ICAF

International Committee on Aeronautical Fatigue and Structural Integrity

Topical National Review: **Sustainable Aviation**

Elke Hombergsmeier et al.
Airbus Defence and Space GmbH

ICAF 2025 - Xi´an - China

Sustainable Aviation

- Where are we with Aviation?
- Where do we want to go?
  - Our Aviation Ambitions
  - Our Strategy @ Airbus
- How do we want to get there?
  - Emission Reductions
    - ZeroE for hydrogen-powered flight
    - X-66 demonstrator for structural efficiency & electrical power generation system
  - Material & Process Technologies
  - Sustainable Aviation Fuel
    - Swiss Roadmap Sustainable Aviation
    - Australian SAF Roadmap
- What are our Challenges & Outlook?

Aviation: An irreplaceable force

4.4 billion
passengers

67,300
routes served globally

61.4 million
tonnes cargo

4,072
airports with scheduled commercial flights

3.9 %
contribution to global GDP*

2023 statistics by ATAG

* (Gross Domestic Product)

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Our Aviation Ambition

- Reducing Greenhouse Gas Emissions
  - Aviation is a significant contributor to greenhouse gas emissions, and the industry is actively working to **reduce its impact.**
- Transitioning to Sustainable Aviation Fuel (SAF)
  - SAF is a renewable jet fuel that can reduce carbon emissions by up to 80% compared to conventional jet fuel. The aviation industry is working to increase the **use of SAF** and develop technologies for its **production.**
- Improving Aircraft Efficiency
  - Efforts are being made to design and manufacture more **fuel-efficient aircraft, optimize flight paths,** and improve **operational procedures** to reduce fuel consumption and emissions.
- Achieving Net-Zero Emissions by 2050*
  - The civil aviation industry has set a goal of achieving net-zero carbon emissions by 2050, which requires a combination of **emission reductions, SAF use,** and other **innovative technologies.**

*ICAO Strategic Plan 2026 - 2050

Decarbonisation strategic approach

Latest generation aircraft

Our latest generation family of aircraft offer around 25% greater efficiency compared to the previous generations

Operations and infrastructures

Operational optimisation solutions can save up to 10% CO_2

Sustainable aviation fuels

SAF can reduce emissions by 80% on average during its full lifecycle.

Disruptive technologies

Our ambition is to bring to the market a hydrogen-powered aircraft

Market-based measures

Regulatory measures: EU ETS / CORSIA

Voluntary measures: DACCS

Reducing the environmental footprint of our operations

Ambition for 2030 compared to 2015:

-63 % CO_2 emissions
CO2

-20 % purchased energy
Energy

-20 % waste collection
Waste and raw materials

-25 % water withdrawal
Water

0 % Progressively absorb ramp-up impacts
VOC* and air emissions

*(Volatile Organic Compounds)

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A cryogenic propulsion system for commercial aviation

Hydrogen storage and distribution for a commercial aircraft implies specific & challenging requirements:

- Weight & space allocation
- Operational
- Industrialization
- Qualification & certification
- Lifetime, inspectability & maintenance
- Safety
- Economically viable configuration

No State of the Art LH_2 tank & systems fulfilling commercial aircrafts requirements

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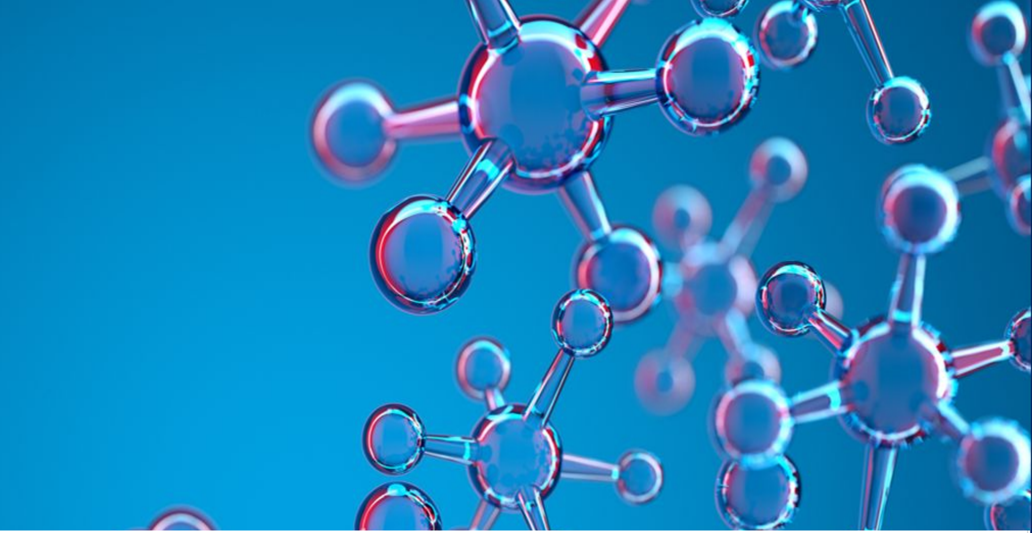
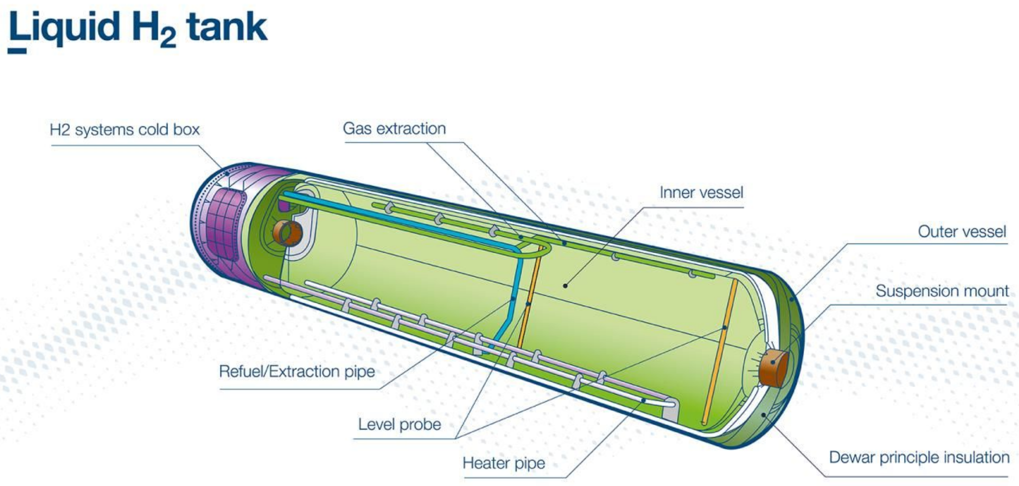
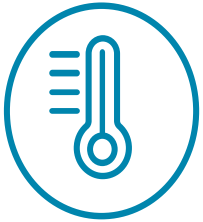




Challenges of H_2 adoption

- **Technology compatibility** with aircraft e.g. **LH_2 storage!**
- **Safety & regulation**: standardization (technology & rules)
- **Infrastructure**: step-by-step transition and long term plan ('Hydrogen Hubs at airports')
- **H_2 availability & cost**: growth of renewable electricity and **hydrogen Ecosystem**

LH_2 tank structure and challenges



Cryogenic temperature

It's freezing cold! 20K ⇔ -253°C

Tightness

Tiny H_2 molecules that try to escape

Fluid motion

Waves and phases change incoming!

Thermal insulation

Keep it cold or the pressure will go up

Weight and Volume

Let's make it fly

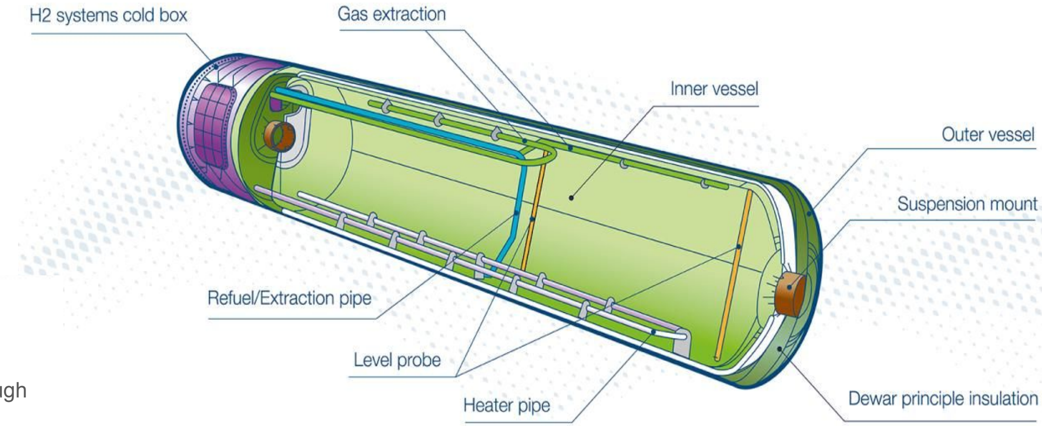
Safety first

Take care it burns
A weak spark may be enough

LH_2 storage conditions

- 20K = -253°C
- Relatively low pressure

Baseline: Dewar
Double wall vacuum insulated **metallic** tank



A composite LH_2 tank is a <u>weight saving</u> opportunity in comparison to the metallic solution
Lower maturity of the Composite technology for an LH_2 tank → Current status: feasibility demonstration

Composite LH_2 tank challenges

Opportunities

- **Weight saving**
- Low cost high volume production
- Reduced structure maintenance

Risks

- Cryo-temperature & thermal cycling H_2 permeation
- Industrial manufacturing
- Systems integration

CFRP tank prototype production - CASA Espacio (2014)

A composite LH_2 tank is a <u>weight saving</u> opportunity in comparison to the metallic solution
Lower maturity of the Composite technology for an LH_2 tank, even though synergies with Space

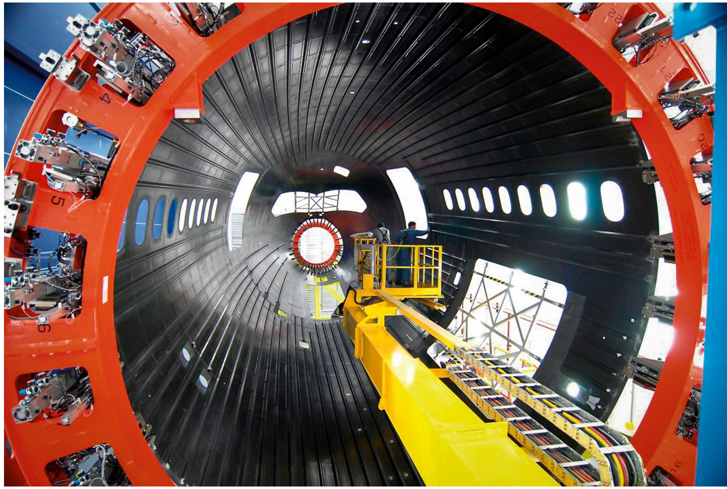
X-66 demonstrator by NASA and Boeing

Second major program focusing on sustainable aviation

The X-66 demonstrator was launched by NASA and Boeing aiming to develop a full-scale demonstrator aircraft (based on modified MD-90) to explore new technologies for fuel-efficient and green aviation, ultimately pushing towards net-zero emissions by 2050

X-66 Structural Aspects

- Transonic truss-braced wing
  - Long, thin wings to reduce drag at high subsonic speeds
  - High bending loads. Challenges in flutter suppression, gust response
- Modifying MD-90 airframe
  - New wing to existing fuselage integration
  - Center of gravity and structural load paths
- Advanced materials
  - Composite materials for high volume fabrication – mainly thermoplastics
  - Focus on damage tolerance, low weight and manufacturability



X-66 Fuselage Fabrication (Thermoplastics)

Our Materials

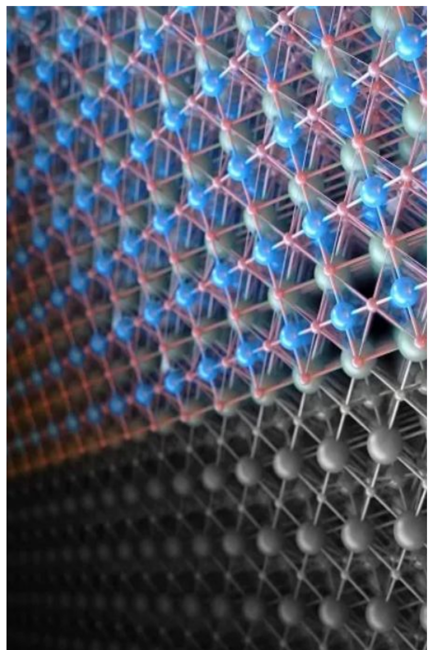
Key challenges and enablers in aerospace industry

Performance

- SAF Price increase
- Materials shortage

Electrification

- Materials for Batteries, Fuel Cells
- Critical Raw Materials Act
- Hydrogen Embrittlement



Sustainability

- Regulatory
- Composites Recycling

Digitalisation

- Complexity
- No Data Continuity

Materials Roadmap

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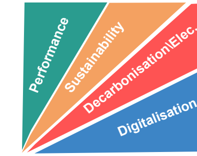
Trends:



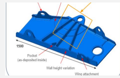
Prepare next generation aircraft

Enabling next generation aircraft by high-rate production processes and co-design

Enabling the future

Preparing full environmental & industrial ambition to enable high-rate sustainable production

ADDITIVE MANUFACTURING PROCESSES



DED Ti64

Circular & pellet based Polymer AM

Scalmalloy High Perfo Alu

DED Steel

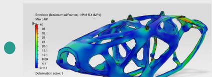
endless fibre reinforced AM

Ti64 Chips upcycling to AM Raw Material: Powder & Wire

Digital Material Development, Parameters & Qualification

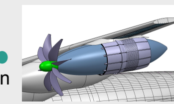
AM of large systems

DED Large Optimized Primary Structure



Highly customized, function integration

Full System-Structure-Hybridization e.g. Structural Heat Exchanger



From 1-1 part replacement for cost saving or supplier derisking towards AM for product value & reduced over

COMPOSITES AND POLYMER MATERIALS AND PROCESSES

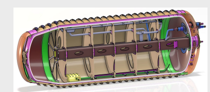
Composite material for high production rates

Substance management

Thermoplastic for large scale production on elementary parts

Sustainable and circular materials

Advance RTM / Fast Cure



CFRP Tanks & distribution systems

Full reuse/recyclability (Prod, EoL) - at minimum energy

Full Circularity (from Eco-Design to EoL)

Enabling full circular Composite & Sustainability ambition, high performance Composite technologies at affordable costs

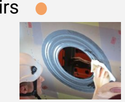
SURFACE & BONDING TECHNOLOGIES

Bonding Automation

Simulation & Modelling

Automation and digitisation in paint shops

Large bonded Repairs



Corrosion Management

Design for dismantling

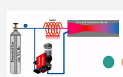
Self healing Coatings

Debonding on demand

Improve maintenance with green technologies, enable structural bonding in major load patches to bring down recurring cost

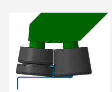
METAL & CERAMIC MATERIALS & PROCESSES

Friction Stir Welding 3D

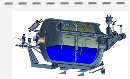


Portable Metallic Repair (Cold Spray)

Low cost forming



Advanced forming (roll/Integrated press)

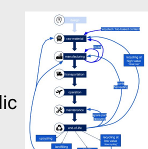


Metallic tank/systems for H2 environment

100% circular metals
Fully sustainable metallic supply chain

Fully implemented critical/ethical metallic and ceramic materials management

Emerging metallics (functional/hybrid)



High performance and cost-efficient technologies to improve the metallic industrial system and enable the sustainable materials ambition

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Composite Sustainability

Dismantling & recycling

Eco-design

Dependence of oil precursors
Energy consumption
Substance compliance

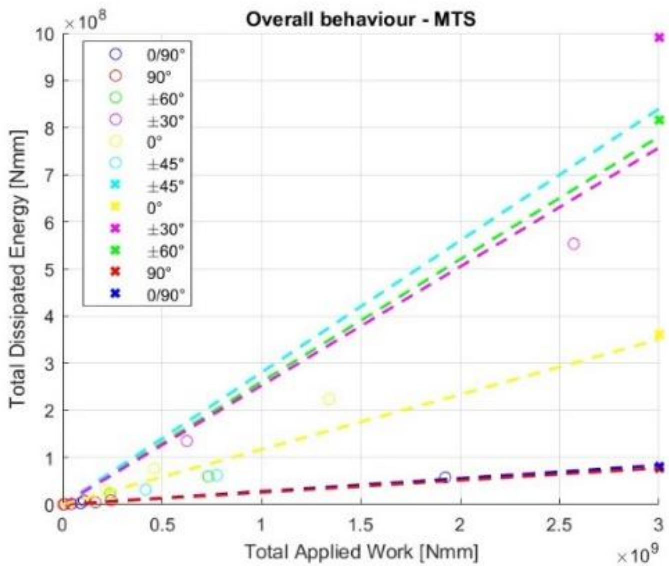
Weight saving!

Auxiliary materials
Energy consumption
Waste Management

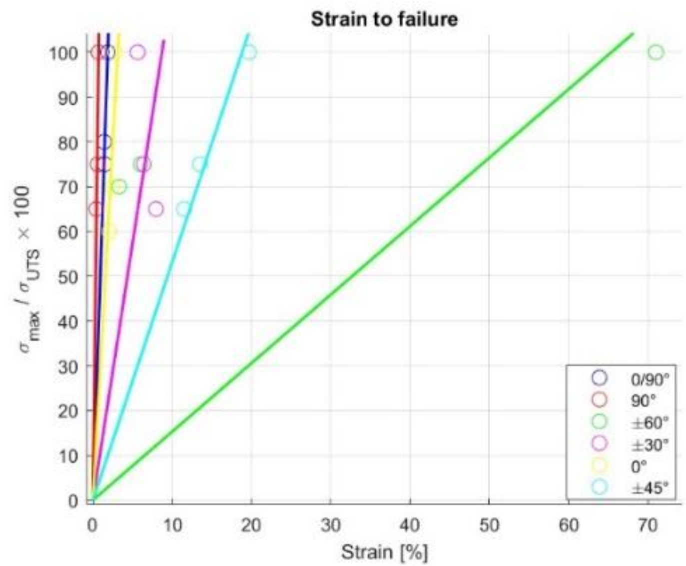
Airbus social & environmental responsibility and compromise

Example WP-activity on Thermoplastics

- Fatigue, Durability & Damage Tolerance of thermoplastic composites
  - Develop true physics-based model to predict F&DT of composites utilizing monotonic test data only through..
  - ..description of strain energy dissipation versus (cyclic) work applied



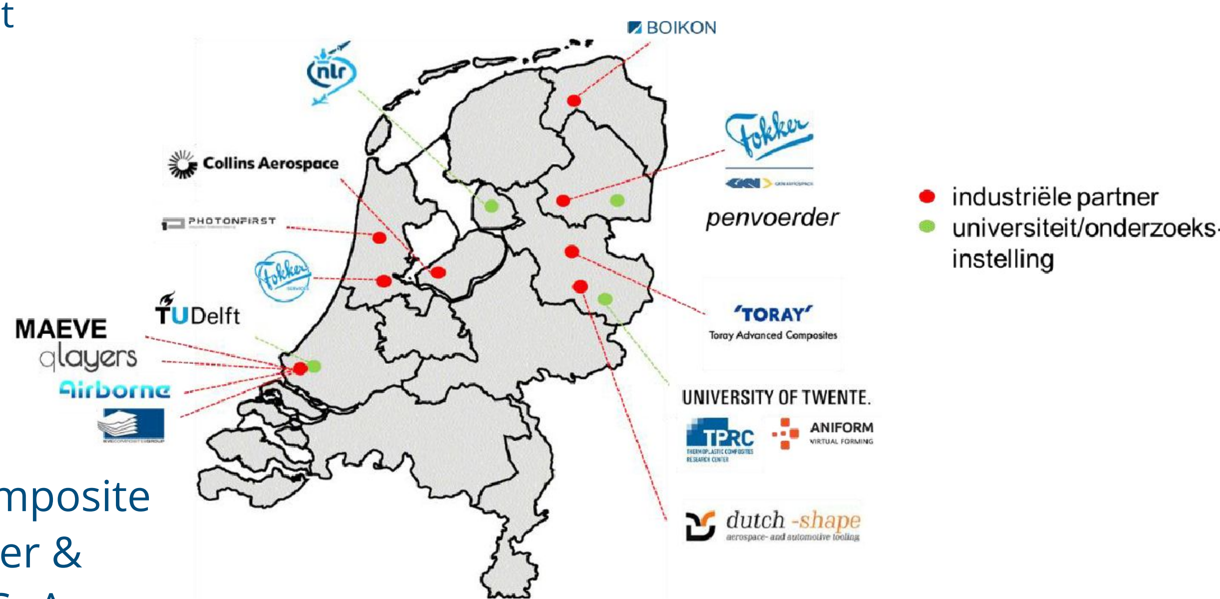
Alignment static and fatigue tests of ratio total dissipated energy/work applied



Linear correlation between total strain to failure in static and fatigue tests

"Dutch Luchtvaart in Transitie" (Growth fund) for Sustainable Aviation

- Dutch initiative of Dutch industry and knowledge institutes on Materials, Manufacturing technology and Structures
  - Develop technologies for thermoplastic composite component and integrated structures with electric and thermal systems which covers
    - Material development
    - Product design
    - Production
    - Certification



...for thermoplastic composite products, 10-15% lighter & 20-23% cheaper than SoA.

Additional Advanced Materials Topics

- Additive Manufacturing of various Aluminium and Titanium alloys → process and performance optimization, incl. surface treatment as well as NDT
- Linear & 3D Friction Stir Welding
- Hybrid joints
- Cold Spray for repair and Laser Shock Peening for riveted joints & repair
- Structural bonded composite repairs

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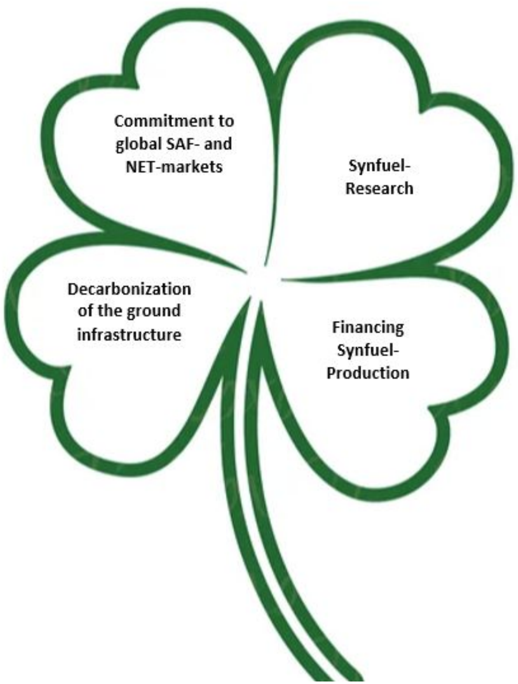
Sustainability in Switzerland

ARCS
Aviation Research Center Switzerland

- **Swiss “Road Map Sustainable Aviation”** from May 2021
  - by the **Aviation Research Center Switzerland** (ARCS; www.arcs.aero) with representatives from **SWISS, the Swiss Business Aviation Association, the national airports of Zurich, Geneva and Basel**, the federal offices **FOCA and FOEN,** as well as **ETH Zurich** and the **Zurich University of Applied Sciences ZHAW** and **easyJet.**
  - This Sustainable Aviation Road Map shows how aviation to and from Switzerland can **reduce its greenhouse gas emissions and climate impact** in line with the goals of the Federal Council's long-term climate strategy.

Sustainability in Switzerland

- In June 2024, the **first assessment** of the current situation was carried out
- However, **air transport is still far below** the new mandate of a **blending quota of 2% in 2025.**
  - The use of newer and more economical aircraft of the last generation has enabled a CO2 reduction of 2%.
  - Progress has also been made in reducing CO2 emissions from ground infrastructure.
  - However the challenge to achieve the goals of zero emission are huge.



Sustainability in Switzerland

sweet swiss energy research for the energy transition
reFuel.ch

- **Research for Sustainability**
  - **Pilatus** is flying all aircraft up to delivery with a high amount of SAF and has a collaboration with Synhelion. Universities performed studies to look into alternative propulsion systems and aircraft concepts.
  - The **Kopter Group** is also working on an innovative hybrid electrical solution based on the AW09 for developing a very sustainable helicopter. The ultimate goal is to offer lower emissions, simplified emergency procedures with efficient operation and high safety standard.
  - The **Swiss Universities** on a project called reFuel.ch on new solutions for de-fossilization using renewable fuels, also doing emission measurements & understanding the impact of this emissions.

Empa Materials Science and Technology · PAUL SCHERRER INSTITUT PSI · ETH zürich · EPFL · n|w Fachhochschule Nordwestschweiz · zh aw · usi Università della Svizzera italiana · Scuola universitaria professionale della Svizzera italiana SUPSI · Universität Basel

reFuel.ch - renewable Fuels and chemicals for Switzerland

Sustainability in Australia - SAF Import

Qantas: AUSTRALIA'S LARGEST IMPORT OF SUSTAINABLE AVIATION FUEL LANDS IN SYDNEY

Qantas, Sydney Airport and Ampol, supported by Qantas' SAF Coalition partners, have marked the largest ever commercial importation of Sustainable Aviation Fuel (SAF) into Australia, with nearly two million litres of unblended SAF, because of its great near-term potential to help decarbonise the aviation industry.

Once blended at a **ratio of approximately 18%,** the fuel could power the equivalent of **900 flights from Sydney to Auckland on Qantas and Jetstar's 737 aircraft,** reducing the resulting carbon emissions from those flights by a total estimated **3,400 tonnes.** This is roughly equivalent to the annual emissions generated by 800 cars.

https://www.qantasnewsroom.com.au/media-releases/australias-largest-import-of-sustainable-aviation-fuel-lands-in-sydney/

Sustainability in Australia - SAF Roadmap

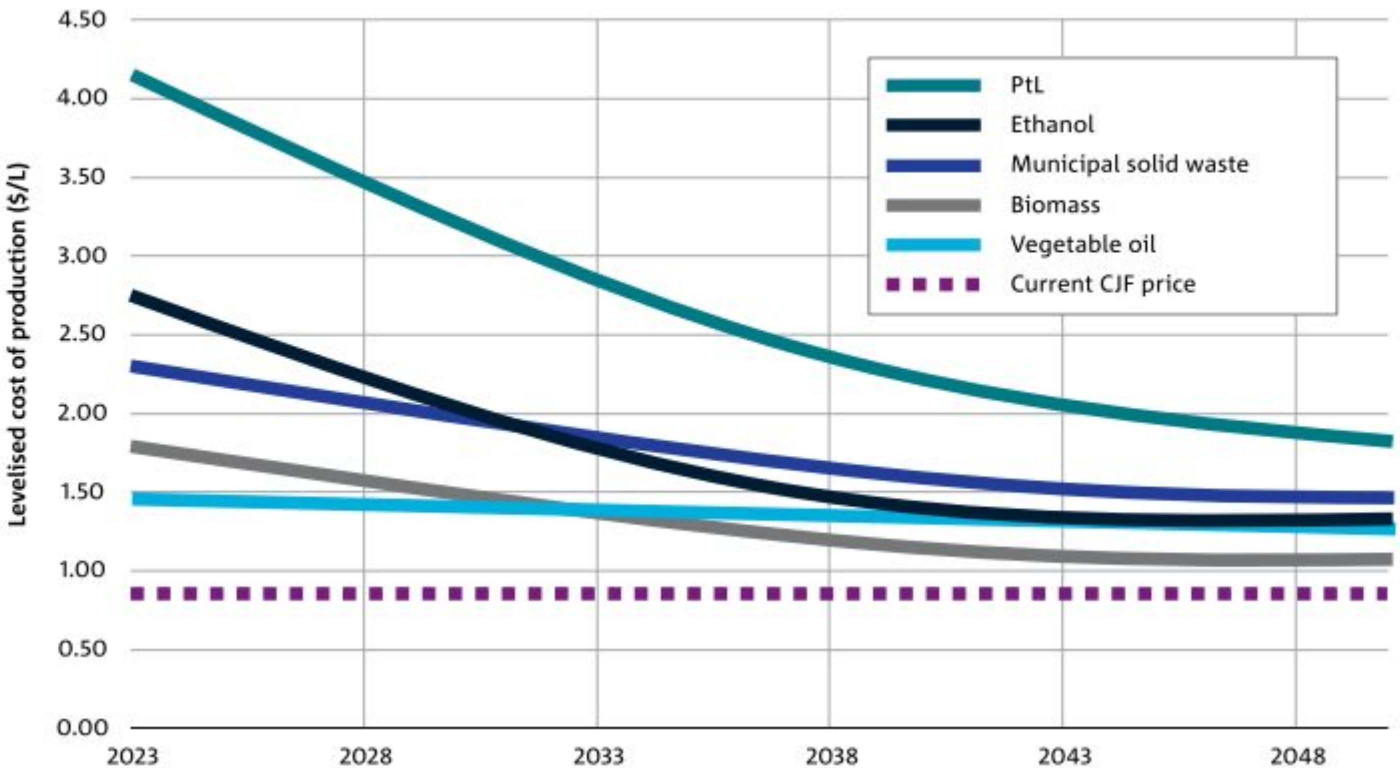
With limited technological options solutions are available to lower emissions effectively, aviation is a challenging sector to decarbonise.

Five main strategies can aid in emissions reduction:

- Improving fuel efficiency by **adopting new fleets** and implementing **more efficient aircraft movements**
- Exploring **new propulsion technologies** such as **battery** and **fuel cell electric planes** as well as **hydrogen combustion**
- Utilising **carbon offsets**
- Considering flight alternatives like **high-speed rail and video conferencing**
- **Sustainable aviation fuel (SAF)**

https://www.csiro.au/-/media/Energy/Sustainable-Aviation-Fuel/Sustainable-Aviation-Fuel-Roadmap.pdf

Sustainability in Australia - SAF Roadmap



Projected levelised cost of production for five key feedstocks

https://www.csiro.au/-/media/Energy/Sustainable-Aviation-Fuel/Sustainable-Aviation-Fuel-Roadmap.pdf

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What are our challenges & outlook?

Airbus delays its ZEROe hydrogen aircraft as UK CAA expands hydrogen programme

Boeing's X-66 experimental airliner has been indefinitely shelved

- Boeing's X-66 experimental airliner has been put on hold
- Plans have been indefinitely shelved
- It was being made in partnership with NASA

- Sustainable future has many challenges down the road:
  - **Low technology maturity** (aerodynamic complexity & electric power system for the X-66, hydrogen propulsion for ZEROe)
  - Materials need **technical feasibility** demonstration
  - Structural **integration** issues
  - Need for re-thinking **manufacturing & industrialization, maintenance** and **operations**
  - **Hydrogen storage & distribution**
  - **Certification** path uncertainty (i.e. test standards & sizing methods under cryogenic conditions)
  - **Safety** and public **acceptance**
  - Collaboration as **key-enablers** (i.e. academia, cryo testing, material development)

Leading sustainable aviation

2030

- Reduce **by 63% Scope 1 & 2** industrial emissions
- Offer up to **100% SAF capability** on our commercial aircraft

2035

- Reduce **by 46% the CO_2 emissions** intensity generated by our commercial aircraft (Scope 3 - use of sold products)

2050

Support the aerospace industry's decarbonisation roadmap, set by ATAG and IATA, to reach **'net-zero carbon emissions' by 2050**

Target validated by the Science Based Targets initiative (SBTi)

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Thank you very much for your attention!