

# Next generation batteries – viable solutions for electric air travel?

Dr Alex Holland – Research Director, IDTechEx



## IDTechEx

### Agenda

- Introduction to eVTOL and eCTOL
- Battery technology landscape
- Li-S batteries and silicon anodes
- Concluding remarks

# How IDTechEx Helps Its Customers

Supporting you at each crucial decision making step



# IDTechEx's Battery Technology, Energy Storage, and EV Research Portfolio...

Technologies

Markets and applications

Materials and circularity

**Advanced Li-Ion Battery Technologies 2024-2034: Technologies, Players, Forecasts**



[www.IDTechEx.com/AdvLithium](http://www.IDTechEx.com/AdvLithium)

**Solid-State and Polymer Batteries 2023-2033: Technology, Forecasts, Players**



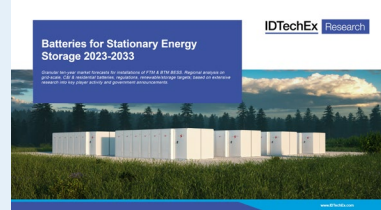
[www.IDTechEx.com/SolidState](http://www.IDTechEx.com/SolidState)

**Li-ion Battery Market 2023-2033: Technologies, Players, Applications, Outlooks and Forecasts**



[www.IDTechEx.com/Lithium](http://www.IDTechEx.com/Lithium)

**Batteries for Stationary Energy Storage 2023-2033**



[www.IDTechEx.com/Stationary](http://www.IDTechEx.com/Stationary)

**Li-ion Battery Recycling Market 2023-2043**



[www.IDTechEx.com/LIRecycling](http://www.IDTechEx.com/LIRecycling)

**Second-life Electric Vehicle Batteries 2023-2033**



[www.IDTechEx.com/SecondLife](http://www.IDTechEx.com/SecondLife)

**Sodium-ion Batteries 2023-2033: Technology, Players, Markets, and Forecasts**



[www.IDTechEx.com/Sodium](http://www.IDTechEx.com/Sodium)

**Long Duration Energy Storage Market 2024-2044: Technologies, Players, Forecasts**



[www.IDTechEx.com/LDES](http://www.IDTechEx.com/LDES)

**Air Taxis: Electric Vertical Take-Off and Landing (eVTOL) Aircraft 2024-2044: Technologies, Players**



[www.idtechex.com/eVTOL](http://www.idtechex.com/eVTOL)

**Battery Markets in Construction, Agriculture & Mining Machines 2024-2034**



[www.IDTechEx.com/CAMBatteries](http://www.IDTechEx.com/CAMBatteries)

**Materials for Electric Vehicle Battery Cells and Packs 2025-2035: Technologies, Markets, Forecasts**



[www.IDTechEx.com/EVBattMat](http://www.IDTechEx.com/EVBattMat)

**Carbon Nanotubes 2023-2033: Market, Technology & Players**



[www.IDTechEx.com/CNT](http://www.IDTechEx.com/CNT)

**Thermal Energy Storage 2024-2034: Technologies, Players, Markets, and Forecasts**



[www.IDTechEx.com/TES](http://www.IDTechEx.com/TES)

**Silicon Anode Battery Technologies and Markets 2025-2035: Players, Technologies, Applications, Markets, Forecasts**



[www.IDTechEx.com/SiliconAnodes](http://www.IDTechEx.com/SiliconAnodes)

**Sustainable Future Aviation 2025-2045: Trends, Technologies, Forecasts**



[www.idtechex.com/SustAviation](http://www.idtechex.com/SustAviation)

**Electric Boats & Ships 2024-2044**



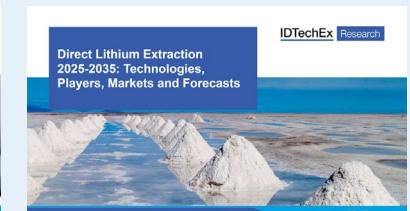
[www.IDTechEx.com/MarineEV](http://www.IDTechEx.com/MarineEV)

**Copper Demand for Cars 2024-2034: Trends, Utilization, Forecasts**



[www.IDTechEx.com/CopperForCars](http://www.IDTechEx.com/CopperForCars)

**Direct Lithium Extraction 2025-2035: Technologies, Players, Markets and Forecasts**



[www.idtechex.com/LithiumExtraction](http://www.idtechex.com/LithiumExtraction)

# Challenges for electric aircraft but industry developments ongoing



## Financial challenges and industry consolidation

- Volocopter file for insolvency
- Lilium narrowly avoid collapse
- Consolidation likely and potential for late mover advantage

## Major players advance

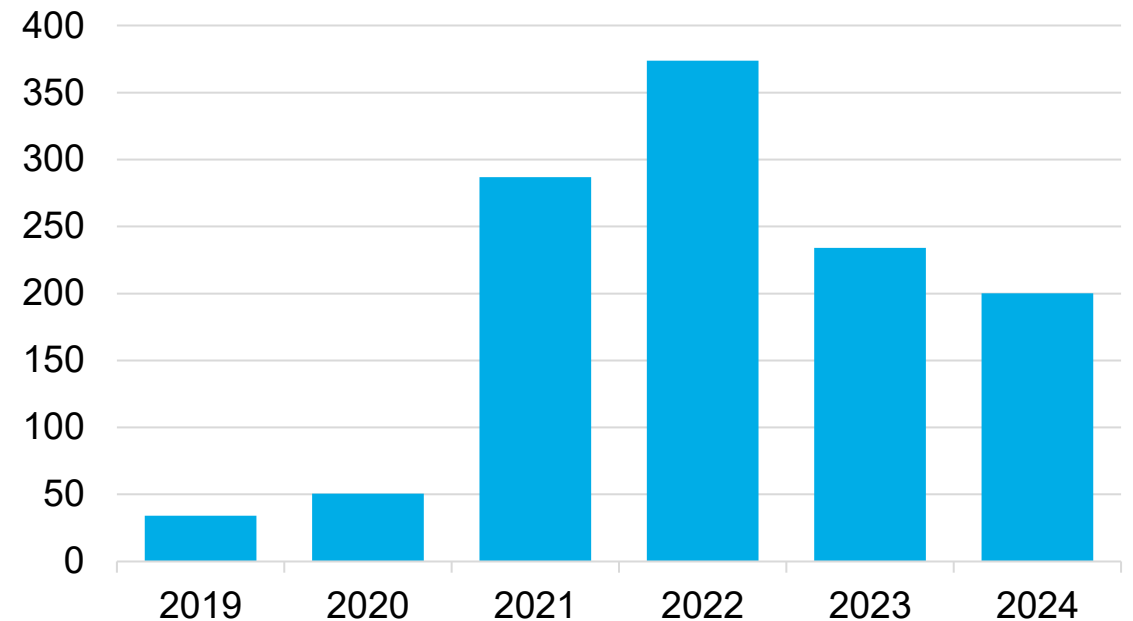
- Joby Aviation enter final stages of FAA certification with TIA tests planned for 2025
- Archer Aviation close to completion of phase 3 FAA certification

## Emergence of Chinese entrants

- Xpend AeroHT unveil tilt-rotor eVTOL
- Autoflight showcase “Prosperity I”
- 50+ companies developing cargo drones or passenger eVTOL
- Cheaper certification in China

Image sources: Eve Air Mobility, Joby Aviation, Ehang, Wright Electric, Piper, Textron,

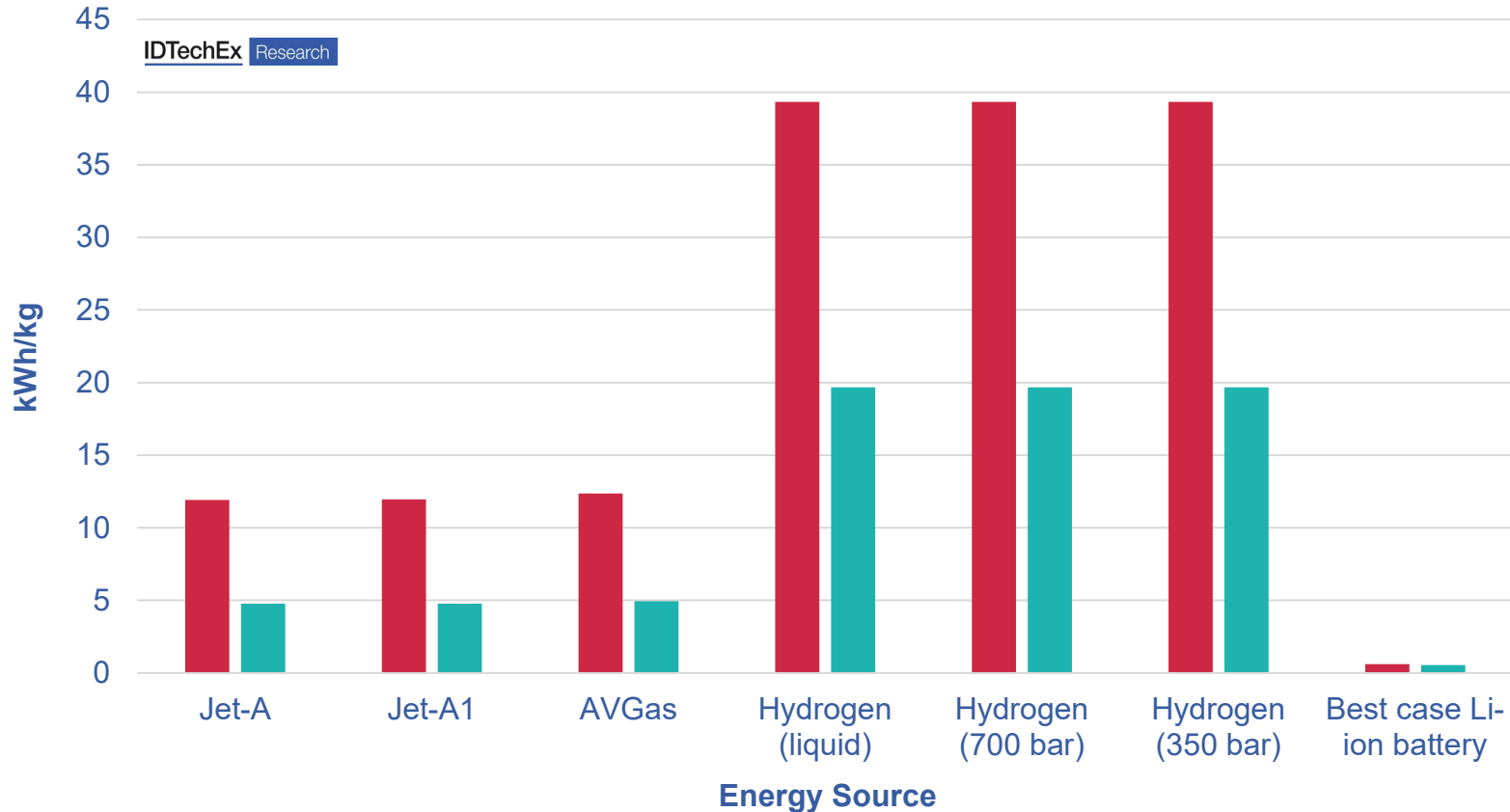
Funding Related to Electric and Hydrogen Airplanes (US\$ million)



Source: Various press releases, collected and presented by IDTechEx

# Batteries are too Heavy for Larger Planes

## Gravimetric Energy Density



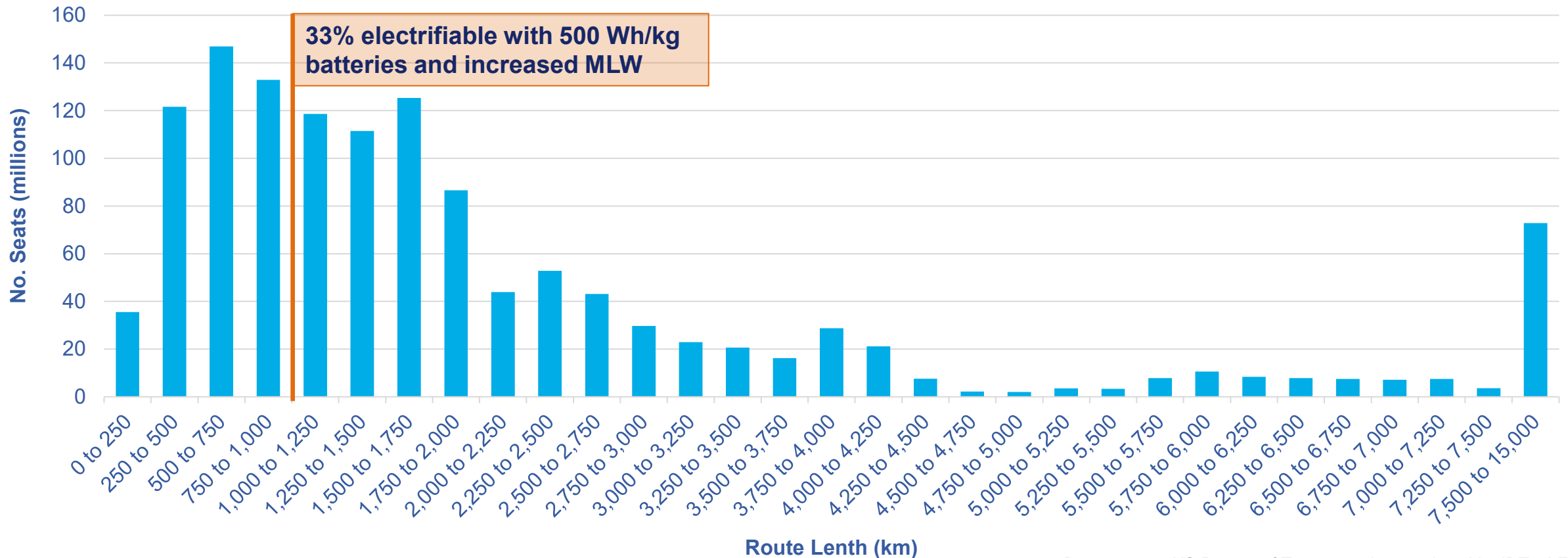
- Gravimetric energy density (kWh/kg)
- Gravimetric energy density (kWh/kg, accounting for efficiency)

- A battery is almost 10 times heavier than jet fuel for the same amount of usable energy. To make matters worse, the battery can only weigh about 50% of the maximum fuel load since the fuel is either burnt or dumped before landing to get under the plane's maximum landing weight (MLW).
- Higher MLWs and better battery technologies are a must to make commercial electric airliners a reality.

# Is electrification viable for commercial flight?

- In short - maybe. Assuming a 500 Wh/kg battery and an increase in MLW, a range of ~600 km becomes possible. This could serve 33% US air travel demand by seating.

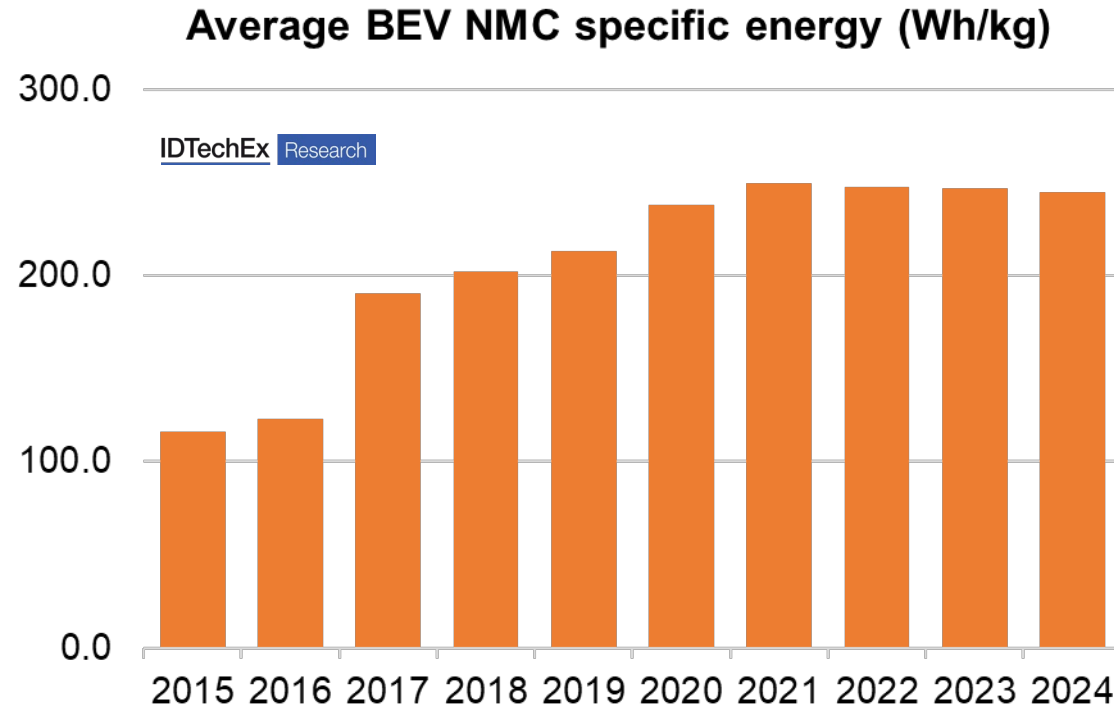
Number of Seats for Different Route Lengths (US only)



Data source: US Bureau of Transportation, analyzed by IDTechEx

# Li-ion batteries reaching their performance ceiling

- Li-ion batteries based on graphite anodes and NMC/NCA or LFP cathodes are reaching their performance limits, especially with respect to energy density.



**2024 state-of-the-art Li-ion**

- 650-700 Wh/l  
250-300 Wh/kg
- 20-30 minute fast charge
- 1000 cycles

# Company landscape highlights silicon and solid-state as ongoing areas of focus

## Lithium-sulphur



## Silicon anodes



## Advanced anodes



## Cathodes



## Solid-state

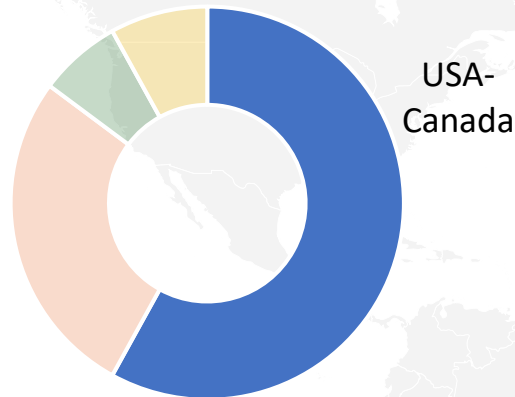




# US in a strong position to capture value from advanced battery technologies...

- US home to a high number of start-ups / earlier stage companies developing and commercialising advanced battery technologies and electrification solutions. Will this translate into global, commercial success?

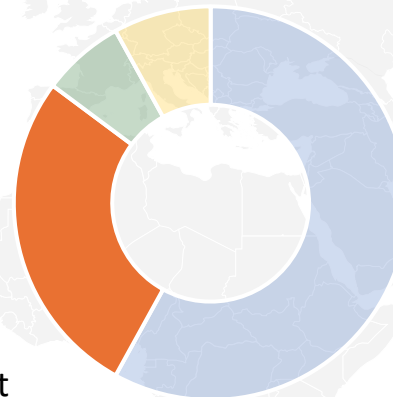
Share of start-ups



USA-Canada

Mix of technologies under development. USA accounts for many of the solid-state, silicon anode, and cathode technology developers.

Share of start-ups

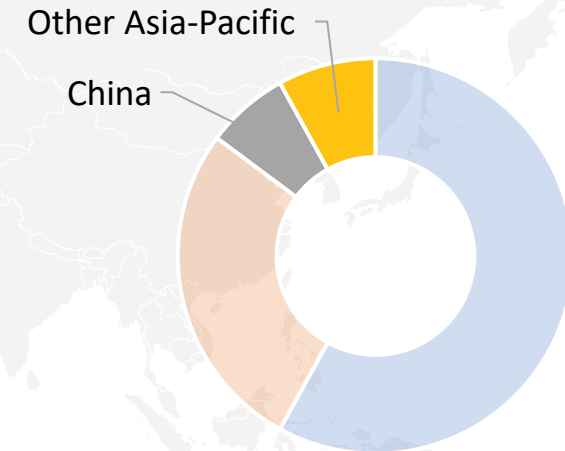


Europe-Middle East

Focus on silicon anodes and solid-state batteries.

IDTechEx Research

Share of start-ups



Other Asia-Pacific

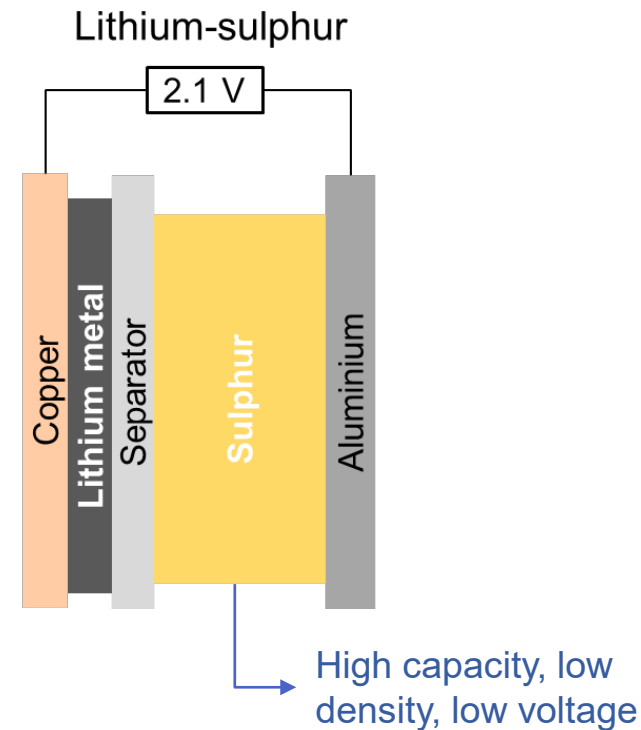
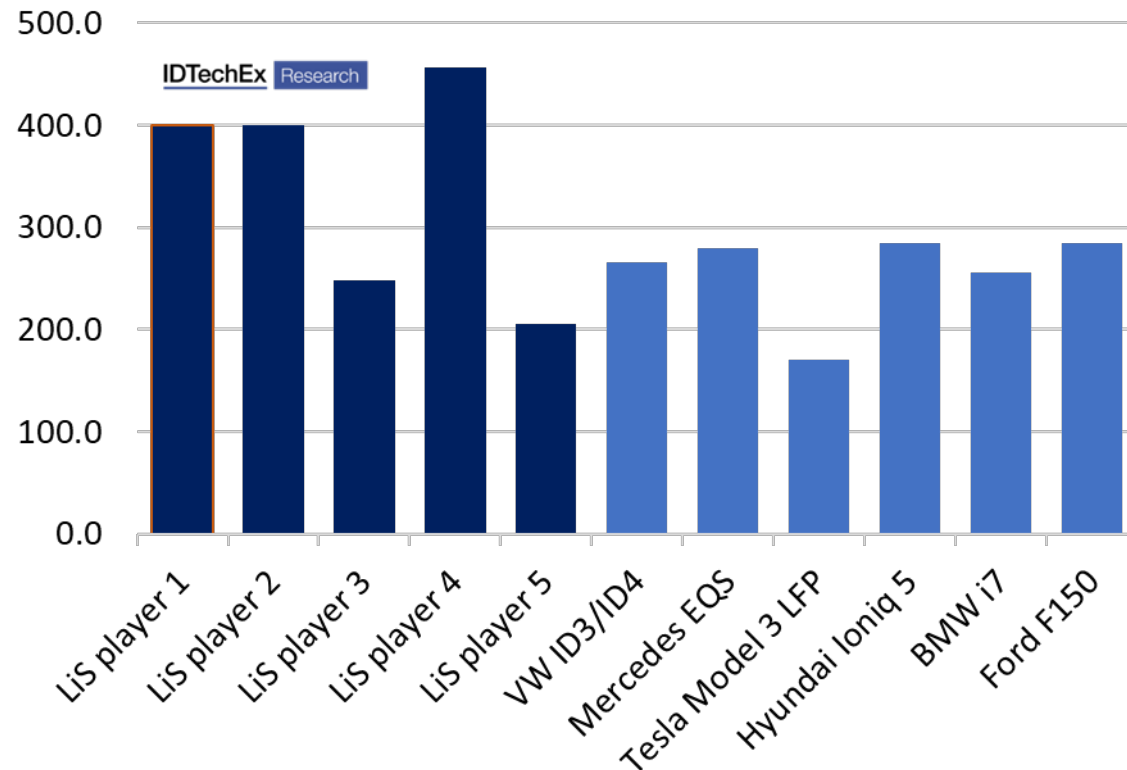
China

**Under-represented as battery development dominated by major industrial players – materials manufacturers, battery manufacturers, automotive OEMs.**

# Reported Li-S characteristics highlights typical advantages and disadvantages

- Li-S can provide a significant improvement to the specific energy of Li-ion cells. Energy density rarely reported.
- Data on cycle life, rate capability, etc are understandably lacking given relatively early stage of Li-S commercialisation.
- Importantly for electric aviation, the power and rate capability of lithium-sulphur is typically at a disadvantage.

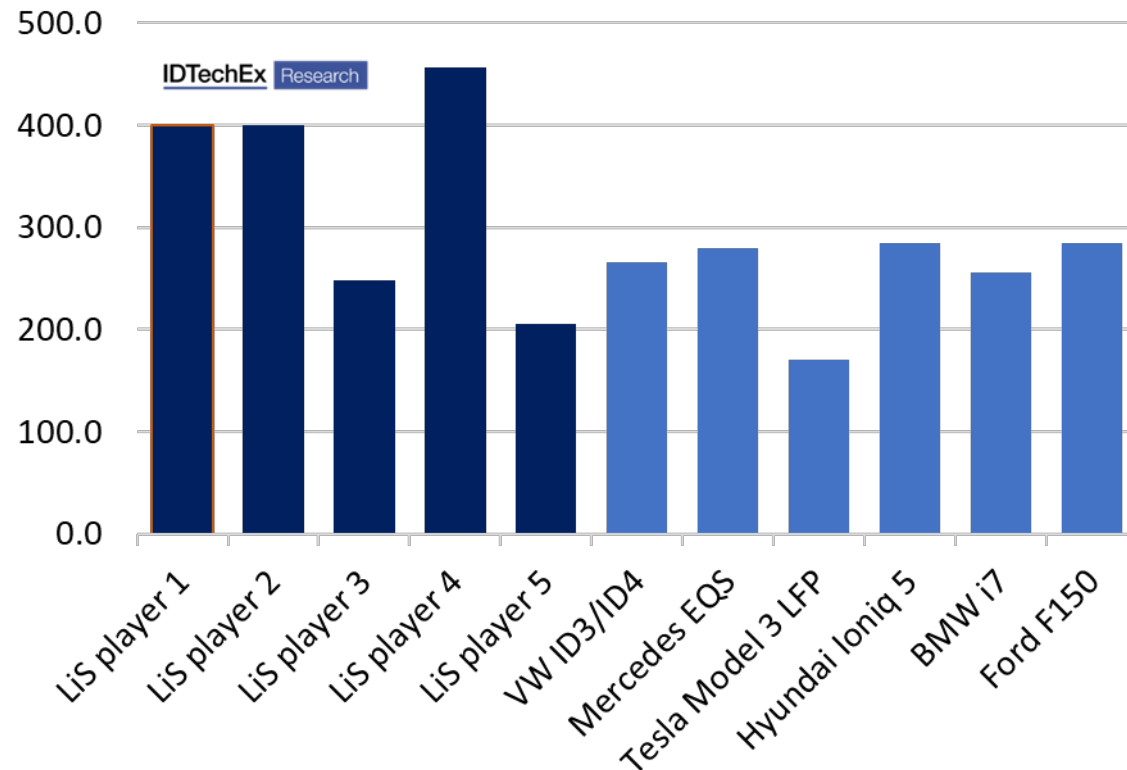
Specific energy comparison (Wh/kg)



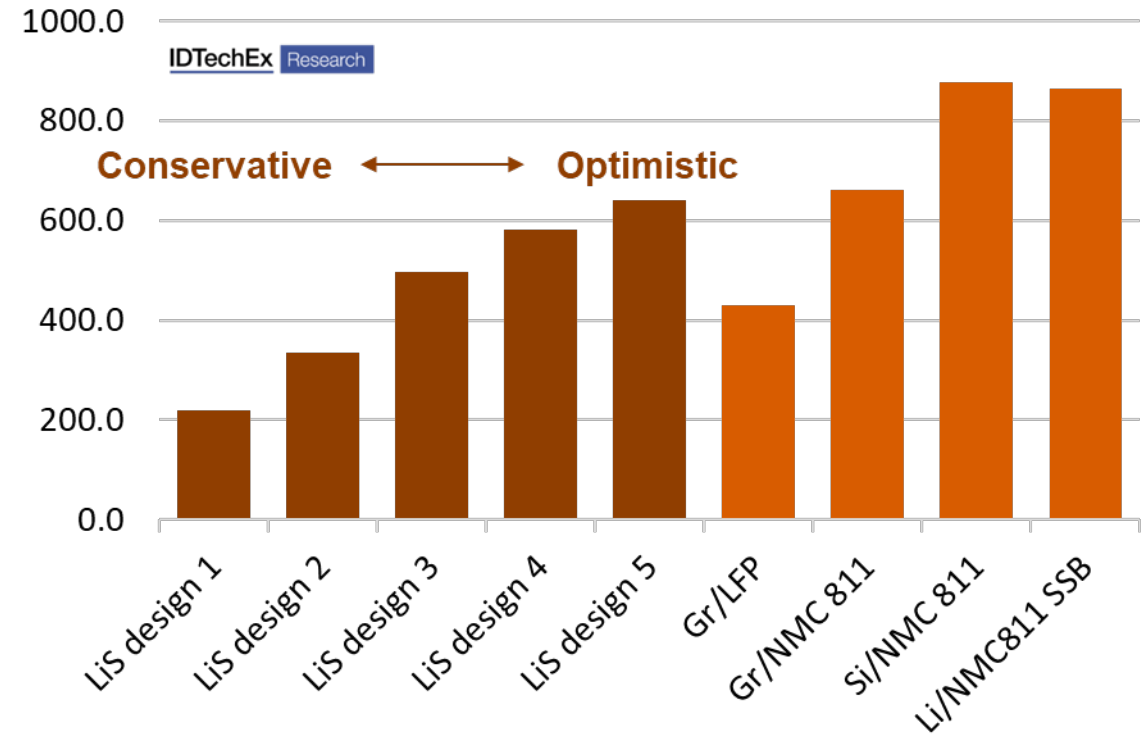
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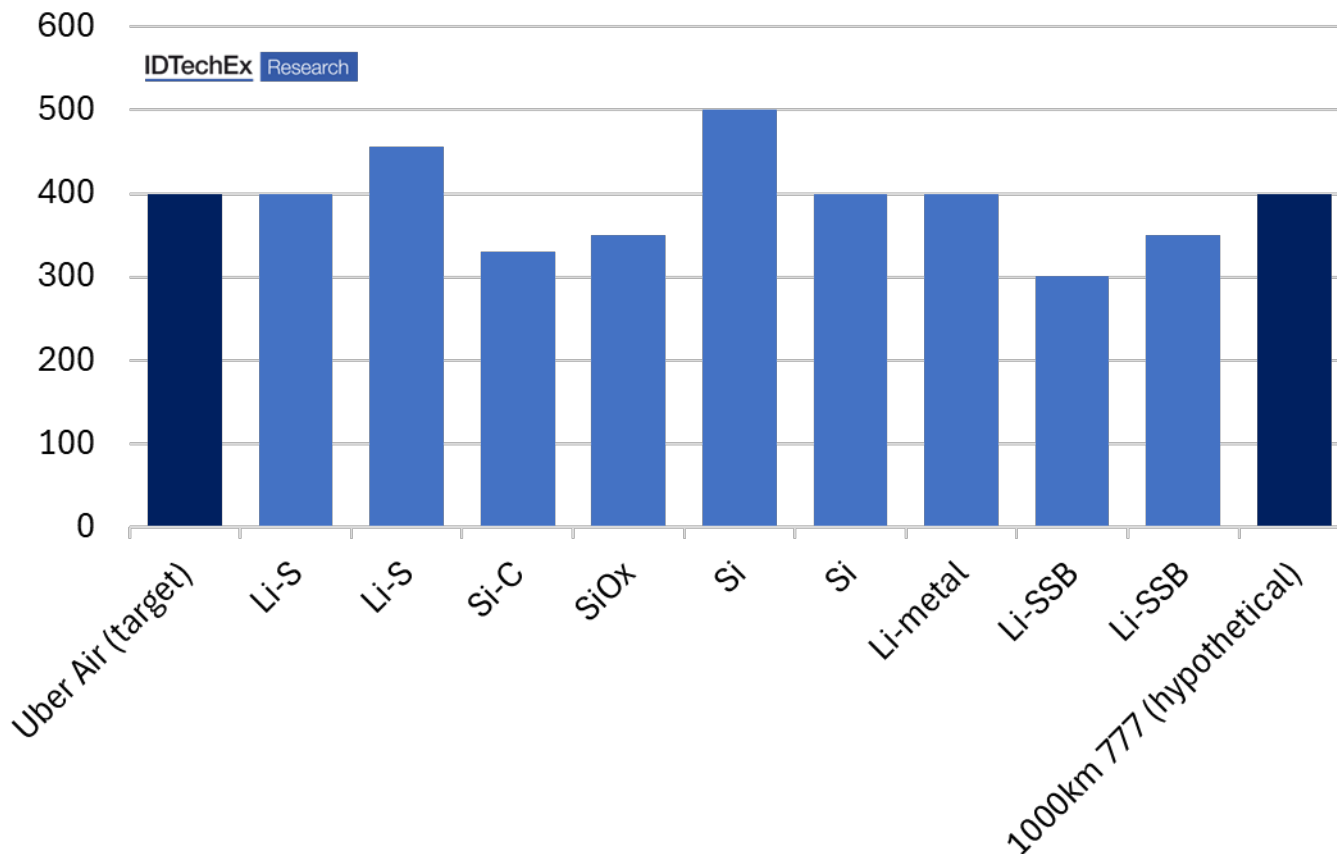
Calculated cell-level energy density (Wh/l)



# Can next-generation meet the requirements of electric aviation?

- Various silicon anode technology developers reporting “more complete” data highlighting improvements to energy density and C-rate, whilst maintain reasonable cycle life around 1000 cycles.

Reported cell specific energies (Wh/kg)



	Specific energy (Wh/kg)	Cycle life	C-rate
<b>Uber Air (target)</b>	400	2000	3C
<b>Li-S</b>	400	300	ND
<b>Li-S</b>	456	ND	ND
<b>Si-C</b>	330	1000	6C/6C
<b>SiO<sub>x</sub></b>	350	1000	1C/1C
<b>Si</b>	500	200	1C/1C
<b>Si</b>	400	300	10C/10C
<b>Li-metal</b>	400	700	4C/4C
<b>Li-SSB</b>	301	ND	4C
<b>Li-SSB</b>	350	650	1C/1C

# Concluding remarks

- Next-generation battery technologies could feasibly meet requirements for air taxis and eVTOL. Mid-high silicon anodes increasingly meeting performance requirements.
- Some electrification starting for small general aviation aircraft to for training or tourism.
- Commercial airlines unlikely to electrify for 10+ years, though non-negligible percentage of routes could feasibly be electrified.
- Lithium-sulphur offers highest gravimetric energy density but characterisation of other important metrics lagging, and development pursued by a small number of companies.
- Solid-state batteries and other electrolyte developments may hold the key to improved/required safety.

## IDTechEx's Battery Technology, Energy Storage, and EV Research Portfolio...

The image displays a grid of 18 research report covers from IDTechEx, organized into three columns: Technologies, Markets and applications, and Materials and circularity. Each cover includes a title, a brief description, and a URL.

Technologies	Markets and applications	Materials and circularity			
<b>Advanced Li-ion Battery Technologies 2024-2034</b> Technologies, Players, Forecasts <a href="http://www.IDTechEx.com/AdvLithium">www.IDTechEx.com/AdvLithium</a>	<b>Solid State and Polymer Batteries</b> 2023-2033: Technology, Forecasts, Players <a href="http://www.IDTechEx.com/SolidState">www.IDTechEx.com/SolidState</a>	<b>Li-ion Battery Market 2022-2033</b> Technologies, Players, Applications, Outlooks and Forecasts <a href="http://www.IDTechEx.com/Lithium">www.IDTechEx.com/Lithium</a>	<b>Stationary Energy Storage 2023-2033</b> <a href="http://www.IDTechEx.com/Stationary">www.IDTechEx.com/Stationary</a>	<b>Li-ion Battery Recycling Market 2023-2034</b> <a href="http://www.IDTechEx.com/LIRecycling">www.IDTechEx.com/LIRecycling</a>	<b>Second-life Electric Vehicle Batteries 2023-2033</b> <a href="http://www.IDTechEx.com/SecondLife">www.IDTechEx.com/SecondLife</a>
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