Tech hopes for the aviation industry

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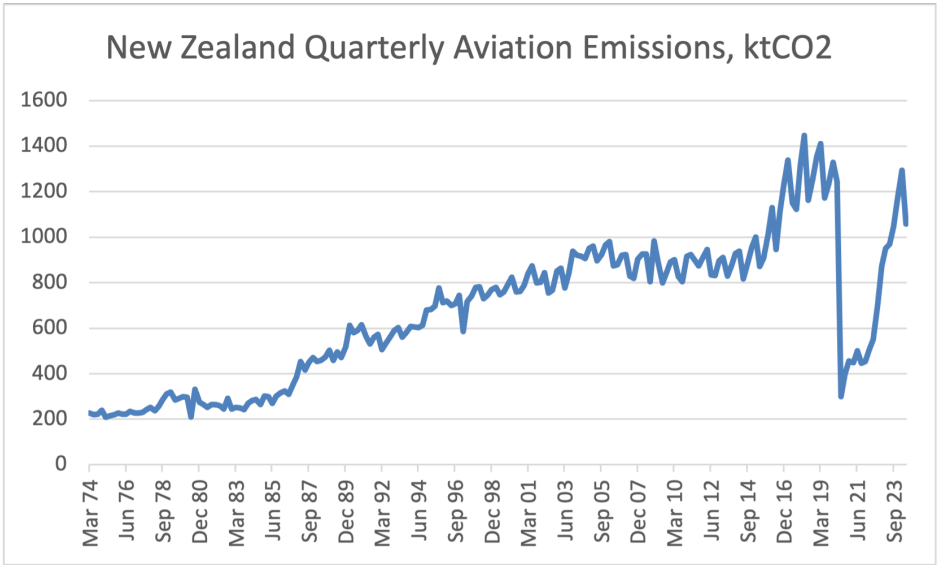
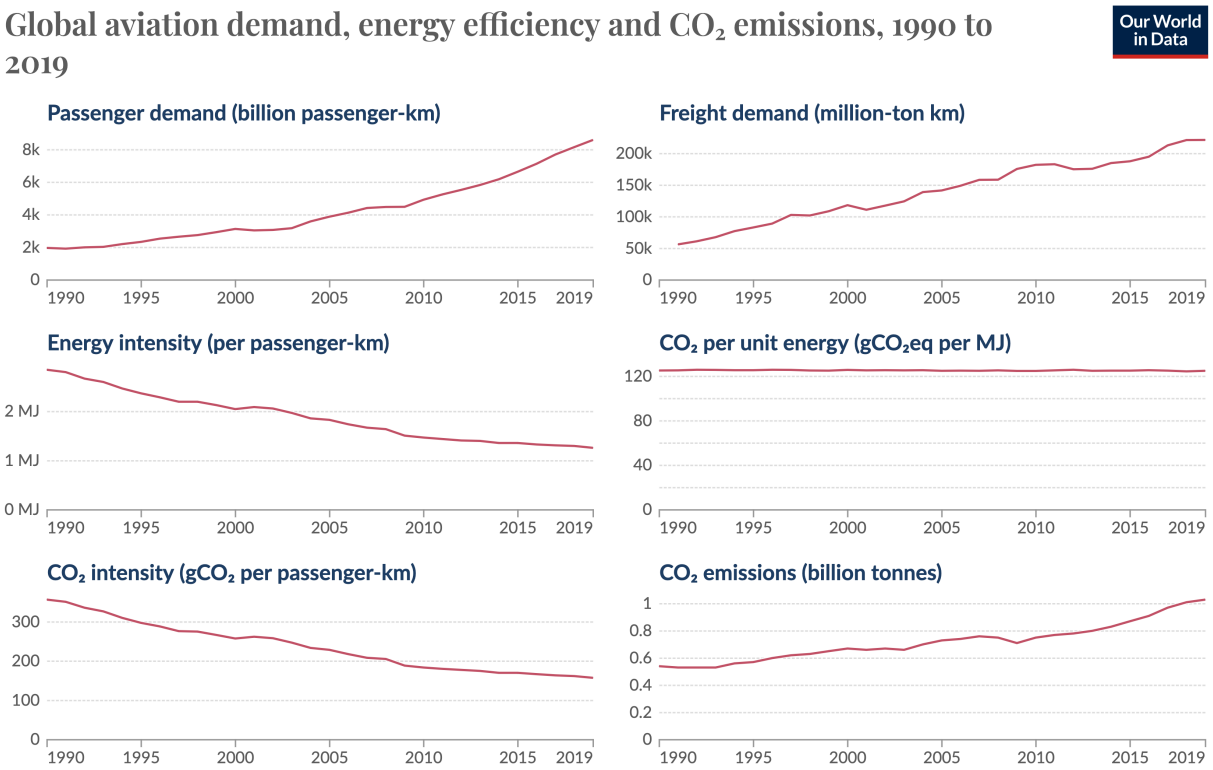
Aviation emissions: Houston, we have a problem



- CO_2 4.9 million tonnes in 2019
- Per-capita 6th highest globally at 1 tonne CO_2 (cf. US 0.56t, EU 0.65t)
- 12% of CO_2 emissions
- Proven ability to grow emissions rapidly:
  International +40%, domestic +20% in 2015–2019
- All large airports planning for significant growth (Auckland $6.6 billion investment)
- Stuart Nash, Nov 2022: "Auckland Airport is now the most connected airport to North America across the whole of Australasia [with direct flights from] Los Angeles, San Francisco, Houston, Dallas, Chicago, New York, Honolulu and Vancouver."

Chris Slane

Challenge: Growth



- Passenger-km $\times 4$ since 1990; efficiency $\times 2$; emissions $\times 2$.
- More passengers travelling further more frequently for shorter stays
- Prices down; comfort and convenience up; families dispersed
- Demand rises with income
- Industry's business model relies on growth

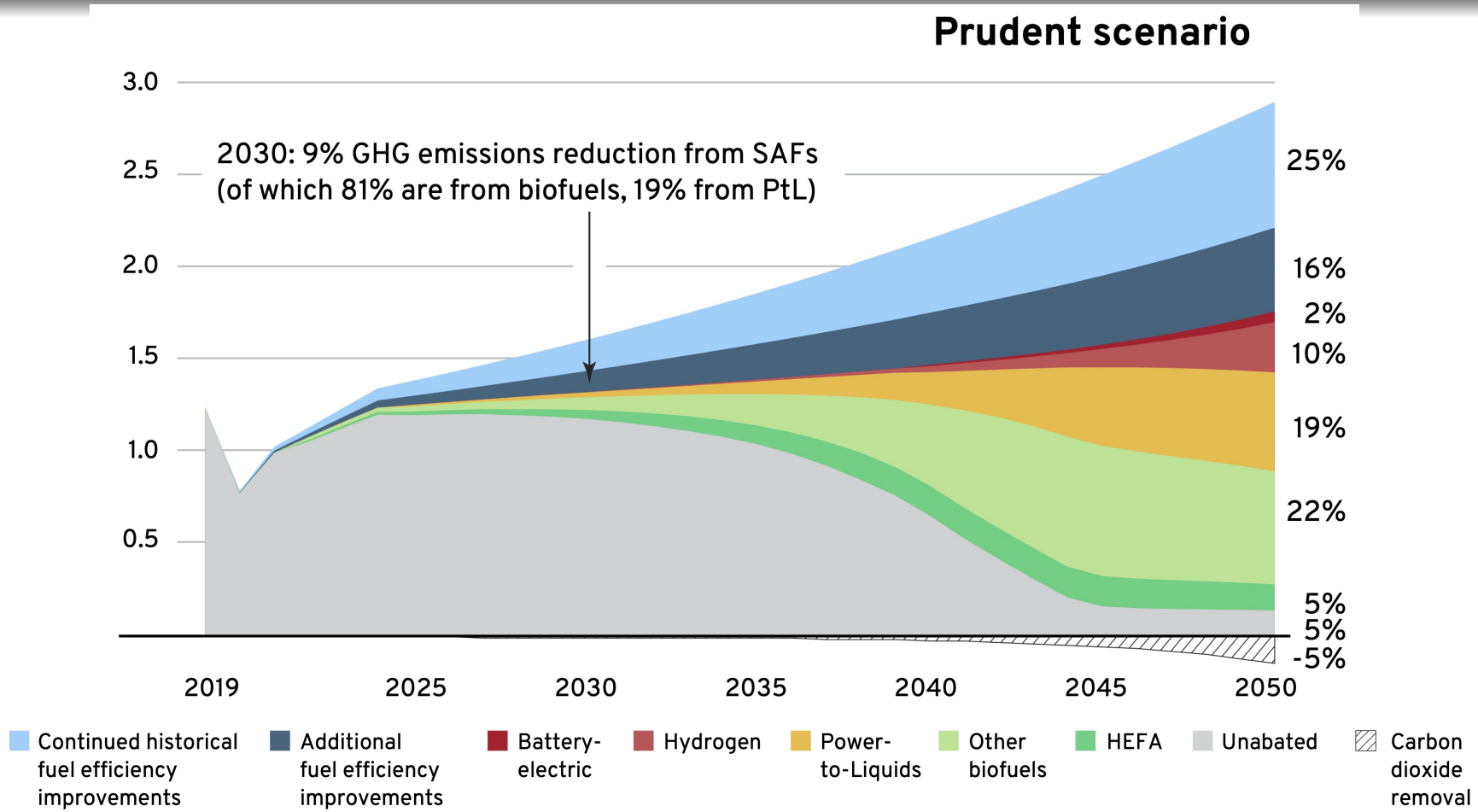
Challenge: States' Interests

- States view aviation as a driver of economic growth (tourism, immigration, trade, construction)
- States view aviation as a symbol of modernity
- States own airlines, airports, aircraft manufacturers

. . . consequently. . .

- No fuel excise duty on aviation fuel
- No GST, ETS, or carbon tax on international aviation
- International aviation not included in national or international (NDC) climate targets (some countries don't even include domestic aviation)

Making Net Zero Possible



- flying less
- efficiency improvements
- Sustainable Aviation Fuels (SAF)
- novel propulsion (hydrogen, battery-electric and hybrid) aircraft.

Battery aircraft

Heart Aerospace ES-19, claimed range 400 km. Ordered by Sounds Air in 2021. Speed 333 km/h, 19 passengers, max weight 8518 kg

$$\begin{aligned}\text{Range } R &= 3.6 e_b w_b \frac{1}{g} \frac{L}{D} \eta f \\ &= (3.6)(220)(0.35)(1/9.8)(16)(0.88)(1) \\ &= 395\,\text{km}\end{aligned}$$

e_b = specific energy of battery in Wh/kg; w_b = battery mass fraction; η = battery-motor-propeller efficiency; f = battery state of health

Battery aircraft

Problems:

- empty weight: 3602 kg
  (6-seat HondaJet, composite: 3379 kg; 19-seat Beech 1900D: 4732 kg)
- reserve requirement:
  Battery health 80%, 45 minute reserve, no alternate airport: 64 km range.
- cancelled 2022

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- Replaced with hybrid ES-30 (coming in 2030?)

Schematic hydrogen fuel-cell aircraft

Exhibit 7

Regional aircraft powered by fuel cells

Revolutionary aircraft

Design mission: 80 PAX, 1,000 km range, cruise speed Mach 0.44

- **Highly efficient** wing
- **2 LH_2 tanks** behind PAX cabin - added weight: 2 tons
- **Distributed propulsion** using electric motors for thrust

Energy demand[1]	-8%
CO_2 reduction	100%
Climate impact reduction	80-90%
Additional cost	5-15% CASK[2]
Entry into service	10-15 years
Propulsion power	Fuel cell system
MTOW[3]	+10%

1. Major assumptions: 30% gravimetric index of LH_2 tank, 90% useable LH_2 fuel, FCS mass 1.75 kW/kg (incl. cooling) and 59% peak efficiency (LHV), e-motors and PMAD with 97%
2. Cost per available seat kilometer
3. Maximum take off weight

"The integration of the liquid hydrogen tank, the fuel distribution system, the high power fuel cell systems, and the electricity distribution remains a challenge that will need to be overcome." – EU *Clean Aviation* report

Airbus March 2025: H_2 combustion projects cancelled, aims for regional fuel cell aircraft towards 2040

Hydrogen has extreme energy requirements

Ian Mason 2017: Converting New Zealand's aviation to hydrogen would need

- 42 TWh of electricity
- 3800 MW of electrolysers at Auckland airport
- powered by 14,000 MW of wind turbines costing $23 billion at 2022 prices

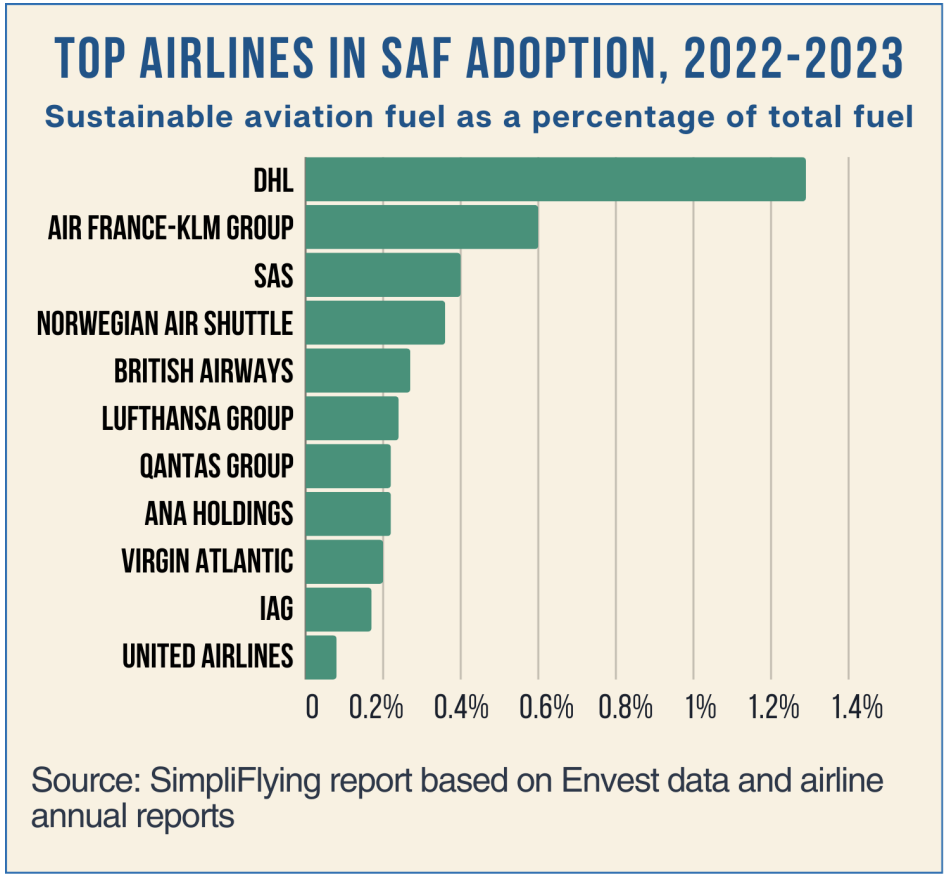
Challenge: Technology

Challenge: Technology









Feedstock challenges:

- Used cooking oil: not enough
- corn, palm oil etc.: displaces natural or arable land
- wood: early stage technology (LanzaJet)
- overall: could require 30% of all available biomass by 2050

E-fuel

norsk e-fuel

Project Mosjøen

Nesbruket, Vefsn Municipality, Norway

Production volume:	50 million liters (40.000 tons)

Project Mosjøen will integrate state-of-the-art, validated and highly innovative technologies. This approach allows us to scale faster, be more agile, and always adapt to the environmental conditions we are given.

Mosjøen and the "Nesbruket Industrial Zone", located adjacent to the local aluminum plant and smelter, has been identified as the ideal location for an industrial-scale Power-to-Liquids plant. An option agreement for a 24,000 square meter site was signed in February 2022. Currently the FEED study is being conducted.

The location in northern Norway offers key advantages such as highly competitive and abundant availability of renewable electricity, excellent know-how due to the process industry through the historical industrial heritage, and the potential to be part of a unique hydrogen and CCU cluster in the region.

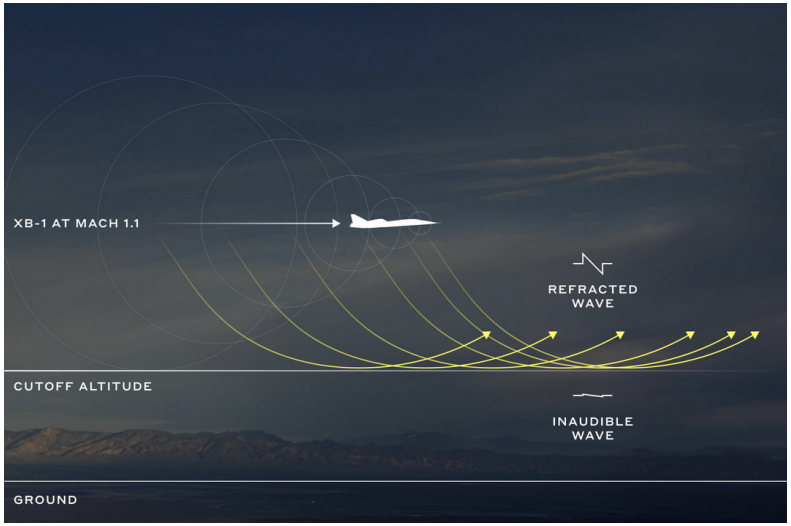
Renewable electricity + water $\longrightarrow$ H_2 + O_2; + CO_2 $\longrightarrow$ jet fuel

Cost $\sim$ \$500 million, would produce 2.5% of NZ's aviation fuel, use 2.5% of NZ's electricity (another \$500 million to build the wind farms, plus dealing with variability); fuel cost $5\times$ fossil

But meanwhile. . . Boom Aerospace

Boom Aerospace (founded 2014) aims to build a Mach 1.7, 80-seat aircraft, the "Overture", with commercial operation by 2030

But meanwhile. . . Boom Aerospace



- Demonstrator flew at Mach 1.1 in February 2025, achieved “boomless” flight
- Retired after two test flights
- Company must now design and build own engine
- 7× fuel consumption. . . but “sustainable fuel”

Summary

- Solar, wind, electric cars etc. have become cheaper with experience and mass production
- But non-existent technologies function as "technologies of prevarication", diminishing the perceived urgency of deploying proven (but possibly unpopular) options now
- The venture capital – startup – media triangle makes it hard to assess credibility and distracts from the central issue
- The preferred "environmental economics" solution – a carbon tax that funds cheaper out-of-sector mitigation – is challenging politically
- The public, governments, tourism industry, airlines, airports, global bodies all look the other way
- Is society able to control technology?
- What is the engineer's responsibility in this situation?
- See *Safe Landing*, `https://safe-landing.org/`: "We [aviation workers] want to live in a world where aviation flourishes in harmony with nature, and the beauty of flying can be enjoyed by all, for generations to come."