FROST & SULLIVAN

Market Engineering

Independent Market Study on Global and China New Energy Materials and Energy Metals Market

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Presented to

CNGR 中伟

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Confidential

Research Scope

Independent Market Study on Global and China New Energy Materials and Energy Metals Market

Research Period	• Base year: 2024 • Historical: 2020 to 2024 • Forecasting: 2025E to 2030 & 2040E & 2050E
Service Market Scope	• New Energy Materials • Energy Matels
Geographical Scope	• Global • China

Assumptions and Methodology

Assumptions:

The market size and forecasts were modeled by Frost & Sullivan based on the following assumptions.

- The social, economic and political conditions in global markets discussed will remain stable during the forecast period;
- Government policies on global and China new energy materials and energy metals market will remain consistent during the forecast period;
- New Energy Materials and Energy Metals Market market will be driven by the factors which are stated in this report.

Methodology:

In preparing the report, Frost & Sullivan has relied on the statistics and information obtained through primary and secondary research.

- Primary research includes interviewing industry participants, competitors, downstream customers and recognized third-party industry associations.
- Secondary research includes reviewing corporate annual reports, databases of relevant official authorities, as well as the exclusive database established by Frost & Sullivan over the past decades.

Glossary of Technical Terms (1/2)

“CAM” active materials used in the cathode of new energy batteries, responsible for storing and releasing electrical energy during charge and discharge cycles.

“cobalt-based materials” cobalt-based new energy materials, mainly include LCO pCAM

“ESS” energy storage system

“EV” new energy vehicles, mainly comprising of battery electric vehicles and plug-in hybrid electric vehicles

“electrolytic nickel” a high-purity form of nickel produced through electrolysis

“high-grade nickel matte” an intermediate smelting product with a nickel content typically exceeding 70%

“high-nickel pCAM/product” nickel-based pCAM with nickel content of at least 80 mol% ›

“LCO” lithium cobalt oxide (LiCoO2), a chemical compound and a commonly used CAM in lithium-ion batteries

“LFMP” lithium iron manganese phosphate (LiFeMnPO4), a type of lithium-ion battery CAM made up of lithium, iron, manganese, and phosphate

“LFP” lithium iron phosphate (LiFePO4), a chemical compound and a commonly used CAM in lithium-ion batteries

“LME” the London Metal Exchange

“low-grade nickel matte” an intermediate smelting product with a nickel content typically ranging between 10% to 30%

“MB” the Metal Bulletin

“MHP” mixed hydroxide precipitate, a nickel intermediate product used in the production of nickel sulfate, nickel plate, and other nickel cobalt materials

“Mid-nickel pCAM/product” nickel-based pCAM with nickel content of at least 50 mol%

“NCA” nickel cobalt aluminum, a nickel-based CAM made up of nickel, cobalt and aluminum

“NCM” nickel cobalt manganese, a nickel-based CAM made up of nickel, cobalt and manganese in varying proportions

Glossary of Technical Terms (2/2)

"new energy battery materials" materials used in the production of new energy batteries, including CAM and their corresponding pCAM, anode, electrolyte fluid and separators

"new energy materials" materials that include (i) new energy battery materials, and (ii) new energy metals

"new energy metals" metals including lithium, nickel, cobalt and copper and their intermediates , which are essential raw materials for producing new energy battery materials and other materials in the new energy industry

"nickel-based materials" Nickel-based new energy materials, mainly include NCM/NCA pCAM

"nickel matte" a nickel intermediate in the extraction and smelting of nickel, including for example, low-grade nickel matte and high-grade nickel matte

"nickel sulfate" an inorganic compound with the chemical formula $NiSO_4$

"NPI" nickel pig iron, a low grade ferro-nickel alloy with a nickel content typically below 15%

"OESBF" a pyrometallurgical technique, utilizing oxygen-enriched sideblown furnace to smelt metal ores

"pCAM" cathode active material (CAM) precursors, the raw materials or precursor compounds used to produce CAM for batteries

"phosphorus-based materials" phosphorus-based new energy materials, mainly include LFP/ LFMP pCAM and LFP/LFMP CAM

"RKEF" a pyrometallurgical technique, utilizing rotary kiln electric furnace to smelt metal ores

"SHFE" the Shanghai Futures Exchange

"SMM" the Shanghai Metals Market

"sodium-based materials" sodium-based new energy materials, mainly include sodium-based pCAM and CAM

"Ultra-high nickel pCAM/product" nickel-based pCAM with nickel content of at least 90 mol%

"XRD data" the information obtained from an X-ray diffraction experiment used to analyze the crystal structure, phase identification, and crystallographic properties of materials

1. Analysis of Global New Energy Materials Market

Analysis of Global Mobility Market —— Electric Vehicles (1/3)

- Global EV sales volume increased from 3.0 million units in 2020 to 18.3 million units in 2024, representing a CAGR of 56.8%. In the forecast period, benefiting from the technological progress and innovation of EVs, the improvement of the industrial chain, the promotion and support of policies in many countries, as well as the ongoing transition from fuel energy to renewable energy, the sales volume is expected to further increase to 57.1 million units by 2030, representing a CAGR of 20.9% from 2024 to 2030. The integration of AI technologies, such as in battery management and autonomous driving, has further enhanced the value proposition of EVs. It is expected to further expand to 92.5 million units by 2040 and 100.9 million units by 2050, with a CAGR of 4.9% from 2030 to 2040 and 0.9% from 2040 to 2050.

- In terms of vehicle types, PV (passenger vehicle) dominates the EV market, with sales increasing from 2.9 million units in 2020 to 17.4 million units in 2024, with a CAGR of 56.6%. It is projected to reach 52.4 million units by 2030, with a CAGR of 20.1%. It is expected to further expand to 82.5 million units by 2040 and 87.9 million units by 2050, with a CAGR of 4.7% from 2030 to 2040 and 0.6% from 2040 to 2050.

- In recent years, driven by advancements in battery technology, improvements in cost efficiency, and supportive incentive policies, the penetration of EVs in the commercial vehicle (CV) sector has grown significantly. The sales volume of electric CVs increased from 0.1 million units in 2020 to 0.9 million units in 2024, with a CAGR of 60.2%. It is expected to reach 4.7 million units by 2030, with a CAGR of 31.9%. It is forecast to further expand to 10.0 million units by 2040 and 13.0 million units by 2050.

Sales Volume of EVs (by vehicle and power types), Global, 2020-2030E & 2040E & 2050E

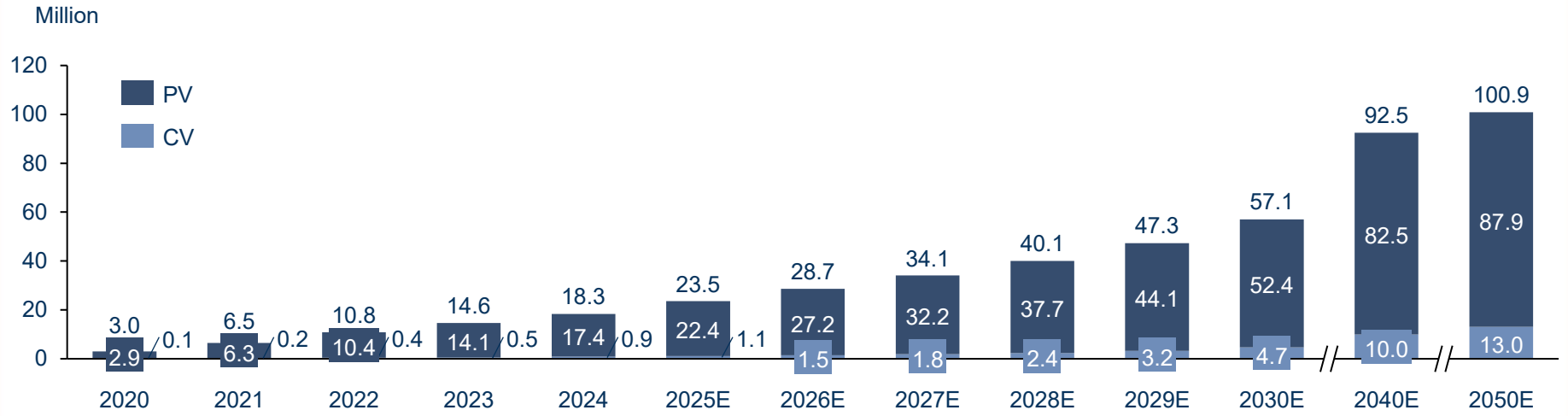
Unit: Million	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
PV	**2.9**	**6.3**	**10.4**	**14.1**	**17.4**	**22.4**	**27.2**	**32.2**	**37.7**	**44.1**	**52.4**	**82.5**	**87.9**	**56.6%**	**20.1%**	**4.7%**	**0.6%**
BEV	2.0	4.5	7.7	10.0	11.0	13.1	15.6	19.1	23.5	29.1	36.6	68.6	77.8	53.0%	22.2%	6.5%	1.3%
PHEV	0.9	1.8	2.7	4.1	6.4	9.3	11.6	13.1	14.2	15.0	15.7	13.9	10.1	64.1%	16.1%	-1.2%	-3.2%
CV	**0.1**	**0.2**	**0.4**	**0.5**	**0.9**	**1.1**	**1.5**	**1.8**	**2.4**	**3.2**	**4.7**	**10.0**	**13.0**	**60.2%**	**31.9%**	**7.8%**	**2.7%**
BEV	0.1	0.2	0.4	0.5	0.9	1.1	1.3	1.7	2.1	2.8	4.2	9.1	12.7	59.2%	30.1%	8.0%	3.4%
PHEV	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.9	0.3	215.6%	66.6%	6.2%	-9.6%
Total	**3.0**	**6.5**	**10.8**	**14.6**	**18.3**	**23.5**	**28.7**	**34.1**	**40.1**	**47.3**	**57.1**	**92.5**	**100.9**	**56.8%**	**20.9%**	**4.9%**	**0.9%**

** Note: The analysis and data of electric vehicles in this report refer to BEV, PHEV and EREV, and EREV is included in the category of PHEV.*

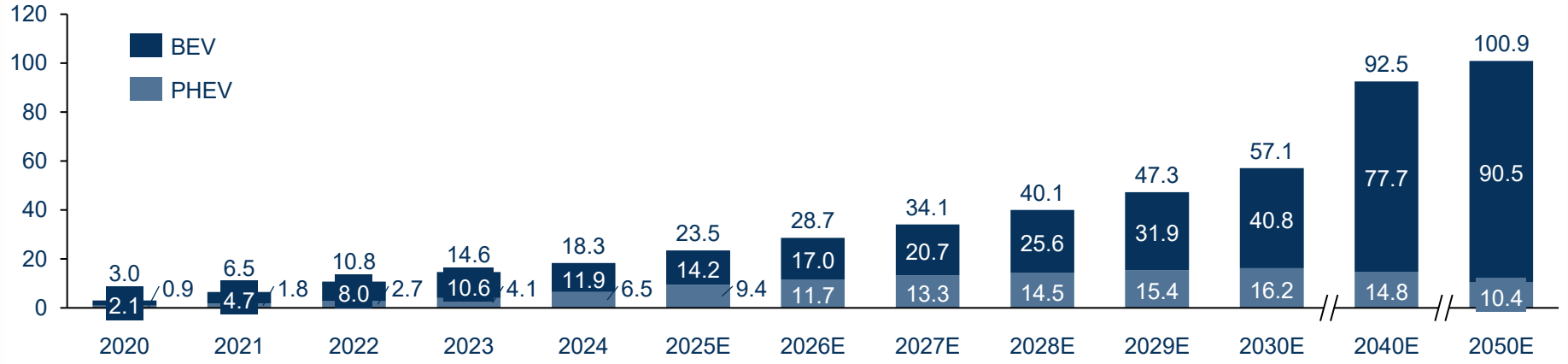
Source: Frost & Sullivan

Charts

Sales Volume of EVs (by vehicle types), Global, 2020-2030E & 2040E & 2050E



Sales Volume of EVs (by power types), Global, 2020-2030E & 2040E & 2050E

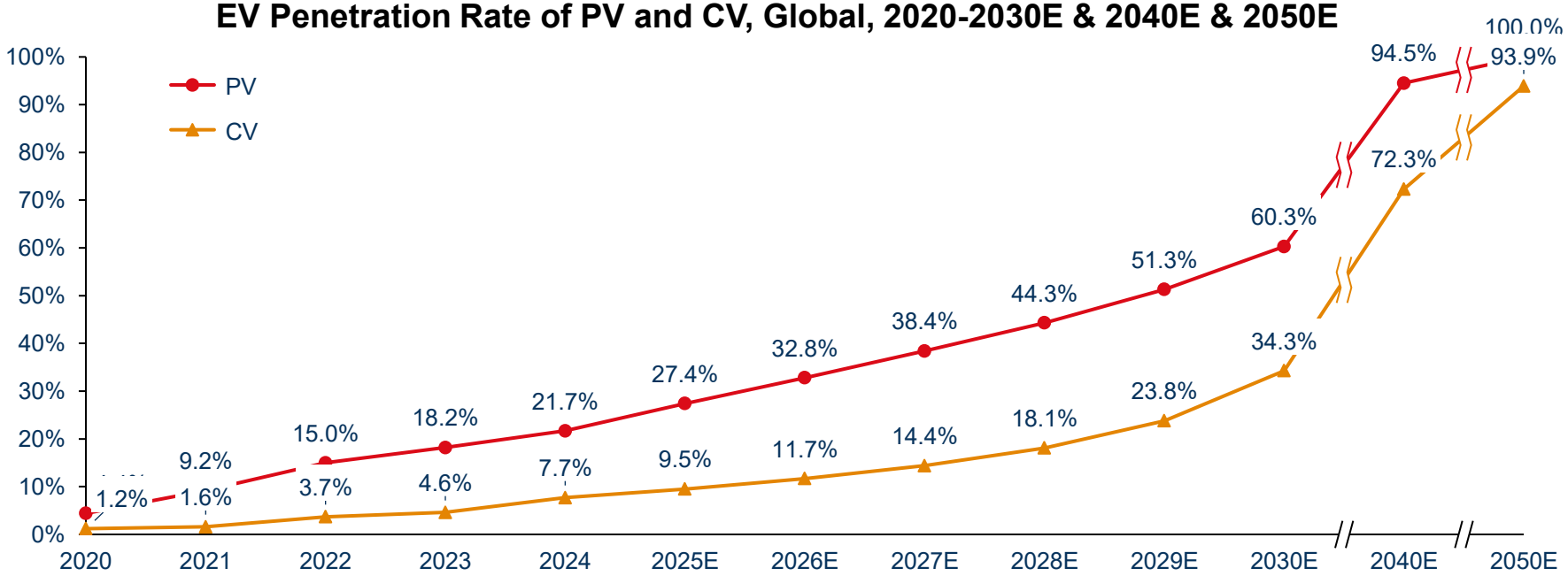


Source: Frost & Sullivan

Analysis of Global Mobility Market —— Electric Vehicles (2/3)

- The EV penetration rate in both the PV and CV sectors is set to rise significantly. For PVs, the rate is projected to surge from 21.7% in 2024 to 60.3% by 2030. Meanwhile, CVs are expected to see a sharp increase from 7.7% in 2024 to 34.3% by 2030. This rapid growth underscores the increasing adoption of EVs in both sectors, driven by technological advancements and supportive policies aiming for decarbonization.

EV Penetration Rate of PV and CV, Global, 2020-2030E & 2040E & 2050E



Unit: %	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E
PV	4.4%	9.2%	15.0%	18.2%	21.7%	27.4%	32.8%	38.4%	44.3%	51.3%	60.3%	94.5%	100.0%
CV	1.2%	1.6%	3.7%	4.6%	7.7%	9.5%	11.7%	14.4%	18.1%	23.8%	34.3%	72.3%	93.9%
Total EV	3.9%	8.1%	13.5%	16.4%	19.9%	25.1%	30.1%	35.2%	40.8%	47.6%	56.8%	91.5%	99.2%

** Note: The analysis and data of electric vehicles in this report refer to BEV, PHEV and EREV, and EREV is included in the category of PHEV.*

Source: Frost & Sullivan

Analysis of Global Mobility Market —— Electric Vehicles (3/3)

- Regionally, the EV market in China has experienced significant growth, increasing from 1.3 million units in 2020 to 13.0 million units in 2024, with a CAGR of 76.3%. The projected market size for China is expected to grow to 32.3 million units by 2030, at a projected CAGR of 16.4% from 2024 to 2030. It is expected to further expand to 34.7 million units by 2040 and 35.5 million units by 2050, with a CAGR of 0.7% from 2030 to 2040 and 0.2% from 2040 to 2050.
- The EV market in North America has shown substantial growth, increasing from 0.4 million units in 2020 to 1.7 million units in 2024, corresponding to a CAGR of 48.8% from 2020 to 2024. The market size for North America is expected to continue growing, reaching 7.3 million units by 2030, at a CAGR of 26.8% from 2024 to 2030. It is forecasted to further expand to 21.2 million units by 2040 and 21.4 million units by 2050, with a CAGR of 11.3% from 2030 to 2040 and 0.1% from 2040 to 2050.
- Similarly, the European EV market has witnessed significant growth with the market size increasing from 1.3 million units in 2020 to 2.9 million units in 2024, reflecting a CAGR of 23.2% from 2020 to 2024. It is expected to grow to 11.1 thousand units by 2030, at a projected CAGR of 25.1% from 2024 to 2030. And growth is expected to continue, reaching 18.4 million units by 2040 and 18.5 million units by 2050, with a CAGR of 5.2% from 2030 to 2040 and 0.0% from 2040 to 2050.
- In Asia (excluding China), the EV market size has increased from 0.1 million units in 2020 to 0.5 million units in 2024, showing a CAGR of 67.2% from 2020 to 2024. It is expected to grow to 4.9 million units by 2030, at a projected CAGR of 44.3% from 2024 to 2030. And it is expected to further expand to 14.0 million units by 2040 and 18.9 million units by 2050, with a CAGR of 11.0% from 2030 to 2040 and 3.1% from 2040 to 2050.
- In other regions, the EV market size has also shown growth, increasing from 0.2 million units in 2024 to 1.4 million units in 2030, with a CAGR of 183.0% from 2020 to 2024 and 43.3% from 2024 to 2030. It is forecasted to further expand to 4.2 million units by 2040 and 6.6 million units by 2050, with a CAGR of 11.3% from 2030 to 2040 and 4.6% from 2040 to 2050.

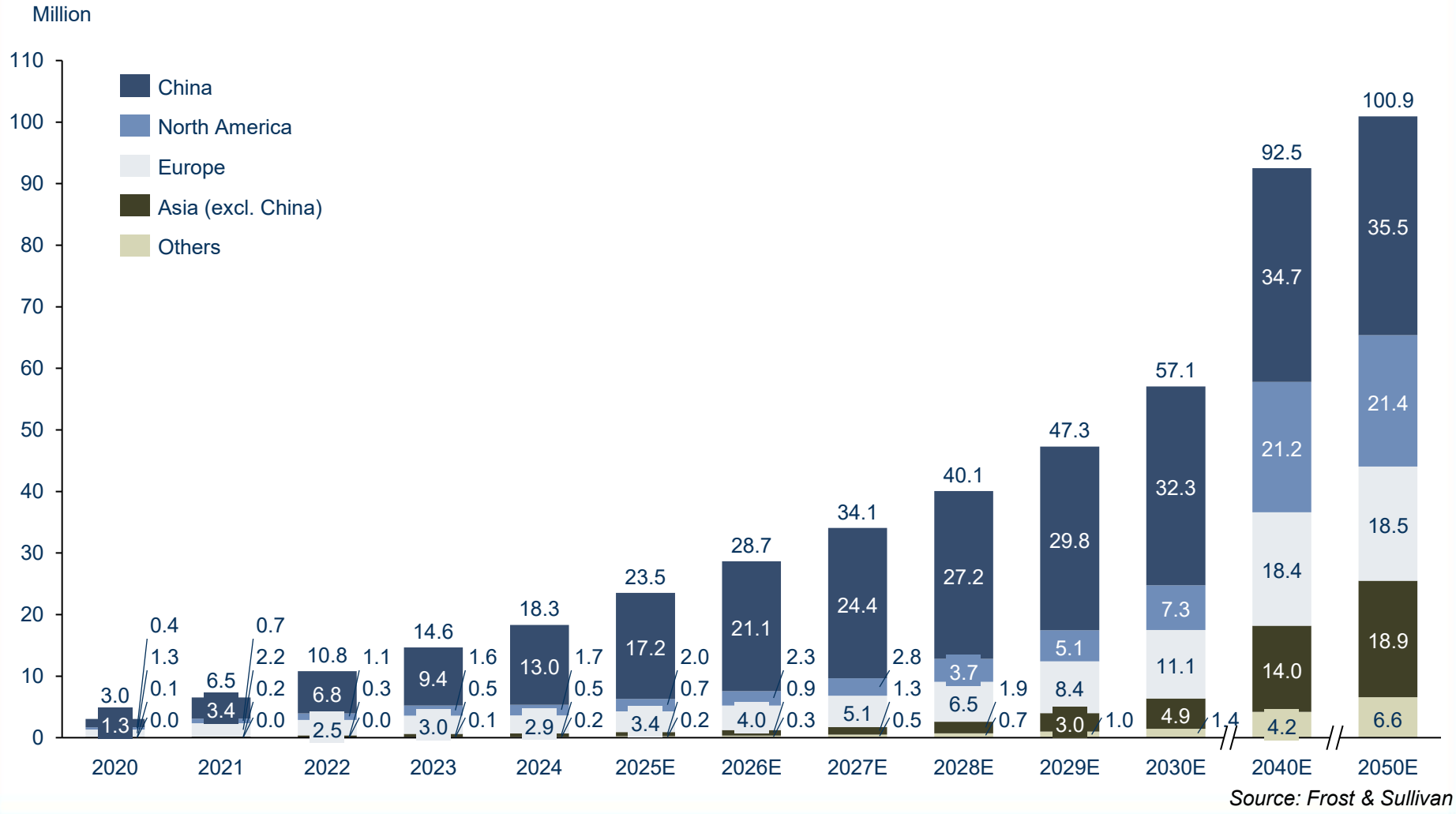
Sales Volume of EVs (by regions), Global, 2020-2030E & 2040E & 2050E

Unit: Million	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
China	1.3	3.4	6.8	9.4	13.0	17.2	21.1	24.4	27.2	29.8	32.3	34.7	35.5	76.3%	16.4%	0.7%	0.2%
North America	0.4	0.7	1.1	1.6	1.7	2.0	2.3	2.8	3.7	5.1	7.3	21.2	21.4	48.8%	26.8%	11.3%	0.1%
Europe	1.3	2.2	2.5	3.0	2.9	3.4	4.0	5.1	6.5	8.4	11.1	18.4	18.5	23.2%	25.1%	5.2%	0.0%
Asia (excl. China)	0.1	0.2	0.3	0.5	0.5	0.7	0.9	1.3	1.9	3.0	4.9	14.0	18.9	67.2%	44.3%	11.0%	3.1%
Others	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.5	0.7	1.0	1.4	4.2	6.6	183.0%	43.3%	11.3%	4.6%
Total	**3.0**	**6.5**	**10.8**	**14.6**	**18.3**	**23.5**	**28.7**	**34.1**	**40.1**	**47.3**	**57.1**	**92.5**	**100.9**	**56.8%**	**20.9%**	**4.9%**	**0.9%**

Source: Frost & Sullivan

Charts

Sales Volume of EVs (by regions), Global, 2020-2030E & 2040E & 2050E

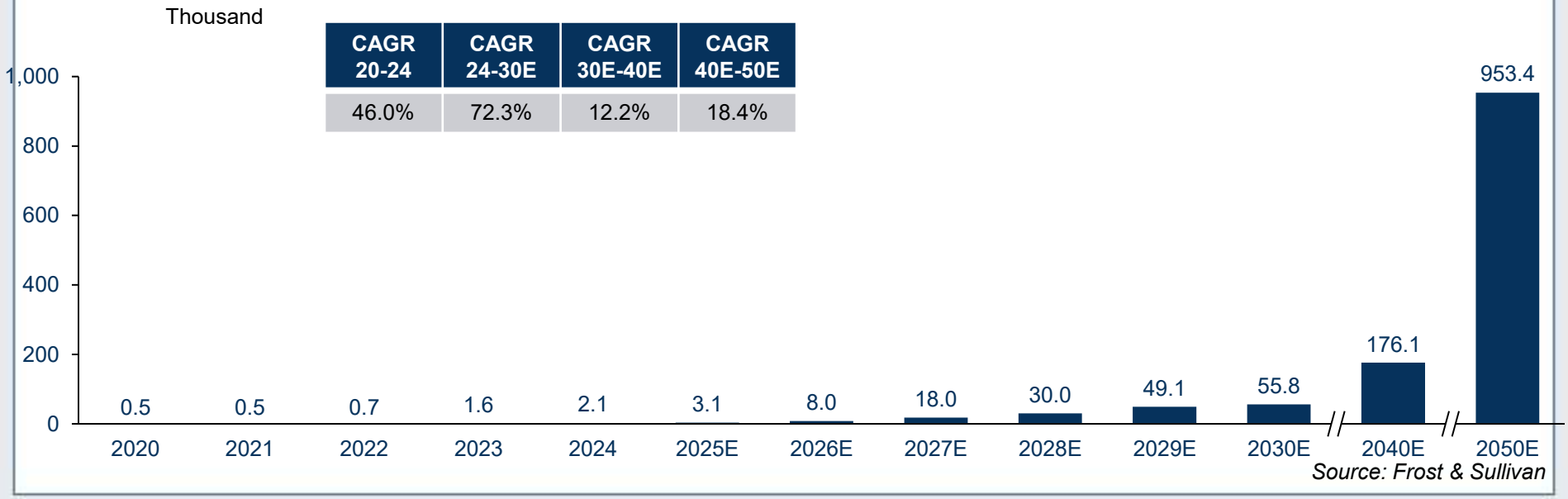


Source: Frost & Sullivan

Analysis of Global Mobility Market —— Electric Vessels (1/2)

- An electric vessel utilizes power batteries to partially or fully substitute fossil fuels for power generation. In comparison to traditional fuel-powered vessels, electric vessels generate lower noise, and brings higher comfort, environmental friendliness, and control flexibility.
- The electric vessel employs lithium-ion batteries as its sole source of power, harnessing electric motors to propel the propeller. This electric power propulsion system is ideally suited for small to medium-sized vessels, encompassing passenger ships, cargo ships, law enforcement boats, tourist boats, and ferries. It boasts zero pollution emissions, low vibration, and minimal noise, offering optimal comfort on board and adapting seamlessly to diverse load and navigation scenarios.
- The global electric vessels market has been witnessing a steady growth trajectory, with the sales volume increasing from 0.5 thousand units in 2020 to 2.1 thousand units by 2024, representing a CAGR of 46.0%. In the forecast period, the sales volume is expected to further increase to 55.8 thousand units by 2030, representing a CAGR of 72.3% from 2024 to 2030. It is forecasted to further expand to 176.1 thousand units by 2040 and 953.4 thousand units by 2050, with a CAGR of 12.2% from 2030 to 2040 and 18.4% from 2040 to 2050.

Sales Volume of Electric Vessels, Global, 2020-2030E & 2040E & 2050E

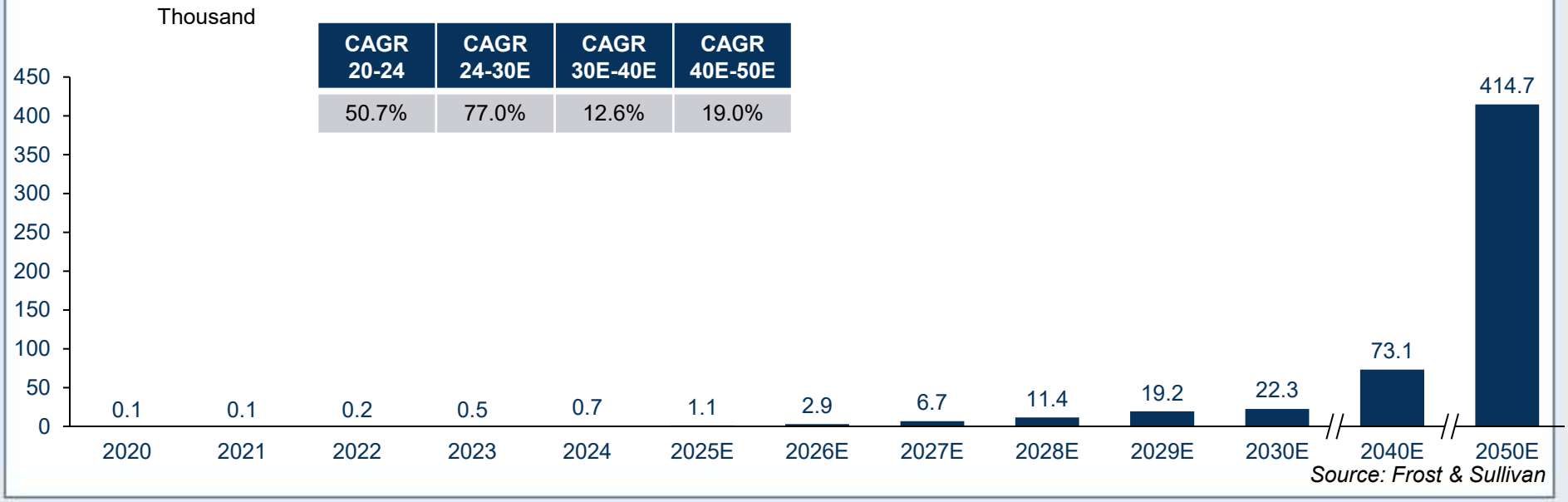


Source: Frost & Sullivan

Analysis of Global Mobility Market —— Electric Vessels (2/2)

- The sales volume of electric vessels in China has been witnessing a steady growth trajectory, with the sales volume increasing from 0.1 thousand units in 2020 to 0.7 thousand units by 2024, representing a CAGR of 50.7%. In the forecast period, the sales volume is expected to further increase to 22.3 thousand units by 2030, representing a CAGR of 77.0% from 2024 to 2030. It forecasted to further expand to 73.1 thousand units by 2040 and 414.7 thousand units by 2050, with a CAGR of 12.6% from 2030 to 2040 and 19.0% from 2040 to 2050.

Sales Volume of Electric Vessels, China, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Mobility Market —— Low-altitude Aircrafts (1/2)

- AI technologies, such as machine learning and computer vision, have enhanced the autonomy, navigation, and operational efficiency of low-altitude aircraft. These advancements have increased the demand for high-density batteries, which are critical for powering AI-driven systems and ensuring longer flight durations. For instance, AI-powered drones and eVTOLs require robust energy solutions to support real-time data processing, obstacle detection, and route optimization. As AI continues to evolve, it is expected to further drive innovation in battery technology, enabling more efficient and sustainable energy storage solutions for low-altitude aircraft. This synergy between AI and battery development will likely accelerate the growth of the low-altitude economy.

- The global low-altitude aircraft market has shown significant growth, driven by advancements in drone and eVTOL technologies. In 2020, the total drone market sales volume stood at 11.3 million units, increasing to 33.8 million units in 2024, reflecting a CAGR of 31.4% from 2020 to 2024. Projections suggest the sales volume will grow to 102.2 million units by 2030, at a projected CAGR of 20.3% from 2024 to 2030. It is anticipated to further expand to 290.8 million units by 2040 and 1059.7 million units by 2050, with a CAGR of 11.0% from 2030 to 2040 and 13.8% from 2040 to 2050.

- The China drone sales volume increased from 4.4 million units in 2020 to 13.0 million units in 2024, reflecting a CAGR of 31.2% from 2020 to 2024. Forecasts indicate growth to 44.5 million units by 2030, at a projected CAGR of 22.8% from 2024 to 2030. Further expansion is anticipated, reaching 130.9 million units by 2040 and 490.3 million units by 2050, with a CAGR of 11.4% from 2030 to 2040 and 14.1% from 2040 to 2050.

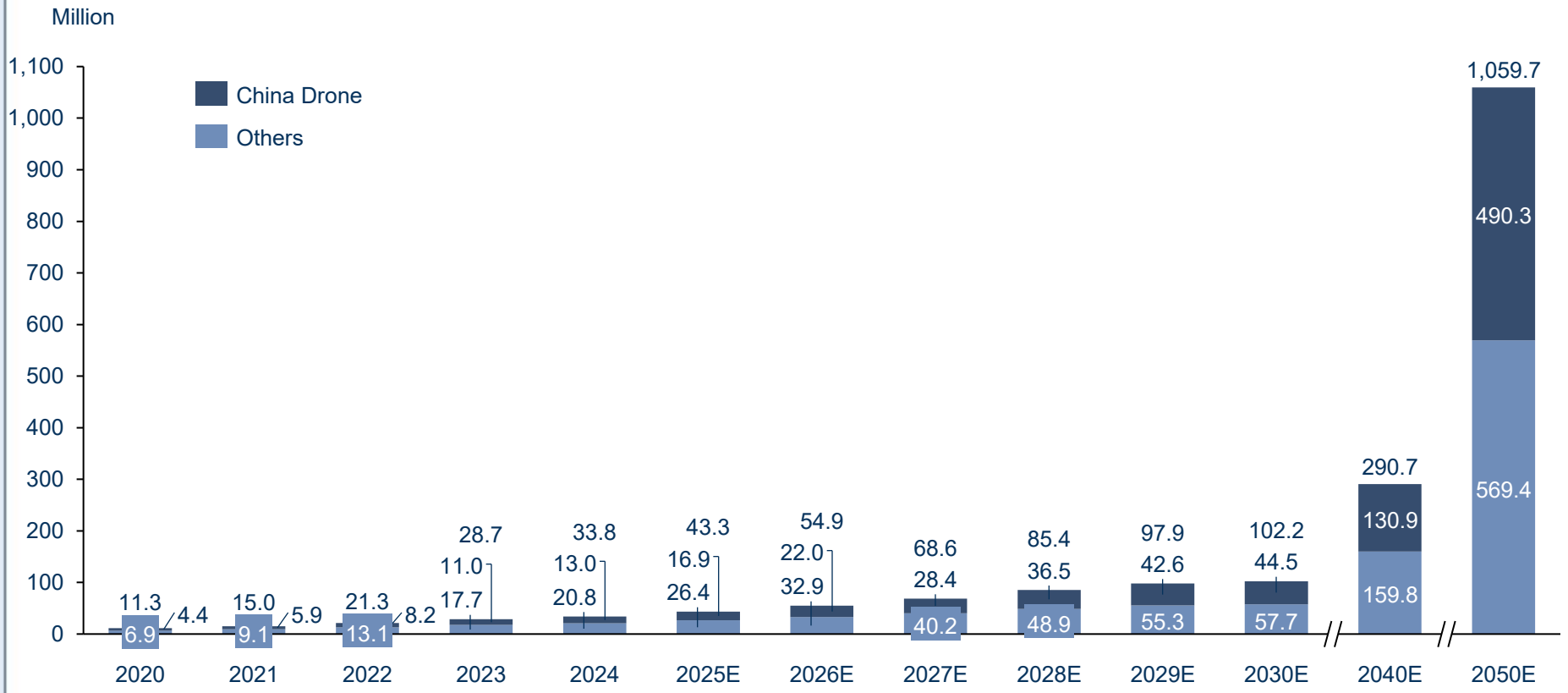
Sales Volume of Low-altitude Aircrafts (by product types), Global and China, 2020-2030E & 2040E & 2050E

Unit: Million	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
Global Drone	11.3	15.0	21.2	28.6	33.8	43.4	54.9	68.7	85.5	97.8	102.2	290.8	1059.7	31.4%	20.3%	11.0%	13.8%
China Drone	4.4	5.9	8.2	11.0	13.0	16.9	22.0	28.4	36.5	42.6	44.5	130.9	490.3	31.2%	22.8%	11.4%	14.1%

Source: Frost & Sullivan

Charts

Sales Volume of Low-altitude Aircrafts (by product types), Global and China, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Mobility Market —— Low-altitude Aircrafts (2/2)

- In 2020, the global eVTOL sales volume stood at 0.1 thousand units, increasing to 1.1 thousand units in 2024, reflecting a CAGR of 117.6% from 2020 to 2024. Projections suggest the sales volume will grow to 53.3 thousand units by 2030, at a projected CAGR of 90.4% from 2024 to 2030. It is anticipated to further expand to 218.8 million units by 2040 and 1000.0 million units by 2050, with a CAGR of 15.2% from 2030 to 2040 and 16.4% from 2040 to 2050.
- China eVTOL sales volume increasing from 0.0 thousand units in 2020 to 0.3 thousand units in 2024, representing a CAGR of 130.0% from 2020 to 2024. Estimates point to growth to 16.0 thousand units by 2030, at a projected CAGR of 96.3% from 2024 to 2030. The sales volume is further expand to 70.0 thousand units by 2040 and 350.0 thousand units by 2050, with a CAGR of 15.9% from 2030 to 2040 and 17.5% from 2040 to 2050.

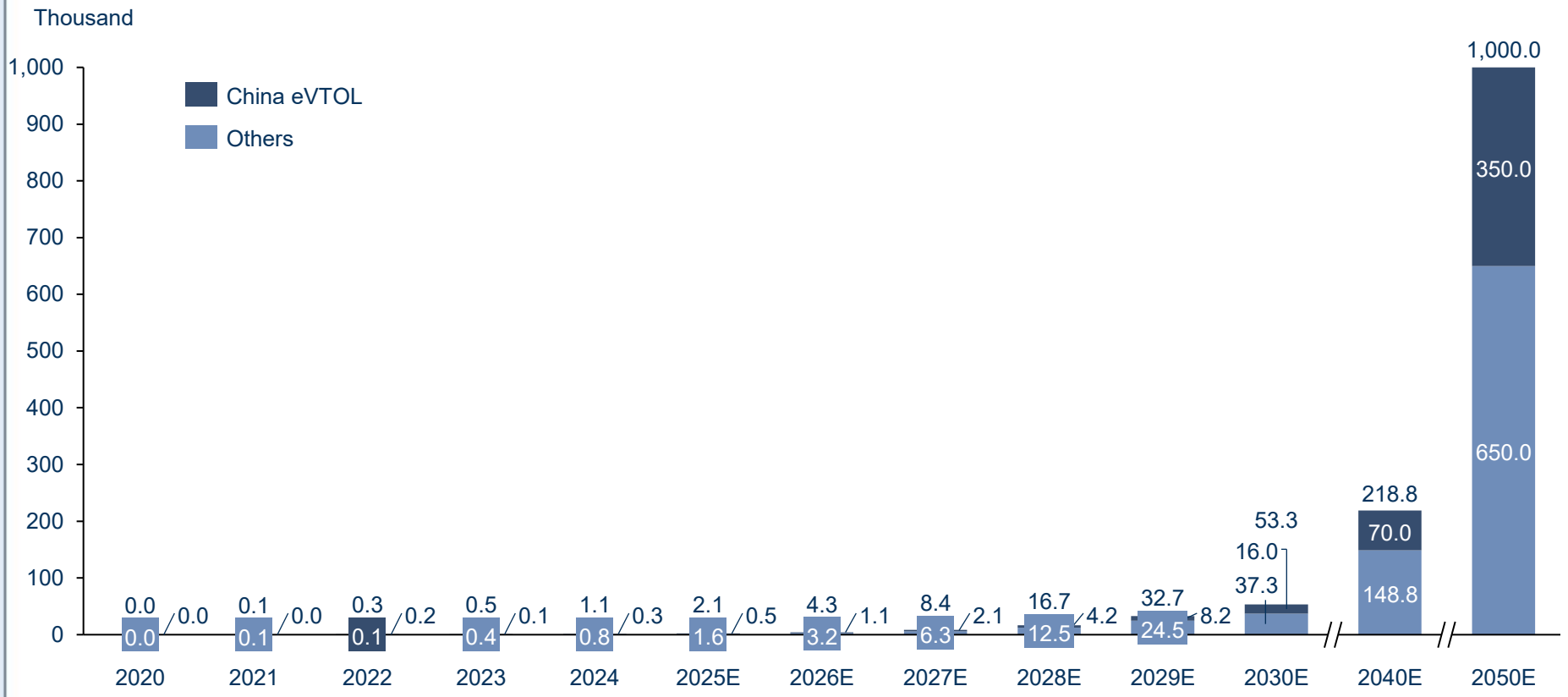
Sales Volume of Low-altitude Aircrafts (by product types), Global and China, 2020-2030E & 2040E & 2050E

Unit: Thousand	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
Global eVTOL	0.1	0.1	0.2	0.5	1.1	2.2	4.3	8.5	16.6	32.6	53.3	218.8	1000.0	117.6%	90.4%	15.2%	16.4%
China eVTOL	0.0	0.0	0.1	0.1	0.3	0.5	1.1	2.1	4.2	8.2	16.0	70.0	350.0	130.0%	96.3%	15.9%	17.5%

Source: Frost & Sullivan

Charts

Sales Value of Low-altitude Aircrafts (by product types), Global and China, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global 3C Electronics Market

- The global 3C electronics market has shown steady growth, driven by AI advancements that accelerate product updates and spur new categories. In 2020, the total shipment volume stood at 2,397.5 million units, increasing to 2,452.1 million units in 2024, reflecting a CAGR of 0.6% from 2020 to 2024. By 2030, total shipments are projected to reach 2,842.8 million units, growing at a CAGR of 2.5% from 2024 to 2030. By 2040, total shipments are expected to reach 2,974.2 million units, and further expand to 3,145.5 million units by 2050, with a CAGR of 0.5% from 2030 to 2040 and 0.6% from 2040 to 2050.
- Smartphones remain the largest segment in the 3C electronics market, with shipment volume decreasing slightly from 1,323.4 million units in 2020 to 1,312.9 million units in 2024, reflecting a CAGR of -0.2%. By 2030, shipments are projected to reach 1,492.1 million units, growing at a CAGR of 2.2% from 2024 to 2030. By 2040, it is expected to reach 1,554.4 million units, and expand to 1,634.9 million units by 2050, with a CAGR of 0.4% from 2030 to 2040 and 0.5% from 2040 to 2050.
- The computing devices segment has shown a slight decline in shipment volume, decreasing from 469.9 million units in 2020 to 451.9 million units in 2024, reflecting a CAGR of -1.0%. By 2030, shipments are projected to reach 500.7 million units, growing at a CAGR of 1.7% from 2024 to 2030. By 2040, it is expected to reach 523.7 million units, and further expand to 552.9 million units by 2050, with a CAGR of 0.4% from 2030 to 2040 and 0.5% from 2040 to 2050.
- The wearables segment has shown strong growth, with shipment volume increasing from 444.7 million units in 2020 to 538.0 million units in 2024, reflecting a CAGR of 4.9%. By 2030, shipments are projected to reach 665.1 million units, growing at a CAGR of 3.6% from 2024 to 2030. By 2040, shipments are expected to reach 701.2 million units, and further expand to 753.4 million units by 2050, with a CAGR of 0.5% from 2030 to 2040 and 0.7% from 2040 to 2050.
- Other consumer electronics decreased from 159.5 million units in 2020 to 149.3 million units in 2024, reflecting a CAGR of -1.6%. By 2030, shipments are projected to reach 185.0 million units, growing at a CAGR of 3.6% from 2024 to 2030. By 2040, shipments are expected to reach 194.9 million units, and further expand to 204.3 million units by 2050, with a CAGR of 0.5% from 2030 to 2040 and 0.5% from 2040 to 2050.
- The rapid integration of AI into 3C electronics has significantly increased the demand for high-energy-density batteries. AI-enabled devices require advanced processing capabilities, real-time data analysis, and enhanced user experiences, all of which consume substantial power. For instance, AI-powered smartphones, which support features like facial recognition and augmented reality, typically require batteries with higher energy density compared to non-AI devices. Furthermore, the development of AI-specific chips, such as NPUs, has further intensified the need for efficient energy solutions. As AI continues to evolve, the demand for innovative battery solutions, such as solid-state batteries and lithium-sulfur batteries, is expected to rise, creating new opportunities for the energy storage industry and driving the next wave of growth in the 3C electronics market.

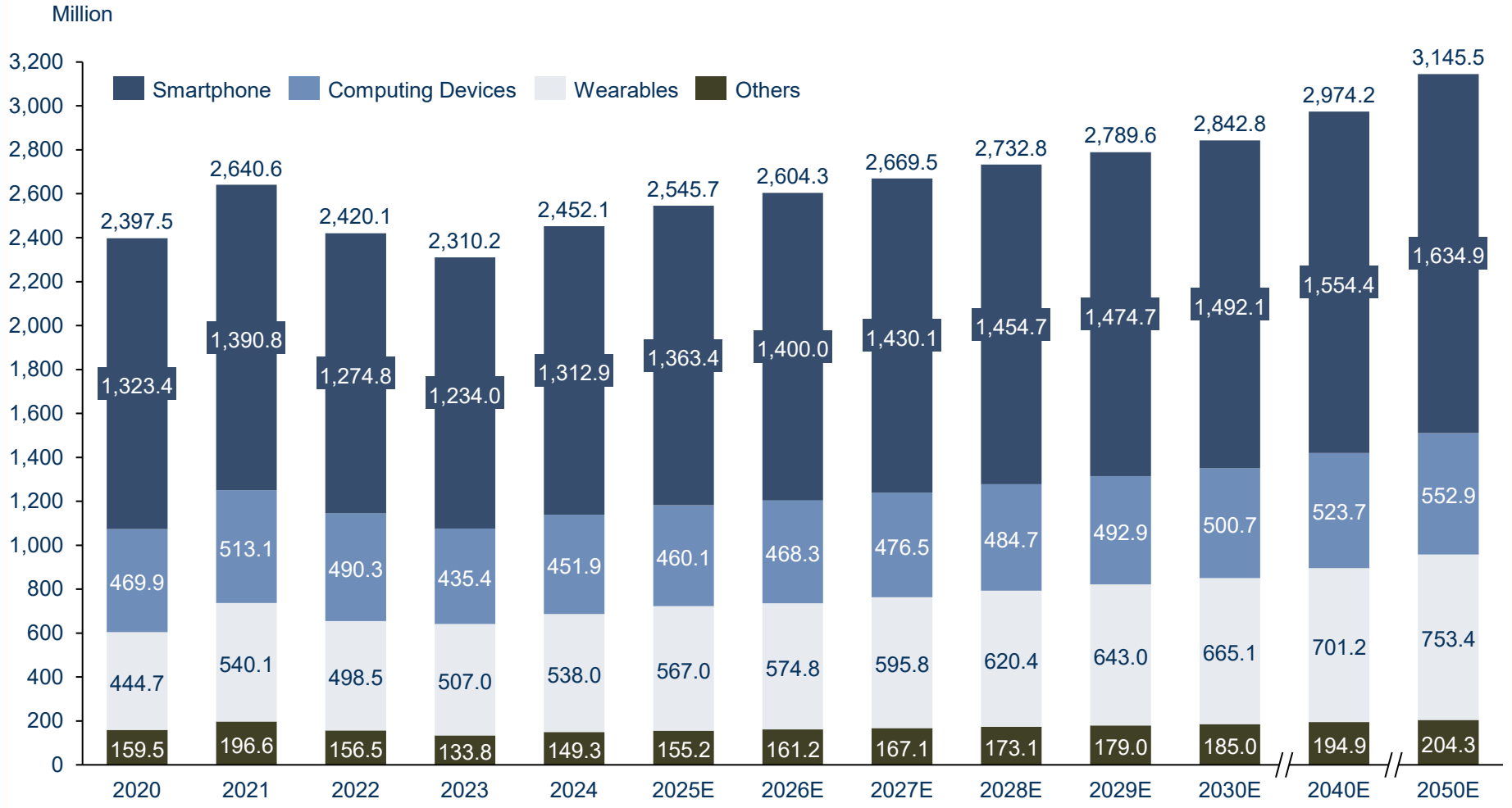
Shipment Volume of 3C Electronics (by products types), Global, 2020-2030E & 2040E & 2050E

Unit: Million	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
Smartphone	1323.4	1390.8	1274.8	1234.0	1312.9	1363.4	1400.0	1430.1	1454.7	1474.7	1492.1	1554.4	1634.9	-0.2%	2.2%	0.4%	0.5%
Computing Devices	469.9	513.1	490.3	435.4	451.9	460.1	468.3	476.5	484.7	492.9	500.7	523.7	552.9	-1.0%	1.7%	0.4%	0.5%
Wearables	444.7	540.1	498.5	507.0	538.0	567.0	574.8	595.8	620.4	643.0	665.1	701.2	753.4	4.9%	3.6%	0.5%	0.7%
Others	159.5	196.6	156.5	133.8	149.3	155.2	161.2	167.1	173.1	179.0	185.0	194.9	204.3	-1.6%	3.6%	0.5%	0.5%
Total	**2397.5**	**2640.6**	**2420.1**	**2310.2**	**2452.1**	**2545.7**	**2604.3**	**2669.5**	**2732.8**	**2789.6**	**2842.8**	**2974.2**	**3145.5**	**0.6%**	**2.5%**	**0.5%**	**0.6%**

Source: Frost & Sullivan

Charts

Shipment Volume of 3C Electronics (by products types), Global, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Robotics Market

- The global robotics market has experienced significant growth, driven by advancements in AI and automation technologies. In 2020, the total shipment volume stood at 2,284.3 thousand units, increasing to 5,019.6 thousand units in 2024, reflecting a CAGR of 21.8% from 2020 to 2024. By 2030, total shipments are projected to reach 13,784.8 thousand units, growing at a CAGR of 18.3% from 2024 to 2030. By 2040, total shipments are expected to reach 57839.9 thousand units, and further expand to 300532.3 thousand units by 2050, with a CAGR of 15.4% from 2030 to 2040 and 17.9% from 2040 to 2050.

- Humanoid robots, while still in the early stages of development, are expected to see exponential growth due to advancements in AI and machine learning. Shipments increased from 0.1 thousand units in 2020 to 8.6 thousand units in 2024, reflecting a remarkable CAGR of 204.2%. Projections suggest shipments will reach 666.2 thousand units by 2030, growing at a CAGR of 106.6% from 2024 to 2030. By 2040, shipments are expected to reach 3261.8 thousand units, and further expand to 18578.4 thousand units by 2050, with a CAGR of 17.2% from 2030 to 2040 and 19.0% from 2040 to 2050. The integration of AI-driven capabilities, such as natural language processing and advanced mobility, is expected to drive the adoption of humanoid robots in sectors like healthcare, retail, and customer service.

- Other robots have shown steady growth, with shipment volume increasing from 2,284.2 thousand units in 2020 to 5,011.0 thousand units in 2024, reflecting a CAGR of 21.7%. By 2030, shipments are projected to reach 13,118.5 thousand units, growing at a CAGR of 17.4% from 2024 to 2030. By 2040, shipments are expected to reach 54578.2 thousand units, and further expand to 281953.9 thousand units by 2050, with a CAGR of 15.3% from 2030 to 2040 and 17.8% from 2040 to 2050.

Shipment Volume of Robots (by products types), Global, 2020-2030E & 2040E & 2050E

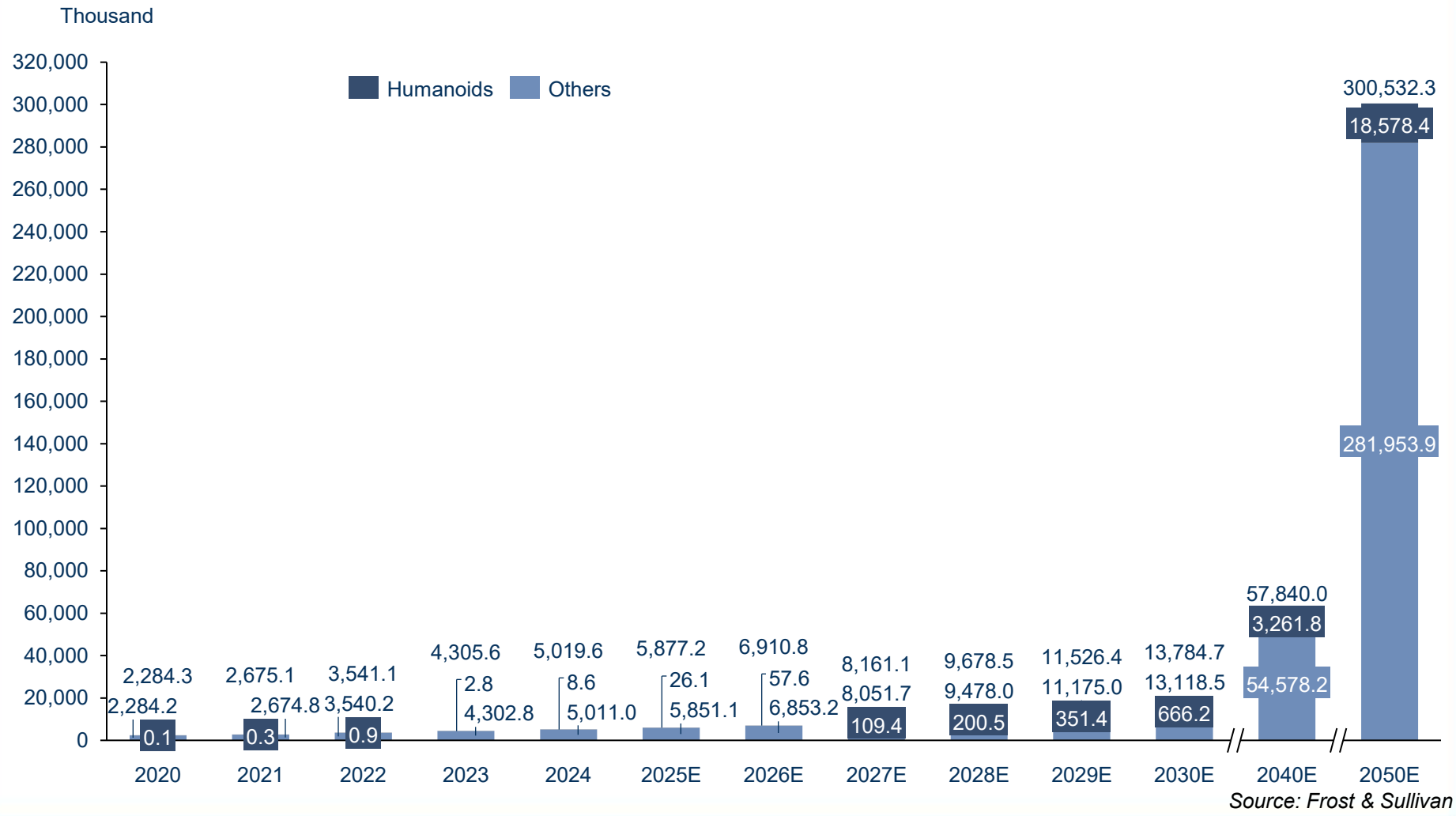
Unit: Thousand	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
Humanoid Robots	0.1	0.3	0.9	2.8	8.6	26.1	57.6	109.4	200.5	351.4	666.2	3,261.8	18,578.4	204.2%	106.6%	17.2%	19.0%
Others	2,284.2	2,674.8	3,540.2	4,302.8	5,011.0	5,851.1	6,853.2	8,051.7	9,478.0	11,175.0	13,118.5	54,578.2	281,953.9	21.7%	17.4%	15.3%	17.8%
Total	**2,284.3**	**2,675.1**	**3,541.1**	**4,305.6**	**5,019.6**	**5,877.2**	**6,910.9**	**8,161.1**	**9,678.5**	**11,526.4**	**13,784.8**	**57,839.9**	**300,532.3**	**21.8%**	**18.3%**	**15.4%**	**17.9%**

Note: Only mobile robots are included in the analysis of this report.

Source: Frost & Sullivan

Charts

Shipment Volume of Robots (by products types), Global, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Introduction and Comparison of New Energy Materials (1/2)

Definition and classification of new energy materials

New energy materials as (i) new energy battery materials, including CAM and their corresponding precursor materials (pCAM), anode, electrolyte fluid and separators; and (ii) new energy metals, mainly lithium, nickel, cobalt and copper and their intermediates, serving as essential raw materials to produce new energy battery materials and other materials in the new energy industry.

New Energy Battery Market Demand

New energy batteries primarily comprise cathode, anode, separators and electrolytes, with cathode playing a pivotal role and accounting for over 50% of the total cost of new energy battery cells, making them the most value adding component of the value chain. Cathode includes both CAM (which participates in the electrochemical reactions) and inactive materials such as binders, conductive additives, and other components that help form the complete cathode structure. CAM is typically the metal oxide or phosphate compound that stores and releases ions such as, lithium or sodium ions in a battery, depending on the specific battery technology.

Based on the primary chemical elements in CAM, the new energy batteries can be divided into (i) ternary batteries, (ii) LCO batteries, (iii) LFP batteries, and (iv) emerging technologies, such as sodium-ion batteries.

New energy batteries have a broad range of (i) existing applications, including mobility batteries for electric vehicles, consumer electronics batteries, as well as ESS batteries, and (ii) emerging, high-potential applications, such as batteries for robotics and mobility batteries for electric vessels and low-altitude aerial vehicles.

Considering cost and battery performance, ternary batteries and LFP batteries have become the dominant battery types in the mobility battery market. Ternary batteries offer higher energy density, compared to LFP batteries. Ternary batteries also have better charging efficiency, while LFP batteries provide longer cycle life and lower material costs. As a result, ternary batteries are widely used in EV especially for mid-to-high end models with longer driving ranges, as well as electric vessels and low-altitude aerial vehicles. Based on these varying characteristics, end customers choose the battery materials that best meet their specific application needs.

Introduction and Comparison of New Energy Materials (2/2)

- The LFP batteries are widely used in the global ESS battery market, primarily due to its balanced energy density and costs, long circle life and safety. The LCO batteries lead the global consumer electronics battery market, primarily due to their features of high energy density, stable voltage, lightweight and compact. High-nickel ternary batteries and LCO batteries are the primary technologies for the robotics and low-altitude aerial vehicles battery markets due to their high energy density and rapid charging capabilities. The table below sets forth the key features and major end applications of the four categories of CAM materials used in new energy batteries.

Introduction and Comparison of CAM

Classification	Nickel-based Material		Cobalt-based Material	Phosphate-based Material	Sodium-based Material*
Precursor	Ternary Precursor		Tricobalt Tetroxide	Iron Phosphate	NFM and NCFM
Cathode Materials	NCM	NCA	LCO	LFP	Layered Oxide
Chemical Component	$Li(Ni_XCo_YMn_Z)O_2$	$Li(Ni_XCo_YAl_Z)O_2$	$LiCoO_2$	$LiFePO_4$	Na_xMO_2
Energy Density (Wh/kg)	High		High	Medium	Low
Cycle Life (times)	Medium		Medium	High	High
Safety	Fair	Medium	Medium	Good	Good
Cost	Medium	Medium	High	Low	Low
Major Application Scenarios	• EV Battery, ESS Battery, eVTOL Battery, Humanoids Battery		• Consumer Electronics Batteries	• EV Battery, ESS Battery	• EV battery and ESS battery

** Sodium-ion batteries are still in the research and development stage, and the technological pathway for cathode materials has yet to be determined. Layered oxides, Prussian blue compounds, and polyanionic compounds are the three promising routes. Layered oxide is used as an example for comparison.*

Source: Frost & Sullivan

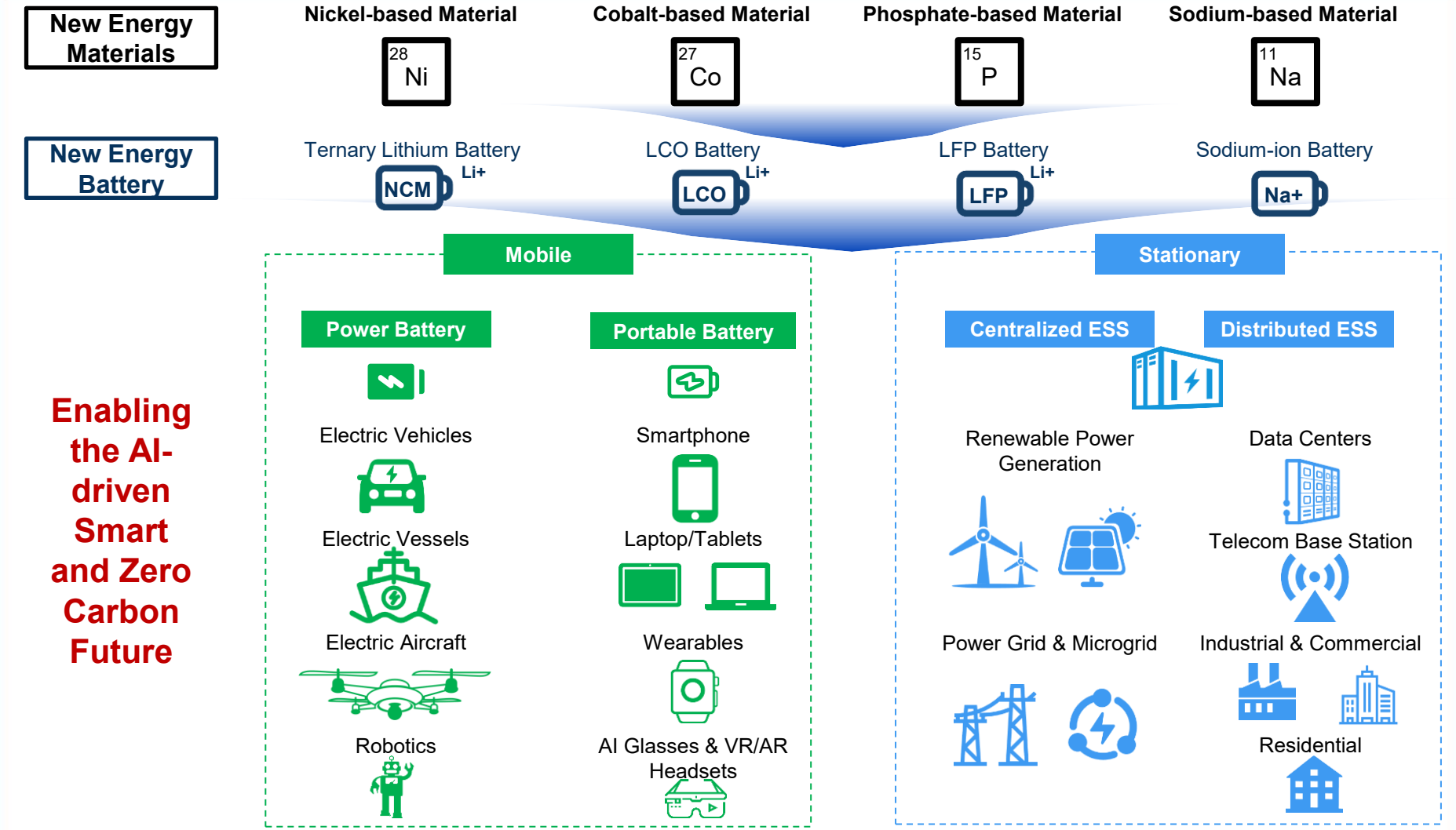
Comparison of Ternary Cathode Materials

- Ternary batteries have advantages of high energy density, better low-temperature performance, high discharge rate and better compatibility with next-generation solid-state battery. Thus, Ternary batteries exhibit substantial growth potential across various high-value and emerging application segments, including long-range EVs, advanced fast-charging technologies, extreme low-temperature environments, next-generation solid-state batteries, eVTOL, and humanoid robotics.
- Among ternary cathode materials, NCM523, NCM622 and NCM811 have wider application scenarios in current phase. Each of them has different proportion of elementary composition and shows different characteristics in application performance.

Comparison of Ternary Cathode Materials			
Ternary Material Type	**NCM523**	**NCM622**	**NCM811**
Proportion of Nickel by Weight	30.8%	37.3%	50.7%
Energy Density (Wh/kg)	200-250	210-270	225-300
Safety	Fair	Fair	Medium
Cost	Medium	Medium	High
Pros	Good comprehensive performance	Fair specific capacity	High specific capacity, good cycling performance
Cons	Relatively low energy density	Relatively high cost	High technical difficulty

Source: Frost & Sullivan

New Energy Materials Enabling the AI-driven Smart and Zero Carbon Future

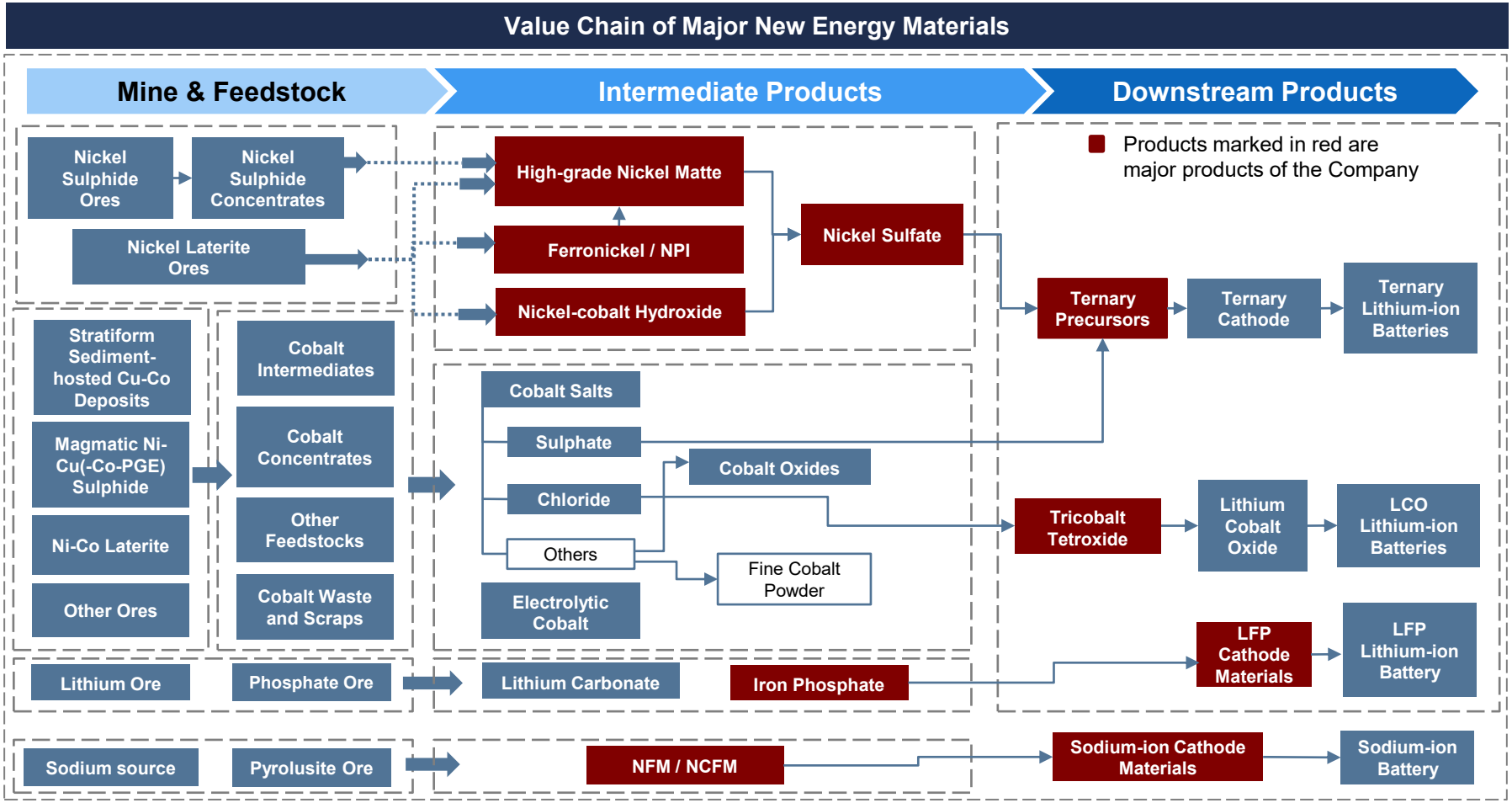


Source: Frost & Sullivan

Value Chain of New Energy Materials (1/2)

The value chain for new energy materials can be categorized into four key segments: (i) mineral mining, smelting, and refining, such as nickel, phosphorus and lithium, into raw materials for new energy materials, (ii) production of new energy materials, (iii) end-market applications, and (iv) recycling of lithium-ion batteries. Achieving strong vertical integration across these segments is critical for success in the industry, from upstream key mineral resources (such as nickel, phosphate and lithium) to downstream close partnerships with battery manufacturers and end-customers, and to recycling. By doing so, companies can optimize operations, enhance profitability and bolster their competitiveness in a dynamic and rapidly evolving market.

Value Chain of New Energy Materials (2/2)



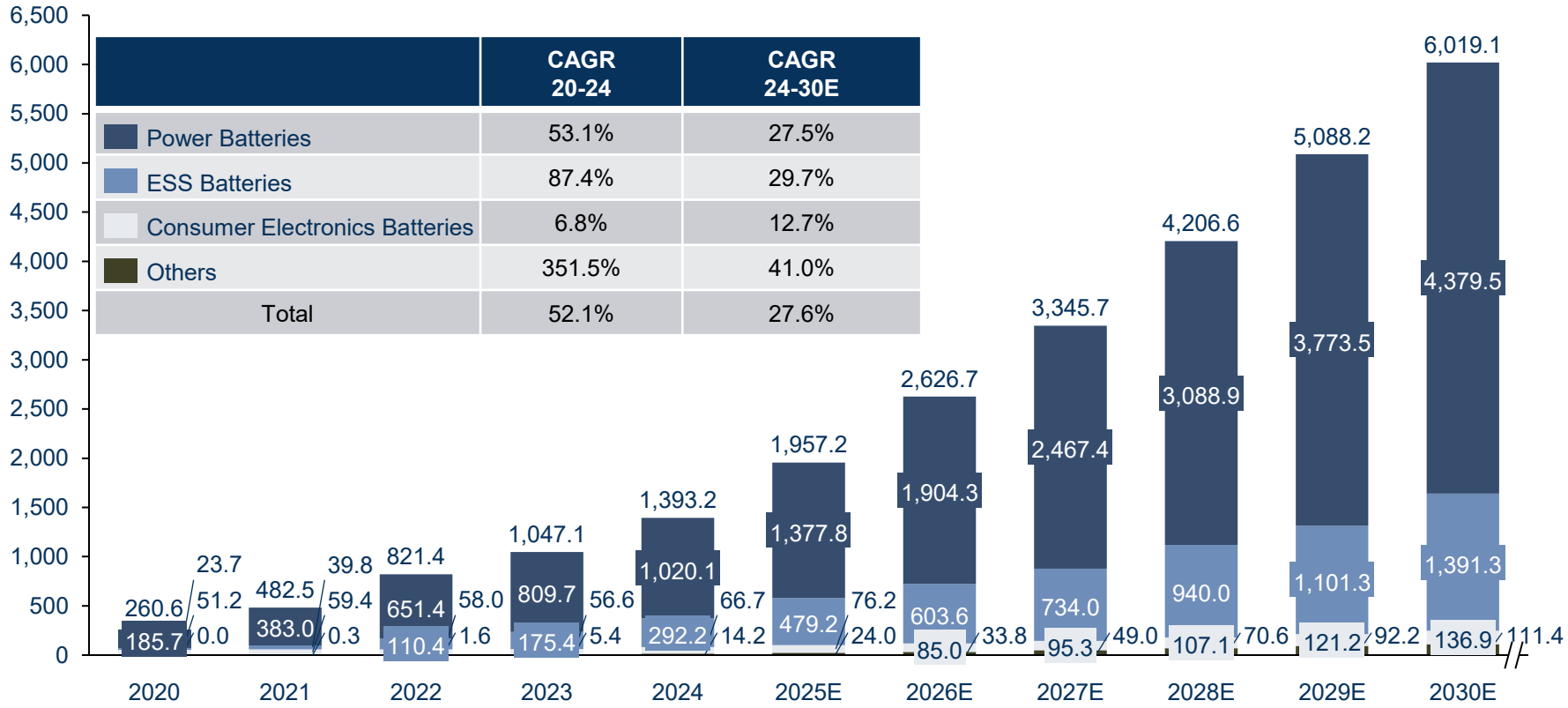
Note: The diagram above does not represent the complete workflow; it only illustrates the key processes and products.

Source: Frost & Sullivan

Analysis of Global New Energy Battery Market

The major end-use applications of new energy battery market include power batteries, ESS batteries, consumer electronics batteries. The shipment volume of new energy batteries increased from 260.6 GWh in 2020 to 1,393.2 GWh in 2024, and is expected to further rise to 6,019.1 GWh by 2030, representing a CAGR of 27.6% between 2024 and 2030.

Shipment of New Energy Battery Market (by End-use Applications), Global, 2020-2030E



	CAGR 20-24	CAGR 24-30E
Power Batteries	53.1%	27.5%
ESS Batteries	87.4%	29.7%
Consumer Electronics Batteries	6.8%	12.7%
Others	351.5%	41.0%
Total	52.1%	27.6%

Note: Power batteries refer to high-energy-density batteries used to provide primary power source for electric vehicles, electric vessels, low-altitude aircrafts, robotics and etc.

Source: Frost & Sullivan

Analysis of Global Mobility Battery Market —— EV Battery (1/4)

- The global EV battery market has experienced exponential growth, driven by the rapid adoption of EVs and advancements in battery technologies. In 2020, the total installed volume stood at 184.4 GWh, increasing to 1,007.7 GWh in 2024, reflecting a CAGR of 52.9%, which is expected to further increase to 4,045.4 GWh in 2030 at a CAGR of 26.1%. By 2040, total installations are expected to reach 9,224.6 GWh, and further expand to 11,135.6 GWh by 2050, with a CAGR of 8.6% from 2030 to 2040 and 1.9% from 2040 to 2050.
- NCM and NCA batteries have been the dominant battery types in the EV market, known for their high energy density and performance. The installed volume of NCM/NCA batteries increased from 127.0 GWh in 2020 to 522.0 GWh in 2024, reflecting a CAGR of 42.4%. By 2030, installations are projected to reach 1,698.2 GWh, growing at a CAGR of 21.7% from 2024 to 2030. By 2040, installations are expected to reach 3,702.0 GWh, and further expand to 4738.6 GWh by 2050, with a CAGR of 8.1% from 2030 to 2040 and 2.5% from 2040 to 2050.
- LFP batteries have gained significant traction due to their cost-effectiveness, safety, and longer lifecycle. The installed volume of LFP batteries increased from 55.9 GWh in 2020 to 483.6 GWh in 2024, reflecting a remarkable CAGR of 71.5%. By 2030, installations are projected to reach 2,292.9 GWh, growing at a CAGR of 29.6% from 2024 to 2030. By 2040, installations are expected to reach 5,344.4 GWh, and further expand to 5971.0 GWh by 2050, with a CAGR of 8.8% from 2030 to 2040 and 1.1% from 2040 to 2050.
- Other battery types, including emerging technologies such as solid-state and lithium-sulfur batteries, have shown promising growth potential. The installed volume of other battery types increased from 1.4 GWh in 2020 to 2.1 GWh in 2024, reflecting a CAGR of 10.6%. By 2030, installations are projected to reach 54.4 GWh, growing at a CAGR of 71.8% from 2024 to 2030. By 2040, installations are expected to reach 178.1 GWh, and further expand to 426.0 GWh by 2050, with a CAGR of 12.6% from 2030 to 2040 and 9.1% from 2040 to 2050.

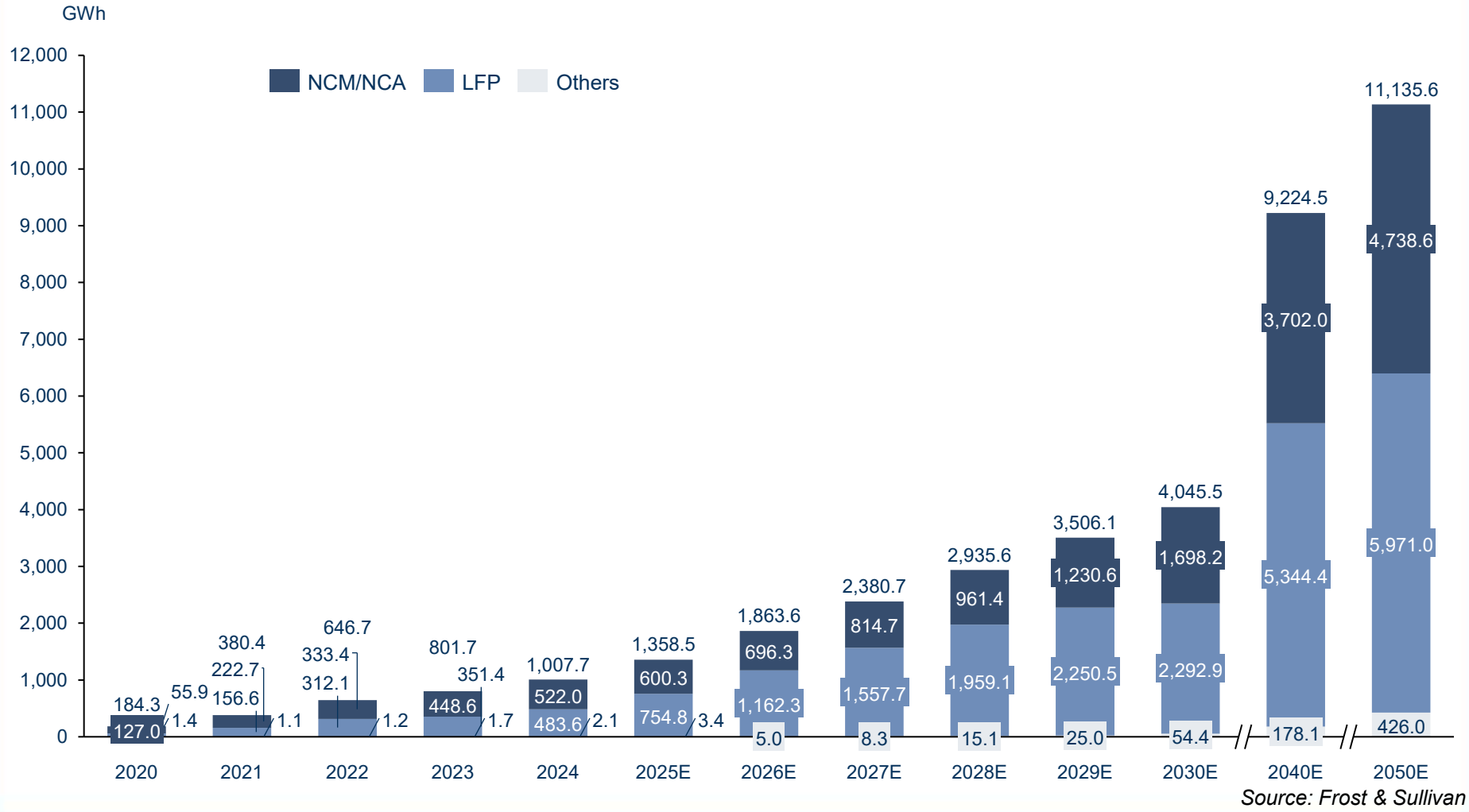
Shipment Volume of EV Batteries (by battery types), Global, 2020-2030E & 2040E & 2050E

Unit: GWh	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
NCM/NCA	127.0	222.7	333.4	448.6	522.0	600.3	696.3	814.7	961.4	1,230.6	1,698.2	3,702.0	4,738.6	42.4%	21.7%	8.1%	2.5%
LFP	55.9	156.6	312.1	351.4	483.6	754.8	1,162.3	1,557.7	1,959.1	2,250.5	2,292.9	5,344.4	5,971.0	71.5%	29.6%	8.8%	1.1%
Others	1.4	1.1	1.2	1.7	2.1	3.4	5.0	8.3	15.1	25.0	54.4	178.1	426.0	10.6%	71.8%	12.6%	9.1%
Total	**184.4**	**380.4**	**646.7**	**801.6**	**1,007.7**	**1,358.6**	**1,863.7**	**2,380.7**	**2,935.5**	**3,506.1**	**4,045.4**	**9,224.6**	**11,135.6**	**52.9%**	**26.1%**	**8.6%**	**1.9%**

Source: Frost & Sullivan

Charts

Shipment Volume of EV Batteries (by battery types), Global, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Mobility Battery Market —— EV Battery (2/4)

- The China EV battery market has witnessed substantial growth, propelled by the swift uptake of EVs and progress in battery technologies. In 2020, the total installed volume was 86.6 GWh, surging to 682.1 GWh in 2024, which indicates a CAGR of 67.5%. By 2030, total installations are forecasted to reach 2,664.9 GWh, growing at a CAGR of 25.5% from 2024 to 2030. By 2040, total installations are anticipated to reach 3,087.7 GWh, and further expand to 3,472.1 GWh by 2050, with a CAGR of 1.5% from 2030 to 2040 and 1.2% from 2040 to 2050.
- NCM and NCA batteries have been the leading battery types in the EV market, renowned for their high energy density and performance. The installed volume of NCM/NCA batteries increased from 42.9 GWh in 2020 to 222.0 GWh in 2024, reflecting a CAGR of 50.9%. By 2030, installations are projected to reach 647.3 GWh, growing at a CAGR of 19.5% from 2024 to 2030. By 2040, installations are expected to reach 904.4 GWh, and further expand to 1121.2 GWh by 2050, with a CAGR of 3.4% from 2030 to 2040 and 2.2% from 2040 to 2050.
- LFP batteries have gained significant momentum due to their cost - effectiveness, safety, and extended lifecycle. The installed volume of LFP batteries increased from 43.2 GWh in 2020 to 495.5 GWh in 2024, reflecting a remarkable CAGR of 80.6%%. By 2030, installations are projected to reach 1983.4 GWh, growing at a CAGR of 27.6% from 2024 to 2030. By 2040, installations are expected to reach 2105.9 GWh, and further expand to 2166.3 GWh by 2050, with a CAGR of 0.6% from 2030 to 2040 and 0.3% from 2040 to 2050.
- Other battery types, including emerging technologies like solid - state and lithium - sulfur batteries, have demonstrated promising growth potential. The installed volume of other battery types increased from 0.5 GWh in 2020 to 0.6 GWh in 2024, reflecting a CAGR of 2.5%. By 2030, installations are projected to reach 34.2 GWh, growing at a CAGR of 96.5% from 2024 to 2030. By 2040, installations are expected to reach 77.3 GWh, and further expand to 184.6 GWh by 2050, with a CAGR of 8.5% from 2030 to 2040 and 9.1% from 2040 to 2050.

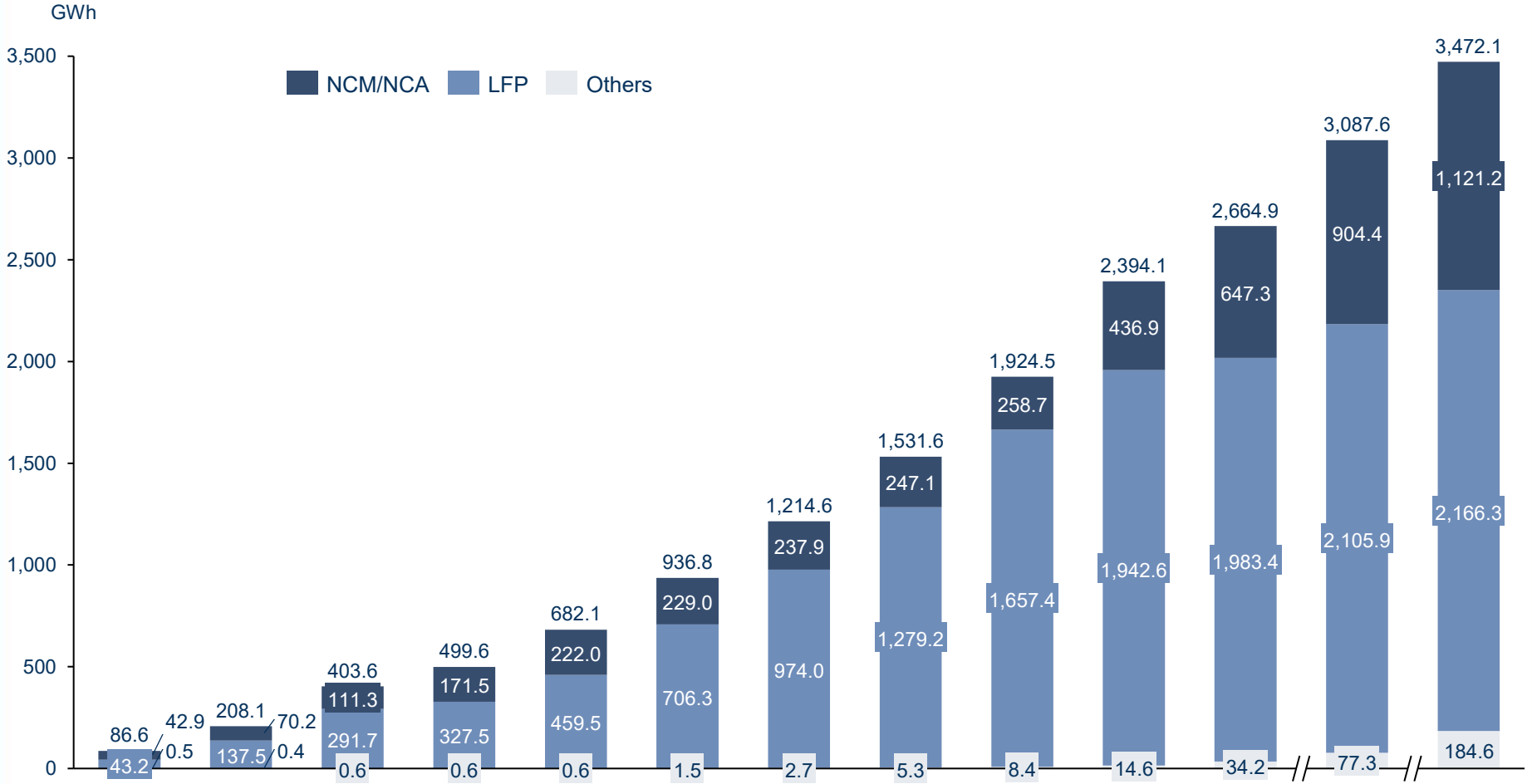
Shipment Volume of EV Batteries (by battery types), China, 2020-2030E & 2040E & 2050E

Unit: GWh	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
NCM/NCA	42.9	70.2	111.3	171.5	222.0	229.0	237.9	247.1	258.7	436.9	647.3	904.4	1121.2	50.9%	19.5%	3.4%	2.2%
LFP	43.2	137.5	291.7	327.5	459.5	706.3	974.0	1279.2	1657.4	1942.6	1983.4	2105.9	2166.3	80.6%	27.6%	0.6%	0.3%
Others	0.5	0.4	0.6	0.6	0.6	1.5	2.7	5.3	8.4	14.6	34.2	77.3	184.6	2.5%	96.5%	8.5%	9.1%
Total	**86.6**	**208.1**	**403.5**	**499.6**	**682.1**	**936.8**	**1,214.5**	**1,531.6**	**1,924.4**	**2,394.2**	**2,664.9**	**3,087.7**	**3,472.1**	**67.5%**	**25.5%**	**1.5%**	**1.2%**

Source: Frost & Sullivan

Charts

Shipment Volume of EV Batteries (by battery types), China, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Mobility Battery Market —— EV Battery (3/4)

- The global EV battery installed volume has witnessed remarkable growth, propelled by the rapid popularization of EVs and progress in battery technologies. In 2020, the total installed volume was 184.4 GWh, surging to 1007.7 GWh in 2024, reflecting a CAGR of 52.9%. By 2030, total installations are projected to reach 4,045.5 GWh, growing at a CAGR of 26.1% from 2024 to 2030. By 2040, total installations are expected to reach 9,224.6 GWh, and further expand to 11,135.6 GWh by 2050, with a CAGR of 8.6% from 2030 to 2040 and 1.9% from 2040 to 2050. This growth is primarily driven by the escalating demand for high-performance batteries that can meet the diverse requirements of EV manufacturers and consumers.

- In terms of vehicle types, PV dominate the EV battery market. The installed volume increased from 171.2 GWh in 2020 to 935.2 GWh in 2024, reflecting a CAGR of 52.9%. By 2030, installations are projected to reach 3,681.9 GWh, growing at a CAGR of 25.7% from 2024 to 2030. By 2040, installations are expected to reach 8,180.5 GWh, and further expand to 9,599.3 GWh by 2050, with a CAGR of 8.3% from 2030 to 2040 and 1.6% from 2040 to 2050. This growth is attributed to the increasing adoption of EVs in the passenger vehicle segment, which is supported by technological innovation, policy incentives, and the shift in consumer preferences towards sustainable mobility solutions.

- The CV segment has also significantly contributed to the growth of the EV battery market. The installed volume increased from 13.2 GWh in 2020 to 72.5 GWh in 2024, reflecting a CAGR of 53.2%. By 2030, installations are projected to reach 363.7 GWh, growing at a CAGR of 30.8% from 2024 to 2030. By 2040, installations are expected to reach 1,044.0 GWh, and further expand to 1,536.3 GWh by 2050, with a CAGR of 11.1% from 2030 to 2040 and 3.9% from 2040 to 2050. The growth is propelled by the rising adoption of electric buses, trucks, and other commercial vehicles.

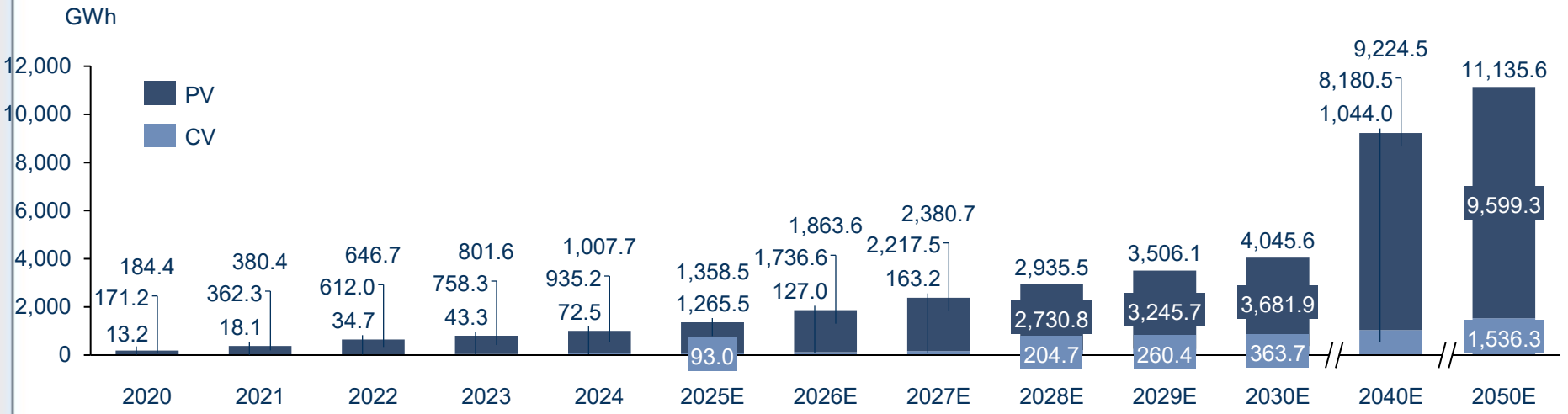
Shipment Volume of EV Batteries (by vehicle and power types), Global, 2020-2030E & 2040E & 2050E

Unit: GWh	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
PV	**171.2**	**362.3**	**612.0**	**758.3**	**935.2**	**1,265.5**	**1,736.6**	**2,217.5**	**2,730.8**	**3,245.7**	**3,681.9**	**8,180.5**	**9,599.3**	**52.9%**	**25.7%**	**8.3%**	**1.6%**
BEV	150.4	322.3	544.2	661.1	779.6	1,013.2	1,357.3	1,705.5	2,077.3	2,437.2	2,884.5	7,235.8	8,859.8	50.9%	24.4%	9.6%	2.0%
PHEV	20.8	40.0	67.8	97.2	155.6	252.3	379.3	512.0	653.5	808.4	797.4	944.7	739.4	65.4%	31.3%	1.7%	-2.4%
CV	**13.2**	**18.1**	**34.7**	**43.3**	**72.5**	**93.0**	**127.0**	**163.2**	**204.7**	**260.4**	**363.7**	**1,044.0**	**1,536.3**	**53.2%**	**30.8%**	**11.1%**	**3.9%**
BEV	13.2	18.1	34.7	43.2	71.9	91.4	123.4	156.9	195.1	247.3	348.4	1006.8	1521.6	52.9%	30.1%	11.2%	4.2%
PHEV	0.0	0.0	0.0	0.1	0.6	1.6	3.6	6.3	9.6	13.1	15.3	37.3	14.7	215.7%	73.4%	9.3%	-8.9%
Total	**184.4**	**380.4**	**646.7**	**801.6**	**1007.7**	**1358.6**	**1863.7**	**2380.7**	**2935.5**	**3506.1**	**4045.5**	**9224.6**	**11135.6**	**52.9%**	**26.1%**	**8.6%**	**1.9%**

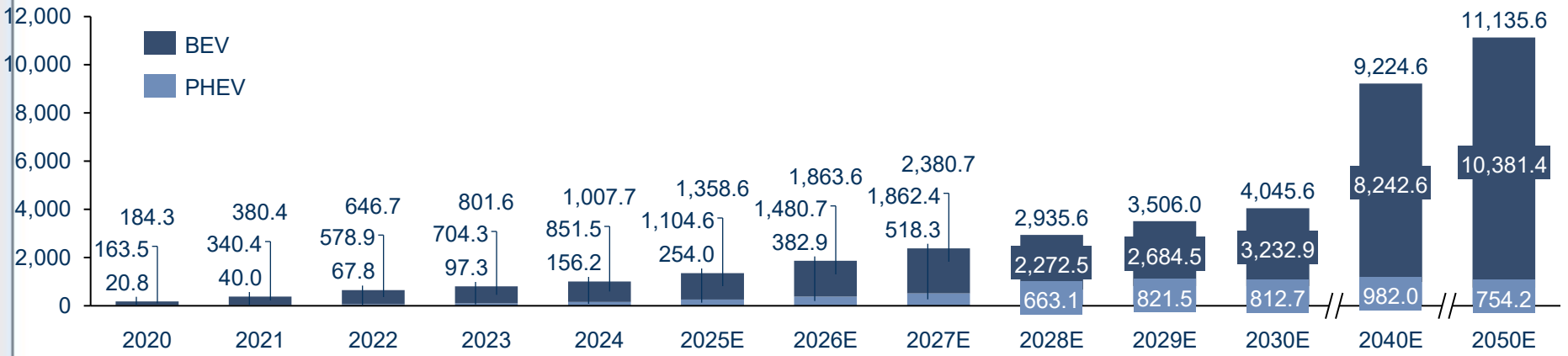
Source: Frost & Sullivan

Charts

Shipment Volume of EV Batteries (by vehicle types), Global, 2020-2030E & 2040E & 2050E



Shipment Volume of EV Batteries (by power types), Global, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Mobility Battery Market —— EV Battery (4/4)

- The EV battery installed volume in China has experienced significant growth, driven by the rapid adoption of EVs and advancements in battery technologies. In 2020, the total installed volume stood at 86.6 GWh, increasing to 682.1 GWh in 2024, reflecting a CAGR of 67.5%. By 2030, total installations are projected to reach 2,664.9 GWh, growing at a CAGR of 25.5% from 2024 to 2030. By 2040, total installations are expected to reach 3,087.7 GWh, and further expand to 3,472.1 GWh by 2050, with a CAGR of 1.5% from 2030 to 2040 and 1.2% from 2040 to 2050.
- In terms of vehicle types, PV dominate the EV battery market, with installed volume increasing from 76.2 GWh in 2020 to 611.3 GWh in 2024, reflecting a CAGR of 68.3%. By 2030, installations are projected to reach 2,435.3 GWh, growing at a CAGR of 25.9% from 2024 to 2030. By 2040, installations are expected to reach 2,622.2 GWh, and further expand to 2,883.1 GWh by 2050, with a CAGR of 0.7% from 2030 to 2040 and 1.0% from 2040 to 2050.
- The CV segment has also contributed to the growth of the EV battery market, with installed volume increasing from 10.4 GWh in 2020 to 70.8 GWh in 2024, reflecting a CAGR of 61.5%. By 2030, installations are projected to reach 229.6 GWh, growing at a CAGR of 21.7% from 2024 to 2030. By 2040, installations are expected to reach 465.5 GWh, and further expand to 588.9 GWh by 2050, with a CAGR of 7.3% from 2030 to 2040 and 2.4% from 2040 to 2050.

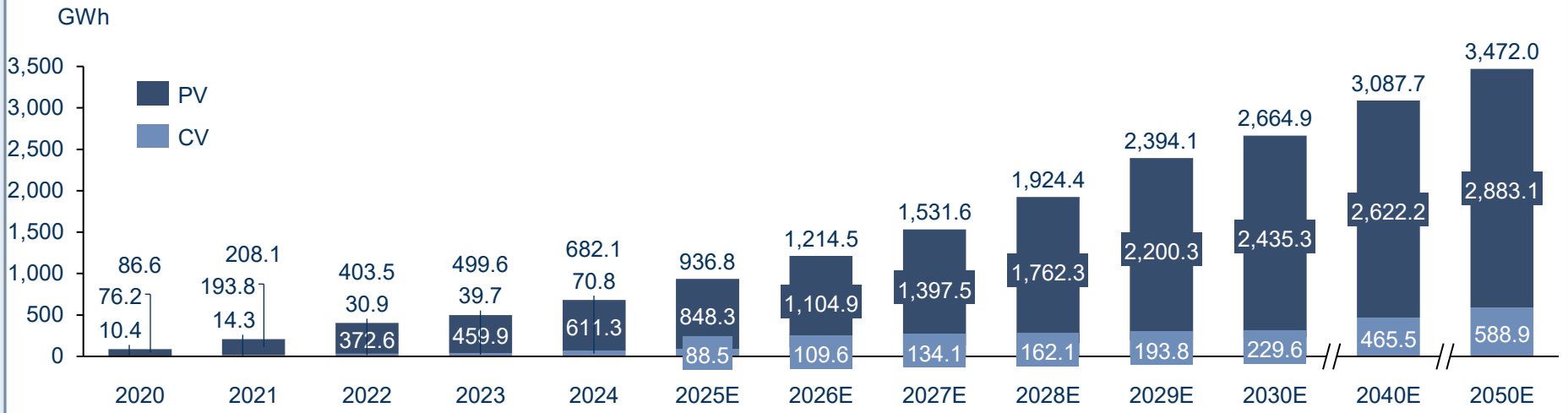
Shipment Volume of EV Batteries (by vehicle and power types), China, 2020-2030E & 2040E & 2050E

Unit: GWh	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
PV	**76.2**	**193.8**	**372.6**	**459.9**	**611.3**	**848.3**	**1,104.9**	**1,397.5**	**1,762.3**	**2,200.3**	**2,435.3**	**2,622.2**	**2,883.1**	**68.3%**	**25.9%**	**0.7%**	**1.0%**
BEV	70.3	179.6	330.0	379.8	469.6	600.8	745.7	913.0	1,127.5	1,367.7	1,571.9	1,838.7	2,189.7	60.8%	22.3%	1.6%	1.8%
PHEV	5.9	14.3	42.6	80.0	141.7	247.5	359.2	484.5	634.8	832.6	863.4	783.5	693.4	121.3%	35.1%	-1.0%	-1.2%
CV	**10.4**	**14.3**	**30.9**	**39.7**	**70.8**	**88.5**	**109.6**	**134.1**	**162.1**	**193.8**	**229.6**	**465.5**	**588.9**	**61.5%**	**21.7%**	**7.3%**	**2.4%**
BEV	10.4	14.3	30.9	39.6	70.2	86.9	106.6	129.6	156.4	187.3	222.6	456.7	577.5	61.2%	21.2%	7.4%	2.4%
PHEV	0.0	0.0	0.0	0.1	0.6	1.6	3.1	4.5	5.7	6.5	7.0	8.8	11.4	NA	51.0%	2.4%	2.7%
Total	**86.6**	**208.1**	**403.5**	**499.6**	**682.1**	**936.8**	**1214.5**	**1531.6**	**1924.4**	**2394.2**	**2664.9**	**3087.7**	**3472.1**	**67.5%**	**25.5%**	**1.5%**	**1.2%**

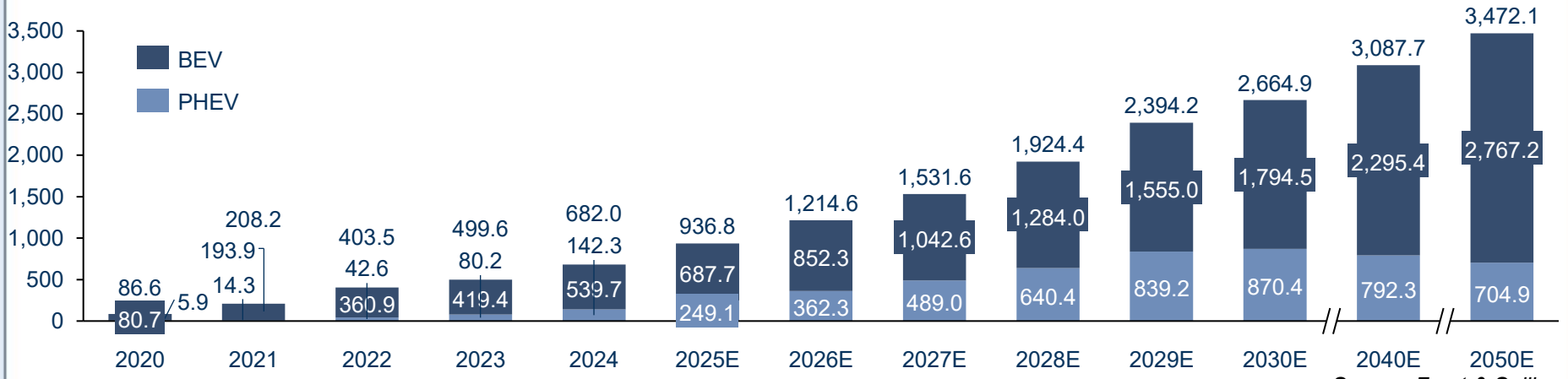
Source: Frost & Sullivan

Charts

Shipment Volume of EV Batteries (by vehicle types), China, 2020-2030E & 2040E & 2050E



Shipment Volume of EV Batteries (by power types), China, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Competitive Landscape of Global EV Battery Market

Ranking of EV Battery Manufacturers (by Installed Volume), Global, 2024

Rank	Company Name	Installed Volume (GWh)	Market Share
1	CATL (宁德时代)	339.3	38.3%
2	BYD (比亚迪)	153.7	17.3%
3	LGES (LG新能源)	96.3	10.9%
4	EVE Battery (亿纬锂能)	39.4	4.4%
5	SK On (SK集团)	39.0	4.4%
6	Panasonic (松下)	35.1	4.0%
7	Samsung SDI (三星)	29.6	3.3%
8	Gotion (国轩高科)	28.5	3.2%
9	EVE Battery (亿纬锂能)	20.3	2.3%
10	SUNWODA (欣旺达)	18.8	2.1%
	Others	86.4	9.7%
	Total	**886.4**	**100.0%**

Ranking of EV Battery Manufacturers (by Installed Volume), China, 2024

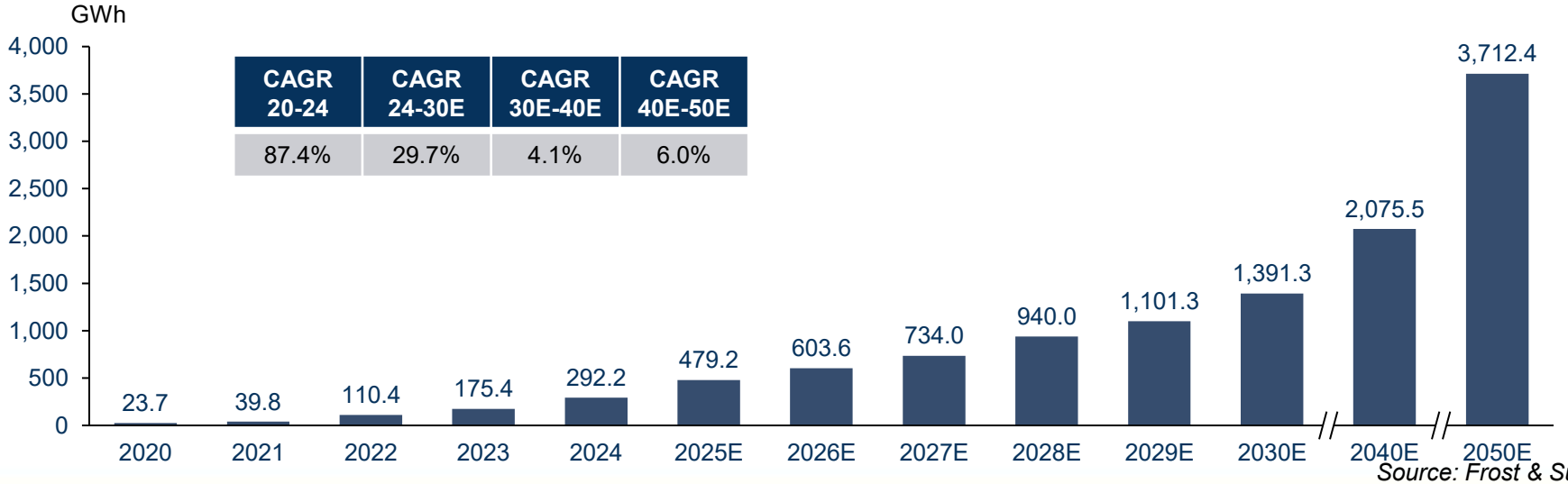
Rank	Company Name	Installed Volume (GWh)	Market Share
1	CATL (宁德时代)	246.0	44.9%
2	BYD (比亚迪)	135.0	24.6%
3	CALB (中创新航)	36.5	6.7%
4	Gotion (国轩高科)	25.0	4.6%
5	EVE Battery (亿纬锂能)	18.7	3.4%
6	SVOLT (蜂巢能源)	17.4	3.2%
7	SUNWODA (欣旺达)	15.8	2.9%
8	REPT (瑞浦兰钧)	12.1	2.2%
9	ZENERGY (正力新能)	9.9	1.8%
10	LGES (LG新能源)	7.7	1.4%
	Others	25.9	4.7%
	Total	**548.4**	**100.0%**

Source: Frost & Sullivan

Analysis of Global ESS Battery Market (1/2)

- The global ESS battery market has experienced significant growth, driven by the increasing adoption of renewable energy and the need for grid stability. In 2020, the total shipment volume stood at 23.7 GWh, increasing to 292.2 GWh in 2024, reflecting a CAGR of 87.4%. By 2030, total shipments are projected to reach 1,391.3 GWh, growing at a CAGR of 29.7% from 2024 to 2030. By 2040, total shipments are expected to reach 2,075.5 GWh, and further expand to 3,712.4 GWh by 2050, with a CAGR of 4.1% from 2030 to 2040 and 6.0% from 2040 to 2050. This growth is fueled by the increasing demand for efficient and sustainable energy storage solutions.

Shipment Volume of ESS Batteries (by battery types), Global, 2020-2030E & 2040E & 2050E

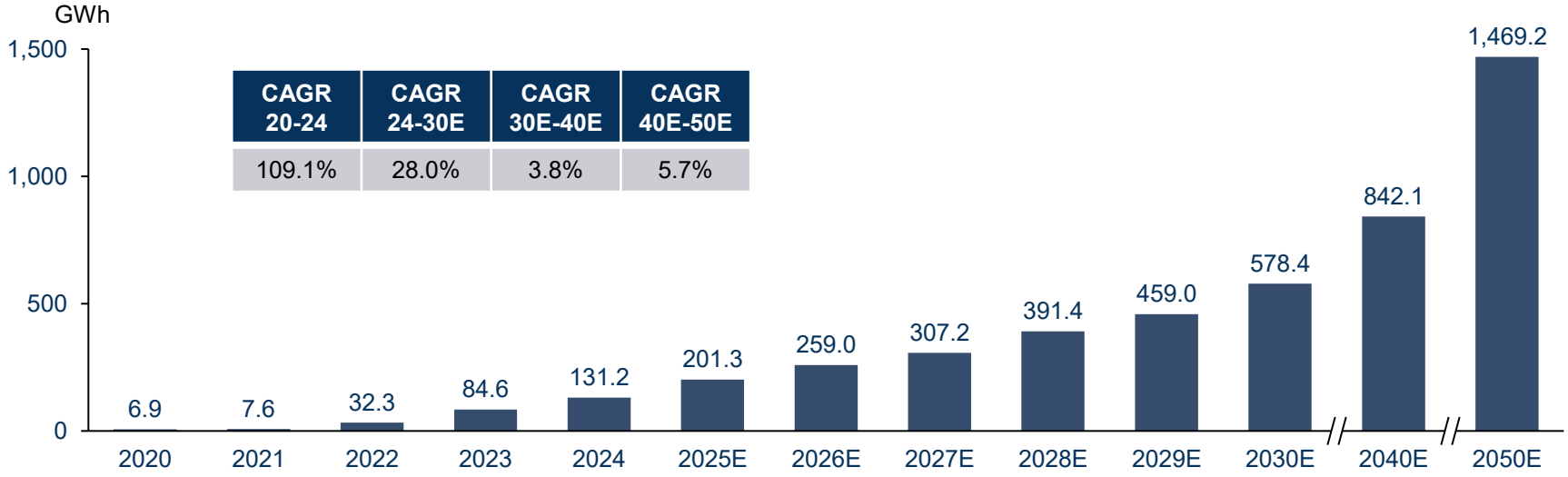


Source: Frost & Sullivan

Analysis of Global ESS Battery Market (2/2)

- In 2020, the total shipment volume of the ESS battery market in China stood at 6.9 GWh, increasing to 131.2 GWh in 2024, reflecting a CAGR of 109.1%. By 2030, total shipments are projected to reach 578.4 GWh, growing at a CAGR of 28.0% from 2024 to 2030. By 2040, total shipments are expected to reach 842.1 GWh, and further expand to 1,469.2 GWh by 2050, with a CAGR of 3.8% from 2030 to 2040 and 5.7% from 2040 to 2050.

Shipment Volume of ESS Batteries (by battery types), China, 2020-2030E & 2040E & 2050E

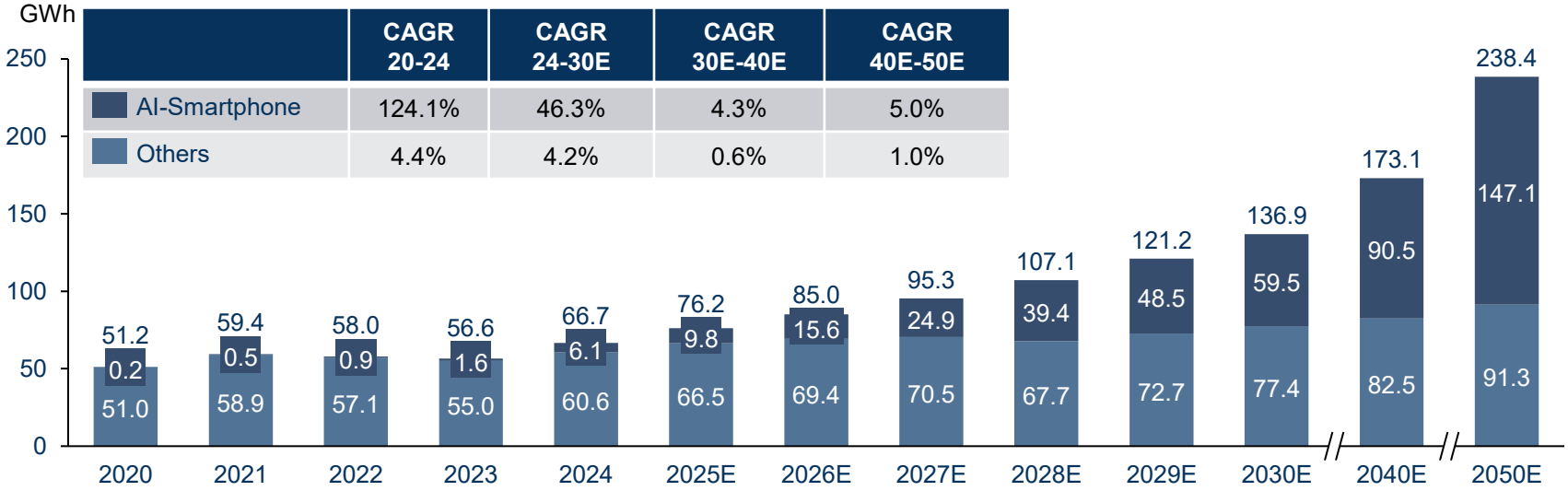


Source: Frost & Sullivan

Analysis of Global 3C Electronics Battery Market (1/2)

- In the 3C Electronics batteries, with the rapid popularization and increasing shipment volumes of smartphones, tablets, and smart wearable devices, high-cost-performance lithium batteries have become an important consideration for consumer electronics manufacturers when sourcing batteries. This trend has led to the gradual replacement of lithium cobalt oxide batteries by ternary lithium batteries in some mid-to-low-end consumer electronics segments.
- In recent years, the market size of AI products in 3C electronics has shown a rapid growth trend, mainly due to the continuous development of artificial intelligence technology and the increasing demand of consumers for intelligent products.
- The global shipment volume of batteries for 3C electronics has shown steady growth, driven by the increasing demand for smart devices and advancements in battery technology. From 2020 to 2024, the total shipment volume increased from 51.2 GWh to 66.7 GWh, reflecting a CAGR of 6.8%. By 2030, shipments are projected to reach 136.9 GWh, with a CAGR of 12.7% from 2024 to 2030. It is expected to expand to 173.1 GWh by 2040 and 238.4 GWh by 2050, representing a CAGR of 2.4% from 2030 to 2040 and a CAGR of 3.3% from 2040 to 2050.

Shipment Volume of 3C Electronics Batteries, Global, 2020-2030E & 2040E & 2050E

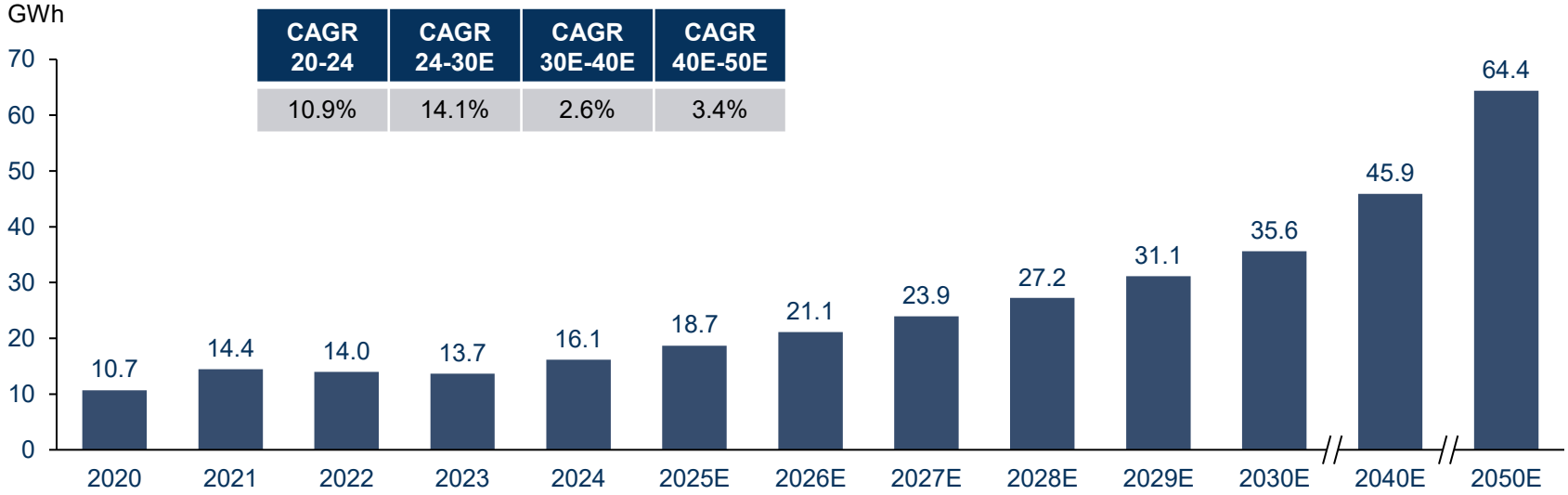


Source: Frost & Sullivan

Analysis of Global 3C Electronics Battery Market (2/2)

- The shipment volume of batteries for 3C electronics in China has experienced steady growth, driven by the country's dominance in global electronics manufacturing and the increasing demand for smart devices. From 2020 to 2024, the total shipment volume of 3C electronics batteries in China increased from 10.7 GWh to 16.1 GWh, reflecting a CAGR of 10.9%. This growth is fueled by the widespread adoption of smartphones, laptops, tablets, and other portable devices, as well as advancements in battery technology that enhance performance and energy efficiency. By 2030, the total shipment volume is projected to reach 35.6 GWh, with a CAGR of 14.1% from 2024 to 2030. It is expected to expand to 45.9 GWh by 2040 and 64.4 GWh by 2050, representing a CAGR of 2.6% from 2030 to 2040 and a CAGR of 3.4% from 2040 to 2050.

Shipment Volume of 3C Electronics Batteries, China, 2020-2030E & 2040E & 2050E



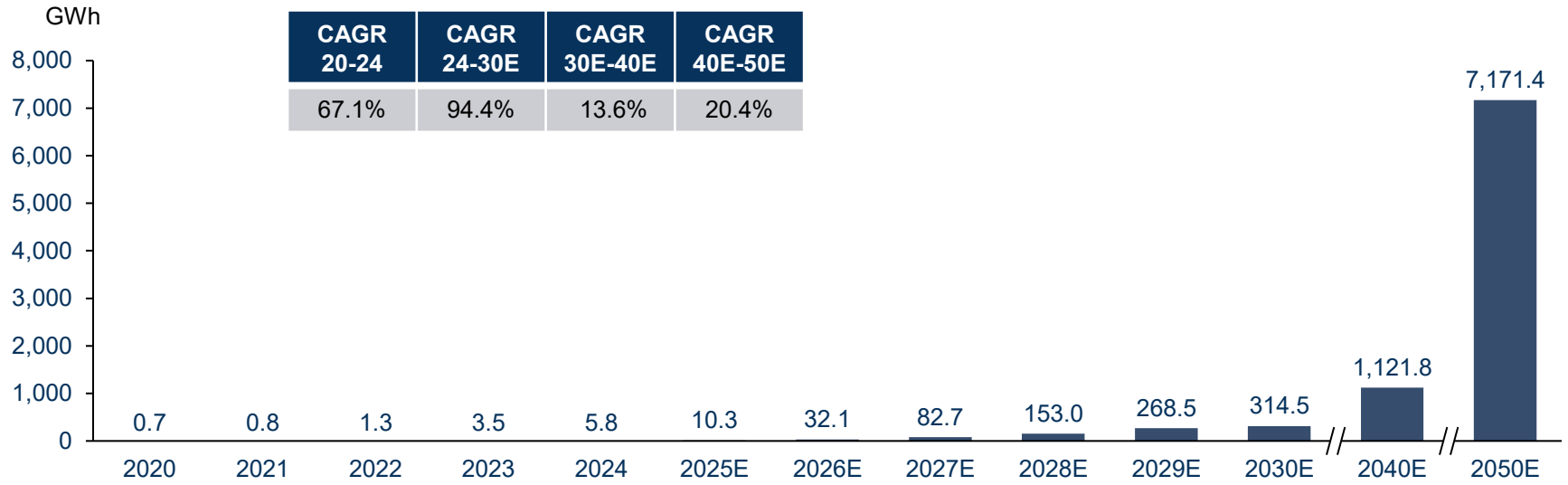
Source: Frost & Sullivan

Analysis of Global E-Vessel Battery Market (1/2)

- The shipment volume of E-vessel batteries is rapidly growing, primarily driven by (i) the acceleration of investments and R&D in the electrification of shipbuilding and shipping industry; (ii) the continuous evolution of power battery technologies; (iii) governments policy incentives for the electric ship industry chain; and (iv) needs by large vessels, such as containerships, to have additional backup batteries to be stored at docks for battery swapping.

- The global shipment volume of batteries for e-vessels has seen significant growth, driven by the increasing adoption of electrification in the maritime industry and the push for sustainable transportation solutions. From 2020 to 2024, the total shipment volume of e-vessel batteries increased from 0.7 GWh to 5.8 GWh, reflecting a CAGR of 67.1%. This growth is fueled by the rising demand for cleaner and more efficient propulsion systems in ships, ferries, and other maritime vessels, as well as advancements in battery technology that enhance energy density and safety. By 2030, the total shipment volume is projected to reach 314.5 GWh, with a CAGR of 94.4% from 2024 to 2030. It is expected to expand to 1121.8 GWh by 2040 and 7171.4 GWh by 2050, representing a CAGR of 13.6% from 2030 to 2040 and a CAGR of 20.4% from 2040 to 2050.

Shipment Volume of E-Vessel Batteries, Global, 2020-2030E & 2040E & 2050E

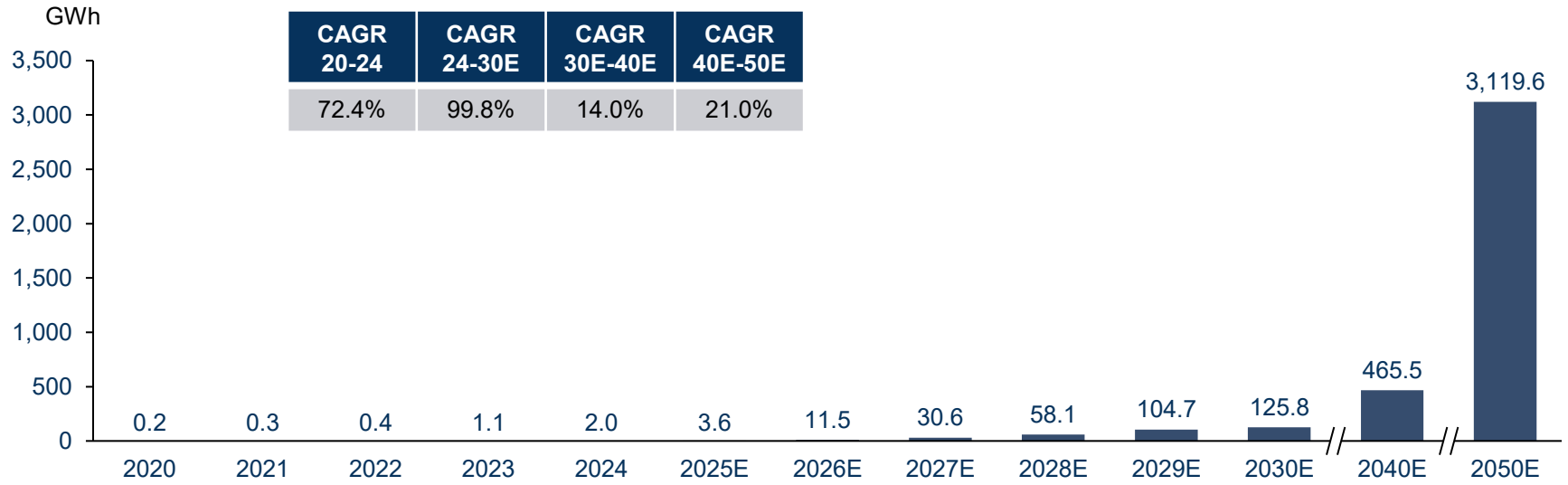


Source: Frost & Sullivan

Analysis of Global E-Vessel Battery Market (2/2)

- The shipment volume of E-Vessel batteries in China has exhibited significant growth from 2020 to 2024, increasing from 0.2 GWh to 2.0 GWh, representing a CAGR of 72.4% during this period. This rapid expansion is driven by the growing awareness of environmental sustainability in the maritime industry and the increasing adoption of electric vessels for both commercial and recreational purposes. Additionally, advancements in battery technology have enhanced the performance and range of E-Vessel batteries, making them more viable for widespread use.
- From 2024 to 2030, the shipment volume is projected to continue its robust growth, with a CAGR of 99.8%. By 2030, the shipment volume is expected to reach 125.8 GWh. This sustained increase is supported by the ongoing global efforts to decarbonize the shipping industry, as well as the increasing demand for zero-emission maritime solutions. Government policies aimed at promoting green shipping and incentivizing the adoption of electric vessels are also key drivers of this growth.
- By 2040, the total shipment volume is expected to reach 465.5 GWh, with a CAGR of 14.0% from 2030 to 2040. By 2050, the volume is anticipated to reach 3119.6 GWh, with a CAGR of 21.0% from 2040 to 2050. This growth is expected to be fueled by the maturation of battery technologies, which will further improve the efficiency and reliability of E-Vessel batteries. Additionally, the increasing integration of electric vessels into global maritime supply chains will drive demand for these batteries, as industries seek to reduce their carbon footprints and comply with stricter environmental regulations.

Shipment Volume of E-Vessel Batteries, China, 2020-2030E & 2040E & 2050E

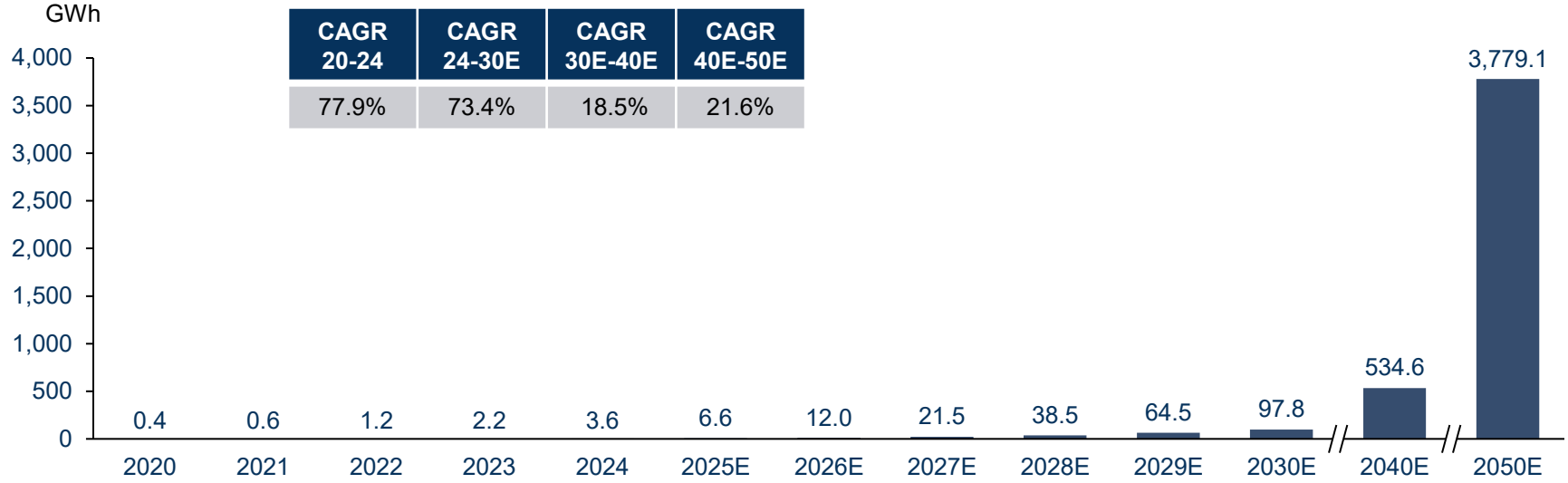


Source: Frost & Sullivan

Analysis of Global Low-altitude Aircraft Battery Market (1/2)

- From 2020 to 2024, the global shipment volume of low-altitude aircraft batteries increased from 0.4 GWh to 3.6 GWh, representing a CAGR of 77.9%. This initial growth phase was driven by the early adoption of electric propulsion systems in small-scale aviation, particularly in applications such as drones and eVTOL. The market's expansion was further supported by advancements in battery technology, which improved energy density and reduced weight, making electric flight more feasible.
- From 2024 to 2030, the shipment volume is projected to grow at a CAGR of 74.3%, reaching 97.8 GWh by 2030. The growing interest in sustainable aviation, coupled with regulatory support for electric flight, will drive demand for high-performance batteries capable of powering larger and more complex aircraft.
- By 2040, the total shipment volume is expected to reach 534.6 GWh, with a CAGR of 18.5% from 2030 to 2040. By 2050, the volume is anticipated to reach 3779.1 GWh, with a CAGR of 21.6% from 2040 to 2050. The long-term growth trajectory will be supported by the global push towards decarbonizing the aviation sector, the increasing adoption of electric aircraft in both commercial and recreational applications, and the ongoing innovation in battery technology.
- Considering the requirements of eVTOL and drones for high energy density, high capacity, and lightweight design, high-nickel ternary batteries and solid-state batteries have broad application prospects in the low-altitude economy sector.

Shipment Volume of Low-altitude Aircraft Batteries, Global, 2020-2030E & 2040E & 2050E

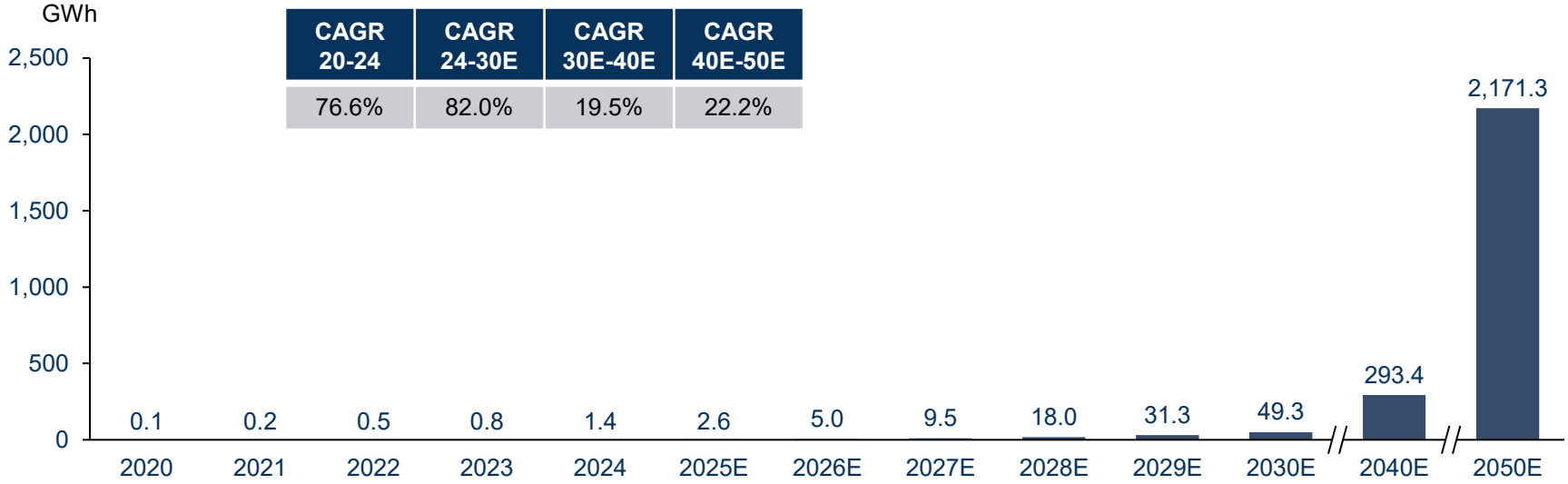


Source: Frost & Sullivan

Analysis of Global Low-altitude Aircraft Battery Market (2/2)

- Between 2020 and 2024, China saw its shipment volume of low-altitude aircraft batteries climb from 0.1 GWh to 1.4 GWh, marking a CAGR of 76.6%. This upsurge was largely spurred by the burgeoning adoption of electric propulsion systems in niche aviation segments, such as drones and UAM crafts. Meanwhile, progress in battery technology that enhanced energy density and slashed weight rendered electric flight increasingly viable.
- From 2024 to 2030, the shipment volume is anticipated to surge at a CAGR of 82.0%, hitting 49.3 GWh by 2030. During this span, low-altitude aircraft batteries are set to permeate commercial and consumer aviation more deeply. The escalating pursuit of sustainable aviation, buttressed by regulatory backing for electric flight, will stoke demand for high-performance batteries capable of powering more sophisticated aircraft.
- By 2040, the total shipment volume is expected to reach 293.4 GWh, with a CAGR of 19.5% from 2030 to 2040. By 2050, the volume is anticipated to reach 2171.3 GWh, with a CAGR of 22.2% from 2040 to 2050. This sustained momentum will be powered by the maturation of electric aviation technologies and the mounting quest for zero-emission flight solutions. The burgeoning of new markets for low-altitude aircraft, including regional air transport and cargo delivery, will also play a role. Ongoing enhancements in battery technology, promising longer flight durations and heftier payload capacities, will further stretch the market's horizons.

Shipment Volume of Low-altitude Aircraft Batteries, China, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Robotics Battery Market (1/3)

- Embodied intelligent robots are poised to emerge as a pivotal driver in boosting lithium battery demand, while accelerating the iterative upgrades of battery technologies toward higher energy density and enhanced safety. With the widespread commercialization of embodied robots, substantial demand for lithium batteries will be generated.

- As the embodied intelligent robot market rapidly expands, the demand for lithium batteries is soaring correspondingly. Serving as the core power source for embodied robots, lithium batteries play a crucial role in advancing the commercialization of the embodied robotics industry. Lithium batteries for embodied intelligent robots must simultaneously meet multiple requirements, including high energy density, high power output, enhanced safety, and extended lifespan. Currently, most embodied intelligent robots primarily adopt cylindrical lithium batteries installed in the central torso area. For example, Tesla's Optimus embodied intelligent robot is equipped with a 2.3kWh, 52V lithium iron phosphate (LFP) cylindrical battery pack. However, due to limited internal space in robots, battery volume cannot be infinitely expanded, resulting in most embodied intelligent robots having an endurance of only 2-4 hours. The application of high-nickel ternary batteries and solid-state batteries holds promise for resolving the "endurance anxiety" of embodied intelligent robots.

- From 2020 to 2024, the global shipment volume of robotics batteries increased from 2.3 GWh to 10.0 GWh, achieving a CAGR of 44.8%. This growth was driven by the rising demand for high-nickel and LCO materials, which are essential for powering intelligent robots due to their high energy density and rapid charging capabilities. These materials enable robots to operate efficiently in diverse applications, from manufacturing and logistics to service sectors.

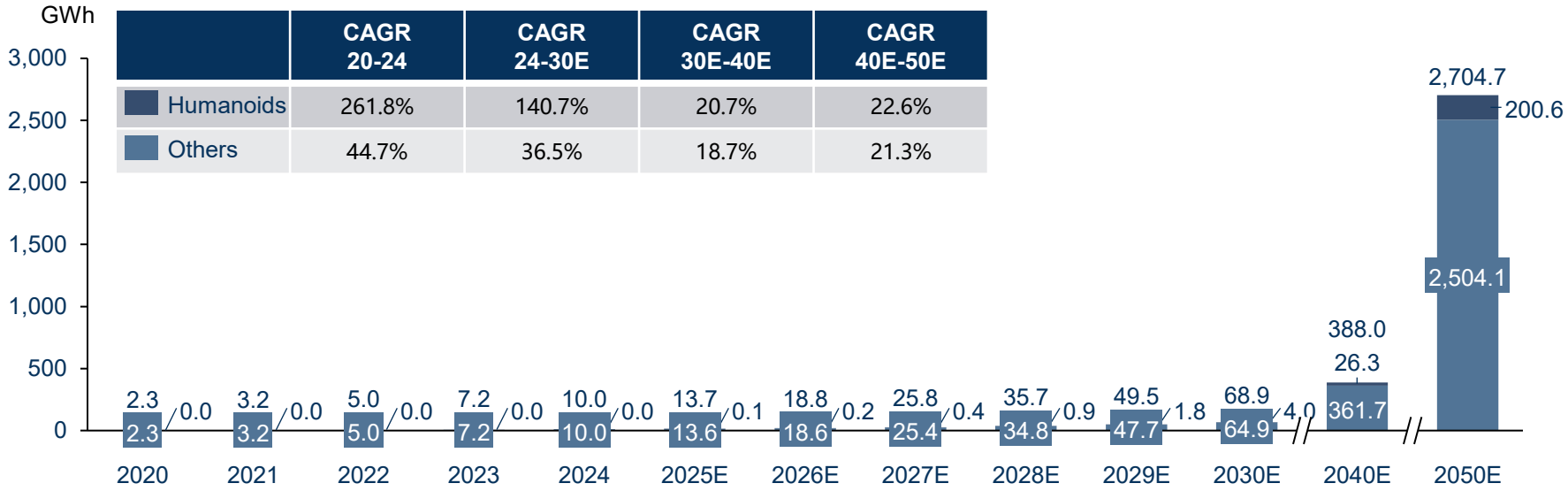
- From 2024 to 2030, the shipment volume is projected to reach 68.9 GWh, with a CAGR of 37.9%. The continued expansion will be fueled by the increasing complexity and adoption of robotics across various industries. High-nickel materials will dominate due to their superior energy density, while LCO materials will remain crucial for applications requiring high power density and quick recharging.

- By 2040, the total shipment volume is expected to reach 388.0 GWh, with a CAGR of 18.9% from 2030 to 2040. By 2050, the volume is anticipated to reach 2704.8 GWh, with a CAGR of 21.4% from 2040 to 2050. The sustained growth will be supported by ongoing advancements in robotics technologies and the increasing demand for sustainable, high-performance batteries to power the next generation of intelligent robots.

Source: Frost & Sullivan

Analysis of Global Robotics Battery Market (2/3)

Shipment Volume of Robotics Batteries, Global, 2020-2030E & 2040E & 2050E

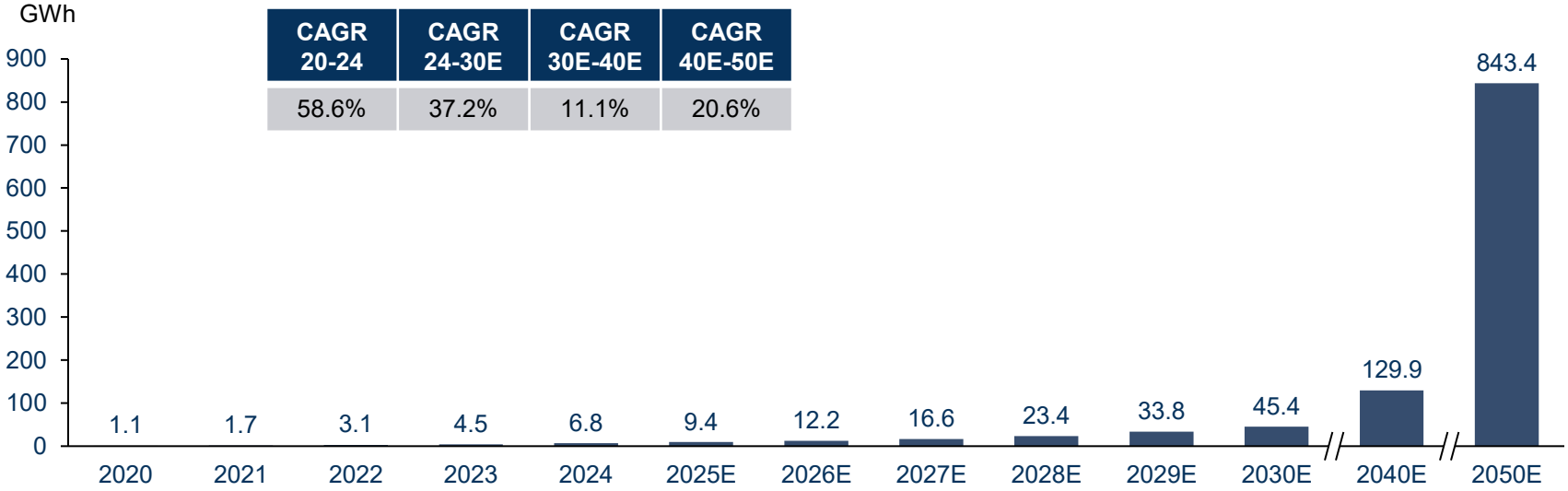


Source: Frost & Sullivan

Analysis of Global Robotics Battery Market (3/3)

- Primarily driven by the rapid expansion of the robotics industry in China, with increasing adoption of intelligent robots across manufacturing, logistics, and service sectors, the shipment volume of robotics batteries in China increased to 6.8 GWh in 2024, achieving a CAGR of 58.6% from 2020 to 2024.
- From 2024 to 2030, the shipment volume is projected to grow at a CAGR of 37.2%, reaching 45.4 GWh by 2030. This period will see continued expansion of the robotics market in China, driven by the increasing sophistication of robotic applications and the need for longer operational times and higher efficiency. High-nickel materials are expected to gain further prominence due to their superior energy density, while LCO materials will remain in high demand for applications requiring rapid charging and high-power density.
- By 2040, the total shipment volume is expected to reach 129.9 GWh, with a CAGR of 11.1% from 2030 to 2040. By 2050, the volume is anticipated to reach 843.4 GWh, with a CAGR of 20.6% from 2040 to 2050. By this time, China's robotics industry will have matured significantly, with widespread adoption across various sectors. The demand for high-nickel and LCO materials will continue to rise, driven by the need for high-performance batteries to power increasingly complex robotic systems. These materials will be crucial for supporting the growth of industrial automation and service robotics.

Shipment Volume of Robotics Batteries, China, 2020-2030E & 2040E & 2050E



Source: Frost & Sullivan

Analysis of Global Phosphorus-based Materials Market

- Phosphorus-based materials mainly include LFP as CAM, and iron phosphate (FP) compound as pCAM.
- The demand for LFP batteries varies across different markets based on cost, performance needs, and industry focus. In China, LFP batteries are widely used in electric vehicles and energy storage due to its industrial maturity, affordability, safety, and long cycle life. Strong government policies, a well-developed supply chain, and the rapid growth of renewable energy projects further drive adoption of LFP batteries, making China the largest market for LFP batteries.
- In contrast, overseas markets are gradually increasing their use of LFP batteries, but with different priorities. While some automakers incorporate LFP batteries in entry-level EV, higher-performance vehicles often still rely on ternary batteries for greater energy density. In energy storage, LFP is gaining traction due to its safety and longevity, especially as renewable energy integration grows. Historically, supply chain limitations and the need for localized production impact adoption rates of LFP batteries in overseas markets, which also shows a great growth potential of LFP batteries in those overseas markets.

Analysis of Global Ternary Precursors Market

- Ternary precursors are the key raw materials for producing ternary cathode materials and ternary battery, including Ni-Co-Mn hydroxide and Ni-Co-Al hydroxide. In recent years, the trend toward high-nickel composition in ternary precursor materials has become increasingly significant, driven primarily by the need to enhance battery energy density and reduce costs. The nickel content has evolved from NCM523 to NCM811 and even ultra-high-nickel 9-series, enabling battery energy density to exceed 300Wh/kg, which meets the range requirements of high-end EVs while reducing cobalt usage. Additionally, advancements in single-crystal technology and nano-coating are progressively addressing challenges related to thermal stability and process complexity. High-nickel ternary materials are expected to become the mainstream technological pathway soon.
- 9-series: This category shows significant growth, especially from 2022 onwards, with a CAGR of 42.3% from 2024 to 2030. As industry inventories are reduced to a relatively reasonable level, terminal demand in 2025 is expected to be smoothly transmitted to the upstream segment, which is likely to drive a recovery in the production and sales of ternary precursors. The shipment volume is projected to increase dramatically, reaching 931.1 thousand tons by 2030.
- 8-series: This category also shows strong growth, with a CAGR of 35.0% from 2020 to 2024 and 32.8% from 2024 to 2030. The shipment volume is expected to reach 1,241.5 thousand tons by 2030.
- 7-series: Similar to the 8-series, the 6-series shows robust growth, with a CAGR of 27.4% from 2020 to 2024 and 23.2% from 2024 to 2030. The shipment volume is projected to reach 527.6 thousand tons by 2030.
- 6-series and others: This category with a CAGR of 9.1% from 2020 to 2024 and -2.6% from 2024 to 2030. The shipment volume is expected to decrease significantly, dropping to 403.5 thousand tons by 2030.
- Overall, the total shipment volume is projected to grow significantly, with a CAGR of 19.5% from 2020 to 2024 and 21.6% from 2024 to 2030, reaching 3,103.7 thousand tons by 2030.The data suggests a shift in demand towards higher series (9-series, 8-series, and 7-series). This could indicate changes in technology, market preferences, or regulatory impacts influencing the demand for different types of ternary precursors.

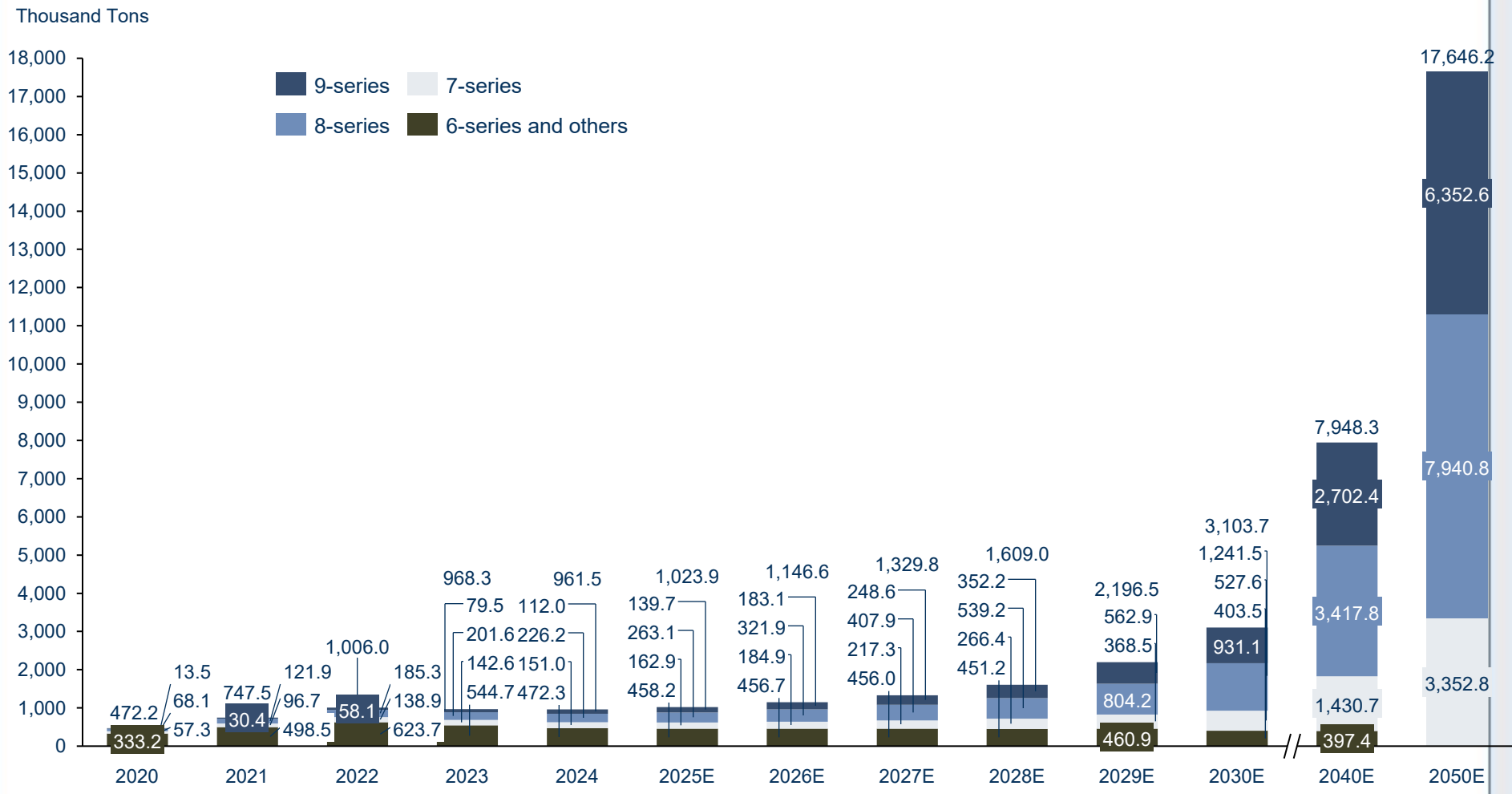
Shipment Volume of Ternary Precursors (by products types), Global, 2017-2030E & 2040E & 2050E

Unit: Thousand Tons	2017	2018	2019	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
9-series	2.1	4.5	8.3	13.5	30.4	58.1	79.5	112.0	139.7	183.1	248.6	352.2	562.9	931.1	2,702.4	6,352.6	69.7%	42.3%	11.2%	8.9%
8-series	21.1	36.2	52.2	68.1	121.9	185.3	201.6	226.2	263.1	321.9	407.9	539.2	804.2	1,241.5	3,417.8	7,940.8	35.0%	32.8%	10.7%	8.8%
7-series	21.1	34.1	46.5	57.3	96.7	138.9	142.6	151.0	162.9	184.9	217.3	266.4	368.5	527.6	1,430.7	3,352.8	27.4%	23.2%	10.5%	8.9%
6-series and others	166.5	245.2	302.1	333.2	498.5	623.7	544.7	472.3	458.2	456.7	456.0	451.2	460.9	403.5	397.4	-	9.1%	-2.6%	-0.2%	-100.0%
Total	**210.7**	**320.1**	**409.2**	**472.2**	**747.5**	**1,006.0**	**968.3**	**961.5**	**1,023.9**	**1,146.6**	**1,329.8**	**1,609.0**	**2,196.5**	**3,103.7**	**7,948.3**	**17,646.2**	**19.5%**	**21.6%**	**9.9%**	**8.3%**

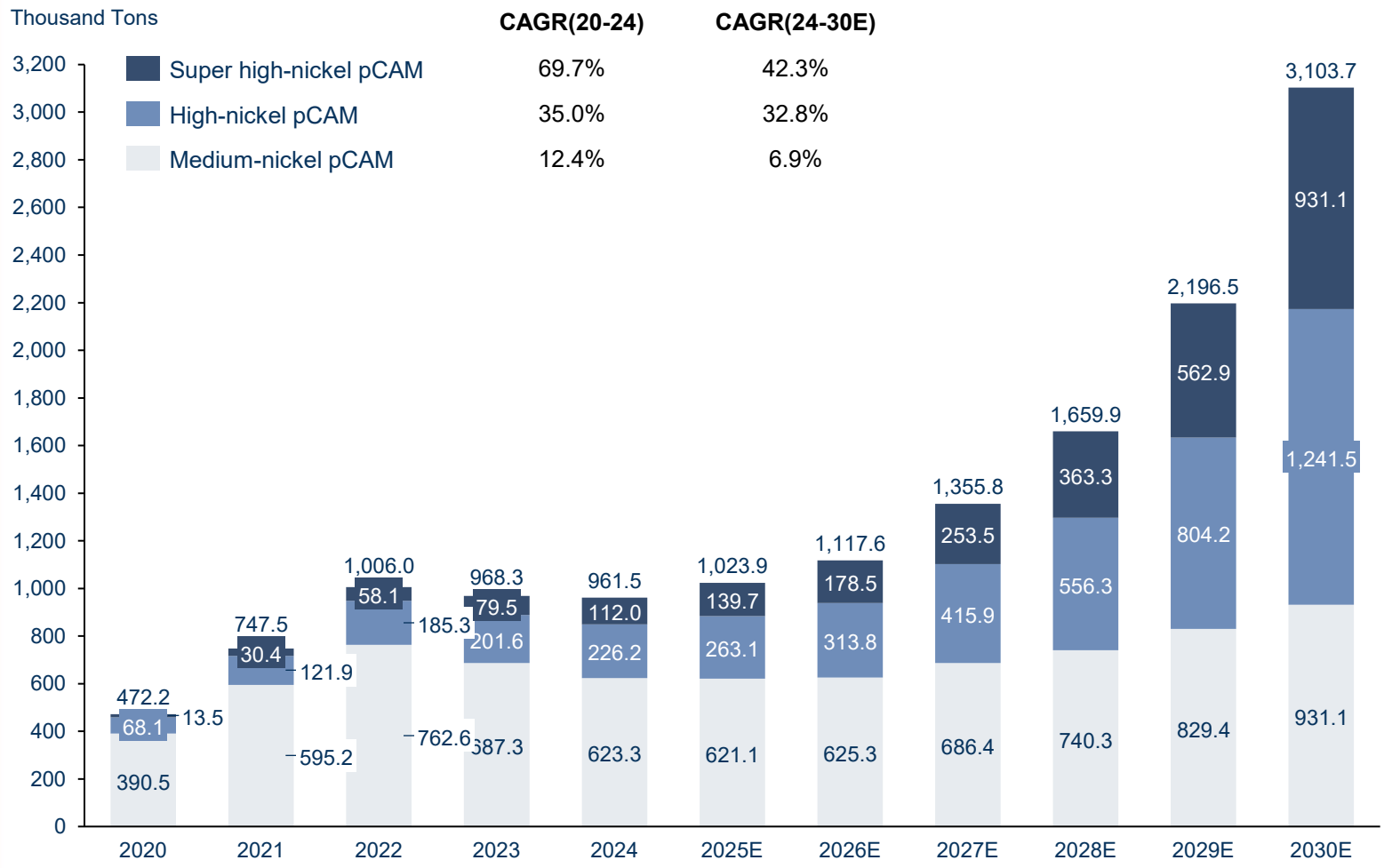
Source: Frost & Sullivan

Charts

Shipment Volume of Nickel-based pCAM by Product Type, Global



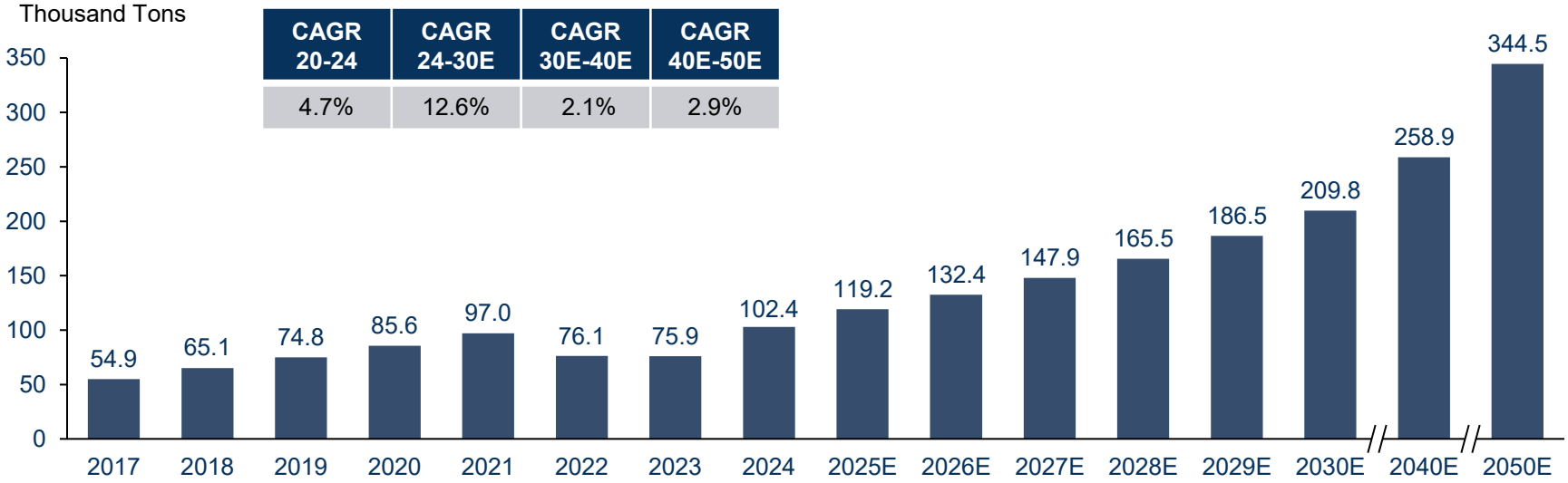
Chart


Thousand Tons
CAGR(20-24)
CAGR(24-30E)
Super high-nickel pCAM
69.7%
42.3%
High-nickel pCAM
35.0%
32.8%
Medium-nickel pCAM
12.4%
6.9%
3,200
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
2020
2021
2022
2023
2024
2025E
2026E
2027E
2028E
2029E
2030E
472.2
68.1
13.5
390.5
747.5
30.4
121.9
595.2
1,006.0
58.1
185.3
762.6
968.3
79.5
201.6
387.3
961.5
112.0
226.2
623.3
1,023.9
139.7
263.1
621.1
1,117.6
178.5
313.8
625.3
1,355.8
253.5
415.9
686.4
1,659.9
363.3
556.3
740.3
2,196.5
562.9
804.2
829.4
3,103.7
931.1
1,241.5
931.1

Analysis of Global Tricobalt Tetroxide Market

- Lithium cobalt oxide batteries, which are manufactured using tricobalt tetroxide as the precursor material, are primarily applied in the consumer electronics sector, including smartphones, tablets, and smart wearable devices.
- The shipment volume of tricobalt tetroxide has shown consistent growth over the years. From 2020 to 2024, the volume increased from 85.6 thousand tons to 102.4 thousand tons, with a CAGR of 4.7% from 2020 to 2024.
- The market is expected to continue growing, with projections indicating an increase to 209.8 thousand tons by 2030. The CAGR from 2024 to 2030 is estimated at 12.6%, suggesting a slightly slower but still robust growth rate. The consistent growth trend suggests that the market will likely continue to expand, driven by ongoing demand in various industries.
- The global tricobalt tetroxide market is characterized by steady and consistent growth. The increasing shipment volumes reflect sustained demand, likely driven by its applications in various industries such as electronics, batteries, and catalysis. The market is expected to continue expanding, albeit at a slightly slower rate in the near future, indicating a mature but still growing industry with ongoing opportunities for development and innovation.

Shipment Volume of Tricobalt Tetroxide, Global, 2017-2030E & 2040E & 2050E



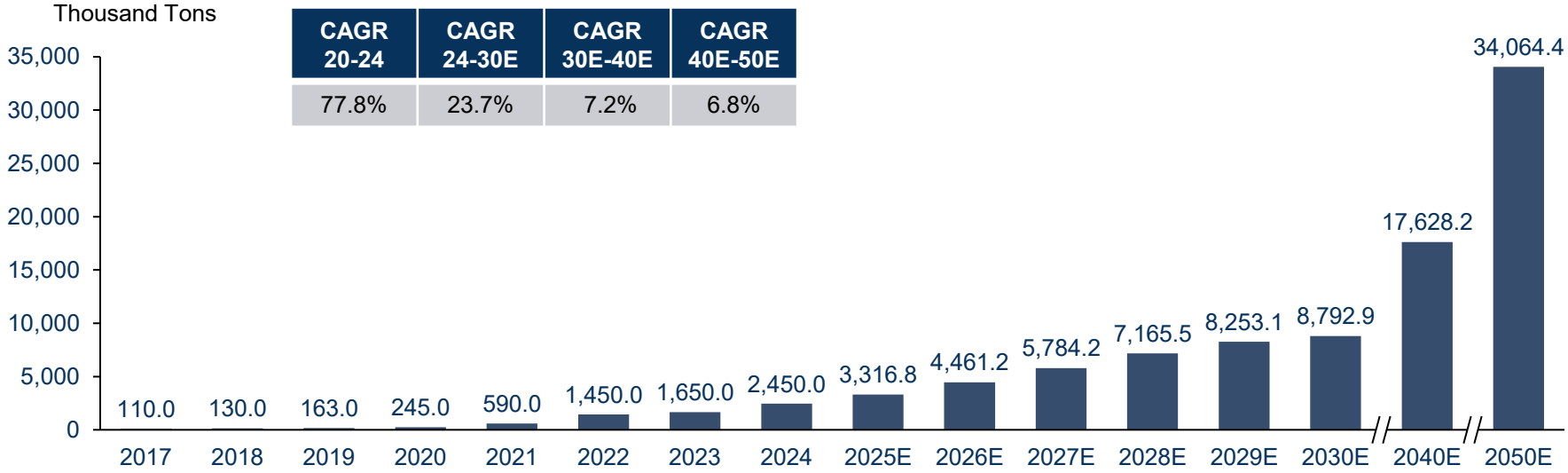
Source: Frost & Sullivan

Analysis of Global Phosphate-based CAM Market

- The primary downstream application of lithium iron phosphate is as a cathode material in lithium iron phosphate (LFP) batteries. With the develop of excellent safety and cost advantages of LFP batteries, their installed capacity in the power battery market is gradually increasing. Meanwhile, the rapid development of the energy storage industry has also created a huge demand space for lithium iron phosphate.

- Due to increased demand for LFP batteries, the global shipment volume of phosphorus-based CAM increased from 245.0 thousand tons in 2020 to 2,450.0 thousand tons in 2024 at a CAGR of 77.8%, which is expected to increase to 8,792.9 thousand tons in 2030 at a CAGR of 23.7% from 2024 to 2030.

Shipment Volume of Phosphate-based CAM, Global, 2017-2030E & 2040E & 2050E

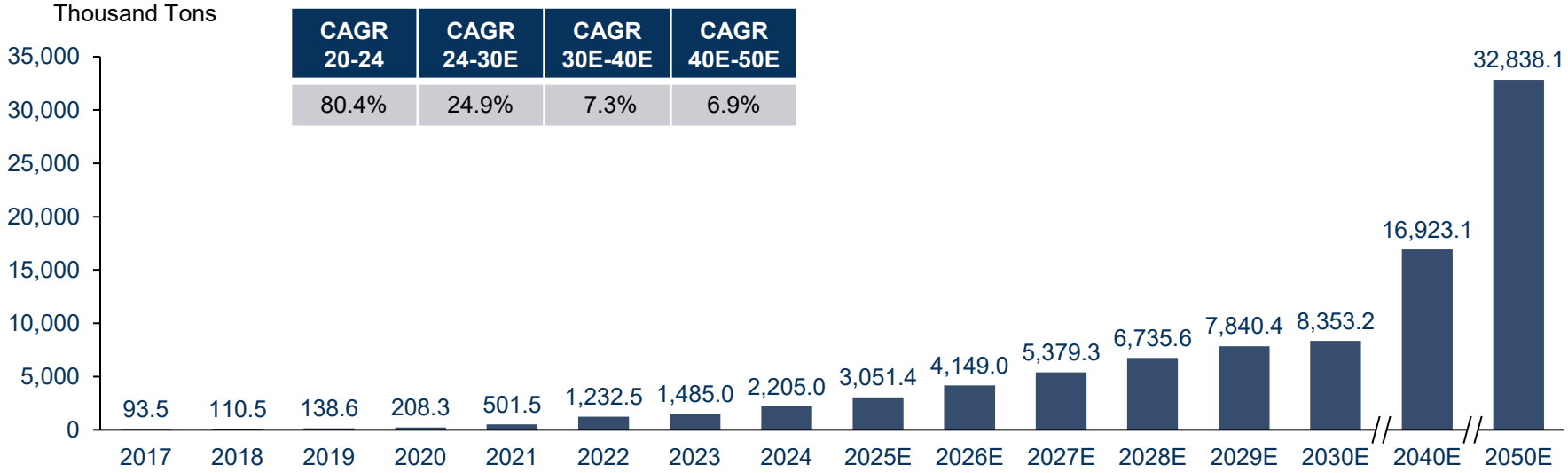


Source: Frost & Sullivan

Analysis of Global Phosphate-based pCAM Market

- The shipment volume of iron phosphate has shown significant growth, particularly from 2020 to 2024, with a CAGR of 80.4%. This indicates a rapidly expanding market during this period.
- Demand for phosphorus-based pCAM is typically proportional to that of phosphorus-based CAM, reflecting their near one-to-one volumetric conversion in the production process. The global shipment volume of phosphorus-based pCAM increased from 208.3 thousand tons in 2020 to 2,205.0 thousand tons in 2024 at a CAGR of 80.4%. The cost advantages of LFP batteries are further amplified. Technological breakthroughs and cost - efficiency benefits are driving the continuous increase in the shipment volume of phosphorus-based pCAM, which is expected to increase to 8,353.2 thousand tons in 2030 at a CAGR of 24.9% from 2024 to 2030.

Shipment Volume of Phosphate-based pCAM, Global, 2017-2030E & 2040E & 2050E



Source: Frost & Sullivan

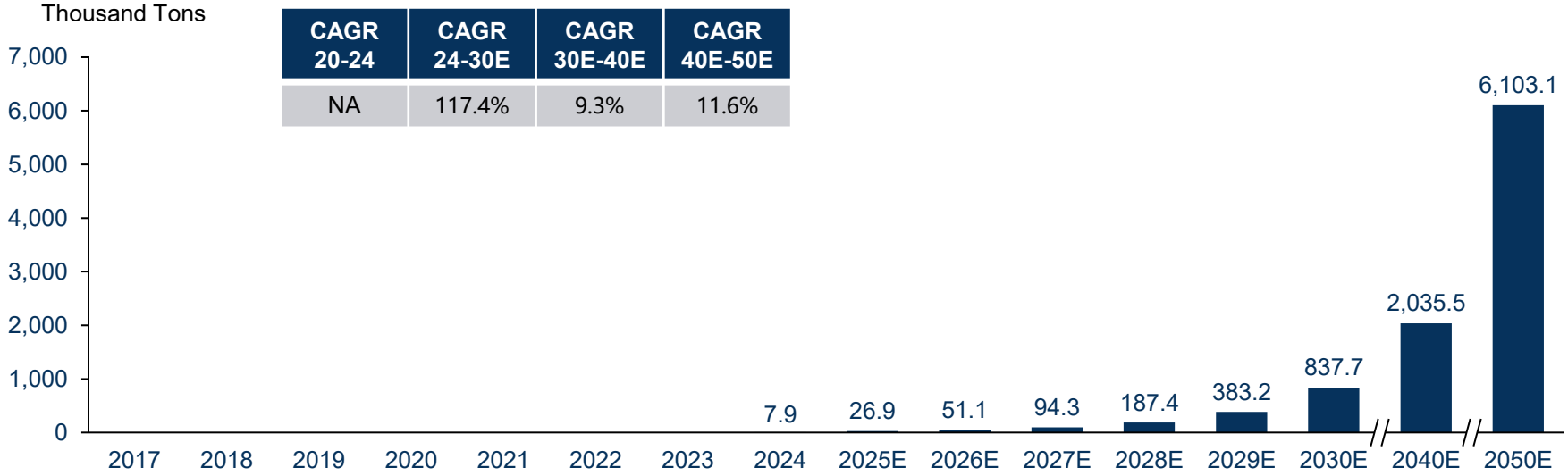
Analysis of Global Sodium-ion Cathode Materials Market

- As the cost advantages of sodium-ion batteries become more pronounced with the acceleration of industrialization, the demand for sodium-ion batteries in fields such as low-speed electric vehicles and grid-side energy storage will continue to increase. The growth in shipments of sodium-ion batteries will directly drive up the value of core materials, such as cathode materials.

- The global shipment volume of sodium-ion cathode materials has demonstrated significant growth, fueled by the rising demand for sustainable energy storage solutions and advancements in sodium-ion battery technology. In 2024, the total shipment volume increased to 7.9 thousand tons, reflecting a remarkable growth. By 2030, shipments are projected to reach 837.7 thousand tons, with a substantial CAGR of 117.4% from 2024 to 2030. It is expected to expand further to 2035.5 thousand tons by 2040 and 6103.1 thousand tons by 2050, representing a steady CAGR of 9.3% from 2030 to 2040 and a continued CAGR of 11.6% from 2040 to 2050.

- Looking ahead, the commercialization of sodium-ion batteries by 2030 is expected to bring significant benefits, including reduced reliance on scarce resources like lithium and cobalt, enhanced energy security, and lower costs for large-scale energy storage systems. This will not only support the global transition to renewable energy but also enable more affordable and accessible energy solutions for emerging markets, driving economic growth and sustainability worldwide.

Shipment Volume of Sodium-ion Cathode Materials, Global, 2017-2030E & 2040E & 2050E



Source: Frost & Sullivan

Drivers of Global New Energy Materials Market (1/2)

Market Drivers	Description
Sustained Growth in Major Downstream Applications	• The continued expansion of core sectors such as NEVs, energy storage, and 3C consumer electronics is driving sustained battery demand. The increasing penetration of AI technologies in applications like autonomous driving and edge computing further accelerates battery consumption. Additionally, the rapid growth of data centers driven by AI development has led to a surge in energy storage demand. In the 3C sector, advancements in 5G/6G networks and AR/VR devices have heightened reliance on high-energy-density batteries, accelerating material innovation and boosting both the demand and performance requirements for batteries and new energy materials.
Emerging Applications Driving High-Performance Material Demand	• Innovative sectors such as eVTOL, humanoid robots, and AI-powered wearable devices present significant growth potential. These applications demand extremely high energy density and discharge rates from batteries. High-performance battery technologies, such as high-nickel ternary and solid-state batteries, are expected to experience substantial demand growth, further accelerating the development of advanced new energy materials.
AI for Science Accelerating Industry Efficiency	• AI is enhancing efficiency across the entire value chain of the new energy materials industry, from R&D and production to deployment. AI enables predictive analysis of material properties, significantly accelerating the research and development process. In manufacturing, digital twin technology optimizes production processes, while AI-driven intelligent control improves production yield rates. Additionally, AI-powered predictive modeling enhances battery lifespan and safety assessments, extending operational cycles and indirectly driving advancements in material technologies.
Policy Synergy Driving Industry Upgrades	• The transformation of the new energy materials industry, alongside the broader transition to renewable energy and smart industries, continues to receive strong policy support from major global economies. For instance, China has extended NEV purchase tax exemptions to accelerate the industry's growth, while the EU's "Green Deal" mandates a ban on internal combustion engine vehicle sales by 2035. The U.S. Department of Energy (DOE) has allocated $250 million to support solid-state battery research. Global policy trends favor high-performance materials such as high-nickel ternary cathodes and silicon-carbon anodes while reinforcing circular economy initiatives. Additionally, regulatory frameworks are evolving to support emerging industries, fostering an integrated ecosystem encompassing R&D, production, and application, thereby forming a comprehensive industrial value chain.

Source: Frost & Sullivan

Drivers of Global New Energy Materials Market (2/2)

Market Drivers	Description
Global Energy Transition	• The global energy transition, driven by the shift from fossil fuels to renewable sources like solar and wind, is accelerating the demand for new energy batteries, and thus the demand for new energy battery materials. As countries aim for carbon neutrality and greater energy security, new energy batteries play a crucial role in stabilizing power grids, enabling energy storage, and supporting the widespread adoption of electric vehicles. This growing demand is reshaping industries, driving investments in battery production and raw material supply chains, and positioning energy storage as a cornerstone of the future energy system.

Source: Frost & Sullivan

Development Trends of Global New Energy Materials Market

Development Trends	Description
Growing Demand for Vertical Integration	• Securing upstream resources such as nickel, phosphate, cobalt and lithium, has become a key competitive advantage. Increasing geopolitical concerns and supply chain disruptions have intensified resource localization efforts. Leading firms are investing in mining assets or securing long-term supply agreements to ensure cost stability and raw material security, improving overall efficiency from resource extraction to material production.
Accelerated Technological Iteration	• AI is transforming materials research by enhancing screening processes and simulating electrochemical properties, significantly shortening development cycles. Advanced materials like high-nickel chemistries, solid-state batteries, and silicon-based anodes are evolving to meet higher energy density and safety demands. Additionally, AI-driven intelligent manufacturing optimizes production parameters and improves yield rates, driving the industry toward more efficient and precise material innovation.
Increasing Market Consolidation	• The new energy materials and battery industries are both experiencing strong consolidation, with large-scale players expanding their market share due to superior cost control, production efficiency, and R&D capabilities. Small and mid-sized companies face increasing barriers in technology and scale. Government policies further strengthen the market position of industry leaders, driving the sector toward higher concentration.
Closer Collaboration with Customers	• Partnerships between new materials material producers, battery manufacturers, and automakers are becoming more integrated, with a focus on co-developing customized material solutions. Demand for high-nickel, low-cobalt, and lithium manganese iron phosphate chemistries is shaping product roadmaps. Long-term supply contracts, closed-loop recycling systems, and joint R&D initiatives enhance supply chain resilience and product consistency, supporting global expansion and regulatory compliance.

Source: Frost & Sullivan

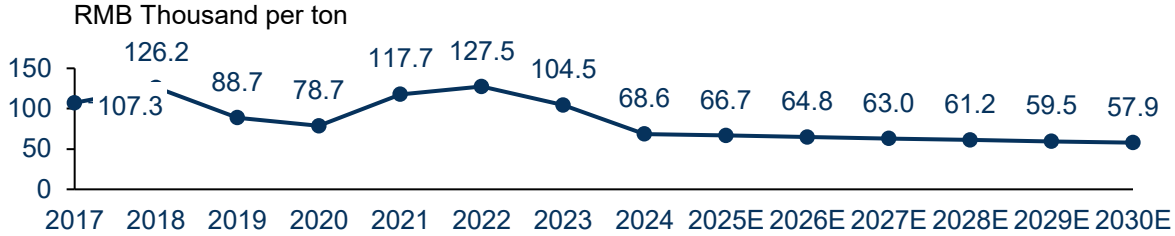
Key Success Factors of Global New Energy Materials Market

KSF	Description
Vertical Integration Capability	• In the new energy materials industry, strong vertical integration enhances cost efficiency, supply chain stability, and product consistency. Companies with upstream control over raw material procurement (such as lithium, nickel, and cobalt) and downstream partnerships with battery manufacturers can better manage price volatility and ensure high-quality material production. Integrated production from raw material refining to final product manufacturing streamlines operations, improves profitability, and enhances competitiveness in a rapidly evolving market.
Technological R&D Strength	• Innovation in material composition, structural design, and process optimization is critical for improving battery performance, including energy density, lifespan, and safety. Companies investing heavily in R&D—leveraging AI-driven material discovery, advanced synthesis techniques, and next-generation technologies—can secure a technological edge. Strong intellectual property (IP) portfolios and collaborations with research institutions further drive advancements, enabling firms to meet evolving performance demands across EVs, energy storage, and consumer electronics applications.
Industrialization Efficiency	• The ability to rapidly scale production while maintaining high product consistency and cost efficiency is a major success factor. Companies with advanced manufacturing automation, high-yield synthesis processes, and stringent quality control systems can achieve economies of scale. AI and digital twin technologies enhance process efficiency, reduce waste, and optimize material properties. Shorter time-to-market for next-generation materials ensures a competitive advantage in the fast-growing battery industry.
Globalization Strategy	• The new energy materials market is increasingly global, requiring strong localization strategies and supply chain resilience. Leading players establish production bases near key markets to comply with trade policies and secure customer proximity. Strategic partnerships with global battery manufacturers and automakers enhance market penetration. Securing stable sources of critical minerals through international investments further strengthens long-term competitiveness in a geopolitically sensitive supply chain landscape.

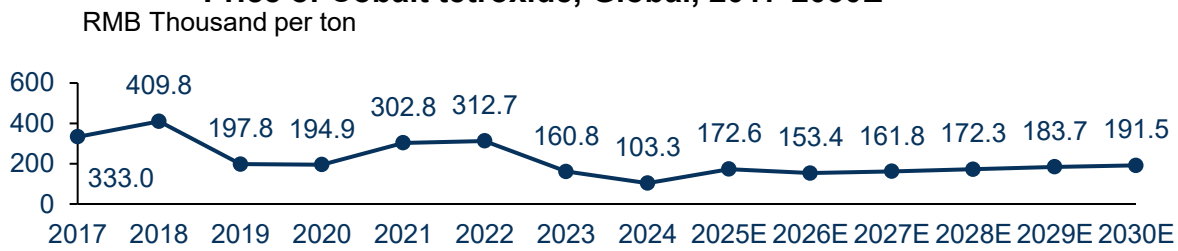
Source: Frost & Sullivan

Price Analysis of Global New Energy Materials Market

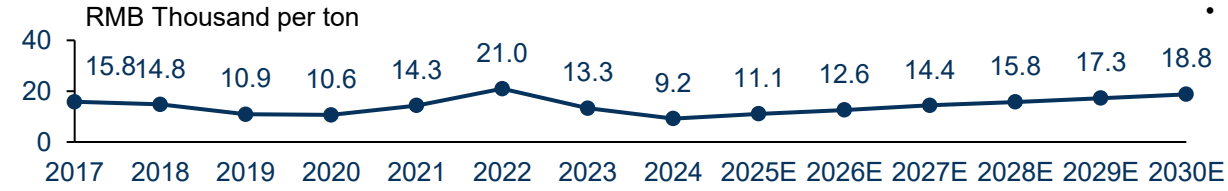
Price of Ternary Precursors, Global, 2017-2030E



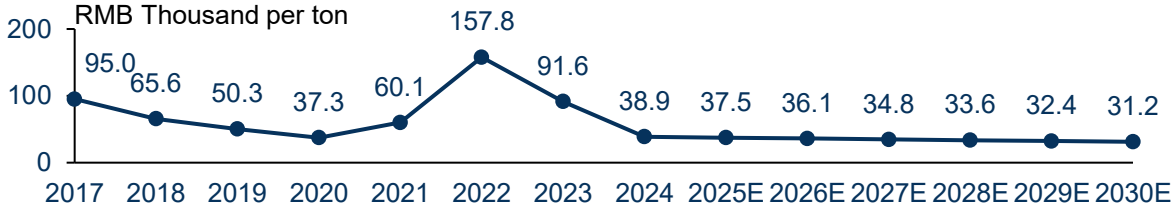
Price of Cobalt tetroxide, Global, 2017-2030E



Price of Iron phosphate, Global, 2017-2030E



Price of Lithium iron phosphate, Global, 2017-2030E

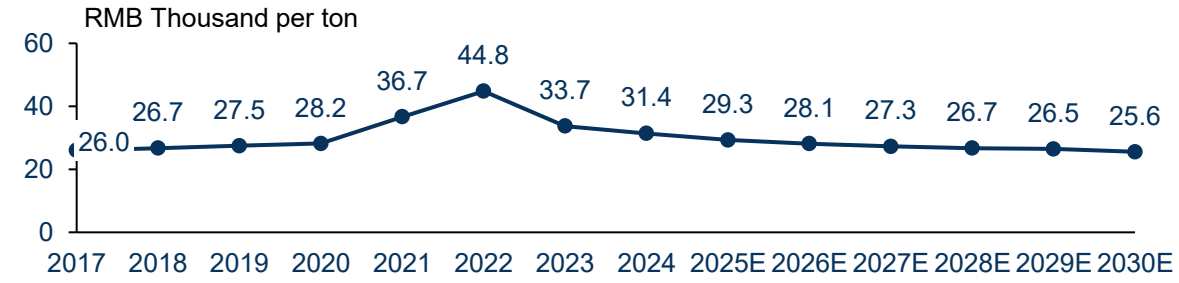


- The price of ternary precursors exhibited fluctuations from 2017 to 2024, starting at RMB 107.3 thousand per ton in 2017, peaking at RMB127.5 thousand per ton in 2022, and declining to RMB 68.6 thousand per ton by 2024. From 2025 to 2030, the price is projected to continue decreasing steadily, reaching RMB 57.9 thousand per ton by 2030.
- The price fluctuated significantly from 2017 to 2024, starting at RMB 333.0 thousand per ton in 2017, peaking at RMB 409.8 thousand per ton in 2018. From 2025 to 2030, the price is projected to increase slightly, from RMB 172.6 to RMB 191.5 thousand per ton.
- The price of lithium iron phosphate fluctuated between 2017 and 2024, starting at RMB 15.8 thousand per ton in 2017, peaking at RMB 21.0 thousand per ton in 2021, and declining to RMB9.2 thousand per ton by 2024. From 2025 to 2030, the price is projected to increase steadily.
- The price of lithium iron phosphate fluctuated between 2017 and 2024, starting at RMB17.9 thousand per ton in 2017, peaking in 2021, and declining to RMB 10.4 thousand per ton by 2024.

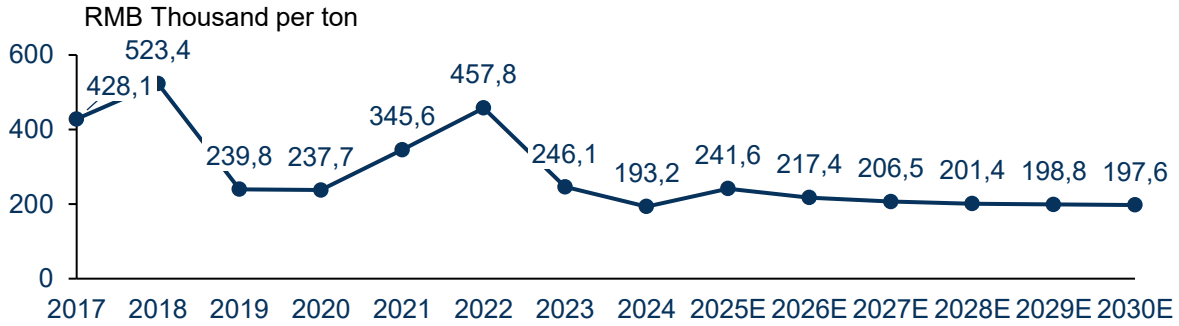
Source: Frost & Sullivan

Raw Material Analysis of Global New Energy Materials Market

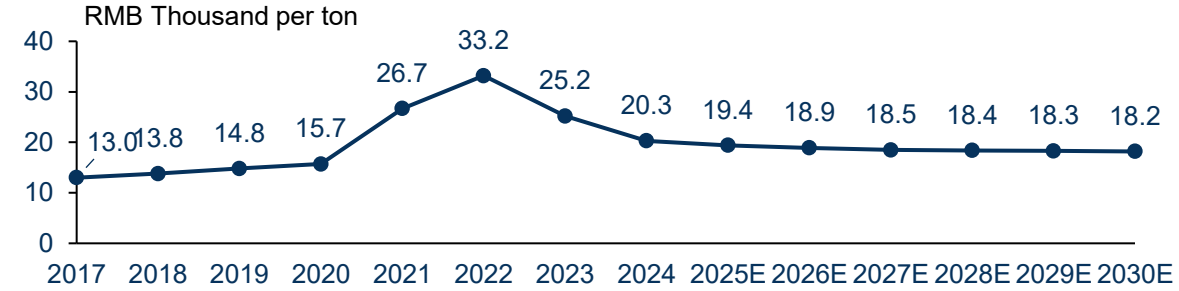
Price of Nickel Sulfate, Global, 2017-2030E



Price of Cobalt, Global, 2017-2030E



Price of White Phosphorus, Global, 2017-2030E



- The price trend of nickel sulfate from 2017 to 2030 demonstrates a pattern of initial gradual increase followed by a significant rise and subsequent decline. and this downward trend is projected to continue, with prices expected to decrease further to RMB 25.57 thousand per ton by 2030.
- The price trend of cobalt from 2017 to 2030 shows significant fluctuations, with an initial rise to RMB523.4 thousand per ton in 2018, followed by a sharp drop in 2018. Prices then rebounded, peaking in 2022, before declining to RMB193.2 thousand per ton in 2024.Due to factors such as the Democratic Republic of the Congo's ban on cobalt exports, global cobalt prices are expected to rise in the first half of 2025 before gradually declining to normal levels.
- The price trend from 2017 to 2030 shows an initial gradual increase, followed by a sharp rise and a subsequent decline. A significant surge occurred in 2021 and 2022. However, a downward trend began in 2023, reducing the price to RMB 25.20 thousand per ton, and this decline is expected to continue, with prices projected to stabilize around RMB18.20 thousand per ton by 2030.

Source: Frost & Sullivan

Market Opportunities of Global New Energy Materials Market

Market Opportunities	Description
Expanding Demand in Applications	• Global demand for new energy materials is expanding across a broad range of applications beyond electric vehicles. Growing sectors such as renewable energy, energy storage, and advanced consumer electronics are driving the need for high-performance battery materials. This diverse demand is pushing manufacturers to continually innovate and improve battery performance, efficiency, and safety. Furthermore, emerging trends in smart devices and industrial automation are broadening the scope of potential applications.
Prospects for Emerging Battery Technologies	• The evolution of battery technologies, particularly in solid-state and sodium-ion systems, presents significant opportunities for the new energy materials industry. Solid-state batteries offer enhanced safety and energy density compared to traditional lithium-ion systems, while sodium-ion batteries, benefiting from abundant and cost-effective raw materials, emerge as a promising alternative. Ongoing advancements in material synthesis and process optimization are rapidly transforming these technologies. This dynamic shift is expected to drive increased demand for innovative, high-performance materials that meet rigorous standards.
Comprehensive Global Policy Support	• Government initiatives and supportive regulatory frameworks are fueling the growth of the new energy materials industry on a global scale. By fostering a favorable policy environment, governments are encouraging collaboration between public and private sectors, which, in turn, accelerates the commercialization of advanced battery materials. This comprehensive support is creating significant market opportunities and strengthening the industry's long-term growth prospects.
Enhanced Customer Collaboration and Ecosystem Integration	• Closer collaboration between new energy material suppliers, battery manufacturers, and end users is emerging as a critical trend in the industry. Such partnerships facilitate the customization of material solutions to meet specific performance and sustainability requirements, driving innovation along the entire supply chain. Long-term agreements, joint R&D projects, and integrated production strategies are becoming more prevalent, aligning product development with market needs. This collaborative approach not only improves supply chain stability and product consistency but also fosters an integrated ecosystem that can quickly adapt to evolving technological and regulatory landscapes, thereby enhancing overall competitiveness.

Source: Frost & Sullivan

2. Analysis of Global Energy Matels Market

Overview of Global Energy Matels Market

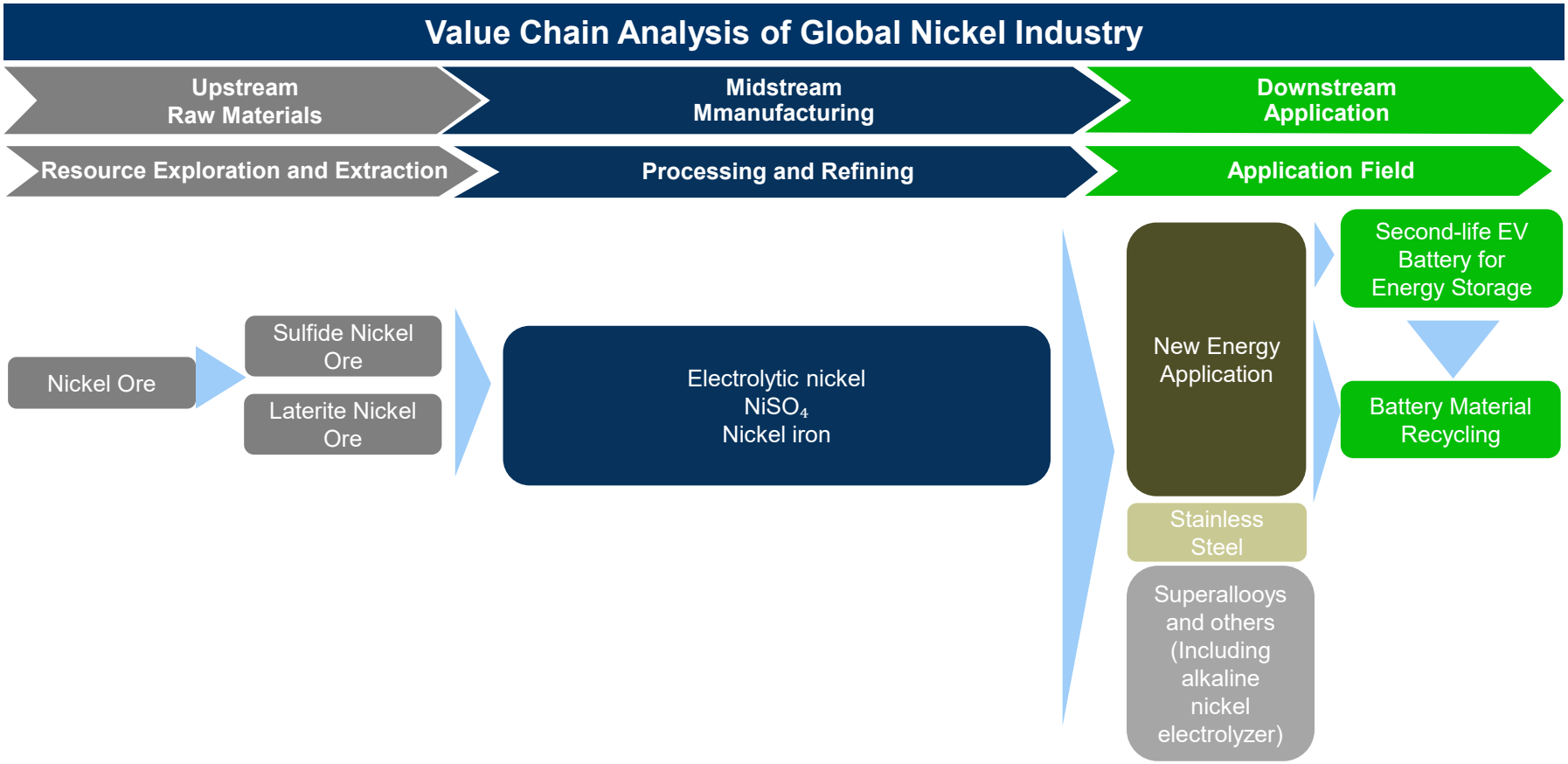
- Energy metals are a group of metallic elements that play a critical role in enabling and advancing modern energy technologies. These metals are essential components in renewable energy systems, energy storage solutions, and electric vehicles (EVs). They include lithium, nickel, cobalt, manganese, vanadium, and rare earth metals like neodymium and dysprosium. Energy metals are characterized by their unique electrochemical, magnetic, and conductive properties, which make them indispensable for technologies such as lithium-ion batteries, wind turbines, solar panels, and hydrogen storage systems.
- Among energy metals, battery metals are the most important category due to their central role in powering the electrification revolution. Metals like lithium, nickel, cobalt, and manganese are key ingredients in lithium-ion batteries, which are the backbone of EVs, portable electronics, and grid-scale energy storage systems. Lithium, in particular, is irreplaceable for its high energy density and lightweight properties, while nickel enhances battery performance and energy capacity. The growing demand for EVs and renewable energy storage has made battery metals a cornerstone of the global energy transition. Their importance is further underscored by the fact that advancements in battery technology directly impact the efficiency, cost, and adoption of clean energy solutions, making battery metals the most critical subset of energy metals.

Battery Metals	Properties	Applications
Lithium	• Lightweight • High electrochemical activity	• Cathode materials: Lithium iron phosphate (LFP), ternary materials (NCM/NCA) • Lectrolyte: Lithium hexafluorophosphate ($LiPF_6$)
Nickel	• High energy density • Excellent electrochemical stability	• Cathode materials: Key component in ternary materials (NCM/NCA)
Cobalt	• High stability • Prevents battery overheating	• Cathode materials: Important component in ternary materials (NCM/NCA)

Source: Frost & Sullivan

Value Chain of Global Nickel Industry

- The upstream segment involves the extraction and mining of raw materials. Nickel is extracted from sulfide ores and laterite ores through smelting or acid leaching. This stage is highly resource-intensive and geographically concentrated, making it vulnerable to supply disruptions. The midstream segment focuses on processing and refining raw materials into usable forms, when nickel is refined into nickel sulfate for batteries or electrolytic nickel for stainless steel and alkaline nickel electrolyzer. This stage requires advanced technologies to ensure high purity and efficiency, with ongoing innovations reducing costs and environmental impact. The downstream segment involves the manufacturing and application of energy metals in end products. Nickel is a key component of ternary CAM (NCM/NCA) in high-energy-density batteries and is also used in stainless steel production.

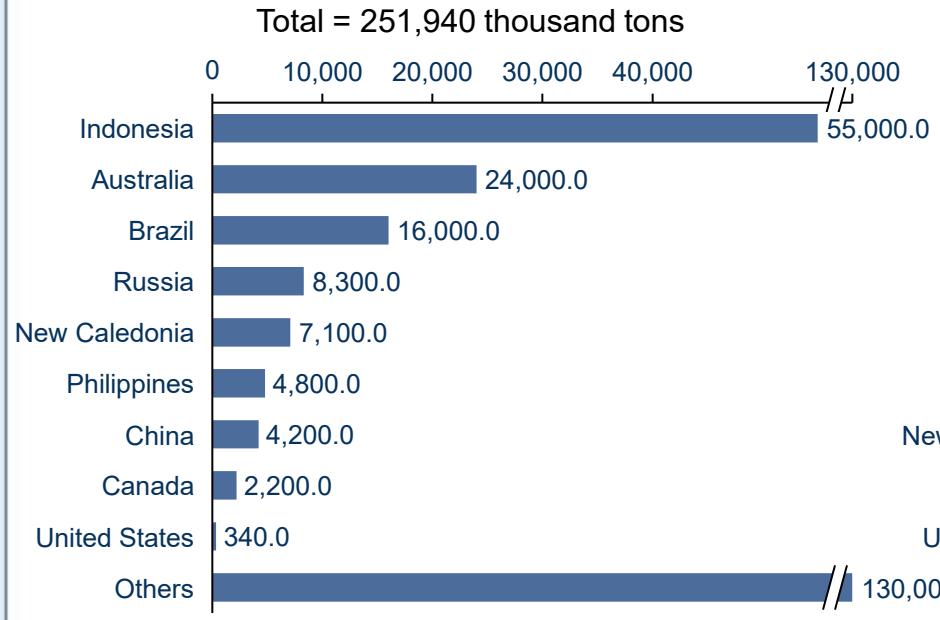


Source: Frost & Sullivan

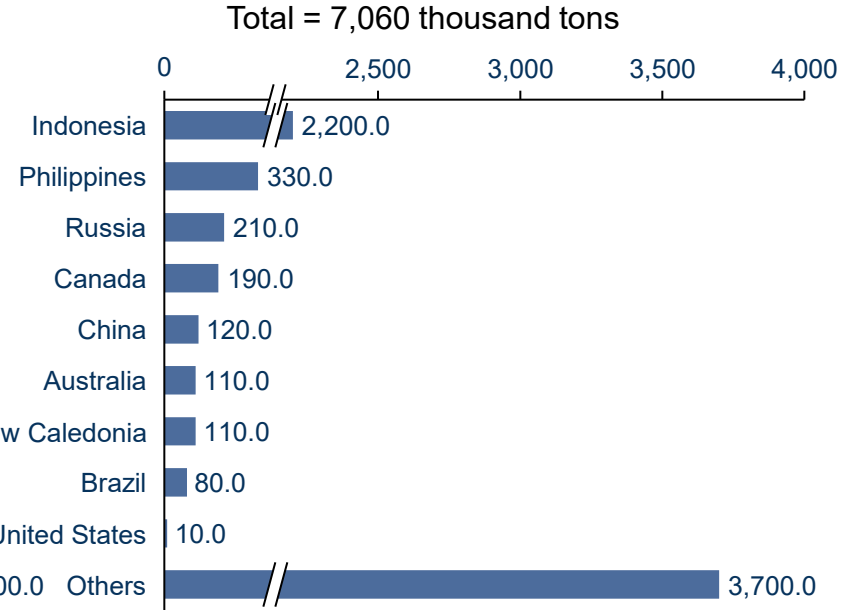
Mine Reserve and Production of Energy Metals (1/3)

- n 2024, global nickel production is led by Indonesia (220 thousand tons), followed by Russia (21 thousand tons) and the Philippines (33 thousand tons). Australia (11 thousand tons), New Caledonia (11 thousand tons), and Brazil (8 thousand tons) also contribute significantly. China (12 thousand tons) and Canada (19 thousand tons) play moderate roles, while the United States (1 thousand tons) has minimal production. This distribution highlights the growing importance of Southeast Asia and traditional mining regions in the nickel supply chain.
- The global nickel reserves are dominated by Indonesia (5,500 thousand tons), which holds the largest share, followed by Australia (2,400 thousand tons) and Brazil (1,600 thousand tons). Russia (830 thousand tons), New Caledonia (710 thousand tons), and the Philippines (480 thousand tons) also possess substantial reserves. China (420 thousand tons) and Canada (220 thousand tons) have smaller but notable reserves, while the United States (34 thousand tons) has limited resources.

Global Nickel Reserve, by Country, 2024



Global Nickel Production, by Country, 2024



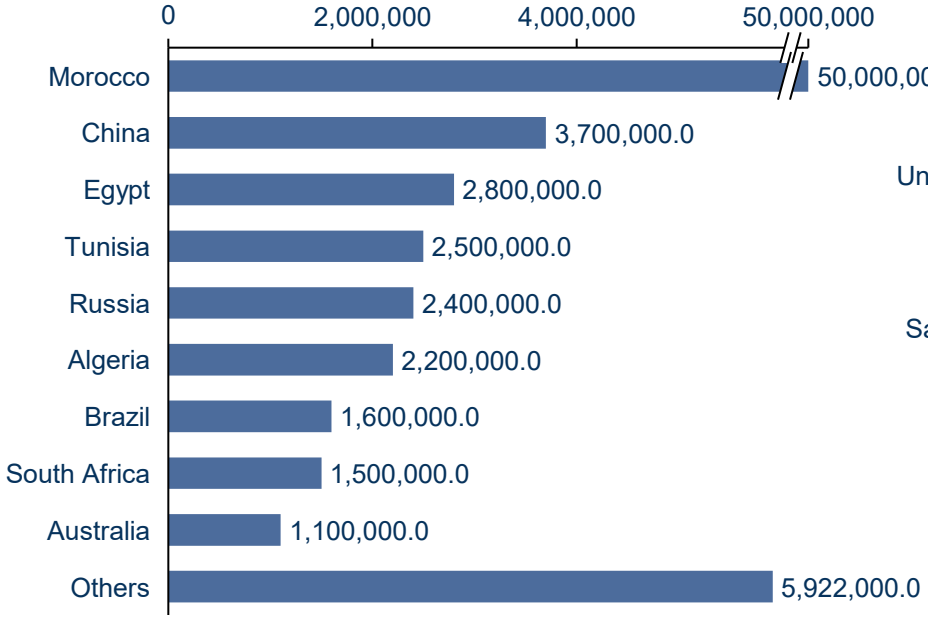
Source: USGS, Frost & Sullivan

Mine Reserve and Production of Energy Metals (2/3)

- In 2024, global phosphate rock production is dominated by China (11,000 thousand tons), followed by Morocco (3,000 thousand tons) and the United States (2,000 thousand tons). Russia (1,400 thousand tons), Jordan (1,200 thousand tons), and Saudi Arabia (950 thousand tons) are also significant producers.
- The global phosphate reserves are overwhelmingly concentrated in Morocco (5,000,000 thousand tons), which holds the largest share by far. China (370,000 thousand tons), Egypt (280,000 thousand tons), and Tunisia (250,000 thousand tons) also possess substantial reserves. Other notable reserves are found in Russia (240,000 thousand tons), Algeria (220,000 thousand tons), and Brazil (160,000 thousand tons). While countries like the United States (100,000 thousand tons) and Jordan (100,000 thousand tons) have smaller reserves, their strategic importance remains significant. This uneven distribution underscores the geopolitical and economic importance of phosphate as a critical resource for global food security.

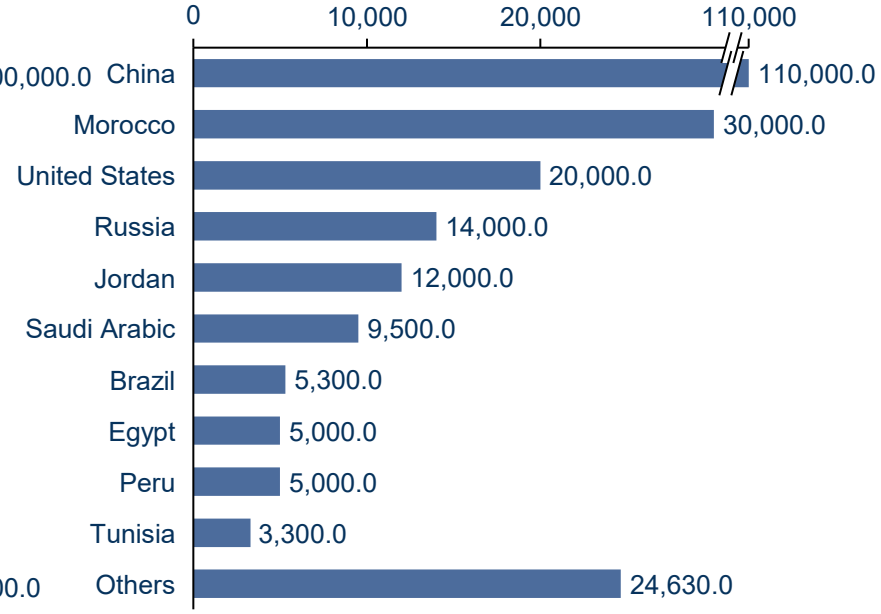
Global Phosphorus Reserve, by Country, 2024

Total = 74,000,000 thousand tons



Global Phosphorus Production, by Country, 2024

Total = 240,000 thousand tons



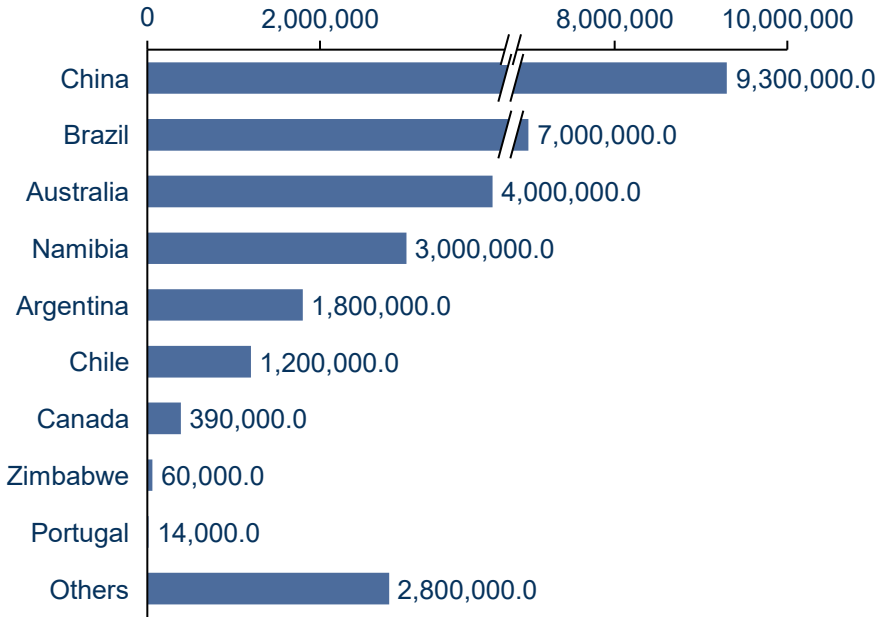
Source: USGS, Frost & Sullivan

Mine Reserve and Production of Energy Metals (3/3)

- In 2024, global lithium production is led by Australia (8,800 thousand tons), Chile (4,900 thousand tons), and China (4,100 thousand tons), which dominate the market. Zimbabwe (2,200 thousand tons), Argentina (1,800 thousand tons), and Brazil (1,000 thousand tons) are also key contributors.
- Lithium reserves are heavily concentrated in China (930,000 thousand tons) and Brazil (700,000 thousand tons), which hold the largest untapped resources. Australia (400,000 thousand tons), Argentina (180,000 thousand tons), and Namibia (300,000 thousand tons) also have significant reserves. Despite high production, Chile (120,000 thousand tons) and Zimbabwe (6,000 thousand tons) have limited reserves, indicating potential future constraints. This disparity underscores the need for increased exploration and investment to meet rising demand.

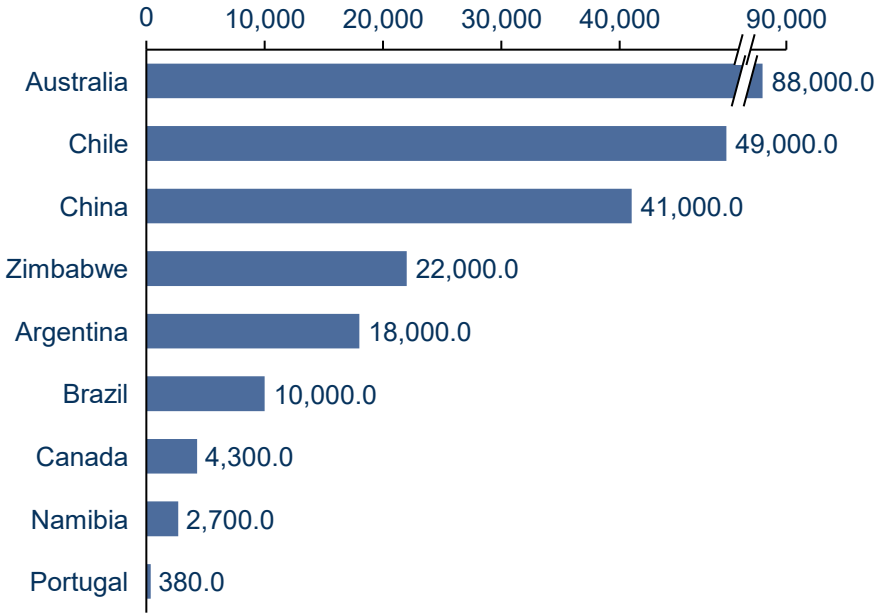
Global Lithium Reserve, by Country, 2024

Total = 30,000,000 thousand tons



Global Lithium Production, by Country, 2024

Total = 240,000 thousand tons



Source: USGS, Frost & Sullivan

Overview of Nickel Products

- Nickel is primarily used in stainless steel, NEV, electroplating and other applications. Nickel can be found in two main ore types – sulphide ores and laterite ores. The nickel content of laterite ores is usually around 0.1%–3%, while that of sulphide ores typically varies from 1% to 2%, depending on the ore quality.
- Nickel is a group VIII metal element with the symbol Ni and atomic number 28. In terms of its physical properties, nickel occurs as a silver-white shiny ferromagnetic solid at room temperature. Nickel also has a relatively high hardness and brittleness. Its tensile strength, machinability, thermodynamic properties, as well as electrochemical behavior is similar to Iron. As for its chemical properties, nickel normally exhibits a +2 oxidation state in its compound. The oxidation of nickel occurs at normal temperature, and it can be oxidized to NiO in the air and form a dense layer that can protect metal inside against corrosion from water vapor and acids.

Nickel Product Classification

Classification	Category	Product Name	Chemical Formula	Downstream Application
Primary Nickel	Class I	Electrolytic Nickel	Ni	Alloys, Ferronickel, Nickel Sulphate
		Nickel Powder	Ni	
		Nickel Briquettes	Ni	
	Class II	Ferronickel	$FeNi$	Stainless Steel, Nickel Sulphate
		Nickel Pig Iron	$FeNi$	
	Nickel Sulphate	Nickel Sulphate	$NiSO_4$	Ternary Material, Electroplating

Source: Frost & Sullivan

Production of Nickel Products

- Nickel's end-market demand is primarily driven by stainless steel production, which accounted for around 65 % of the total nickel product market in 2024, where it enhances strength and corrosion resistance in construction, appliances, and industrial applications. The new energy application, which accounted for around 15% of the total nickel product market in 2024, is the fastest-growing segment, fueled by the rise of EV and ESS, as high-nickel ternary batteries improve energy density. Superalloys, which accounted for around 15% in 2024 for power generation, aerospace and medical industries. In addition, a smaller amount is used in plating and coating, where it provides durability in automotive, marine, and industrial applications, and foundry and casting, along with electronics, catalysts, and currency. In 2040 and 2050, the production of nickel products is expected to further increase to 8,119.8 thousand tons and 10,273.0 thousand tons respectively.

Production Volume of Nickel Products by End Market, Global, 2020-2030E

Unit: Thousand Tons	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	CAGR 20-24	CAGR 24-30E
Stainless Steel	1,754.6	1,801.4	2,071.0	2,227.3	2,281.8	2,317.3	2,379.8	2,443.5	2,500.0	2,564.0	2,628.6	6.8%	2.4%
Battery	74.7	151.3	263.2	383.0	545.0	620.3	788.5	963.5	1,125.6	1,324.2	1,524.2	64.3%	18.7%
Superalloys	73.9	149.7	253.3	386.9	509.8	583.2	727.4	856.3	978.0	1,116.5	1,245.2	62.1%	16.0%
Others	586.8	505.6	472.5	362.8	179.4	128.1	106.3	89.8	116.7	115.6	103.1	-25.6%	-8.8%
Total	**2,490.0**	**2,608.0**	**3,060.0**	**3,360.0**	**3,516.0**	**3,649.0**	**4,001.9**	**4,353.1**	**4,720.3**	**5,120.3**	**5,501.1**	**9.0%**	**7.7%**

Source: Frost & Sullivan

Drivers of Global Energy Matels Market

Market Drivers	Description
Diversified Resource Development	• The energy metal industry relies heavily on supply chain stability. However, the scarcity and concentration of upstream resources, such as cobalt from the Democratic Republic of Congo, pose risks of supply disruptions and price volatility. To mitigate these risks, Chinese companies are expanding their resource bases through overseas mergers and acquisitions, particularly in Africa and South America. They are also enhancing recycling technologies to reduce dependence on primary minerals. Additionally, China's Belt and Road Initiative is fostering cooperation with resource-rich countries to ensure a stable supply of raw materials.
Growth in New Energy Demand	• The global push for carbon neutrality is driving a shift towards clean energy sources like wind and solar, increasing demand for energy metals. The new energy vehicle (NEV) sector is also booming, with electric vehicles (EVs) becoming a key direction for future transportation. The rising sales of NEVs have led to explosive growth in demand for lithium, cobalt, and nickel, essential components of lithium-ion batteries. This trend is a core driver of the energy metal industry's rapid development.
Technological Innovation	• Technological advancements are transforming the energy metal industry. Improved exploration and mining technologies are enhancing resource development efficiency and reducing environmental impact. Advances in waste battery recycling are increasing resource recycling rates and supply chain stability. Meanwhile, the growth of new energy vehicles and energy storage is driving demand for high-performance metals, prompting companies to invest more in R&D to meet market needs for higher energy density and safer battery materials.
Policy Support	• Governments around the world are rolling out policies to support the development of the new energy industry. In the downstream application sector, such as new energy vehicles (NEVs), China has extended and optimized its tax exemption policy on vehicle purchases. On the resource development side, China has issued relevant policies which require mining companies to achieve coordinated development in resource utilization, ecological restoration, and environmental governance during the extraction process.

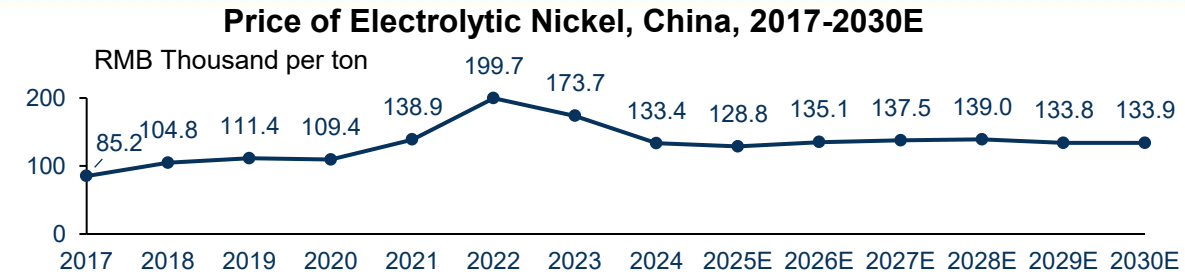
Source: Frost & Sullivan

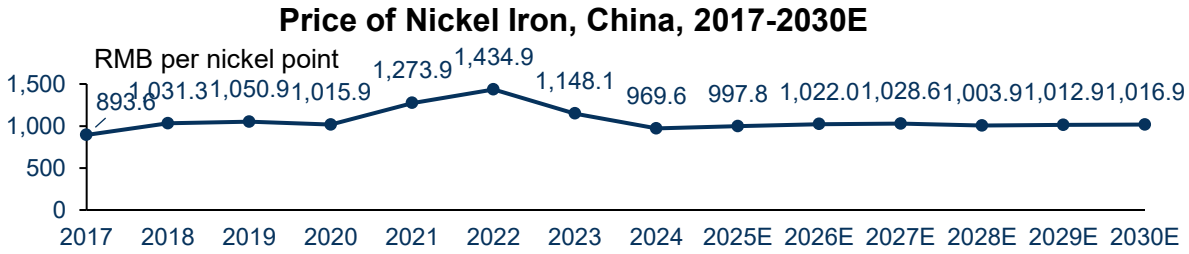
Development Trends of Global Energy Matels Market

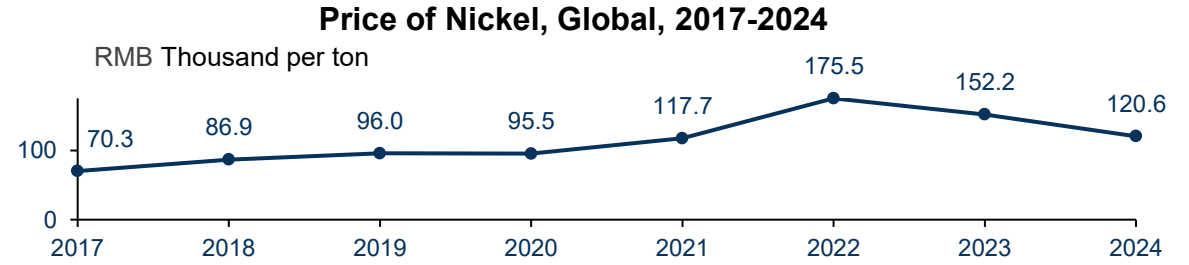
Development Trends	Description
Accelerated Vertical Integration of the Industrial Chain	• To address the uncertainty of resource supply and enhance competitiveness, energy metal companies are accelerating vertical integration of the industrial chain through acquisitions and other means. A full-industry-chain layout, from upstream resource extraction to downstream material processing, enables companies to secure stable and low-cost raw materials. This allows them to better control costs, ensure supply, and gain greater pricing power over end-users, thereby strengthening their competitiveness in the global market.
Expansion of Recycling and Utilization	• With the increasing awareness of environmental protection and technological progress, the importance of recycling and utilizing energy metals has become more prominent. By improving the recycling rate of waste batteries and other metal-containing waste materials, companies can not only reduce their dependence on primary mineral resources but also effectively enhance the stability and sustainability of their supply chains, while minimizing environmental impact.
Increasing demand of cobalt and nickel related products	• The favorable government policies on NEVs coupled with the global roll-out of 5G networks and increasing popularity of NEVs and smart wearable devices have greatly stimulated and will continue to stimulate the domestic demand and supply of NEVs and consumer electronics, which will also drive up the market demand for power batteries and consumer electronics batteries, and ultimately, its raw materials including cobalt and nickel related products.
Green and Low-Carbon Development	• Amid the global green transition, the energy metal industry is accelerating its shift towards greener and low-carbon practices. Companies need to enhance the construction of environmental protection facilities and the application of green mining technologies to meet increasingly stringent environmental standards. Meanwhile, policy support and technological innovation are driving the sustainable development of the energy metal industry, enabling it to play a more significant role in the low-carbon economy.

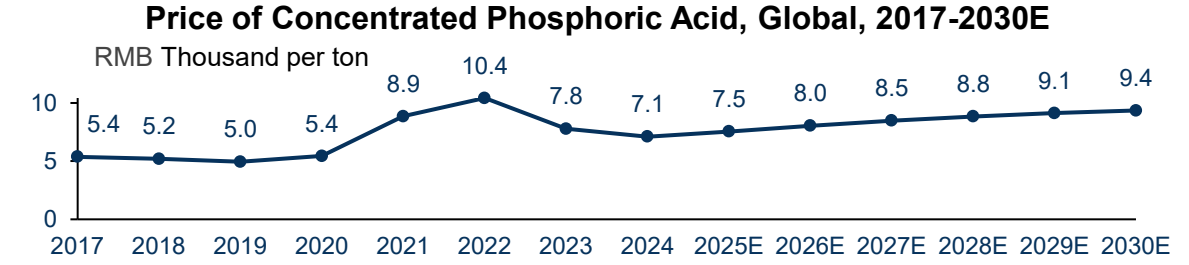
Source: Frost & Sullivan

Raw Material Analysis of Global New Energy Materials Market









- Between 2017 and 2022, the price of electrolytic nickel in China rose from RMB 85.2 thousand per ton to RMB 199.7 thousand per ton, driven by tight global supply and surging new energy vehicle demand. Since 2022, the price has declined to RMB 133.4 thousand per ton by 2024 due to increased Indonesian supply, and is expected to stabilize as the market balances.
- As a key raw material for stainless steel, nickel iron reached a peak of RMB 1,434.9 thousand per ton in 2022, driven by demand from the stainless-steel sectors. However, with slowing demand growth and impacts from Indonesia's export policies and overcapacity, prices declined. By 2024, the price in China fell to RMB 969.6 thousand per ton.
- Global nickel prices rose from RMB 70.3 thousand per ton in 2017 to RMB 175.5 thousand per ton in 2022, driven by supply constraints due to Indonesia's ore export ban and increased demand from the new energy vehicle and stainless-steel sectors. However, after 2022, the rapid expansion of Indonesia's nickel production, especially in electrolytic nickel and nickel pig iron, led to a global supply surplus and a decline in prices. By 2024, global nickel prices had dropped to RMB 120.6 thousand per ton.

Source: Frost & Sullivan

Entry Barriers of Global Energy Matels Market

Entry Barriers	Description
Raw Material supply	• Due to the long-term partnerships with major mining companies and international traders, only large refineries are able to sign long-term supply agreements with upstream suppliers, while other competitors can only have an unstable supply at a higher price due to their relatively small purchasing volumes.
Client Resources	• The quality of refined cobalt and nickel will directly affect the quality of lithium-ion battery products and therefore the end products. Hence, major downstream consumers tend to have very strict requirements on the processing level of refineries and have established their long-term cooperation with specific refineries with good relationship.
Capital Requirements	• Both nickel and cobalt refining industries are highly capital-intensive. In addition to investment in establishment of production facilities and procurement of machinery and equipment, the ordinary business operations must also retain a certain amount of liquidity to procure feedstock and chemical reactants.
Technology Requirements	• Refining cobalt and nickel require specific technology know-hows and most leading nickel and cobalt refineries with advanced automated smart production systems have their own advantages in terms of professional talents, technology and patents acquired. New entrants without the relevant technology know-how is difficult to enter into the industry.

Source: Frost & Sullivan

Opportunities of Global Energy Matels Market

Market Opportunities	Description
Resource Development and Capacity Expansion	• The accelerating global energy transition has led to a surging demand for critical energy metals such as lithium, nickel, and cobalt. Enterprises can seize high-quality resources and expand their production capacity by developing high-grade mines and deploying emerging technologies like saltwater lithium extraction and deep-sea mining. This resource development strategy not only helps meet the market's growing demand for energy metals but also lays a solid foundation for enterprises to compete in the future market.
Technological Innovation and Process Upgrading	• The rapid development of emerging technologies such as high-nickel low-cobalt batteries and solid-state batteries is reshaping the demand structure for energy metals. Enterprises need to increase their R&D investment in low-carbon metallurgy and battery recycling technologies to reduce carbon emissions and actively embrace the circular economy. Through technological innovation and process upgrading, enterprises can not only improve resource utilization efficiency but also enhance their market competitiveness in the context of sustainable development.
Supply Chain Integration and Global Layout	• The increasing geopolitical risks and the trend of supply chain regionalization are driving enterprises to accelerate vertical integration of the industrial chain and establish localized production capacities in resource-rich countries or major consumer markets. This strategic layout helps enterprises enhance their bargaining power, mitigate risks associated with trade barriers, and ensure the stability and security of the supply chain. By adopting a global layout, enterprises can better cope with market fluctuations, optimize resource allocation, and achieve sustainable development.
Application Expansion and Diversified Development	• With technological progress and the transformation of energy structures, the application scenarios for energy metals are expanding from traditional fields to emerging onesEnterprises can develop high-value-added products such as hydrogen fuel cell catalysts and zirconium materials for nuclear reactors and establish strategic cooperation with downstream application enterprises to explore new growth points. This diversified layout can not only disperse market risks but also enhance the technological barriers and profitability of enterprises.

Source: Frost & Sullivan

3. Competitive Landscape of Global New Energy Materials Market

Competitive Landscape of Global Battery Cathode Material Market

Market Competitive Structure of Battery Cathode Material Market, Global

Resource-to-Cathode Participants

- Resource-to-cathode participants are the most competitive in the battery cathode material market. They own mineral resources and cover the production of both precursors and cathode materials, achieving a full-industry-chain layout. This integration allows them to strategically position across various battery systems, leveraging synergies between resources and the industrial chain. As a result, they enjoy enhanced risk resistance, significant cost advantages, and diverse product offerings in the market.

Resource-to-Precursor Integrated Participants

- Resource-to-precursor integrated type of participants refers to enterprises whose traditional businesses are resources exploitation, smelting or recycling in the upstream industry value chain, then expanding their business to precursor field, or even further to downstream cathode material field.

Precursor-Focused Participants

- Precursor-focused type of participants refers to enterprises that are focusing on the R&D, manufacture and sales of precursors. The source of raw material such as cobalt, nickel and manganese for these participants are mainly from purchasing from third-party suppliers.

Note: Companies listed above are illustrative examples only, not all players in the market.

Source: Frost & Sullivan

Competitive Landscape of Global Battery Cathode Material Market

Global Ranking of pCAM Market (by sales value), Global, 2024

Rank	Company Name	Sales Value (RMB Bilion)	Market Share
1	**The Company**	19.1	21.8%
2	Company A	~18	20.7%
3	Company B	~10	11.4%
4	Company C	~10	11.4%
5	Company K	~9	9.1%

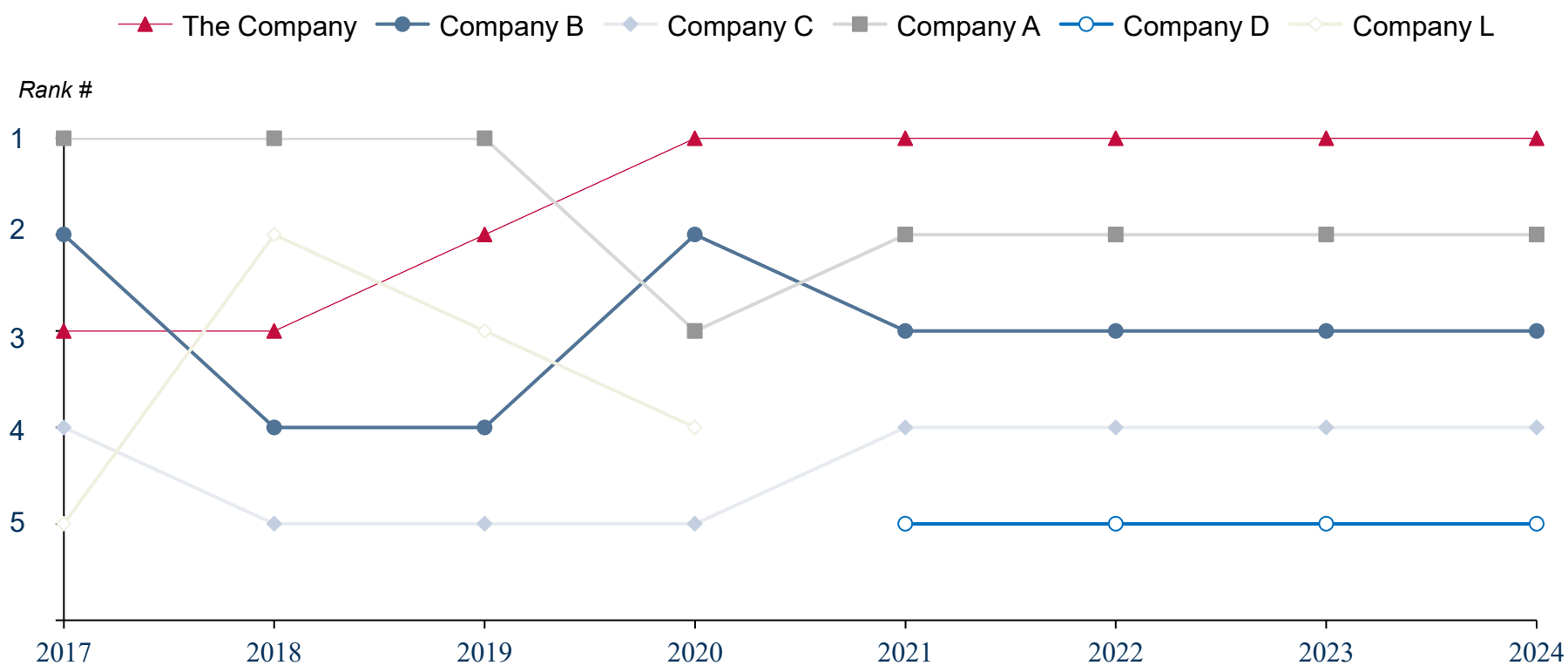
Note: The sales value is estimated based on the shipment volume with reference to the average market price of each kind of pCAM.

Source: Frost & Sullivan

Competitive Landscape of Global Ternary Precursors Market (1/3)

- In terms of shipment volume, the Company is the world's largest supplier of ternary precursors and has ranked first in the global ternary precursors market for five consecutive years from 2020 to 2024.

Ranking of Ternary Precursors Market (by shipment volume), Global, 2017-2024



Source: Frost & Sullivan

Competitive Landscape of the Global Ternary Precursor Market (1/2)

Market Ranking of Ternary Precursors, (by shipment volume), Global, 2017

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	Company A	21.0	9.9%
2	Company B	13.3	6.3%
3	**The Company**	**12.8**	**6.1%**
4	Company C	8.3	3.9%
5	Company L	8.0	3.8%
	Others	147.9	70.0%
	Total	**211.2**	**100.0%**

Market Ranking of Ternary Precursors (by shipment volume), Global, 2018

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	Company L	40.0	12.5%
2	Company A	40.0	12.5%
3	**The Company**	**19.2**	**6.0%**
4	Company B	19.0	5.9%
5	Company C	13.1	4.1%
	Others	189.5	59.0%
	Total	**320.9**	**100.0%**

Market Ranking of Ternary Precursors (by shipment volume), Global, 2019

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	Company A	60.1	14.6%
2	**The Company**	**44.2**	**10.8%**
3	Company L	29.1	7.1%
4	Company B	29.1	7.1%
5	Company C	14.1	3.4%
	Others	233.7	57.0%
	Total	**410.2**	**100.0%**

Market Ranking of Ternary Precursors (by shipment volume), Global, 2020

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**76.1**	**16.1%**
2	Company B	55.0	11.6%
3	Company A	41.5	8.8%
4	Company L	34.8	7.4%
5	Company C	33.3	7.0%
	Others	232.7	49.1%
	Total	**473.4**	**100.0%**

来源：弗若斯特沙利文

Competitive Landscape of the Global Ternary Precursor Market (2/2)

Market Ranking of Ternary Precursors (by shipment volume), Global, 2021

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**152.3**	**19.9%**
2	Company A	91.0	11.9%
3	Company B	65.2	8.5%
4	Company C	59.1	7.7%
5	Company D	40.3	5.3%
	Others	357.3	46.7%
	Total	**765.2**	**100.0%**

Market Ranking of Ternary Precursors (by shipment volume), Global, 2022

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**200.9**	**19.2%**
2	Company A	152.3	14.6%
3	Company B	105.1	10.1%
4	Company C	84.8	8.1%
5	Company D	44.9	4.3%
	Others	456.9	43.7%
	Total	**1,044.9**	**100.0%**

Market Ranking of Ternary Precursors (by shipment volume), Global, 2023

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**215.2**	**21.3%**
2	Company A	180.3	17.9%
3	Company B	150.4	14.9%
4	Company C	129.1	12.8%
5	Company D	79.6	7.9%
	Others	255.2	25.3%
	Total	**1,009.9**	**100.0%**

Market Ranking of Ternary Precursors (by shipment volume), Global, 2024

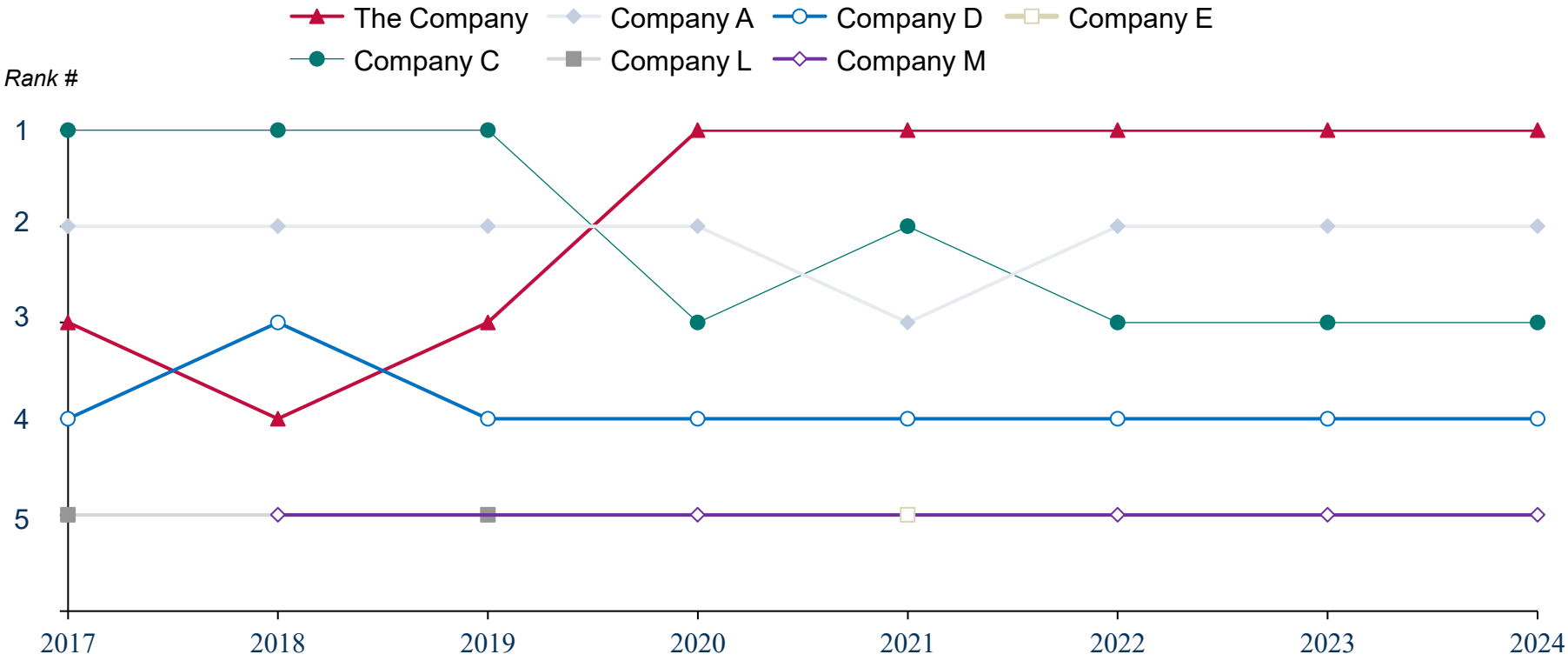
Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**195.5**	**20.3%**
2	Company A	189.0	19.7%
3	Company B	174.9	18.2%
4	Company C	106.4	11.1%
5	Company D	67.5	7.0%
	Others	228.2	23.7%
	Total	**961.5**	**100.0%**

来源：弗若斯特沙利文

Competitive Landscape of Global Tricobalt Tetroxide Market (1/3)

- In terms of shipment volume, the Company is the world's largest supplier of tricobalt tetroxide and has ranked first in the global ternary precursors market for five consecutive years from 2020 to 2024.

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2017-2024



Source: Frost & Sullivan

Competitive Landscape of the Global Tricobalt Tetroxide Market (1/2)

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2017

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	Company C	15.7	28.6%
2	Company A	11.0	20.0%
3	Company D	5.0	9.1%
4	Company L	4.0	7.3%
5	**The Company**	**1.6**	**2.9%**
	Others	17.6	32.0%
	Total	**54.9**	**100.0%**

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2018

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	Company C	15.7	24.1%
2	Company A	10.0	15.4%
3	Company D	9.7	14.9%
4	Company M	4.0	6.1%
5	**The Company**	**1.4**	**2.1%**
	Others	24.4	37.5%
	Total	**65.1**	**100.0%**

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2019

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	Company C	17.0	22.8%
2	Company A	10.0	13.4%
3	Company D	8.0	10.7%
4	**The Company**	**7.9**	**10.5%**
5	Company L	4.0	5.4%
	Others	27.9	37.3%
	Total	**74.8**	**100.0%**

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2020

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**20.0**	**23.4%**
2	Company A	15.4	18.0%
3	Company C	13.0	15.2%
4	Company D	6.0	7.0%
5	Company E	4.0	4.7%
	Others	27.1	31.7%
	Total	**85.6**	**100.0%**

来源：弗若斯特沙利文

Competitive Landscape of the Global Tricobalt Tetroxide Market (2/2)

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2021

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**23.3**	**24.1%**
2	Company A	16.1	16.6%
3	Company C	10.0	10.3%
4	Company E	9.0	9.3%
5	Company D	7.0	7.2%
	Others	31.6	32.6%
	Total	**97.0**	**100.0%**

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2022

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**15.4**	**15.2%**
2	Company A	14.8	14.6%
3	Company C	10.0	9.8%
4	Company D	8.0	7.8%
5	Company M	8.0	7.8%
	Others	45.4	44.7%
	Total	**101.5**	**100.0%**

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2023

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**19.4**	**16.7%**
2	Company A	11.0	9.4%
3	Company C	11.0	9.4%
4	Company D	8.0	6.8%
5	Company M	7.0	6.0%
	Others	42.5	43.0%
	Total	**99.0**	**100.0%**

Ranking of Tricobalt Tetroxide Market (by shipment volume), Global, 2024

Rank	Company	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	**28.6**	**28.0%**
2	Company A	20.7	20.2%
3	Company E	15.0	14.6%
4	Company C	14.0	13.7%
5	Company D	10.0	9.8%
	Others	14.1	13.8%
	Total	**102.4**	**100.0%**

来源：弗若斯特沙利文

Competitive Landscape of Global Iron Phosphate Market (1/3)

Ranking of Iron Phosphate Market (by shipment volume), Global, 2017

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	13.0	17.5%
2	Company N	12.0	16.0%
3	Company O	11.0	14.8%
4	Company P	5.0	6.8%
5	Company Q	4.4	5.9%
	Others	29.1	39.1%
	Total	**74.6**	**100.0%**

Ranking of Iron Phosphate Market (by shipment volume), Global, 2018

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	15.0	18.0%
2	Company N	12.0	14.5%
3	Company O	10.0	12.1%
4	Company Q	8.0	9.7%
5	Company P	5.0	6.0%
	Others	33.1	39.8%
	Total	**83.1**	**100.0%**

Ranking of Iron Phosphate Market (by shipment volume), Global, 2019

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	18.0	18.7%
2	Company N	14.9	15.5%
3	Company P	12.0	12.4%
4	Company Q	10.0	10.3%
5	Company O	18.1	18.7%
	Others	23.7	24.5%
	Total	**96.7**	**100.0%**

Ranking of Iron Phosphate Market (by shipment volume), Global, 2020

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	23.9	19.9%
	Company N	18.1	15.1%
2	Company P	16.0	13.3%
3	Company Q	15.0	12.5%
4	Company O	19.0	15.8%
	Others	28.1	23.4%
	Total	**120.2**	**100.0%**

Source: Frost & Sullivan

Competitive Landscape of Global Iron Phosphate Market (2/3)

Ranking of Iron Phosphate Market (by shipment volume), Global, 2021

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	72.5	18.7%
2	Company N	43.2	11.1%
3	Company P	36.0	9.3%
3	Company Q	32.9	8.5%
4	Company O	37.8	9.7%
	Others	166.1	42.8%
	Total	**388.4**	**100.0%**

Ranking of Iron Phosphate Market (by shipment volume), Global, 2022

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	275.5	26.4%
2	Company O	154.8	14.8%
3	Company Q	119.3	11.4%
4	Company N	95.1	9.1%
5	Company P	82.4	7.9%
	Others	315.9	30.3%
	Total	**1,042.9**	**100.0%**

Ranking of Iron Phosphate Market (by shipment volume), Global, 2023

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	261.0	17.6%
2	Company O	203.0	13.7%
3	Company Q	143.6	9.7%
4	Company R	116.0	7.8%
5	Company S	95.7	6.4%
	Others	667.1	44.9%
	Total	**1,486.4**	**100.0%**

Ranking of Iron Phosphate Market (by shipment volume), Global, 2024

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	682.3	31.5%
2	Company O	219.9	10.2%
3	Company T	95.9	4.4%
4	Company U	78.9	3.6%
5	**The Company**	**77.9**	**3.2%**
	Others	1,007.7	46.6%
	Total	**2,164.2**	**100.0%**

Source: Frost & Sullivan

Competitive Landscape of Global Iron Phosphate Market (3/3)

Ranking of Iron Phosphate Market (by external shipment volume), Global, 2025Q1

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	**The Company**	27.1	8.4%
2	Company T	25.2	7.8%
3	Company B	20.0	6.2%
4	Company V	16.1	5.0%
5	Company W	20.0	6.2%
	Others	214.2	66.5%
	Total	**322.5**	**100.0%**

Source: Frost & Sullivan

Competitive Landscape of Global Lithium Iron Phosphate Market (1/3)

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2017

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company X	12.0	15.4%
2	Company Y	13.0	16.7%
3	Company Z	8.0	10.3%
4	Company Q	5.0	6.4%
5	Company AA	5.0	6.4%
	Others	34.8	44.8%
	Total	**77.7**	**100.0%**

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2018

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company AB	14.0	16.0%
2	Company X	11.7	13.4%
3	Company AC	9.0	10.3%
4	Company Z	8.1	9.2%
5	Company O	8.1	9.2%
	Others	36.7	41.9%
	Total	**87.5**	**100.0%**

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2019

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company O	14.7	14.3%
2	Company AB	12.5	12.2%
3	Company AC	11.6	11.2%
4	Company X	10.9	10.6%
5	Company K	10.9	10.6%
	Others	42.2	41.1%
	Total	**102.9**	**100.0%**

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2020

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company AB	27.9	22.1%
2	Company K	22.1	17.4%
3	Company AC	21.1	16.7%
4	Company X	20.1	15.9%
5	Company O	18.8	14.9%
	Others	16.5	13.1%
	Total	**126.5**	**100.0%**

Source: Frost & Sullivan

Competitive Landscape of Global Lithium Iron Phosphate Market (2/3)

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2021

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	121.3	29.6%
2	Company AB	90.3	22.0%
3	Company AC	50.2	12.2%
4	Company O	40.0	9.8%
5	Company S	30.5	7.4%
	Others	78.0	19.0%
	Total	**410.3**	**100.0%**

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2022

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	323.9	29.4%
2	Company AB	243.6	22.1%
3	Company AD	92.2	8.4%
4	Company R	95.1	8.6%
5	Company O	91.4	8.3%
	Others	256.9	23.3%
	Total	**1,103.0**	**100.0%**

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2023

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	506.8	32.3%
2	Company AB	219.5	14.0%
3	Company O	164.1	10.5%
4	Company S	108.1	6.9%
5	Company R	92.4	5.9%
	Others	478.0	30.5%
	Total	**1,568.9**	**100.0%**

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2024

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	686.0	30.0%
2	Company AB	237.7	10.4%
3	Company O	217.3	9.5%
4	Company S	176.6	7.7%
5	Company AE	142.6	6.2%
	Others	826.2	36.1%
	Total	**2,286.4**	**100.0%**

Source: Frost & Sullivan

Competitive Landscape of Global Lithium Iron Phosphate Market (3/3)

Ranking of Lithium Iron Phosphate Market (by shipment volume), Global, 2025.1

Rank	Company Name	Shipment Volume (Thousand Tons)	Market Share
1	Company K	77.0	29.0%
2	Company AB	28.9	10.9%
3	Company O	25.1	9.5%
4	Company S	20.0	7.5%
5	Company AE	17.0	6.4%
	Others	97.5	36.7%
	Total	**265.4**	**100.0%**

Source: Frost & Sullivan

Comparison of Major New Energy Materials Companies (1/2)

Company	The Company	Company C	Company A
Revenue (RMB Billion)	34.3	66.3	30.5
Proportion of Overseas Revenue (%)	39.6%	56.1%	29.7%
Proportion of R&D Investment (%)	3.1%	2.2%	4.7%
Proportion of R&D Personnel (%)	12.3%	7.1%.	15.4%
Coverage of Customer Resources*			
Cathode Material Enterprises	4	3	2
Battery Enterprises	8	6	7
OEM	3	6	4

Note: The base year for the above information is 2023, and it is based on the companies' overall business operations.
** The data reflects the number of companies covered by the top ten enterprises in each industry globally.*

Source: Frost & Sullivan

Comparison of Major New Energy Materials Companies (2/2)

Company	The Company	Company C	Company A
Coverage of Production Types			
Nickel-based Materials	√	√	√
Cobalt-based Materials	√	√	√
Phosphorus-based Materials	√	×	√
Sodium-based Materials	√	×	√
Energy Metals	√	√	√
Coverage of Ore Resources			
Nickel Ore	√	√	√
Phosphate Ore	√	×	×
Lithium Ore	√	√	×

Source: Frost & Sullivan

Entry Barriers of Global New Energy Materials Market

Entry Barriers	Description
Resource Barrier	The production of LFP cathode materials requires many raw materials including lithium, iron, phosphorus, and carbon, each of which come from different sources. These raw materials account for approximately 80% to 85% of the total cost of LFP cathode material production. Therefore, a stable supply of raw materials at reasonable cost is a key to entering the market. Since only large producers can secure stable and quality supply, other competitors face unstable supply at higher prices due to their relatively small purchasing volumes, thus forming the resource barrier for new entrants.
Capital Barrier	The production of LFP cathode materials requires substantial capital investment for factory construction, R&D, and production. Leading manufacturers leverage economies of scale to reduce costs, expand capacity, and sustain R&D investments in advanced LFP materials. Insufficient capital makes it difficult for new entrants to afford expensive production facilities, limiting their ability to compete. This results in a capital barrier, allowing established leaders to maintain advantages in power density, cost, performance, and quality.
Client Recognition Barrier	The quality of cathode materials is critical for the performance and safety of lithium-ion batteries, making downstream customers highly selective. Lithium-ion battery manufacturers impose stringent entry requirements and thorough screening processes that can last months or even a year. Once a supplier is accredited, customers tend to maintain long-term partnerships, making it difficult for new entrants to break into established supply chains. Additionally, leading manufacturers are expanding overseas production capabilities to meet international market demands while reducing costs and risks. This expansion further consolidates their market positions and creates a significant client recognition barrier in both domestic and overseas markets.
Technical Barrier	Given the industry's relative novelty and highly customized nature, extensive R&D experience is essential for securing a competitive market position. Established companies, with their seasoned R&D and production teams, have accumulated significant technical know-how and proprietary knowledge. This concentration of technical expertise in leading enterprises forms a formidable technical barrier, making it challenging for newcomers to match the performance, quality, and reliability of existing products without substantial investment in R&D and technology acquisition.

Source: Frost & Sullivan

4. Analysis of Lithium-ion Battery Recycling and Reutilization Solution Market

Definition of Lithium-ion Battery Recycling and Reutilization Solution Market

- Lithium-ion battery recycling and reutilization solutions refer to the recovery, dismantling and extraction of valuable metals and materials from lithium-ion batteries at the end of their life cycle. The solutions maximize the recycling and utilization of valuable materials in batteries, reduce the negative impacts on the environment, and achieve the purpose of resource reuse and environmental protection.
- Lithium-ion battery recycling and reutilization solutions can be categorized according to recycling paths. Depending on different recycling paths, lithium-ion battery recycling and reutilization solutions can be classified into second-life use and recycling.

Classification by Recycling Paths

Classification	Remaining Battery Life	Battery Type	Recycling Technology	Main Application
Second-life Use	20%-80%	• Lithium Ferric Phosphate Battery	• Battery Disassembly, Testing, Screening, Recombination, etc.	• Energy storage lithium-ion battery • Lithium batteries for low-speed electric vehicles • Others
Recycling	Below 20%	• Ternary Lithium-ion Battery • Lithium Ferric Phosphate Battery	• Pre-discharging, Battery Disassembly, Separation, Dissolution/ Incineration/ Leaching, Impurity Removal, etc.	• All kinds of lithium-ion batteries • Powder metallurgy • Others

Major Recycled Materials of Lithium-ion Battery Recycling and Reutilization Solutions

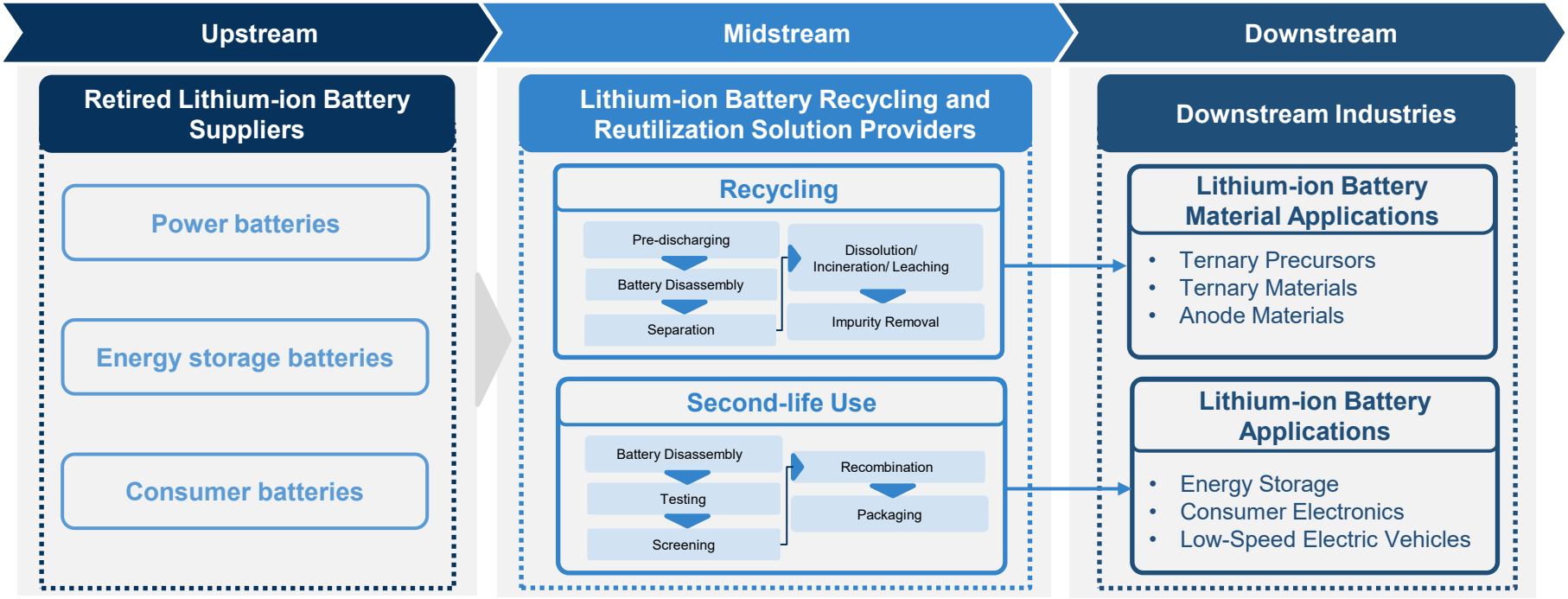
Recycling Path	Major Recycled Materials	
Second-life Use	Lithium-ion Battery	Recycled the whole lithium-ion batteries.
	Lithium-ion Battery Component	Recycled components such as battery modules or cells.
Recycling	Valuable Metal	Recycled cobalt, lithium, nickel and other valuable metals in lithium-ion batteries.
	Other Materials	Recycled non-metallic components in batteries, such as plastics, electronic components, among others.

Source: Frost & Sullivan

Value Chain of Lithium-ion Battery Recycling and Reutilization Solution Market

- The value chain of lithium-ion battery recycling and reutilization solution market consists of upstream retired lithium-ion battery suppliers, midstream lithium-ion battery recycling and reutilization solution providers, and downstream industries including lithium-ion battery applications and lithium-ion battery material applications.
- The value chain of the lithium battery recycling and reutilization solution market consists of the following three major segments: Upstream Suppliers: These include lithium-ion battery manufacturers, EV makers, and specialized recyclers who collect and sort retired batteries for transport to midstream processors; Midstream Recyclers: They use advanced technologies to dismantle retired batteries, extract valuable materials like cells and metals, and safely handle hazardous substances; Downstream Industries: These use recycled materials to produce new battery components or repurpose batteries for applications in energy storage, consumer electronics, and low-speed EVs.

Value Chain of Lithium-ion Battery Recycling and Reutilization Solution Market

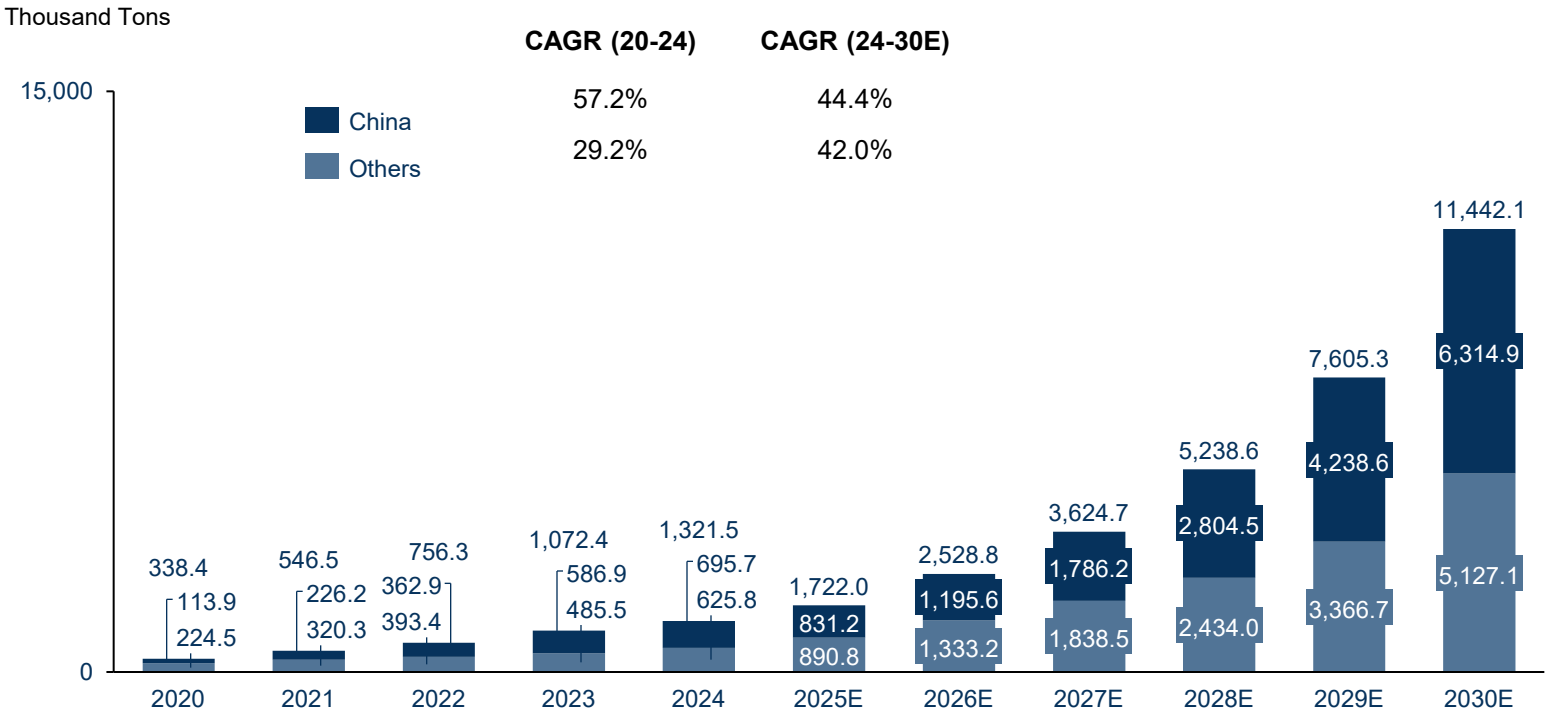


Source: Frost & Sullivan

Treatment Volume of Lithium-ion Battery Recycling and Reutilization Solution Market

- From 2020 to 2024, the global treatment volume of lithium-ion battery recycling increased from 338.4 thousand tons to 1, 321.5 thousand tons, representing a CAGR of 40.6%. Due to the surge in supply of retired lithium-ion batteries, by 2030, the global treatment volume of lithium-ion battery recycling is expected to reach 11,442.1 thousand tons, representing a CAGR of 43.3% from 2024 to 2030. By 2040 and 2050, the treatment volume of the global and China's lithium-ion battery recycling will further increase, ultimately reaching 88,432.2 thousand tons and 50,406.4 thousand tons respectively.

Treatment Volume of Lithium-ion Battery Recycling and Reutilization Solution Market, Global and China, 2020-2030E



Source: Frost & Sullivan

Sales Revenue of Recycled Material of Lithium-ion Battery Recycling and Reutilization Solution Market

- From 2020 to 2024, the global sales revenue of recycled materials in lithium-ion battery recycling and reutilization solution market increased from RMB10.1 billion to RMB50.5 billion, with a CAGR of 49.5%. During the same period, the sales revenue of recycled materials in lithium-ion battery recycling and reutilization solution market in China increased from RMB1.7 billion to RMB23.0 billion, representing a CAGR of 91.9%.
- With the increasing sales volume of recycled materials, by 2030, the global sales revenue of recycled materials in lithium-ion battery recycling and reutilization solution market is expected to reach RMB480.4 billion, representing a CAGR of 45.6% from 2024 to 2030. Meanwhile, the sales revenue of recycled materials in lithium-ion battery recycling and reutilization solution market in China is expected to reach RMB159.4 billion by 2030, growing at a CAGR of 38.0% from 2024 to 2030.
- During the forecast period, the global and China's sales revenue of lithium-ion battery recycling and reutilization solution markets are expected to further grow, reaching 1,754.0 thousand tons and 526.2 thousand tons respectively in 2040, and 3,604.1 thousand tons and 973.1 thousand tons in 2050.

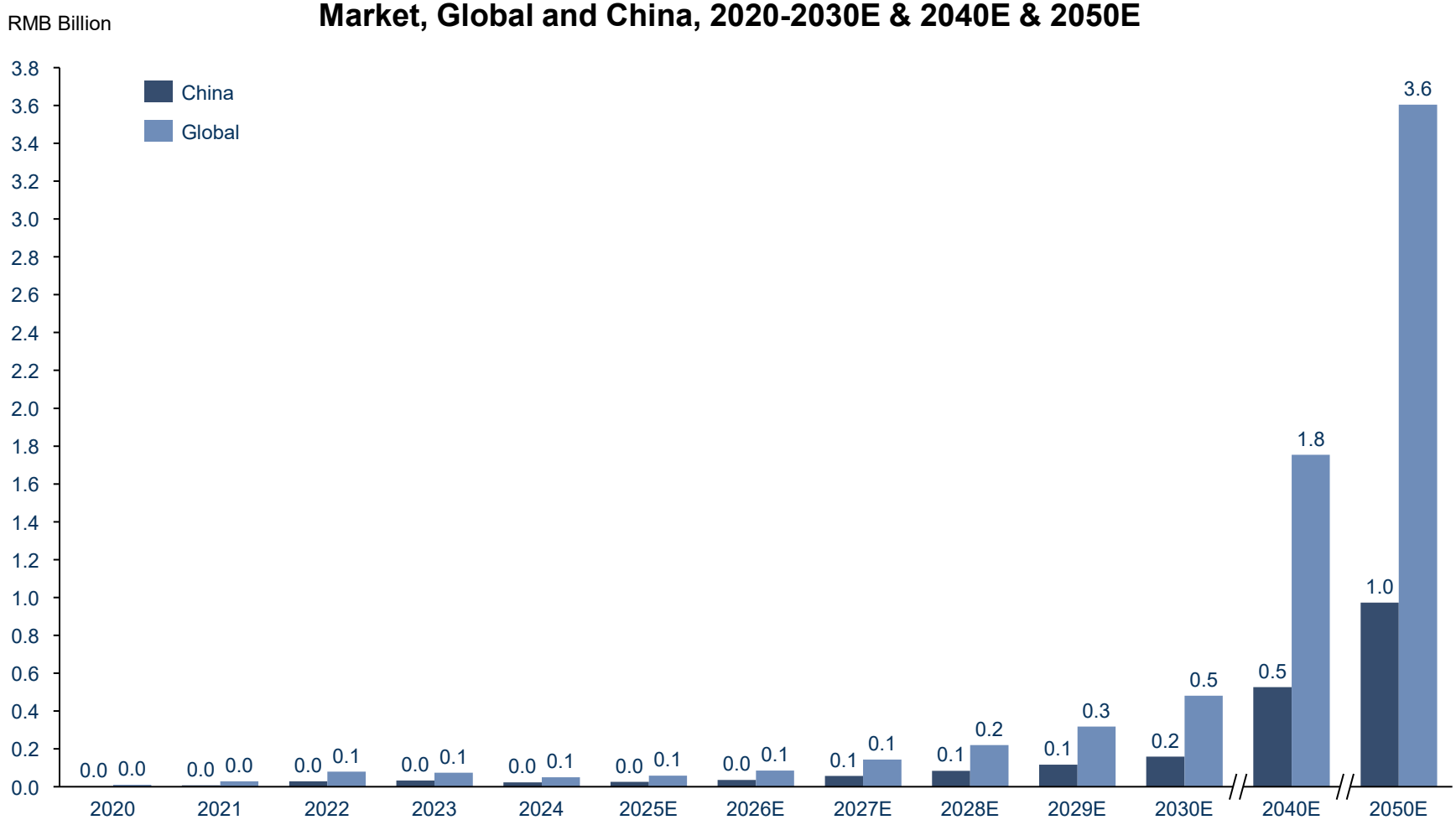
Sales Revenue of Recycled Material of Lithium-ion Battery Recycling and Reutilization Solution Market, Global and China, 2020-2030E & 2040E & 2050E

Unit: RMB Billion	2020	2021	2022	2023	2024	2025E	2026E	2027E	2028E	2029E	2030E	2040E	2050E	CAGR 20-24	CAGR 24-30E	CAGR 30E-40E	CAGR 40E-50E
China	1.7	7.1	28.2	32.4	23.0	25.8	36.0	57.6	84.5	117.0	159.4	526.2	973.1	91.9%	38.0%	12.7%	6.3%
Global	10.1	28.7	79.8	73.6	50.5	58.8	85.6	142.9	219.3	318.3	480.4	1,754.0	3,604.1	49.5%	45.6%	13.8%	7.5%

Source: Frost & Sullivan

Charts

Sales Revenue of Recycled Material of Lithium-ion Battery Recycling and Reutilization Solution Market, Global and China, 2020-2030E & 2040E & 2050E

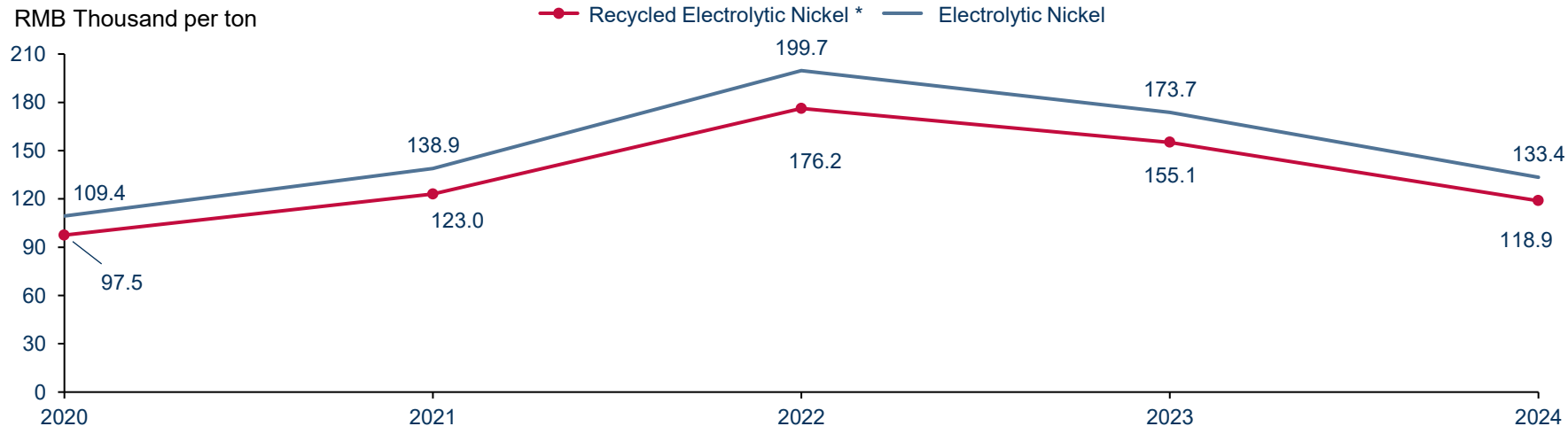


Source: Frost & Sullivan

Cost Efficiency of Recycled Material of Lithium-ion Battery Recycling and Reutilization for New Energy Materials Company

- Recycled electrolytic nickel, as an important recycled resource product, primarily derives its raw materials from waste nickel-containing materials, such as spent batteries and nickel alloy scraps. The recycling and utilization of these waste materials not only align with environmental protection principles but also provide a significant cost advantage for the production of recycled electrolytic nickel due to their relatively low acquisition costs. Additionally, the production process of recycled electrolytic nickel is less affected by fluctuations in raw material supply and market prices. Its price is generally more stable and more cost-effective compared to conventional electrolytic nickel. This price stability enables recycled electrolytic nickel to offer more reliable cost control for downstream enterprises, reducing uncertainties in the production process.
- In 2024, the price of recycled electrolytic nickel was RMB 118.9 thousand per ton, while that of conventional electrolytic nickel was RMB 133.4 thousand per ton. This indicates that recycled electrolytic nickel has a clear price advantage, especially against the backdrop of the current global tight supply and frequent price fluctuations of nickel resources. With the increasing awareness of environmental protection and the continuous advancement of resource recycling technology, recycled electrolytic nickel has a broad market prospect and is expected to become an important part of nickel resource supply in the future.

Price of Electrolytic Nickel (by types), China, 2020-2024



** The price of recycled electrolytic nickel for 2024 is a forecasted figure and will be updated further based on market developments.*

Source: Frost & Sullivan

Drivers of Global Recycled Material of Lithium-ion Battery Recycling and Reutilization Solution Market

Market Drivers	Description
Favorable Policies and Regulations	• Governments globally are actively promoting comprehensive policies and regulations to support the development of the lithium-ion battery recycling and reutilization solution market. In mainland China, the regulatory framework encompasses both environmental protection and industry standardization. MIIT issued the "Specification Conditions for Lithium-ion Battery Industry (2024 Edition)" (鋰離子電池行業規範條件(2024年本)), promoting recycling design and lifecycle management, while the State Council issued the "Opinions on Accelerating the Construction of a Waste Recycling System" (關於加快構建廢棄物迴圈利用體系的意見) in 2024, proposing to strengthen the recycling of retired power batteries. In addition, the MIIT issued the "Industry Specification Conditions for Comprehensive Utilization of Retired Power Batteries for New Energy Vehicles (2024 Edition)" (新能源汽車廢舊動力電池綜合利用行業規範條件(2024年本)), proposing to actively develop the R&D and application of recycling technologies and improve traceability management systems. Internationally, the European Union has also released the Battery Regulation in 2022, which proposes to promote high-level recycling of retired battery materials.
Surge in Supply of Retired Lithium-ion Batteries	• Lithium-ion batteries are used in a variety of fast-growing industries, such as EVs, energy storage and consumer electronics. The electrochemical performance of a lithium-ion battery deteriorates when the remaining life of the battery is reduced to less than 80%. Such battery needs to be recycled when it is unable to meet the relevant power requirements. As the life of lithium-ion batteries shortens and the need for battery replacement emerges, the volume of retired lithium-ion batteries flowing into the recycling and reutilization solutions market significantly increases. The volume of retired lithium-ion batteries globally and in mainland China had grown at a CAGR of 38.6% and 41.5%, respectively, from 2019 to 2023, and is projected to grow at a CAGR of 35.7% and 37.5%, respectively, from 2023 to 2030. The surge in the supply of retired lithium-ion batteries has spurred high demand for battery recycling and reutilization solutions.
Effectively Relieve the Shortage of Raw Materials Supply	• The rapid development of downstream industries such as EVs has intensified demand for lithium-ion batteries and their key metals (including lithium, nickel and cobalt), resulting in a shortage of mineral resources. By 2030, the global demand for lithium, nickel and cobalt is expected to reach 531 thousand tons, 4,754 thousand tons and 344 thousand tons, respectively, while the supply shortfall of lithium, nickel and cobalt is expected to reach 81 thousand tons, 450 thousand tons and 18 thousand tons, respectively. Recycling valuable metals from retired batteries helps meet this growing demand while reducing reliance on foreign raw material imports and effectively alleviating supply shortages.

Source: Frost & Sullivan

Development Trends of Global Recycled Material of Lithium-ion Battery Recycling and Reutilization Solution Market

Development Trends	Description
Qualification Barrier	• The PRC government has issued the Industry Normative Conditions for the Comprehensive Reutilization of Retired Power Batteries for New Energy Vehicles (新能源汽車廢舊動力蓄電池綜合利用行業規範條件) since 2019, established a whitelist system, and certified and cultivated a number of backbone enterprises for lithium-ion battery recycling in order to improve industry standardization. While not mandatory and the application acceptance for the 2024 whitelist is currently suspended, being on this whitelist still significantly influences partnerships with lithium-ion batteries, lithium-ion battery manufacturers and EV manufacturers, creating a substantial barrier for new entrants.
Technology Barrier	• Wet recycling, the industry's mainstream technology, offers high recovery rate and low energy consumption. However, the process requires sophisticated technical expertise to manage corrosive chemicals safely and meet environmental requirements, whilst strong technical capabilities are required to achieve the recovery of all valuable materials from retired lithium-ion batteries, and reutilization of both battery cathodes and anodes. Further, with the continuous upgrading of battery materials and battery pack structures, established players have been dedicated to improving recycling processes and positioning themselves at the forefront of industry advancement with continuous investment in R&D, presenting a significant barrier for new market participants.
Capital Barrier	• The lithium-ion battery recycling and utilization solutions industry is a capital-intensive industry. Obtaining retired batteries, configuring production equipment, and research and development processes all require significant capital investment. Leading market players with strong financial background can better capitalize on market opportunities in a fast-growing industry while new entrants face significant challenges in funding substantial up-front capital investment.
Channel Barrier	• As the current recycling volume of retired lithium-ion batteries in mainland China is less than the total recycling capacity of all market participants, establishing stable and sufficient recycling channels has become one of the important factors to success. Leading players have secured partnerships with key suppliers such as EV manufacturers, lithium-ion battery manufacturers and retired vehicle dismantlers, making it difficult for new entrants to establish comparable supply networks in the short term.
Customer Barrier	• Established players enjoy strong reputations and long-term strategic relationships with downstream customers. New entrants face significant challenges in building similar customer relationships and securing market share against these established partnerships.

Source: Frost & Sullivan

Supplementary information (1/7)

- New energy materials as (i) new energy battery materials, including cathode active materials (CAM) and their corresponding precursor materials (pCAM), anode materials, electrolyte fluid and separators; and (ii) new energy metals, mainly lithium, nickel, cobalt and copper and their intermediate products, serving as essential raw materials to produce new energy battery materials and other materials in the new energy industry. New energy battery materials are critical to the development and application of new energy batteries, including lithium-ion batteries and other innovative battery technologies, which power new energy solutions, energy storage systems (ESS) and energy-saving applications.

- New energy batteries primarily comprise cathode materials, separators, anode materials and electrolytes, with cathode materials playing a pivotal role and accounting for over 50% of the total cost of new energy battery cells, making them the most value adding component of the value chain. Cathode materials include both CAM (which participates in the electrochemical reactions) and inactive materials such as binders, conductive additives, and other components that help form the complete cathode structure. CAM is typically the metal oxide or phosphate compound that stores and releases ions such as, lithium or sodium ions in a battery, depending on the specific battery technology.

- Based on the primary chemical elements in CAM, the new energy batteries can be divided into (i) ternary batteries, with NCM/NCA as the CAM, (ii) cobalt batteries, with LCO as the CAM, (iii) LFP batteries, with LFP as the CAM, and (iv) emerging technologies, such as sodium-ion batteries. The table below sets forth the key features and major end applications of the four categories of CAM materials used in new energy batteries.

- New energy batteries have a broad range of (i) existing applications, including mobility batteries for electric vehicles and vessels, consumer electronics batteries, as well as ESS batteries, and (ii) emerging, high-potential applications, such as batteries for robotics and mobility batteries for low-altitude aerial vehicles.

Source: Frost & Sullivan

Supplementary information (2/7)

- Considering cost and battery performance, ternary batteries and LFP batteries have become the dominant battery types in the mobility battery market. Ternary batteries offer higher energy density, ranging from 200 to 300 Wh/kg, compared to LFP batteries, which range from 160 to 200 Wh/kg. Ternary batteries also have better charging efficiency, while LFP batteries provide longer cycle life and lower material costs. As a result, ternary batteries are widely used in EVs and electric vessels, especially for mid-to-high end models with longer driving ranges, as well as low-altitude aerial vehicles. On the other hand, LFP batteries are generally considered to be more cost-effective.

- In 2024, the penetration rate of EV achieved 19.9%.

- Globally, the EV batteries for new energy vehicles are mainly ternary batteries, ESS batteries are primarily lithium iron phosphate (LFP) batteries, and 3C batteries are predominantly lithium cobalt oxide (LCO) batteries.

- The global eVTOL sales volume is expected to increase primarily driven by the [the commercial needs in wide application scenarios of, for example, agriculture, delivery and security, and the advancement in technology, for example, the wide application of AI and improvement in materials and battery performance.

- Globally, the batteries for electric ships are mainly LFP batteries. Drones primarily use lithium polymer batteries. In the future, eVTOLs are expected to shift towards ternary batteries.

- The LFP batteries dominate the global ESS battery market with over 97.2% market share, primarily due to its balanced energy density and costs, long circle life, safety and capable of withstanding a wide range of extreme operating temperatures. With continuous breakthrough in technology and improvement in production process, the sodium-based batteries, as an emerging technology, are expected to be a supplement to LFP batteries in the ESS battery market.

- Among which the global shipment volume of LFP batteries increased from 79.2GWh in 2020 to 787.7 GWh in 2024 at a CAGR of 77.6%, and expected to increase to 3,736.9GWh in 2030 at a CAGR of 29.6%.

Source: Frost & Sullivan

Supplementary information (3/7)

- Cobalt enhances battery performance by increasing energy density and thermal stability, which is crucial for powering the complex movements and computations of humanoid robots. In robotics, nickel-based alloys provide the necessary strength and durability for robotic joints and structural components. Ternary batteries and LCO batteries have dominated the robotics batter markets due to their high energy density and rapid charging capabilities.

- The global shipment volume of ternary batteries increased from 132.2GWh in 2020 to 539.7GWh in 2024 at a CAGR of 42.1%, and is expected to increase to 1,835.4GWh in 2030 at a CAGR of 22.6%.

- The high-nickel pCAM increased from 81.7 thousand tons in 2020 to 338.2 thousand tons in 2024 at a CAGR of 42.7%, and is expected to increase to 2,172.6 thousand tons in 2030 at a CAGR of 36.3%. In 2024, the global shipment volume of high-nickel pCAM accounted for 17.3% of the global shipment volume of nickel-based pCAM, which is expected to increase to 70.0% in 2030.

- The LCO batteries lead the global consumer electronics battery market, primarily due to their features of high energy density, stable voltage, lightweight and compact.

- The EV-related demand for pCAM is expected to grow at a higher CAGR of 26.8% from 1,904.6 thousand tons in 2024 to 7,903.1 thousand tons in 2030 as compared to that of the EV during the same period, primarily due to the higher average battery capacity per vehicle as a result of higher power demand from features such as long-range driving and AI-powered applications.

- The global shipment volume of LFP batteries among the ESS batteries increased from 21.3 GWh in 2020 to 284.1 GWh in 2024 at a CAGR of 91.1%, and expected to increase to 1,096.3 GWh in 2030 at a CAGR of 25.2%. ESS-related demand for pCAM is expected to grow by a CAGR of 30.5% from 2024 to 2030 to reach 3,162.1 thousand tons in 2024.

Source: Frost & Sullivan

Supplementary information (4/7)

- The LCO batteries dominate the global consumer electronics battery market, primarily due to their features of high energy density, stable voltage, lightweight and compact. Currently, there is no major competing battery technologies for consumer electronics application.

- Affected by the market demand for consumer electronics, particularly the increasing demand for power capacity per unit device brought about by technological trends such as AI, the global shipment volume of consumer electronics batteries fluctuated from 2020 to 2024, and is expected to grow steadily from 66.7 GWh in 2024 to 136.9 GWh in 2030 at a CAGR of 12.7%, among which the LCO batteries is expected to continue to dominate the global consumer electronics battery market with global shipment volume increasing from 62.7 GWh in 2024 to 124.6 GWh in 2030 at a CAGR of 12.1%. Consumer electronicsrelated demand for pCAM is expected to grow by a CAGR of 12.8% from 2024 to 2030 to reach 275.2 thousand tons in 2030.

- The global shipment volume of LFP CAM increased from 245.0 thousand tons in 2020 to 2,450.0 thousand tons in 2024 at a CAGR of 77.8%, which is expected increase to 8,829.0 thousand tons in 2030 at a CAGR of 23.8% from 2024 to 2030.

- The price of nickel demonstrated a gradual increase from USD10.4 thousand per ton in 2017 to USD26.1 thousand per ton in 2022, which then declined steadily to USD16.8 thousand per ton in 2024.

- Among them, the global shipment volume of ternary batteries increased from 0.8 GWh in 2020 to 4.1 GWh in 2024 at a CAGR of 50.6%, and is expected to increase to 48.9 GWh in 2030 at a CAGR of 51.1%, and further increase to 314.3 GWh in 2040, at a CAGR of 20.4% from 2030 to 2040, and 2,353.2 GWh in 2050, at a CAGR of 22.3% from 2040 to 2050. The higher historical and estimated growth rates of installed volume of robotics batteries than the growth rates of shipment volume of robotics are primarily due to higher power demand as robotics technologies advance.

Source: Frost & Sullivan

Supplementary information (5/7)

- Nickel's end-market demand is primarily driven by stainless steel production, which accounted for around 65-70% of the total nickel product market in 2024, where it enhances strength and corrosion resistance in construction, appliances, and industrial applications. The battery sector, which accounted for around 10-15% of the total nickel product market in 2024, is the fastest-growing segment, fueled by the rise of EVs and ESS, as high-nickel ternary batteries improve energy density. Superalloys, which accounted for around 5-10% support aerospace in 2024, power generation, and medical industries. And a smaller amount is used in plating and coating, where it provides durability in automotive, marine, and industrial applications, and foundry and casting, along with electronics, catalysts, and currency.

- The volume of retired lithium-ion batteries globally increased rapidly from 349.5 thousand tons from 2020 to 1,014.3 thousand tons in 2024 at a CAGR of 30.5%, which is projected to grow at a CAGR of 38.6% from 2025 to 2030.

- The LFP batteries have been widely used in the global ESS battery market with 97.2% market share in 2024, primarily due to its balanced energy density and costs, long circle life and safety.

- In 2024, the global shipment volume of high and ultra-high nickel pCAM accounted for 35.2% of the global shipment volume of nickelbased pCAM, which is expected to increase to 70.0% in 2030.

- The global shipment volume of cobalt-based pCAM has shown consistent growth over the years. The global shipment volume increased from 85.6 thousand tons in 2020 to 102.4 thousand tons in 2024 at a CAGR of 4.6%, and is expected to increase to 209.8 thousand tons in 2030 at a CAGR of 12.7% from 2024 to 2030.

- Due to increased demand for LFP batteries, the global shipment volume of LFP CAM increased from 245.0 thousand tons in 2020 to 2,450.0 thousand tons in 2024 at a CAGR of 77.8%, which is expected to increase to 8,792.9 thousand tons in 2030 at a CAGR of 23.7% from 2024 to 2030.

- The price of nickel demonstrated a gradual increase from RMB70,300 per ton in 2017 to RMB175,700 per ton in 2022, which then declined steadily to RMB120,600 per ton in 2024.

Source: Frost & Sullivan

Supplementary information (6/7)

- Nickel-based pCAM, phosphorus-based pCAM and cobalt-based pCAM are the mainstream pCAM. In terms of sales value, the nickelbased pCAM, phosphorus-based pCAM and cobalt-based pCAM accounted for 75.2%, 23.1% and 1.2% of the total pCAM market in 2024, together of which accounted for 99.6% of the overall pCAM market in terms of sales value in 2024.

- Typically, more than 96.7% of the nickel-based materials are used in EV and low-altitude aerial vehicles, almost all of the cobalt-based materials are used in consumer electronics, and more than 97.5% of the phosphorus-based materials are used in EV and ESS.

- Among the major kinds of new energy metal materials, the production volume of nickel, cobalt, lithium and copper was 3.5 million metal tons, 0.3 million metal tons, 0.2 million metal tons and 23.0 million metal tons globally in 2024, respectively.

- By sales value, the market size of pCAM of RMB87.7 billion and market size of new energy metals of RMB2,455.8 billion accounted for approximately 3.2% and 90.6% of the global market size of new energy materials in 2024, respectively, which consisted of (i) new energy battery materials of RMB256.0 billion, including pCAM, CAM, anodes, electrolyte fluid and separators, and (ii) the new energy metals of RMB2,455.8 billion, including lithium, nickel, cobalt and copper.

- The prices of nickel is expected to continue to decrease during 2025 while at a relatively modest rate, which is expected to continuously affect our results of operations.

- The validation timeline for new suppliers of new energy battery materials typically includes three phases (i.e. the lab-scale production, pilot-scale production, and mass production) and takes one to two years for EV and ESS applications with domestic customers, and three to four years for overseas customers, and one to two years for consumer electronics.

- As of the Latest Practicable Date, the majority of company's downstream customers do not mainly sell their products to the United States since the wide variety of end-products incorporating our products are sold across the globe.

Source: Frost & Sullivan

Supplementary information (7/7)

- The impact of geopolitical tensions on both downstream and adjacent industries and customers remains relatively limited.
- As innovative products, sodium-based materials and the corresponding sodium-ion batteries are still in a relatively early stage of development and currently have not yet generated significant downstream demand.
- Due to industry-wide over-supply of LFP and LFP pCAM, while the raw material costs did not decrease to the same extent during such period, which was line with the industry trending.
- Such decrease was primarily due to industry-wide over-supply of LFP and LFP pCAM in the market, while the raw material costs did not decrease to the same extent during such period, which was line with the industry trending.

Source: Frost & Sullivan

Thank You

Partner with you on the Road to Growth