At the CORE of Umicore's
Battery Materials

Umicore's battery materials innovation roadmap for next-generation EV technologies

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New Business Incubation

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Longer-term trends for EVs

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Solid-state batteries to unlock the next level of battery performance

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Key take-aways

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Longer-term trends for EVs:

taking the step beyond liquid lithium-ion batteries

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The race for the super battery

Faster, further, cheaper, more sustainable

"We want to have a future where mobility is accessible to all. We are innovating, ***driving costs down*** *and packaging the latest technologies in all our vehicles, from the most affordable ones to the high-performance offerings."*

Stellantis

"BMW plans to use ***the new solid-state battery*** *in the "Neue Klasse", which will be launched in 2025. The Neue Klasse represents a new generation of vehicles that will* ***set new standards*** *in terms of electrification."*

BMW

"Many players in the automotive market are fighting for the ***sensational new sodium-ion battery*** *that could well change the future of the electric car. Renault is ahead of its competitors."*

Renault

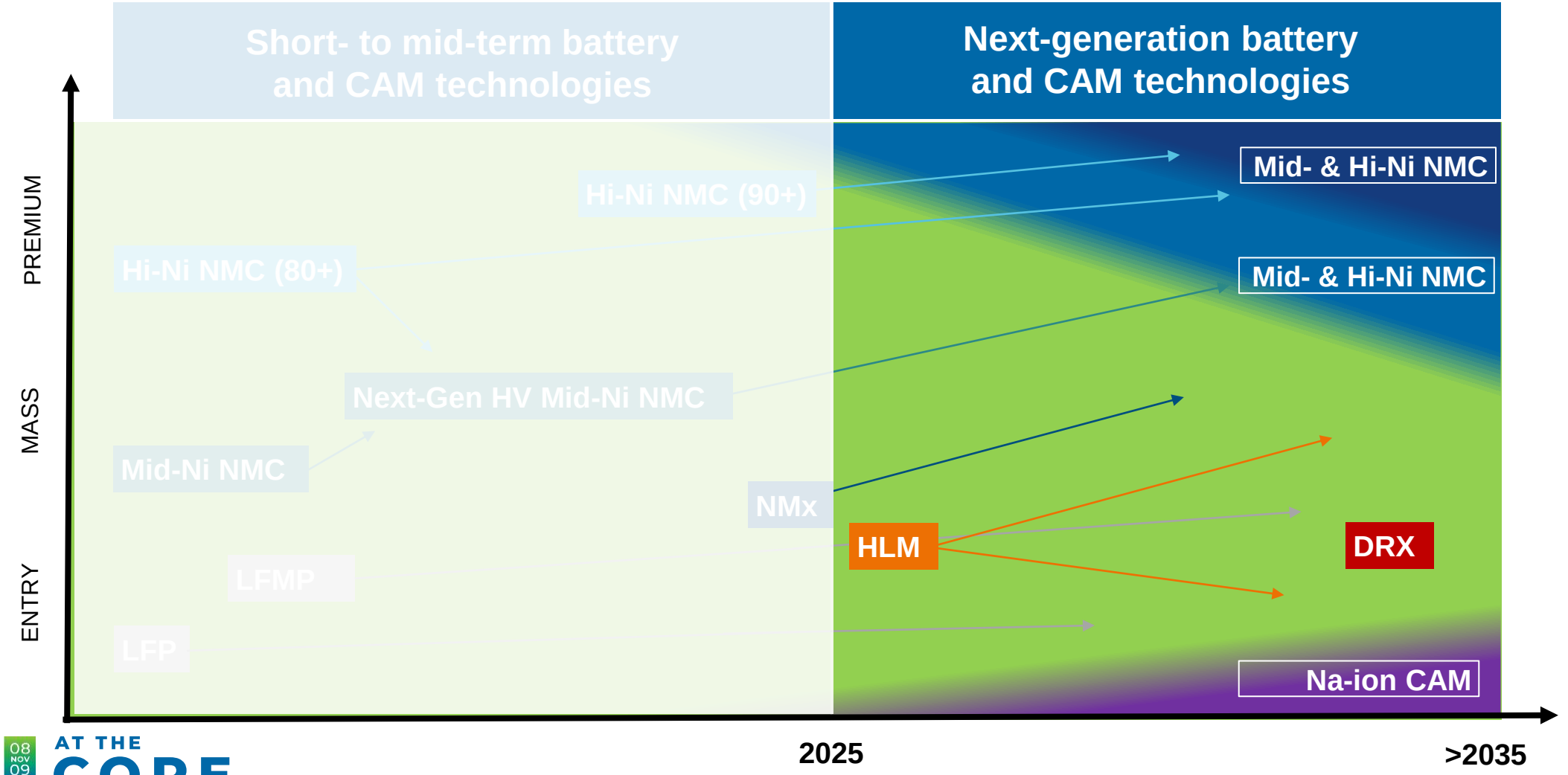
"A consortium of the nation's best battery scientists led by Lawrence Berkeley National Laboratory will accelerate the commercialization ***of a new family of battery cathode materials called DRX*** *or disordered rock salt. DRX cathodes could provide lithium-ion batteries with* ***higher energy density*** *and make batteries for electric vehicles* ***more sustainable."***

Berkeley Lab

Different next-gen battery technologies in car OEMs' roadmaps to unlock higher energy density, lower costs and better sustainability performance

Wide spectrum of next-gen EV batteries

Fully reflected in Umicore's battery materials innovation roadmap



Liquid Li-ion battery

NEW TYPES OF BATTERIES

All-solid-state battery

Semi-solid-state battery

Na-ion battery

Source: Umicore

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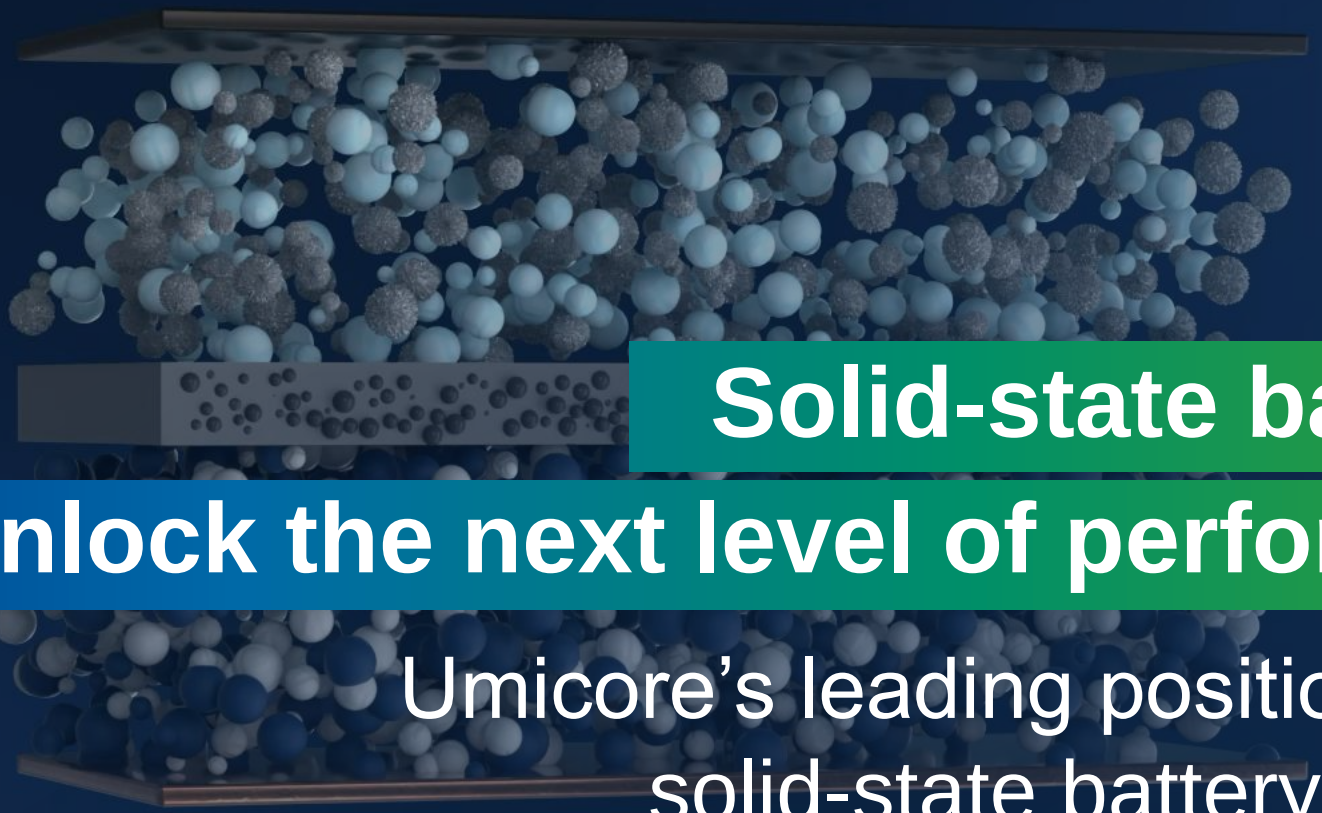

Solid-state batteries to unlock the next level of performance

Umicore’s leading positioning as a solid-state battery materials technology provider

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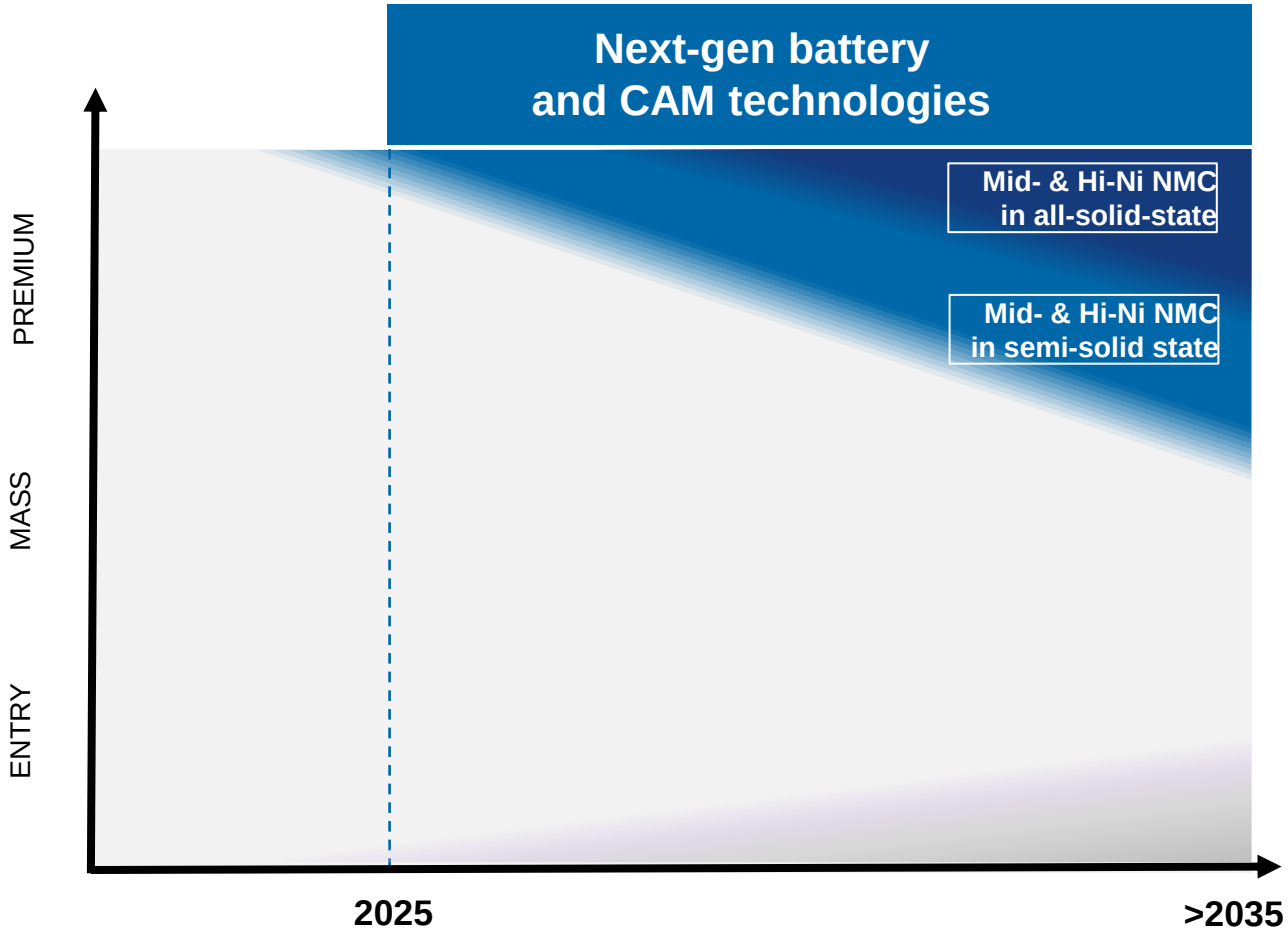
From liquid to semi-solid to all-solid-state

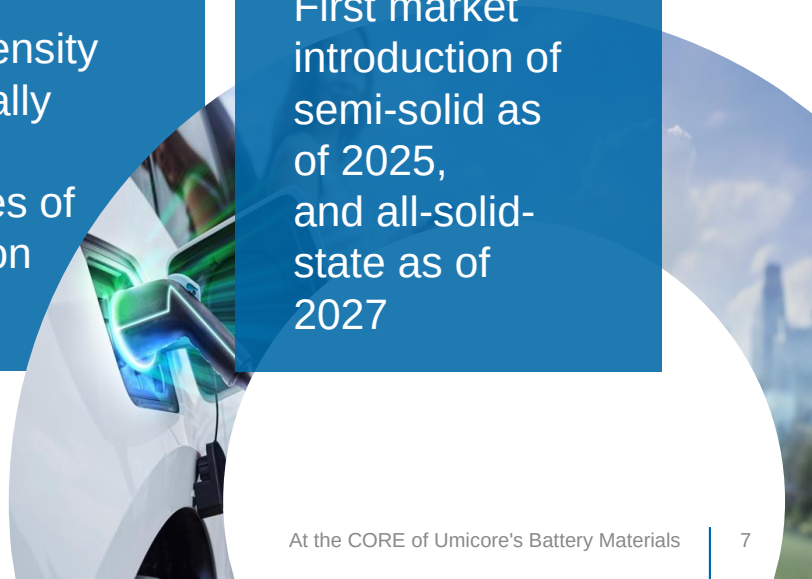
Unlocking the next level of performance



Solid-state batteries unlock superior energy density; initially for premium and later also for mass EVs

Energy density substantially beyond capabilities of liquid Li-ion batteries

First market introduction of semi-solid as of 2025, and all-solid-state as of 2027



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Solid-state batteries

Unlocking the next level of performance

*“A trip of 700 km on one charge. A recharge from zero to full in roughly 10-15 minutes. All with **minimal safety concerns**. The solid-state battery promises to be a game changer not just for electric vehicles. EVs will have a **range more than twice the distance of a conventional Li-ion** battery under the same conditions. All accomplished **without sacrificing interior space** in even the most compact vehicle.”*

Toyota

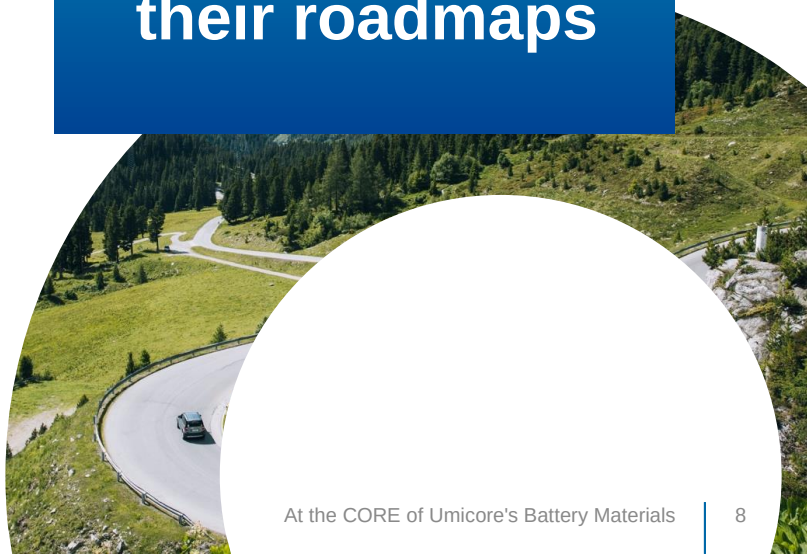
*“We believe that **range and efficiency** are the new industry benchmarks for electric cars. Solid-state technology helps **to cut down battery size and weight**. “*

Mercedes-Benz

*“We are **accelerating development of solid-state** batteries that will give our products **more range, as well as faster charging and lighter weight**”*

Stellantis

Major car OEMs have incorporated solid-state batteries in their roadmaps



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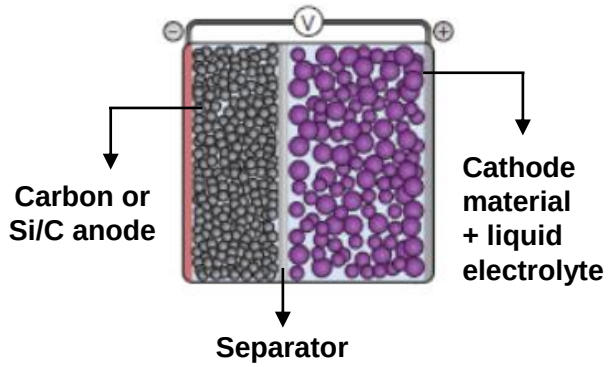
Solid-state batteries

When the electrolyte becomes (semi) solid

Liquid (advanced) Li-ion

Energy density target: 250-350 Wh/kg and 600-800 Wh/L

Mass production since 2021 for advanced Li-ion

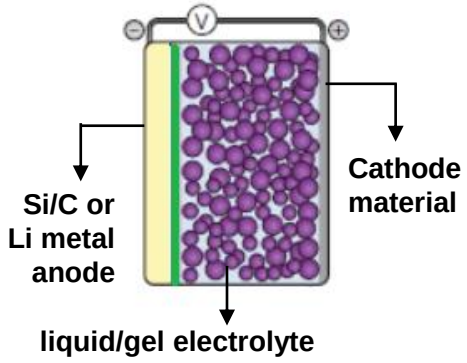


Umicore Hi-Ni NMC and HLM CAM (including high voltage for advanced Li-ion)

Semi-solid state

Energy density target: 350-400 Wh/kg and 650-850 Wh/L

Market introduction semi - solid with Si anode as of 2025

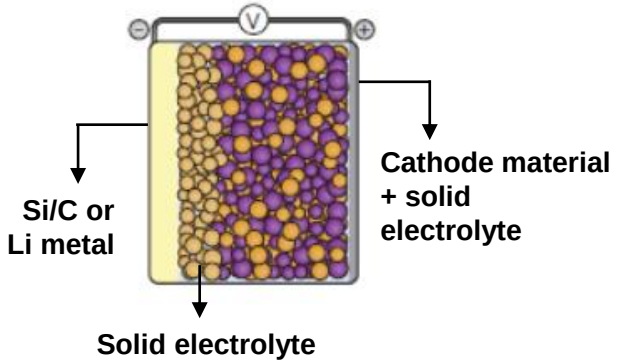


Next-gen Umicore NMC (including high-voltage products)

All-solid state (ASSB)

Energy density target: 450-550 Wh/kg and 900-1200 Wh/L

Market introduction as of 2027

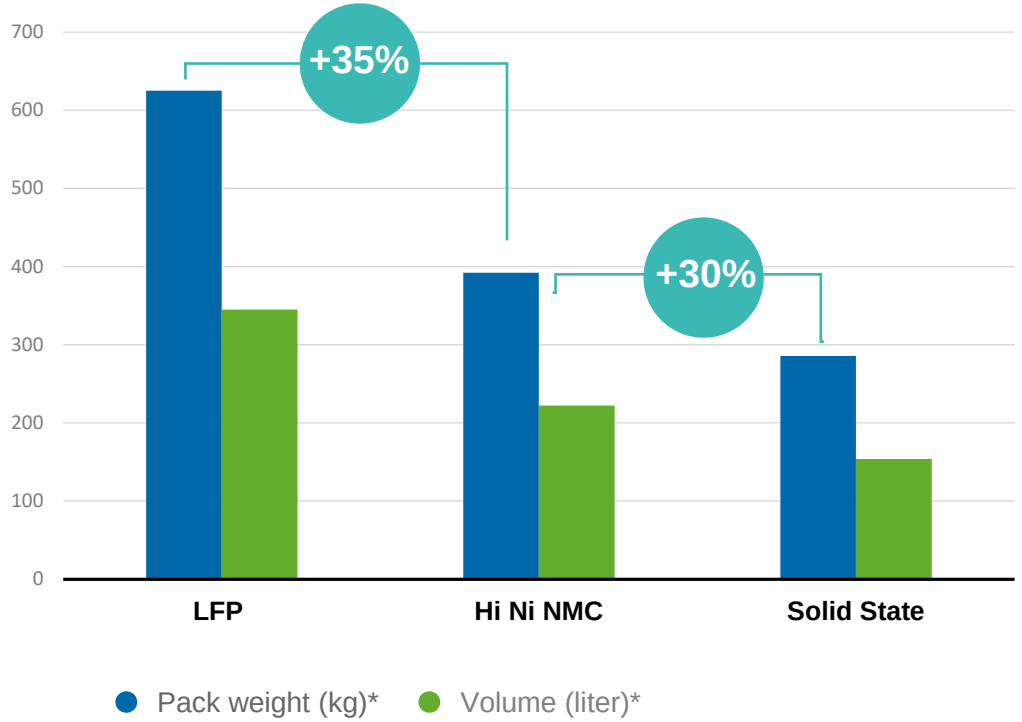


Tailor-made Umicore NMC and 'catholyte'

Solid-state batteries

Unlocking superior performance

Gravimetric and volumetric performance of mature all-solid-state battery vs liquid Li-ion (cell to pack)



Higher energy density

Allowing longer driving range or smaller batteries

Higher safety and faster charging

Battery more tolerant to heat, greatly reducing risks of ignition or explosion

Efficiency gains

Simplified packaging and cooling systems reducing total weight and size of battery pack leading to battery range improvement

Lower overall $/kWh beyond 2030 on pack level versus advanced liquid Li-ion NMC due to high energy density and simplified pack integration

*Simulation based on 100kWh battery pack, commercial LFP and NMC cell to pack configurations and solid-state development

Umicore’s head-start in solid-state batteries

Developing new opportunities based on leading NMC position today

Offensive R&D strategy on SSB since 2017:

- **Validate time to market** and **winning SSB technologies**
- **Extend** Umicore’s battery materials **innovative edge** also on post liquid Li-ion battery technologies
- **Adjacent positioning** for extra value creation
  - Scout competing electrolyte technologies and impact on Umicore products
  - Opportunistic step toward next-generation anodes

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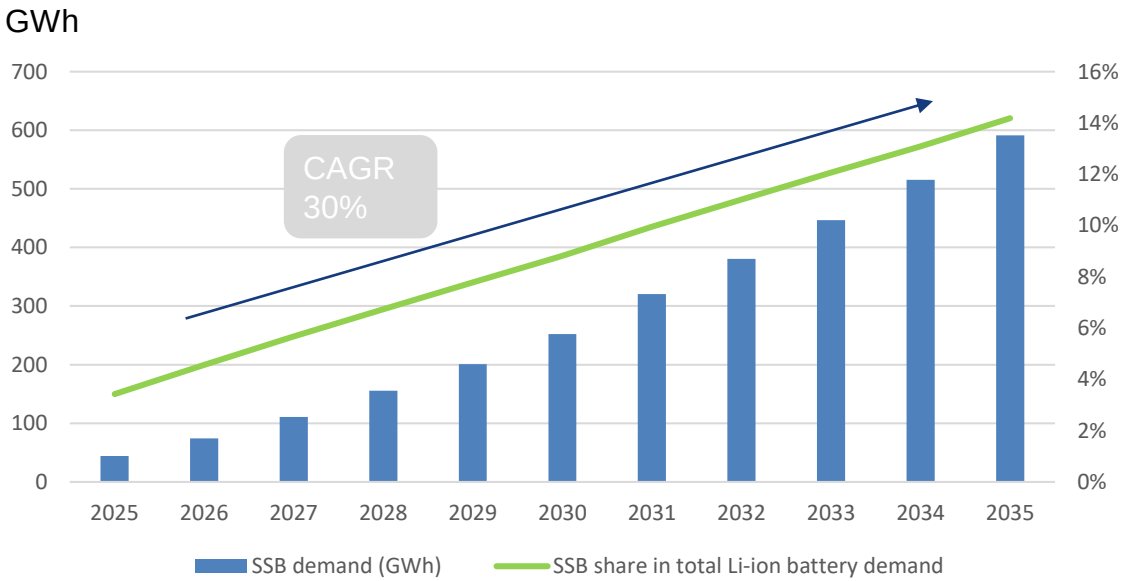
Clear view on SSB market and technology dynamics

Validate time to market and winning technologies

Clear view on SSB market and technology dynamics

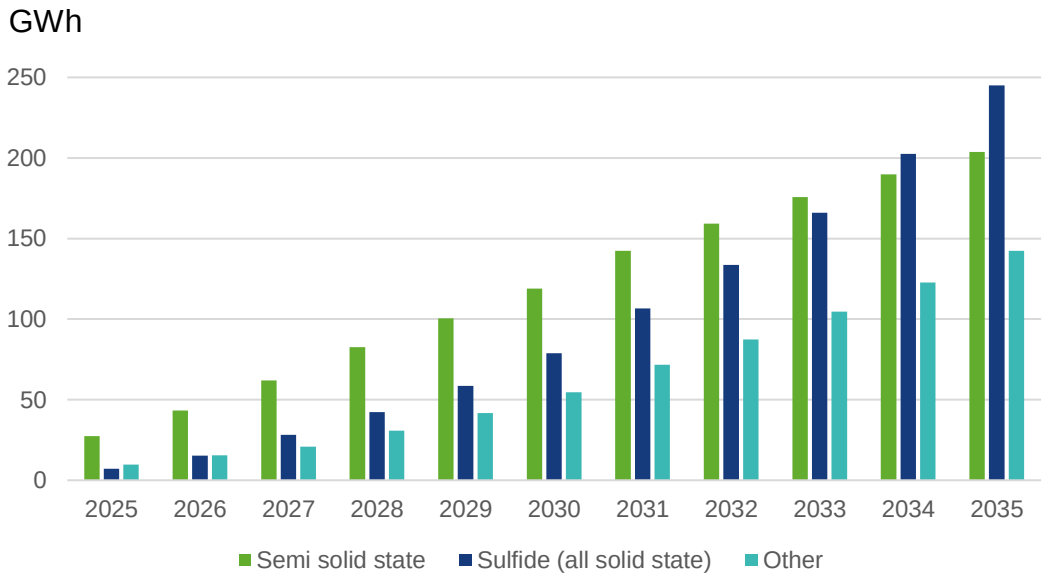
SSB demand forecast



Source: Umicore market model

Demand for solid-state batteries growing with ~30% CAGR, to represent about 14% of total EV Li-ion battery demand in 2035

SSB type



Source: Umicore market model

Rapid introduction of semi-solid batteries, to be progressively taken over by all-solid-state batteries, mainly sulfide-based as of 2030

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Full portfolio of IP protected semi- and all-solid-state battery dedicated CAM materials

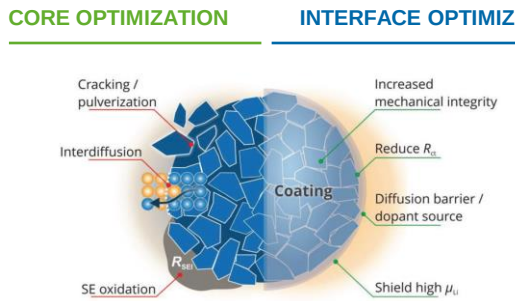
Advanced process innovation (e.g. compatibility with Umicore’s existing production lines and large-scale prototyping center)

Umicore CAM integrated in solid-state demo cars as of 2024 with mass production SOP before the end of decade

Extend Umicore's battery materials innovative edge

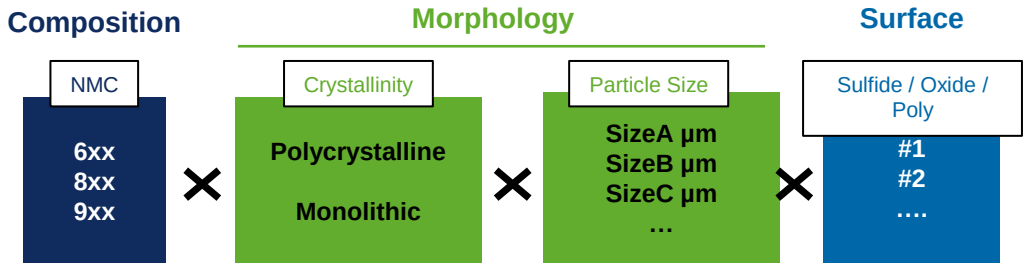
Full portfolio of IP protected semi and all-solid-state CAM

- **Maximum performance** through **core optimization** (composition, morphology, particle size and doping) **and surface engineering** (advanced coatings for SSBs)



Source:
Culver et al, Advanced Energy Materials (2019): https://doi.org/10.1002/aenm.201900626

- **Umicore's "Building Block" tailored approach** to different cell systems (electrolytes, electrodes and cell designs) and applications (operating conditions, target metrics)
- **Excellent start from leading monolithic Hi-Ni NMC position today**



- Strong **collaboration with partners** (universities and cell OEMs)
- **44 patents** filed related to SSB materials

Publicly disclosed partnerships

Extend Umicore’s battery materials innovative edge

Advanced process innovation: robust testing methodology and co-optimization with solid-state cells

Proper development of CAM for solid-state batteries requires strong integration capabilities to test products in relevant environment

Over the past 7 years, Umicore has acquired extensive know-how in solid-state electrode formulations and manufacturing (wet and dry), characterization and cell testing

This allows us to provide customers with optimized recipes for maximized CAM performance of

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Solid-State Battery Prototyping Center

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Extend Umicore's battery materials innovative edge

Umicore CAM integrated in solid-state demo cars as of 2024, mass production expected before end of decade

Stage A

Product design verification and lab sampling

- 4 battery OEMs
- 1 car OEM (Asia)
- 1 solid-state start-up company
- JDAs and ongoing tests for both semi-solid and all-solid state battery materials (including sole supplier status)

Stage B

Process scale-up and pilot sampling

- 4 battery OEMs
- 2 car OEMs (Japan)
- 2 solid-state start-up companies
- JDAs and MoUs for both semi-solid and all-solid state battery materials (including sole supplier status)

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Umicore’s headstart in solid-state batteries

Developing new opportunities based on leading NMC position today

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launch of “catholyte” with leader in the solid electrolyte field

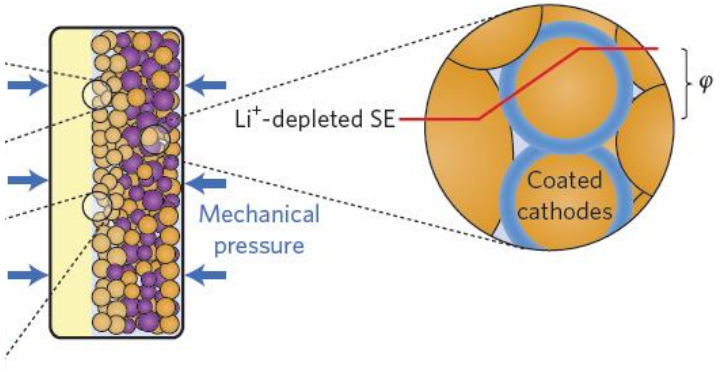
Si/C materials for semi-solid and all-solid-state batteries in advanced screening phase

Catholyte enabling break-through in SSB

Launch of catholyte materials unlocking additional value creation

All-solid-state sulfide battery still has hurdles to overcome:

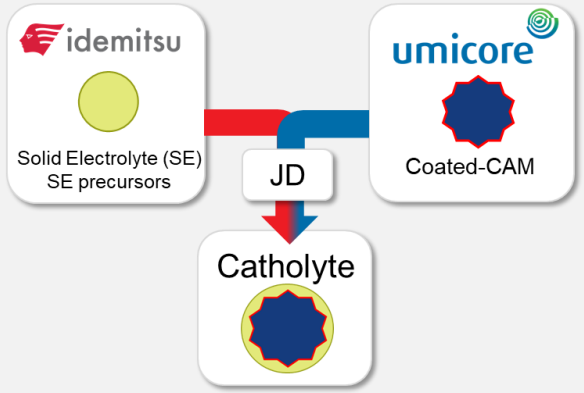
- High resistivity in electrode leading to power and temperature performance issues
- High amount of SE in electrode resulting in lower-than-expected energy density
- Solid contact between particles requiring pressure around cell



Source:
After Janek et al, Nat. En., 2016

Innovative “catholyte” material developed with electrolyte leader:

- Collaboration with Idemitsu on CAM-electrolyte achieving better power, higher energy density and simplified integration
- Assessment of various manufacturing routes with proof-of-concept validation by partner OEMs



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Idemitsu
Mr. Nakamoto

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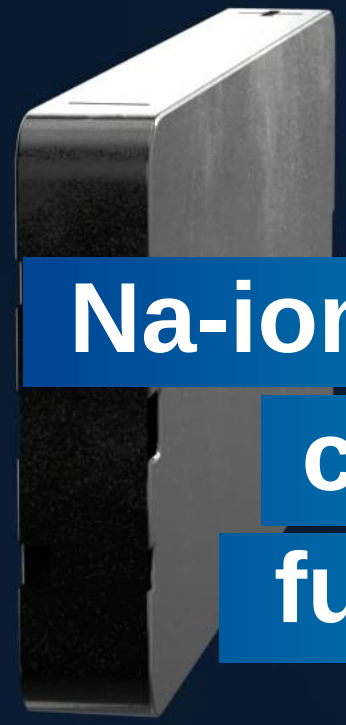

Na-ion batteries and DRX cathode materials to further reduce costs:

Umicore’s pioneering role

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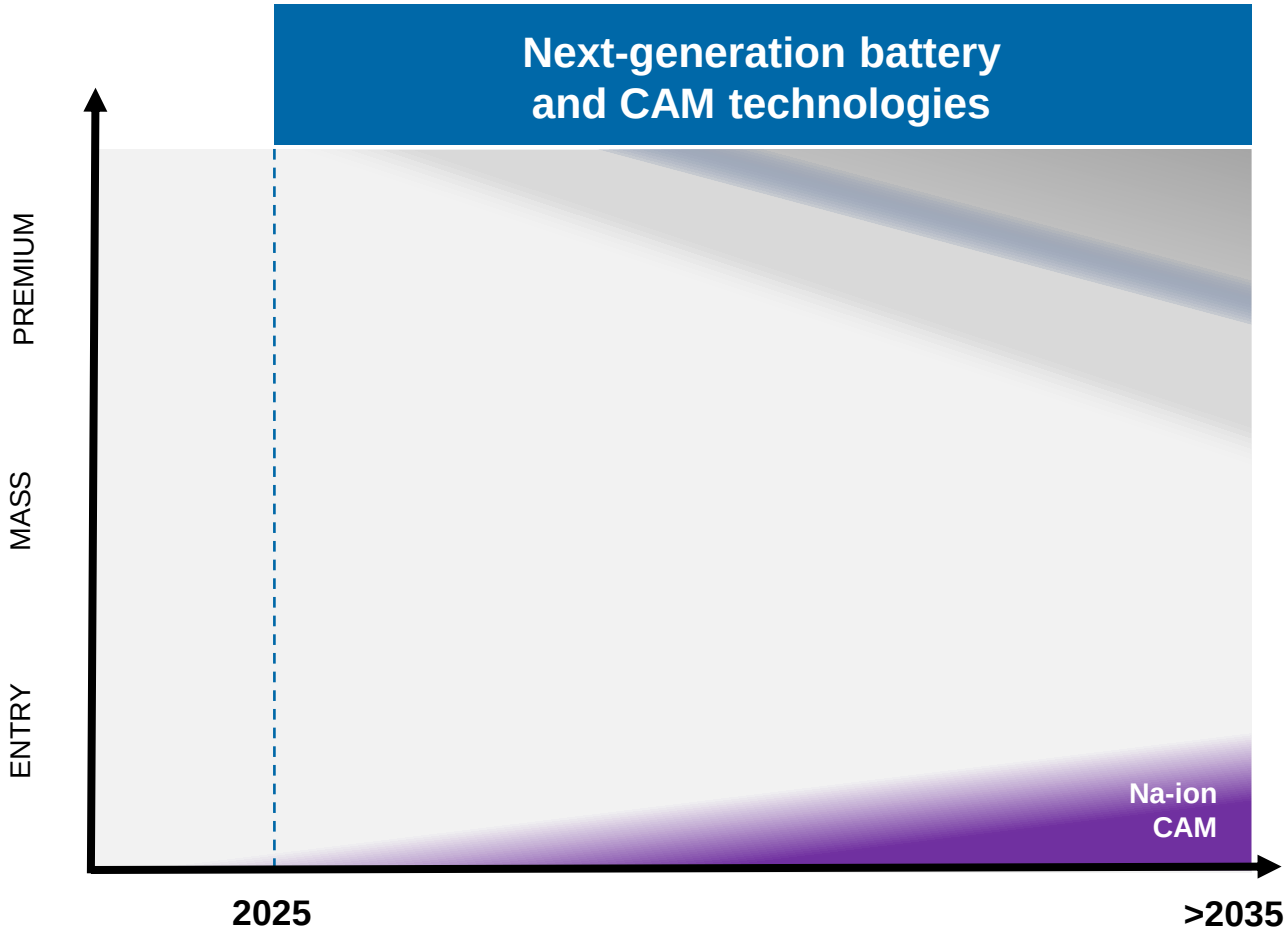
Sodium-ion batteries (Na-ion)

Moving beyond Li-ion



Na-ion batteries have the potential to further drive down costs for entry segment

Same energy density as LFP but ca. 20% cost advantage*

Current phase: ongoing innovation to achieve LFP energy density levels as of 2026

*Linked to long-term Li pricing

Na-ion batteries

Driving EV costs further down

Sodium is an abundant low-cost, safe and sustainable material with chemical properties similar to lithium

Compared to LFP, Na-ion is a high-power technology with a better cost structure

Very promising technology for future globalization of entry segment (city cars) in light of expansion of urban zero emission zones > 2025

Various types of Na-ion technologies coexist:

V/F-based polyanion
similar process to LFP,
focus on power and cycle

Mn-based oxide -- technology of choice for transportation segment
similar process to NMC, focus on energy density

Prussian blue-based
organo-metallic chemistry,
focus on power, cycle and cost

Na-ion batteries

Umicore's pioneering role to further reduce costs for entry segment

Umicore focusing on

Mn-based oxide similar process to NMC, focus on energy density

Opportunity for Umicore in Na-ion CAM material

Strong advantages versus LFP

- Better performance under extreme temperature environment (low/high)
- Better fast-charging, life and safety performance
- Lower cost and cost volatility due to materials used

Technical hurdles to overcome

- Low energy density – more developments needed
- Absence of hard carbon supply chain

Through its unique competencies (crystalline structure and doping) Umicore's CAM allows to reach energy density levels required for the entry segment: **as of 2025 long-term energy density at par with LFP***

Cost structure to improve with supply chain maturation: **long-term cost expected to be 20% lower versus LFP***

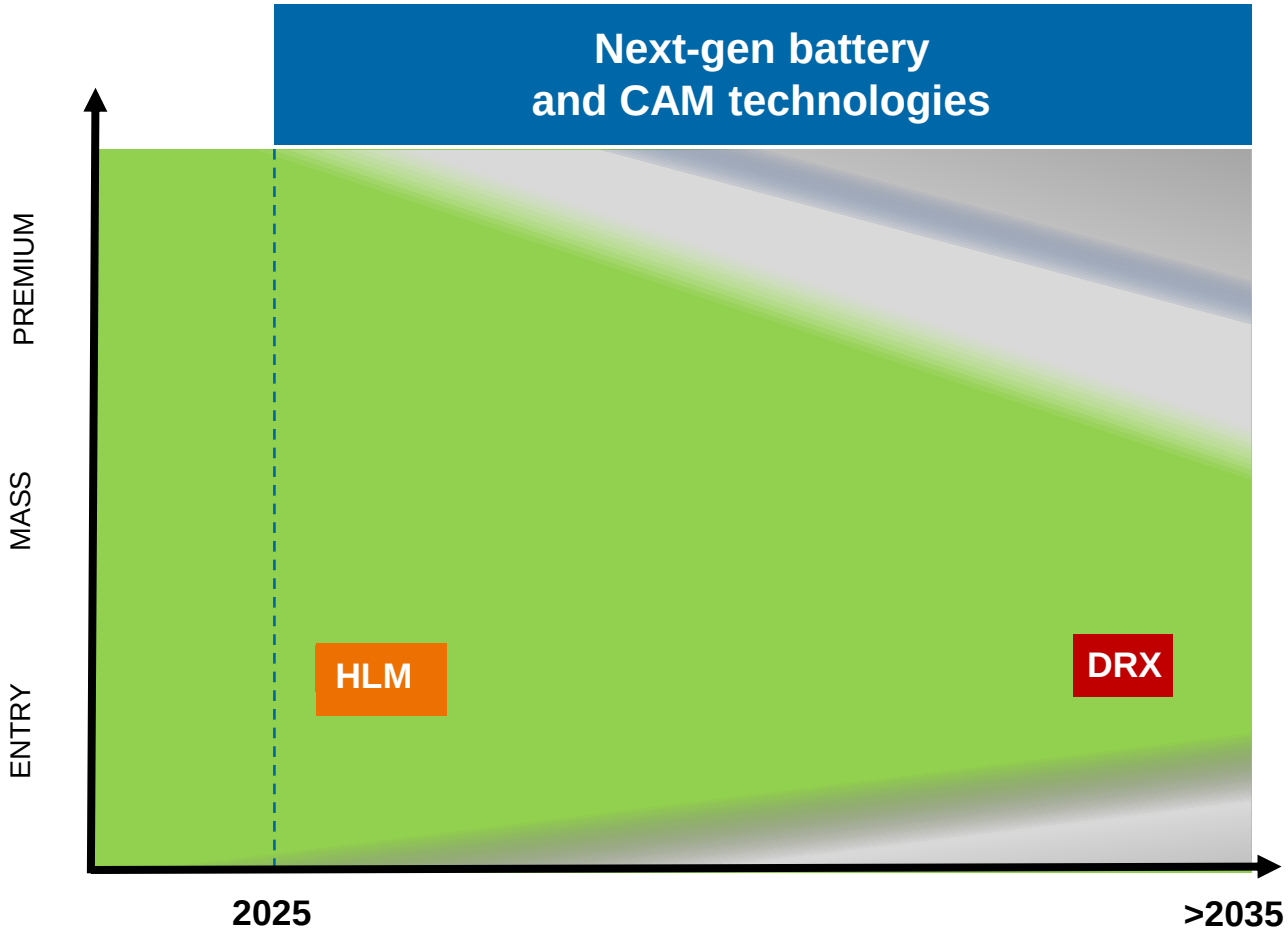
Advanced pCAM/CAM designs needed to achieve targeted performance metrics **=> no commoditized technology**

Can be produced on existing NMC production lines

*Total cell price USD/kWh based on long-term metal prices – based on internal and external research

Disordered rocksalt (DRX) CAM

For Li-ion batteries



DRX CAM in Li-ion batteries have longer-term potential to further drive down costs in mass market segment

Promise of energy density at par with HLM, but at significant cost advantage

Current phase: validation of performance claims in lab

Li-ion battery with DRX CAM

Promising potential in the longer-term

Promising DRX CAM technology for liquid Li-ion batteries:

- Li-rich // Co & Ni free
- Advantages: low metal base, very high capacity rate, safety => cost improvement vs HLM for mass market segment
- Challenges: cycling stability and integration to be optimized

Umicore among the pioneers:

- Active in exploring DRX CAM materials with Prof. Ceder at MIT/UCB for the last decade
- Base IP secured and programs with downstream partners planned to start in 2024 to further validate value proposition
- Current status: further validation of performance claims

*"**DRX cathodes** can be made with almost any transition metal instead of nickel and cobalt. That versatility **is key if we want to replace gasoline vehicles** with electric vehicles."*

Gerbrand Ceder, Berkeley Lab faculty senior scientist, Materials Sciences Division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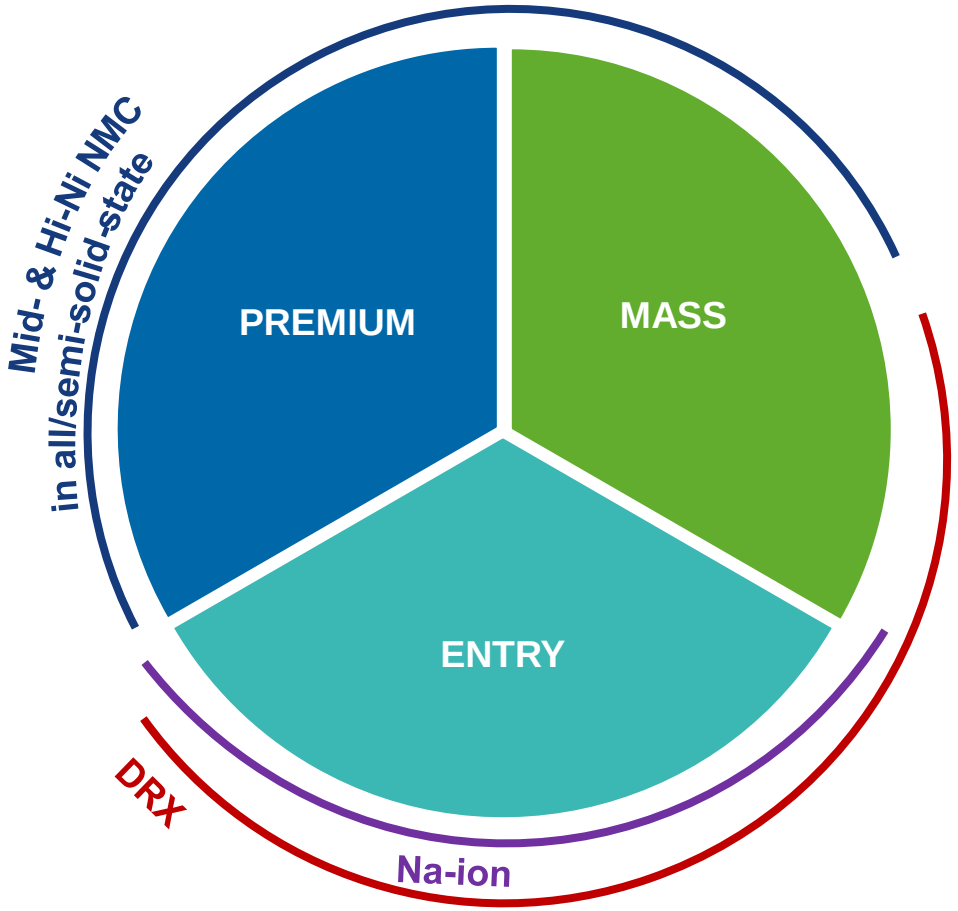
Key take-aways



Clear view on next-gen technology solutions to meet car OEMs and cell manufacturers' needs for different EV segments

Clear trend of continued product and process innovation (no commoditization)

Umicore uniquely positioned to capture potential of these next-gen technologies:

- Excellent starting position from industry-leading Hi-Ni NMC position today
- Leading position as solid-state battery materials provider with key product and process innovations and multiple customer collaborations
- Pioneering position in Na-ion battery materials and DRX CAM
- All technologies compatible with existing production infrastructure

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OF UMICORE'S BATTERY MATERIALS

NOVEMBER 8TH AND 9TH

WROCLAW & NYSA

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