Hydrogen as fuel for... Aircraft

Fifth Hydrogen Day in University of Tartu, Chemicum
15.10.2021

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First – Some history of Hydrogen in Aviation

1783
- **First Hydrogen Balloon flight**

1900
- **First Zeppelin (LZ1)**

1937
- **Hindenburg ….**

1937
- The Heinkel HeS 1 experimental gaseous hydrogen fuelled centrifugal jet engine is tested at Hirth in March- the **first working jet engine**

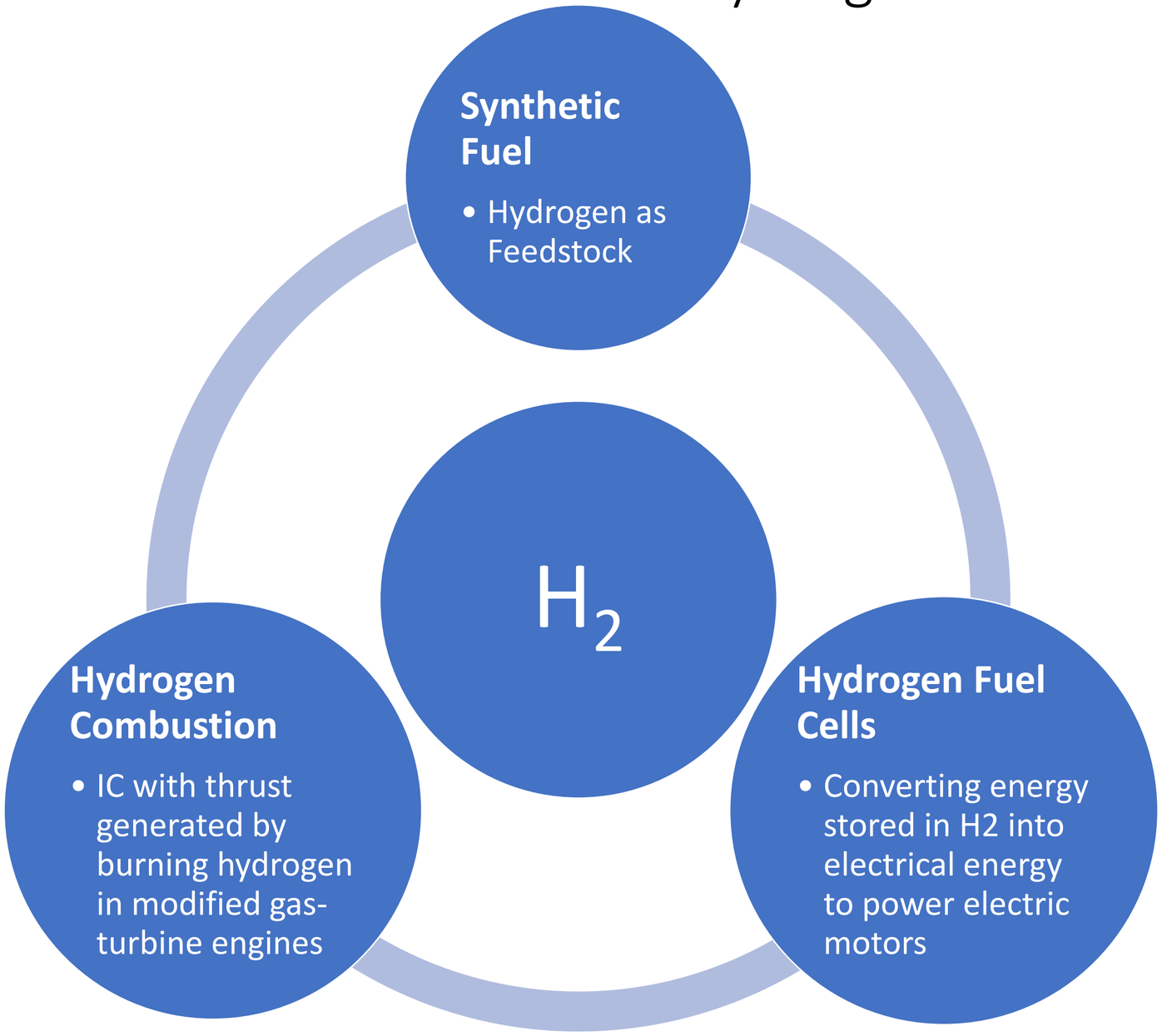
1943
- Liquid Hydrogen tested as rocket fuel

1965
- **Project Gemini, first commercial use of a fuel cell** (second human space flight)

1988
- **First flight** of Tupolev Tu-155 running on hydrogen

Hydrogen Aviation in the 21st Century

3 Uses of Hydrogen in Aviation



Type of aircrafts included:

- **Type I**: full electric aircraft powered by hydrogen fuel cells and batteries
- **Type II**: hybrid aircraft. Architecture: thermal engines using hydrocarbon fuels and/or SAF (or e-kerosene) + electric system powered by hydrogen FC and batteries
- **Type III**: aircraft powered by thermal engines burning hydrogen (LH2)

Type of fuel included:

- pressurized hydrogen,
- liquefied hydrogen,
- e-kerosene,

Selection of frontrunners

- **ZeroAvia**
  - 2020 September modified Malibu Mirage, historic flight in Cranfield, England
  - Commercialised 2024 19 seater, for ~400 km trips (Dornier 228)
  - 2025-30 = 50 seats+

- **DLR / Pipistrel**
  - HY4 (4-seater) – first flight 2016 Stuttgard, based on Pipistrel Taurus G4

4x11 kW fuel cells and 2x10 kWh batteries

- **Airbus**
  - 3 concepts for 2035 vision, 2025 Product selection 100-200 pax 1000-2000+ nm
  - Helicopter design released

- **Skai**
  - Hydrogen eVTOL, 4 h flight time

[HyFlyer : EMEC: European Marine Energy Centre](#)

Project partners:

EMEC HYDROGEN

Intelligent Energy

ZEROAVIA

Funders:

UKRI Innovate UK

AEROSPACE TECHNOLOGY INSTITUTE

[Airbus reveals new zero-emission concept aircraft - Innovation - Airbus](#)

[Hydrogen-Powered VTOL Aircraft (skai.co)](#)

[New DLR-HY4 - The First Hydrogen-Powered Aircraft Debuts at Stuttgart Airport - FuelCellsWorks](#)

Are Hydrogen Powered Aircraft about to take-off?

(Pun intended)

Zero Emission Aicraft has just two options – Hydrogen or batteries

SAF (Sustainable Aviation Fuels) is a quick drop-in to decarbonise medium-long haul till commercial h_2 can enter market in 2035 and scale till 2050+

Commitment - France has invested €1.5 billion in support of Airbus' plans to develop zero emission aircraft

Most aviation emissions are created in short-medium haul!

There are 10 000 short haul regional aircraft as the first target (~20 pax), can be converted within 10-20 years

Market estimate $27.68 billion by 2030, growing to $174.02 billion by 2040 at a CAGR of 20.2%

Attractive for early-mover airports – First time they can „home-grow" their own aviation fuel and enter a new business!

While Hydrogen is 3x as energy dense as Kerosene, it also takes up 4x more space – not yet suitable for long-haul.

For larger aircraft / longer distances, hydrogen should be kept as liquid hydrogen to reduce system weight and volumetric space requirements.

Problems with full electrification in Aviation

Battery technologies not mature enough for aviation, earliest expected is ~2025-2026 for 19-seaters

Required energy density for Aviation starts at 500 Wh/kg to truly take off, todays batteries are closer to 250-270 Wh/kg.

Hydrogen Fuel Cells are at 800 Wh/kg extending their applications and companies like HyPoint are heading towards 1500-2000 Wh/kg within this decade

To fast charge a 19-pax battery aircraft without sacrificing turnaround times the airport has to have 1MW dedicated fast-charge infrastructure (per plane), required safety margins or lifetime implications are not yet clear.

Same 19-pax hydrogen aircraft would require about 100kg of h2, however infrastructure is also not yet clear.

Parameter	Nomenclature	Units	Hydrogen (H_2)	Kerosene	Ammonia (NH_3)	Battery
Specific Energy	$\frac{\Delta h_{fuel}\ for\ fluids}{E_{battery}}$	MJ/kg	~120	~43	~18	~2

Current estimates and potential

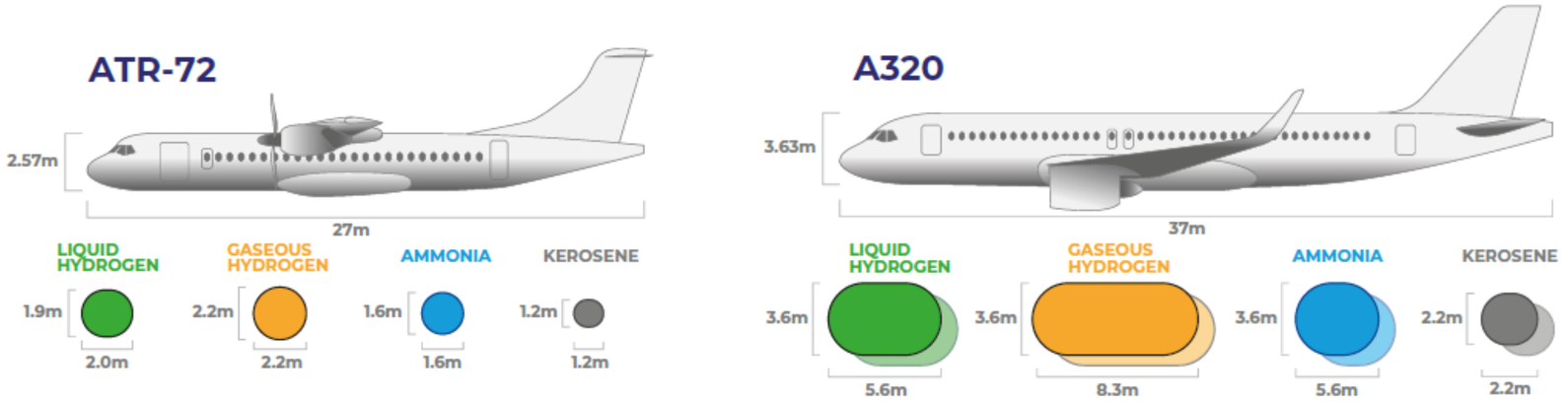


Figure 5. Relative tank size for different zero-carbon emission fuels, with kerosene provided for comparison. Here x 2 tanks are required for the storage of each fuel illustrated for the A320.

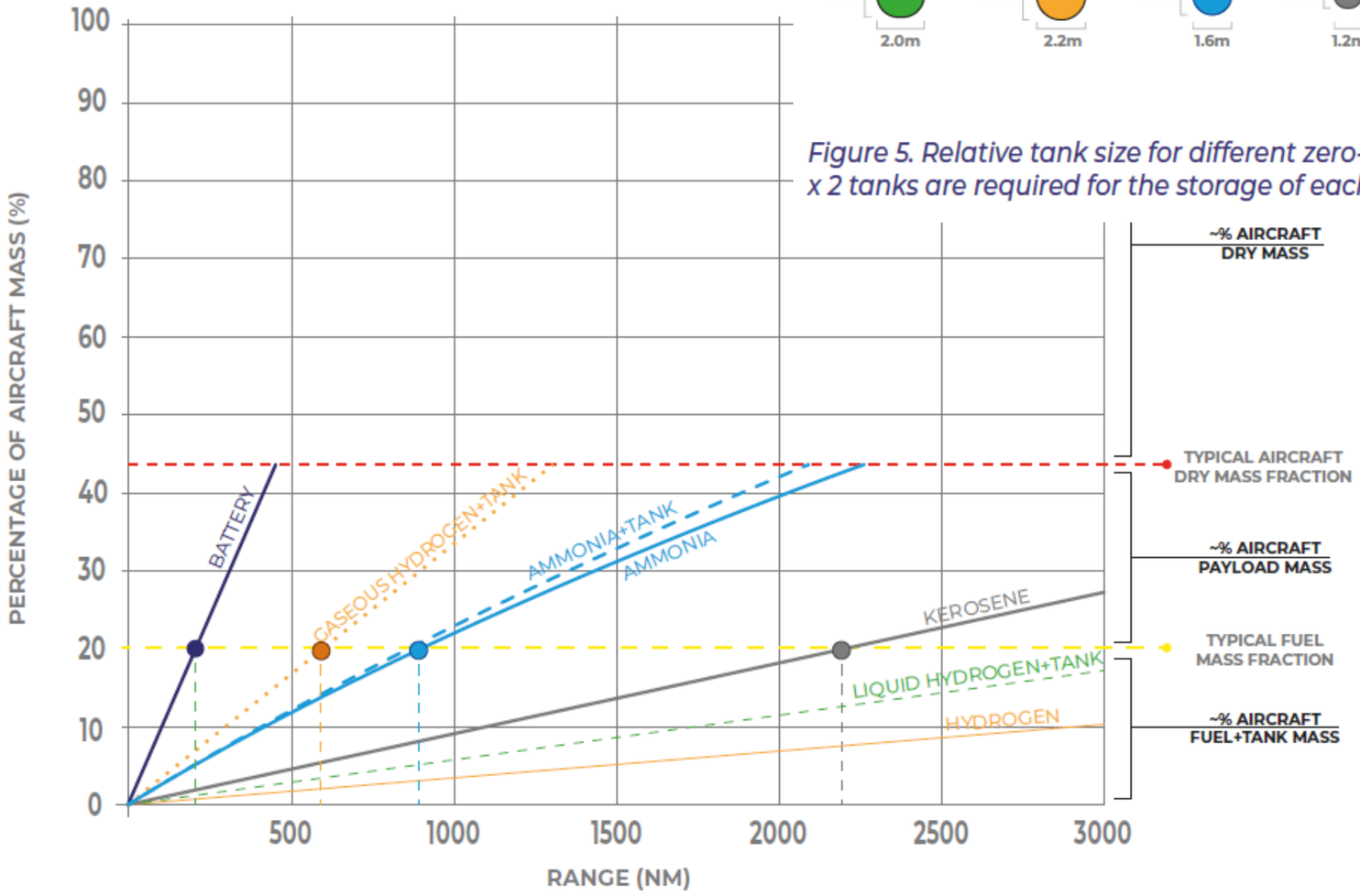
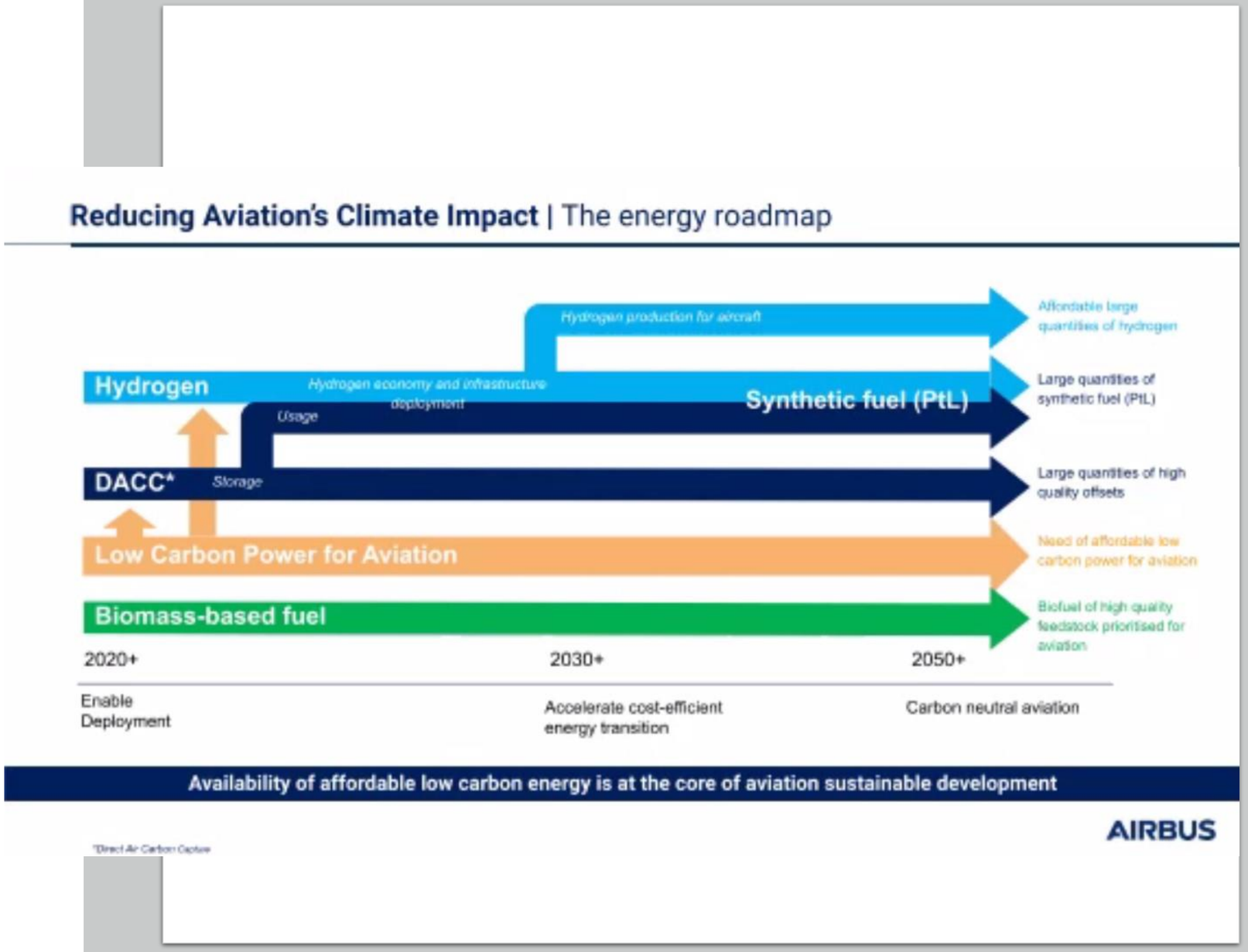


Figure 4. Fuel + tank storage mass and payload mass fractions vs aircraft range in nautical miles (nm)[2] .

What will 2050 look like?

- 100-300 airports with 5-10 million tonnes of liquid hydrogen per year and 10 000 LH2 powered planes in the skies.
- Larger airports serving 150 LH2 take offs per day (150 tonnes of LH2/day = 400 MW)
- 10-20 mobile refuellers
- 1 trailer per 10 aircraft (15-20 minutes refuelling time)



Main emissions are Short and Medium-haul flights

The passenger car standards are **95 g/km of CO2**
UK low emission standard is **75 g/km of CO2**

Select an airport

TLL - Tallinn

Legend

TLL

Tallinn

#1 in Estonia

for total flight emissions of passengers

X

Total flight emissions of passengers ?

0.16

Measure = million tonnes CO_2

Total distance flown by fare-paying passengers ?

1.65

Measure = billion kms

Carbon emissions per passenger, per kilometer ?

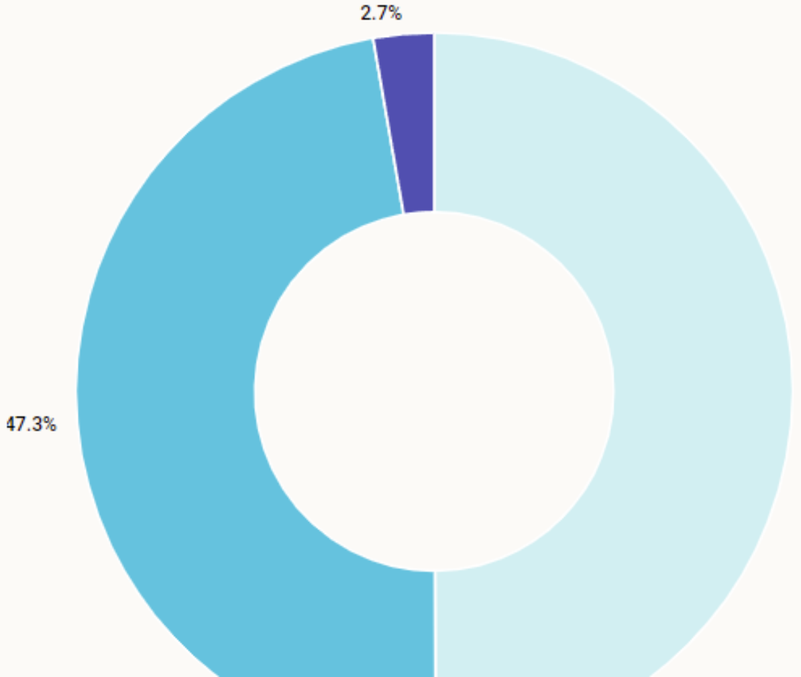
97

Measure = grams CO_2 per passenger km

Emissions from this airport are equivalent to the yearly emissions from

80,000 cars

Passenger traffic by distance flown



Short haul

0.82
billion km

115
grams of CO_2 per passenger km

Medium haul

0.78
billion km

78
grams of CO_2 per passenger km

Long haul

0.05
billion km

73
grams of CO_2 per passenger km

*The sum of short-, medium-, and long-haul passenger traffic may not be the same as the total traffic due to rounding

Aviation as an Ecosystem

- **To advance hydrogen propulsion technology infrastructure requirements need to be taken into account**. **To enable hydrogen flights through Europe a hydrogen hub network** on relevant European airports **has to be established,** including liquid hydrogen.

- **Develop airports into hydrogen hubs** to also serve local non-aviation users (mobility, logistics, etc.) as **the fastest first step is to start building up hydrogen infrastructure at airports before the service entry of hydrogen aircraft**. It is relevant to use hydrogen also for ground operations equipment.

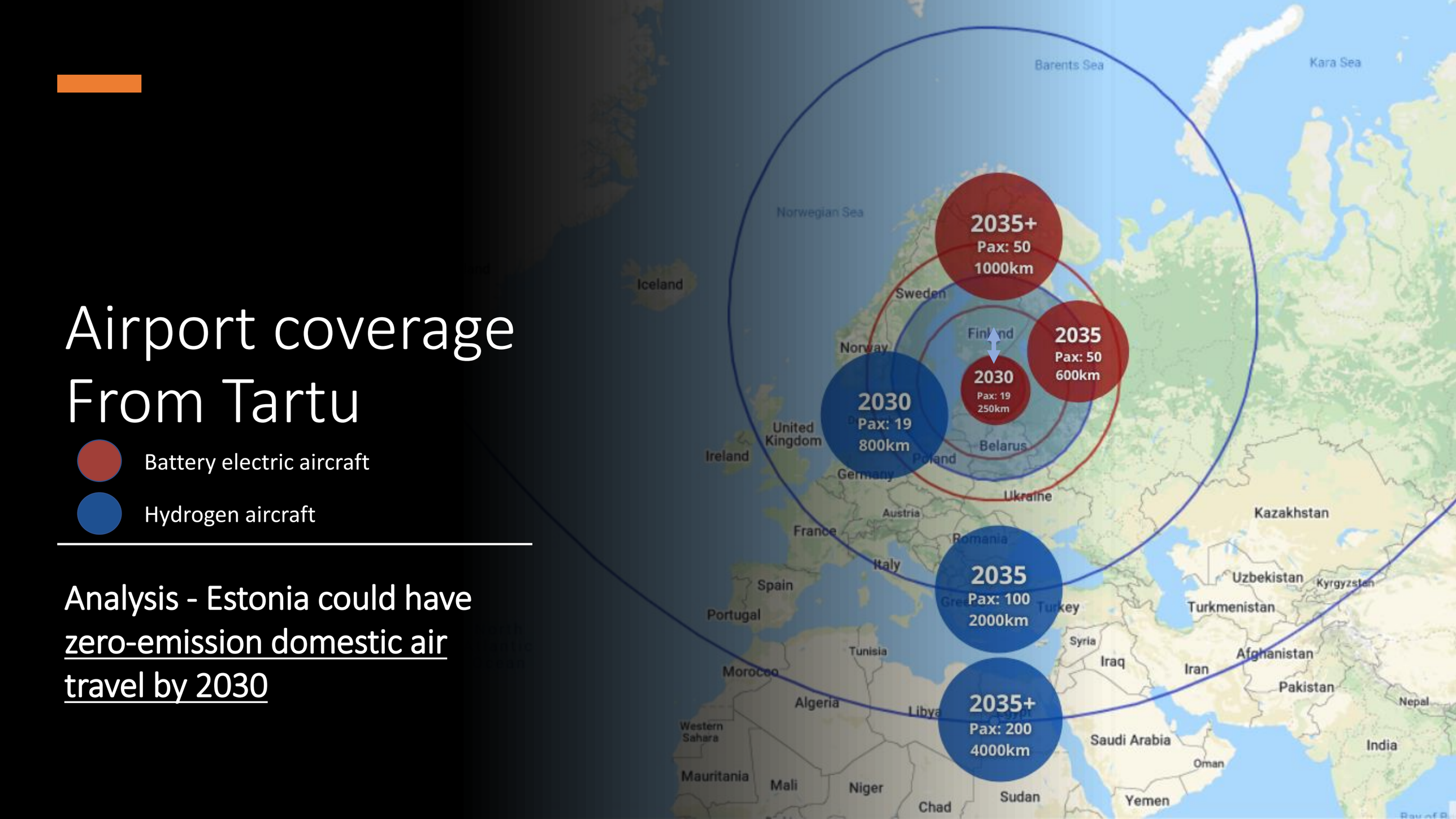
Regional Air Mobility and Point-to-Point air travel will become vital with the rise of zero-emission aviation aiming to offer climate neutral travel within 500 km.

Airport coverage From Tartu

Battery electric aircraft

Hydrogen aircraft

Analysis - Estonia could have zero-emission domestic air travel by 2030



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Estonian Association of Hydrogen Technologies

European Clean Hydrogen Alliance

Kick-starting the EU Hydrogen Industry to achieve the EU climate goals

SKYCORP