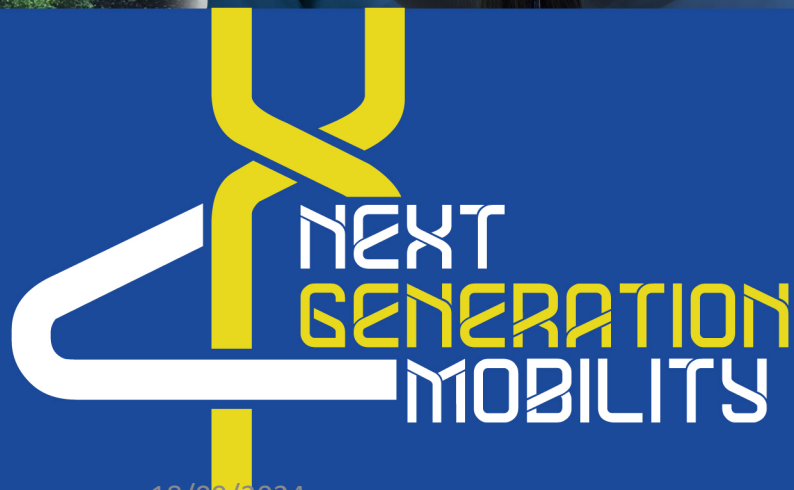


CITIES BELONG TO THE NEW GENERATION

www.ngmobility.it



18/09/2024

18-19
SETTEMBRE

2024
CENTRO CONGRESSI
UNIONE INDUSTRIALI TORINO

Organized by
NEXT GENERATION MOBILITY





Navigating turbulences in future aerospace mobility

ABOUT US ...

Be2Hub s.r.l was founded in 2009 by a **team of professionals** who shared an ambitious challenge: supporting **small and medium enterprizes** in advanced **energy management**.

Several collaborations with big companies in advanced studies for the **industrialization of high performance Lithium cells** have strenghten our knowledge, so that high end **Battery prototypes** were designed and realized by Be2Hub.

Since 2023 Be2Hub has been working on **electrochemical cells analysis and measurement** and on **innovative BMS development**, in order to give 360° support to the customers.

HV BATTERY PACKS CONCEPTS AND PROTOTYPES



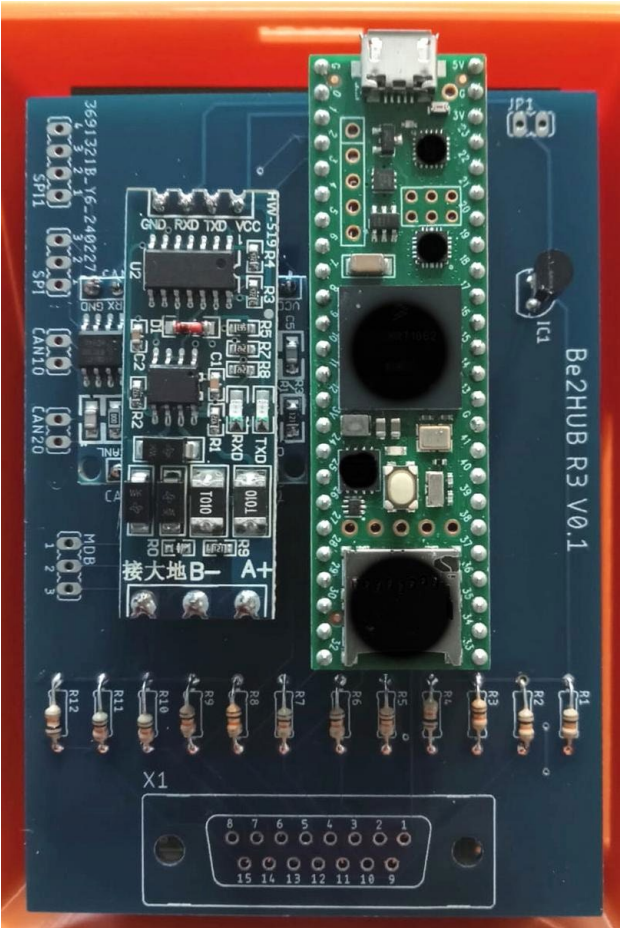
- Conception of **vehicular battery systems** and development of prototype especially focusing on:
 - **Risk Analysis** and preliminary design optimization
 - **Thermal management** {Cooling and Pre-conditioning}
 - **Battery management** {SOC, SOH, SOF}
 - Prototype: **modular and scalable system**
- Housing and assembly design of the battery system, including the integration inside the vehicle
- Cooling concept and simulations
- Development and dimensioning of HV wiring system
- Testing activities and performance checks
- Ensuring complete system integration with the vehicle electrical drive train
- Implementation of early diagnosis functions
- Support in concept validation on test bench and on the vehicle

HV BATTERY PACKS VALIDATION & PRE-PRODUCTION



- **Testing and measurement** activities on cells: a key support in choosing the best solution
- Supplier's management until production release of HV battery systems:
 - Support for **Validation activities** according to OEM-requirements
 - Support & **Selection of suppliers**, creation of requirement specifications
 - Enabling of battery suppliers into customer specific development processes
- ▶ Advisory in **design, risk analysis** and verification of **safety functions** of the battery system
- ▶ Support for functional-, **hardware- and software development**
- ▶ Implementation of **software modules** into battery management environment
- ▶ Battery pack layout optimization to match mechanical and functional requirements of the end user.

MMU3 - FW REV. 3.00



Be2Hub confirms the requirements already indicated in April: 200 Hz
The testing at 230 Hz has been already conducted, but not certified.

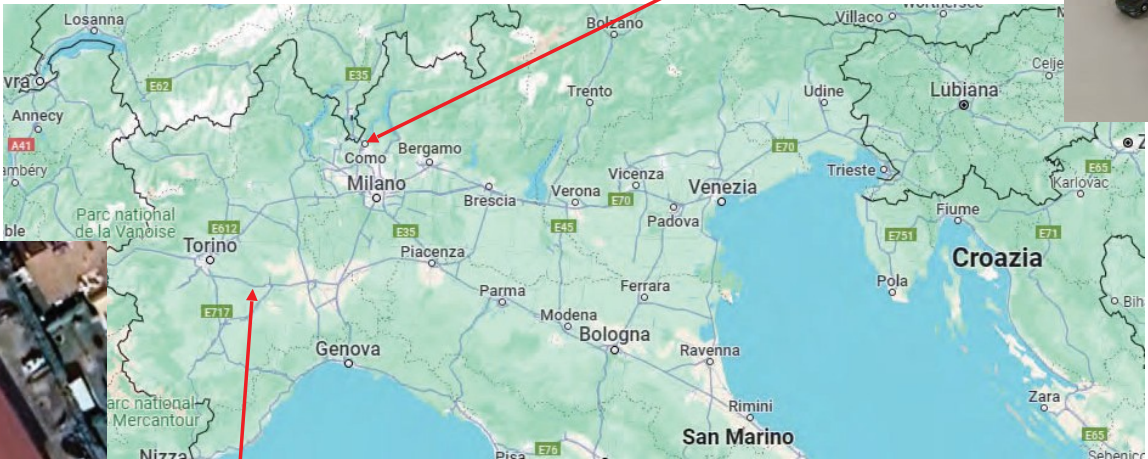
2024 APRIL Validated performances

- ADC 16 channels 24 bit resolution for Voltage
- ADC 12 channels 12 bit resolution for Temperature and Pressure
- N.2 FD Can Bus lines for Master BMS Communication
- N.1 Modbus Line for External Monitor/Debug
- 5ms Time Cycle (200Hz frequency sampling)
- <100mA Power Consumption
- Active Balancing System
- Extended dynamic EIS

BE2HUB LOCATIONS TODAY



Headquarter
Chemistry Lab



Engineering
Testing Lab

ELECTRIC FLIGHT PLATFORM OPPORTUNITIES

RECHARGEABLE, HIGH-ENERGY AND RATE CAPABLE CELL

Aviation Platforms:

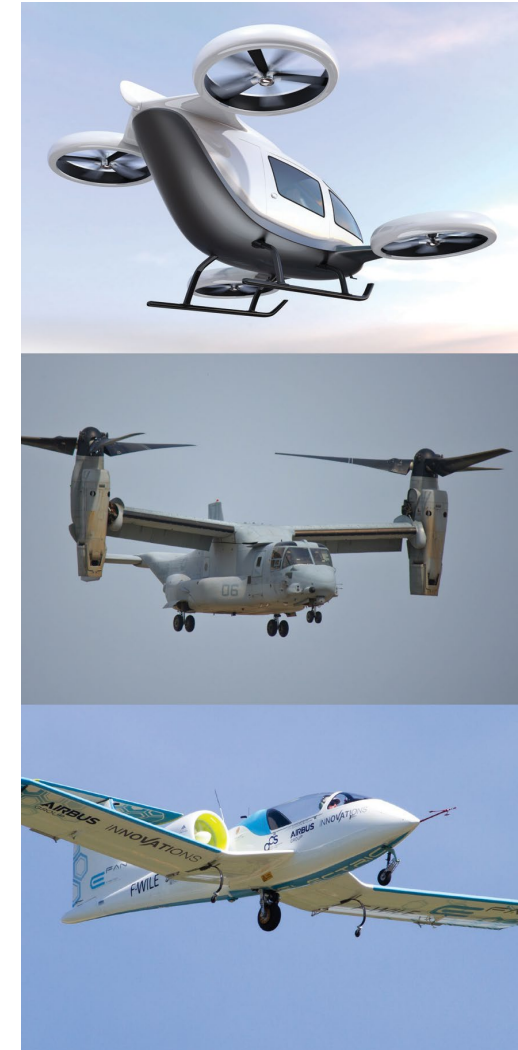
- Electric vertical take-off and landing (eVTOL)
 - Urban air mobility (UAM), regional air mobility (RAM), air taxi
- Future vertical lift (FVL)
- Next-generation Department of Defense rotorcraft
- Hybrid propulsion
 - Mixed propulsion to improve efficiency
 - Electric motor supplements base fuel engine load

Application Requirements:

- High power for lift-off and descent
- Must include the gross vehicle weight including the craft, passengers and cargo
- High energy for extended range
- Optimal balance of power and energy: 4 to 8C discharge
- High-cycle life to decrease operating cost
- Safety certifications: UN38.3, FAA DO-311A

Required Battery-Level Capabilities:

- High-specific energy: $> 300 \text{ Wh/kg}$
- High-discharge rate capability/specific power (kW/kg)
- Fast-recharge capability: $\geq 4\text{C}$
- High-cycle life: $> 1,000$ at 80-100% depth-of-discharge (DoD)

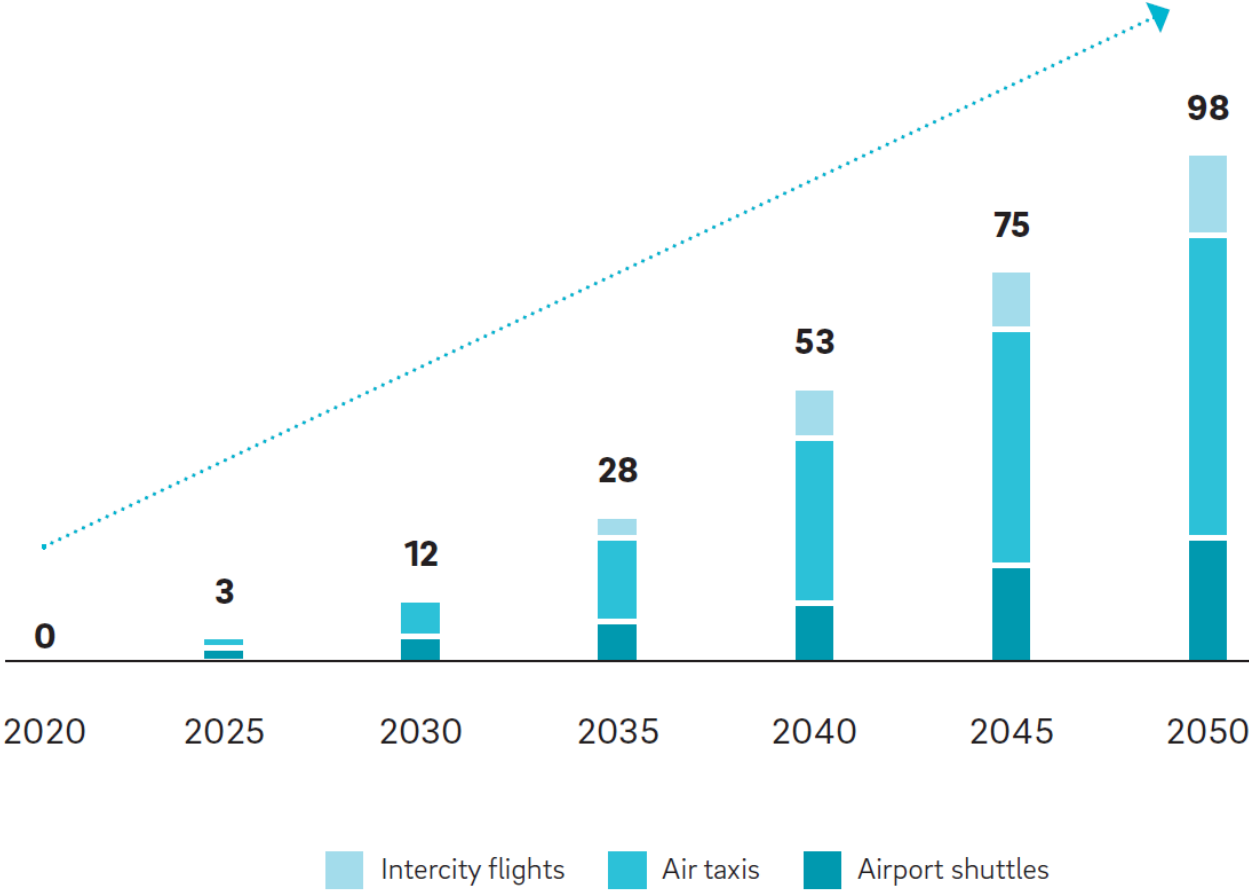


FUTURE ISSUES IN MOBILITY

- Technology Development and Innovation
- Charging Infrastructures and Network
- Maintenance logistics
- Policy and Government support, laws and authorizations
- Consumers Demand Awareness growth
- Ticket Price reduction

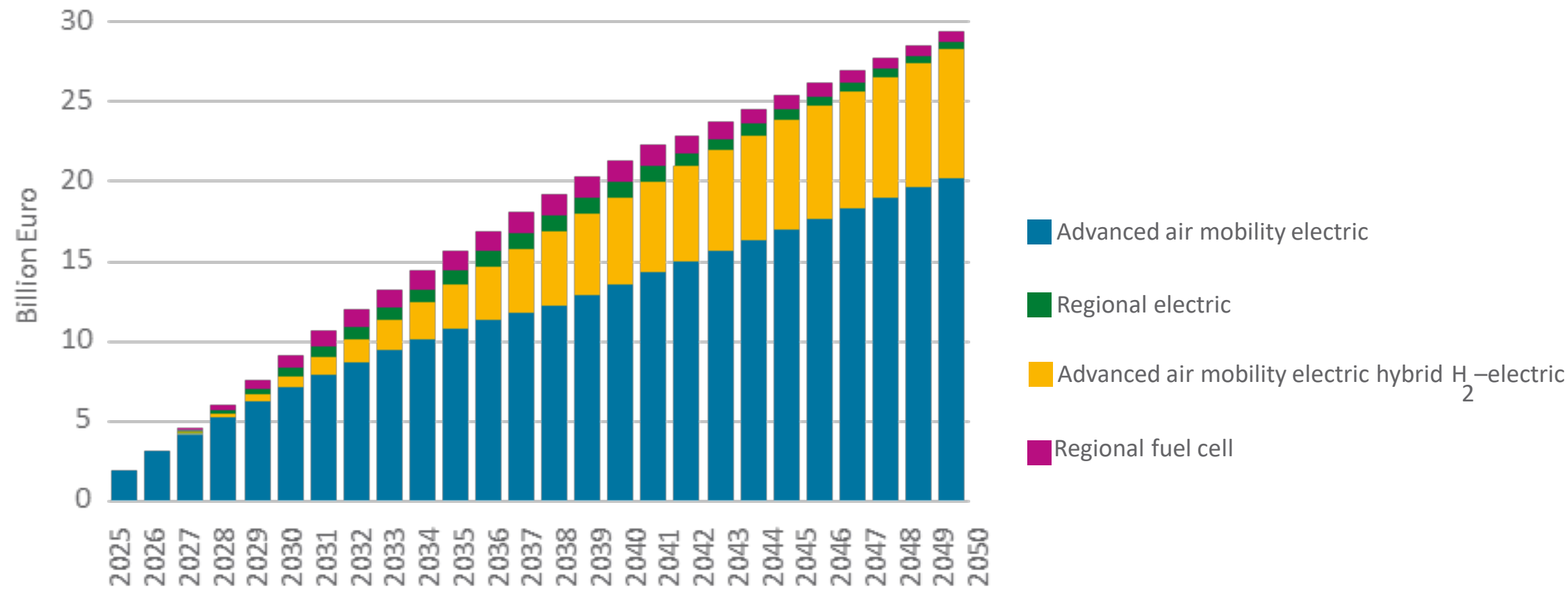


PASSENGER DRONE OPERATIONS FORECAST NUMBER OF PASSENGER DRONES IN UAM OPERATION WORLDWIDE ['000]



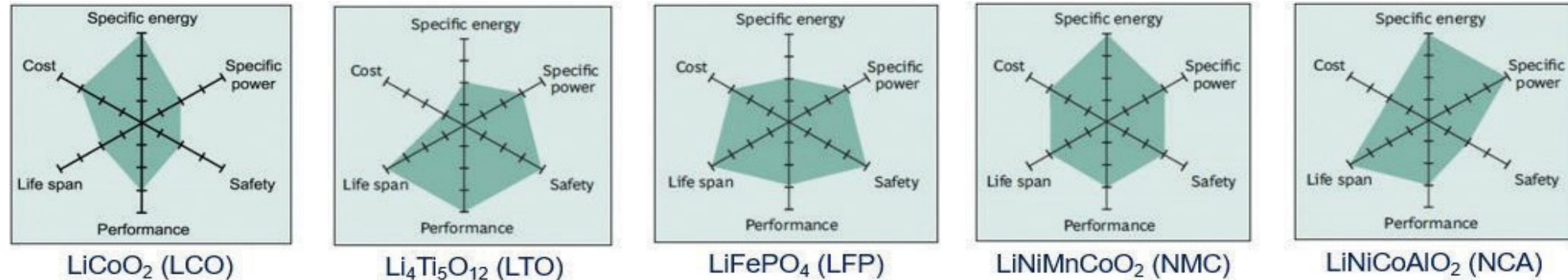
Note: Estimated that ~100 cities will have UAM operations in 2050
 Source: Roland Berger

GLOBAL ANNUAL MARKET REVENUES FROM THE MANUFACTURE OF ELECTRIC PLANES



Source: ATI Market Model

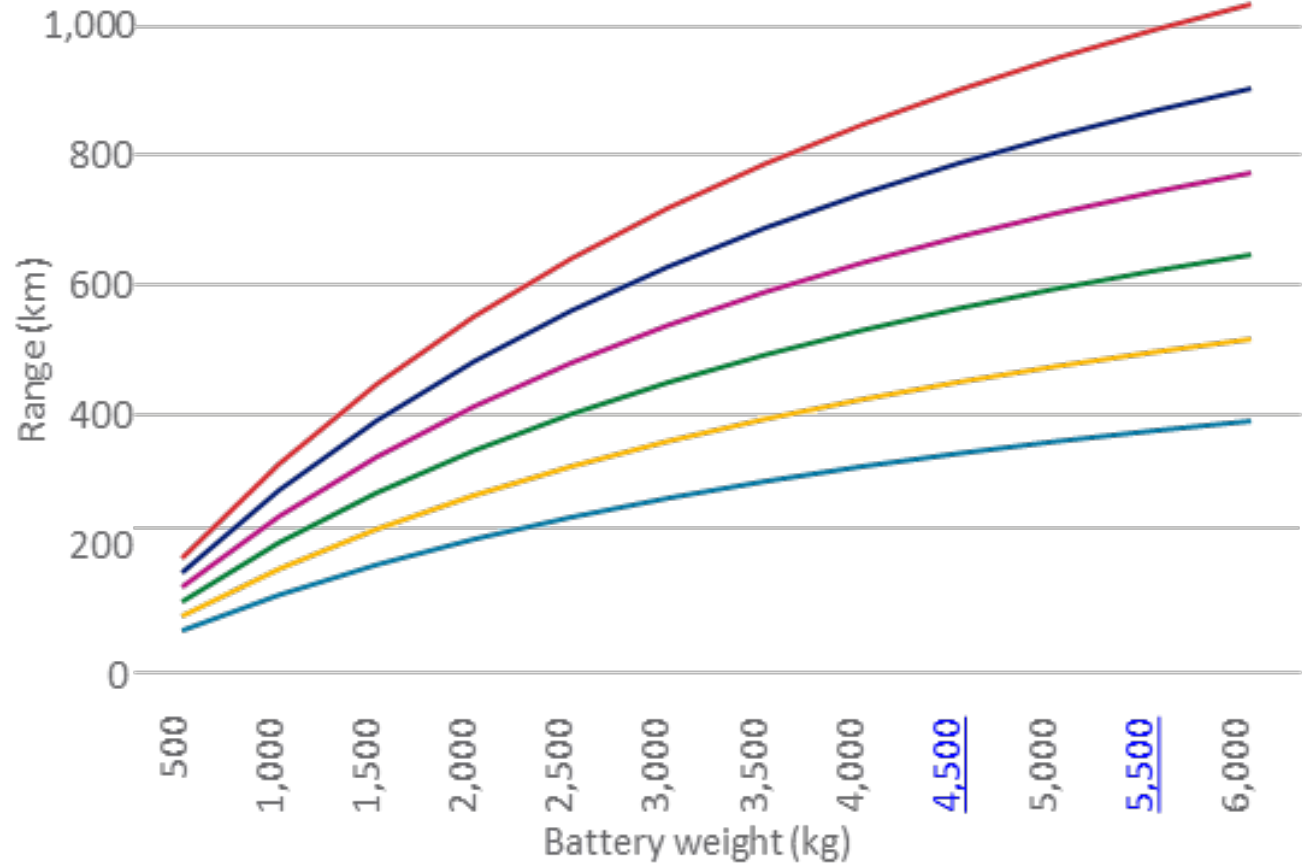
LITHIUM-ION ELECTROCHEMISTRY CAPABILITIES AND TRADES



- Flight requirements must extend cell capabilities beyond the present state-of-the-art cathode and anode materials, electrolytes and interfaces, e.g. solid-state
- Theoretical capabilities of any electrochemical couple are limited by practical means necessary to harness the energy potential
- ALL cells have varying degrees of required volume and mass overhead
 - ✓ Can, cover, pouch, current collectors, tabs, electrolyte, separator
- Optimization of these supporting elements to increase active material content will further improve the cell's energy and power densities...***potential impacts to safety?***

Charts courtesy of Cadex Electronics/Battery University:
www.slideshare.net/AndrewGelston/types-of-lithiumion

ELECTRIC AIRCRAFT CRUISE RANGE BY GRAVIMETRIC ENERGY DENSITY



Eviation Alice Example



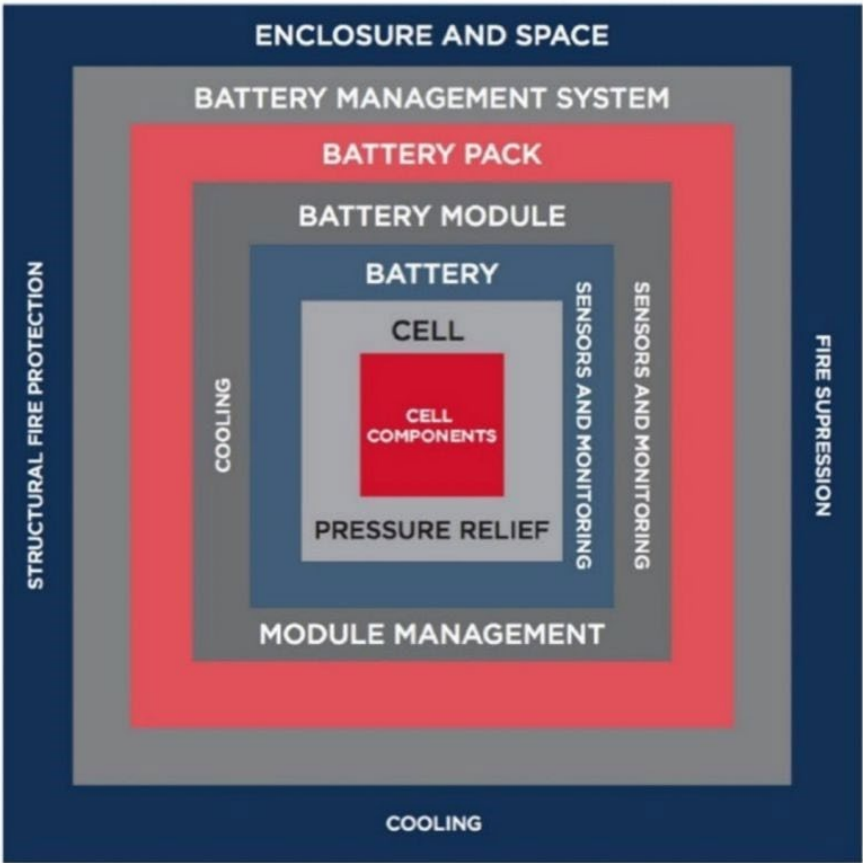
It should cruise at 220 kn (407 km/h, down from 240 kn), have 440 nmi range, 100 nmi (185 km) less than previously, be powered by an 820 kWh lithium-ion battery weighing 3,720 kg (8,200 lb), down from a 920 kWh battery weighing 3,600 kg, would have a 6,350 kg maximum take-off weight, down from 6,668 kg, an altitude ceiling of 32,000 ft and a maximum payload of 1,134 kg

- 300 Wh/kg
- 400 Wh/kg
- 500 Wh/kg
- 600 Wh/kg
- 700 Wh/kg
- 800 Wh/kg

Source: BNEF (February 2022). Electric Aircraft Propulsion: Technology and Industry

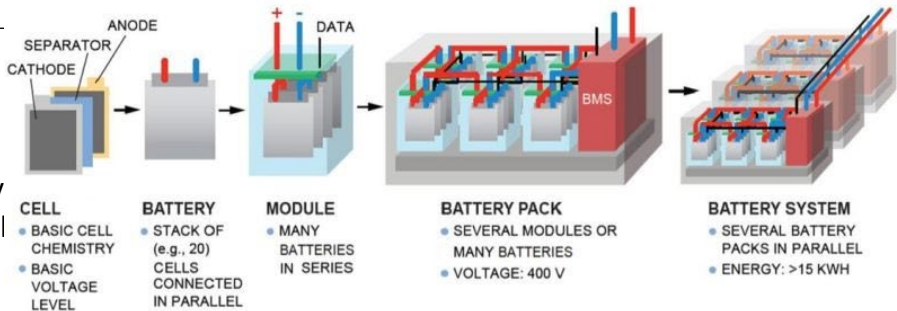
CELL LEVEL ENERGY DENSITY AND PERFORMANCE METRICS

Technology development	Current (NMC vs LFP)
Current gravimetric ED Wh/kg	~280
Future gravimetric ED Wh/kg	~300
Current volumetric ED Wh/L	~700
Future volumetric ED Wh/L	~800
Power capability	Average
High temperature operation	Poor
Low temperature operation	Average



GY

	Solid state sulfidic	Solid state oxidic
	-	-
	~500*	~400*
	-	-
	~1,200*	~1,200*
	Good	Good
	Good	Good
	Poor	Poor

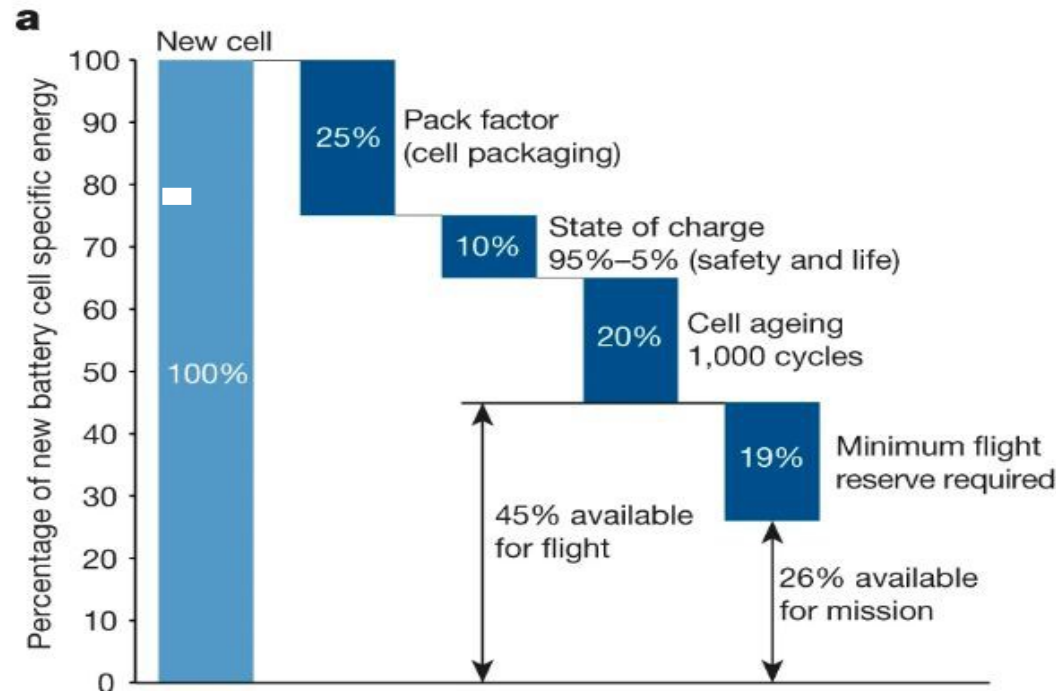


Source: Faraday Institution research. Energy density
 Note: * Denotes energy density values for future cell

and on cell format and design.
 rcially.

Aviation-specific cells are some time away from scale production. Aircrafts leveraging existing technology are likely to have the jump on certification and first-mover advantage, while only being able to support short-range aircrafts.

For aviation, the entire specific energy of a cell cannot be used for the mission profile. Packaging, safety, ageing and regulatory requirements for reserve energy mean that only 26% of the new cell specific energy is realizable for the flight mission.



Source: [Viswanathan et al.](#), Company websites

	Product (Cell/Module)	Chemistry	Targeted ED [Wh/kg]	Power	Select Aircraft partners
	C (pouch)	Li metal	380	2 kW/kg	-
	C (pouch)	Si nanowire	360-500 1150 Wh/L	10C	-
	C (pouch)	811 NCM, >90% SiOx	>300 Wh/kg (340 at C/3)	>3 kW/kg	Lilium
	C (cyl.)	NMC/A, Gr	>230 Wh/kg	-	Archer
	Module	-	205	-	NASA, Supernal, Plana
	Module (Husky2P50)	Molicel cells	215	7C (6 min), 1.56 kW/kg	Dovetail
	Module (cyl. cells)	-	196	-	Rolls Royce, Heart, Cuberg
	Module (cyl. cells)	-	200	-	Piper , Pratt & Whitney , BRM Aero
	Module (TB60 ,24P8S)	LFP (A123)	66	-	Conventional aircrafts

ELECTRICAL PROPULSION ARCHITECTURES

There are three main architectures for Electrical Propulsion

Hybrid-electric

Hybrid-electric is one of two architectures – Parallel or Series hybrid. Additional electric energy can be used for acceleration and in times of high power demand, and bi-directional flow of power is possible between the generator and battery.



Parallel hybrid



Series hybrid

Turbo-electric

The kinetic energy of a turbo shaft is transformed into electric energy via a generator to drive multiple, distributed fans, with the fans driven by electric motors.



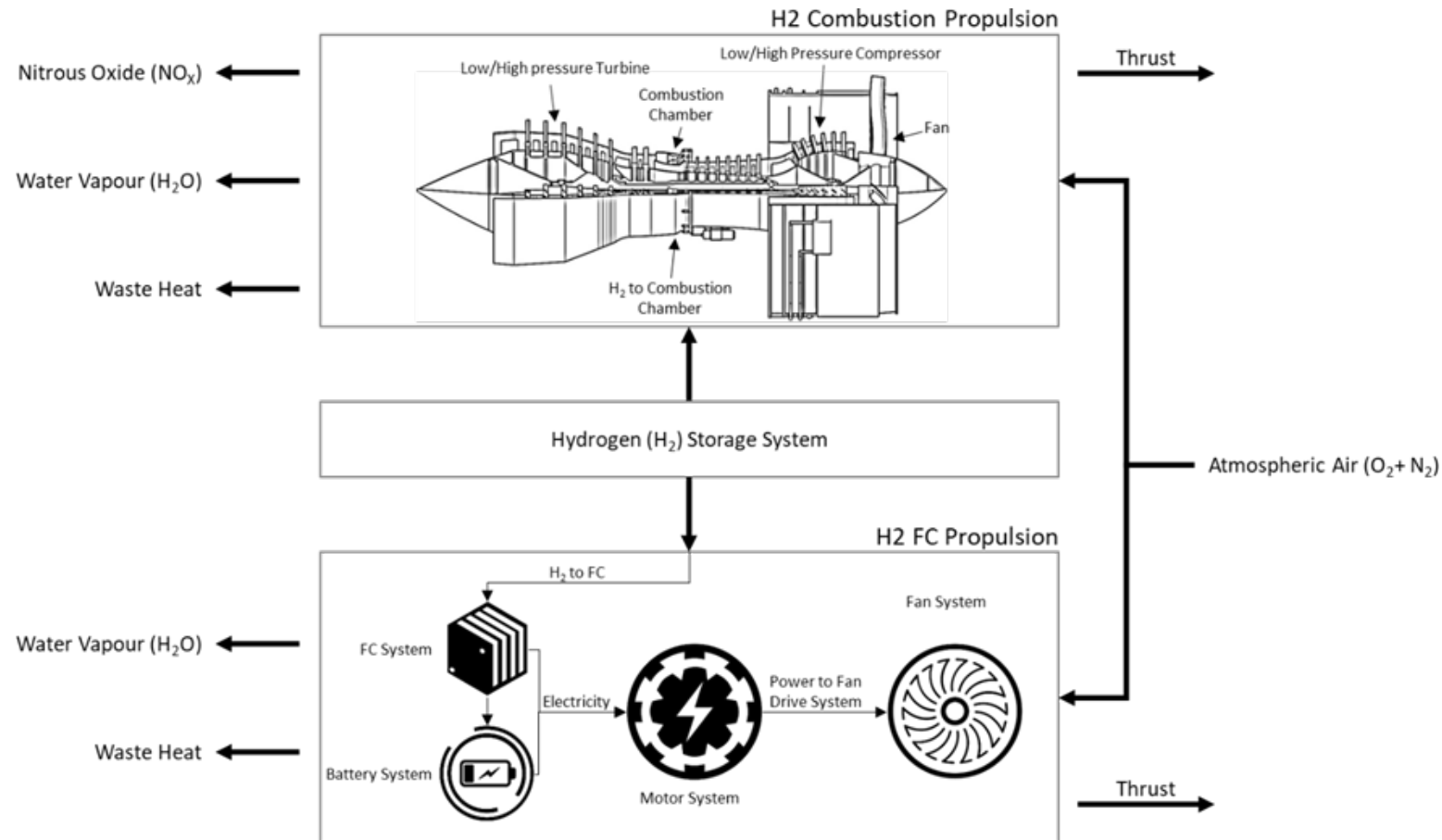
All electric

One, or multiple, fans are driven by electric motors with energy stored in a battery.



Source: NASA, Roland Berger

POSSIBLE HYDROGEN-FUELED PROPULSION METHOD CONFIGURATIONS



Source: Thomson, R., Weichenhain, U., and Sachdeva, N. (2020).

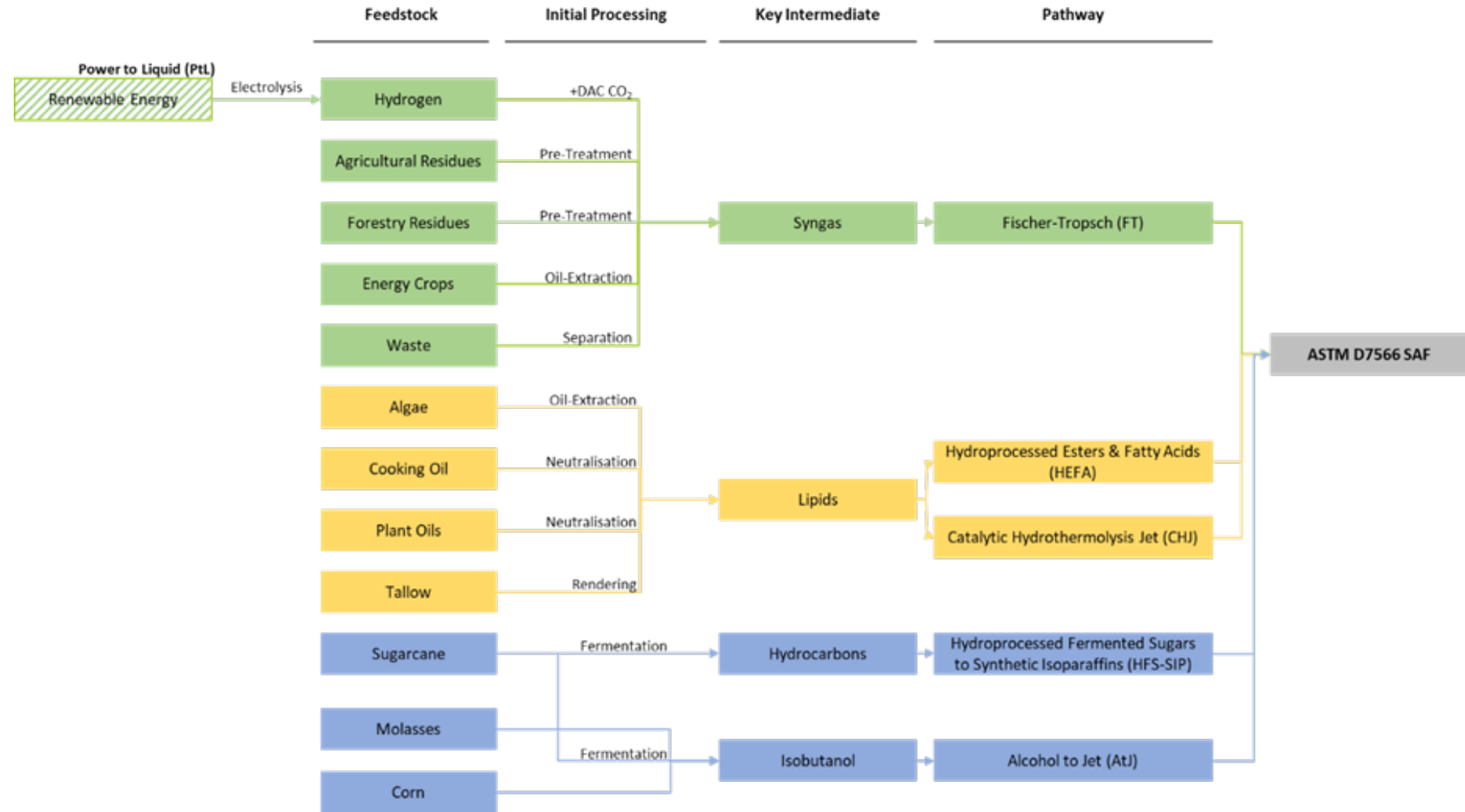
<https://www.rolandberger.com/en/Insights/Publications/Hydrogen-A-future-fuel-for-aviation.html>

COMPARISON OF CURRENT EMERGING BATTERY TECHNOLOGIES

Battery	Lithium-ion battery	Sodium-ion battery	Fuel cell
Advantages	1.High energy density 2.Long service life 3.Fast charging speed 4.Relatively environmentally friendly	1.Abundant sodium resources 2.High energy density 3.Long service life 4.High Safety	1.High efficiency 2.Long service life 3..Relatively environmentally friendly 4.Renewable resources
Limitations	1.The charge and discharge rate is low 2.Poor safety	1.The charge and discharge rate is low 2.Large volume 3.The operating temperature range is narrow	1.Higher cost 2.Poor stability 3.Fuel storage and delivery are troublesome

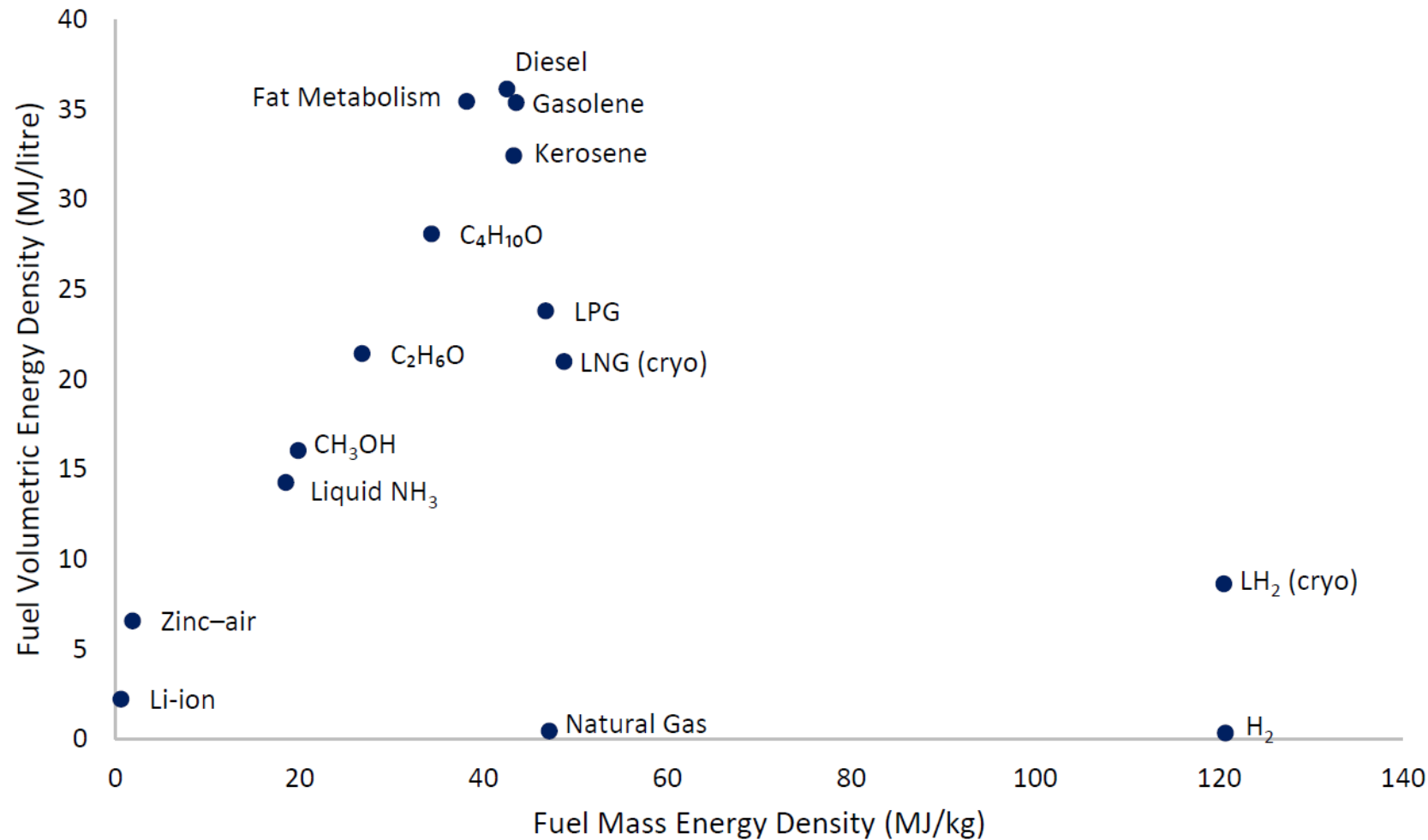
Source: J. Zhang, Z. Zhu, H. Wang, Power Source Technology, 39, 1323-1326 (2015)

METHODS FOR SAF PRODUCTION



Source: Roland Berger. (2020). 'Sustainable Aviation Fuels - the best solution to large sustainable aircraft?'
https://www.rolandberger.com/publications/publication_pdf/roland_berger_sustainable_aviation_fuels.pdf

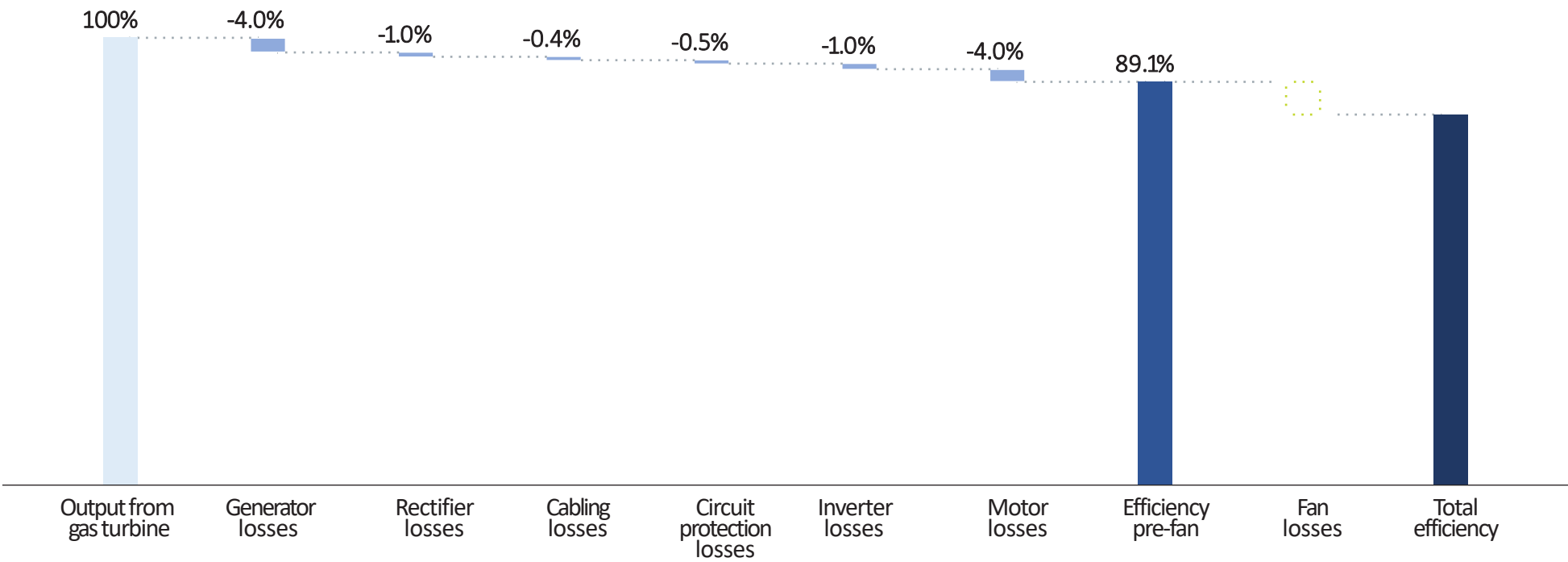
MASS AND VOLUME ENERGY DENSITIES OF DIFFERENT ENERGY CARRIERS



Source: Rao, A., and Yin, F. (n.d.). 'A Hybrid Engine concept for Multi-fuel Blended Wing Body.'
https://www.researchgate.net/publication/270759537_A_Hybrid_Engine_Concept_for_Multi-fuel_Blended_Wing_Body

EFFICIENCY LOSSES IN THE ELECTRICAL POWER CHAIN FOR HYBRID-ELECTRIC APPLICATIONS

Current electrical power chain inefficiencies remain, so hybrid-electric is unviable except in niche applications.



Source: NASA, Roland Berger

TECHNOLOGY POTENTIAL OF LOW CARBON FUELS

	Battery-electric	Hydrogen	SAFs
Efficiency of fuel production and propulsion system	60%	25%	15%
Maximum range in 2050	Few 100s km up to 1,000 km	2,500 km up to no limitation	No limitation
Expected large-scale market entry	Around 2035–40		<2030
Share of cumulative GHG emissions reduction from renewable fuels (2022–50)	2%–3%	8%–22%	75%–91%
Share of final energy demand in 2050	~2%	13%–32%	65%–85%

Source: Aviation Transition Strategy (July 2022).

CONCLUSIONS

Pressure to reduce carbon emissions from air travel is rising. Though **battery technology** has lower energy density compared to fossil fuels, it is promising for short-haul and domestic flights. Battery-electric aircraft face inefficiencies, particularly in energy conversion for propulsion, but improvements in energy density, safety, fast charging, and thermal management are essential for commercial success.

Hydrogen-powered aircraft may be more suitable for long-haul flights, offering higher energy density despite lower efficiency due to energy losses in converting hydrogen into electricity. However, commercial adoption of hydrogen planes is expected to be slow, likely delayed until after 2050, due to issues like **safe storage** and **infrastructure challenges**.

Developing infrastructure for sustainable aviation fuels (SAF), batteries, and hydrogen, along with **safety standards**, will be critical for widespread adoption. This includes creating a network for refueling, recharging, and maintaining these new aircraft technologies, requiring global collaboration for common safety standards.