Global Sustainable Aviation

TRANSFORMING THE AIR TRANSPORT SYSTEM: THE PATH TO NET-ZERO

Joachim Szodruch

2 November 2026

ICGA 2026

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ICAO • OACI • ИКАО
国际民航组织 • ايكاو

ACI EUROPE
AIRPORTS COUNCIL INTERNATIONAL

IATA

International Federation of Air Line Pilots' Associations
IFALPA
The Global Voice of Pilots

ICCAIA

ATAG
AIR TRANSPORT ACTION GROUP

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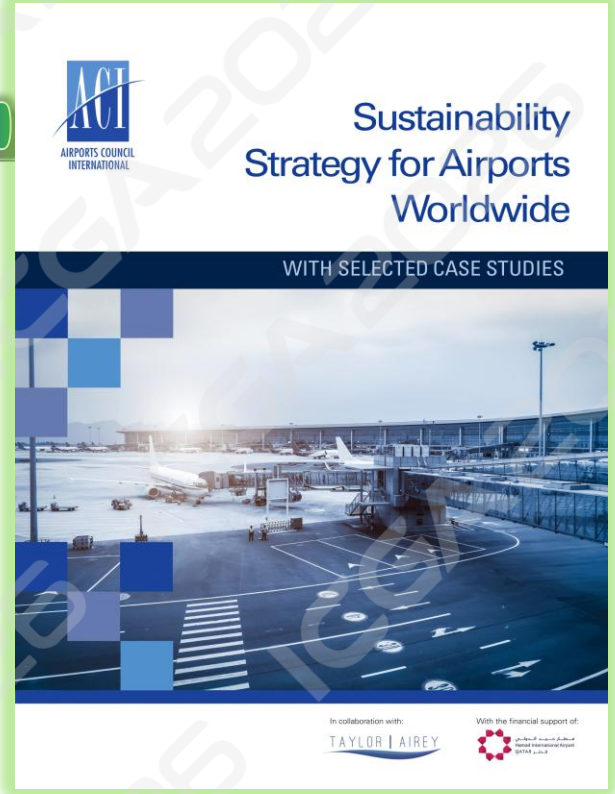
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INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

IDAS
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Global Network of 27 Public Aeronautical R&D Institutions

IFAR | International Forum for Aviation Research



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IFAR's Core Values

1
Information exchange and networking among the principals at IFAR Summits

2
Information exchange & discussion on technical issues to enable bilateral / multilateral international collaboration

3
Human resources development (empowering early career employees)

4
External partnership
Partners such as:
ICAS (2016)
ICAO (2020)






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The Lucasiewicz Research Institute of Aviation ILOT

hosted the IFAR Summit in 2026 on their 100th anniversary
With 19 global IFAR member institutes in attendance



The future of aviation rests on our ability to meet sustainability objectives while leveraging international cooperation

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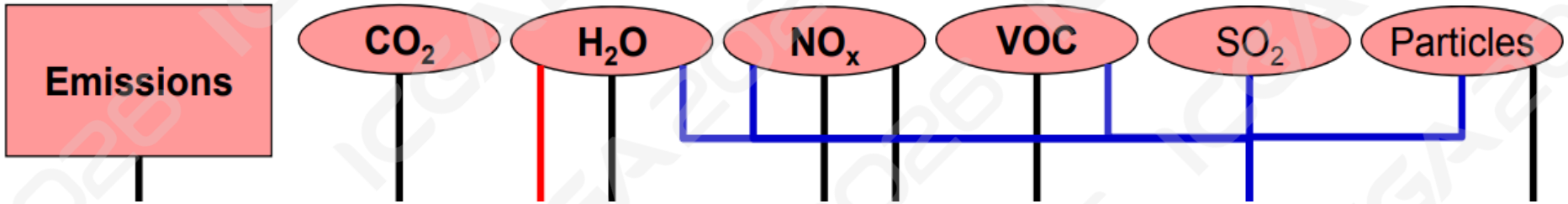
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Environmental

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Atmospheric effects of emissions from aviation

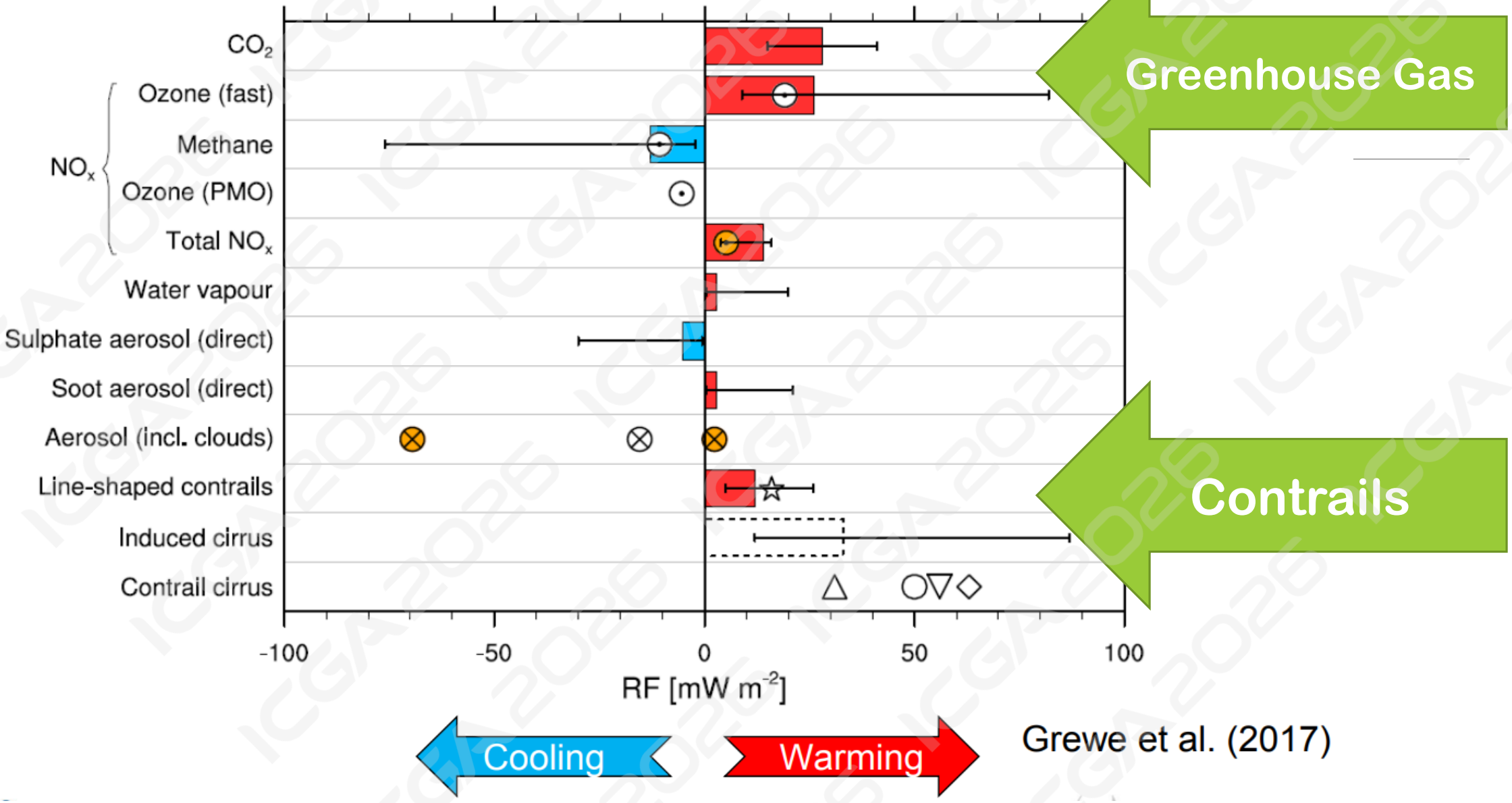


Source DLR

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*(VOC volatile organic compounds)

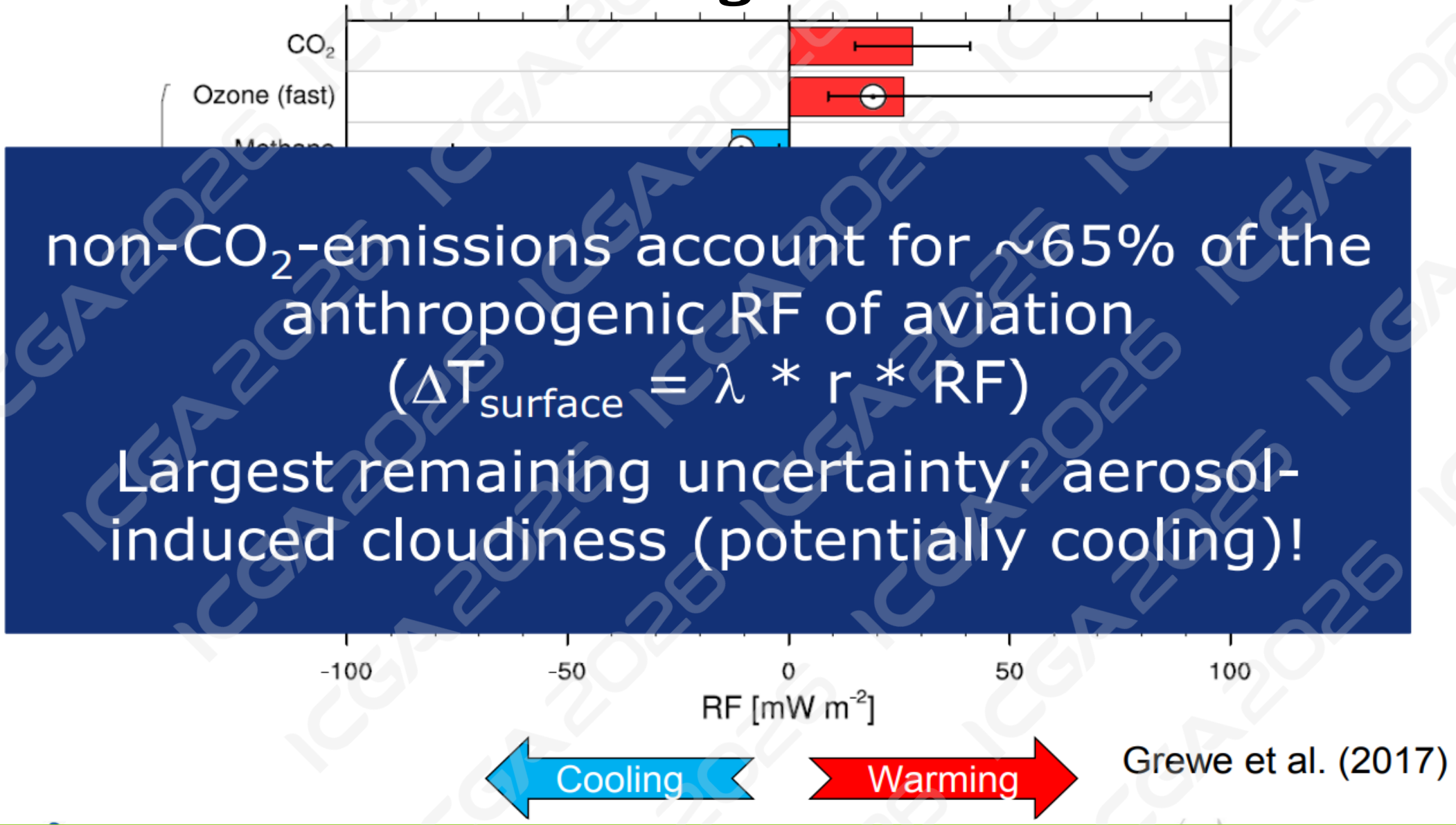
Effective Radiative Forcing



Grewe et al. (2017)

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Effective Radiative Forcing



non-CO_2-emissions account for ~65% of the anthropogenic RF of aviation

($\Delta T_{surface} = \lambda * r * RF$)

Largest remaining uncertainty: aerosol-induced cloudiness (potentially cooling)!

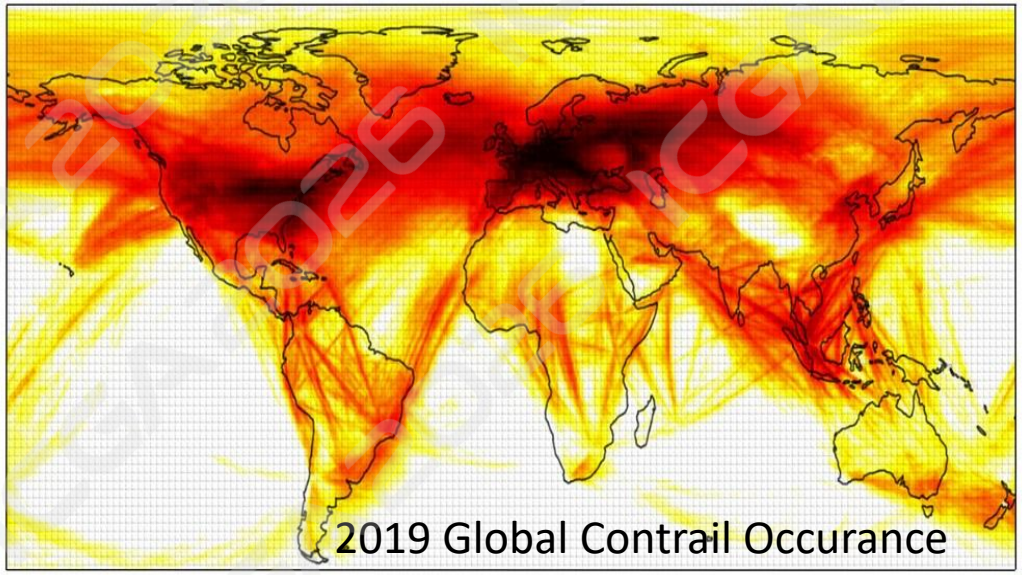
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Recent Contrail Research

Gulfstream G800 with Rolls-Royce Pearl 700 Engine
Up to 50.000 feet max Altitude



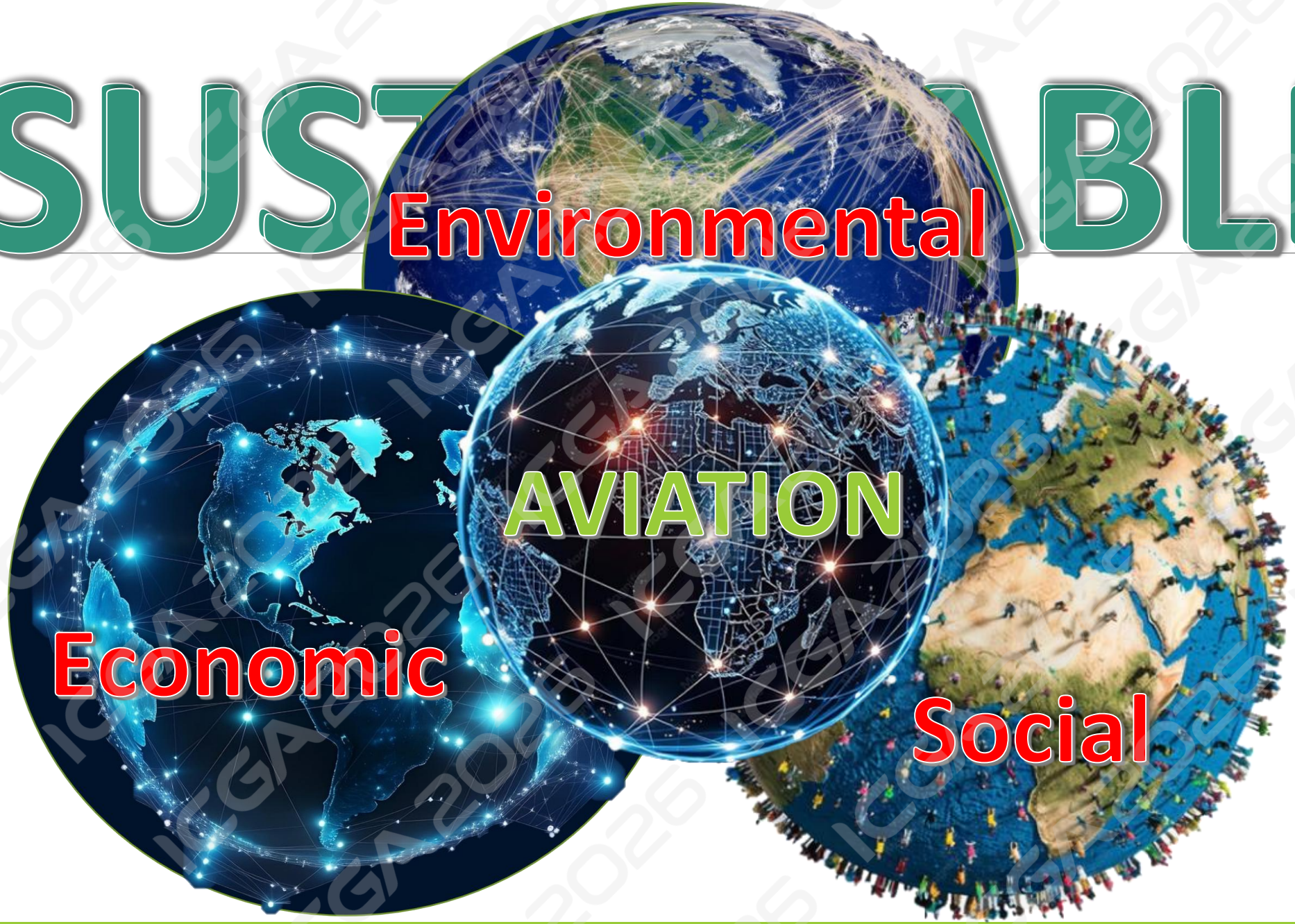
- **Fuel:** hydroprocessed **HEFA SAF**, entirely free of sulfur and aromatics.
- **Soot Reduction:** significantly fewer soot particles.
- **Contrail Mitigation:** 56% reduction in contrail ice crystals
- **Climate Benefits:** 26% reduction in the net warming impact



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FAA, NASA, DLR, Rolls-Royce, and Missouri University of Science and Technology.

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The Air Transport System



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The Air Transport System

Upstream Infrastructure - The Energy Options

Air Traffic Management (ATM) - Smart Skies

Airport of the Future

Next Gen Aircraft Technologies

New Ways of Working

Policy, Market Mechanisms & The Verdict

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Upstream Infrastructure - The Energy Options

Sustainable Aviation Fuel (SAF)

- Same characteristics like kerosene
- Made from biomass (BtL) or
- Made from synthetic H2 + CO2 (PtL)
- Carbon neutral (if using CO2 capturing)
- Reduced emissions such as soot & NOx
- Very energy demanding production

Liquid Hydrogen (LH2)

- Liquified at -253°C / 2-3 bar
- 4x volume and 3x lighter than kerosene
- Zero CO2 emissions
- Non-CO2 emissions reduced (zero with FC)
- Increased water vapor emissions
- Energy demanding production

Battery

- Very energy efficient power train (>90%)
- ~30x more heavy than kerosene
- Raw materials environmentally critical

Fuel Cell (FC)

- Better energy efficiency than turbine
- Only water vapor emissions
- High mass & high energy demand for cooling

Hybrid Electric (HEP)

- Flexible distribution of energy
- Range extender, booster, mild hybrid

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Comparison of climate impact from H2 propulsion and synfuel*

Change of in-flight emissions and emission related effects[1]

	Direct CO_2	NO_x	Water vapor[2]	Contrails, cirrus
Synfuel	-0% / -100% (Net)[3]	-0%	-0%	-10-40%
Hydrogen turbine	-100%	-50-80%	+150%	-30-50%
Hydrogen fuel cell	-100%	-100%	+150%	-60-80%

1. Assuming decarbonized production and transportation of fuels in 2050
2. 10 times lower climate impact than from CO_2 emissions
3. Net CO_2 neutral if produced with CO_2 captured from the air
4. Measured in CO_2 equivalent compared to full climate impact of kerosene-powered aviation

*Hydrogen Powered Aviation, McKinsey 2020

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Air Traffic Management (ATM) - Smart Skies

Extended Arrival Management (AMAN)	250kg CO2 / flight
Optimized / Continuous Descent	180Kg CO2 / flight
Optimized Climb Profiles	50Kg CO2 / flight
Datalink Vertical Clearances	90Kg CO2 / flight
Formation Flying (Wake Energy Retrieval)	5-10% cruise fuel
Green Ground Operations	50% ground emissions
Greener Routing and Carbon-Aware Control	20% Non-CO2 emission

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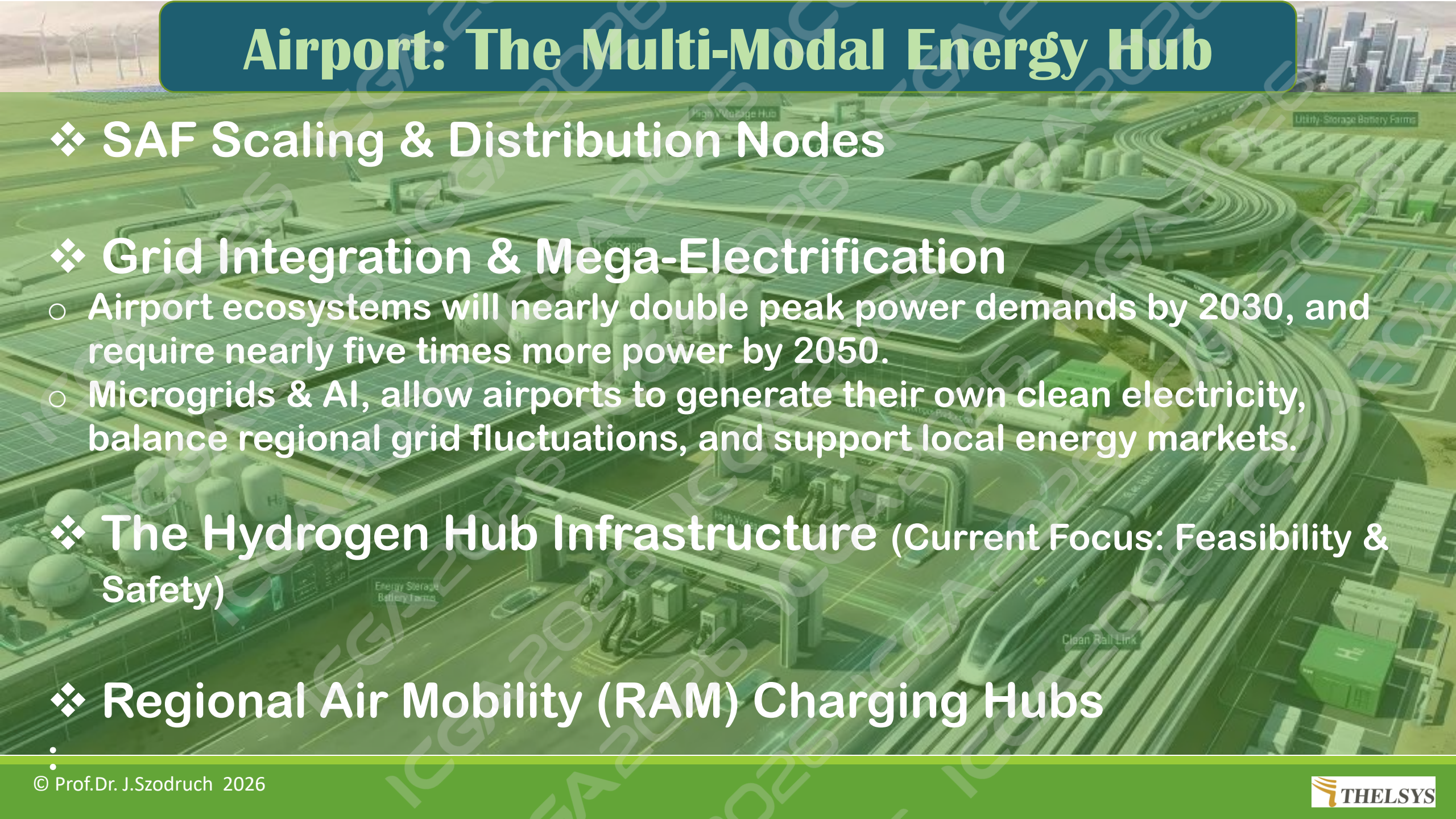
Airport of the Future



- Airport decarbonisation technologies
- Digital identity and biometrics for seamless travel
- Smartphones and the digital evolution of airport retail
- Intelligent Automation
- Digital Twins — virtual of airport and airspace operations
- Digitalisation and AI in air cargo logistics

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Airport: The Multi-Modal Energy Hub



- ❖ SAF Scaling & Distribution Nodes
- ❖ Grid Integration & Mega-Electrification
  - Airport ecosystems will nearly double peak power demands by 2030, and require nearly five times more power by 2050.
  - Microgrids & AI, allow airports to generate their own clean electricity, balance regional grid fluctuations, and support local energy markets.
- ❖ The Hydrogen Hub Infrastructure (Current Focus: Feasibility & Safety)
- ❖ Regional Air Mobility (RAM) Charging Hubs

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Next Gen Aircraft Technologies



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Next Gen Aircraft Technologies

Aerodynamics and Configurations

- Blended Wing Body (BWB)
- Transonic Laminar Flow
- Active Flow Control
- Open Fan Rotors Integration
- High Aspect Ratio wings & Foldable Wingtips





Alternative Propulsion

- Open Rotor
- Advanced Turbofans
- Hydrogen Fuel Cells
- Hybrid and Electric Syste





Advanced Materials

- Lightweight bio-fibres
- Bio-sourced resins
- Advanced composites

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Global CTO‘s Statement (Le Bourget)

The Strategy

- fuel efficiency and CO2
- sustainable, alternate aviation fuels.
- radically new aircraft and propulsion technology

The Targets

- 75 percent reduction in CO2,
- 90 percent drop in NOX and a
- 65 percent decrease in noise by 2050.
- global agreements through ICAO as part of the certification process

Aviation’s Third Era

- new architectures, advanced engine thermodynamic efficiencies, electric and hybrid-electric propulsion, digitization, artificial intelligence, materials and manufacturing,
- novel designs with aircraft drag management and distributing propulsion and new materials.

AIRBUS

BOEING

DASSAULT AVIATION

GE Aviation

ROLLS ROYCE

SAFRAN

United Technologies

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Global RTO's Statement - IFAR

A Statement by 13 IFAR Research Establishments (2020)

RE's research into radical technologies of tomorrow leading to Focus Areas of

- **Sustainable aviation fuels**
- **Climate-optimized routing**
- **Urban air mobility**
  and electric flight will provide additional technological advancement and open up new dimensions of sustainable mobility.
- **Product Life Cycle** with minimum impact



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IFAR | INTERNATIONAL FORUM FOR AVIATION RESEARCH

Aircraft Systems Architectures



- More Electric Aircraft (MEA) &Power-by-Wire
  - Electro-Hydrostatic Actuators (EHAs)
  - Bleedless electric compressors
- Cloud-connected & adaptive AI avionics
  - Single-Pilot Operations
  - Prognostics & Health Management (PHM)
- Advanced Thermal & Energy Management

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Advanced Production and MRO Technologies



- Circular Economy
- Advanced Materials & 5-Axis Machining & AM
- Predictive Quality & Metrology
- Digital Twins & IoT Sensors
- Predictive Maintenance Systems
- Augmented Reality (AR) Guidance

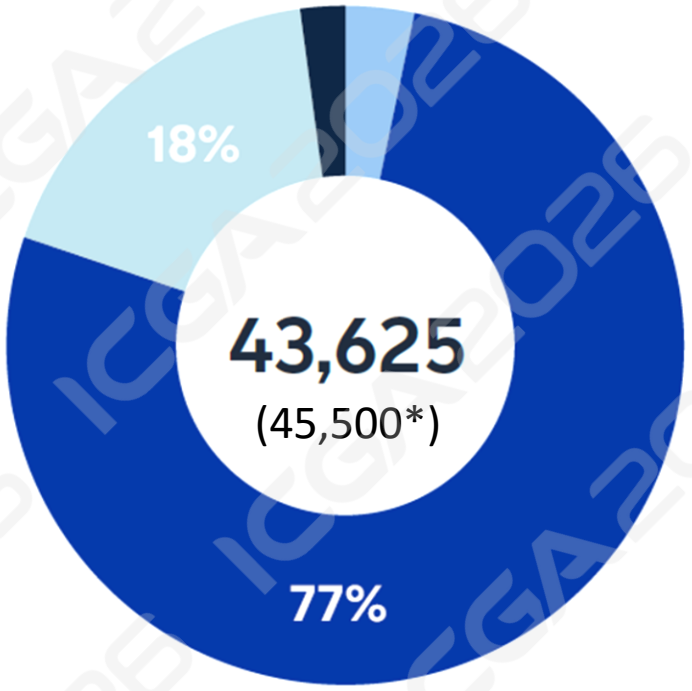
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Fleet Renewal

Boeing CMO 2026



2025 Fleet





2045 Fleet

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* Airbus GMF, >100 Seats

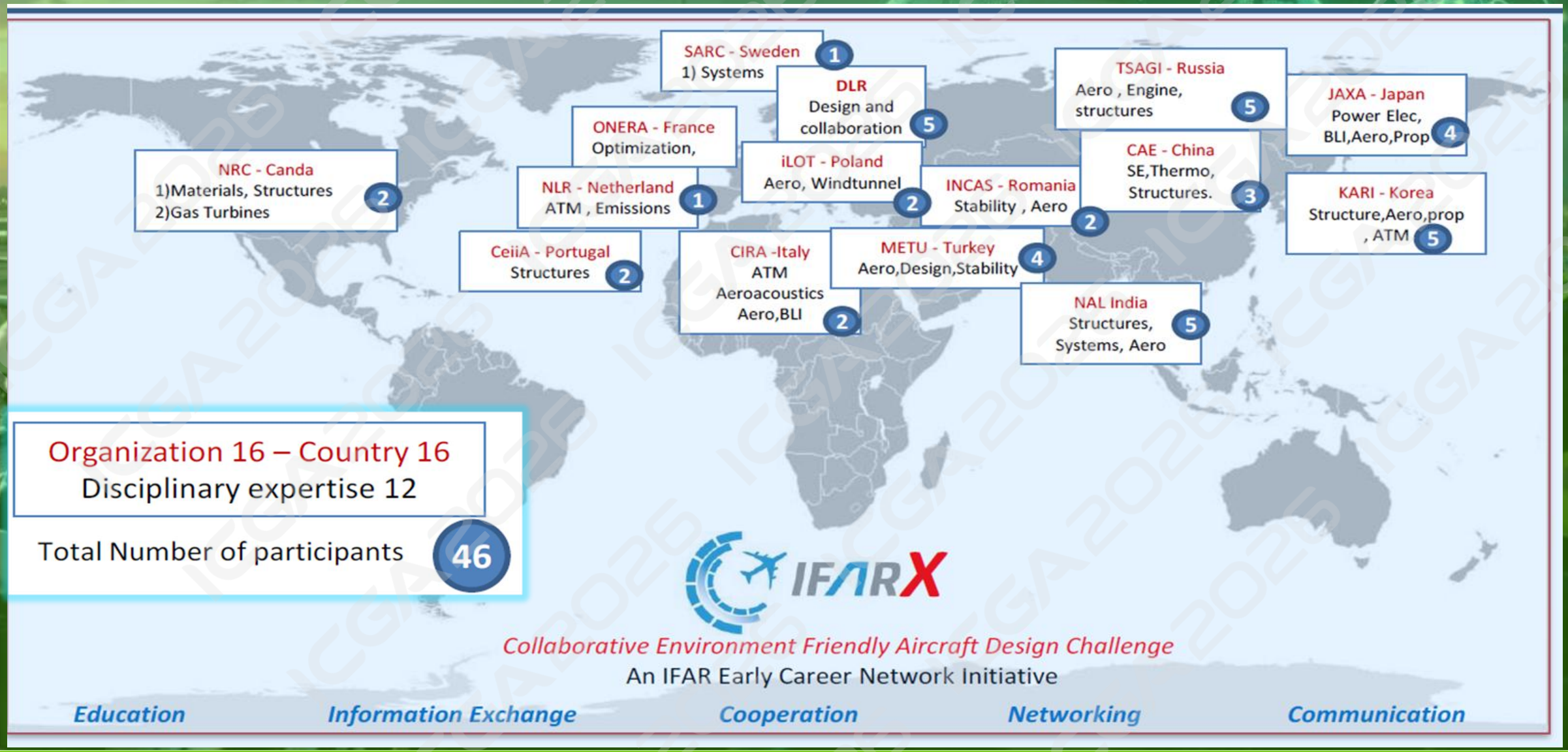
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New Ways of Working



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IFAR X – Early Career Network Initiative



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IFAR X – Early Career Network Initiative







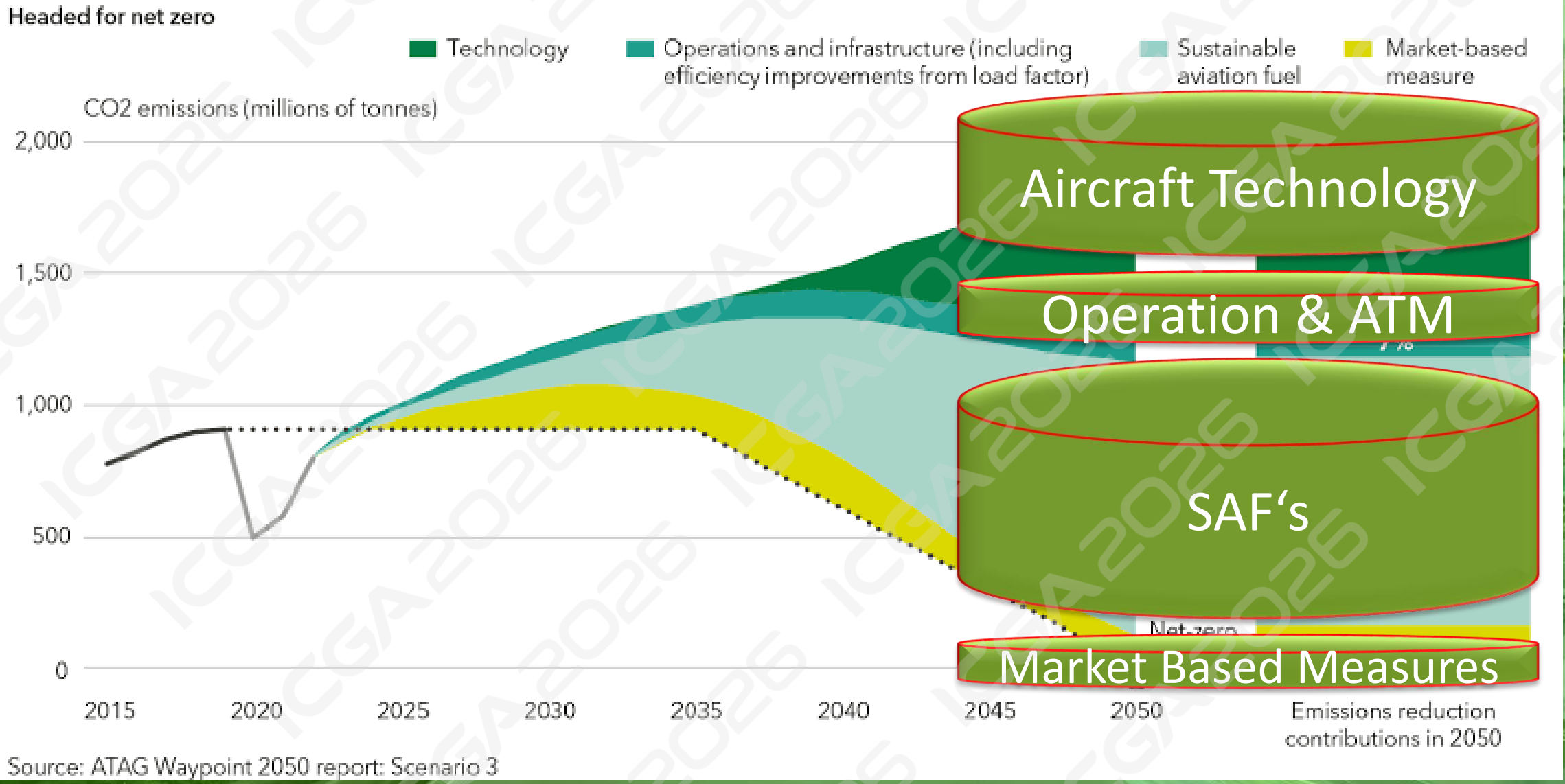


2019-20 Collaboratively create distributed design environment and design a **reference aircraft**. And Further Green Hybrid Electric Aircraft

2020+ Make use of distributed design environment for designing **green aircraft meeting flightpath 2050 goals**.

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The Path to Net-Zero



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The Central Challenges

❖ Renewable Energy Availability:

Transitioning global aviation to e-fuels (and hydrogen) will require thousands of terawatt-hours (TWh) of green electricity by **2050**—a multiple of today's total global production from wind and solar power.

❖ Capital Costs & Scaling:

Building SAF refineries (and H_2 infrastructure) at airports requires global investments in the **triple-digit billions** per year.

❖ Fleet Renewal Rates:

Airlines must replace their existing fleets with more efficient models at a faster pace, which is currently limited by economics and potentially by supply chain bottlenecks among engine and aircraft manufacturers.

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Regulation, Investments and Carbon Removal

❖ Blending Mandates*:

Legal regulations require fuel suppliers to blend sustainable aviation fuel (SAF) in increasing increments (e.g., 2% SAF starting in 2025, 6% by 2030, and 70% by 2050, including a fixed e-fuel share)

❖ CO_2 Pricing & Certificates:

The EU Emissions Trading System (EU ETS) and CORSIA** steadily increase the cost of fossil jet fuel, closing the price gap with SAF.

❖ Direct Air Carbon Capture and Storage (DACCS):

Might be available on an industrial scale by 2040, so unavoidable residual emissions could be compensated through permanent geological storage.

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*ReFuelEU Aviation

** 2nd Phase 2027 mandatory

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Budget & Economy: Estimated Magnitude of Capital Requirements

❖ Investment Requirements (CAPEX)

- Approximately 4 to 5 trillion US dollars in investments by 2050 (ATAG and McKinsey).
- Over 80% of this capital will not flow into aircraft manufacturing itself, but into building the upstream energy infrastructure (renewable energy plants, refineries etc.).
- Competition with energy demands of other sectors (steel, chemical industries, power grid decarbonization).

❖ Operating Costs (OPEX) and Economic Viability*

- **Fossil jet fuel:** approx. **600 – 800 USD** per metric ton.
- **HEFA-SAF** (from waste oils): approx. **1,800 – 2,500 USD** per metric ton.
- **PtL / E-Fuels** (Synthetic jet fuel): approx. **3,000 – 4,500 USD** per metric ton.
- TOC for a complete transition to PtL would double pure flight operation costs.

❖ Ticket Price Increase Estimation

- Europe 100€ + 40€ and International 700€ + 250€

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* e-fuels.com, IATA, and ReFuelEU Aviation

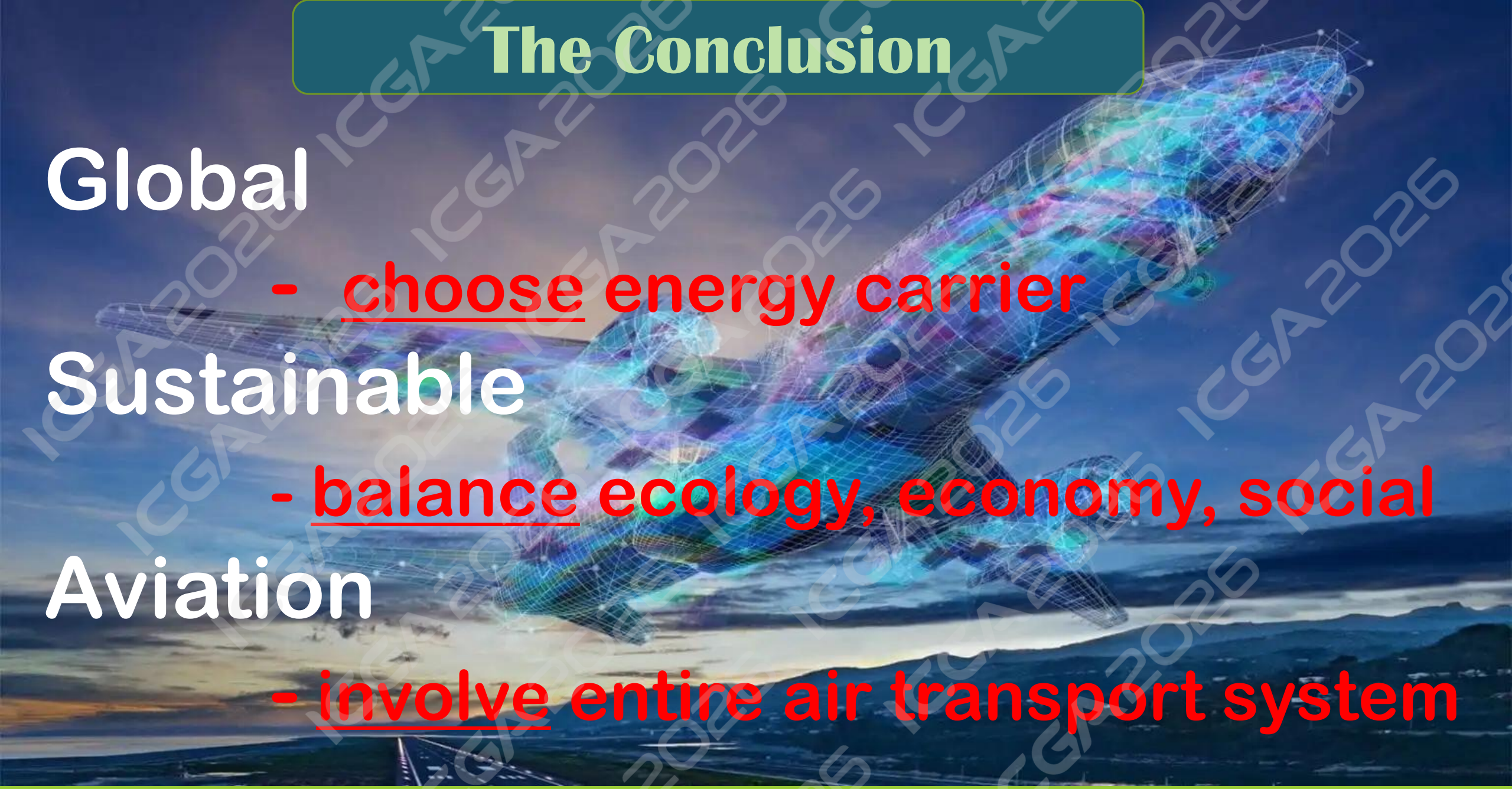
The Verdict

The net zero 2050 target is currently failing neither because of physics nor because of the availability of capital per se,

but because of the lack of an economically viable “global business model” for the transition phase.

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The Conclusion



Global

- choose energy carrier

Sustainable

- balance ecology, economy, social

Aviation

- involve entire air transport system

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感谢您的关注和兴趣

















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