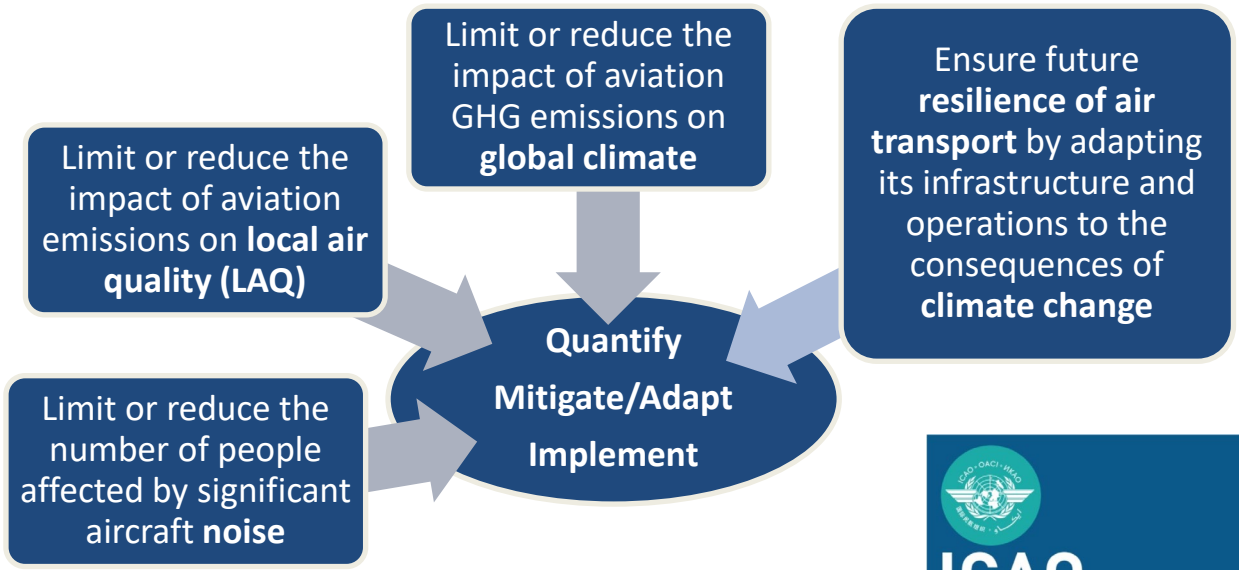
Electric Innovations for Sustainable Aviation

Second Phase of the ICAO Assistance Project with the EU Funding :
"*Capacity Building for CO_2 Mitigation from International Aviation*

Third Meeting
25 to 27 July 2023

Neil Dickson
Chief, Environmental Standards, ICAO

ICAO Environmental Goals and 41st Assembly Session



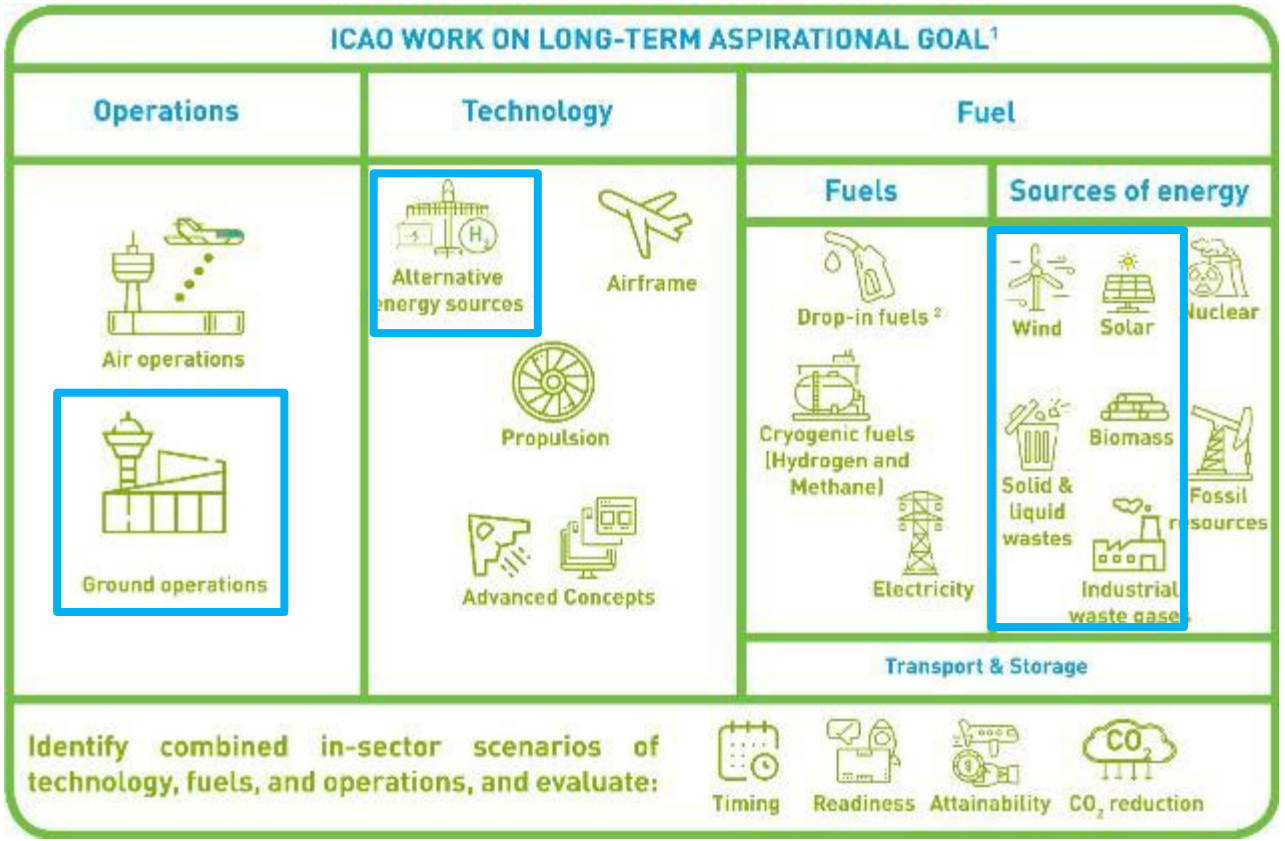
41st ASSEMBLY RESOLUTIONS

ICAO LTAG Process and Innovations

Open, transparent and inclusive:

Innovations:

In-sector focused:



ICAO Basket of CO2 Mitigation Measures

Aircraft technology	**First-ever global CO_2 certification Standard for new types and in-production aeroplanes. Fast-paced innovation (new designs, composite materials, hybrid-electric aircraft, renewable energy sources, etc.).**	
Operational improvements	**CO_2 benefits from air traffic management; air navigation; green airports; etc.**	
Sustainable aviation fuels	**Over 315,000 commercial flights with drop-in aviation fuels; 8 conversion processes; 9 airports distributing drop-in aviation fuels**	
Market-based measures	**Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)**	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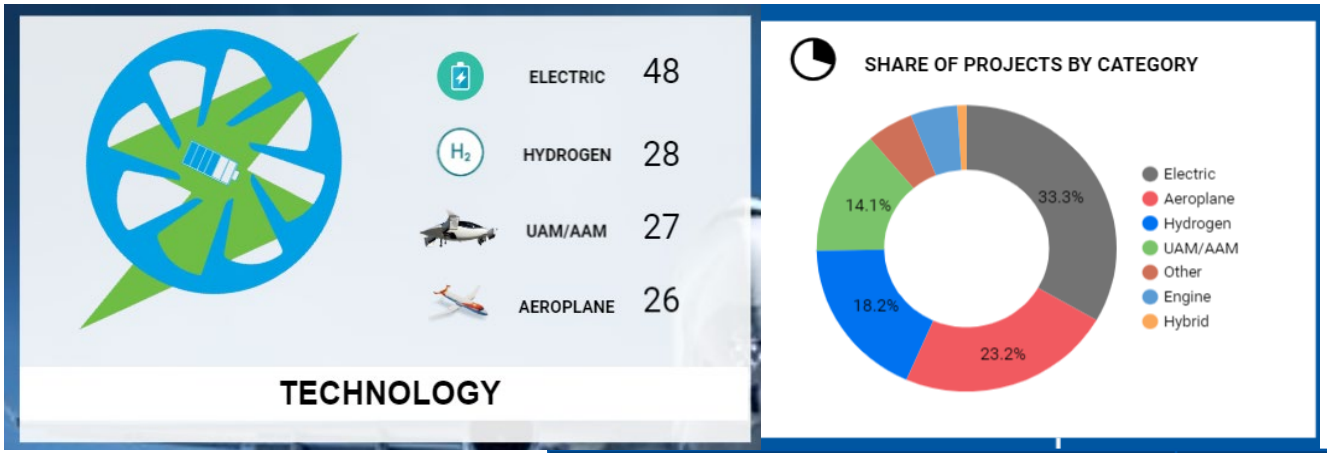
Innovation Driving Sustainable Aviation
First Edition - November 2021
H2
ICAO

ICAO Tracker Tool for Technology



ICAO TV

Stocktaking 2022	Stocktaking 2023
Technology Tracker Entries – 109	Technology Tracker Entries – 129
• Aeroplane – 21	• Aeroplane – 26
• Electric – 44	• Electric – 48
• Hydrogen – 23	• Hydrogen – 28
• UAM/AAM– 21	• UAM/AAM – 27

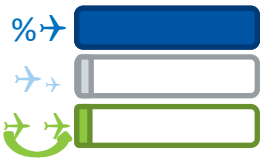
Already Certified Electric Aircraft

Beyond zero emissions, the certified noise level achieved by the Pipistrel Velis Electro was 60 dB(A), which is 10 dB(A) lower than the noise level of the Virus SW 121 (same aeroplane but equipped with a conventional combustion engine).

Electric Aviation – Opportunities and Challenges

Opportunities

- Long term (>2040)
- Reductions in up to 100%
- Reduction of Local Air Quality pollutants
- Reduced maintenance cost



Challenges

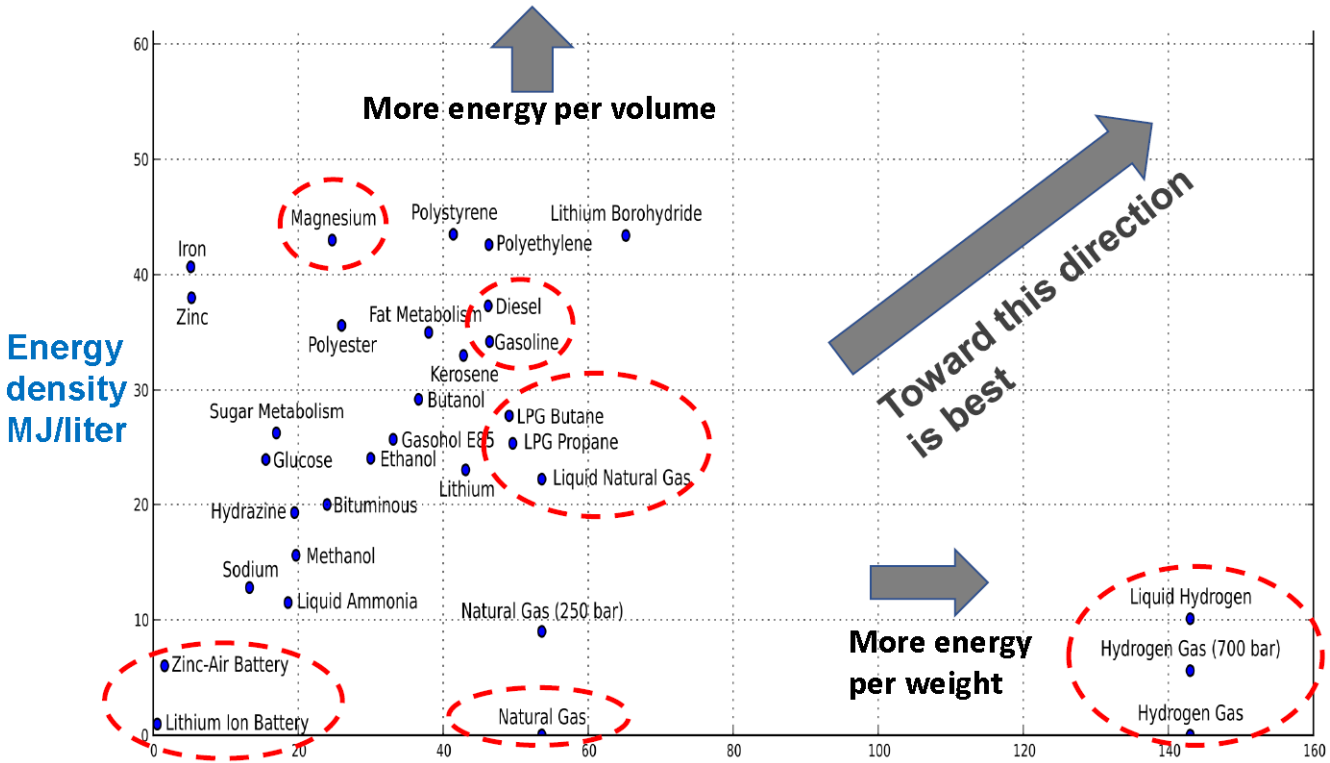
- Availability of clean electrical energy
- Transportation and network
- Storage, battery capacity, lithium availability
- Depend on energy mix
- Applicability very limited by power density
- Infrastructure required

Key energy figure

- Per day, electrification of all flights from YUL would need ~3X the household energy usage of Montreal.

Images courtesies of: Lilium, Alpha electro Pipistrel

Obstacles for Electric Aviation



Lithium battery advantages: clean, simple and cost is going down. Con: needs higher specific energy, recycleability, and to be less volatile.

Today hydrogen and fuelcell still too expensive, difficult to transport to charging stations, not safe enough, and does not have the "power density" required for flight.

Reference: Prof. James Wang, Director of eVTOL Research and Innovation Centre, Singapore. Presentation on "What innovations can we expect from electric VTOL aircraft in this decade", ICAO Global Symposium on the Implementation of Innovation in Aviation, 2020.

Electric Aviation – Battery Limitations

NASA - Evolution of Electrified Aircraft Market with Improvements in Battery Technology

Battery Pack Specific Energy	Potential Missions	Potential Market Introduction
SOA (150 – 170 Wh/kg)	  	Initial commercial introduction possible for all-electric with limited range and payload, extended capability with hybrid-electric
300 Wh/kg	 	All-electric eVTOL urban air mobility with 4 passenger and 50+ mile range; 20-passenger all-electric commuter
400 Wh/kg Sweet spot for eVTOL	 	Desired capability for all-electric eVTOL urban air mobility, long-range all-electric commuter, Initial version of small hybrid-electric regional
500 Wh/kg	 	Expansion to various classes of hybrid-electric regional aircraft, short-range 150 Passenger, single aisle hybrid-electric aircraft
> 700 Wh/kg	 	Single aisle, 150 passenger single-aisle aircraft, long range

ICAO Stocktaking 2020 - Electric Aviation

Zeroavia: First Commercial Aircraft on Hydrogen-Electric Propulsion

ICAO Stocktaking 2020 - Electric Aviation

Lilium eVTOL project

- eVTOL aircraft could provide a high-speed regional connectivity with a low environmental footprint;
- The Lilium Jet announced a range of 300km, a top speed of 300km/h and a payload of four passengers, one pilot and carry-on;
- Fully electric, the Lilium Jet is expected to be low noise, high safety and requires minimal infrastructure due to its ability to take-off and land vertically, even in urban environments.

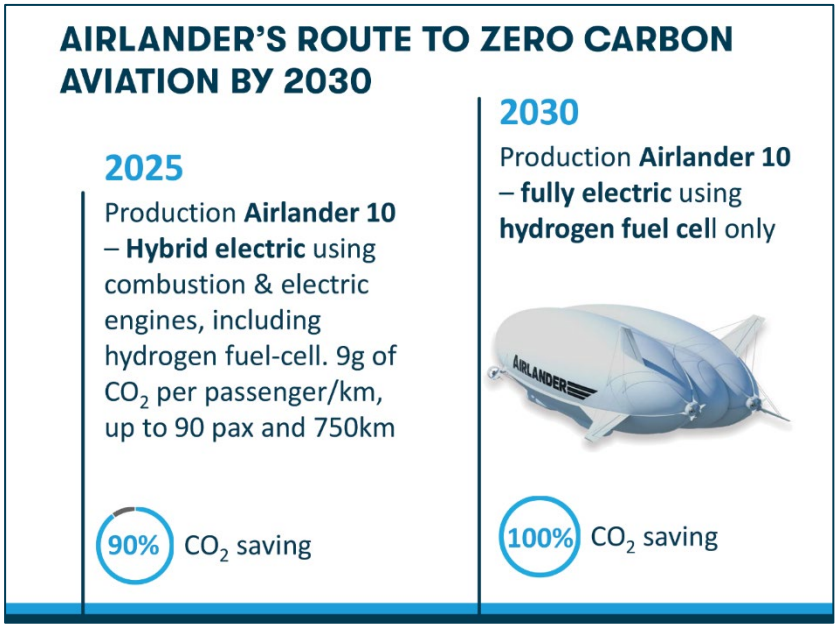
ICAO Stocktaking 2020 - Electric Aviation

MagniX: Middle Mile Small and Regional all-electric propeller aircraft

- Proposing to changing our view of air transportation:
- Connecting communities with smaller airports and smaller aircraft;
- Electric propulsion systems (including motors and power electronics) designed for commercial aircraft;
- 280KW – 2MW for multiple sources of electricity.

ICAO Stocktaking 2020 - Electric Aviation

Airlander: novel concept of airships



ICAO Stocktaking 2021

1. Pre-Stocktaking
Battery technology, fueling aviation electrification
16 March 2021

2. Pre-Stocktaking
Hydrogen, getting to zero carbon flights
15 April 2021

3. Pre-Stocktaking
Synthetic fuels for aviation
6 May 2021

4. Pre-Stocktaking
e-VTOL and urban air mobility – a new systemic and sustainable approach for air travel
4 June 2021

5. Pre-Stocktaking
Infrastructure development for supplying clean energy for air travel
27 July 2021

6. Pre-Stocktaking
2021 ICAO Stocktaking preview
10 August 2021

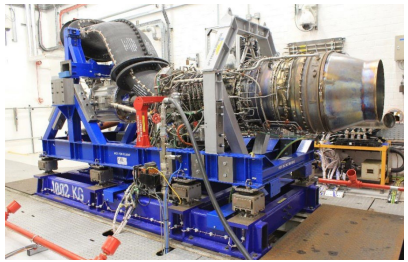
2021 ICAO STOCKTAKING
31 August - 3 September 2021

ICAO Stocktaking 2021 - Electric Aviation

- Demonstrating the feasibility of electric propulsion: kW and MW class power capability demonstrated for a range of market sectors:
  - Urban air mobility
  - General aviation
  - Commuter
  - Regional

eVTOL / UAM

All electric



Hybrid electric kW & MW

ICAO Stocktaking 2021 - Electric Aviation, eVTOL

ICAO Stocktaking 2021 - Electric Aviation

Rolls-Royce - Electrification in Aerospace

Urban Air Mobility	Small prop	Commuter	Regional	Narrowbody & small/ medium bizjets	Widebody & large bizjets

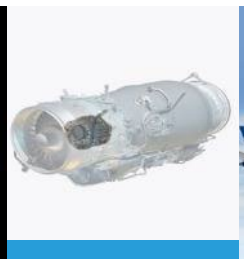
All electric

Hybrid electric

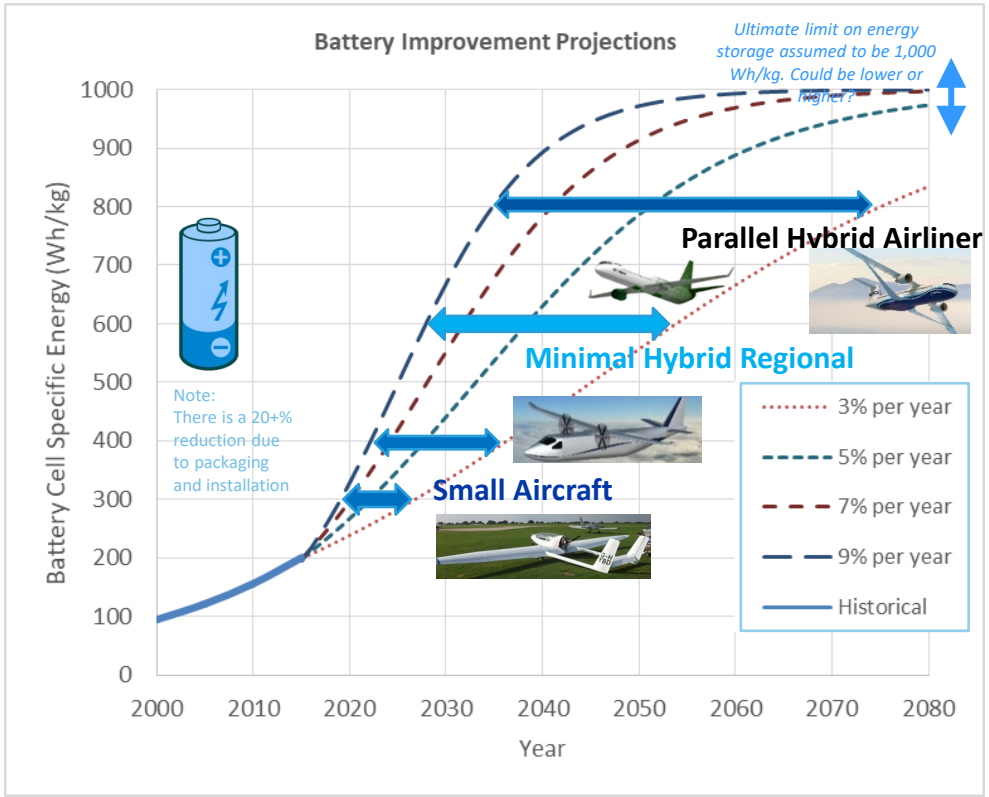
More electric








ICAO Stocktaking 2021 - Electric Aviation



Boeing Electric Aircraft Studies

3%-9% Annual Growth to 1,000 Wh/kg

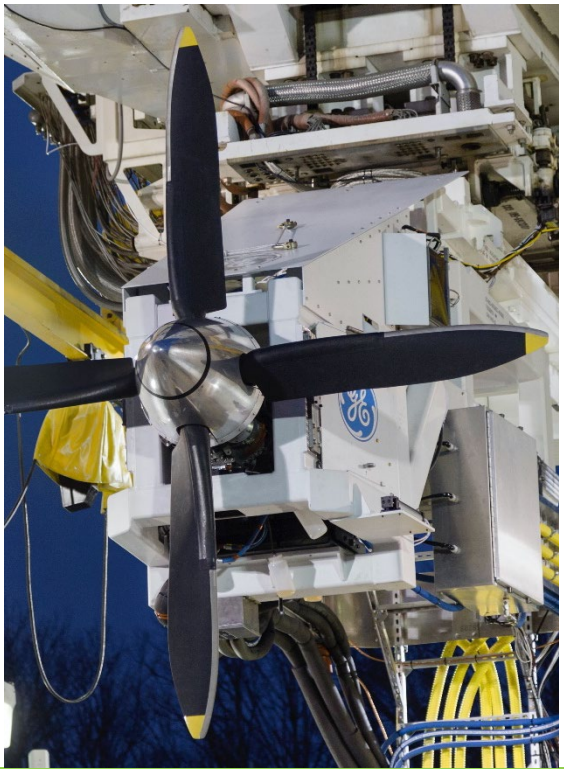
- Feasibility and EIS/IOC of useful airliner determined by energy storage capability;
- Electric and Hybrid Electric (w/energy storage) yield environmental benefits only if sustainable energy used in charging grid;
- Electric aircraft to date are an order of magnitude smaller and lower power than a regional size airliner.

ICAO Stocktaking 2022 - Electric Aviation

GE Aerospace - Bringing hybrid electric flight to reality

GE hybrid electric technology maturation

- 2015-2016: F110 engine power generation
- 2016: First generation electric machine demonstration
- 2017-2018: Power integration system test
- 2019: Second generation electric machine ground and altitude test
- 2020: Third generation power converter ground and altitude test



ICAO Stocktaking 2022 - Electric Aviation

Archer - Advancing the Benefits of Sustainable Air Mobility to Support Aviation Decarbonization

Aircraft & Technology

- Focused on certification of green/clean technologies
- Supply chain partners that share our sustainability objectives

Aircraft Production

- Sustainable production methods and facility development

Eco-friendly Vertiports

- Leverage green technologies and materials
- Microgrid designs

Recycle of Batteries from Flight Vehicles

- Power storage at vertiports after useful life for aircraft

Charging Infrastructure

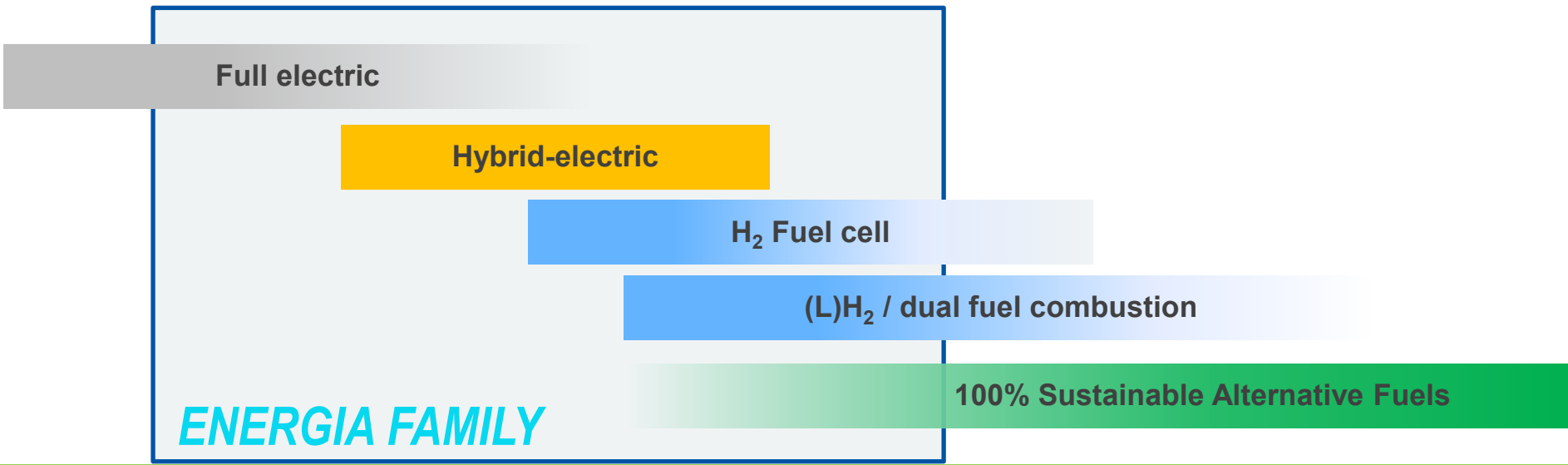
- Solar/wind energy

ICAO Stocktaking 2022 - Electric Aviation

Embraer Sustainability Roadmap

< 100km — *range requirements* — *> 10,000km*

1-9 PAX	10-19 PAX	20-49 PAX	50-99 PAX	100-149 PAX	150+ PAX



ICAO Stocktaking 2023 - Electric Aviation

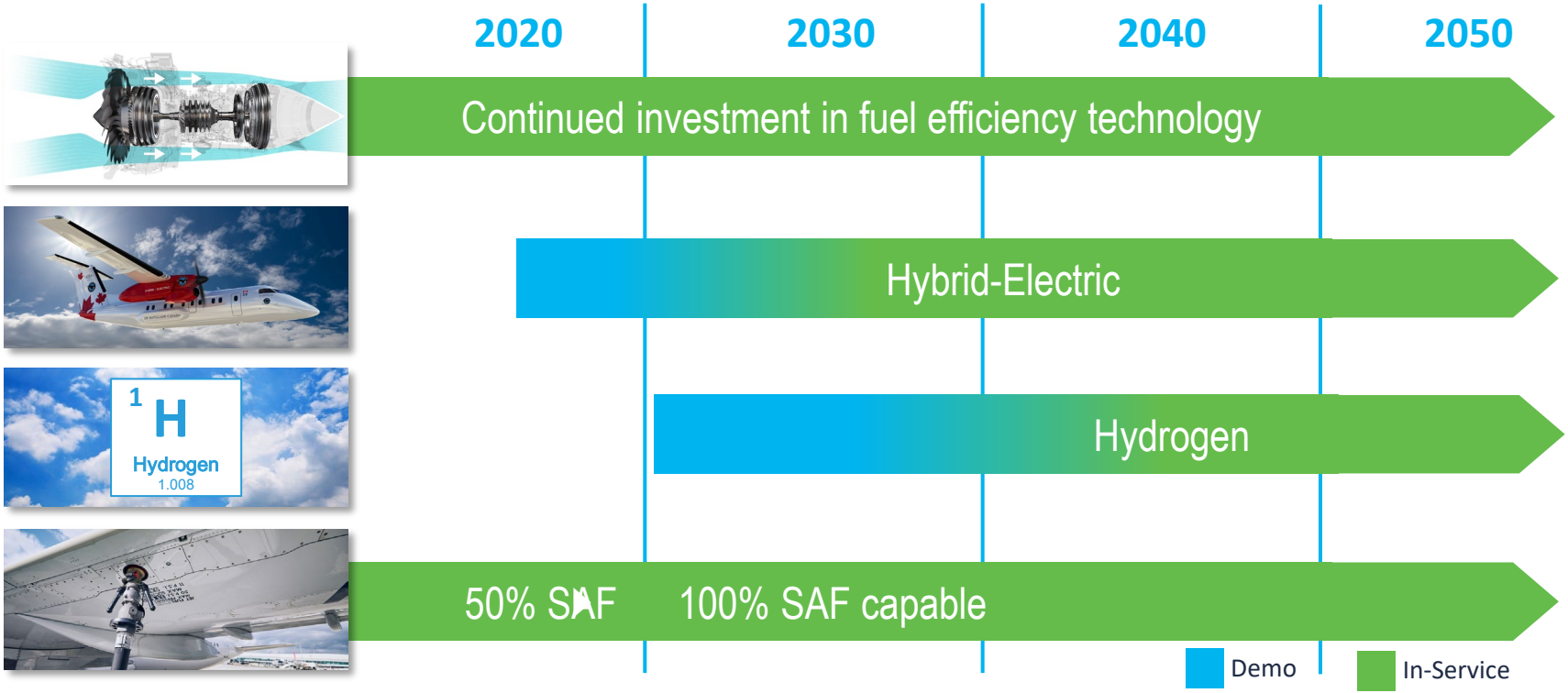
Zeroavia Near Zero-Emission Aviation Outlook

	Reduction in climate impact			Scalability	Net Impact	Key challenges
	Direct CO2	NOx	Water vapour & contrails			
H2-electric	🟢	🟢	🟢	🟢	🟢	Weight of the powertrain; Higher volume fuel tanks required
H2 combustion	🟢	🔴	🔴	🟢	🟡	Higher non-CO2 climate impact than fossil fuels; Even higher volume fuel tanks required
Sustainable aviation fuels	🟡	🔴	🔴	🟢	🟢	Bio feedstock sustainability; High cost of synthetic fuels Same in-flight emissions
Battery electric	🟢	🟢	🟢	🔴	🟡	Weight of battery precludes large aircraft; Frequent replacement
Hybrid-electric	🟡	🔴	🔴	🟡	🟡	Small incremental impact (10-20% max) on both economics and climate

🟢 Comprehensive 🟡 Moderate 🔴 Limited

ICAO Stocktaking 2023 - Electric Aviation

Pratt & Whitney multiple pathways to decarbonize aviation



Electric Aviation and Green Airports

What are “Green Airports”?

In the 1960’s: Noise

In the 1970’s: Local Air Quality

In the 1980’s - 1990’s: Environmental management Systems

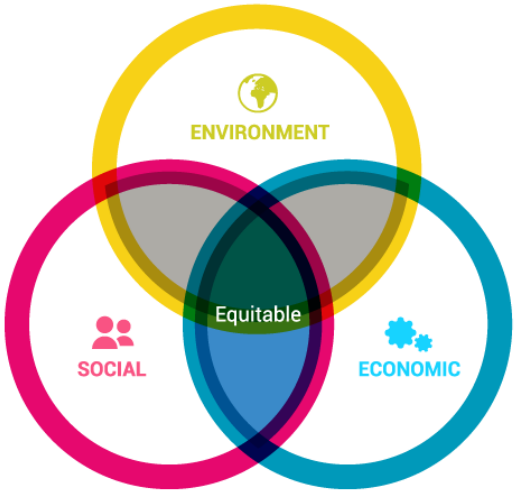
Since 2000: Climate change, Community engagement, Clean Energy

In 2020s: Green Infrastructure, Innovative Operations and Resilient

Green airports can become hubs for clean energy, and central to urban air mobility infrastructure

Eco-Airport Toolkit e-collection

1. **Renewable energy at airports**
2. **Airport environmental management systems**
3. Waste management at airports
4. **Eco-design of airport buildings**
5. Climate resilient airports
6. Water management at airports
7. Air quality management
8. Sustainable airport surface access (drafted)



Summary

- **Now is the time to design the green sustainable aviation future.**
- **Small electric aircraft are entering the market, and the eVTOL projects are already performing test flights – electric aviation is growing and enabling reductions in carbon emissions.**
- **Bigger aircraft concepts are based on hybrid layouts due to the battery technology energy density challenges.**
- **Airfleet electrification requires green energy sources, infrastructure readiness and clear certification procedures.**
- **ICAO is working on Standardization Roadmap for the innovative aircraft.**
- **Global engagement and cooperation is the key and ICAO plays a crucial and leading role.**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