# Hydrogen-Electric Aviation

H2 Market Meetup
Jan 25th 2024

Ivar Aune
CEO
SiriNor

# SiriNor’s purpose statement

Our purpose is to deliver true zero emission jet engines

that benefit our planet

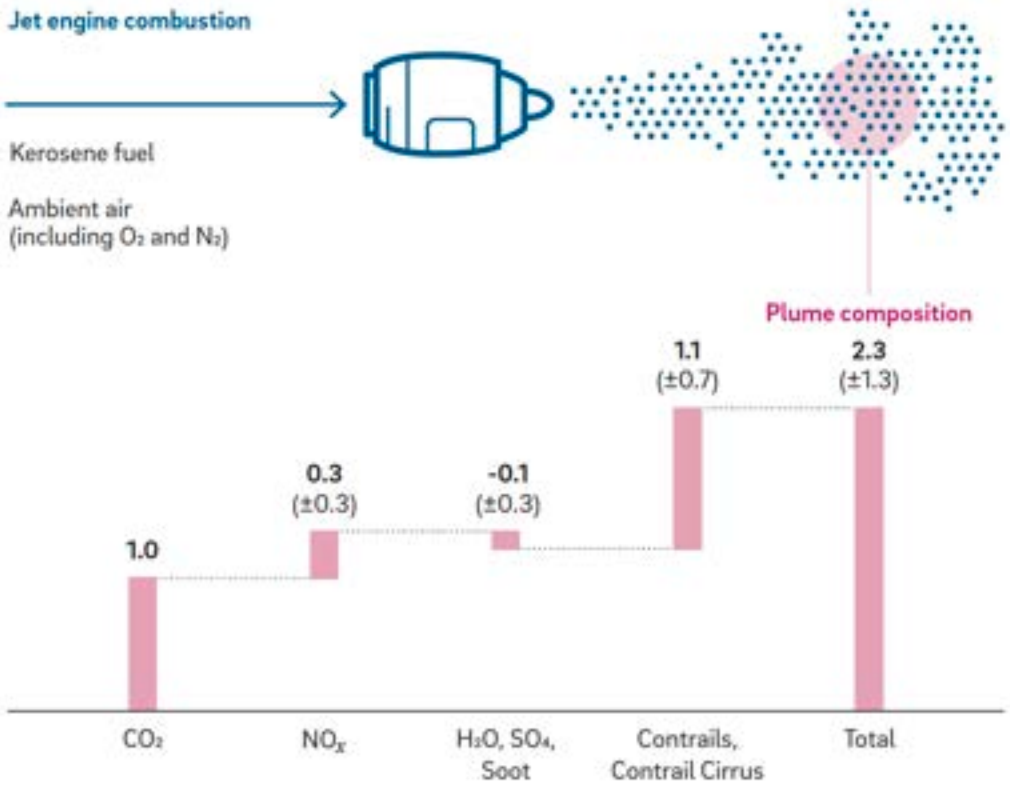
by eliminating greenhouse gas emissions from aviation.

Our stakeholders range from shareholders and employees

to anyone who is, or will be, affected by climate change.

We are committed to creating value for them all.

# Aviation emits 1 billion tons of $CO_2$ a year, but its climate footprint is 2-4 times that of $CO_2$ alone




1 Radiative Forcing (RF) measures the balance of energy moving into vs. out of the Earth's atmosphere (i.e., the instantaneous impact on global warming); 2 Global Warming Potential, as a proportion of the impact of $CO_2$ alone, over a 50 year timeframe

Source: Lee et al 2020, IPCC, Roland Berger

# We can and we must make aviation green
# We are at the intersection of 3 global mega trends

**Global Warming**
Hydrogen-electric propulsion will take you to the skies without emissions or flight shame

**Electrification and hydrogen**
Hydrogen-electric propulsion is future proof and will survive the transition from fossil fuels

**Global mobility**
Doubling the number of flights by 2050 requires sustainable solutions such as hydrogen-electric propulsion

# Sustainable options depend on flight distance

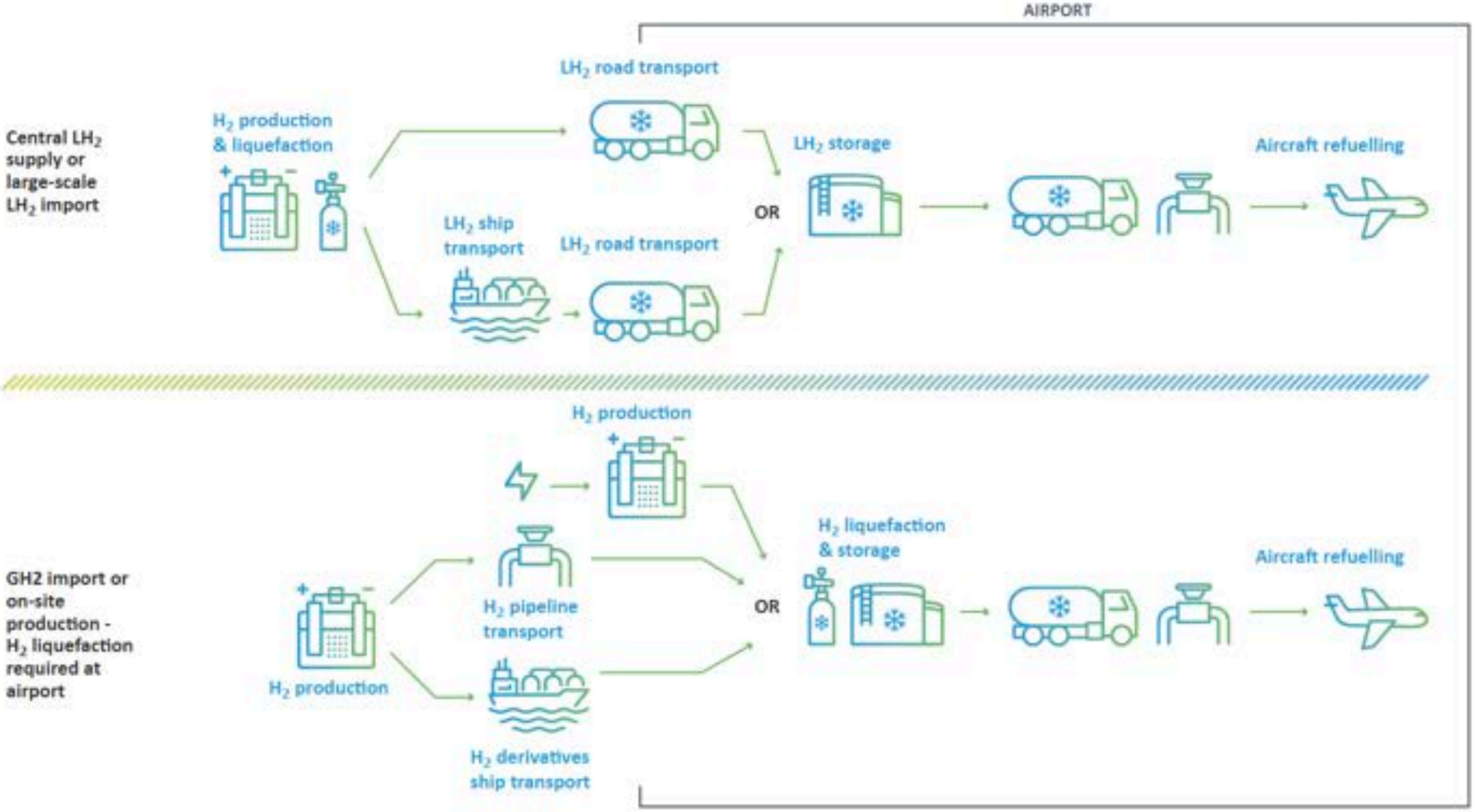
| FLIGHT DISTANCE [KM] | % OF CO2 EMISSIONS | % OF FLIGHTS | TYPICAL ENGINE TECHNOLOGIES | TODAY'S APPLICABLE PROPULSION TECHNOLOGIES | RELEVANT FOR SIRINOR? |
|---|---|---|---|---|---|
| 0 - 500 | 4.3 | 30.6 | Propellers and turboprops | Batteries up to 200 km, hydrogen & fuel cells above | No |
| 500 -1500 | 20.6 | 43.6 | Turboprops and jet turbines | Hydrogen and fuel cells | Yes |
| 1500 - 4000 | 23.2 | 19.6 | Jet turbines | Hydrogen and fuel cells | Yes |
| > 4000 | 51.9 | 6.2 | Jet turbines | Kerosene with SAF or hydrogen combustion | If FC technology allows for it |

Sources: EUROCONTROL/SiriNor

# A brief history of aerospace and H2FC

- 1965-1966: The NASA Gemini program pioneers the use of fuel cells in space, and a similar technology was subsequently used in the Apollo and Space Shuttle programs
- 2008: Boeing fly a two-seat Dimona motor-glider powered by a hydrogen fuel cell/lithium battery hybrid system
- 2009: The world’s first manned and purely hydrogen-powered aircraft -developed by a team of engineers at the German Aerospace Center (DLR) - takes off
- 2023: ZeroAvia (UK) take their 19-seat Dornier 228 twin-engine aircraft on its maiden flight (FC/gaseous H2)
- 2023: Universal Hydrogen (US) fly the world's largest hydrogen fuel cell airliner, a modified 40-seat De Havilland Dash 8 (FC/gaseous H2)
- 2023: H2FLY (Ger) complete the world’s first piloted flight of a liquid hydrogen powered electric aircraft (FC/liquid H2)

# Hydrogen supply scenarios




Source: Alliance for Zero-Emission Aviation

# Liquid hydrogen cost estimation

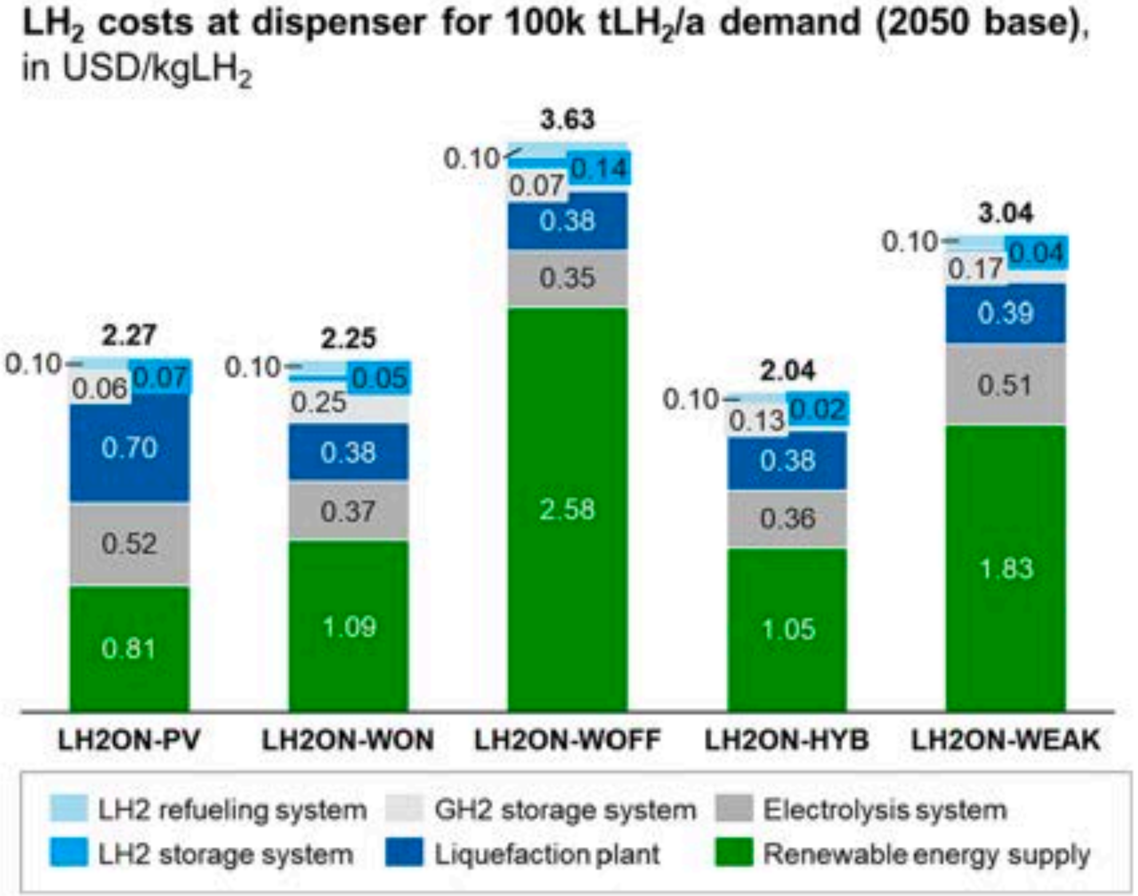
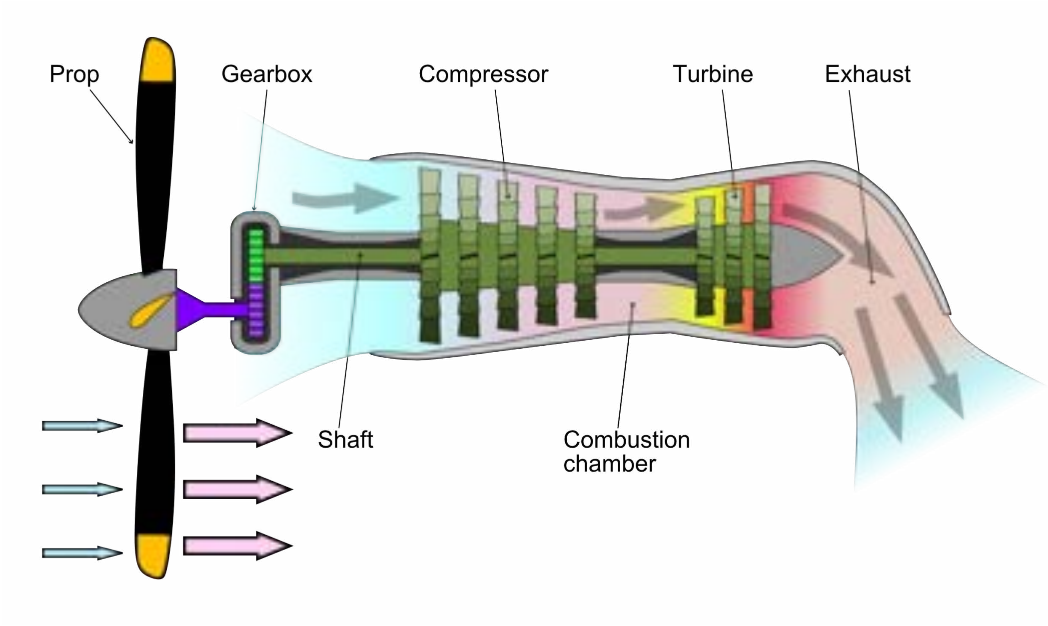


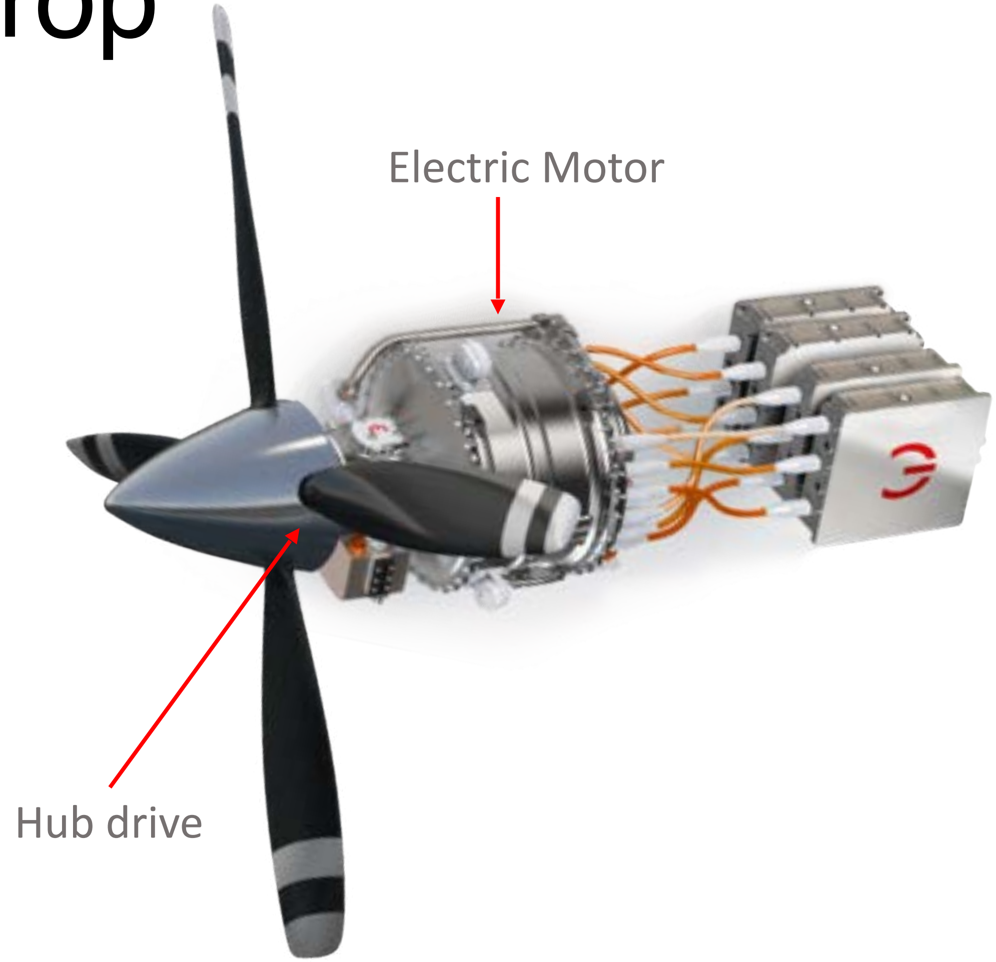

**Fig. 4.** LH$_2$ supply costs at the dispenser for on-site setups at five locations: PV, wind onshore (WON), wind offshore (WOFF), great hybrid conditions (HYB), weaker hybrid conditions (WEAK); 2050 base case scenario with 100 k tLH$_2$/a demand.

Source: H2-powered aviation – Design and economics of green LH2 supply for airports,
J. Hoelzen, L. Koenemann, L. Kistner, F. Schenke, A. Bensmann , R. Hanke-Rauschenbach

# The current industry focus is mainly on electrifying the turboprop

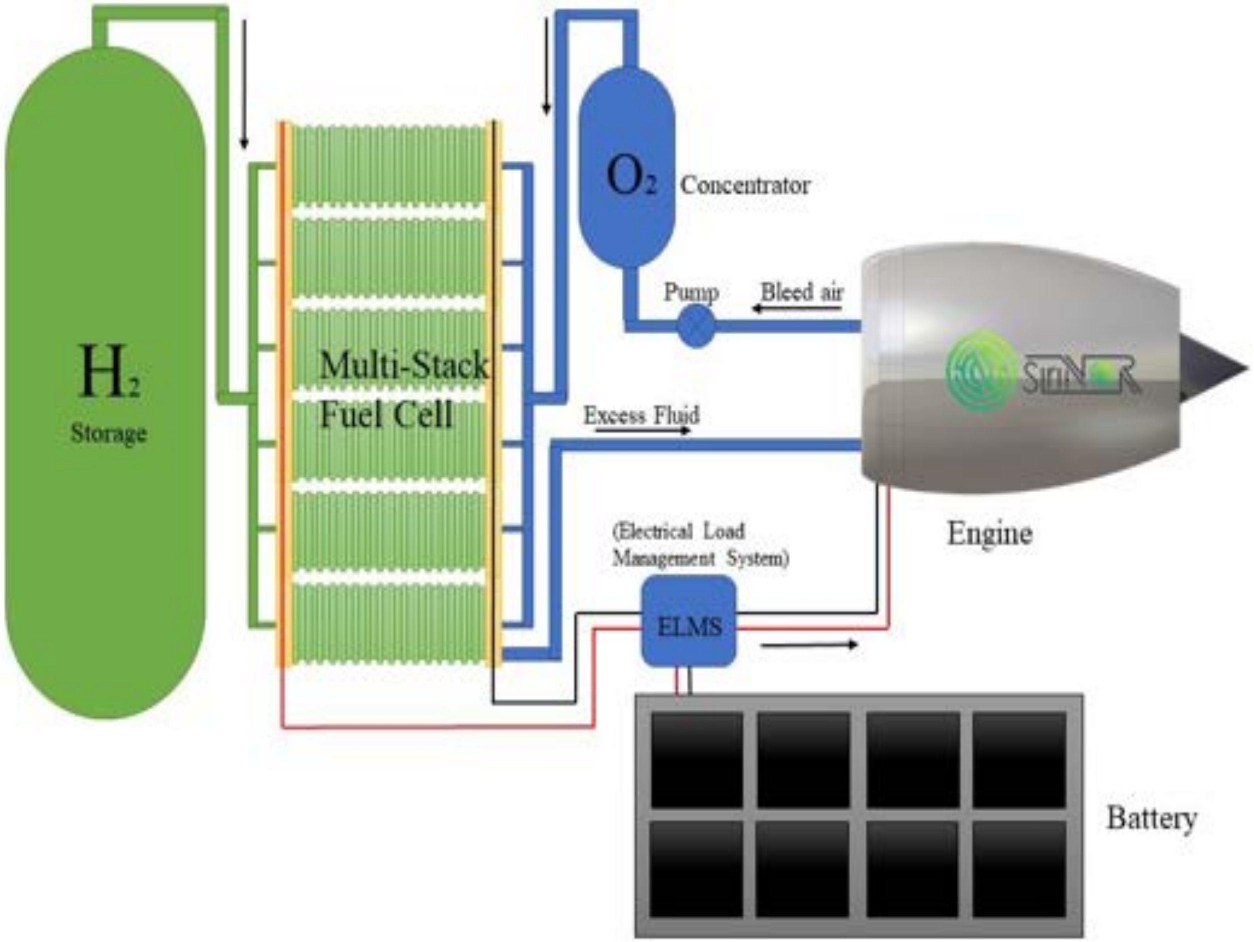



**CURRENT TECH**




**NEW TECH**

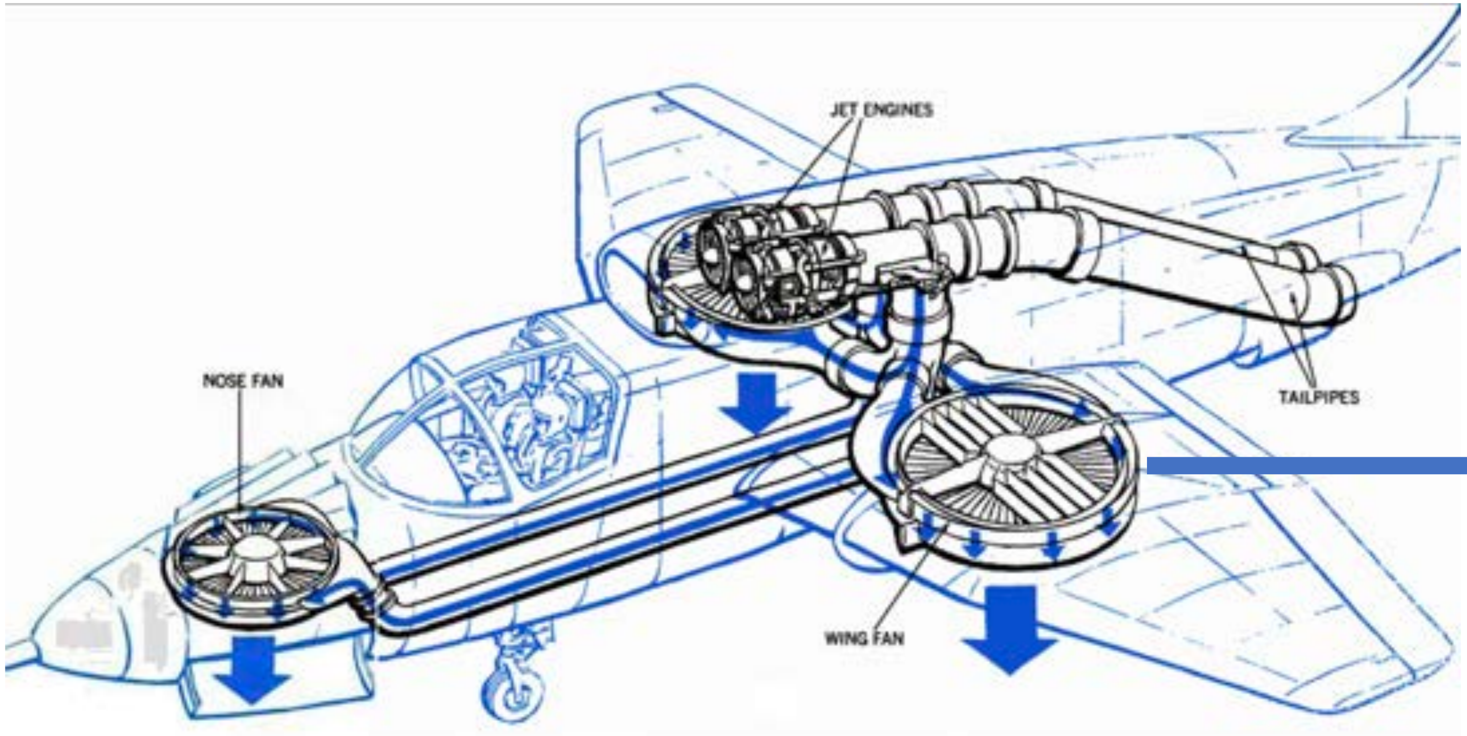
# Our focus: Jet turbines




- True disruptive potential up to the mid-range segment populated by Airbus A320s and Boeing 737s
- No combustion and zero emissions
- Same size, 20-30% less weight
- 25-35% lower sales price - USD 2-4 million saved per engine
- Est. 15-25% lower maintenance cost
- Low noise – reduced from 140 to max. 80 db – means airports can stay open 24/7 accepting more traffic without claiming more land to build additional runways
- Higher cruising speed – 1100 km/hr – may aid in improving aircraft utilization

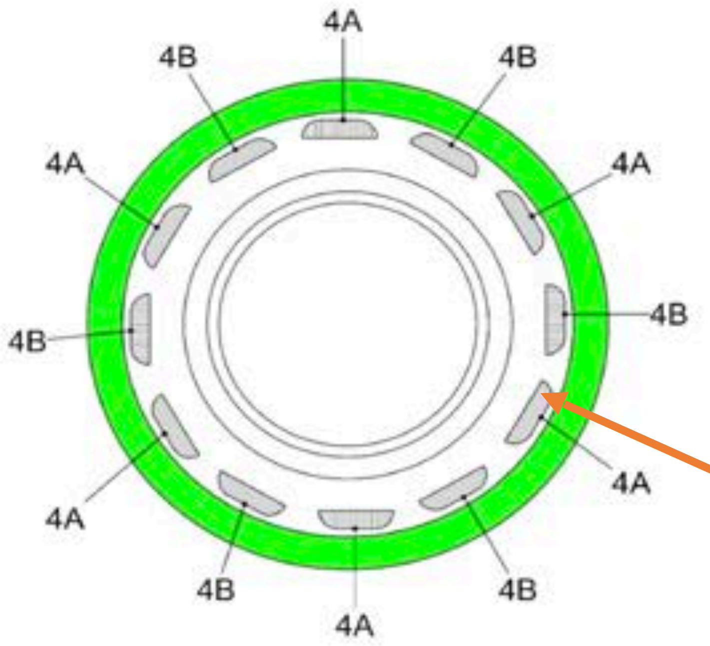
# Tip turbines – tried and tested

**RYAN XV-5A VERTIFAN**

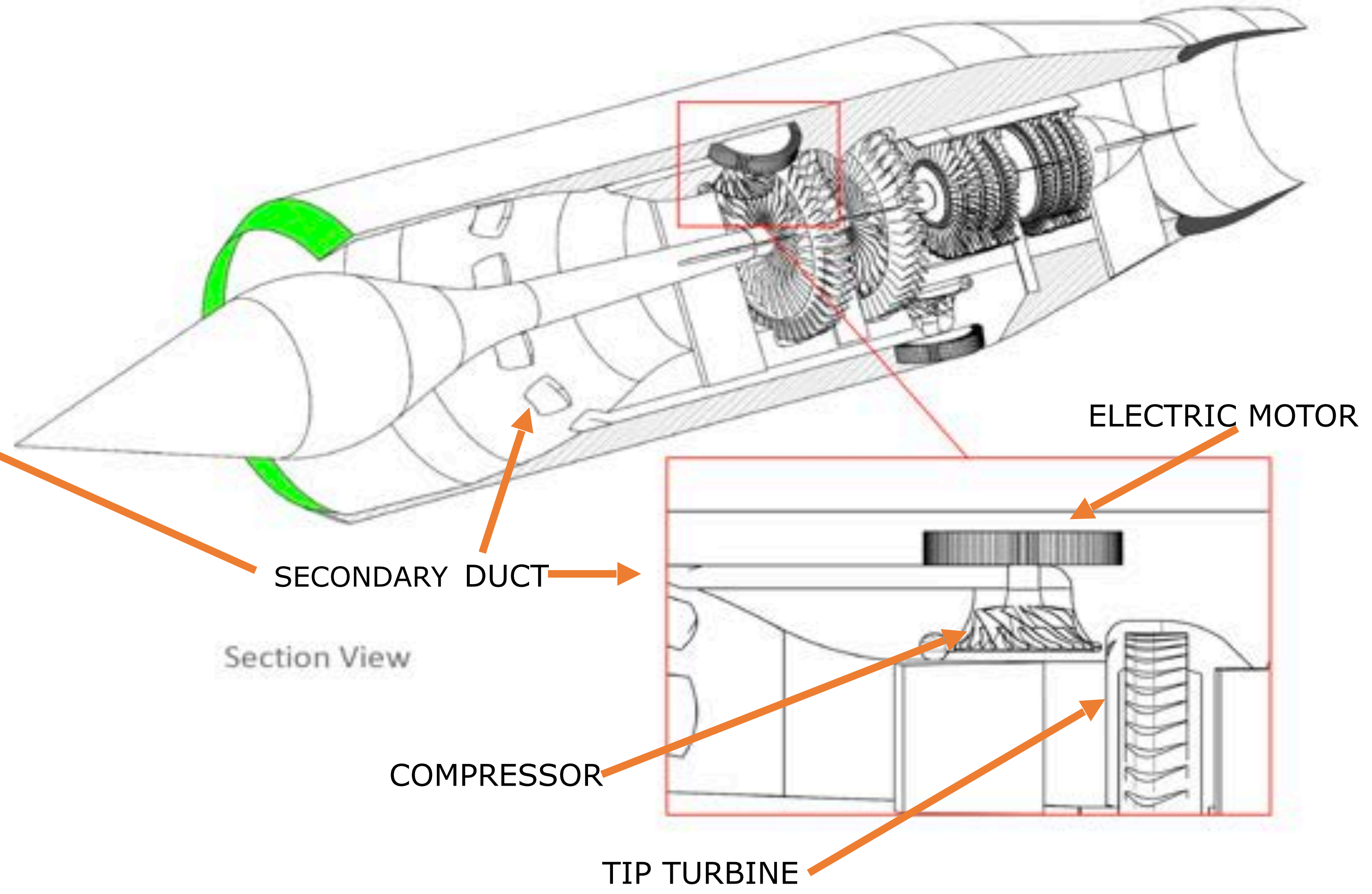



**Tip Turbine**

# Our tip turbine requires 34% less energy than a hub driven turbine

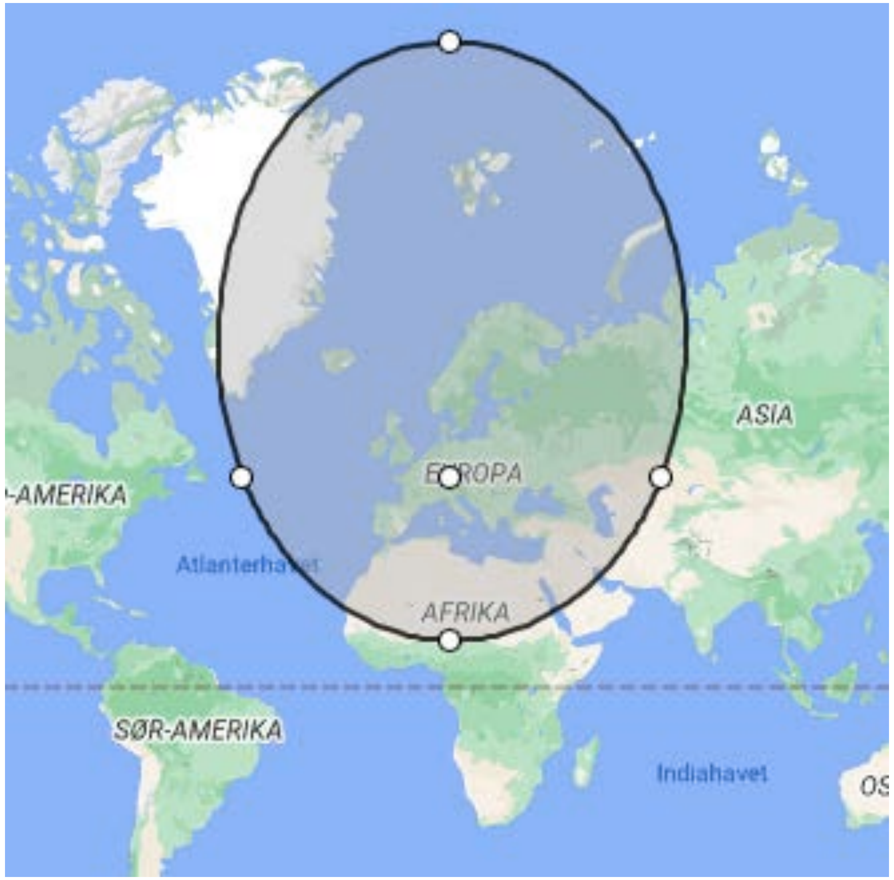



Secondary Duct Channel Division for Individual Compressors




Section View

# What is possible today?




- ✓ 33 000 aircraft criss-cross European skies every day
- ✓ They emit more than 400 000 tons of $CO_2$ every single day
- ✓ SiriNor's jet turbines can offer 4 000 km zero-emission flight range, proven by external feasibility study (19-seat aircraft)
- ✓ 4 000 km range covers 63% of all flights departing from European airports

# SiriNor - status and plans

## To date

- ✓ Core team assembled
- ✓ Indian subsidiary established
- ✓ Raised USD 400k, incl from Shell E4
- ✓ Third party feasibility study done
- ✓ LOI with Sea Cheetah (US) signed
- ✓ 2 PCT applications filed

## Going forward

- **Raise up to USD 3m in 2024**
- Build & test Sea Cheetah engine
- First pre-orders in 2024
- Initiate commercial manufacturing
- Certified and commercial by 2026
- USD 100m revenue by 2030

# Join the aviation revolution

Sign up to our newsletter

Follow us on LinkedIn

# Backup slides

# Go-to-market strategy

**Ground-Effect Vehicles (GEV)**

- B2B
- Small to heavy marine crafts
- Ex: Sea Cheetah
- First LOI / customer
- Potential revenue within 3 years


**Jet aircraft**

- B2B
- Initially small to medium aircraft such as G650, A319, E195, Fokker 100, CRJ 100/200
- Then larger aircraft such as A320, Boeing 737
- Potential revenue after 5 years

# Our team

Abhijeet Inamdar
Co Founder

Lars Erik Robertsen
Co Founder

Pramod Vaditya
Chief Propulsion Engineer

Anil Kommagalla
Design & Simulation Engineer

Dhanya T M
Structural Engineer

Bharadwaraj Y
CFD Engineer

Maruthu Pandiyan
Project Lead / Simulation

Ivar Aune
CEO

Kristina Bollingmo
CCO

Hans Jørgen Elnæs
Aviation Advisor & Board Member

Ravinder Singh
Aviation/ Regulations Advisor

Angela Smoller
Financial Advisor

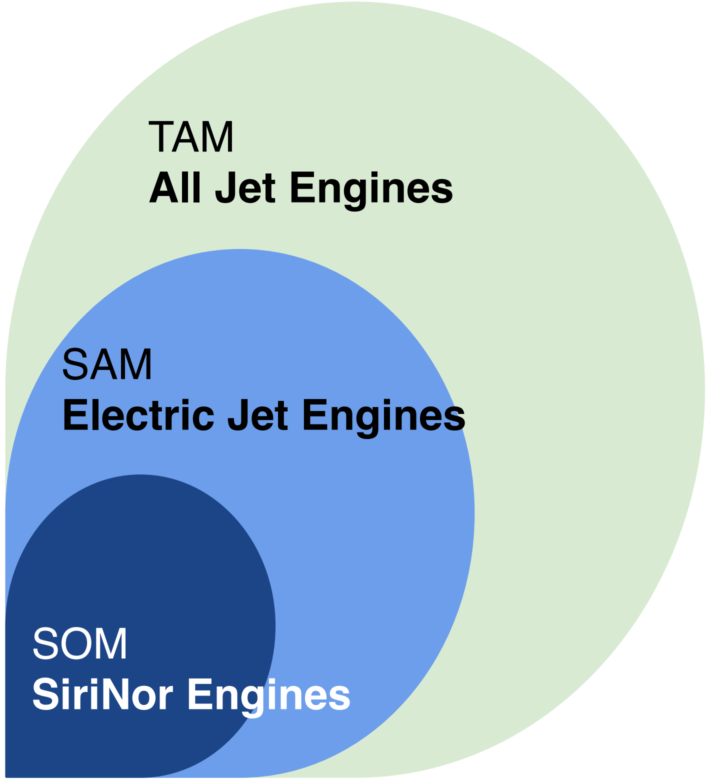
Dr Jagadeesh Gopalan
Technical Advisor

Ravi Andrews
Procurement

*Key Credentials*

- 2 Serial founders
- 3 PhDs in Aerospace Engineering
- Aviation industry experience: Varig, Qatar Airways, Ryanair, Honeywell, Airbus
- More than 30 patents
- Diverse team
- 4 (former) VC investors

# Market size




| 2026 | 2030 | 2040 |
|---|---|---|
| $65B | $100B | $200B |
| $1B | $10B | $50B |
| $10M | $100M | $1B |

# Roadmap

**2021**

**Launch**

SiriNor AS is registered in Norway
Provisional patent filed
Indian subsidiary established
Core team in place

**2022 / 23**

**Feasibility / MVP**

Successfully completed feasibility study.
Build and test an MVP

**2024/25**

**Engine Prototype / Technology Validation**

Build and test  a full-scale hydrogen-electric jet turbine
Potential pre-orders by 2024

**2026**

**Revenue**

1st engine sale, secure additional pre-orders, and clients,  operational experience with turbine before introduction to aviation

**2028/29**

**Commercial readiness** | **Potential Commercialization / Licensing / Contract Manufacturing**

# Hydrogen in aviation


Source: NACO white paper - Preparing airports for hydrogen flight