ICAO 2023 STOCKTAKING

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Near Zero-Emission Aviation

ICAO Stocktaking, 11 July 2023

ZEROAVIA

Hydrogen, the Only Path to Near Zero- Emission Aviation

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	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

Source: Market research; analyst reports.

H2-Electric Out-Competes PtL and H2 Combustion

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DAC+FT synthetic fuel production vs liquid hydrogen

	Make	Use	Maintain	Overall Efficiency[3]	Relative cost[3]
Syn-fuel (Close-coupled DAC[1])	25-35% Efficient	Syn-fuel Combustion	25-55% Efficient[2]	Higher	6-19%	>> +200%
		H_2 Combustion	25-55% Efficient[2]	Higher	13-33%	>> +40%
Liquid Hydrogen	50-60% Efficient	H_2 Electric	50-65% Efficient[2]	Lower	25-39%	Reference cost

Core temp: 1700°C
Pressure 50:1
NOx vs CO_2 (SAF)

Temp: <200°C
Pressure <5:1
No NOx

Fuel and maintenance is 35-50% of an airline's direct operating costs

H2-Electric Will Work for All Types of Airframes

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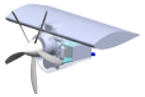
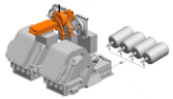
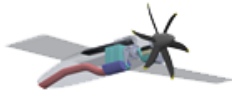
	2025	2027		2029	2032+
					
	ZA600	**ZA600b - eVTOL**	**ZA2000**	**ZA2000RJ**	**ZA10000**
Shaft power	500-750 kW	100-750 kW	2-4 MW	5+ MW	10+ MW
PAX	10 - 20 seats	2 – 15 seats	30 - 90 seats	30 - 90 seats	100 - 200 seats
Range	up to 500nm	Up to 300nm	up to 1,000nm	up to 1,000nm	up to 3,000nm
H_2 storage	Gas	Gas or Liquid	Liquid	Liquid	Liquid
Fuel cell technology	LTPEM	HTPEM	Next generation LTPEM / HTPEM	HTPEM	HTPEM
Current # of engines in circulation	78k	38k heli + 100k eVTOL	12k	8k + 46k[1]	34k
Retrofit/linefit	Retrofit & linefit	Retrofit & new design	Retrofit & linefit	Retrofit & linefit	Retrofit & linefit
Airframes (illustrative selection)	 D228  Cessna Caravan  Twin Otter  Otto 500L+	 PA-890  	 Dash 8-400  ATR 72  EMB NGTP	 CRJ700  E170	 A320  Boeing 737  A220

Q1 2023: ZeroAvia Makes Aviation History

On Jan 19, 2023 ZeroAvia made aviation history, flying world's largest aircraft powered with an H_2-Electric engine, validating technology

Dornier-228 Test Flight Program

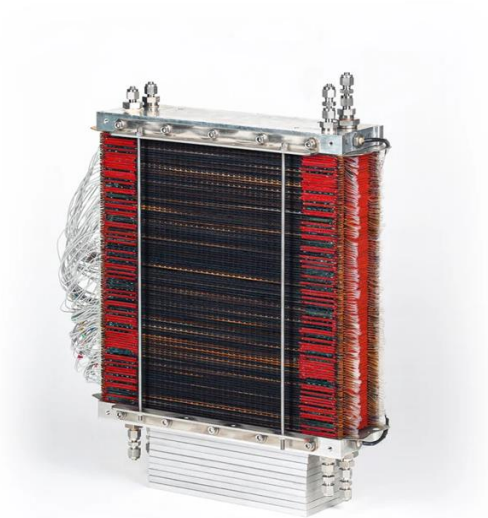
Alaska, ZeroAvia developing largest zero-emission aircraft

ZeroAvia unveils world's most advanced electric motor technology for aviation, paving way for hydrogen-electric engines for Dash 8 and similar airframes

Core Tech Development

- 20,000 RPM architecture to achieve record power densities
- Demonstrated in ground test with largest commercial prop
- 1->5MW modular power for regional aircraft

- World-first pressurized HTPEM FC achieving record-breaking power density
- Development unlocks large turboprop and regional jet applications, and narrowbody aircraft within 10 years



Takeaways

Latest ZeroAvia announcements

- MONTE Signs Definitive Purchase Agreement for ZeroAvia Hydrogen-Electric Engines
- Technical study with MHIRJ confirms feasibility of hydrogen-electric-powered CRJ aircraft

ZeroAvia not alone in H2 Aviation

- Startups: Joby/HyFly, Universal Hydrogen
- Legacy: Airbus, Rolls Royce, GE Aerospace, Safran, Hyundai

US advancing hydrogen aviation policy

- Current FAA reauthorization language in Congress a significant step forward
- FAA: Certification, Airports, ASCENT

Key Challenges

- Need proper metric for emissions and tech agnostic approach
- Acknowledge a role for hydrogen aviation before 2050
- Incentivize adoption

ICAO ENVIRONMENT

2023 ICAO STOCKTAKING AND PRE-CAAF/3 POLICY AND FINANCE CONSULTATION

11 to 13 July 2023
Montréal, ICAO Headquarters