



CONSULTING AND ENGINEERING

## Future of hydrogen in aviation

NAG Hydrogen Webinar

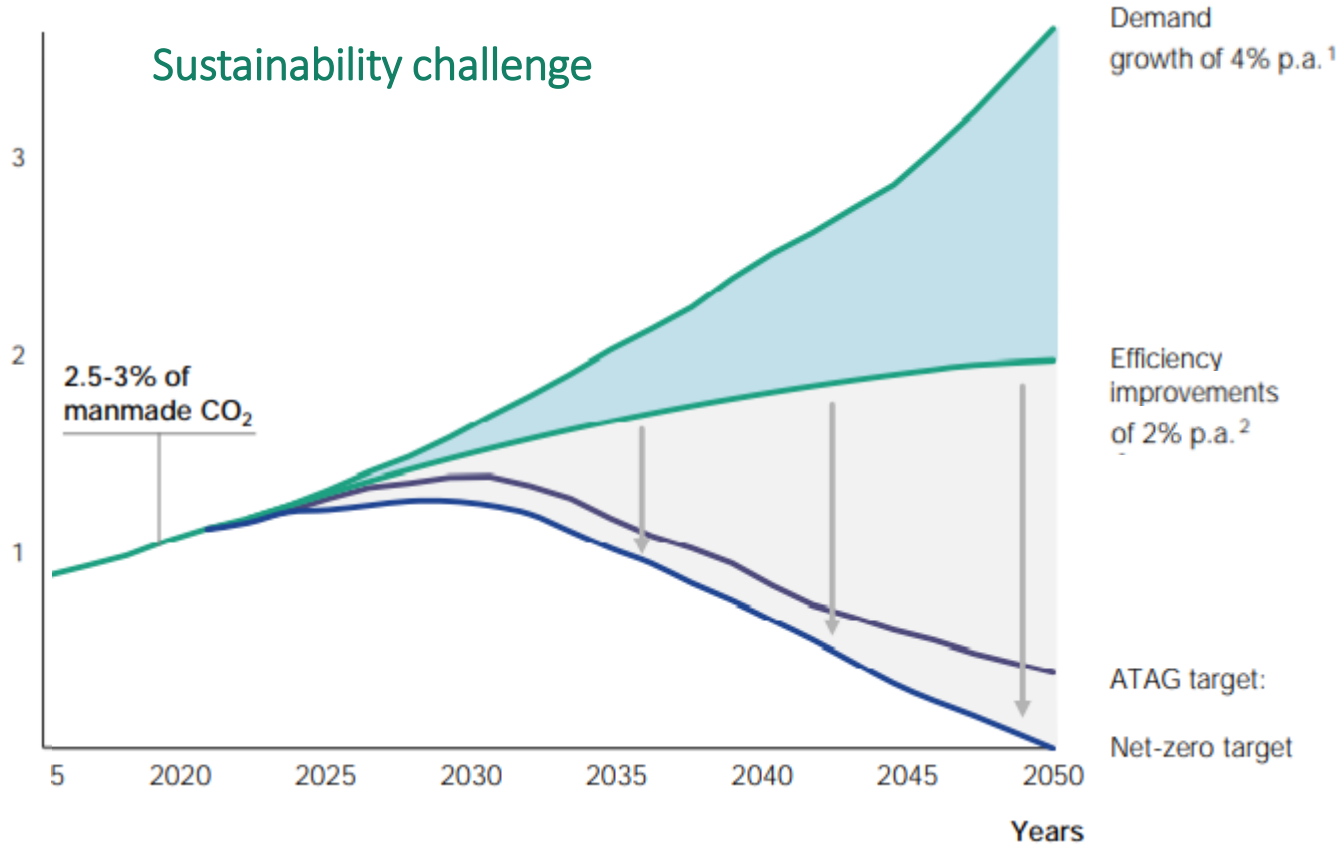
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# There is no silver bullet, or is there?



## Sustainability solution space

- Improved air operations (ATM)
- Fleet upgrades, known a/c types
- Fleet upgrades, future a/c types
  - Lighter a/c & more efficient engines
  - Hydrogen (combustion & fuel cell)
  - Electric / hybrid
- SAF
  - Biofuel
  - Synthetic kerosene
- Market based measures
  - ETS
  - CORSIA
  - Taxation
  - Regulations
- And more...

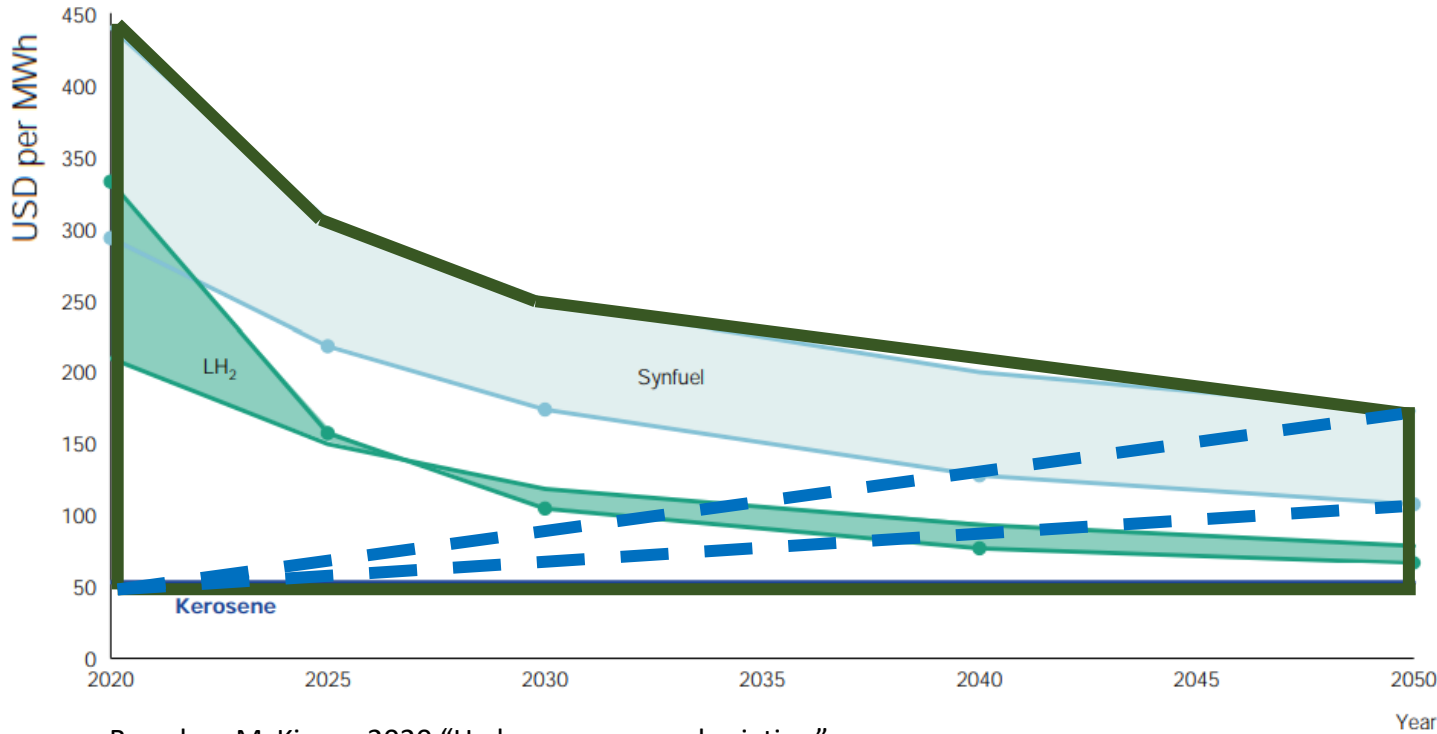


Technical solutions that involve a form of hydrogen as energy carrier

Market Segment	Flight [%]	Number of planes (civil)	CO2 emission [%]
Long range	8%	4218	41%
Single aisle	66%	14492	53%
Regional aviation	26%	4207	6%

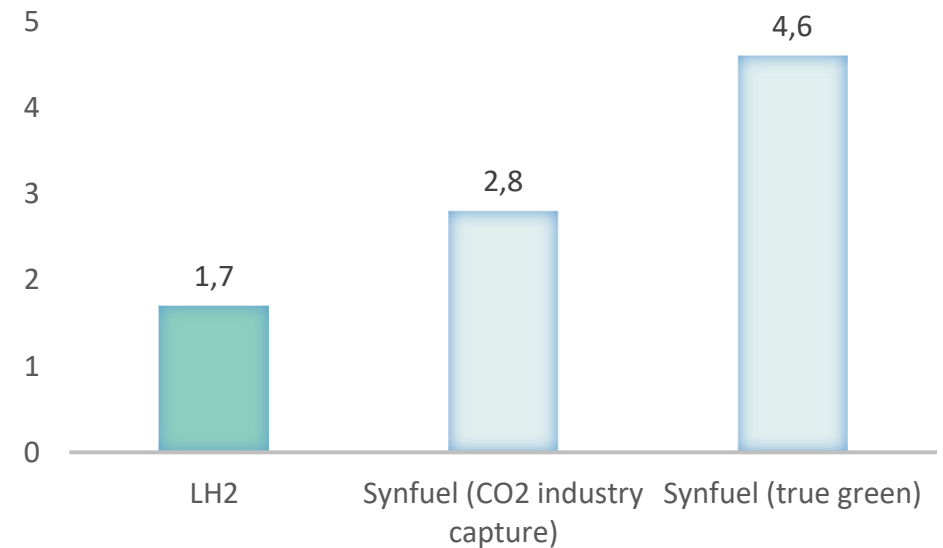
Data obtained from dvbbank, dvd overview of commercial aircraft 2018-2019

# Where is the tipping point? – Hydrogen cost ↓, kerosene cost ↑



Based on McKinsey 2020 "Hydrogen-powered aviation".

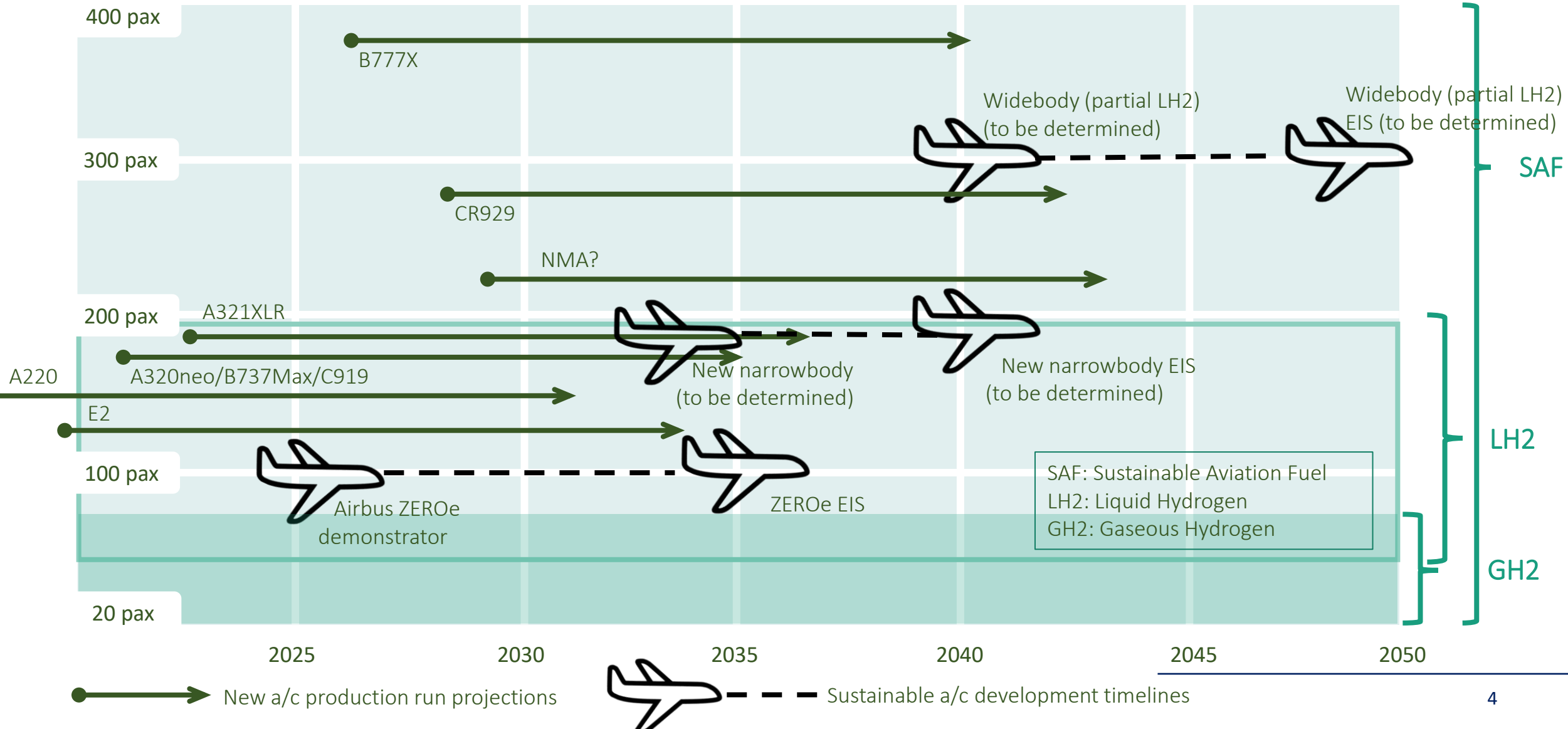
## ENERGY REQUIRED [KWH] TO PRODUCE 1 KWH OF AVIATION FUEL (2040)



— Gap between cost of sustainable technologies and kerosene based solutions

— Kerosene price projections

# Which technologies can be applied where and when?



# What are the consequences for hydrogen in aviation?

- The industry is in a 'storming phase' to develop one or more new dominant solutions.
- **Design & certification risks and costs are very high** and disruptive for new technologies (advice: start as early as possible with certification in order to prevent unnecessary iterations and delays).
- **OEM's are risk averse due to past failures** (e.g. B787 battery or cabling A380):
  - SAF (blend) allows gradual introduction and therefore we think it offers much lower risks than hydrogen powertrain solutions. This is especially the case for the long range market where the technical challenges are even more substantial than other markets. But scaling and price development of SAF's are a challenge.
  - Hydrogen powertrains have an economic advantage in the regional and single aisle market but come with technical and operational disruptions and risks.
- **Hydrogen closest to silver bullet, but there is no single target** (when including non CO2 effects).
- Promising work by Aerodelft, ZeroAvia, Airbus ZeroE concepts.