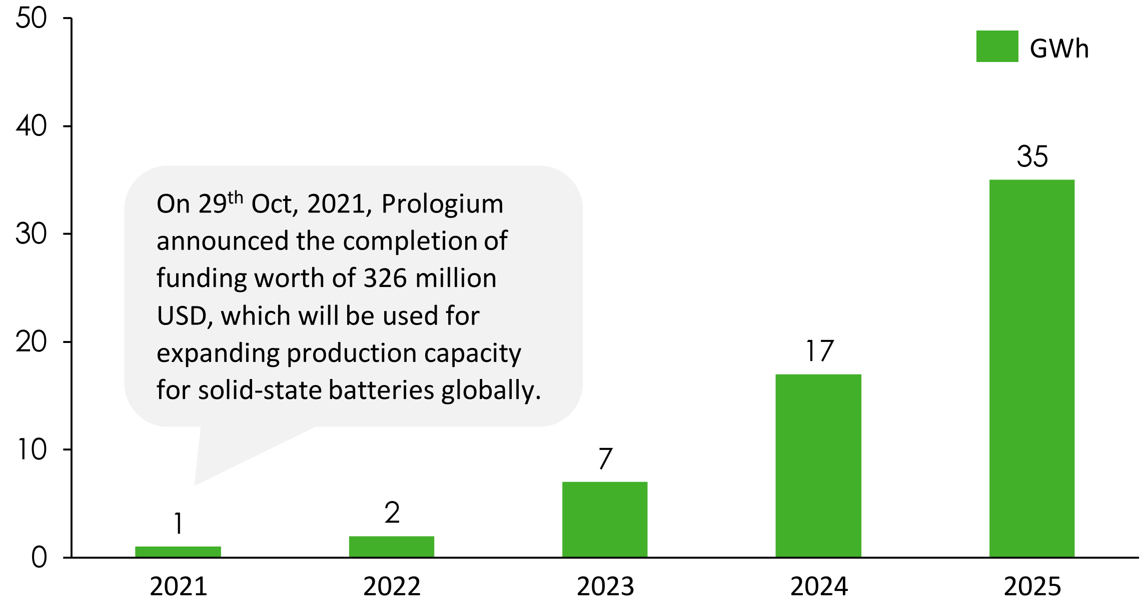
Prologium has well-defined mass-production plans, which focus on increasing energy density as well as production capacity. Products are expected to be deployed in EVs at scale around 2022 midyear.

Energy density plan for mass-produced solid-state batteries



In terms of R&D, Prologium has already produced prototype cell with an energy density of 383Wh/kg in 2021.

Production capacity plan for solid-state batteries



On 29th Oct, 2021, Prologium announced the completion of funding worth of 326 million USD, which will be used for expanding production capacity for solid-state batteries globally.

- While the costs of solid-state cell is higher than liquid cell at similar energy density level, significant cost advantages are found when comparing the entire battery packs. According to published estimation by Prologium, prices of solid-state and liquid batteries are equivalent when solid-state production capacity reaches 7GWh or above.
- Currently, the main markets for Prologium's mass-produced products are consumer electronics (FLCB, PLCB), special equipment for extreme environment (LCB), and energy storage etc. The company is also set to focus on different model positioning in the NEV market, providing solid-state LFP (for economic models) and solid-state NCM (for higher-end models) solutions.

Source: Prologium's official website, public information, Deloitte analysis.

Case Analysis: Sulphide Route Practice—Toyota (1/2)

As a former leading internal combustion engine manufacturer, Toyota has shifted priorities in recent years towards electric conversion. To achieve carbon neutrality, Toyota has focused on battery development, heavily investing in full solid-state batteries.

Solid-state battery plans from an OEM perspective

Develop solid-state batteries initially for HEVs

- In 1997, Toyota introduced the 1st generation of Prius, which were the pioneers of NEVs.
- In 2004, Toyota started developing ASS batteries, with an aim to increase energy density and to reduce battery size in HEVs.
- In 2010, Toyota introduced sulphide solid-state batteries.
- In 2014, sources claimed that the energy density of prototype batteries in Toyota's lab has reached 400 Wh/kg.

Collaborate with domestic industrial leaders to accelerate mass-production

- In 2017, Toyota has allocated more than 200 people to accelerate the R&D process of solid-state batteries.
- In 2018, collaborating with 23 vehicle, battery and material manufacturers including Panasonic, Honda, Nissan etc., and 15 academic institutions including Kyoto University and RIKEN, Toyota worked on core ASS battery technology.
- In 2019, jointly announced with Panasonic to establish a JV to develop and produced batteries for EVs etc. This JV focuses on developing and mass-producing solid-state batteries.

Commercialize ASS batteries with a progressive approach

- In 2020, Toyota built a vehicle loaded with ASS batteries and piloted on test route to obtain driving data. Licenses were then granted for vehicle loaded with ASS batteries and test drive was conducted in the same year.
- In 2021, Toyota announced its goal to install solid-state batteries on EVs, the firm is establishing a stable battery supply system, aiming to commercialize ASS batteries.
- In 2022, Toyota confirmed that ASS batteries will be first loaded on Toyota HEV model.

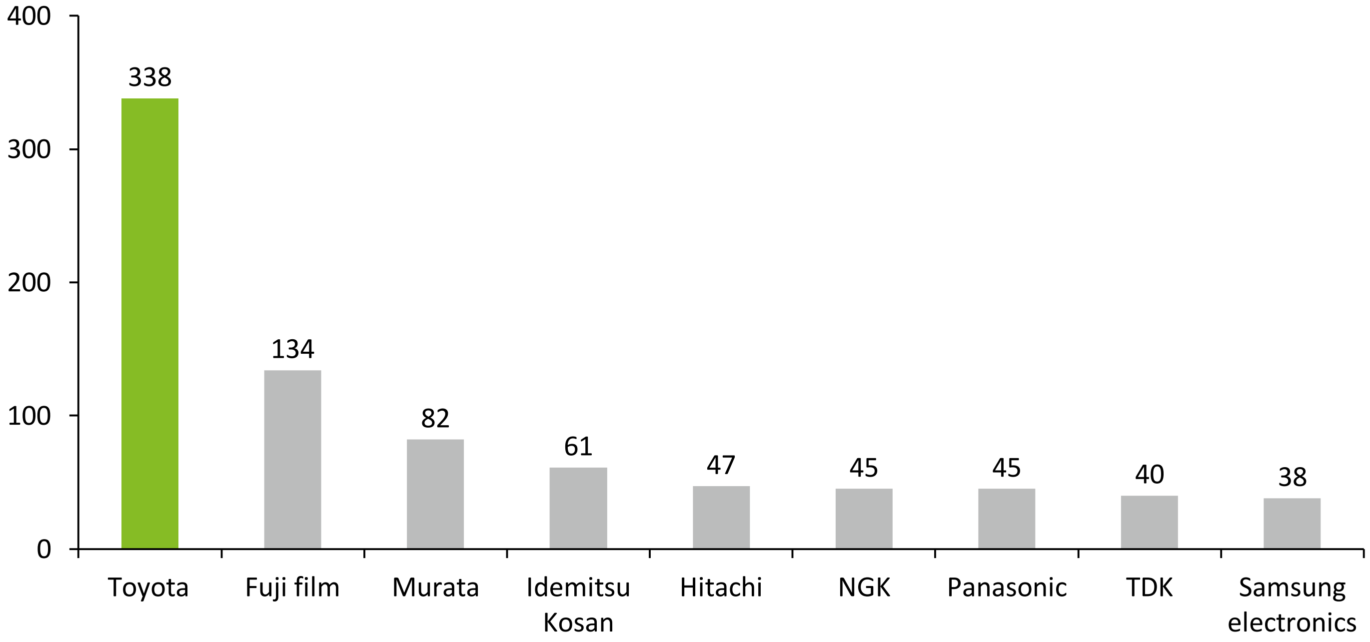
- Toyota insisted on going down the route of HEVs at the early stage, so that the development of EVs was relatively slow. But in fact, their new energy technology is currently under diverse development, e.g. in areas of fuel batteries, solid-state batteries, Ni-MH batteries, Li batteries, fluoride batteries, and each part of components of NEVs. Therefore, they are still in good shape of technical preparation for developing EVs.
- Toyota has piloted on the prototype vehicle loaded with ASS batteries, while lacking a working prototype has been one of the weaknesses for many solid-state battery start-ups.

Source: Toyota press conference, official website, public information, Deloitte analysis

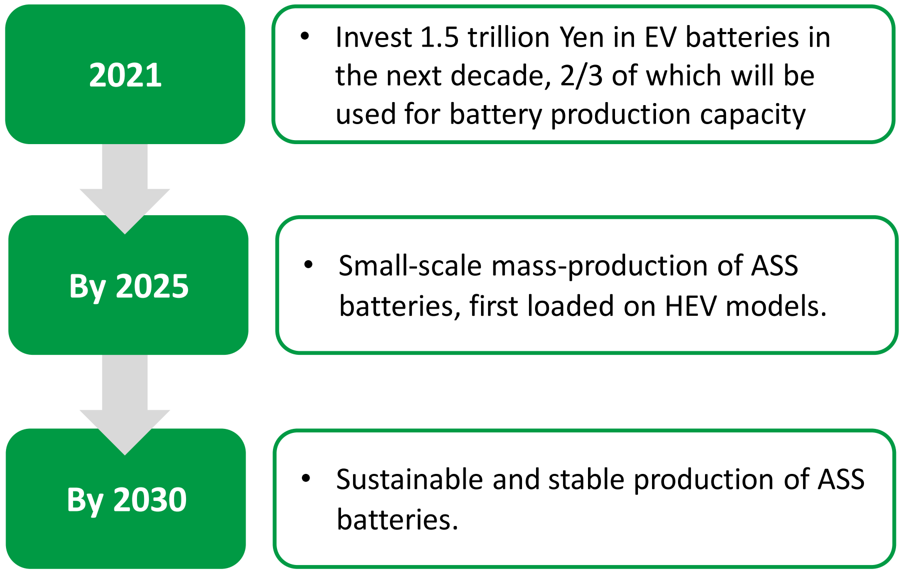
Case Analysis: Sulphide Route Practice—Toyota (2/2)

Toyota has attained leadership position in the route of sulphide electrolyte with its long-term experience in solid-state batteries, coupled with mass production plan for full solid-state batteries.

Numbers of global solid electrolyte patent by company, as of 2020



Toyota's mass production plan for solid-state batteries



2021

- Invest 1.5 trillion Yen in EV batteries in the next decade, 2/3 of which will be used for battery production capacity

By 2025

- Small-scale mass-production of ASS batteries, first loaded on HEV models.

By 2030

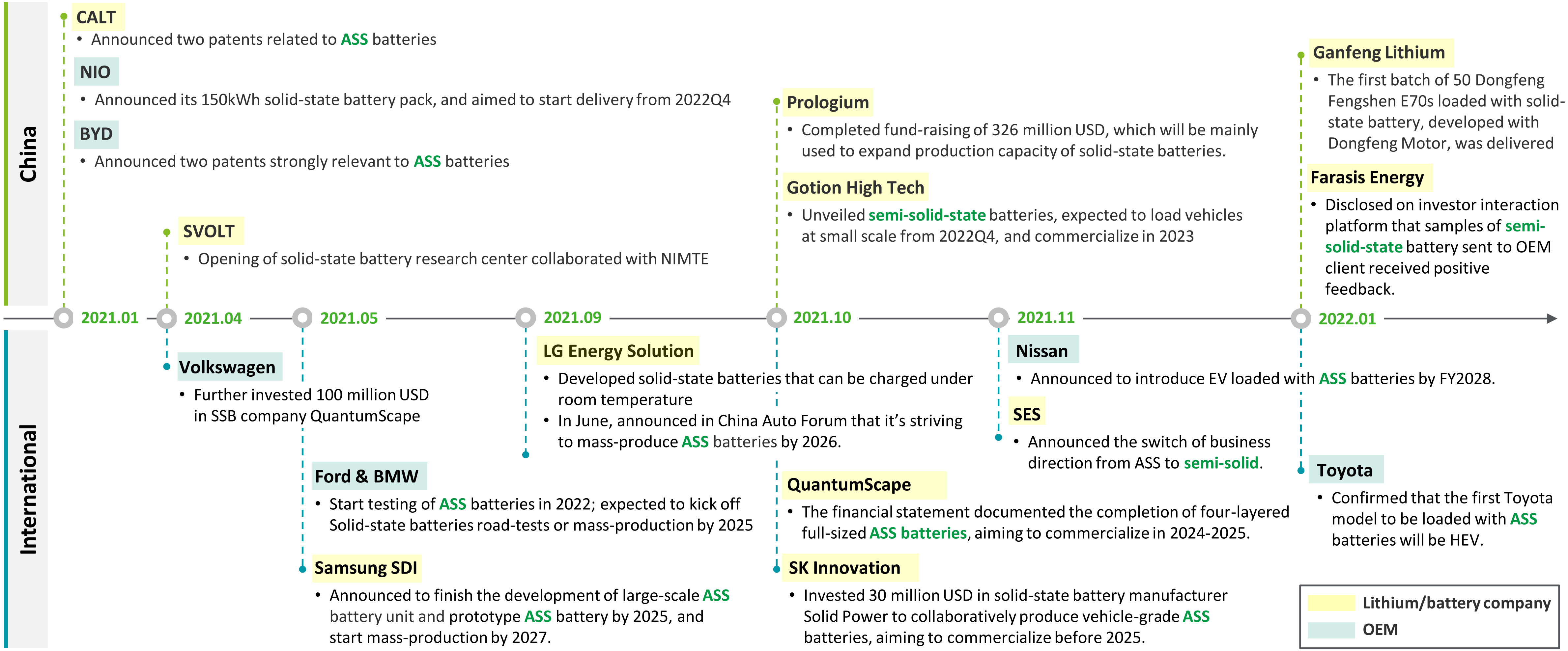
- Sustainable and stable production of ASS batteries.

- After decades of technology accumulation for developing solid-state batteries, Toyota has not only acquired patents in areas including solid electrolyte materials and production techniques of solid-state batteries, but also developed all-rounded technical route and process for recycling and reusing cathode materials and solid sulphide electrolytes. Toyota is the company with most solid battery related patents in the world.
- Before mass production, Toyota needs to address issues such as short battery life of its ASS batteries found in prototype vehicle testing.

Source: Derwent Innovations Index patent database, Toyota press conference, official website, public information, Deloitte analysis

R&D and Industrialization Progress of Solid-state Batteries – China vs International

Lithium companies, battery manufacturers and OEMs are proactively engaging in the field of solid-state batteries, but currently the industry is still in its infancy of moving from semi-solid to ASS. Critical technical challenges of ASS imply that it could take a while before commercial industrialization.



China

CALT
- Announced two patents related to **ASS** batteries

NIO
- Announced its 150kWh solid-state battery pack, and aimed to start delivery from 2022Q4

BYD
- Announced two patents strongly relevant to **ASS** batteries

SVOLT
- Opening of solid-state battery research center collaborated with NIMTE

Prologium
- Completed fund-raising of 326 million USD, which will be mainly used to expand production capacity of solid-state batteries.

Gotion High Tech
- Unveiled **semi-solid-state** batteries, expected to load vehicles at small scale from 2022Q4, and commercialize in 2023

Ganfeng Lithium
- The first batch of 50 Dongfeng Fengshen E70s loaded with solid-state battery, developed with Dongfeng Motor, was delivered

Farasis Energy
- Disclosed on investor interaction platform that samples of **semi-solid-state** battery sent to OEM client received positive feedback.

2021.01 — 2021.04 — 2021.05 — 2021.09 — 2021.10 — 2021.11 — 2022.01 →

International

Volkswagen
- Further invested 100 million USD in SSB company QuantumScape

Ford & BMW
- Start testing of **ASS** batteries in 2022; expected to kick off Solid-state batteries road-tests or mass-production by 2025

Samsung SDI
- Announced to finish the development of large-scale **ASS** battery unit and prototype **ASS** battery by 2025, and start mass-production by 2027.

LG Energy Solution
- Developed solid-state batteries that can be charged under room temperature
- In June, announced in China Auto Forum that it's striving to mass-produce **ASS** batteries by 2026.

QuantumScape
- The financial statement documented the completion of four-layered full-sized **ASS batteries**, aiming to commercialize in 2024-2025.

SK Innovation
- Invested 30 million USD in solid-state battery manufacturer Solid Power to collaboratively produce vehicle-grade **ASS** batteries, aiming to commercialize before 2025.

Nissan
- Announced to introduce EV loaded with **ASS** batteries by FY2028.

SES
- Announced the switch of business direction from ASS to **semi-solid**.

Toyota
- Confirmed that the first Toyota model to be loaded with **ASS** batteries will be HEV.

🟨 Lithium/battery company
🟩 OEM

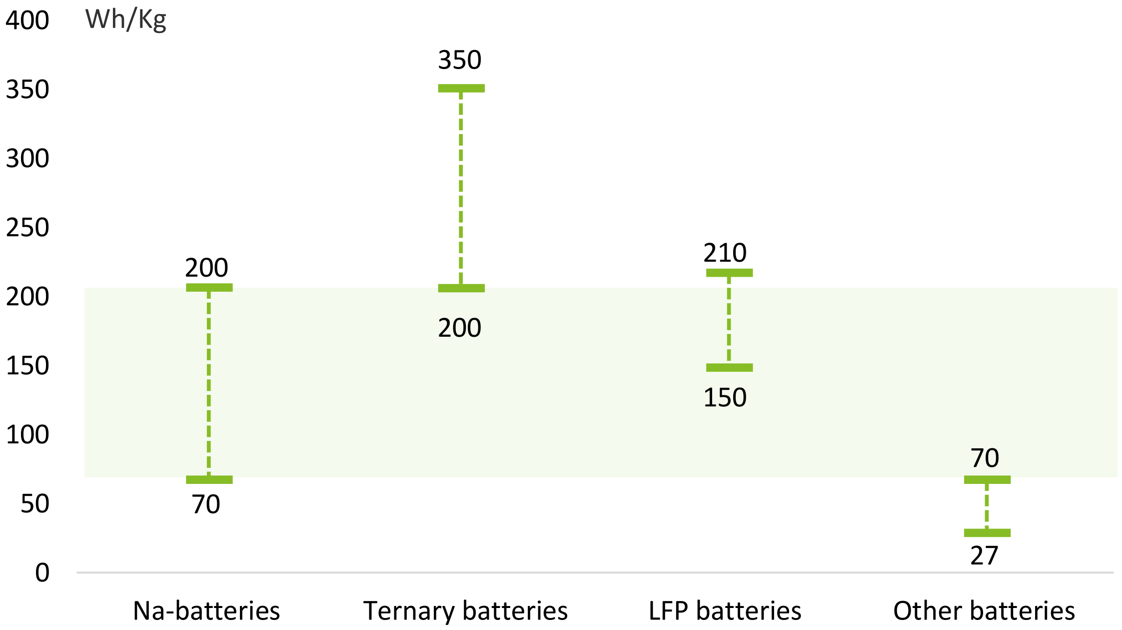
Source: Qianzhan, company official websites, public information, Deloitte analysis

Sodium-ion Battery & Application Prospects

Characteristics and Advantages of Sodium-ion Battery

The long-term development of lithium-ion battery (LIB) could be constrained by shortage of lithium resources. As such, sodium-ion battery (SIB) might become an important alternative considering its abundant resources, high cost-effectiveness and high safety.

Energy density comparison between SIB and LIB

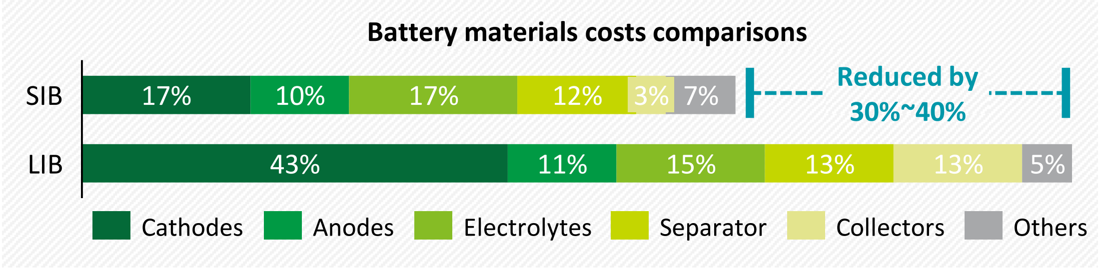


- SIB shows superior performance regarding of fast-charging and low-temperature capacity, its range of energy density also partly overlaps with that of LFP batteries. However, its cycling life is shorter than Li-batteries in general.

SIB with advantages in cost reduction and safety

Low cost

- In light of the **abundance of sodium resources** and **lower costs associated with aluminium foil anode collectors**, the material costs of SIB are highly favourable.



Safety

- The chemical properties of Sodium ion is highly stable, with relatively high electrical resistance, which makes Na-battery outperforms Li-battery when working under heat or coldness. **Thermal stability** of sample Na-battery products was found to **far exceed national requirements** in testing.

Compatibility

- SIB and LIB **share similar functional principles and structures**. The R&D of electrolytes and separators for SIB can be developed on established technology for LIB, and **the production process of SIB compatible with current LIB production equipment.**

Source: Everbright security, TF security, public information, Deloitte analysis

Application of Sodium-ion Battery

Energy storage represents a significant potential for sodium-ion battery applications. In the future, SIB and LIB applications may be able to complement each other

Application prospects of SIB

- Due to low energy density in SIB, where there is an improvement ceiling, SIB is hypothesized to act more as a supplement in segments of the new energy market. SIB is expected to serve as an alternative solution for **energy storage or low-speed commuting vehicles that do not require high energy density and are cost-sensitive. Its impacts on the medium-to-high end passenger vehicle market will be relatively limited**.

Application prospect 1： energy storage

- Household/business energy storage

- Renewable energy storage station

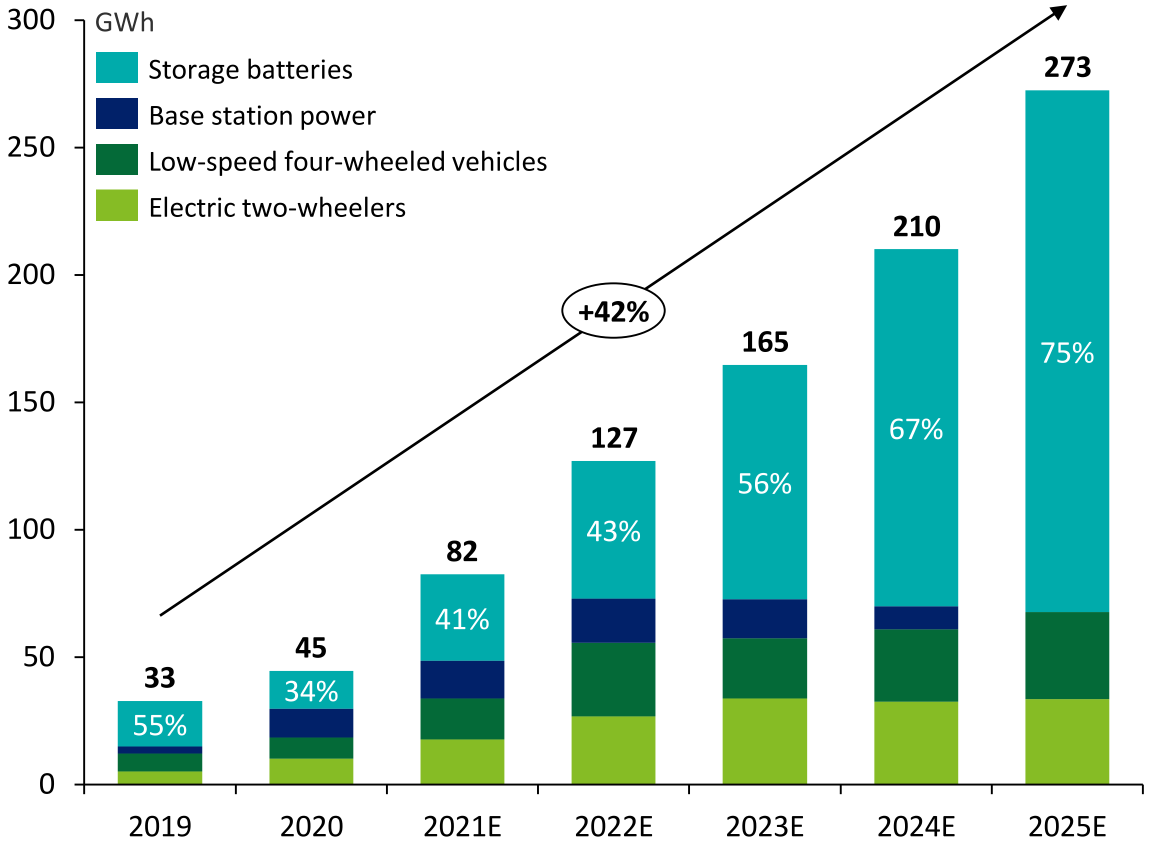
- Base station power/ energy storage

Application prospect 2： motor power

- Electric two-wheeler

- Low-speed four-wheeled vehicles

Installed capacity projection of SIB by potential application

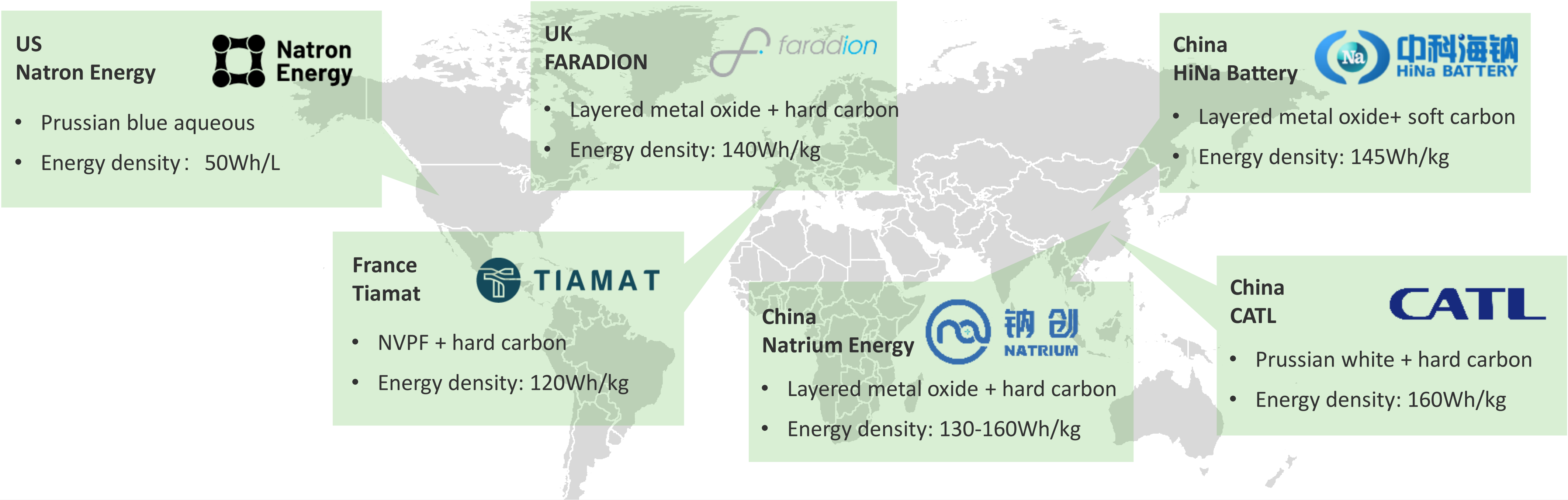


Source: China Bicycle Association, CPCA, Everbright securities, Founder securities, public information, Deloitte analysis

Global Developmental Progress of Sodium-ion Battery

While the international industrialization of SIB is still in its infancy, a number of Chinese companies have arguably taken leading positions in the technical development level of sodium-ion batteries.

Technical landscape of global major sodium-ion battery companies



US
Natron Energy

- Prussian blue aqueous
- Energy density： 50Wh/L

UK
FARADION

- Layered metal oxide + hard carbon
- Energy density: 140Wh/kg

China
HiNa Battery

- Layered metal oxide+ soft carbon
- Energy density: 145Wh/kg

France
Tiamat

- NVPF + hard carbon
- Energy density: 120Wh/kg

China
Natrium Energy

- Layered metal oxide + hard carbon
- Energy density: 130-160Wh/kg

China
CATL

- Prussian white + hard carbon
- Energy density: 160Wh/kg

- Faradion (UK) is the first company in the world to specialize in SIB, and after its foundation in 2011, the industrialization process of SIB ushered in a comprehensive growth globally.
- Different routes of production have their own advantages and drawbacks. For example, the advantage of layered metal oxide, as showcased by Chinese SIB leading player HiNa battery, is that it is compatible with current production technologies for LIB, however there are also safety concerns yet to resolve.

Source: ESCN, company official websites, CATL sodium-ion battery press conference, public information, Deloitte analysis

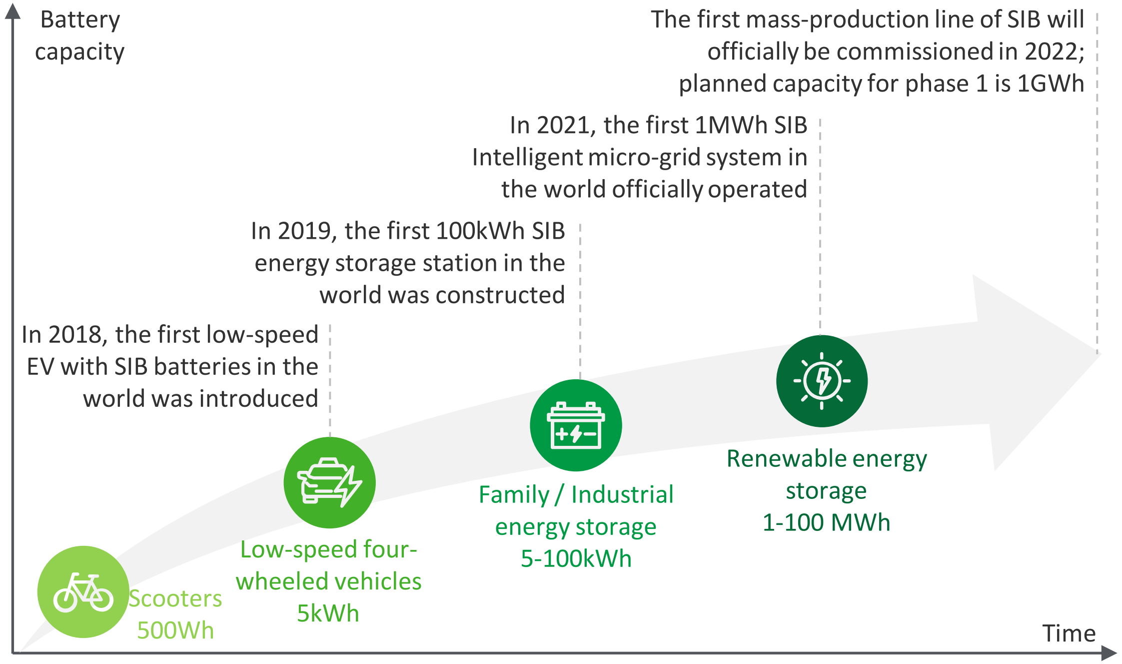
Case Analysis: HaiNa Battery & CATL

SIB leading player HaiNa battery focuses on product development and applications in energy storage to promote overall SIB industrialization. Meanwhile, the entry of battery giant CATL stimulates the growth of the overall value chain, and potentially expands the future applications of SIB.

SIB leading player in China: HaiNa Battery

- Founded in 2017, technical competence of HaiNa Battery was leveraged from the Institute of Physics, CAS. The industrialization progress of its SIB products is market-leading.

Industrialization progress of HaiNa battery



The first mass-production line of SIB will officially be commissioned in 2022; planned capacity for phase 1 is 1GWh

In 2021, the first 1MWh SIB Intelligent micro-grid system in the world officially operated

In 2019, the first 100kWh SIB energy storage station in the world was constructed

In 2018, the first low-speed EV with SIB batteries in the world was introduced

Scooters
500Wh

Low-speed four-wheeled vehicles
5kWh

Family / Industrial energy storage
5-100kWh

Renewable energy storage
1-100 MWh

SIB application innovator: CATL

- LIB giant CATL announced its first generation of SIB in July, 2021, and started commercial collaboration with OEMs and energy storage clients, whose primary industry chain is expected to be formed by 2023.

World-leading energy density

1st Generation → 2nd Generation

160Wh/kg → **200Wh/kg**

By modifying characteristics of cathode and anode materials, the cell energy density of CATL's 1st gen SIB is record-breaking. The 2nd gen SIB might adopt anode-free technology to further improve energy density.

Innovative Li-Na mix & match pack

AB Battery System Solution

Na | **BMS[1]** | **Li**

CATL innovatively mixes Sodium-ion cells and Lithium-ion cells in one battery pack, and achieves precise control of different chemistry batteries through BMS.

- Having set foot in SIB industry, CATL may improve its competence in the high-potential energy storage market. Meanwhile, its breakthrough on the energy density of SIB and innovative Na-Li pack solutions are expected to further introduce SIB into new application scenarios in the field of power battery.

Note: 1. BMS-Battery Management System

Source: Business official websites, CATL SIB press conference, Everbright securities, public information, Deloitte analysis

EV Battery Development from Automotive OEMs Perspective

Three Strategic Issues that OEMs Should Consider on Battery Development

OEMs need to take into account consumer demand for products, the advancement of vehicle platforms and related technologies R&D, and the stability of raw materials supply and price.

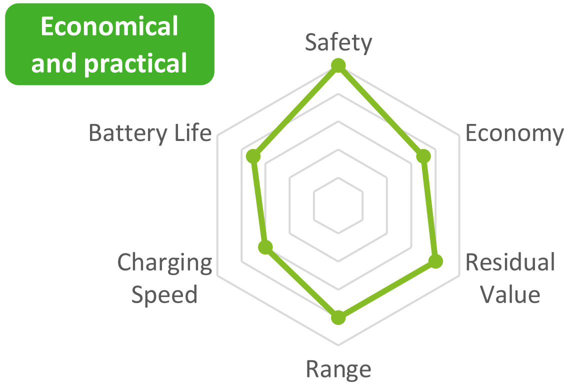
Strategic Issue	**How would consumer demands for different product experiences affect OEMs' choice of battery technologies?**	**How could OEMs ensure the advancement of vehicle platforms and related technologies given rapid battery technology iteration?**	**How will OEMs ensure supply stability and cost optimization under the tight raw material supply and rising prices?**
Specific challenge	Consumers still have various pain points for battery experience, and **different types of consumers have different concerns** about battery – Based on the needs of different market segments and product matrix planning, **how to choose and configure the existing battery material system**? – How to influence or manage **the battery R&D of collaborative suppliers** to meet the expectations of the end market?	With **short upgrading cycle** of battery technology, the iteration of anode and cathode materials, structural innovation, and the emergence of new technologies such as semi/all-solid-state electrolyte, OEMs have less **control over battery technology development** – Does the company's **vehicle models roadmap** for short to long-term match the **technological development trend** of EV batteries? – **What capabilities** do OEMs need to have to response battery technology development and rapid upgrades?	The continuously rising prices of raw materials (e.g. **lithium, cobalt,** etc.) and shortage in supply lead to the instability in battery prices and supply – Considering both supply and demand, does the company need to **penetrate upwards** into battery manufacturing? If so, through what approach? – Facing the constraints of the future lithium resource shortage on the industry, what **strategic planning and risk avoiding measures** does the company have?
High-level advice for OEMs	• Select matching battery materials and technical solutions according to demand of different types of consumers • Integrate the battery, motor and electric control technology to create unique advantages of selling points and application scenarios • Balance the battery cost, sales volume and revenue of different models to optimize the overall battery technology application scheme	• Build forward-looking research ability and predict the future iteration speed and evolution path of battery technology • Strengthen cooperation with battery manufacturers to quickly integrate new technologies within the platform life cycle • Strengthen the standardization and modularization of battery structure design to provide compatibility and expansibility for chemical material iteration	• Strengthen cooperation with one or more battery manufacturers to ensure stable price and supply • Vertically integrated with midstream key material suppliers • Invest in upstream suppliers of the industrial chain to further understand the dynamics and trends of raw material market, and hedge raw material supply risks

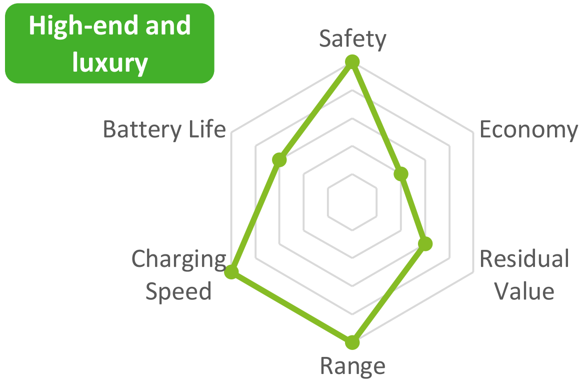
The Influence of Consumer Demand on Battery Choice

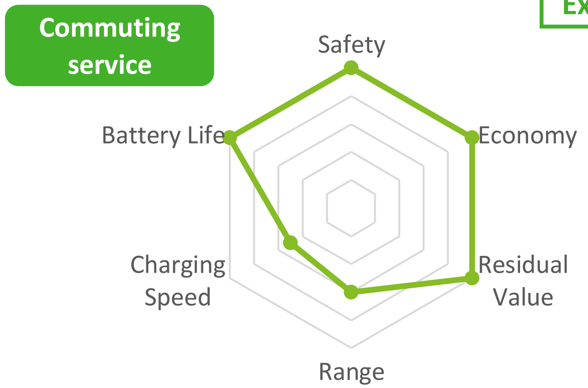
OEMs need to select battery technology solutions according to their product positioning and the demand of target customers.

Demand of three main user types[1]

Example







Note: 1. “Battery Life" refers to the times of charge and discharge, and “Economy" refers to the difference in purchase price of EV due to different battery technologies

Insights for OEMs

1 Select matching battery materials and technical solutions according to demand of different types of consumers

- Deeply understand the core demands of various consumers in different market segments for batteries, and convert them into requirements for battery technologies
- Design battery technical solutions/specifications and choose technical routes according to the battery technologies requirements

2 Integrate the battery, motor and electric control technology to create unique advantages of selling points and application scenarios

- Based on battery technology, consider its deep integration with other functional modules of the vehicle (e.g. BMS, electric drive, braking, steering, etc.)
- Consider consumer demand throughout a battery’s life cycle, including the deployment of business ecosystem such as charging and replacement of batteries, vehicle-battery separation, etc

3 Balance the battery cost, sales volume and revenue of different models to optimize the overall battery technology application scheme

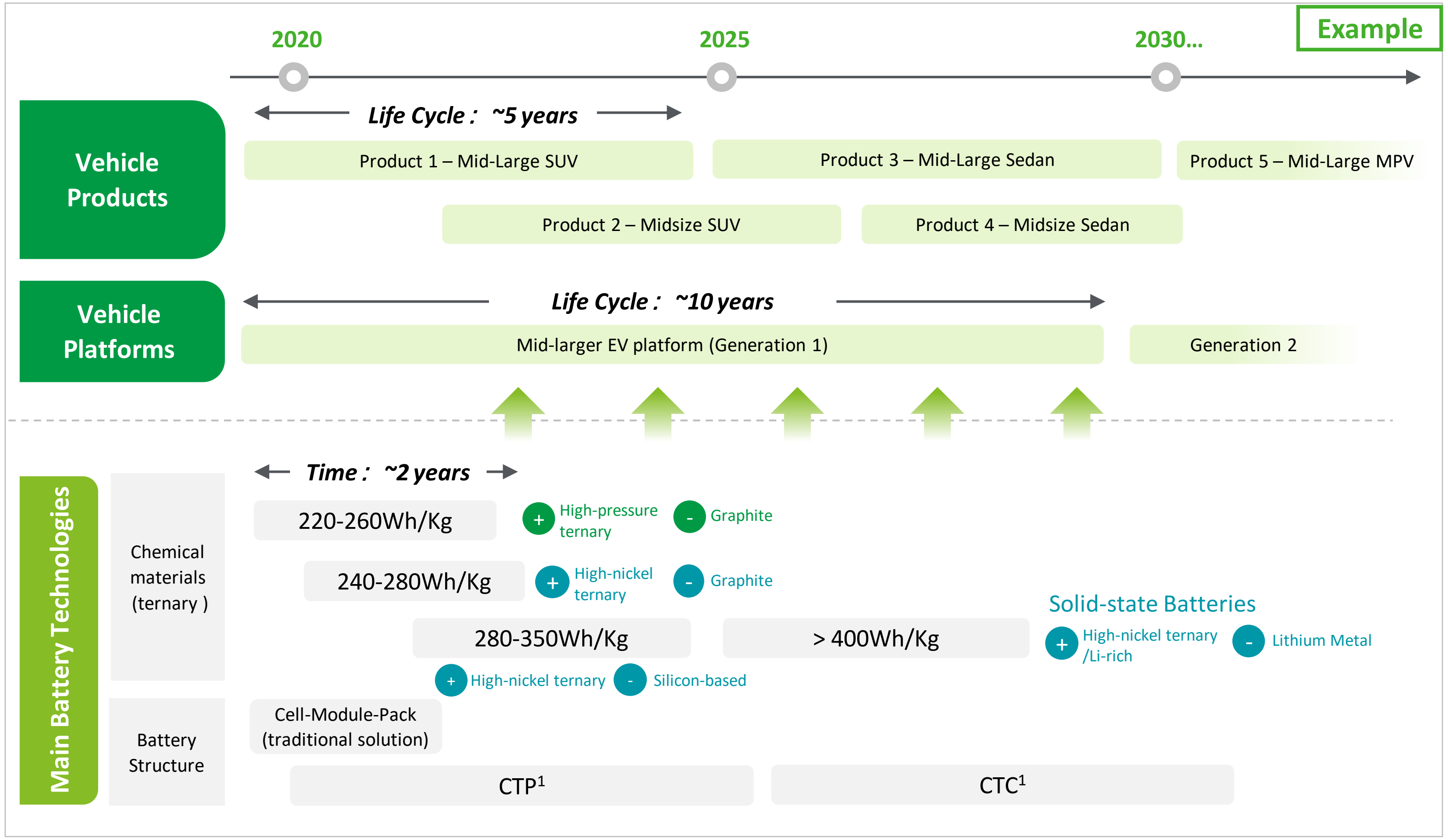
- Consider a variety of battery technology routes and solutions to fully cover the demands of consumers in target market segments
- Build a cross-platform and cross-product integrated financial model for EV battery to optimize the economic benefits of battery technical solutions

Source: Deloitte analysis

Advancement of Vehicle Platform and Related Technology

With the fast iteration of battery technologies, OEMs need to strengthen the synchronous development in related fields in order to rapidly integrate the latest battery technology into their product pipeline.

Development example of electric vehicle platform VS battery technology



Example

2020 2025 2030…

Vehicle Products

Life Cycle: ~5 years

Product 1 – Mid-Large SUV

Product 2 – Midsize SUV

Product 3 – Mid-Large Sedan

Product 4 – Midsize Sedan

Product 5 – Mid-Large MPV

Vehicle Platforms

Life Cycle: ~10 years

Mid-larger EV platform (Generation 1)

Generation 2

Main Battery Technologies

Time: ~2 years

Chemical materials (ternary)

- 220-260Wh/Kg: + High-pressure ternary; - Graphite
- 240-280Wh/Kg: + High-nickel ternary; - Graphite
- 280-350Wh/Kg: + High-nickel ternary; - Silicon-based
- > 400Wh/Kg: Solid-state Batteries: + High-nickel ternary /Li-rich; - Lithium Metal

Battery Structure

- Cell-Module-Pack (traditional solution)
- CTP[1]
- CTC[1]

Notes: 1. CTP-Cell to Pack, CTC-Cell to Chassis

Source: public information, Deloitte analysis

Insights for OEMs

EV platforms generally undergo technical iterations every ten years, while the development speed of EV battery technologies is much faster. Besides, due to traditional OEMs' insufficient control of battery technology, their EV platforms technologies may lack of overall competitiveness. Therefore, OEMs need to ensure the following when planning on EV platform development and related core technologies:

- **Build forward-looking research ability and predict the future iteration speed and evolution path of battery technology**
  - E.g. The integrated die-casting technology of Tesla's chassis was initially designed to adapt to the CTC battery structure in order to significantly reduce the weight of the vehicle
- **Strengthen cooperation with battery manufacturers to quickly integrate new technologies within the platform life cycle**
  - E.g. NiO deeply cooperates with CATL, and constantly integrate with innovative battery technologies (e.g. CTP, ternary-LFP battery pack and semi-solid battery) based on NIO NP platform
- **Strengthen the standardization and modularization of battery structure design to provide compatibility and expansibility for chemical material iteration**
  - E.g. under the traditional integration mode, the MEB platform of Volkswagen Group has flexible battery design and arrangement, which can provide different models with different range according to the number of battery modules

Raw Material Supply Chain Stability and Cost Optimization

OEMs need to strengthen their collaborations with battery suppliers and selectively integrate upstream and midstream suppliers vertically.

Example of OEMs' upstream integration / collaboration

	Upstream raw material suppliers			Midstream refined material suppliers		Battery suppliers	
	Lithium mines, Salt lakes	Nickel	Cobalt	Li_2CO_3, LiOH, Li metal	Precursors, cathode materials	Ternary lithium battery	LFP battery
Key players	Pilbara, Allkem	BHP Billiton, Tsingshan	Glencore, Huayou Cobalt	Ganfeng Lithium, Tianqi Lithium	Shanshan Co, CNGR	LG, Samsung, CATL	
Challenges for OEMs	• Tight supply of lithium concentrate and lithium salts caused prices to soar; and construction cycle of new capacity are relatively long • Cobalt is a very scarce and strategic metal with high price tag			• Rapid iteration of cathode material technology requires a certain level of know-how on technical issues		• Rising prices in up/midstream have led to rising cell costs, which resulted in battery suppliers raising prices	
Strategic moves of OEMs	Long term supply / underwriting agreement			Long term supply agreement		Long term supply agreement	
	Investment				Investment	Investment	
		Establishment of JV	Establishment of JV		Establishment of JV	Establishment of JV	
						Independent-development or acquisition	

Insights for OEMs

- **Strengthen cooperation with one or more battery suppliers to ensure stable battery price and supply**
  - Ensure the supply and price stability of raw materials by signing strategic supply agreements (e.g. BMW and CATL), investing in shares (e.g.Volkswagen's investment in Gotion High-tech) and setting up JV (e.g. some domestic OEMs and CATL); A few OEMs choose to develop their own batteries (such as GWM and GAC)
  - In terms of partners, introduce tier-2 suppliers that meet technical and supply requirements, so as to improve the bargaining power whilst reducing over-reliance on existing suppliers
- **Vertically integrate with key midstream material suppliers**
  - BMW signed a long term supply agreement with Ganfeng Lithium; Volkswagen and Huayou Cobalt jointly established a ternary cathode material firm
- **For OEMs with strong ability of integration, appropriately invest in upstream suppliers to further understand the raw material market dynamics and trends, and hedge supply risks**
  - Sign strategic supply / underwriting agreements with upstream suppliers (e.g. GWM underwrites the Pilgangoora mine in Australia), directly invest in mineral resources or set up JV (e.g. Toyota's investment in Orocobre)

Source: company official websites, public information, Deloitte analysis

Business Implications of EV Battery Trends

Business Implications of EV Battery Trends for Lithium and Battery Companies

Leading lithium companies and battery manufacturers should carefully consider the following issues from a strategic perspective.

Overall strategic planning
(Where to play)

- Does the company have clear and reasonable **battery technology roadmap** for 3-5 years/5-10 years that matches its own technical characteristics?
- What are the plans for the **commercialization and capacity construction** of battery technology? What are the advantages, positioning and core application areas of the company's battery products?
- How to treat **the relationships with upstream and downstream companies**? Are there needs to vertically expand upstream to secure battery materials and even raw materials such as lithium resources? Is better for the company to mainly play the role of supplier to downstream OEMs or to establish strategic collaborations with them?

Technological R&D planning
(How to play)

- How to choose or prioritize the route of technological development between **material upgrades and structural renovations**?
- How to balance or strategically allocate R&D investment in different technological routes, in order to accelerate battery's R&D process and improve technological advancement in the face of fierce competition?

- Should the **R&D targets** focus on semi-solid battery, or regard it as a interim solution before achieving the ultimate goal of ASS batteries?
- What depth should R&D investment and technological development target to reach, in order to avoid "missing steps"?
- Given **great changes of production lines** from liquid to solid-state batteries, should the company plan ahead or wait and see?

- Facing the constraints of the future lithium resource shortage on the industry, what **strategic planning and alternatives** does the company currently have?
- Considering the sustainable development of the company, is it necessary to prepare **battery technologies of other material systems**? Is the company planning to cut into the development of SIB technology that is similar in principle with LIB?

Short-to-medium term → Long term → Future

Business Implications of EV Battery Trends for Automotive OEMs

Leading automotive OEMs should carefully consider the following issues from a strategic perspective.

Overall strategic planning
(Where to play)

- Does the company's **vehicle models roadmap** for 3-5 years/5-10 years match the technological development trend of EV batteries?
- Which EV battery R&D route should the company adopt? Is it to **do independent R&D or seek external collaborations**? **What capabilities and strengths** need to be built?
- Considering both supply and demand, does the company need to **penetrate upwards into battery manufacturing**? If so, enter which sector? Through what approach?

Technological R&D planning
(How to play)

How to meet market demands and achieve product differentiation?

- Based on the needs of different market segments and product matrix planning, **how to choose and configure the existing battery material system**? Should the company go for ternary or LFP or other batteries?
- How to influence or manage the battery R&D of collaborative suppliers to meet the expectations of the end market?

How to create a leading edge in battery technology?

- Would the company consider to accelerate the development of solid-state battery technology and increase R&D investment?
- Which **solid electrolyte route** to adopt? Polymer, oxide or sulphide route?
- How to develop SSB ability? Would the company consider to **improve independent R&D capability** to avoid excessive reliance on battery manufacturers in the future?

How to maintain the stability of raw material and battery capacity supply?

- Facing the constraints of the future lithium resource shortage on the industry, what **strategic planning and alternatives** does the company currently have?
- How does the company view the feasibility of sodium-ion batteries in the field of EV batteries and even for passenger EVs? Would the company consider to implement relevant plans?

Short-to-medium term → Long term → Future

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