DIPARTIMENTO DI INGEGNERIA INDUSTRIALE

Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Aerospaziale

Design solutions to overcome hydrogen-powered aviation challenges

Tutor universitario: Prof. Ernesto Benini

Laureando: Frizziero Nicola

Matricola: 1216834

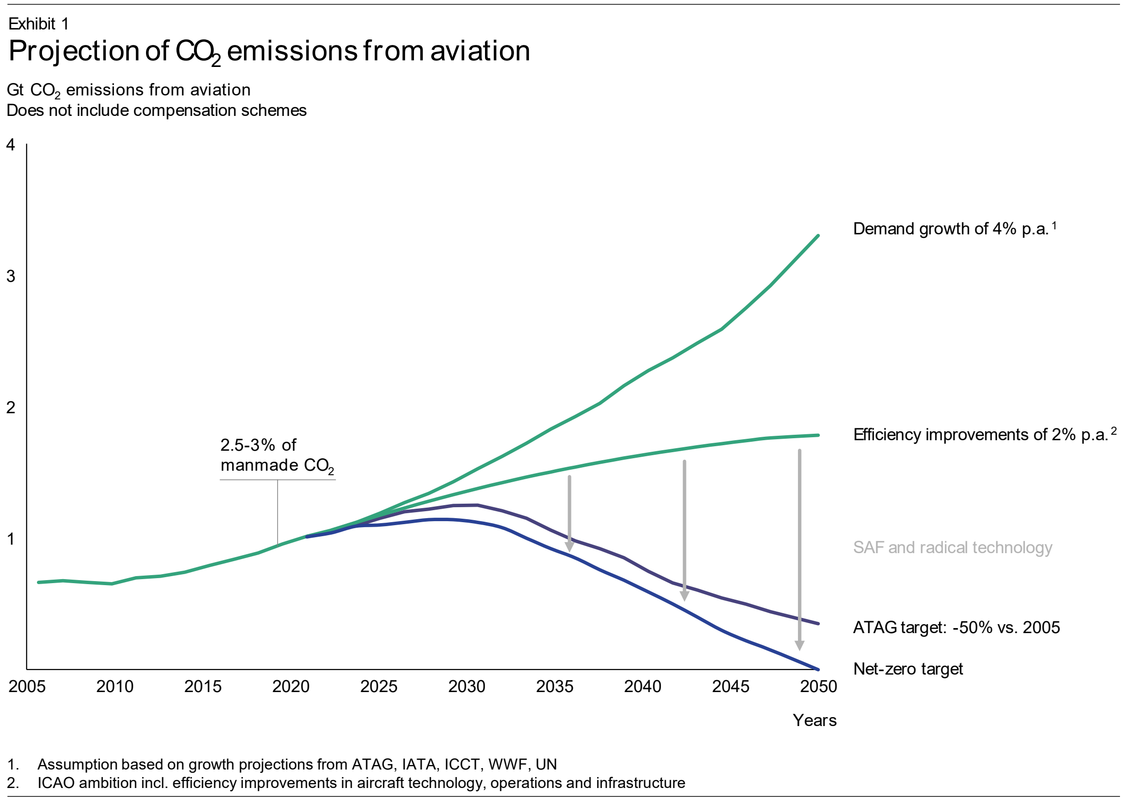
Padova, 20/09/2022

The impact of aviation on climate

- 3-7% of global CO_2 equivalent
- 900 tons of CO_2 today p.a.
- 3-5% increase of demand p.a.
- 1.5 % efficiency improvements p.a.
- 1.5-2 gigatons of CO_2 in 2050

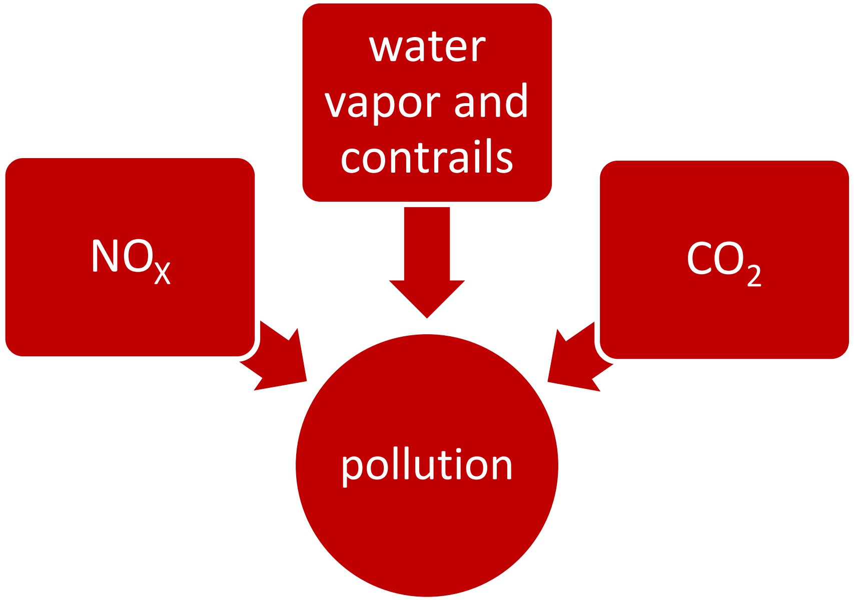
↓

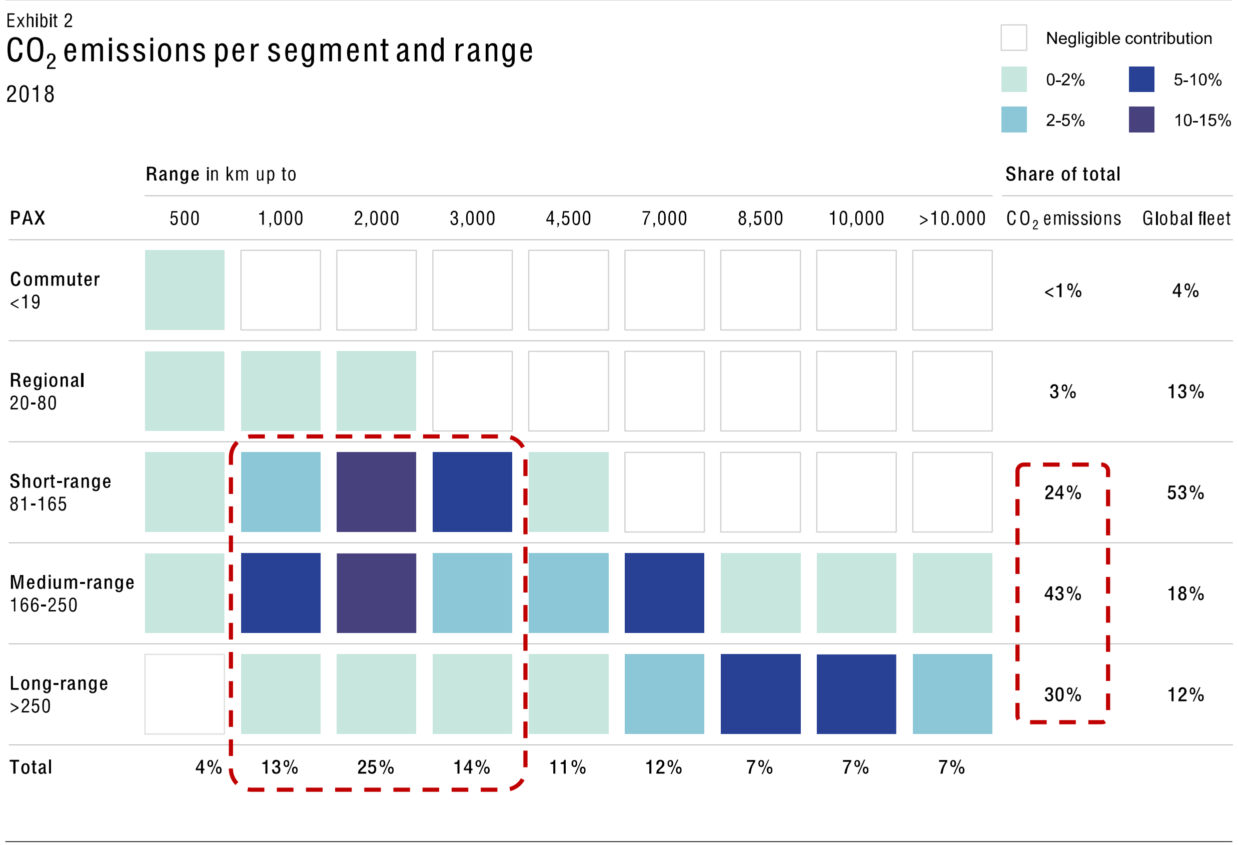
- Neutral growth starting from 2020
- 50% emission reduction in 2050



Projection of CO_2 emissions from aviation, credits:[1]

Pollution analysis





CO_2 emissions per segment and range credits: [1]

New fuels benchmark

Biofuels and synfuels

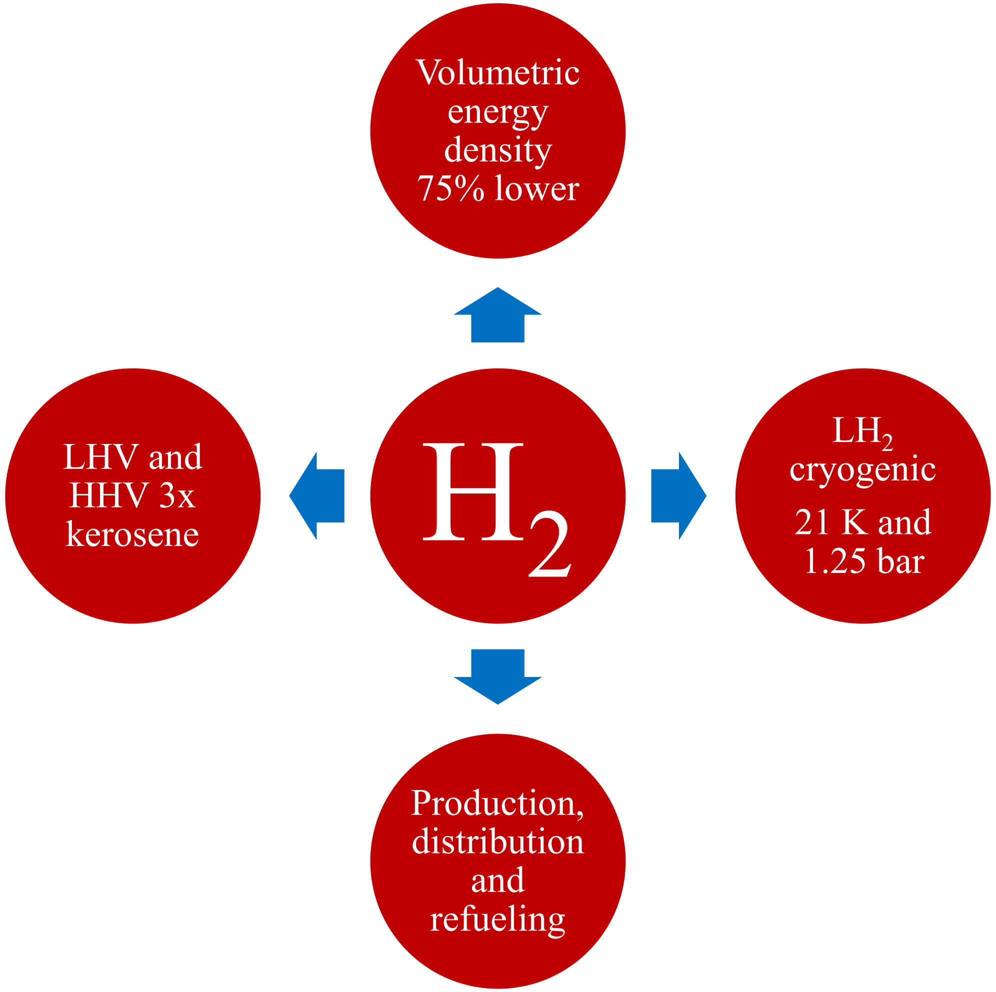
- Drop-in fuel
- Biomass production for biofuels
- Zero net impact if CO_2 from direct air capture for synfuels
- Energy required

H_2

- Not drop in fuel
- Energy required
- Carbon-free
- Cryogenic

Synthetic fuel, credits efuelpacific.com

H_2: properties & challenges



Hydrogen, credits e3g.org

Hydrogen propulsion integration

Technical specification

Revolutionary aircraft

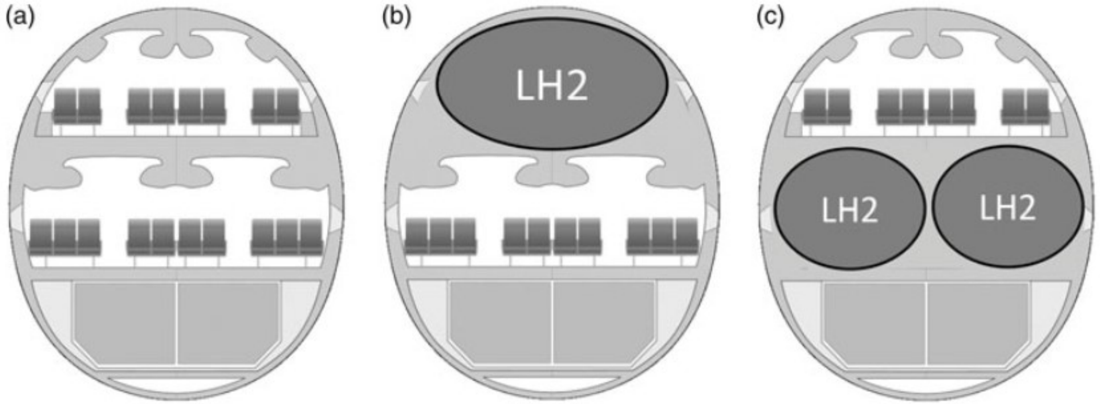
Blended Wing And Body, credits [5]

Evolutionary aircraft

Tanks integration, credits [3]

Evolutionary aircrafts

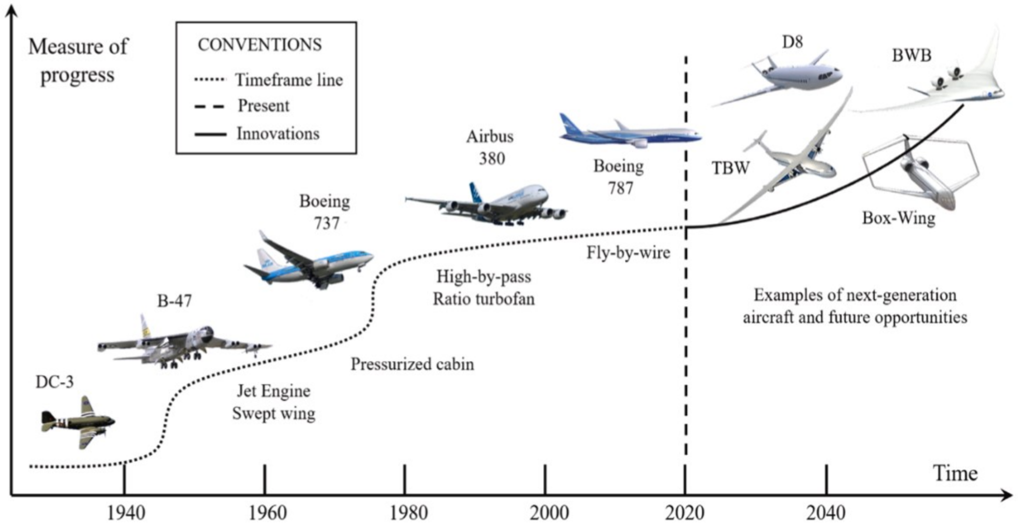
- Experience on manufacturing, safety and reliability
- Faster EIS
- New systems design
- Trade-off between range in kilometers and payload
- Autonomy constrains



Tanks integration, credits: [3]

Revolutionary aircrafts

- CTW might not be suitable for future challenges
- Leverage of existing concept to exploit new design opportunities
- Completely new manufacturing
- Long EIS time



Airframe evolution, credits: [4]

Revolutionary concepts

Flying V, credits [5]

BWB, credits: airbus.com

Strut-braced wings, credits [5]

- Aerodynamics
- Light weight (GTOW)
- Structural loads
- Improved stability
- Lower fuel consumption

- Compatibility with airport infrastructure
- Technology readiness level

Fuel cell vs Gas turbine

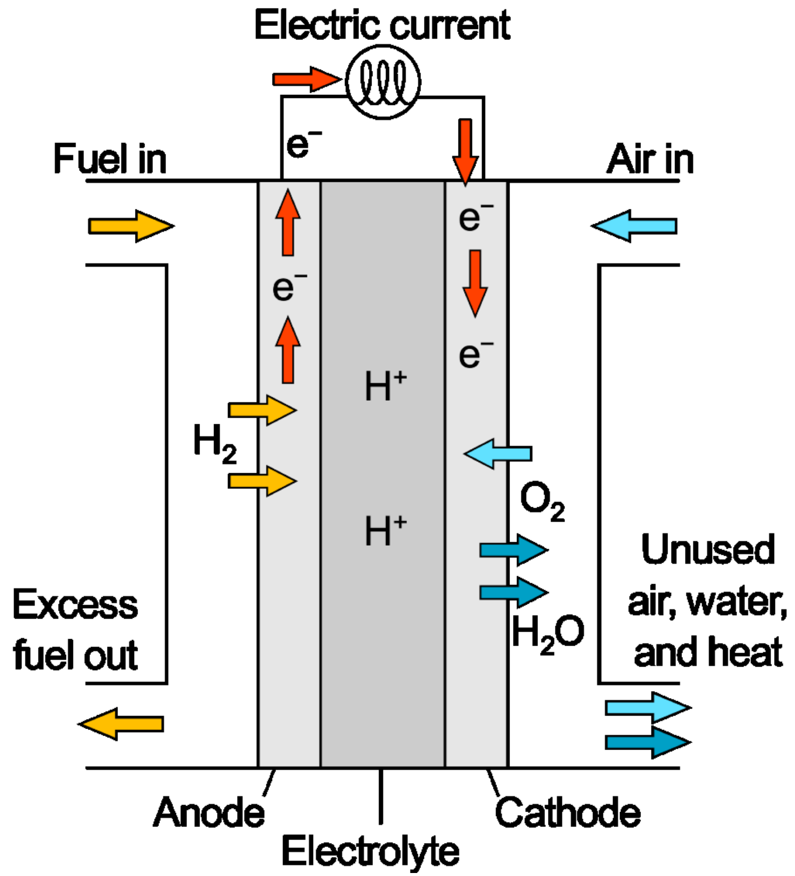
- Thrust requirements
- Emissions
- Fuel cells for commuters or regional aircrafts

	Change of in-flight emissions and emission related effects[1]				Climate impact reduction potential[4]
	Direct CO_2	NO_x	Water vapor[2]	Contrails, cirrus	
Synfuel	-0% / -100% (Net)[3]	-0%	-0%	-10-40%	-30-60%[3]
Hydrogen turbine	-100%	-50-80%	+150%	-30-50%	-50-75%
Hydrogen fuel cell	-100%	-100%	+150%	-60-80%	-75-90%

Change of in-flight emissions and emission related effects, credits: [6]

Fuel cell

- Specific power
- Advantage on using electric thrusters
- Oxygen intake
- Thermal control



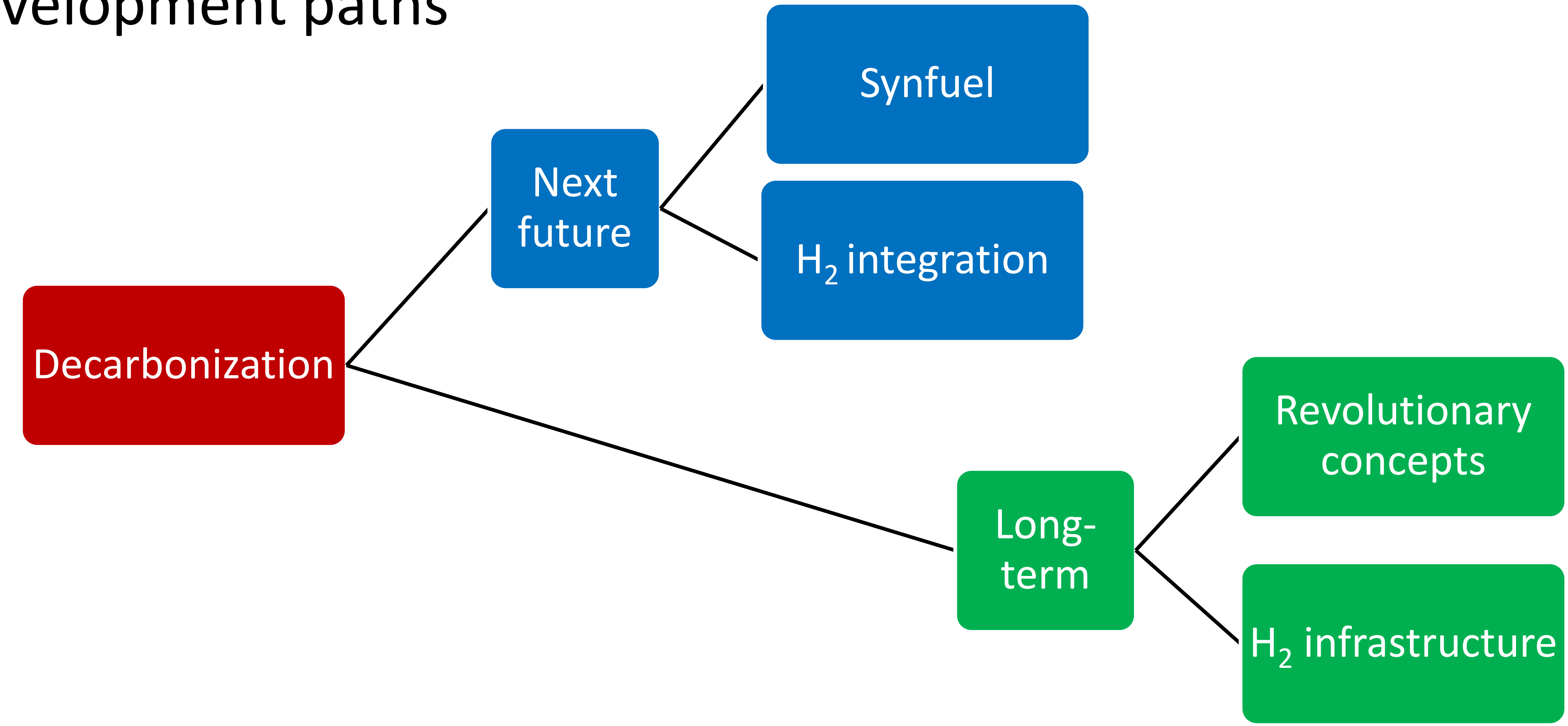
Functioning of a proton exchange membrane fuel cell, credits: Wikipedia

Gas turbine

- Several tests with currently used engines
- No huge differences in terms of performance
- Lower specific fuel consumption
- NO_x and lean combustion
- Development paths in CC

Turbofan inlet, credits: boldmethod.com

Development paths



BIBLIOGRAPHY

[1] Clean Sky 2, FCH *Hydrogen-powered aviation*

[2] Christina Penke, Christoph Falter, Valentin Battingen, *Pathways-and-environmental-assessment-for-the-introduction-of-renewable-hydrogen-into-the-aviation-sectorSustainable-Production-Life-Cycle-Engineering-and-Management*

[3] J.Huete, D.Naiianda, P. Pilidis \textit *Propulsion system integration for a first-generation hydrogen civil airliner*

[4] Arun K. Sehra, Woodrow Whitlow Jr. *Propulsion and power for 21st century aviation*

[5] Pedro D. Bravo-Mosquera, Fernando M. Catalano, David W. Zingg *Unconventional aircraft for civil aviation: A review of concepts and design methodologies*

[6] Sebastian Nicolay, Stanislav Karpuk, Yaolong Liu, Ali Elham *Conceptual design and optimization of a general aviation aircraft with fuel cells and hydrogen*

[7] M.Z. Wan Yahya, M.H. Azami, Mark Savill, Yi-Guang Li, S. A. Khan, Mahammad Salman Wariman *Modelling of a Three-Shaft High-Bypass-Ratio Engine Performance and Emission Prediction Using Hydrogen Fuels*

[8] Ozgur Balli, Emre Ozbek, Selcuk Ekici, Adnan Midilli, T. Hikmet Karakoc *Thermodynamic comparison of TF33 turbofan engine fueled by hydrogen in benchmark with kerosene*

[9] Halil Yalcin Akdeniz, Ozgur Balli *Impact of different fuel usages on thermodynamic performances of a high bypass turbofan engine used in commercial aircraft*

[10] Parisa Derakhshandeh, Abolfazl Ahmadi, Reza Dashti *Simulation and technical-economic-environmental optimization of the General Electric GE90 hydrogen turbofan engine*