Hydrogen for Aviation

A Webinar Hosted by AIAA Northeast Region
December 15, 2020

Dr. Bruce J. Holmes
D.E., FAIAA, FRAeS, Comm, Instr, AMEL, ASEL, ASES, CFI, AIGI, CE-525, Remote Pilot, FAA Master Pilot

Chief Technology Officer
Alakai Technologies Corporation

Topics

A Technology View

- Why Hydrogen?
- Why Liquid Hydrogen?
- Vehicle Design Implications

An Infrastructure View

- How to achieve H2 at scale?
- H2 at airports

A Sustainability View

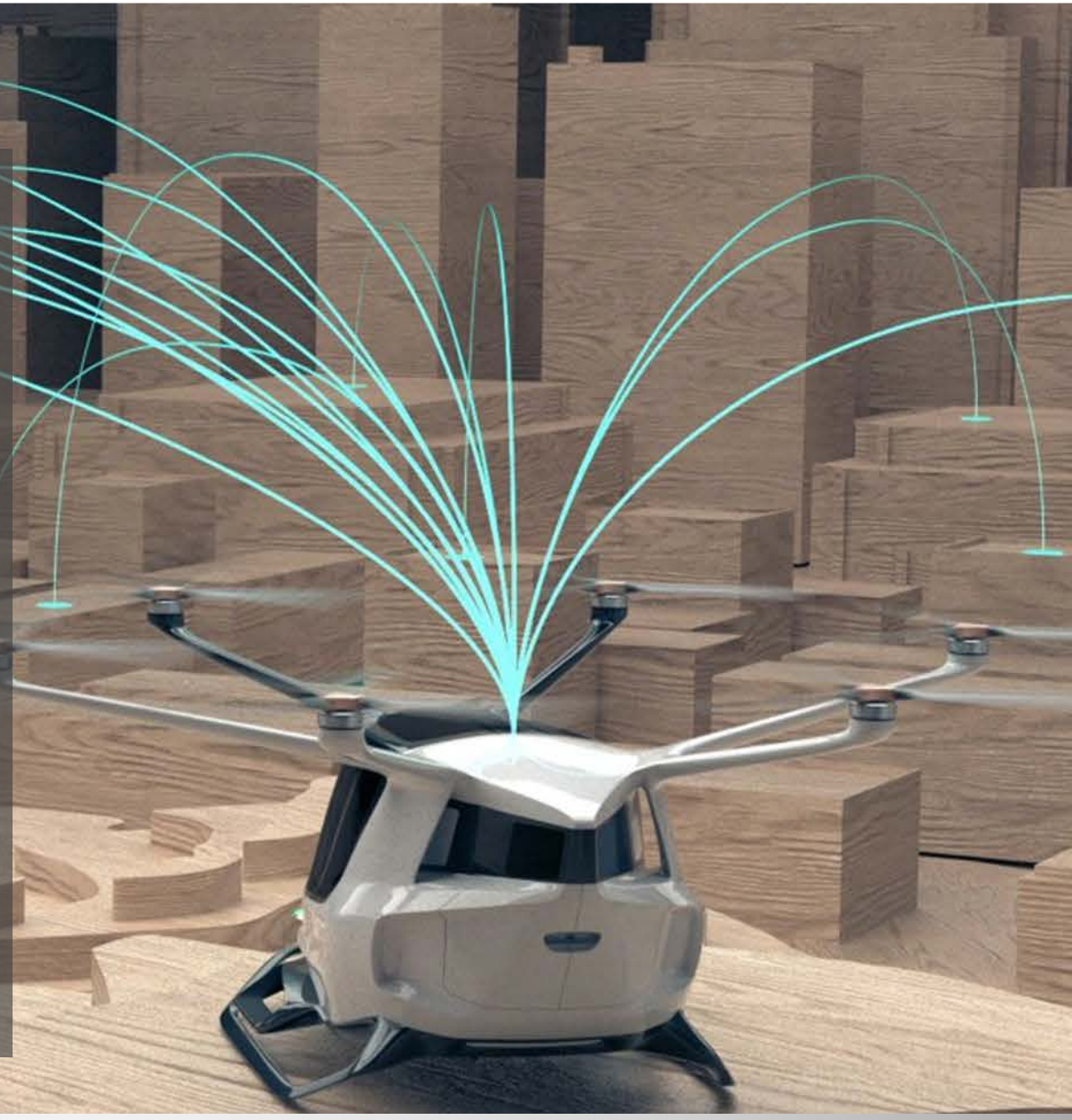
- Recycle – Reuse
- Brown, Grey, Blue and Green H2

What is SKAI?

Skai is an advanced air mobility (AAM) system built with a relentless focus on simplicity- the first hydrogen fuel-cell powered electric vertical take off and landing vehicle.

Skai is comprised of multiple patent protected vertical take off and landing vehicles, air mobility services, and innovations in fuel source/propulsion systems. Its unique brand position and market entry strategy enable faster revenue generation and long-term sector leadership.

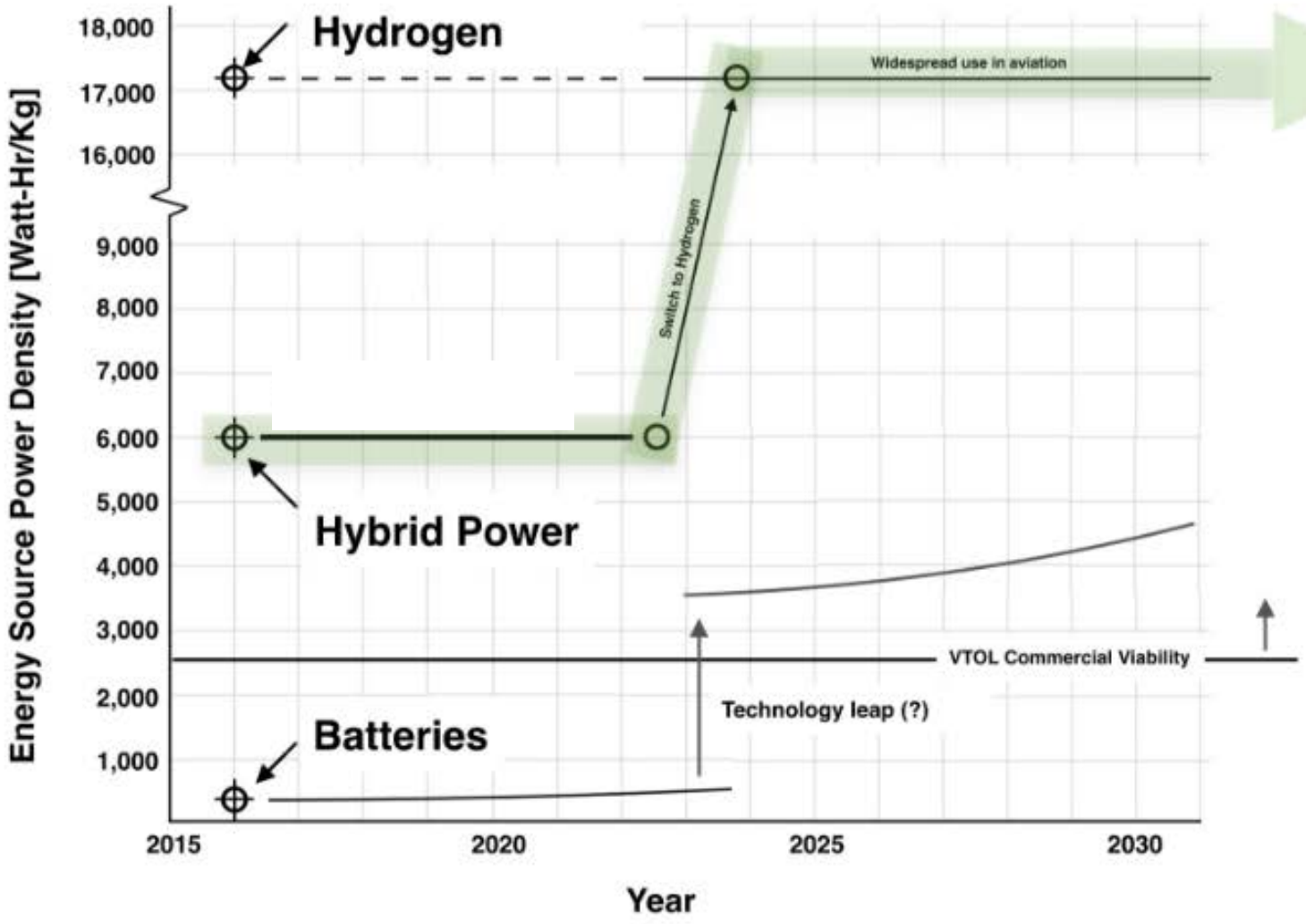
- All Electric Vertical Take Off and Landing
- Hydrogen fuel cell powered, with zero pollution
- Piloted, Ground-Piloted and Fully Autonomous Flight
- Point-to-Any-Point Transportation

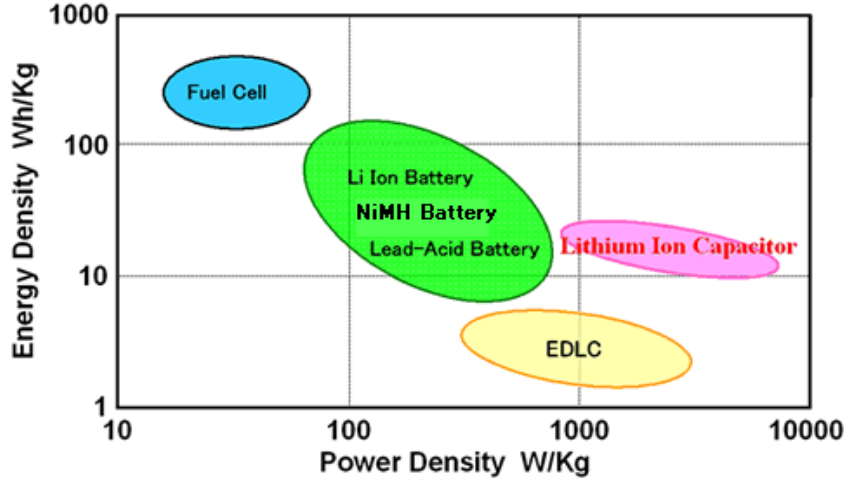


skai

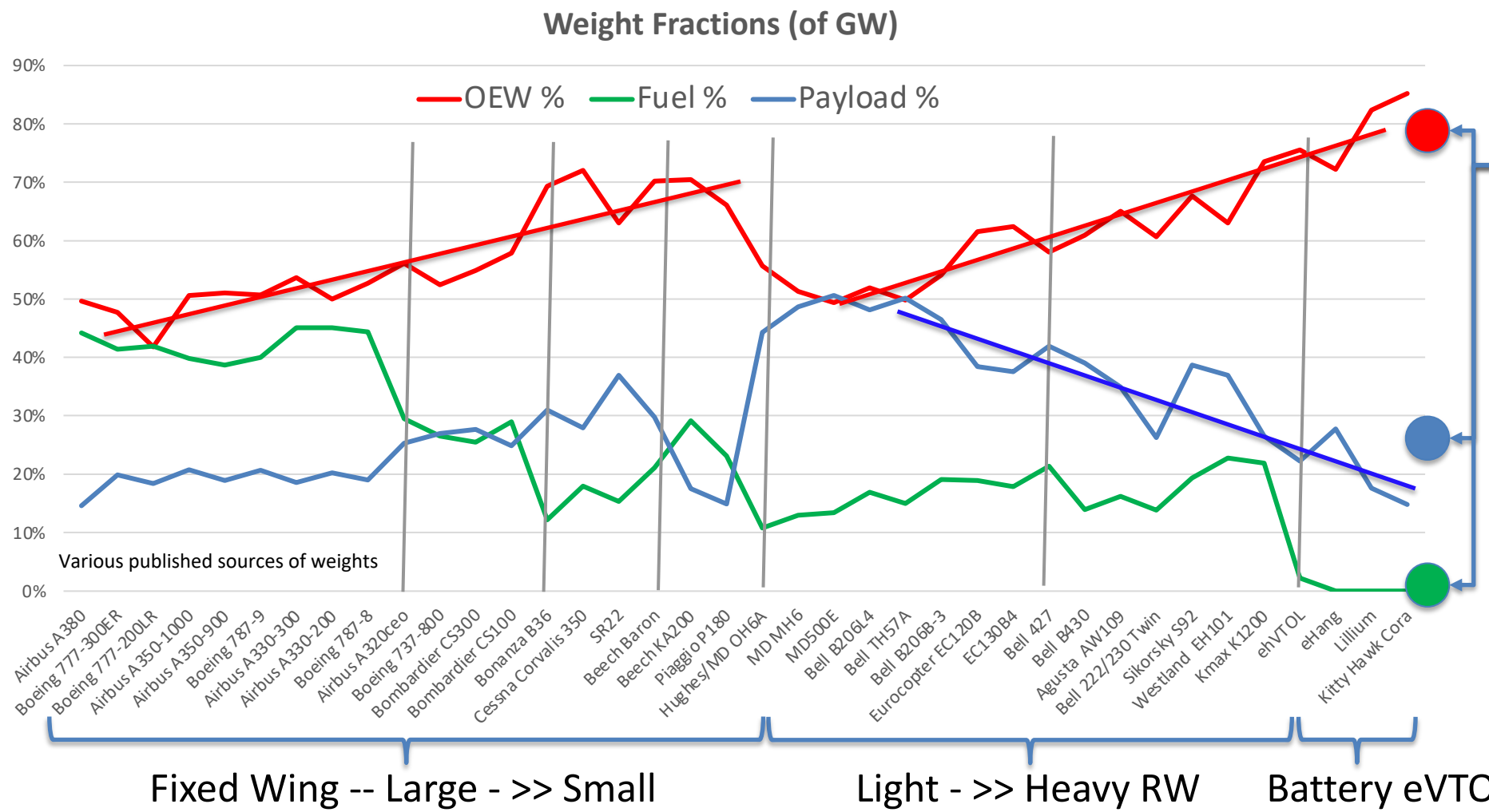
Fueled by Hydrogen, Powered by Simplicity

Overall Competitive Picture & LH2 Advantage



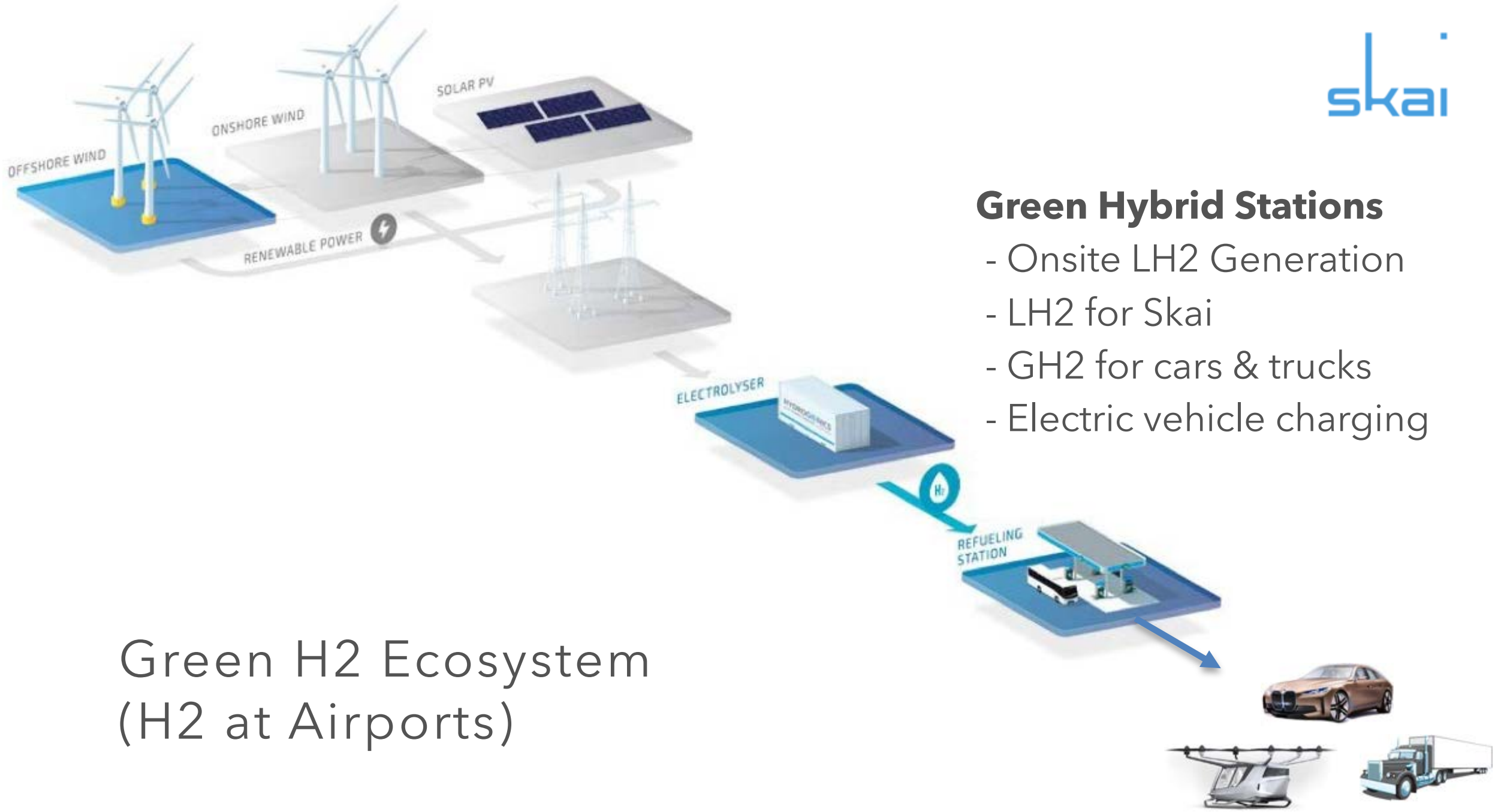


Weight Fraction Trends Among Different Aircraft Types



LH2 HFC eVTOL Mass Fractions (of GW)

LH2 HFC Powertrain Systems are competitive in Mass Fractions with Similar Air Vehicles.



Green Hybrid Stations

- Onsite LH2 Generation
- LH2 for Skai
- GH2 for cars & trucks
- Electric vehicle charging

Green H2 Ecosystem (H2 at Airports)

A Sustainability View

Why Batteries?

Why Hydrogen?

Image Credit: NASA

Historical Evolution of Aircraft Configurations

Pre-Electric

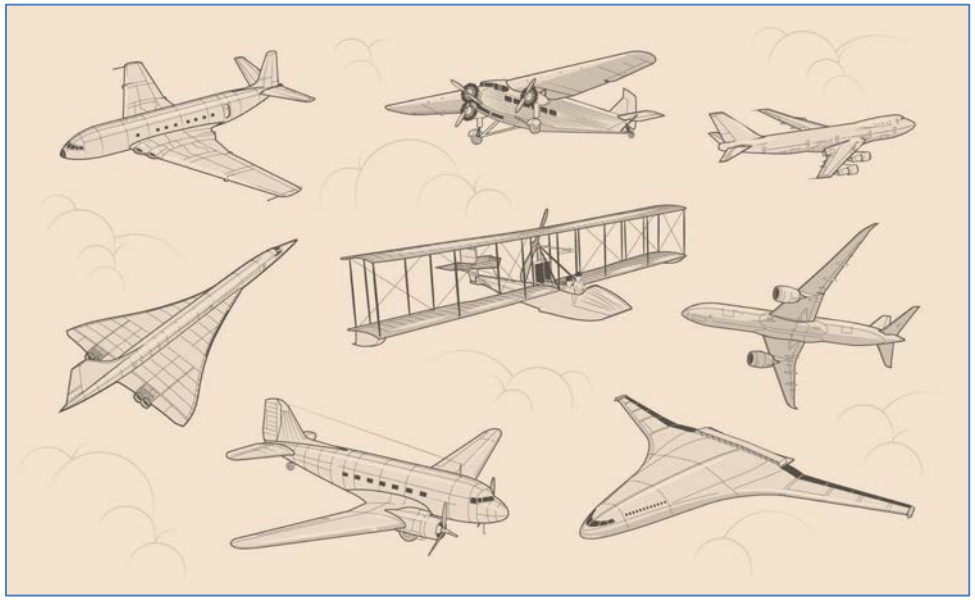


Image Credit: National Geographic

Neo-Electric

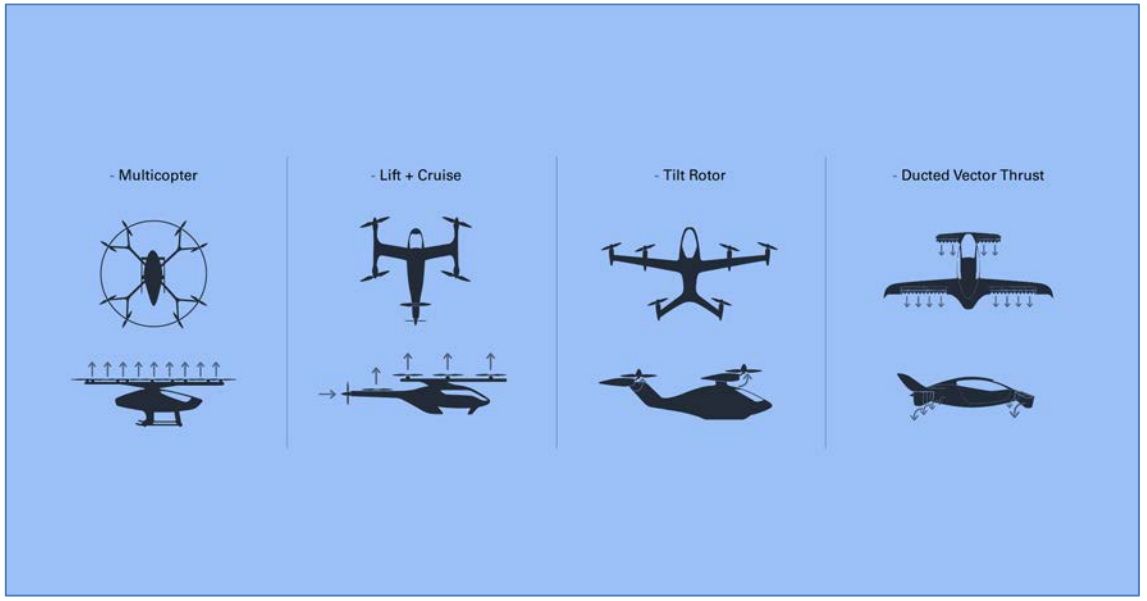


Image Credit: Lilium

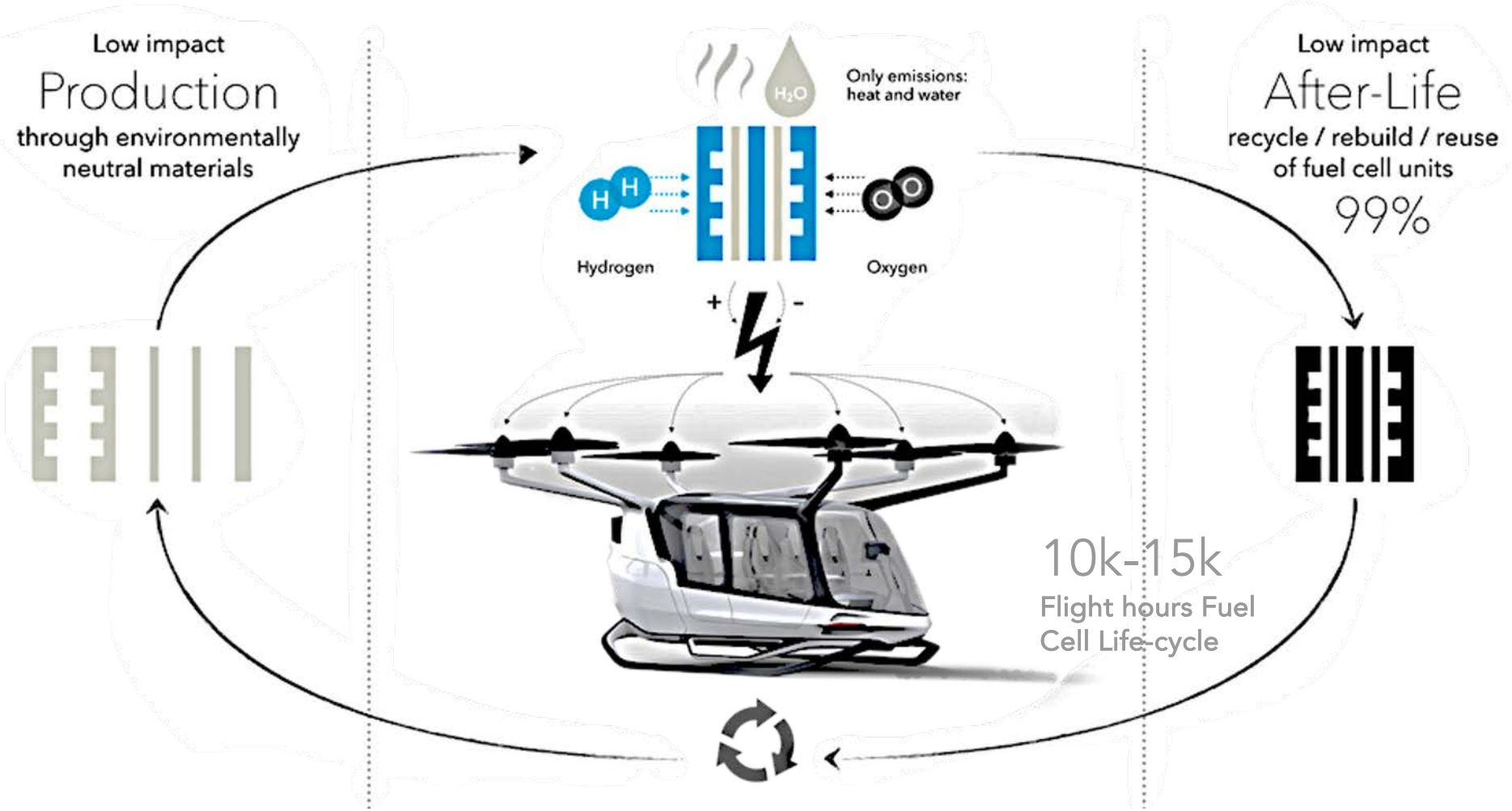
Colors of Hydrogen

- Green Hydrogen – Made through electrolysis from renewable electricity
- Blue Hydrogen – Steam reforming of natural gas with CO2 capture.
- Gray Hydrogen – Steam reforming of natural gas feedstock.
- Black Hydrogen – Steam reforming of coal feedstock.

Decreasing Carbon Footprint

As solar PV prices have fallen 90% since 2009
and wind turbine prices by ~60% since 2010
the economics of Green hydrogen continue to advance.

Hydrogen Lifecycle and Benefits

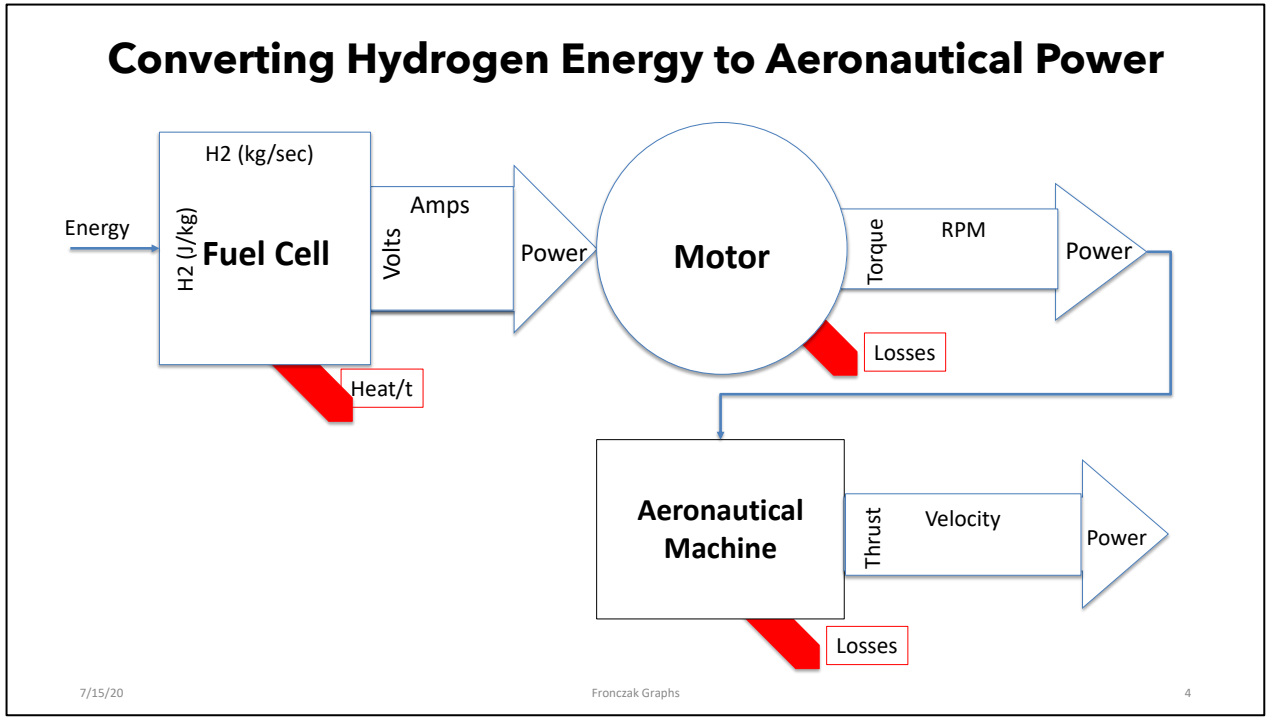


Fueled by Hydrogen, Powered by Simplicity

When System Efficiency May Not Be *The* Priority

LH2 HFC powertrain system losses come from (After losses for H2 production, transport, storage, and liquefaction):

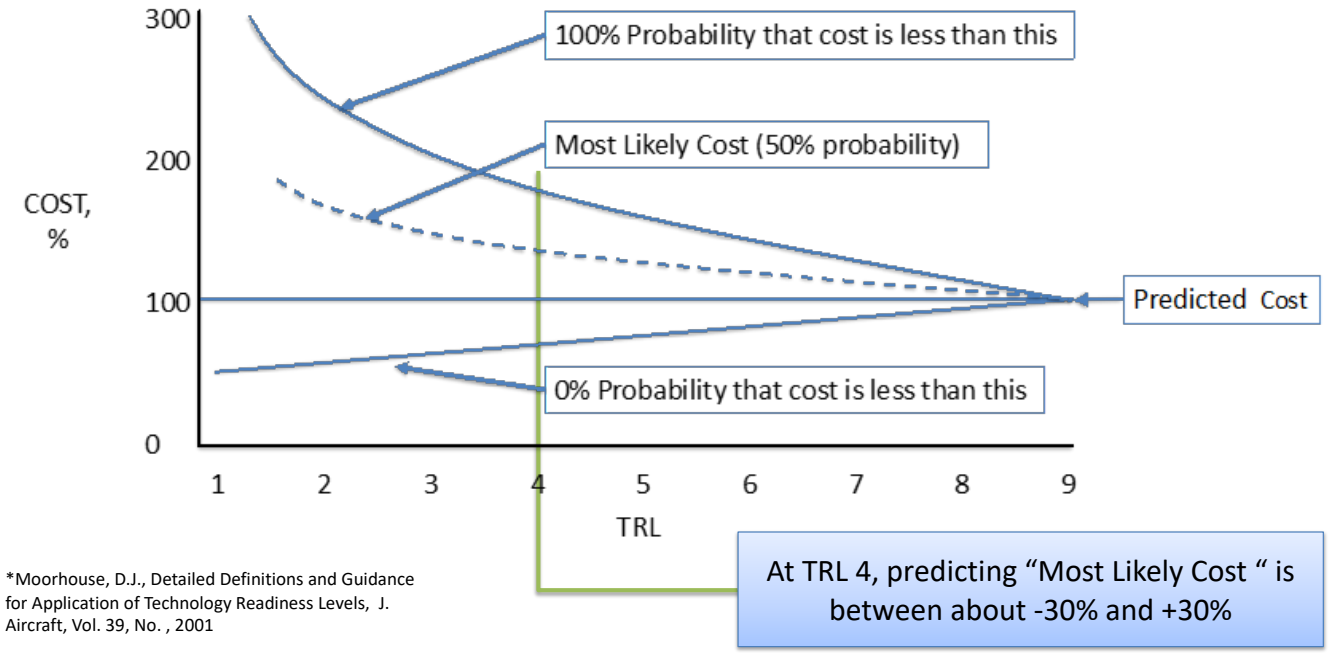
- Rotor Blades = 22-28% f (induced loss)
- Fuel Cells = 40 to 50% loss (Heat, Water)
- Fuel Cell Support Equipment (BoP) = 10% loss
- Cooling Systems = 5% loss
- Downwash from rotors on airframe = 7% loss
- Aerodynamics = f (viscid & inviscid losses)
- Geared Motors = 5-10% loss
- And others …



Law of Abundances and Scarcities:
"As a scarcity becomes an abundancy,
consume (waste if necessary) that which is in abundance, to solve human needs."

Technology Readiness Levels (TRL)

Predicting Development Costs with TRL*



*Moorhouse, D.J., Detailed Definitions and Guidance for Application of Technology Readiness Levels, J. Aircraft, Vol. 39, No. , 2001

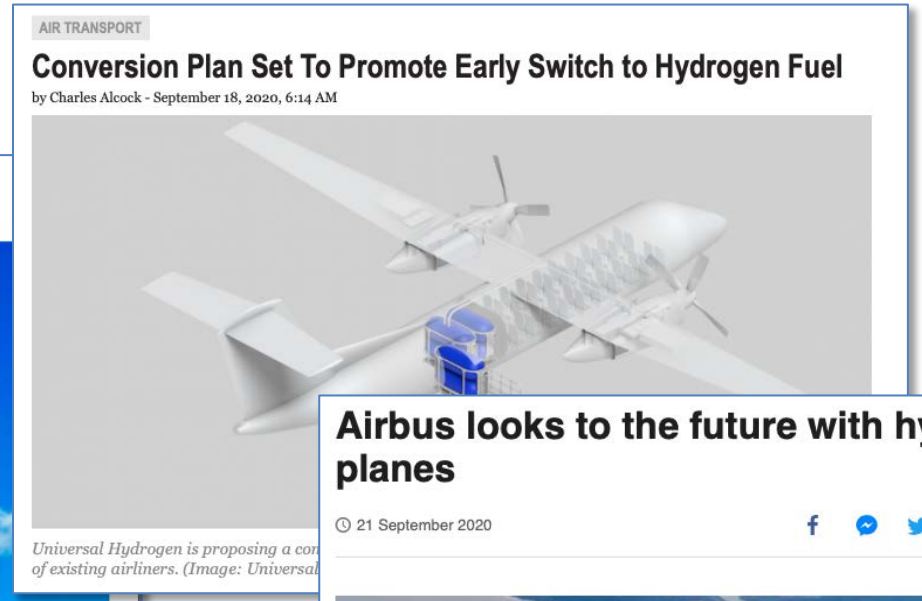
HFC Systems R&D:

- Electro-Chem-Physics modeling
- Stack efficiencies
- Balance of Plant optimization
- Fuel Cell Plate materials
- Life cycle modeling and testing
- FAA compliance for certification
- Stack longevity
- Digital twin systems
- LH2 crash dynamics and design
- PPE-free fueling system safety
- GH2 and LH2 storage systems
- Hybrid powertrain architectures

Aeronautical Industry Pre-Competitive Collaboration needed to accelerate pace and to share the risks of TRL advancement.

Hydrogen Coming Of Age

- Ten nations have committed to advancement toward hydrogen economies over the coming years.
- Primary drivers are environmental sustainability and Total Cost of Ownership (TCO).
- Aeronautical H2 ecosystem includes OEMs and suppliers across the enterprise.



Hydrogen Technology Trajectories

- The cost to produce hydrogen fuel cells has fallen 65% since 2010 and is projected to fall another 50% by 2025, as volume scales (https://blog.ballard.com/fuel-cell-price-drop), bringing the cost down from more than $1,000/kW a few years ago ($100,000 per car) to about $60/kW (about $6,000 per car) and with a DOE goal of $30/kW in coming years.
- This year, Microsoft has pledged to become carbon negative by 2030, in part using HFCs to power Azure datacenter servers, in a cost-competitive replacement of diesel fuel powered generators, with H2 delivered by H2-powered long-haul vehicles, to ensure five-nines (99.999%) reliability. (https://news.microsoft.com/innovation-stories/hydrogen-datacenters/)
- Hydrogen production costs are forecast to decline by 50% by 2030, making H2cost-competitive with some conventional fuels (https://hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective/)
- Before the impact of any technological breakthroughs are considered, the Total Cost of Ownership of hydrogen vehicles is forecast to decline about 45%, at about 600,000 vehicles per year (https://hydrogencouncil.com/wp-content/uploads/2020/01/Path-to-Hydrogen-Competitiveness_Full-Study-1.pdf)

Change the World

Hydrogen Powered
Aerial Transport
Solutions

Everyday Air Mobility.
Fueled by Hydrogen.
Powered by Simplicity.

Thank You!

skai

Backup