



Upscaling solid-state batteries: challenges and roadmaps from R&D to industrial production

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**Short introduction
to Sphere Energy**

**Industrial process
challenges for SSBs**

**The duty of R&D and
Sphere's contribution**

Summary



The background features a dark, deep purple gradient. A series of wavy, glowing lines in shades of purple, pink, and magenta flow horizontally across the center. These lines are composed of numerous small, bright dots, creating a sense of motion and digital energy. The overall aesthetic is futuristic and high-tech.

Leverage the battery to win!

Become the market leader through highly innovative products, based on the right battery technology.

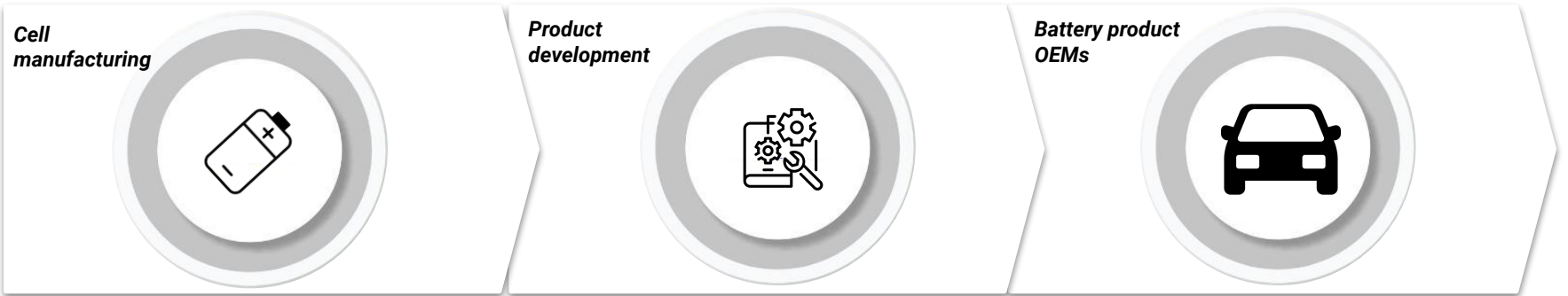


Addressing the key challenges of the battery market

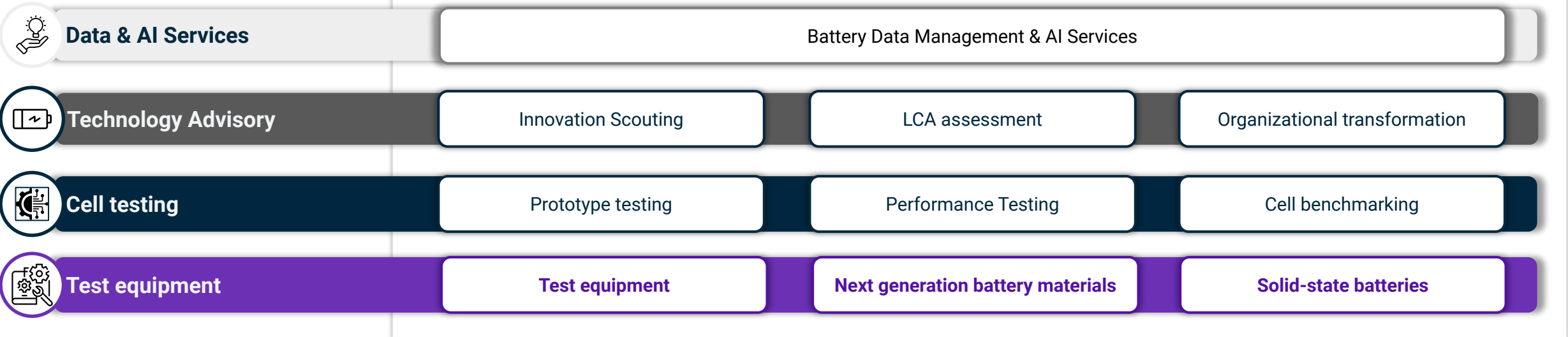
We accelerate the success of our clients and differentiate us through domain expertise & data.



Our clients



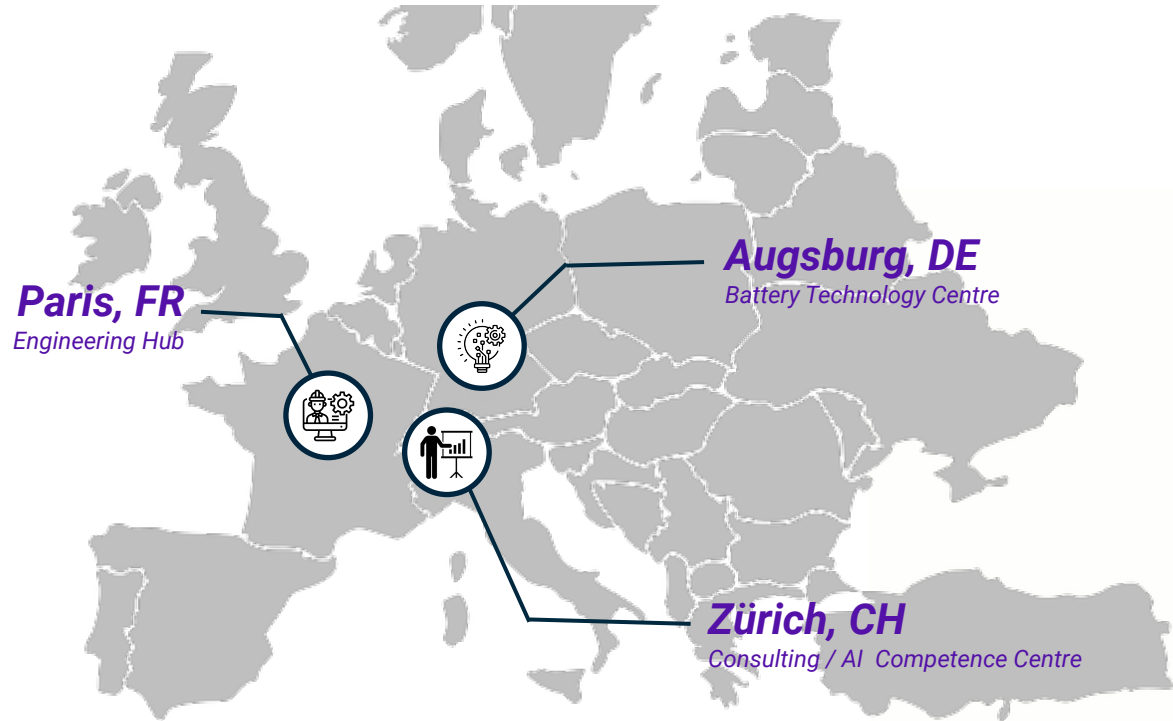
Our Services





Introduction to Sphere-Energy

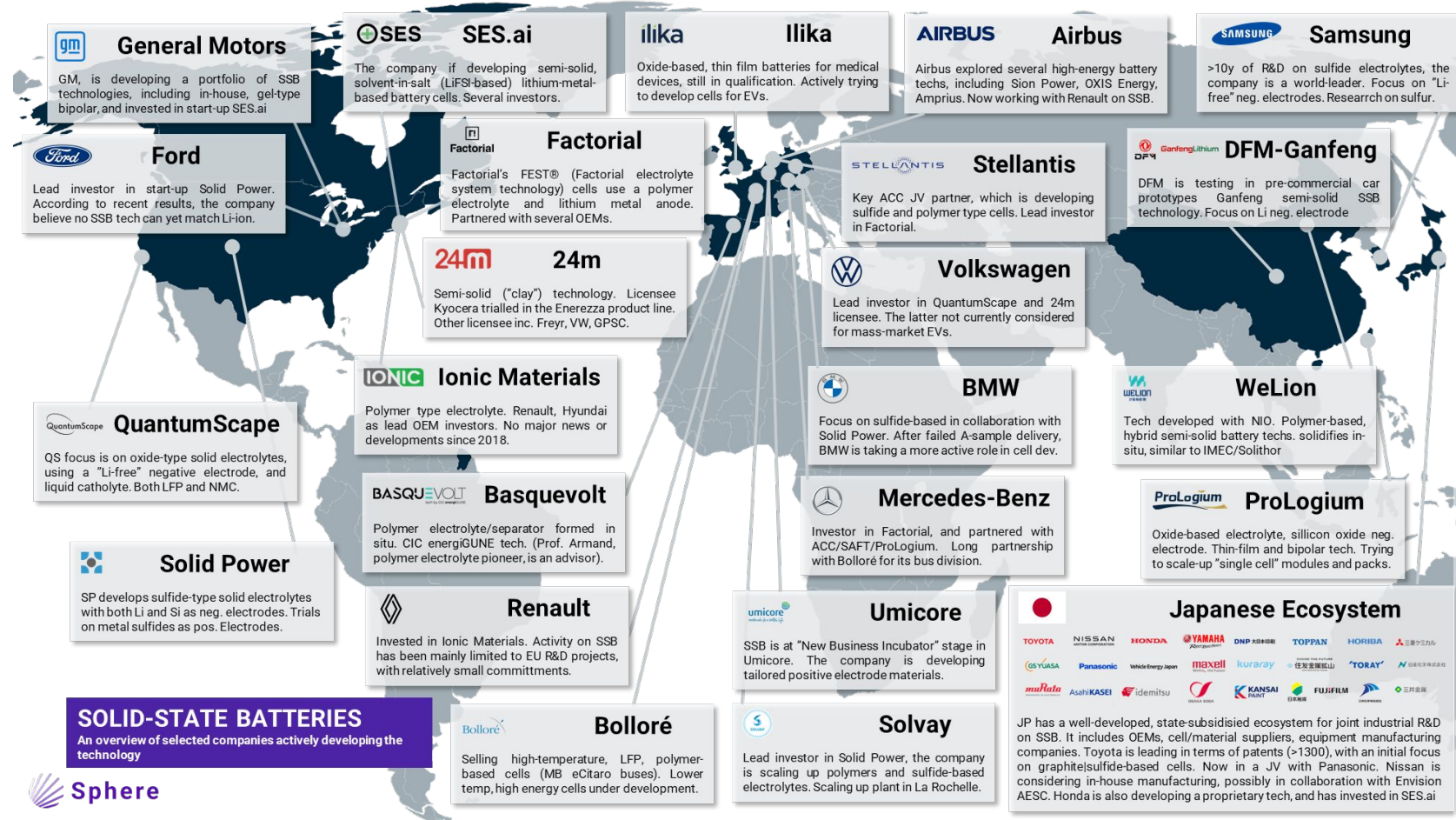
International team of battery and data experts.





Solid State Batteries... where do we start

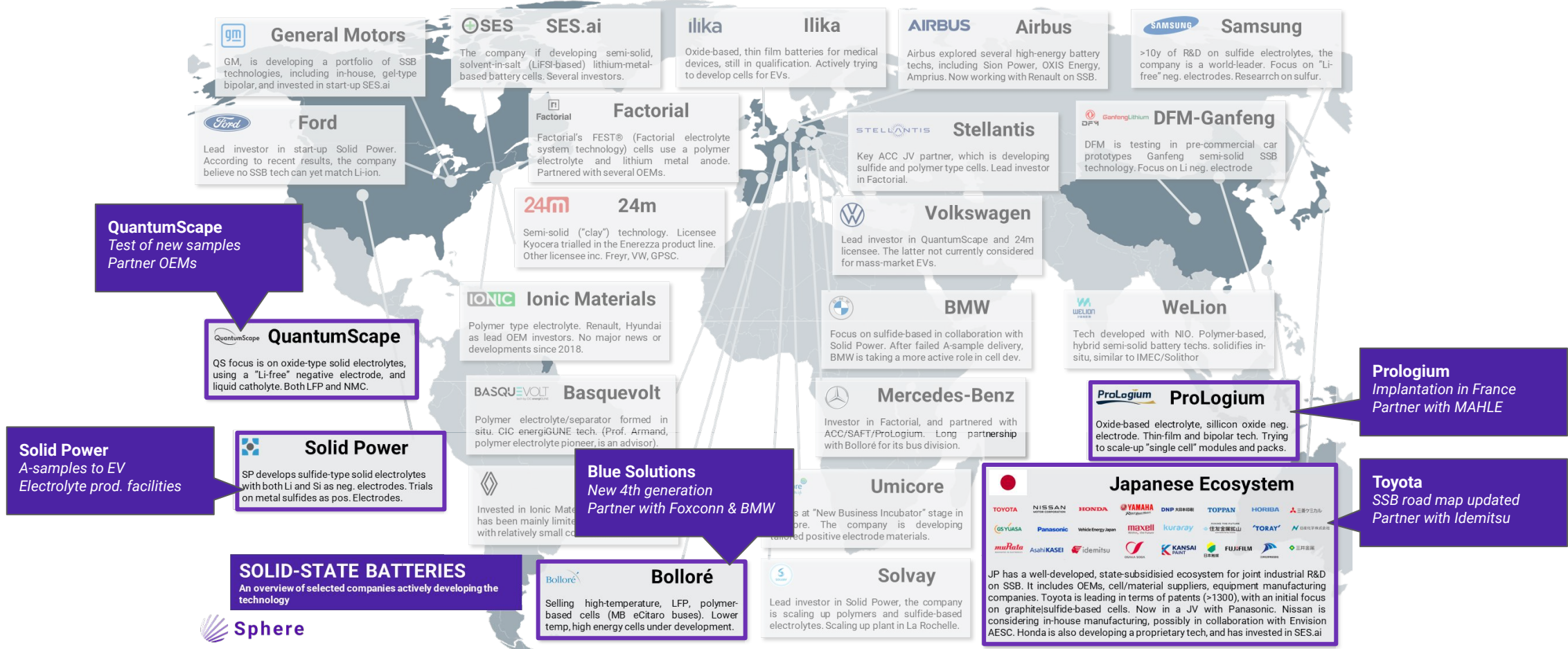
Significant commitments and robust momentum within this market.





Solid State Batteries... where do we start

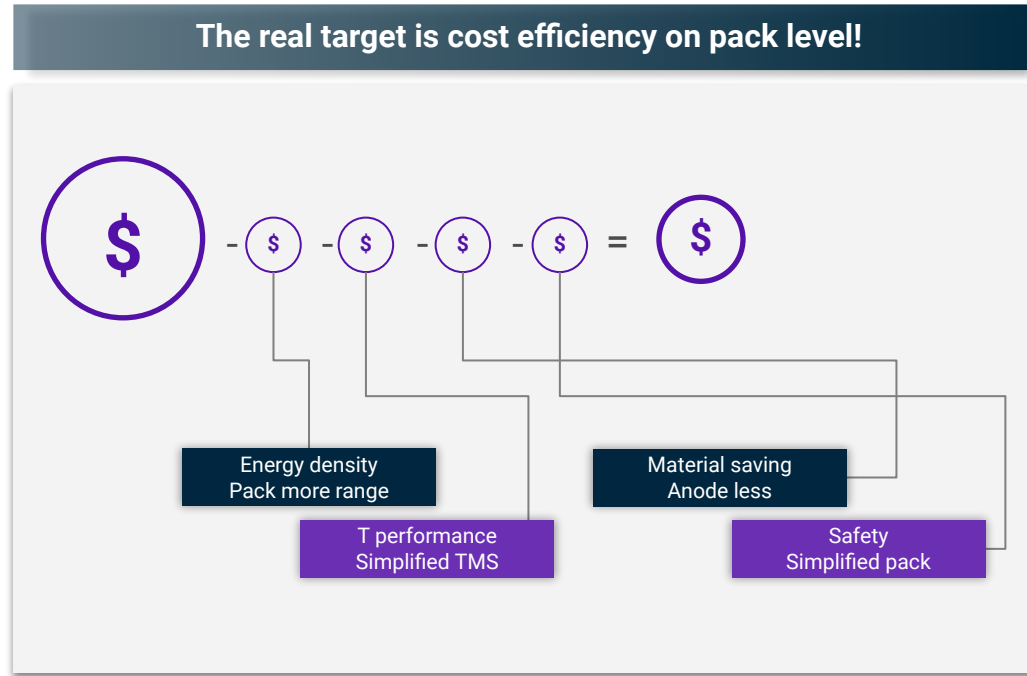
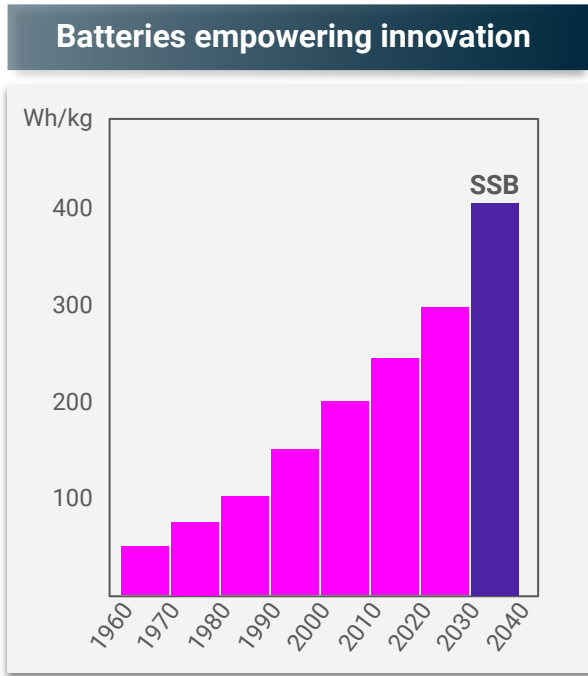
Significant commitments and robust momentum within this market.





Pushing the limits of energy storage

In a very competitive market



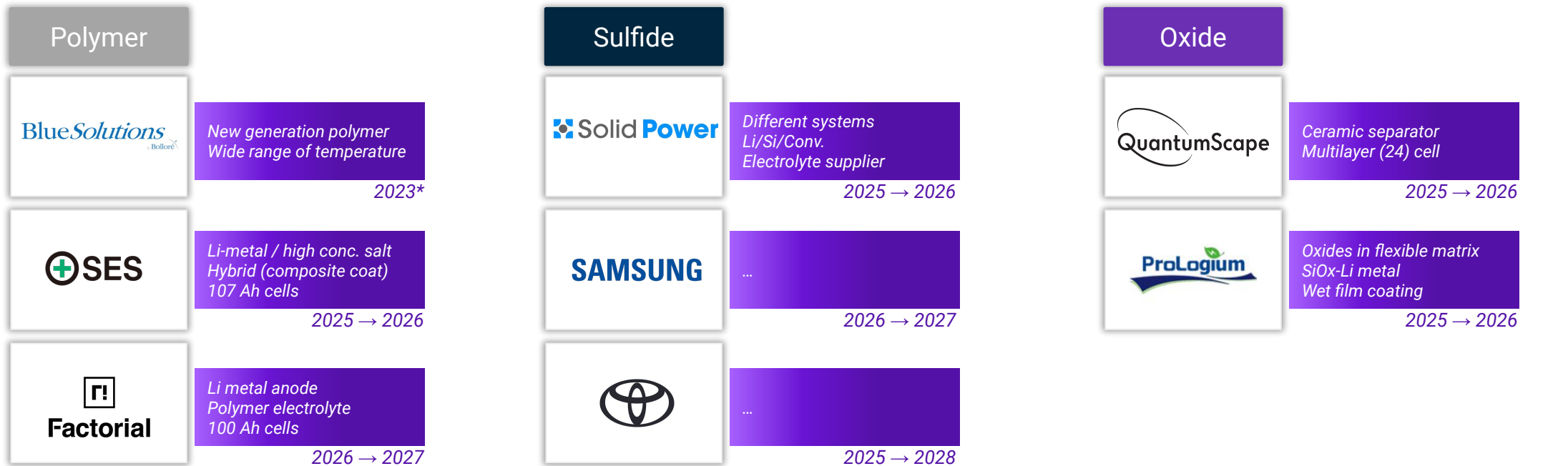
- ### Innovation
- Progressive shift towards full solid**
1. Semi-solid
 2. Almost-solid
 3. All-solid
- Different types of electrolytes**
- Polymer - mature
 - Sulfide - semi-mature
 - Oxide - semi-mature

ASSB technology can be a game changer for pack level cost - when produced at scale!



Pick your tech!

Main players and their battery technology choice



+

- Manufacturability
- Processability

-

- Operating temp
- Dendrite protection

+

- High conductivity
- Electrode compatibility

-

- High cost
- Sensitive production

+

- High voltage
- Safety

-

- Manufacturability
- Mechanical stability



But it takes time to create a new battery

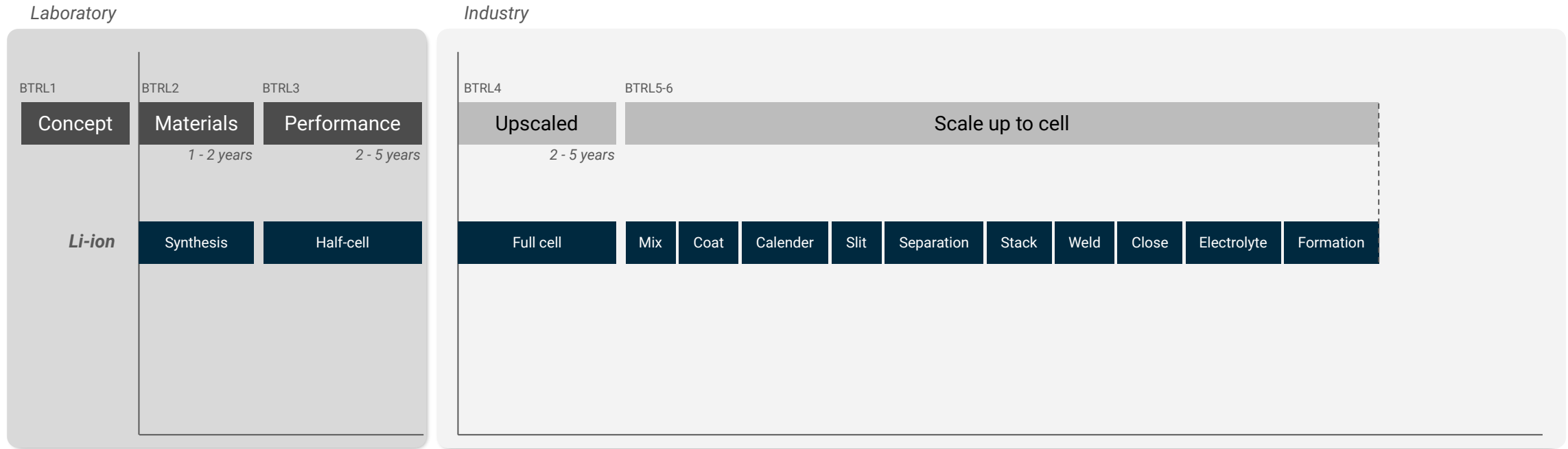
Even based on classic Li-ion technology know-how





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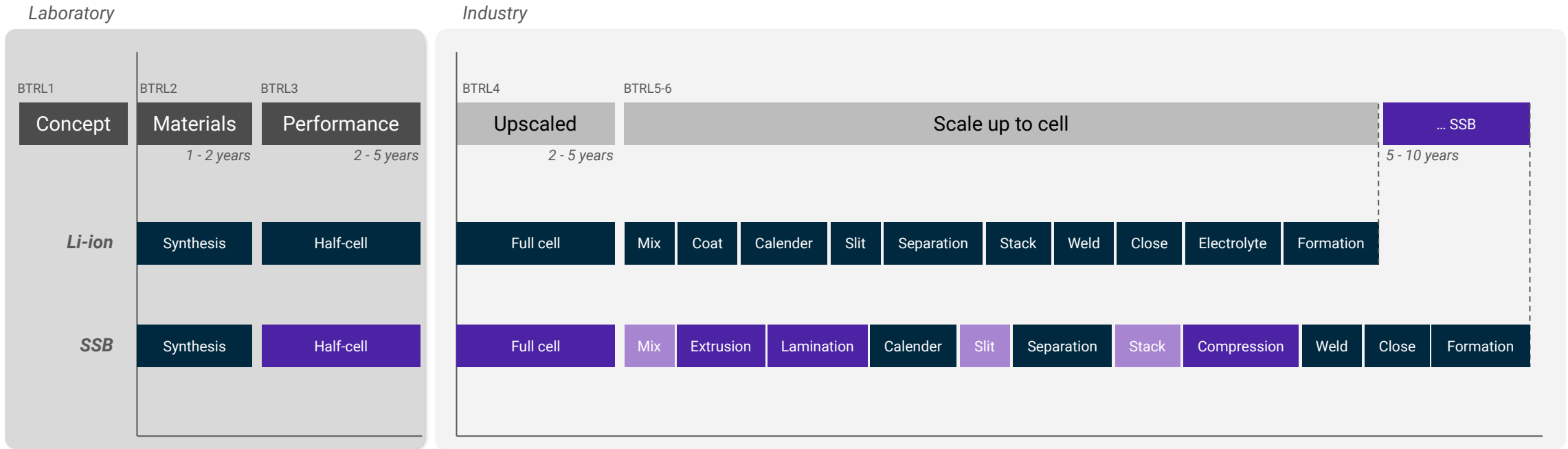
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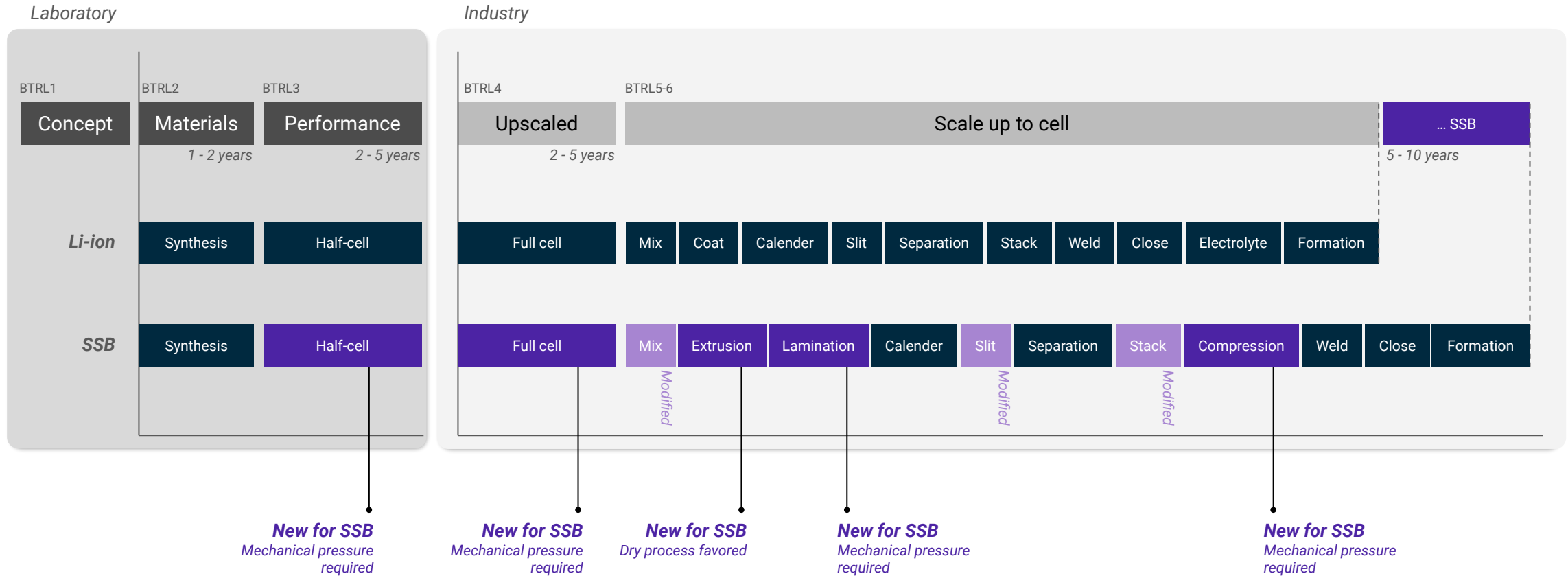
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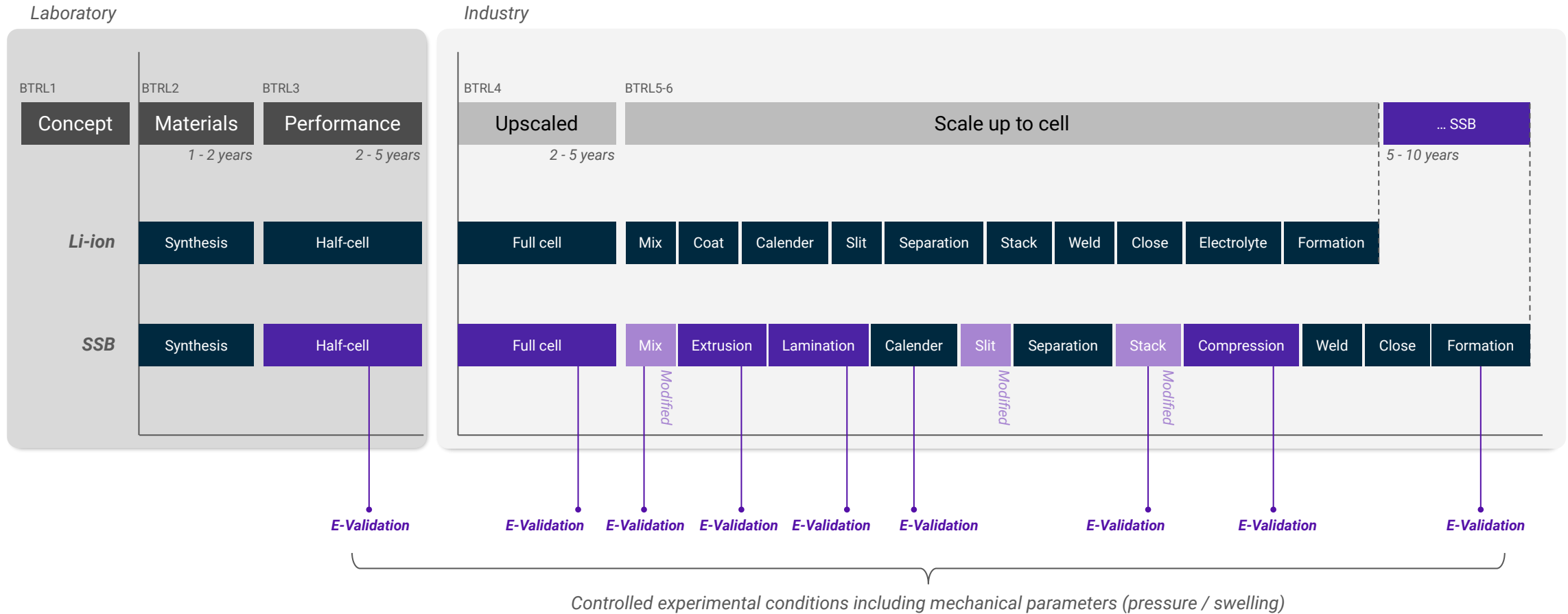
Processes of classic Li-ion technology production need to be adapted





But it takes time to create a new battery

Need for reshaped electrochemical validation at different levels of the development process





The characterization challenge for SSBs

Why is it so hard to measure electrochemical performance - even on research level?

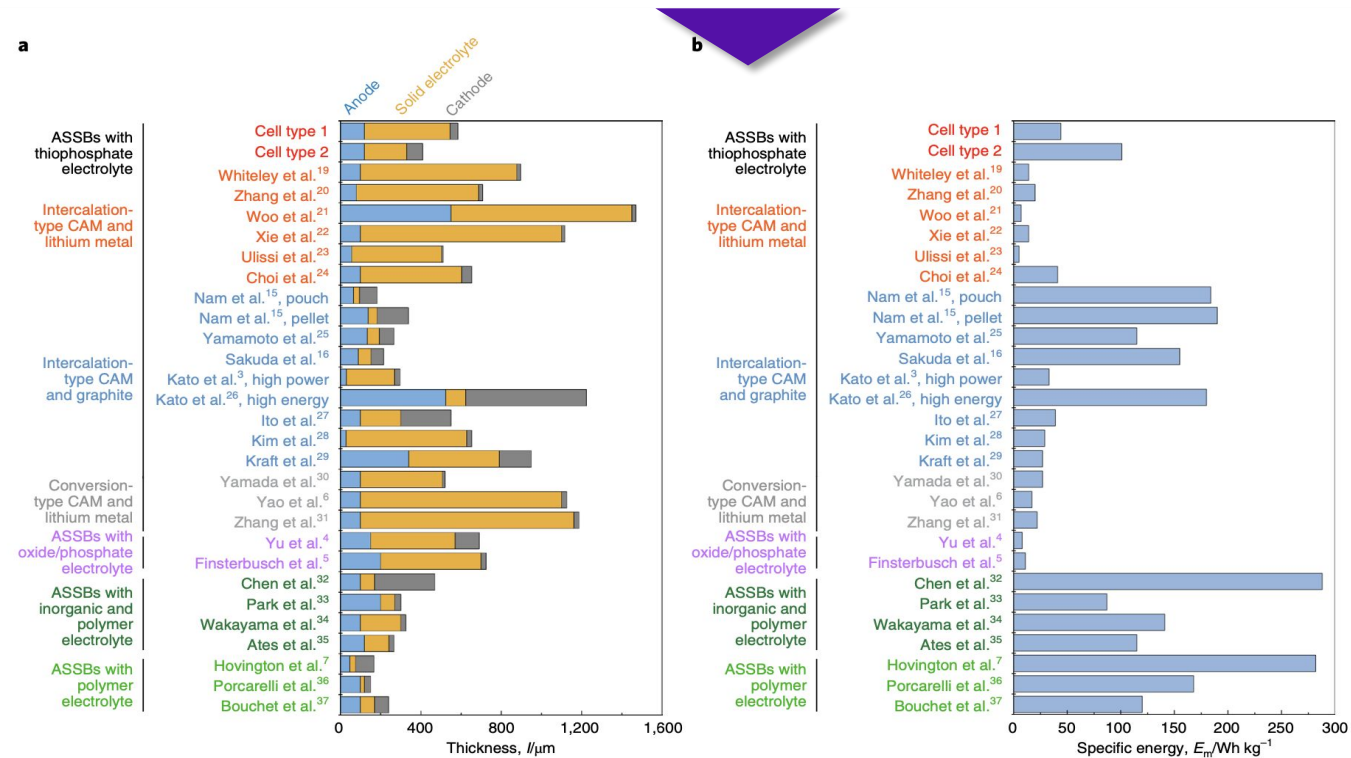


Fig. 2 | Relationship between layer thicknesses and specific energies of analysed ASSBs. a,b. Representation of layer thicknesses of ASSBs (a) and the corresponding cell-specific energies as histograms (b). Corresponding data are available in Supplementary Tables 2 and 4.

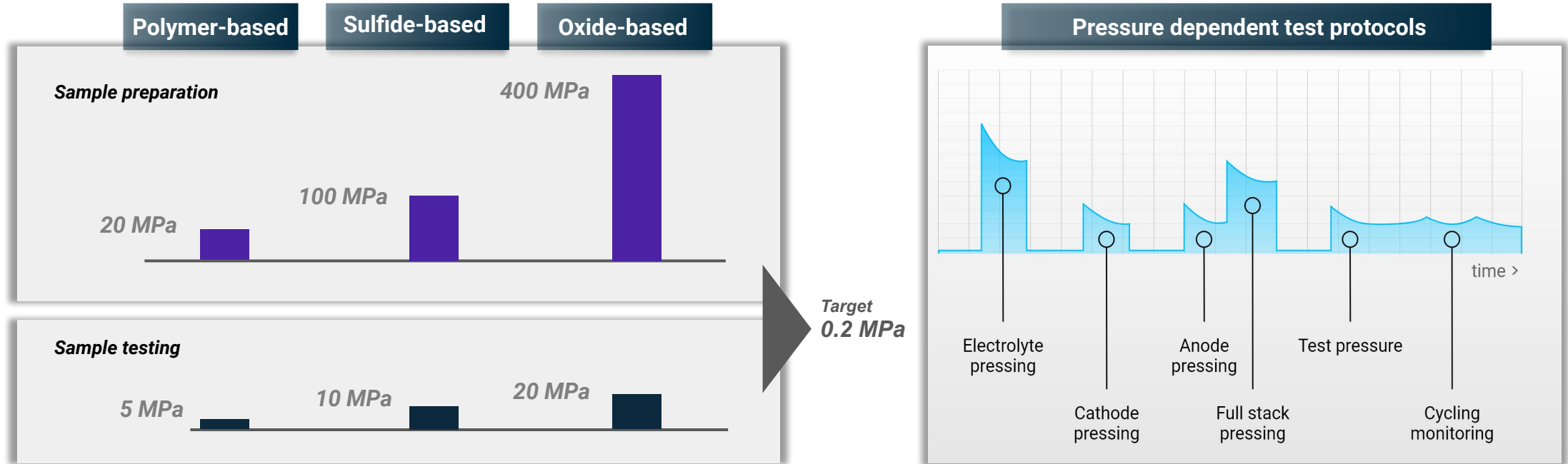
“This demonstrates that the differences in specific energy and specific power of the multitude of available SSBs”

Randau et al. *Nature Energy* volume 5, pages 259–270 (2020)



Every technology needs its own conditions - it's hard to compare!

Detailed reporting, especially of pressures is essential to draw conclusions.

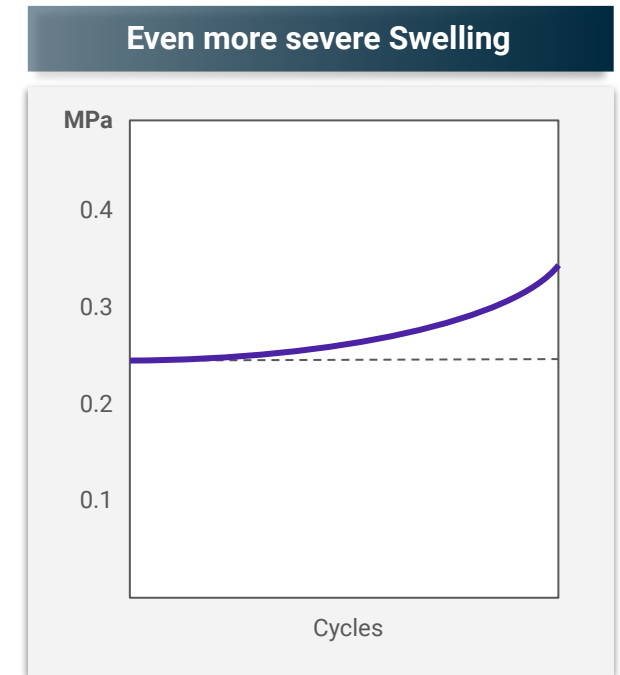
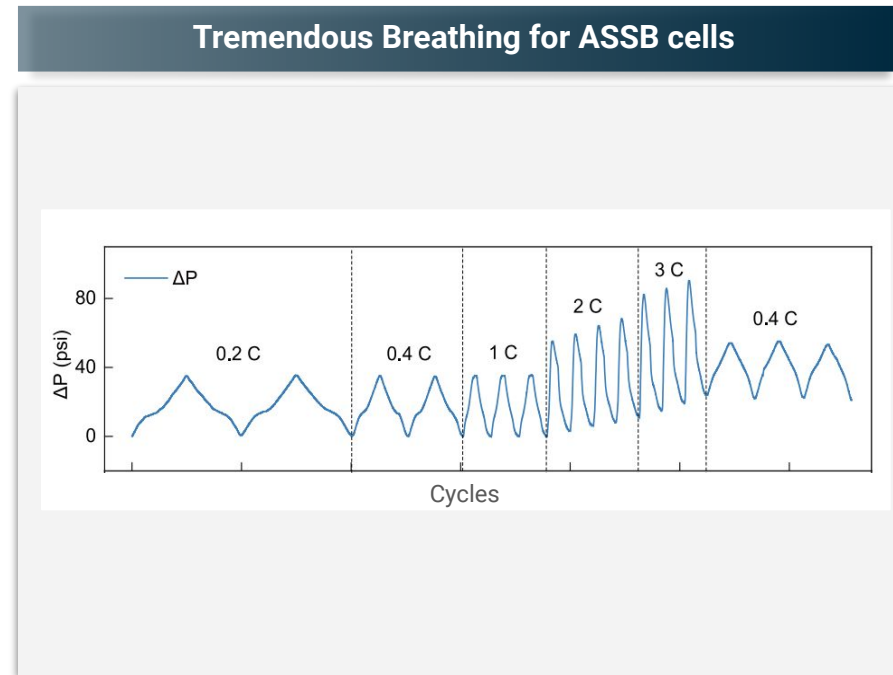
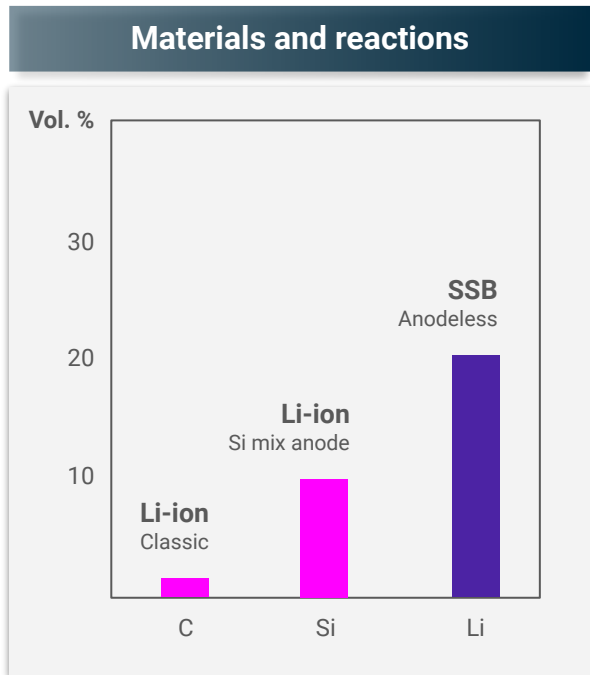


From material processing, sample preparation, up to electrochemical tests - mechanical aspects are key for data reliability



Mechanical aspects are getting even harder to manage with SSBs

Great effect of Li plating/stripping on breathing and swelling

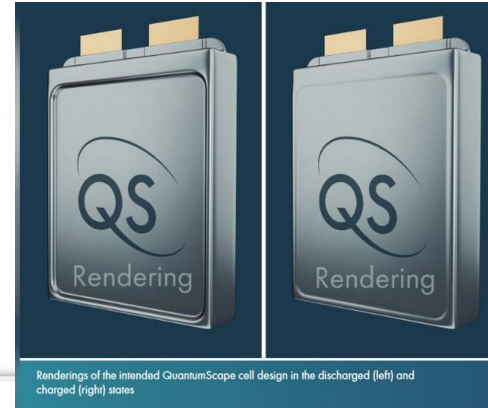


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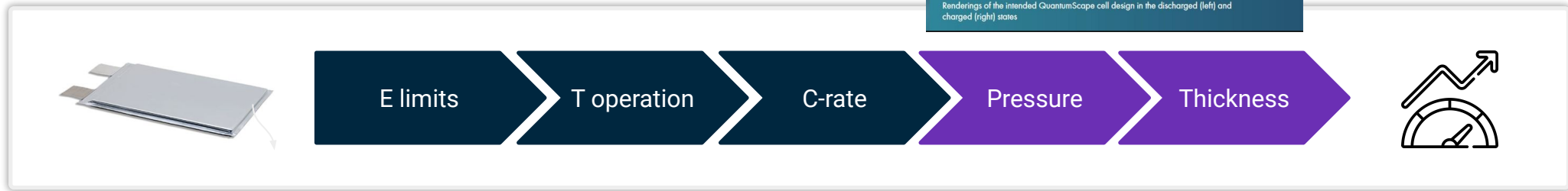


New parameters are needed for performance

Precise control of energy dense systems



Renderings of the intended QuantumScope cell design in the discharged (left) and charged (right) states



*Classical parameters
Classical approach*



*New parameters for ensuring performance
New approach*

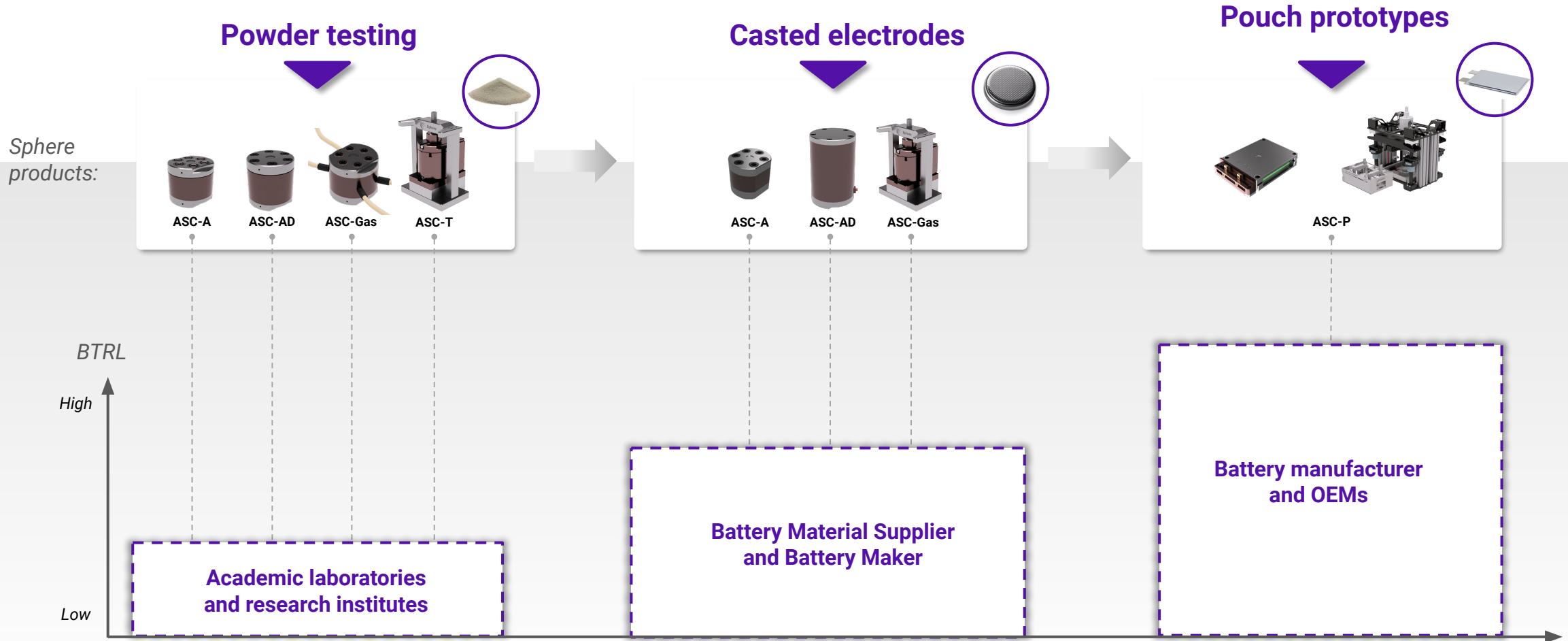
High-energy density cells

Li-ion / Si content
SSB / Li metal or anode less



Sphere's approach for electrochemical characterization of SSBs systems

Tailored tests from laboratory measurements up to cell prototypes

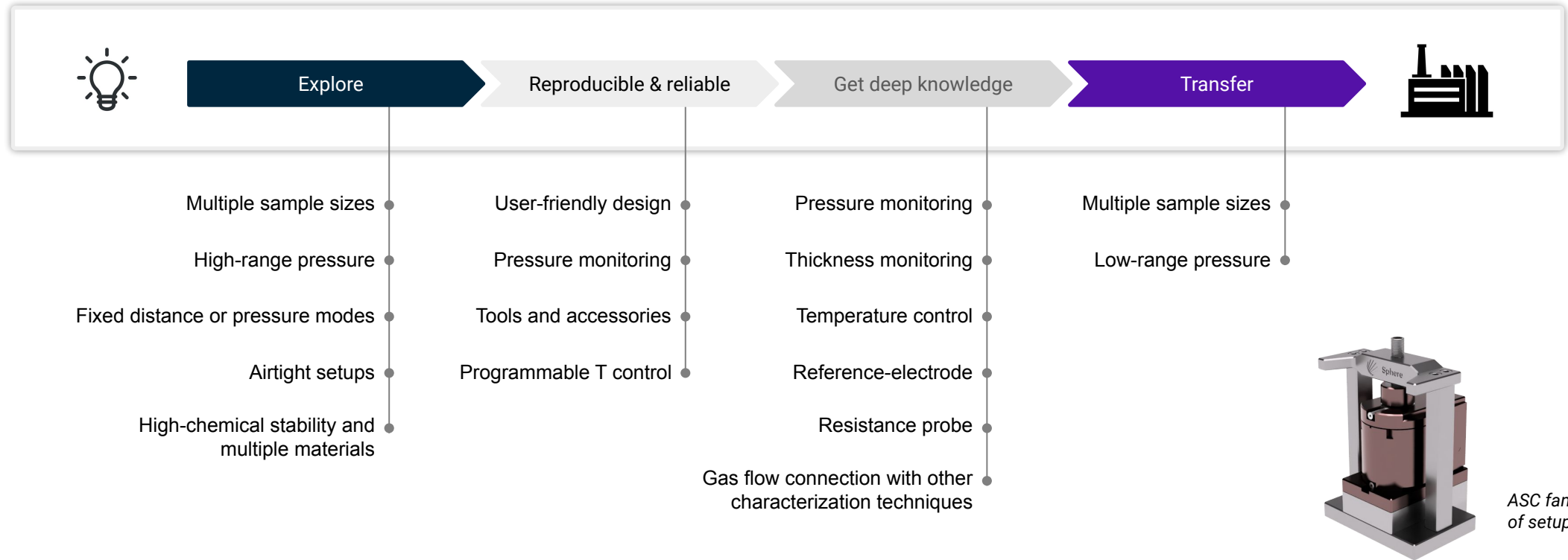




Direct connection between the innovation and features

Developed hand-in-hand with R&D experts

Key added values for our clients:



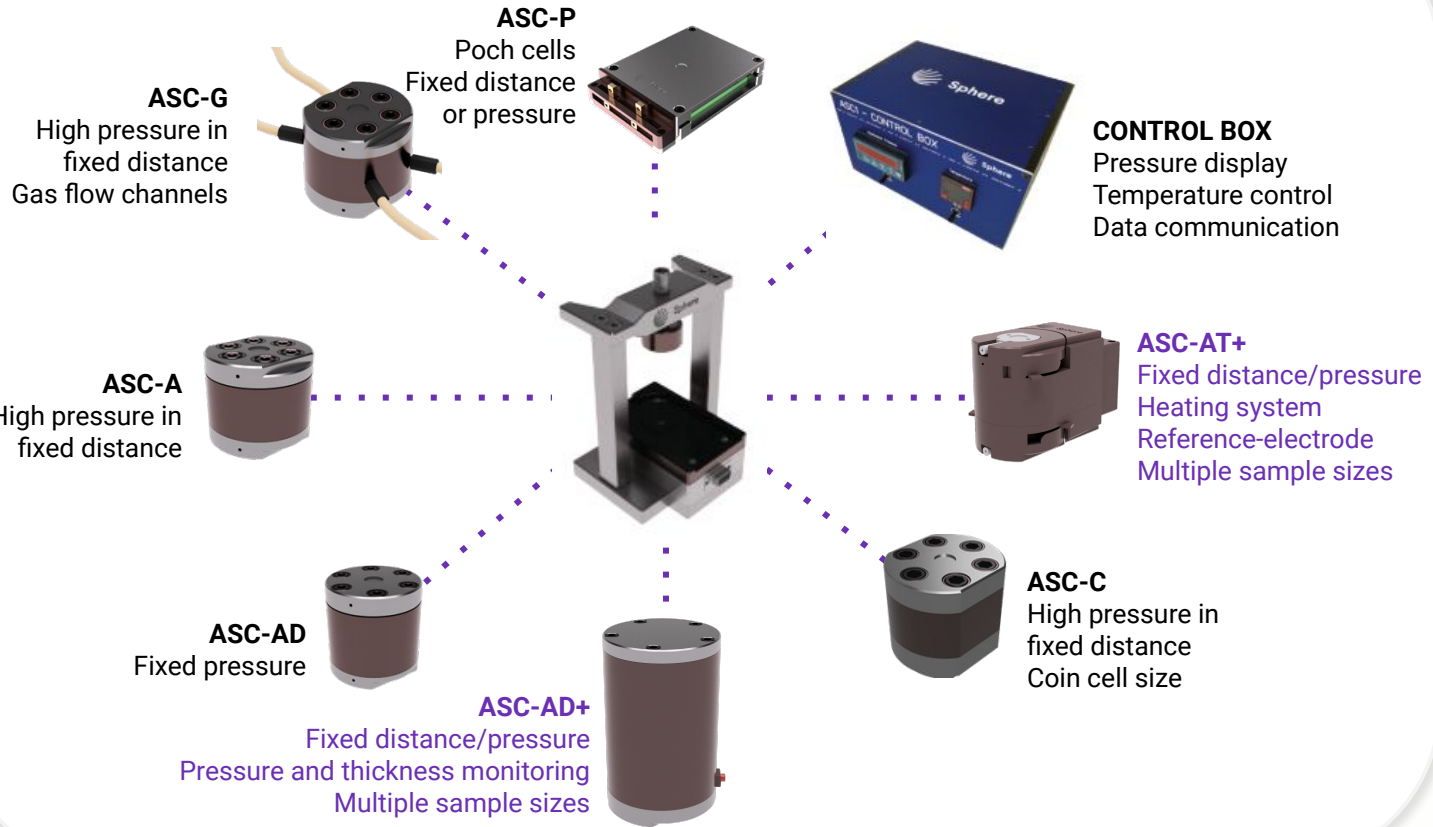
Key features for demanding market needs



Flexible and compatible setups for interactive tests

One frame fits all solution - interconnectivity with different setups

Spheres combinatory product portfolio



Flexibility

Setups that can be exchangeable

Common platform through our mechanical press and monitoring systems

Maximizing combination of different features

Compatibility

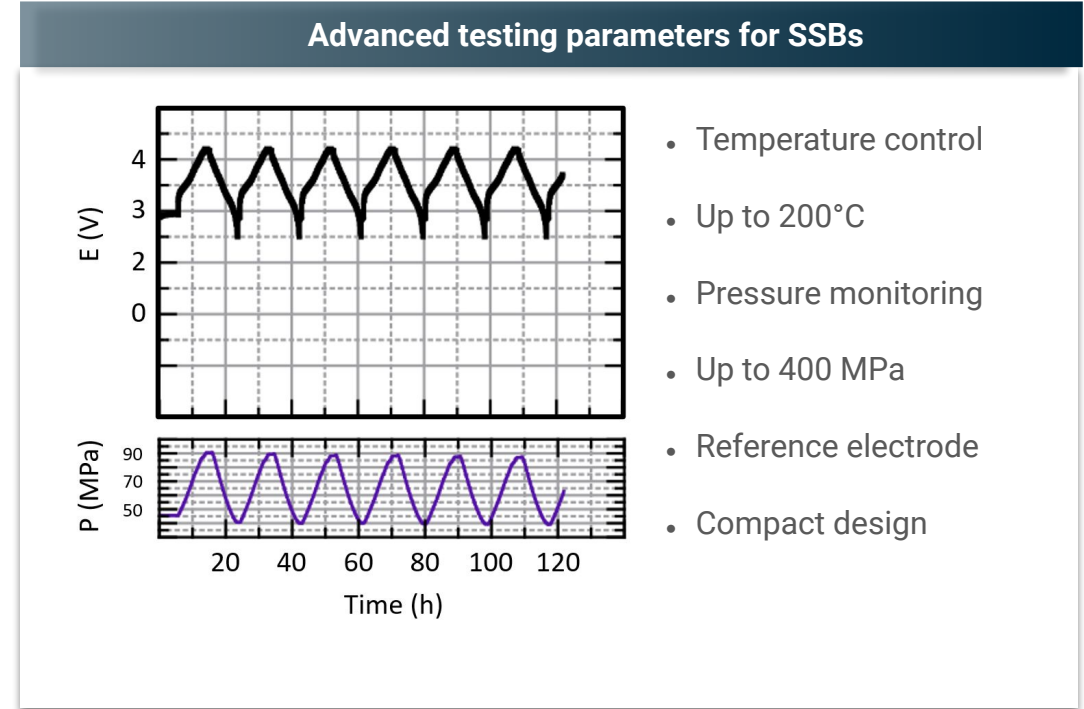
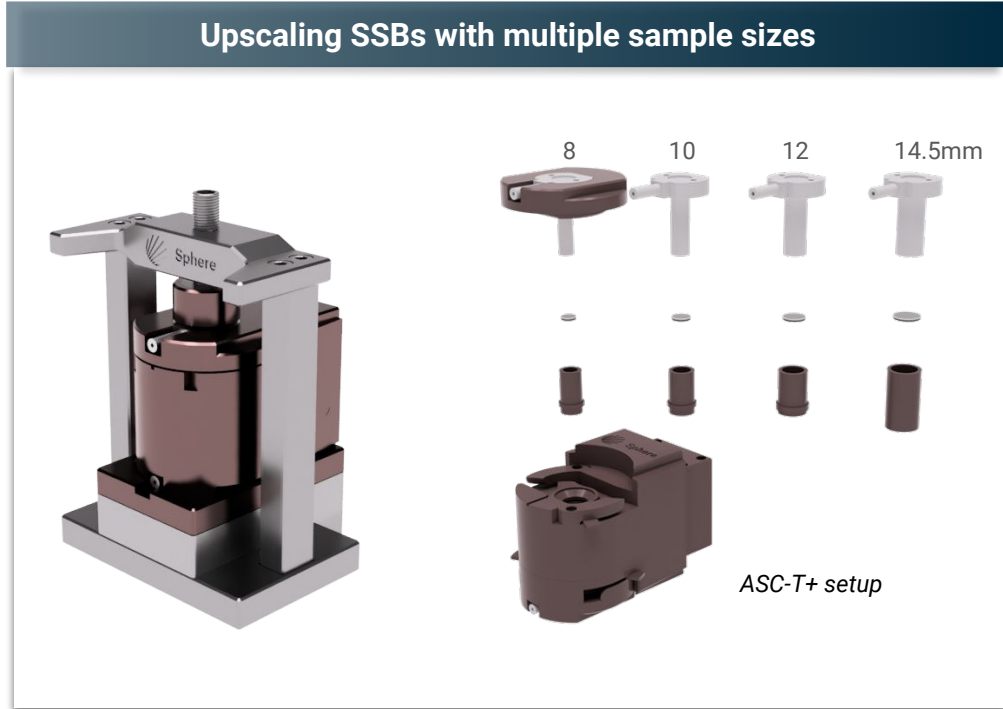
Setups are designed to always fit into our pressure monitoring platform

New setups can be seen as payable upgrades improving the capabilities available at the user end



[ASC-T+] understanding the performance of SSBs when scaling up

Characterization of SSBs samples at wide range of BTRLs

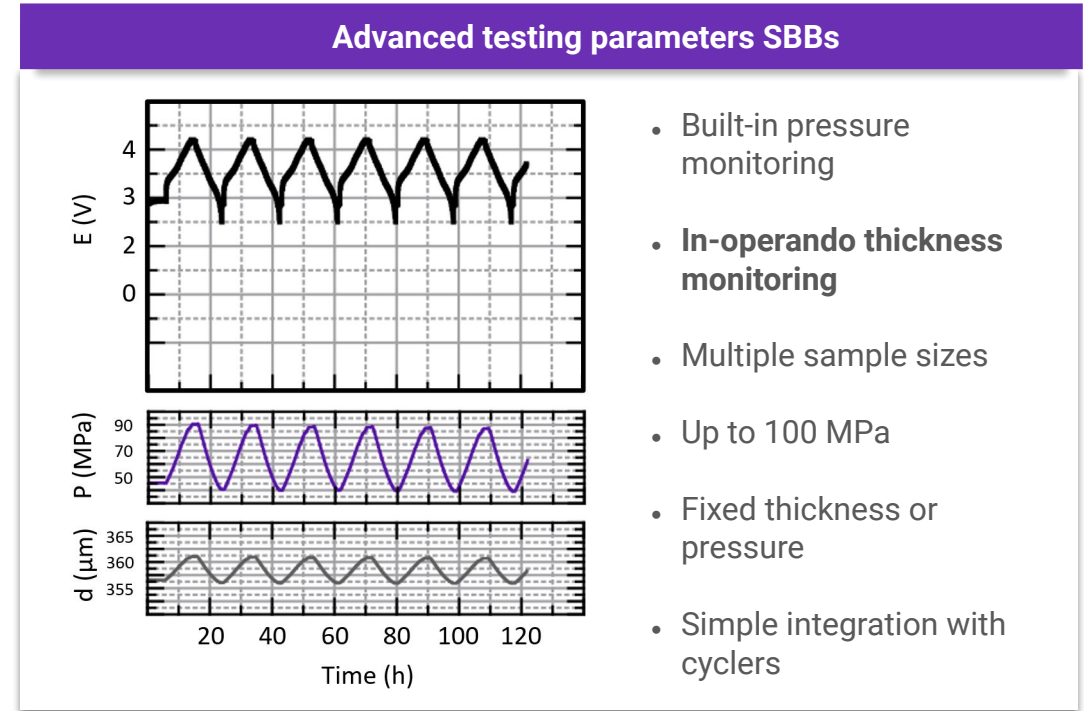
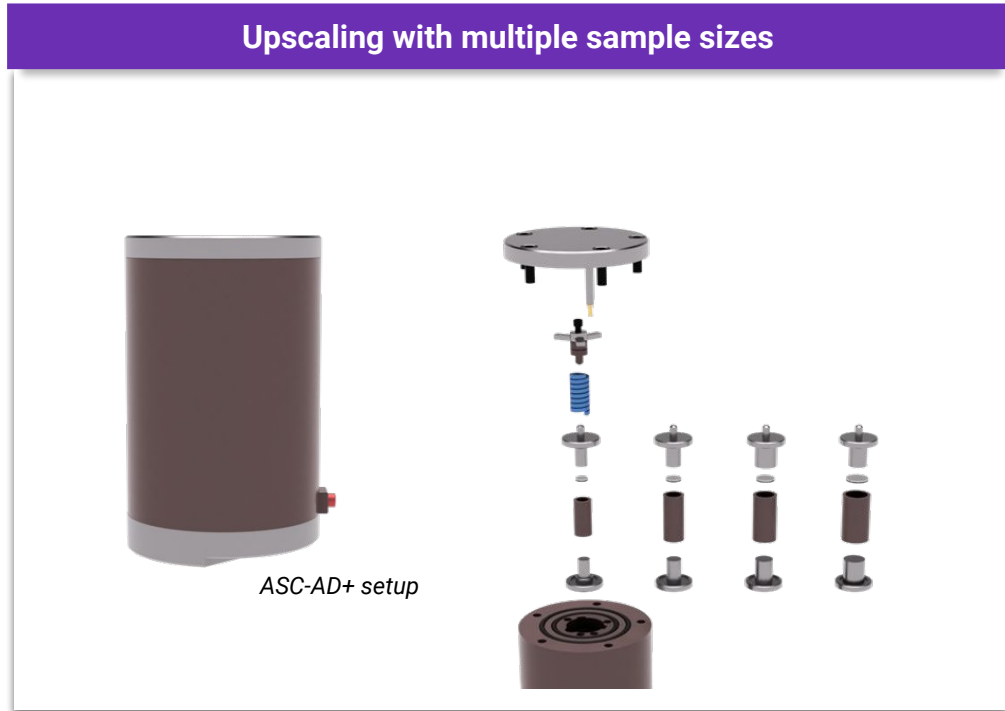


Access over key characterization parameters while upscaling SSBs



[ASC-AD+] precise thickness measurements even at OEM's target conditions

Fine-tuning performance at low-pressure levels



Turn-key solution for validation tests at high BTRLs



From laboratory scale to large-scale production

Key points to be addressed to unveil a faster upscaling process

Key takeaways



Commercialization is coming!

Great progress and technologies coming to the market soon



SSB competitive at pack level

Potential financial benefits when considering the pack



New mechanical aspects to consider

R&D and upscaling now requires a new testing approach



New equipment new design!

From equipment, to processes, to validation tests. Everything will change!



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