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Connecting the dots in energy storage

Where Technology Risk-Takers Diverge: Five Open Decisions on the Road to Solid-State & Solid-Liquid Electrolyte Battery Launches

Anode Posture · Operating Pressure · Processing Route · Stack Architecture · Market Entry – Based on an AI-Supported Patent Analysis

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1 Hypothesis: The Sulfide Surge Is the Industry's Answer to the No-Fire / No-Explosion Principle

China's GB 38031-2025 "no fire, no explosion" mandate◆ (in force 7/2026) makes **intrinsic propagation resistance** decisive. Industry **prioritizes sulfides** – thermally the best fit among high-rate chemistries* – and must build everything new, incl. a **layered H_2S safety concept** (26 of 40 covered companies): every layer patentable. Sulfide's share of chemistry-assigned patent families (40%→≈61%, 2022→2026) reflects **engineering surface, not market proximity** – the least-filed track, solid-liquid, is the furthest scaled.

2 Hypothesis: Companies De-Risk by Running Parallel Electrolyte Tracks In-House

Past capability jumps were enabled by beachhead niche markets – for sulfide-class cells that ladder is thin*, so **staging has moved in-house**: **17 of 40 covered companies hold patent portfolios with three or more electrolyte classes in depth**, sequenced – **solid-liquid ships and ramps now, sulfide staged behind** (small-batch targets 2027+◆). Pack designers and component suppliers face **divergent requirements per track***: stack pressure, architecture, processing route.

3 Takeaway: 2026–2028 Is an Unusually Dense Validation Window

Independently scheduled events now cluster: **China's no-fire / no-explosion type approval becomes mandatory (7/2026◆)**, solid-liquid mass-production ramps (2026◆), sulfide precursor plant and small-batch launches (2027◆), premium-vehicle deployments (2027–28◆) – each settles part of one of the five open decisions. Gates to watch: **≤1 MPa full-cell operation, <20 micrometer solid electrolyte layers at roll-to-roll speed, layered H_2S control at type approval**.

* author hypothesis, reasoned beyond the patent record · ◆ public-information anchor (official / regulatory sources, references available)

Methodology – AI-Supported Patent Analysis, Anchored by Continuous Expert Curation

Forward-looking author views, traceable to the underlying patent record

1. **Patent capture** – 8,500+ patent families published since 2022 · EPO-sourced, covering >100 patent offices · 41 leading innovators tracked individually plus the broader field.
2. **AI full-document analysis** – OCR-assisted reading of complete documents incl. tables and figures – one structured technical summary per patent family, multilingual.
3. **Classification & KPI extraction** – Electrolyte class, development focus, and quantitative values (conductivity, operating pressure) extracted and plausibility-screened before any statistic is drawn.
4. **Continuous expert curation** – Triweekly subject-matter expert screening since early 2022 anchors significance, validation gates and the forward-looking reads on this poster.

Traceability rule (excl. case studies): every quantitative statement on this poster is supported by at least two patent families from at least two independent applicants. The underlying publication numbers – with EPO and Google Patents links – plus all public-information anchors are available.

* author hypothesis, reasoned beyond the patent record · ◆ public-information anchor (official, regulatory or peer-reviewed sources)

Patent analysis-related confidence grades used in the decision panels:

STRONG EVIDENCE IN PATENTS multiple corroborating patent families from independent applicants, incl. scale or full-cell evidence

MODERATE EVIDENCE IN PATENTS narrower evidence base – few patent families, or sub-scale / component-level data only

THIN EVIDENCE IN PATENTS limited or indirect evidence – early-stage, single-configuration, or inferred from adjacent disclosures

Data source: European Patent Office (covers >100 patent offices globally). Patent families, not granted patents, grant status, geographic coverage and claim scope vary within patent families. Patent family counts reflect IP strategy as much as R&D intensity. This poster supports technical decision-making, it is not legal advice, and all IP-law questions belong with qualified patent counsel.

Decision 1 – Anode Posture

Li-metal excess vs. 'Anode-free' vs. Si-based · the energy-vs-manufacturability bet

Li-metal excess foil – Thin Li foil carries the lithium inventory, engineered interlayers manage plating and stripping.
3,011 patent families reference Li-metal anodes · 687 (2022) → 817 (2025) per year ('anode-free' excluded)

'Anode-free' / in-situ plated – Lithium plated from the cathode on first charge, no anode coating line, highest volumetric density.
526 patent families reference 'anode-free' designs · 70 (2022) → 201 (2025) per year

Si-based composite – High-capacity Si tamed by composite design, closest to incumbent electrode manufacturing.
648 patent families reference Si-based anodes · 140 (2022) → 220 (2025) per year

	Li-metal excess	'Anode-free'	Si-based
Performance advantage	Precursor to 'anode-free'*	Best volumetric density, rate-limited by plating	Fast-charge tolerant
Manufacturability	≈20 µm foil solved (extrusion-type process), PVD routes target ≈5 µm, at-scale cost still to be validated*	Simplest bill of materials, hardest plating uniformity*	Reuses incumbent coating lines
Failure modes	Dendrites / critical current density, interlayer chemistry decisive (in-situ polymerized networks, mechanical suppression layers)	First-cycle Li loss, nucleation control via seed layers with tight composition windows	Expansion management: compliant current collectors, fibrous interlayers, particle engineering
Cost direction	Li-foil premium, foil-width limits	Lowest materials cost, yield risk carries it*	Metallurgical-Si cost path attractive*

COMMERCIALIZATION STATUS
Direct-path sulfide EV programs **likely pair with Si-based anodes at launch** according to patent filings and prototypes of multiple majors, Li-metal is typically positioned as the later energy step*, 'anode-free' is the fastest-growing anode signal (≈3× since 2022, vs. ≈1.2× Li-metal excess foil and ≈1.6× Si) with the least application deployment evidence.

WHAT WOULD SETTLE IT*
Critical current density at ≤1 MPa in multi-layer pouch cells · first-cycle inefficiency budgets at pack level · inline methods that verify uniform lithium plating at production-line scale & speed.

Counts: patent families whose AI-based summary references the respective anode posture, across the full 8,500+ patent family corpus (publication dates since 2022). Li-metal excess foil count excludes patent families also flagged 'anode-free'.

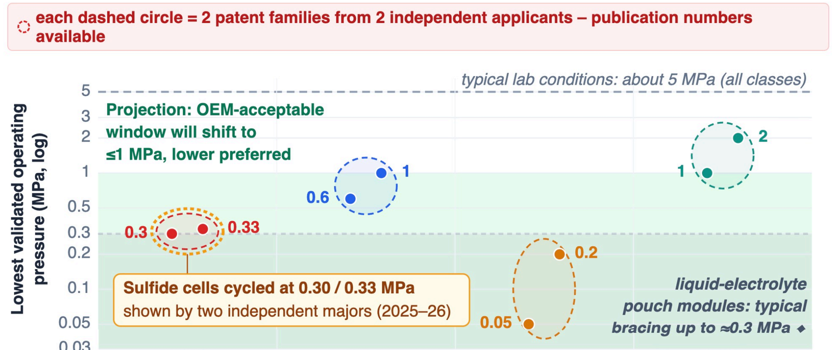
Decision 2 – Operating Pressure

Engineer the pack around multi-MPa fixtures vs. materials route to ≤1 MPa – seven of eight validated cells now sit at or below 1 MPa

Engineer around 2–5+ MPa – Rigid fixtures, springs or hydraulics maintain stack pressure, proven in prototypes, heavy and costly at pack level as cell area grows.
typical lab conditions: about 5 MPa across all classes

Materials route to ≤1 MPa – Interface-forming additives, softening phases, elastomeric networks and engineered interlayers reduce the pressure the chemistry demands.
lowest validated cycling: 0.05–2 MPa, depending on chemistry

each dashed circle = 2 patent families from 2 independent applicants – publication numbers available



	Multi-MPa fixtures	Materials route ≤1 MPa
Performance	Full rate / cycle datasets at 2–5 MPa STRONG EVIDENCE IN PATENTS	Sub-scale cells with favorable retention STRONG EVIDENCE IN PATENTS
Manufacturability	Fixture mass, cost & uniformity burden grow with cell area MODERATE EVIDENCE IN PATENTS	Pouch-compatible, simplifies module hardware MODERATE EVIDENCE IN PATENTS
Failure modes	Pressure gradients → localized plating in large formats	Void formation / contact loss over life without external force
Cost direction	Pack hardware and mass penalty per kWh	Additive & processing cost, less hardware

COMMERCIALIZATION STATUS
Every chemistry class now carries **validated low-pressure cell data inside the OEM window** – notably **sulfide cells cycled at 0.30 / 0.33 MPa by two independent majors (2025–26)**, via molecular-crystal additives and self-healing elastomeric networks. Typical practice still sits at 5 MPa – at production scale the number is either solved (no excess stack pressure) or secret.

WHAT WOULD SETTLE IT*
Multi-layer pouch operation at ≤1 MPa over automotive cycle life · pressure uniformity across large formats · the same retention at automotive cell format as in coin cells.

Pairs: lowest **measured** operating / clamp pressure with accompanying cell-test data, one value per patent family, two independent applicants per class (validation rule), claim-range bounds and process pressures excluded. Oxide-polymer composites omitted: the two-independent-applicants threshold is not met at operating-pressure level.

Validation Level by Chemistry Track – How Far Each Route Has Scaled

Manufacturing-validation ladder per track · produced volumes where publicly disclosed ◆

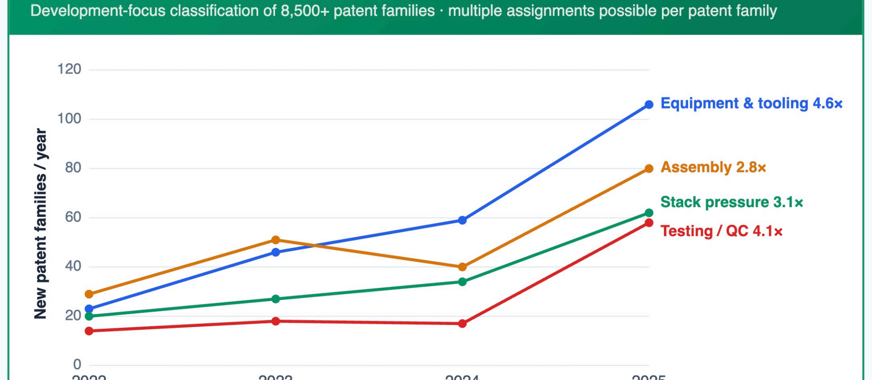
Chemistry track	Lab	Ah cells	Pilot / small batch	GWh prod.	Multi-GWh fleet	Status & produced volume (only EV-related)
Solid-liquid / semi-solid	●	●	●	●	●	**5.9 GWh** shipped in China in 2025◆ on **≈44 GWh** operational capacity◆ · EVs on the road since 2023◆ · 200 MWh grid storage◆ · a completed **2.3 GWh** line begins series supply to a European OEM's next-generation model (2026–27)◆ · a ceramic-separator GWh-class plant has shipped **>800,000 cells◆**. **Key open gate:** differentiation & margin vs. fast-improving incumbent liquid cells
All-solid polymer	●	●	●	●	○	**>1 GWh produced cumulatively** since 2011◆ (Li-metal / polymer, heated operation up to 80 °C, buses, stationary) · room-temperature generation announced for ≈2027+◆ · engineered polymers / oligomers now reach ≈3–6.5×10^{-3} S/cm at RT. **Key open gate:** room-temperature performance at scale without heating
Polymer-oxide composite	●	●	●	○	○	First **0.5 GWh** all-solid line (polymer-inorganic composite, >400 Wh/kg) commissioned late 2025◆ – sample cells rolling, prototype vehicles 2026, mass delivery targeted 2027◆ · best measured lab values 8.5–9.7×10^{-3} S/cm. **Key open gate:** interface stability over automotive life
Oxide	●	●	○	○	○	Ah-class prototypes: the leading configuration pairs an **all-solid oxide separator with a liquid catholyte** ('anode-free' Li-metal) – B-samples in vehicle testing◆, a pilot production line inaugurated 2026◆, and a major OEM's battery unit holds a license for up to **40 GWh/year** of industrialization◆. **Bulk all-solid oxide cells** remain at laboratory scale. **Key open gate:** sintered thin layers at cost, current density
Sulfide	●	●	○	○	○	Commercial today **only at microscale** (hermetic industrial cells, small volume in GWh terms) · 20 Ah samples since 2024◆ · small-batch launches 2027+◆ · dedicated 1,000 t/year Li_2S precursor plant Q3 2027◆. **Key open gate:** layered H_2S emission risk mitigation through type approval, process yield
Halide / oxyhalide	●	●	○	○	○	Being industrialized **bottom-up via specialty applications**: the field's largest halide patent portfolio holder commits to **samples by March 2027◆** for industrial robots, tire-pressure monitoring and high-temperature equipment, commercial specialty production 2027–28◆ and **drone-battery mass production from 2029◆** (80% SoC in 3 minutes). Multi-halide designs balance oxidation stability, conductivity and raw-material cost – in EV stacks, halides appear as a **cathode-side complement** (Decision 4). **Key open gate:** low resistance across compositionally distinct halide layers after prolonged high-temperature cycling, anodes beyond LTO (halide–lithium reactivity)

Key insight: validation level and patent filing volume are **inverted** – the track with the fewest patent filings (solid-liquid) is the furthest scaled, while the patent filing leader (sulfide, ≈61% of 2026 chemistry-assigned patent families) remains commercial only at microscale. Read together with Hypothesis 1: patent filing volume tracks how much must be built new, not proximity to market. Practical consequence: filing volume is a poor proxy for market proximity – it maps where the most must still be built and solved, i.e. where technology risk and supplier opportunity concentrate.

Ladder assessment: author view* based on public information ◆ (references available) combined with the patent record. GWh figures as publicly reported, capacity ≠ shipments. The ladder tracks scale-up toward large-format (EV-class) cells: launched microscale products are genuine commercialization at small produced volume (though typically providing high added-value). All-solid polymer produced volume includes heated Li-metal / polymer systems (operating temperature up to 80 °C).

Downstream Patent Filings Are Compounding While Chemistry Questions Stay Open

Development-focus classification of 8,500+ patent families · multiple assignments possible per patent family



4.6×	4.1×	3.1×	2.8×
Production equipment & tooling (23 → 106 patent families/year)	Battery testing / inspection & QC (14 → 58 patent families/year)	Stack-pressure management (20 → 62 patent families/year)	Cell assembly / integration (29 → 80 patent families/year)

Reading: companies are tooling up – equipment, quality control, pressure management and assembly patent filings compound at 3–4.6× while core electrolyte patent filings grew ≈13% over the same window. This is capacity being prepared for the 2026–2028 validation window, on top of – not instead of – the open chemistry decisions. A higher multiple marks where industrialization problem-solving is most intense right now – active build-out, not maturity.

2026 year-to-date volumes track the 2025 run-rate (partial year, not plotted).

The Validation Window 2026–2028 – Which Event Settles Which Decision?

Independently scheduled, publicly announced timelines by various industry protagonists ◆ (regulatory dates, company announcements) suggest open decisions will be gradually settled as market & technical validation data becomes available · decision mapping: author assessment*

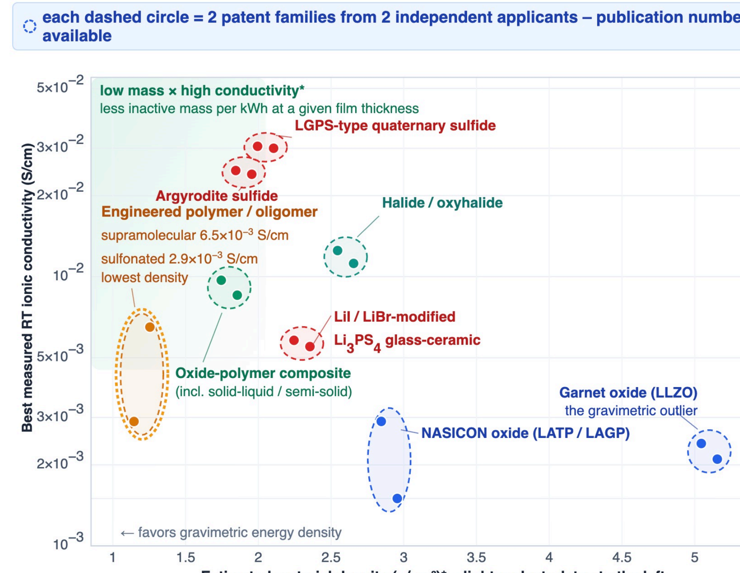
07 / 2026	2026	2027	2027–28	2028+
No-fire / no-explosion type approval becomes mandatory in China ◆ – currently the only jurisdiction with this requirement, other markets may follow*. Thermal-propagation containment and post-fast-charge safety tests raise the bar for every architecture, incl. incumbent liquid cells. MARKET ENTRY ARCHITECTURE	**Solid-liquid mass-production ramps ◆** – bridge-track cells move from aviation / premium niches to volume lines, margin data vs. incumbents starts accumulating. MARKET ENTRY ANODE	**Sulfide small-batch launches, dedicated precursor plant on line ◆** – first supply-chain economics and process-yield reality for the direct path. MARKET ENTRY PROCESSING	**Premium-vehicle deployments of all-solid cells ◆** – anode posture and operating-pressure posture become visible in actual products and their pack hardware. ANODE PRESSURE	**First automotive field data at scale** – life, safety and warranty evidence begins to settle the remaining bets, incl. solid-liquid stack durability. PRESSURE ARCHITECTURE PROCESSING

Decision tags: ANODE Decision 1 · PRESSURE Decision 2 · PROCESSING Decision 3 · ARCHITECTURE Decision 4 · MARKET ENTRY Decision 5. ◆ = public-information anchor, references available.

Measured Ionic Conductivity vs. Estimated Material Density – Key Electrolyte Materials

Two best measured values per material, each from an independent applicant = the validation rule

each dashed circle = 2 patent families from 2 independent applicants – publication numbers available



Key insight: the sulfide, halide and oxide-polymer composite classes clear 5×10^{-3} S/cm, and engineered polymers / oligomers reach 3–6.5×10^{-3} S/cm – at these levels, bulk conductivity stops being the discriminator: a 20 µm film at 5×10^{-3} S/cm contributes only ≈0.4 Ω·cm² area-specific resistance*. What separates the tracks is **how thin a separator film each material can sustain while still blocking short circuits and meeting safety requirements** – film thickness × density, not bulk conductivity, sets the electrolyte's resistance and weight in the cell. The race has moved to <20 µm, ideally <10 µm film viability: mechanical robustness against dendrite penetration, defect-free processability at thickness, and the safety / regulatory dossier. **Feasibility pointer*:** incumbent liquid-cell separators already ship well below 10 µm in mass production – sub-10 µm roll-to-roll film handling is proven; with the right composite solid electrolytes this should be reachable too, though <20 µm remains a demanding near-term goal, e.g. for sulfides.

Values: best plausibility-screened, **measured** room-temperature conductivities reported in the patent filings (pellet / membrane level, computational predictions and claim-range bounds excluded), one value per patent family, two independent applicants per material (validation rule). * Densities are class-level literature estimates, not extracted from patent filings, halide / oxychloride placed at a class midpoint (≈2.4–3.3 g/cm³ depending on metal). Measurement conditions vary by patent filing.

Decision 3 – Processing Route

Wet slurry vs. dry / solvent-free – where separator and electrode economics are decided

Wet slurry – Binder / solvent systems engineered around polar-solvent incompatibility (nonpolar solvent chemistry, staged binder molecular weights, pre-ionized salt carriers), reuses coating know-how.
carries today's pilot lines across majors

Dry / solvent-free – Binder fibrillation, dry biaxial stretching, dry powder surface modification, no solvent recovery loop, direct lamination onto electrodes.
dry-route signal doubled: 77→160 patent families/year (2022→2025)

	Wet slurry	Dry / solvent-free
Performance	Uniform thin layers, residual-solvent effects manageable MODERATE EVIDENCE IN PATENTS	Dry-stretched membranes at 10 µm solvent-free, 5–8 µm with a plasticizer-extraction step (polymer matrix, halide- or oxide-filled) · sulfide films via dry PTFE fibrillation, 10 µm measured as a layer rolled onto the anode THIN EVIDENCE IN PATENTS
Manufacturability	Solvent recovery & drying capex / opex well understood STRONG EVIDENCE IN PATENTS	Roll-to-roll width and speed unproven at scale THIN EVIDENCE IN PATENTS
Failure modes	Residual solvent ↔ electrolyte degradation, binder–solvent–electrolyte compatibility triangle	Pinholes / thickness variation, binder-fibril fatigue over cycling
Cost direction	Solvent loop dominates operating cost	Lower opex if yield holds – that is the bet

COMMERCIALIZATION STATUS
Wet routes carry the current pilot lines of multiple majors, dry-route validation is mostly half-cell or hybrid-cell so far – including dry-stretched membranes tested as safety inserts inside conventional liquid cells rather than as full solid-state separators.

WHAT WOULD SETTLE IT*
<10 µm free-standing separator at roll-to-roll speed and width with published yield · full-cell (not hybrid) validation of dry-processed layers · the solvent-loop-cost vs. dry-capex crossover at GWh scale.

Case Study A – The Dual-Track Cell Maker

World-scale producer · solid-liquid shipping now · all-solid sulfide staged behind

TRACK 1 · SOLID-LIQUID (POLYMER / OLIGOMER) · TRACK 2 · ALL-SOLID SULFIDE

Deployed Aviation & high-end EVs today, >1,000 km pack-level ranges shown.	**2026 ramp ◆** Solid-liquid mass production announced, 500 Wh/kg headline cells.
20 Ah samples Sulfide trial production since 2024, ≈1,000-person all-solid R&D team ◆.	**2027 → <2030 ◆** Sulfide small-batch launch, then large-scale application goal.

KEY MATERIAL CONCEPTS ACROSS BOTH TRACKS

1. **Supramolecular ionic-liquid / oligomer electrolyte** – π-π-stacked ion channels: 6.5 × 10^{-3} S/cm bulk, 2.4 × 10^{-3} S/cm in membrane, >438 °C boiling point – Li-metal cells without heating requirements.
2. **Gradient-crosslinked polymer matrix for crash safety** – Spatially varied crosslinking: soft at electrode interfaces, rigid in bulk – 5.7 mm deformation under 100 kN in 70 Ah-class cells, lighter pack structures.
3. **"Reinforced-concrete" sulfide separator** – Ceramic fiber networks + phase-change toughening particles: fracture toughness up to 5.32 MPa·$m^{1/2}$ (≈25× baseline) against dendrite-driven cracking.
4. **Layered H_2S defense** – Amphiphilic molecular surface layers on sulfide particles + oxysulfide doping – targeting ppm-level emissions under industrial dew-point control, backed by cell / pack engineering layers.

CRITICAL READS
Track 1: dendrite-driven shorts appear controlled – possibly at the expense of maximum fast-charge rates, optimization and cost-down still open against improving incumbents. **Track 2:** four gates before EV scale – solid-solid interface contact, dendrite control, H_2S environmental sensitivity, manufacturing process control, multi-thousand-cycle prototype claims carry a capacity-fluctuation caveat.

TIMELINE (PUBLICLY DISCLOSED) ◆

2024 – 20 Ah sulfide samples → 2026 – Solid-liquid mass production → 2027 – Sulfide small batch → <2030 – Sulfide scale goal

Congruency check: statements vs. patent filings – Public messaging and the patent portfolio align on the dual track, the headline solid-liquid product's underlying supramolecular chemistry is visible in patent filings but absent from public communication.

Third option – A small halide / oxyhalide patent filing track – consistent with the cathode-side-complement pattern of Decision 4 – is not featured publicly.

Decision 4 – Stack Architecture

One electrolyte everywhere vs. hybrid multilayer stacks – each chemistry where it is strongest

Single-chemistry stack – One electrolyte throughout the cell, fewest interfaces – but one chemistry must satisfy both electrode environments simultaneously.
default configuration in most portfolios

Hybrid multilayer stack – Halide facing the high-voltage cathode, sulfide facing the anode, oxide or polymer as barrier / bonding layers, catholyte–anolyte bilayers on the solid-liquid side.
multilayer-architecture signal ≈490→830 patent families/year (2022→2025)

	Single chemistry	Hybrid multilayer
Performance	Deepest full-cell evidence base STRONG EVIDENCE IN PATENTS	Each interface locally optimized, oxidation stability measured to 4.7 V MODERATE EVIDENCE IN PATENTS
Manufacturability	Fewer deposition / lamination steps STRONG EVIDENCE IN PATENTS	Layer-count cost, alignment & lamination precision THIN EVIDENCE IN PATENTS
Failure modes	One chemistry's weakness appears everywhere in the cell	Interface count multiplies degradation paths, longevity evidence thin
Cost direction	Baseline	Added functional layers vs. avoided protective coatings – unresolved

COMMERCIALIZATION STATUS
Hybrid stacks are at lab / prototype scale – halide-facing-cathode designs with oxide barrier layers, sulfide-buffered oxide separators, and room-temperature-assembled catholyte / anolyte bilayers all appear in patent filings of multiple independent majors. Halides increasingly show up as a **cathode-side complement** rather than a standalone chemistry bet.

WHAT WOULD SETTLE IT*
Delamination-free thermal and pressure cycling over life · interfacial-resistance stability across ≥1,000 cycles in multilayer builds · cost per added functional layer at format scale.

Decision 5 – Market Entry

Solid-liquid bridge now vs. direct all-solid – two risk classes, one portfolio

Solid-liquid bridge now – Gigafactory-compatible cells shipping in aviation and premium EVs, generates field data and cash. The risk class: **differentiation** against fast-improving incumbent liquid cells.
gigafactory scale today · mass-production ramps announced from 2026 ◆

Direct all-solid – Skip the commercially thin intermediate markets and aim at the regulated EV endgame. The risk class: **feasibility**, compressed into few validation events.
small-batch targets 2027+ ◆ · microscale industrial cells the sole commercial rung today

	Solid-liquid bridge	Direct all-solid
Performance	300–500 Wh/kg depending on anode posture STRONG EVIDENCE IN PATENTS	400–500 Wh/kg targets at prototype level MODERATE EVIDENCE IN PATENTS
Manufacturability	Reuses incumbent lines and supply chains STRONG EVIDENCE IN PATENTS	New process environment end-to-end THIN EVIDENCE IN PATENTS
Failure modes	Dendrite control at fast charge, margin erosion by incumbent cost curves	Layered H_2S emission risk mitigation must hold through production, field use, recycling – and pass type approval
Cost direction	Near-incumbent at scale	Premium until the fixed process costs amortize

COMMERCIALIZATION STATUS
The dominant pattern is **sequencing, not choosing**: 23 of 40 covered companies hold a solid-liquid track – of these, **16 pair it with a staged all-solid sulfide program** and **21 with other all-solid chemistries** (oxide, polymer, composite, halide), of which 15 with both, the solid-liquid products funding and de-risking the staged all-solid options.

WHAT WOULD SETTLE IT*
Bridge-cell margins against the incumbent LFP / high-Ni cost trajectory · type approvals under (e.g. China's) no-fire / no-explosion mandate ◆ · which track captures the 2027–28 premium-vehicle window.

Solid-liquid track: ≥2 patent families in the liquid-containing composite class or ≥3 semi-solid-flagged patent families. All-solid pairing: ≥3 patent families in the respective class.

Case Study B – The Direct All-Solid Integrator

Vertically integrating automaker · sulfide electrolyte · Si-based anode at launch

TARGETS

≥1,000 km Vehicle range target ◆ with stacked prismatic cells.	**<10 min** SOC 10→80% charging ◆ enabled by >10^{-3} S/cm conductivity.
≈500 patent families Published since 2022 – the largest portfolio in class.	**1,000 t/year Li_2S** Dedicated precursor plant ◆ operational Q3 2027.

KEY MATERIAL CONCEPTS

1. **Quality-controlled sulfide via low-oxygen solution synthesis** – 4.1 × 10^{-3} S/cm; controlled-atmosphere synthesis (<300 ppm O_2) cuts the resistance after 1,000 cycles from 346–400 to 210–235 Ω·cm², moisture-resistant ether-modifier coatings relax dry-room requirements.
2. **Dual-layer & halide cathode-interface systems** – Coatings on the cathode active-material particles: an oxide inner layer directly on the particle plus a sulfide-conductive outer layer, or halide coatings with high oxidation stability – chemically isolating the particle from the bulk sulfide electrolyte, the hybrid-stack pattern of Decision 4 applied at the particle level.
3. **Si-tolerant current collector & bipolar assembly** – Resin current collectors with carbon networks absorb Si expansion, bipolar stacking with deformation-controlled hot pressing.

CRITICAL RISK
Toxic H_2S emission upon moisture / water contact across production, field use and recycling – addressed as a layered defense (particle coatings, process atmosphere, hermetic packaging, pack-level gas management), which must hold through type approval and vehicle lifetime.

Timeline history: launch guidance moved 2020 → 2023 → 2026 → 2027–28 – repeated deferrals warrant a cautious reading of the current schedule.

TIMELINE (PUBLICLY DISCLOSED) ◆

2026 – Production start → 2027 – Precursor plant on line → 2027–28 – Premium EV deployment → ≈2030 – Mass production goal

Multi-partner supply chain – Sulfide electrolyte producer, cathode material supplier and equipment partners bound in ahead of launch – the fixed-cost side of the direct path.

Congruency check: statements vs. patent filings – >1,000 km and multi-decade-life claims are public, no cell-level cycling at specified rates has been published – patent filings show 1,000-cycle interfacial-resistance stability. A large oxide side-track is prominent in patent filings, for which no public statements were identified.