B.A

BatteryMBA

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Has the time come for Giga scale investment into Na-Ion cell manufacturing?

Introduction

In this case study you are a cell manufacturing company based in the US producing lithium-ion cells at a capacity of 3GWh. You have gained investment from a fundraising round for $50M. You are exploring if you expand on your existing LFP chemistry cell production or place the capital into the manufacturing of sodium-ion cells to gain access to an emerging market and spread the risk of your technology exposure.

1. Is there an opportunity for sodium ion technology to compete with lithium ion, in which market segments?
2. How are the incumbent cell makers minimising any risk from nascent supply chains, does this change your business plan?
3. Does the current regulatory environment in the US suggest there are markets which will be in part incentivised?

Energy Storage industry status & review:

The global energy storage & Lithium-ion battery industry has seen tremendous growth over the last three years, and it is expected that the trend will continue with the world-wide demand growing at a CAGR of 30%. The announced new cell Gigafactory

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plant capacities are also matching this pace (**Exhibit 1**[1]). The EV sector is the main driver behind this, and overall demand is expected to reach 4500 GWh by 2030.

Though the growing demand and the investments into cell manufacturing are highly encouraging, there are also serious concerns on the supply side – where for most of the key raw materials like Lithium, Nickel, Cobalt and graphite, the supply is expected to be falling behind the exponentially growing demand. It is also expected that to meet the projected demand by 2035, multiple new mines / plants must be realised and start actual commercial scale production (**Exhibit 2 [2], Exhibit 3 [3]**). For Lithium, as of 2022, the visible projects cover less than 50% of the 2030 demand.

The mining of minerals is typically a lengthy process with a typical average duration from source discovery until actual mining / production spanning between 10 to 15 years. With lack of risk capital being the key bottleneck, the longer-term trends over the last five decades indicate that a lot of discoveries were also left undeveloped. (**Exhibit 4 [4], Exhibit 5 [5]**)

As the data and the trends indicate that for Li-ion battery industry growth and meeting projected demands, the supply of key raw materials will become the bottleneck, and this could well be a "decade of short supply" in the Li-ion battery industry.

The research & development of alternative battery technologies like Na-ion batteries has seen noteworthy progress over the last years, and they are seen as potential cost-effective alternatives and less volatile to market prices. The stress on the Li-ion battery supply chain, the resultant increase in the prices has led to more vigorous work in the field, with most of the major Asian battery cell manufacturers and emerging technology developers in EU and the USA developing Na-ion based battery technologies to maturity (**Exhibit 6, Exhibit 7 both [6]**).

Sodium vs. Lithium Technologies and Their Applications

Lithium-ion batteries (LIB) represent the current state of the art for most commercial energy storage applications including electrified powertrains, home energy storage, and consumer electronics. Several anode and cathode chemistries exist within the LIB market with the predominant configuration being a combination of graphite-based anode and Nickel Manganese Cobalt (NMC) or Lithium Iron Phosphate (LFP) based cathodes. Here lithium ions act as the ionic charge carrier between the electrodes in the battery and are advantageous since lithium has a low atomic weight of only 6.941 amu which enables high energy density (Wh/L) and specific energy (Wh/kg) in the resulting cells.

There are differences in the characteristics of NMC versus LFP cathodes. At a cell level NMC can achieve much higher energy densities than that of LFP and is therefore employed in applications where high performance is critical. LFP is cheaper and has greater price stability as it is not concerned with the availability of Nickel and Cobalt which experience large price volatility (**Exhibit 6 [6]**). LFP is also a more stable chemistry with higher cycle life. LFP has been reintroduced into automaker product roadmaps in recent years with the rise in price volatility for some battery critical materials. Due to its lower energy density but increased safety and cycle life compared to NMC, it is also the current preferred choice for battery energy storage systems (BESS).

Sodium ion batteries (SIB), while having been a known chemistry for nearly 50 years, have only recently experienced a resurgence in development and commercialisation due to the cost and scarcity associated with its lithium counterpart. While sodium has a significantly higher atomic weight than lithium, coming in at about 22.990 amu (331% higher than lithium) it is also significantly more abundant on earth, coming in as the 6th most abundant element and making up 2.36%wt in the earth's crust [7].

The existing production levels of sodium are also significant due to its use in many other industries and production is distributed around the world. According to the 2023 USGS Mineral Commodity Survey, sodium chloride (NaCl) presently has a global production of 42 million tons [8]. Furthermore, while China is the leading producer of NaCl with 22% of the global mine production, other countries including India (15.5%), USA (14.5%), Germany (5.2%), and Canada (3.8%) contribute significantly to the global supply.

While the use of sodium as the charge carrier in secondary batteries has some advantages compared to lithium, it does not alleviate all concerns about the use of expensive and/or conflict minerals. While some SIB chemistries do avoid the use of elements such as cobalt, nickel, and manganese, such as the Prussian Blue CAM (cathode active material) used by Natron [9], there are many other variants in research and development that do not. On the anode side, SIB may use similar active materials to LIB such as graphite and hard carbon. Other options include materials containing titanium, tin, and molybdenum. On the cathode side, an array of CAM has been investigated with many containing nickel, manganese, or vanadium.

SIB offers performance characteristics that are distinct from LIB which make them more or less suitable for some specific applications when cost and availability are not considered. Compared to the leading LIB chemistry using NMC811 and graphite, SIB based on NaMOx (sodium metal oxide) cathodes, such as that produced by Faradion, offer good cycle life, calendar life, safety and high temperature operation, as well as the ability to be produced in all standard battery geometric configurations (pouch, prismatic, and cylindrical) [10]. However, SIB do suffer from relatively poor energy density and specific energy as well as poor low temperature performance. SIB currently provides energy densities of only about 1/3 and specific energy about half that of commercial LIB cells. **Exhibit 8 [11]** gives an indication of the trade-offs between specific characteristics of NIBs vs LIBs.

From an application perspective, the performance properties SIB make current generation SIB technologies an attractive option for applications such as medical devices where safety is a top priority as well as grid levelling and back-up power supply devices, where high cycle life outweighs the need for high energy density and specific energy. Examples of companies developing SIB for BESS applications include

AMTE Power, Faradion and Nation Energie. AMTE Power is developing a 20Ah SIB pouch cell with specific energy of 135-140Wh/kg which is targeted towards BESS applications [12]. Faradion is working with Nation Energie to develop SIBs for BESS applications and their first BESS was recently installed in Australia [13].

However, due to the wide availability and expected lower cost of SIB batteries compared with their LIB counterparts, SIBs are also an attractive option for other applications where ultra-high performance is not required such as economy vehicles and personal mobility devices. Recently several auto manufacturers, including VW and BYD [14] have announced the application of SIB battery technology to their vehicles. SIBs are also an excellent drop-in replacement for 12V starter-lighting-ignition lead-acid batteries for low-cost electric transport, this is because Na-ion has higher energy density than lead acid batteries, as well as improved performance over a wide temperature range.

Exhibit 7 [6] presents a comparison of the current state-of-the-art specific energy of sodium-ion cells compared to commercially available LFP cells with graphite or Si-based anodes (next generation higher capacity anode material). Specific energy of sodium-ion cells is approaching LFP cell performance in some instances. Performance of sodium-ion cells at pack-level has been modelled in the context of the Worldwide Harmonized Light-Duty Vehicles Test Procedure (WLTP) standard to determine potential driving ranges of various sodium-ion packs (**Exhibit 9 [6]**). This illustrates the necessary improvements to be made in the specific energy achievable at pack-level to compete with NMC and LFP battery pack performance.

Another opportunity for SIB to alleviate LIB supply chain pressures may align to the emerging high energy density/longer-range/slower charging versus smaller pack/lower energy density/fast-charge debate. This hypothesis states that smaller packs which have fast charging capability use fewer materials but can be charged quickly and comparably to ICE vehicles which makes the lower energy density less of an issue [15]. This is typically discussed with respect to LFP. SIB technology, which presents lower specific energy than LFP, does have advantages with respect to power capability and potentially higher cycle life which could be exploited to enable this.

An overview of the deployment of SIB in various markets is depicted in **Exhibit 10 [16]**.

Market & supply chain

Sodium's larger ionic radius (1.02 Å vs. 0.76 Å for Li+) means the existing active materials used for lithium ion are not suitable for sodium intercalation (the ions struggle to fit within the interlayer spacing available in typical LIB active materials). As a result the existing supply chains for lithium ion (commercialised in 1991) raw materials cannot be utilised. Instead, new investment and manufacturing capacity is required for this technology.

At the cell production level, there are however opportunities for the technology to 'drop in', with many similarities to the incumbent LIB technology. The use of aluminium current collectors for both the positive and negative electrode. Copper (used as the current collector for the negative, anode, electrodes in LIBs) carries a near 10 fold premium over aluminium at the time of writing. Shipping at zero volts, a benefit to reduced risk in transport and shelf-life decay, also resulting in reduced costs.

The predominant driver to the recent commercial interest in sodium ion technology has been the uptick in LIB cost. The cost has trended away from the much sought after 100 $/kWh and up to ca. 150 $/kWh, because of the increasing lithium price during 2022 (**Exhibit 11** at the time of writing, this has however since fallen 50% from its peak). In contrast, a precursor to NIB CAM is trona (trisodium hydrogendicarbonate dihydrate), at the time of writing this is 100x cheaper than lithium carbonate, **Exhibit 12**. Further, the transient price nature of the critical materials involved in lithium ion cell production has created a cost down opportunity for sodium, a significantly more abundant material (sodium is around 2.83% of the earth's crust vs lithium at 0.01%), to co-exist in secondary batteries, despite is lower energy density.
An illustrative balance of the bill of materials required for the various technologies can be found in **Exhibit 13**, where the pricing assumed is a forward projection from Wood Mackenzie. At its largest, there is a 20% benefit in $/kWh between Prussian white NIB and LFP based LIB. Within the same research, Wood Mackenzie believes in a base case of 40GWh of NIB production, 100GWh if the technology is rolled out significantly before 2025.

Sodium-ion cell companies

It is reported by Benchmark mineral intelligence that there are 28 sodium ion plants currently operating at a total capacity of 3.1GWh, against a total market of 700GWh for lithium ions. 40% of the projected 100GWh of NIB factories built by 2030, will be from converted LIB cell plants. The entrants range from giants like CATL, BYD to start ups gaining funding like Faradion or Tiamat. A summary of the latest entrants in the information available can be found in **Exhibit 14**. In contrast to the LIB market, where capacity is currently ca. 700GWh. Significantly, the majority of NIB manufacturers have chosen to vertically integrate at least some portion of the raw material manufacturing, be that anode active material, cathode material.

Anode Active Material companies

In the 1990's, some of the first applications of lithium ion cells used hard carbon, manufactured by Kureha. Feedstocks include; walnut, lignin, sugar, corn husk and most recently the greatest promise – coconut and crab shells. Carbonisation takes place in the absence of air at around 1000°C for 4-6hrs (suggesting a similar cost to manufacture as current NMC CAMs). Due to the relatively low carbon content of feedstocks and consequently poor yields, the final price of current hard carbons is higher than that of graphites used in LIB (22$/kg vs. 10$/kg for graphites [19]). After the adoption of graphite later, the scale of production for hard carbon has been limited due to the unique application (vs. graphite, which can be used for many applications). Consequently, the largest available volumes today are a result of the dominant graphite players seeking to capitalise on new markets or smaller volume players continuing their research. No commitments to volumes have been publicly shared however there are rumours that demand will quickly outstrip manufacturing supply in the short term.

- Kureha Battery Materials (Japan) - est. 4kT
- BTR (China) – no confirmed capacities, biomass based
- Kaijin (China)
- SQ Group (China), 10kT – expanding to 100kT, bio based
- Stora Enso (Finland) – business development stage for 50kT, lignin based product
- DFD New Energy (China)
- Phillips 66 (US/UK)
- Kuraray (Japan)
- JFE Chemical (Japan)
- Sumitomo Bakelite (Japan)

Cathode Active Material companies

Three main classes of cathode materials lead the sodium-ion market;

Polyanionic (Tiamat [France])

- 4000 cycles at 1C to 90% SOH documented
- Can be adopted by existing LIB manufacturing lines however
- 120mAh/g achieved practically

Prussian Blue Analogues (Natron Energy [USA], CATL [China], Altris [Sweden]

- 800-1000 cycles documented
- Comprised of abundant elements, likely the lowest cost base CAM
- Can be adopted by existing LIB manufacturing lines however
- 140 mAh/g achieved practically

Layered Transition Metal Oxides (Faradion [UK], HiNa [China], LiFUN [China], SVOLT [China], EVE [China])

- 800 cycles documented
- Similar manufacturing process to existing lithium ion layered cathode materials
- 100-190 mAh/g documented
- 30% lower rate capability than LFP used in LIB cells.

Separator, electrolyte, and conductive additive companies

- Existing suppliers of separator materials for LIB known to supply suitable NIB appropriate materials.
- Electrolyte companies producing LiPF6 are suggested to manufacture NaPF6 with relative ease.
- Suppliers of conductive additives able to supply carbon black / CNTs without significant changes to production methods.

Policy and Incentives for Next Gen Chemistries

For this case study, we examined the recent laws and policies passed by the US legislature to incentivize investment in the battery storage and mining of battery-related minerals, in particular, the Inflation Reduction Act (IRA) and the Infrastructure Investment and Jobs Act (IIJA, also known as Bipartisan Infrastructure Law (BIL)). Neither legislation is solely focused on investment in batteries and battery-related minerals. Rather, these laws focus on a broad range of energy transition issues, including hydrogen, carbon capture and storage, and various sources of renewable energy.

The primary difference between the two structures is that the IRA incentivizes investment from project developers as well as consumers (in some instances) and provides them with tax credits for complying with the provisions of the IRA. Such tax credits correspondingly reduce their tax liability and in some limited instances, the project developers can even get checks in the mail from the IRS. However, that incentive does not extend to project developers and private companies investing in battery storage and battery-related minerals.

IIJA, on the other hand, enables various departments and offices of the Government, primarily of the Department of Energy (DOE), to provide loans, grants, or loan guarantees to project developers (or a consortium of parties) where despite promising technologies, they are struggling to secure commercial financing. These offices include DOE's Loan Program Office (LPO), Office of Energy Efficiency and Renewable Energy (EERE), The Office of Clean Energy Demonstrations (OCED), Advanced Research Projects Agency-Energy (ARPA-E), Office of Fossil Energy and Carbon Management (FECM), to name a few.

Inflation Reduction Act

IRA earmarks approximately $370 billion for clean energy and climate change mitigation initiatives and is considered an unprecedented level of support from the US Federal Government for the transition to sustainable energy. As long as the energy source is carbon neutral, IRA encourages a variety of clean energy sources, including energy storage, nuclear power, clean energy vehicles, hydrogen, and CCUS. IRA extends and establishes Production Tax Credits (PTCs) or Investment Tax Credits (ITCs) for the development of energy projects, giving producers the option to choose between the two based on which works best for them.

IRA amends the Internal Revenue Code of 1986 (IRC or the Tax Code) to allow project developers and consumers to benefit from the aforementioned tax credits. There are multiple sections that provide incentives for battery production and manufacturing in the US.

Section 45X

IRA adds in a new Section 45X (Advanced manufacturing production credit) of the Tax Code, which provides tax credits for the production of "eligible components." While that includes components related to solar, wind (onshore and offshore), and inverters, for the purposes of this case study, we have just focused on "applicable critical minerals" and "qualifying battery components."

Production of such eligible components must occur in the US and the components must be sold between December 31, 2022, and January 1, 2033. However, the phase-out of such tax credits begins January 1, 2030, onwards and completely phases out for production and sale of such eligible components from January 1, 2033, onwards. The PTC applies to cathode and anode materials used in batteries as well as critical battery minerals that are converted or purified to battery-grade readiness.

Critical Battery Minerals

IRA lists 50 critical battery minerals that developers can benefit from and allows for a PTC equivalent to 10% of the costs incurred by the taxpayer with respect to the production of such minerals. These critical minerals include aluminium, cobalt, graphite, lithium, manganese, nickel, vanadium, titanium, manganese, and magnesium. However, the list does not include the production of sodium, molybdenum, iron, phosphorus, and fluorine, as some of the essential battery elements required for the manufacturing of sodium batteries. The reason for their exclusion from Section 45 X is beyond the scope of this case study.

In order to benefit from the critical minerals component of Section 45X of the Tax Code, the critical mineral included in the list must be converted from one state to another or purified to a minimum purity, which would not be in any instance less than 99%. For instance, in the case of aluminium, it must be converted from bauxite to a minimum purity of 99 by mass or purified to a minimum purity of 99.9% aluminium by mass. Similarly, lithium must be converted from lithium carbonate or lithium hydroxide or alternatively, must be purified to a minimum purity of 99.9% lithium by mass.

Qualifying Battery Components

Qualifying Battery Components include electrode active materials, battery cells, and battery modules.

"Electrode active materials" include cathode materials, anode materials, anode foils, and electrochemically active materials, including solvents, additives, and electrolyte salts that contribute to the electrochemical processes necessary for energy storage. In the case of such electrode active materials, the IRA provides an incentive equal to 10% of the costs incurred by the taxpayer with respect to the production of such materials.

For battery cells, the IRA provides a tax credit equivalent to $35/KWh, so long as the battery cell's energy density is at least 100 Wh/L and it's capable of storing at least 12 Wh of energy.

For battery modules, the tax credit is $10/KWh unless the battery modules do not use battery cells, in which case the tax credit is $45/KWh. The aggregate capacity of such battery modules must at least be 7 kWh. However, one limitation applicable to both battery cells and battery modules is that their capacity-to-power ratio cannot exceed 100:1.

Section 48E

Section 48E (Clean electricity investment credit) of the Tax Code allows for an ITC for investment in energy storage, which is defined as "property (other than property primarily used in the transportation of goods or individuals and not for the production of electricity) which receives, stores, and delivers energy for conversion to electricity (or, in the case of hydrogen, which stores energy), and has a nameplate capacity of not less than 5 kilowatt hours."

IRA allows for a 6% base investment tax credit, which can go up to 30% where the taxpayer complies with the prevailing wages and apprenticeship requirements of IRA, which are beyond the scope of this case study. Additionally, the taxpayer would be eligible for an additional 10% of tax credits where the energy storage property is placed in an "energy community."

Section 30D

Section 30D (Clean vehicle credit) is a consumer-focused tax credit that reduces their tax liability for purchasing an EV. Tax credits are for consumers of EVs that are “acquired for use or lease by the taxpayer and not for resale”, must be a motor vehicle (as defined by Clean Air Act), and final assembly must be within North America. Section 30D provides a tax credit equivalent to $7,500, which is bifurcated into two requirements; $3,750 for complying with the "critical minerals component", and $3,750 for complying with the "battery component".

To benefit from the "critical minerals component", the percentage of applicable critical minerals (contained in a battery) that are extracted or processed either in the US or in any country with which the US has a free trade agreement in effect, or recycled in North America, is equal to or greater than the “applicable percentage.” The applicable percentage starts at 40% and incrementally ramps up to 80% by January 1, 2027.

Similarly, for battery components, IRA prescribes that they must have a capacity of not less than 7 kWh, and must be capable of being recharged from an external source of electricity. Additionally, the percentage of the value of components contained in such batteries that were manufactured or assembled in North America is equal to or greater than the "applicable percentage," which starts at 50% and incrementally ramps up to 100% by January 1, 2029.

Summary of Risks

Technology

- BESS is a key area for LIB start ups to prove manufacturing capability, a price war for this market could quickly ensue
- Proving comparable performance to LFP at system level for automotive applications

Government policy

- The focus for energy storage and in particular energy storage for electro-mobility has been significantly directed at lithium ion (outside of China)

Supply chain

- Supply of NIB CAM/AAM still nascent vs. LIB
- Recycling less commercially incentivised due to low cost of materials
- Competition in performance of LFP versus SIB means that SIB supply chain may be underdeveloped if SIB demand is low and low cost compared to LFP may not achieved

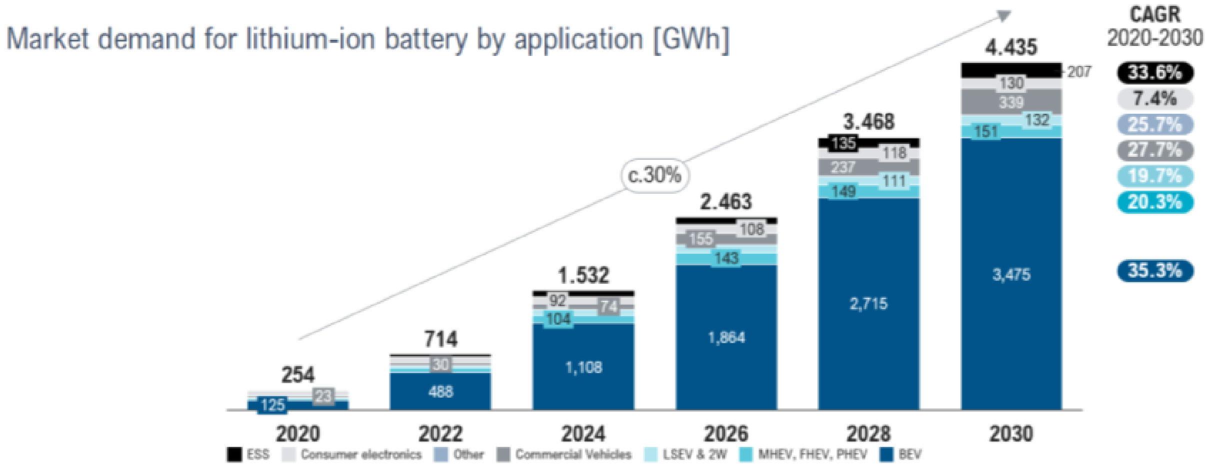
Conclusion

The key fundamentals to your decision to invest the $50M into your existing LFP cell production versus diversification into the sodium ion market has been shared. The following questions should aid your choice in approach:

1. Is there an opportunity for sodium ion technology to compete with lithium ion, in which market segments?
2. How are the incumbent cell makers minimising any risk from nascent supply chains, does this change your business plan?
3. Does the current regulatory environment in the US suggest there are markets which will be in part incentivised?

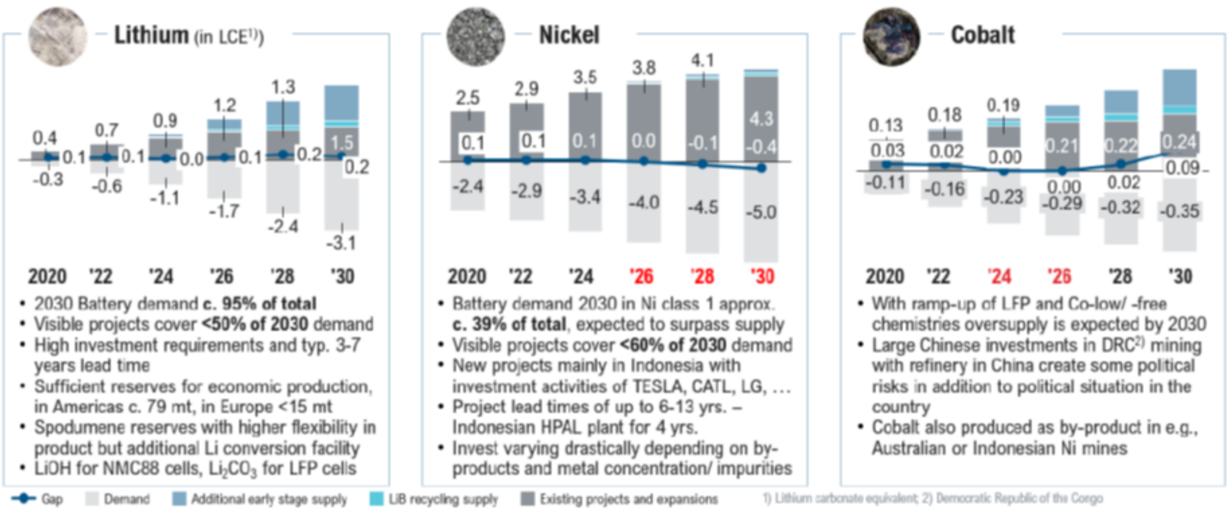
Exhibits

Exhibit 1: Market demand for Lithium-ion battery by application



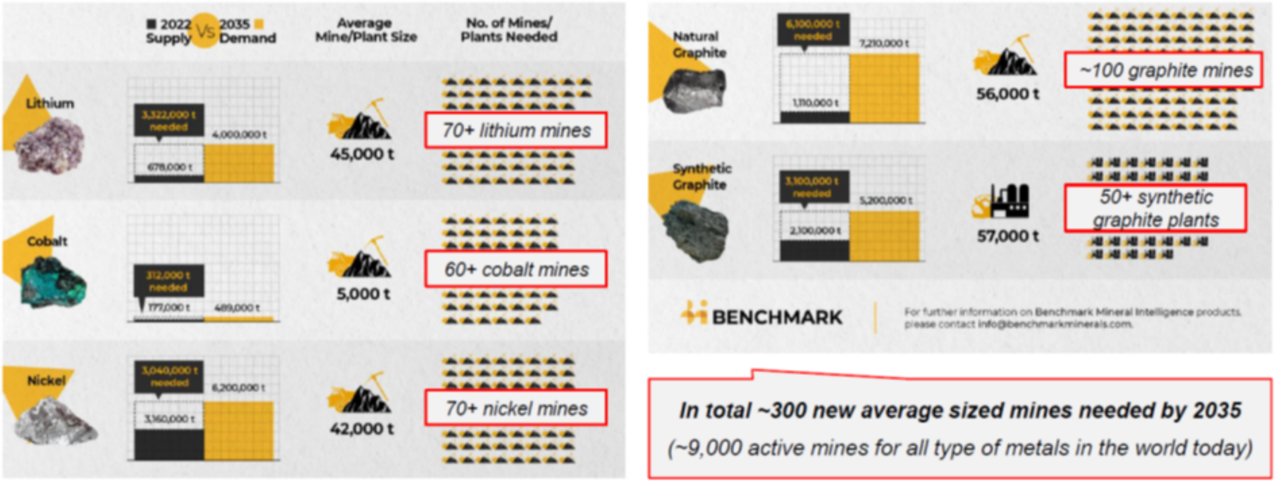
Source: [1] Battery MBA course lecture by Roland Berger, 01/023

Exhibit 2: Supply chain risks: demand, supply from existing projects, LiB recycling and additional early stage projects for key battery raw materials (Li as LCE, Ni, Co).



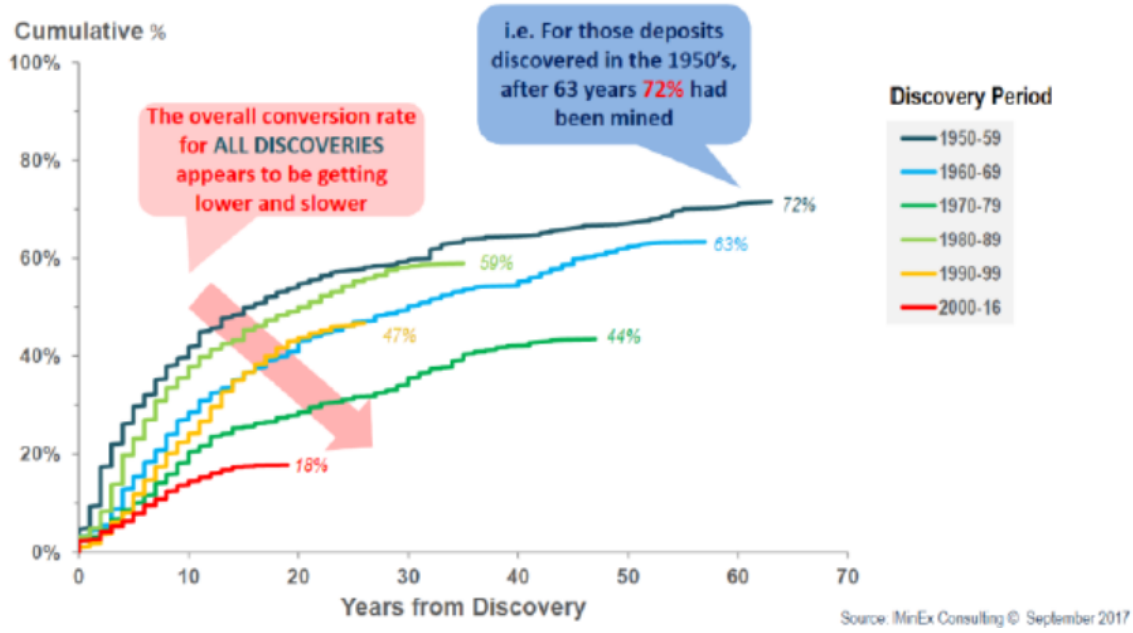
Source: [2] Compiled by Roland Berger with data from BMO, Deutsche Bank, Fast markets, Roskill and presented in BatteryMBA class 01/2023.

Exhibit 3: Supply chain stress in battery industry: number of new mines needed for key battery raw material to meet the 2035 demand.



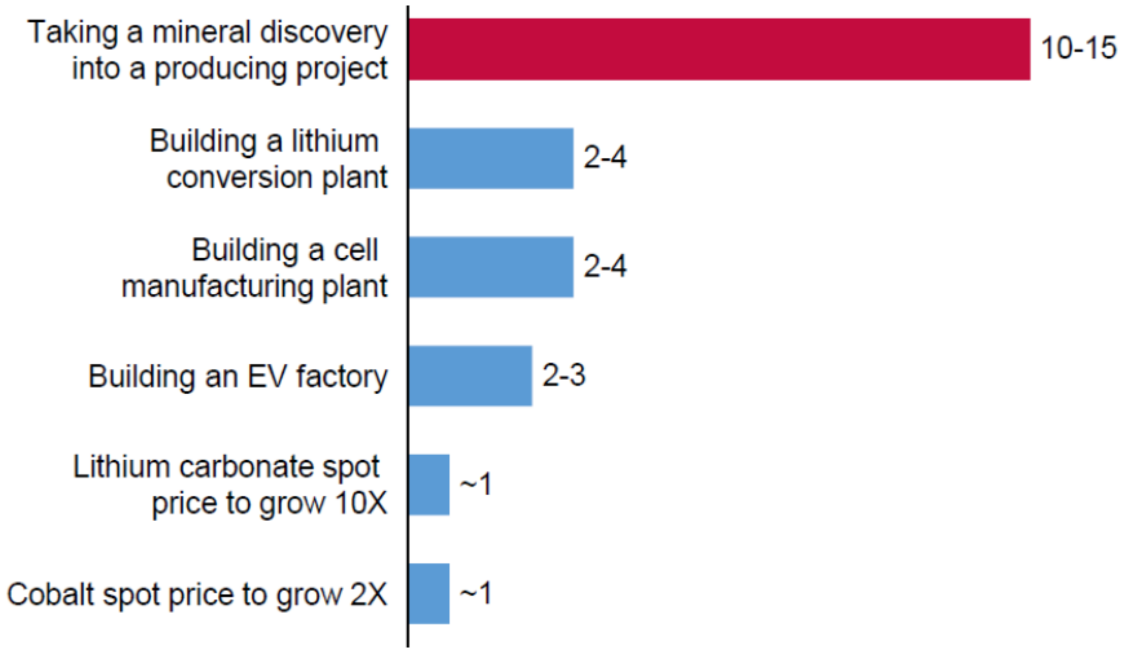
Source: [3] Benchmark intelligence, S&P global.

Exhibit 4: Conversion rate of ore discoveries by decade 1950-2016, Conversion rate = no. of new mines producing / no. of mines discovered



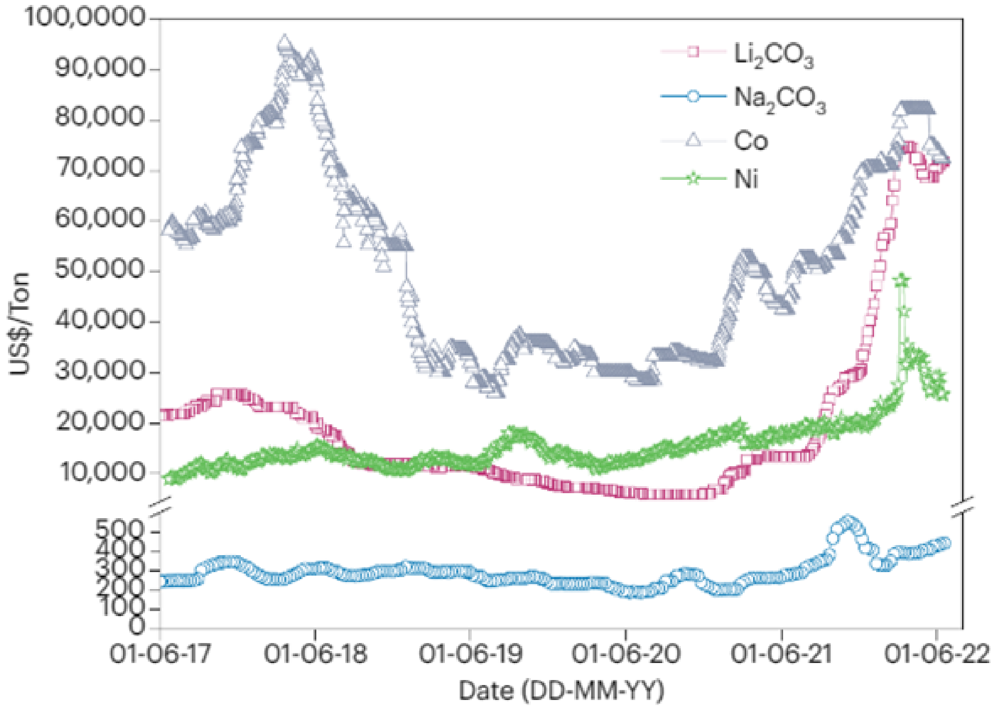
Source: [4] S&P global, MinEx consulting, China Mining conference 2017

Exhibit 5: Prognosis of duration of various critical steps involved and the impact on the pricing on the critical raw material seen over the last 18 months.



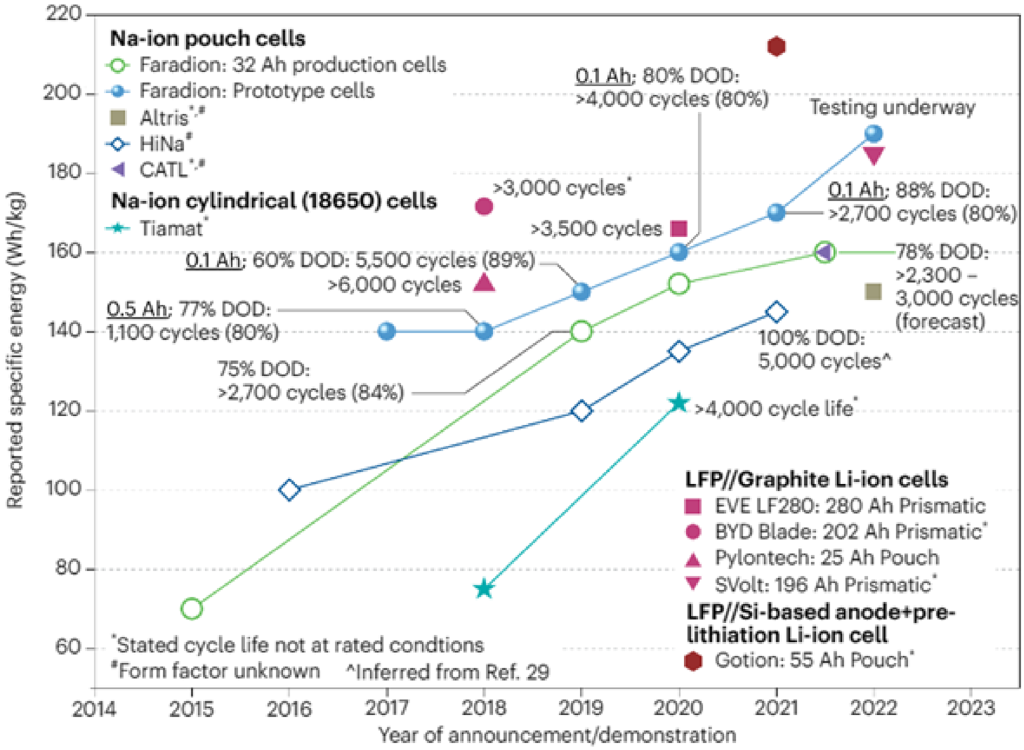
Source: [5] BatteryMBA lecture cohort 7 – Sandvik 01/2023.

Exhibit 6: Comparison of chronological price development of critical raw materials used in Li-B and Na-B



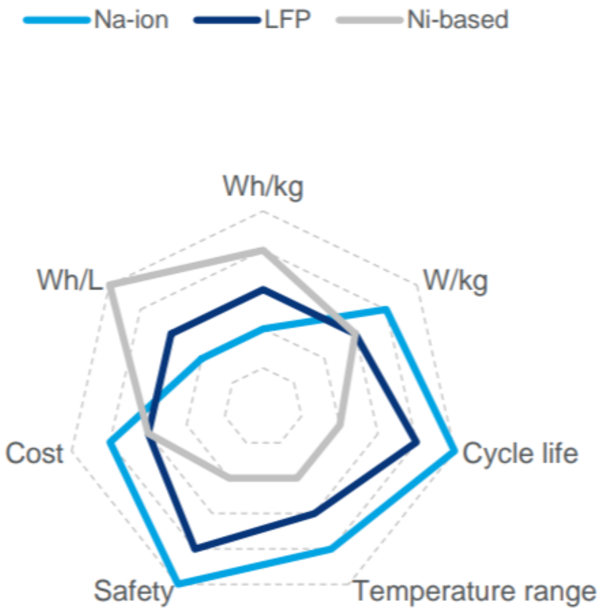
Source: [6] https://www.nature.com/articles/s41560-023-01215-w

Exhibit 7: Development status and current maturity level of different Na-ion battery technologies, from multiple cell builders, technology developers.



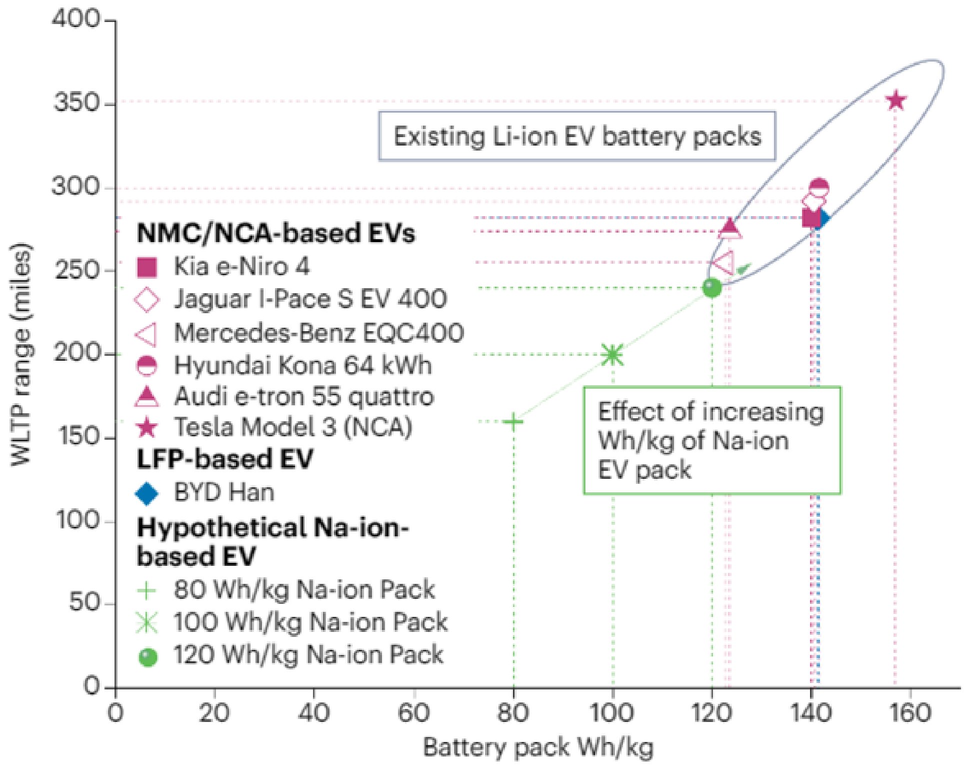
Source: [6] https://www.nature.com/articles/s41560-023-01215-w

Exhibit 8: Sodium-ion cell performance compared to that of Ni-based and LFP.



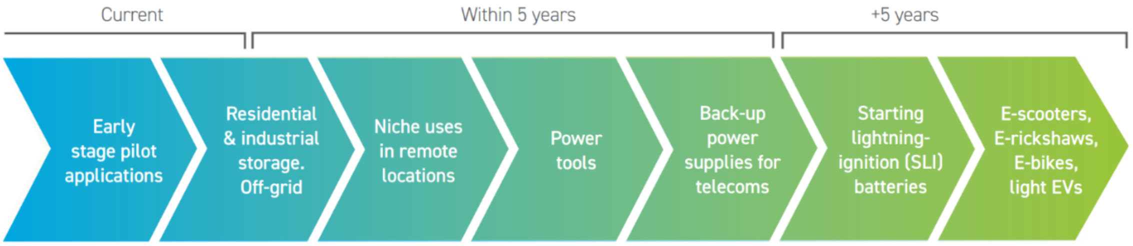
Source: [11]
https://www.woodmac.com/reports/metals-sodium-ion-update-a-make-or-break-year-for-the-battery-market-disruptor-150097670/

Exhibit 9: Comparison of Na-ion based battery packs of different specific energy with existing Li-B battery packs in terms of potential WLTP ranges that could be achieved.



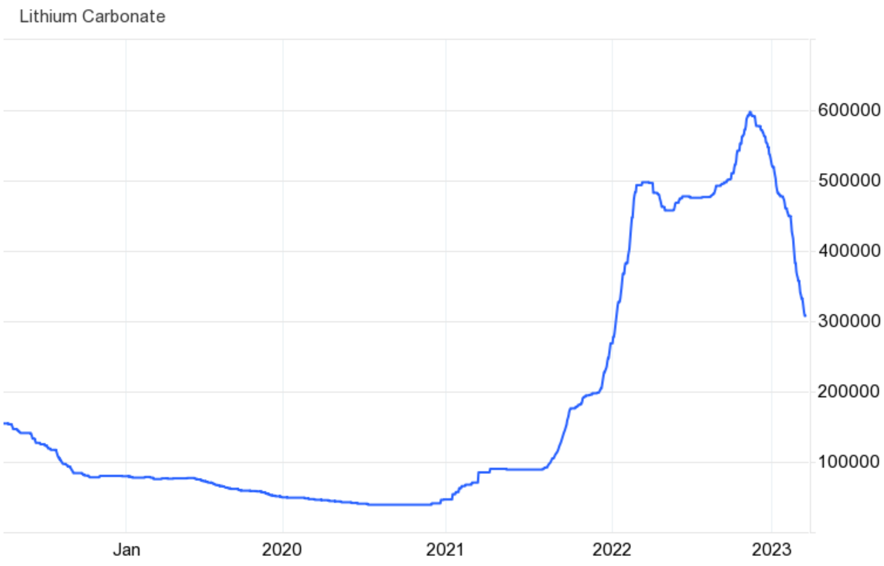
Source: [6] https://www.nature.com/articles/s41560-023-01215-w

Exhibit 10: SIB deployment timeline in various markets.



Source: [15]
https://www.faraday.ac.uk/wp-content/uploads/2021/06/Faraday_Insights_11_FINAL.pdf

Exhibit 11: Lithium carbonate price CNY/metric tonne

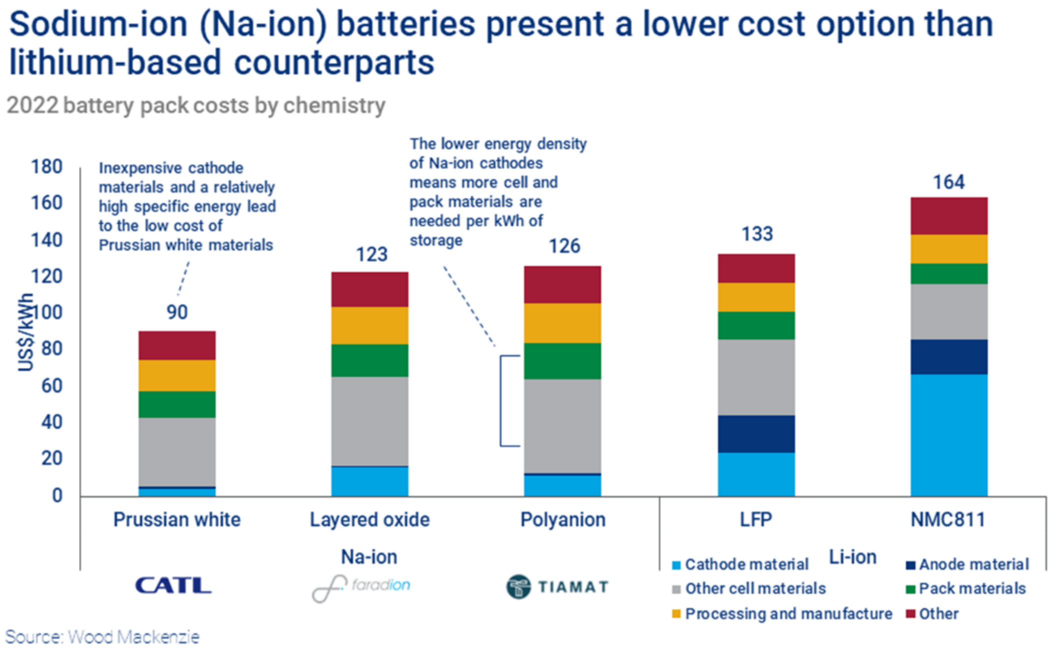


Source: [17] Tradingeconomics.com

Exhibit 12: Sodium carbonate (from Trona) price CNY/metric tonne

Source: [17] Tradingeconomics.com

Exhibit 13 – BOM comparison of various cell formats



Source: [11] Wood Mackenzie - [Sodium-ion batteries: disrupt and conquer? | Wood Mackenzie]

Exhibit 14: Summary of sodium ion battery cell manufacturers

Na+ Battery (SIB) Manufacturers Overview

Manufacturers	Estab.	Collaboration / Investments /Announcements	Cell Energy De.(Wh/Kg)	Charge / dis-charge cycle	Mass Prod.	Website:
FARADION Advanced Energy Storage Solutions	2011, UK	-> Collab. (ESS) : Faradion's IP w/ AMTE 's design & manufacturing. ->2021, Faradion was **acquired by Reliance Industries** of India. -> **w/ IPLTech,** for SIB for **electric Commercial Vehicles** in India	155	3000 cycles	Giga-factory planned in India.	https://faradion.co.uk/
CATL	2011, China	-> CATL released the 1st SIB in July 2021 w/ energy density 160Wh/Kg. -> Next-generation sodium-ion battery energy density will >200Wh/kg. -> Plans to form a basic industrial chain by 2023.	160	Undisclosed	Production Capacity undisclosed.	https://www.catl.com/en/
Natron Energy	2012, USA	-> w/ Clarios : strategic agreement - production of large-scale SIB. -> Developing SIB for >10 years. Mass Manufacturing Q2, 2023.	20-30	50,000 cycles	0.6 GWh/yr in 2023	https://natron.energy/
中科海钠 HiNa BATTERY	2017, China	-> HUA YANG GROUP cooperated w/ HiNa BATTERY & Three Gorges Group to build cathode and anode production lines and SIB cell production lines.	145	4500 cycles	2022: 1 GWh/year Long Term : 5 GWh/yr.	https://www.hinabattery.com/
容百科技 RONBAY TECHNOLOGY	2014, China	-> In the process of technical R&D and production line construction of ferromanganese **Prussian white & layered oxide cathode** materials for SIB	Undisclosed	Undisclosed	Ton-level output in 2022	http://www.ronbaymat.com/
ZOOLNASM 众钠能源	2021, China	-> ZOOLNASH's product is a sodium iron sulfate battery, and its patented method for preparing high-performance cathode materials. -> Investment : Country Garden VC affiliated w/ major developer.	Undisclosed	Undisclosed	2023	http://www.zoolnasm.com/
钠创 NATRIUM	2018, China	-> R&D and production of cathode materials & electrolytes for SIB. -> Downstream customers include Honeycomb Energy, etc. -> App : ESS, electric 2W/3W, low-speed EVs	130-160	5000 cycles	Launch in 2022; 80,000mt of Cathode & Anode materials /year in 3-5 years.	http://natriumenergy.cn/
EVE	2014, China	-> 2022 : Cylindrical, ≥135Wh/kg, 10C Rate w/ 10m FC to 80% SOC, 2500 cycles. -> 2024 : SIB 140-160Wh/kg 6000+ cycles 50$/kWh, -> 2026 : SIB 140-160Wh/kg 10000+ cycles 30$/kWh.	135-160	2500-10,000 cycles	2023	https://www.evebattery.com/en
Tiamat Energy	2017, France	-> Tiamat designs, develops and manufactures SIB for mobility & ESS. -> Develop low-voltage systems for xEVs for electromobility from 2025.	90-120	5000 cycles	6 GWh/year by 2030.	http://www.tiamat-energy.com/
LiFUN	2013, China	-> Low-speed EVs, EV buses, stationary storage batteries for household use -> Presented the 1st consumer-grade SIB.	140	4000 cycles	2023	http://www.lifuntech.com/
Nippon Electric Glass	1944, Japan	-> Exhibit of All-Oxide All-Solid-State Sodium (Na) Ion Secondary Battery (2022)	Undisclosed	Undisclosed	2025	https://www.neg.co.jp/en/
BYD	2003, China	-> BYD to launch electric hatchbacks with new Sodium-ion batteries. -> New BYD Dolphin EV hatchback was recently spotted tested in Sydney	Undisclosed	Undisclosed	2023	BYD News

Source: [18]
https://www.linkedin.com/posts/himanshu-bhatt-6b544a19_sodium-ion-battery-manufacturers-activity-7016994803242475520-mPPb/?originalSubdomain=me

Sources

[1] Battery MBA course lecture by Roland Berger, 01/2023
[2] Compiled by Roland Berger with data from BMO, Deutsche Bank, Fast markets, Raskill and presented in BatteryMBA class 01/2023.
[3] Benchmark intelligence, S&P global.
[4] S&P global, MinEx consulting, China Mining conference 2017
[5] BatteryMBA lecture – Sandvik 01/2023.
[6] https://www.nature.com/articles/s41560-023-01215-w
[7]https://www.worldatlas.com/articles/the-most-abundant-elements-in-the-earth-s-crust.html
[8] https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-salt.pdf
[9]
https://www.businesswire.com/news/home/20221017006023/en/Natron-and-Arxada-Announce-World%E2%80%99s-First-Large-Scale-Production-of-Battery-Grade-Prussian-Blue-Materials
[10]
https://www.volta.foundation/annual-battery-report
[11]
https://www.woodmac.com/reports/metals-sodium-ion-update-a-make-or-break-year-for-the-battery-market-disruptor-150097670/
[12] https://amtepower.com/our-products/
[13] https://faradion.co.uk/first-faradion-battery-installed-in-australia/
[14]
https://www.notebookcheck.net/First-electric-car-with-cheap-sodium-ion-battery-offers-157-miles-of-range-as-it-appears-out-of-a-VW-partnership.697298.0.html#:~:text=The%20first%20generation%20of%20mass,safer%20than%20its%20lithium%20counterparts
[15]
https://www.faraday.ac.uk/wp-content/uploads/2021/06/Faraday_Insights_11_FINAL.pdf
[16]
Size-matters-the-economic-and-environmental-impact-of-smaller-EV-batteries-1.pdf (exa-watt.com)
[17] Tradingeconomics.com
[18]
https://www.linkedin.com/posts/himanshu-bhatt-6b544a19_sodium-ion-battery-manufacturers-activity-7016994803242475520-mPPb/?originalSubdomain=me
[19]
https://www.tycorun.com/blogs/news/top-10-sodium-ion-batteries-anode-materials-suppliers-in-the-world
[20]
https://www.sciencedirect.com/science/article/pii/S2542435120302403