“Creating an International Market Place for Sustainable Aviation Fuel”

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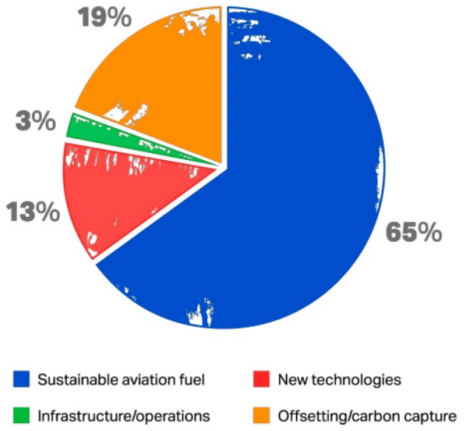
Since 2018, Global Conversation on Aviation Emission has fully changed

The plan

Contribution to achieving Net Zero Carbon in 2050



Net Zero 2050 is achievable through:

Combination of measures

- Sustainable Aviation Fuel, new , technologies, operational and infrastructure improvements, and offsetting/carbon capture

Collective effort

- of the entire industry together with governments, oil producers and investors

IATA FLY NET ZERO

American Airlines and Deloitte Pioneer Market-Based Solution to Reduce Carbon Emissions from Air Travel

Boeing, Netflix and Microsoft among founders of new business alliance on sustainable aviation fuels

Why Microsoft Is Buying Sustainable Jet Fuel For Alaska Airlines

Tech giant Microsoft announced a partnership with Alaska Airlines this Thursday to cut its CO_2 emissions through sustainable jet fuel. The agreement involves Microsoft purchasing sustainable aviation fuel (SAF) on routes popular with its employees.

United partners with corporate America to ramp up sustainable fuels

Through a new partnership with some of the country's largest corporations, the Eco-Skies Alliance, United will triple its use of sustainable aviation fuel this year.

„Flightshaming“ had impact:
- Sceptical industry associations IATA, ATAG, A4E, etc. all with 2050 „Net-Zero targets“
- UNFCCC/Science-Based Targets with Roadmaps to „True Zero Carbon Aviation“ – no offsets
- Regulators in EU, US and beyond with schemes to ramp up „Sustainable Aviation Fuels“
- Corporate Aviation Customers with ambitious schemes to buy SAF directly
- Global UN Agency ICAO working towards „Long Term Goal“

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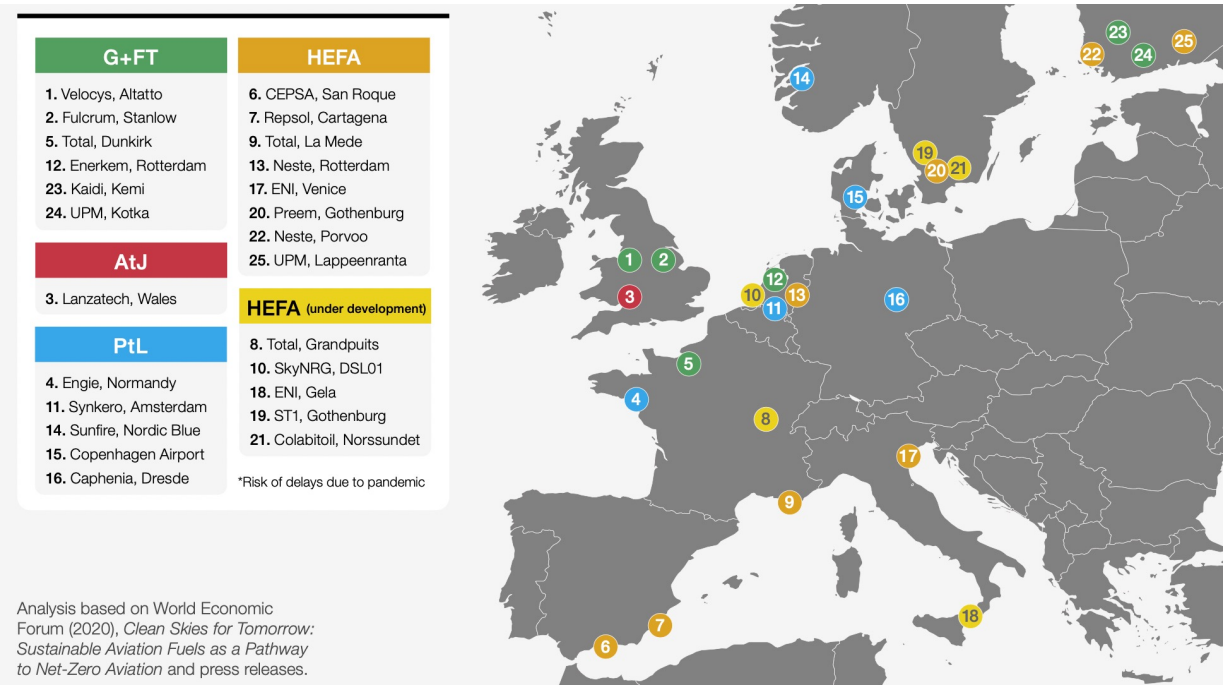
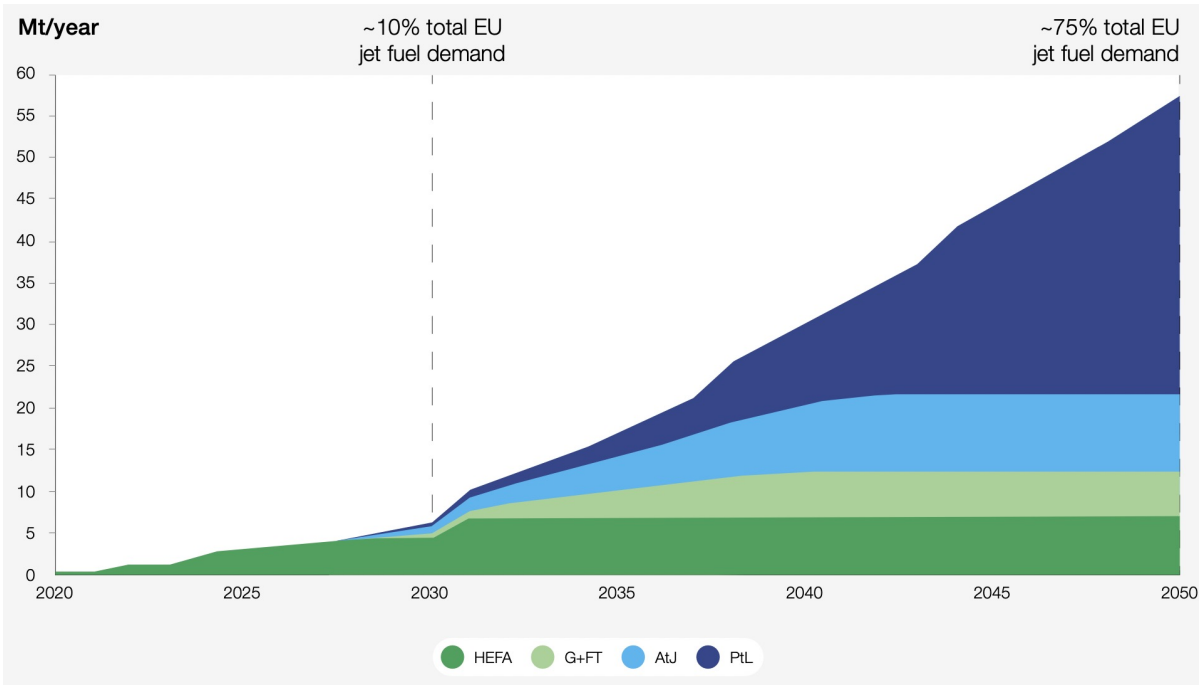
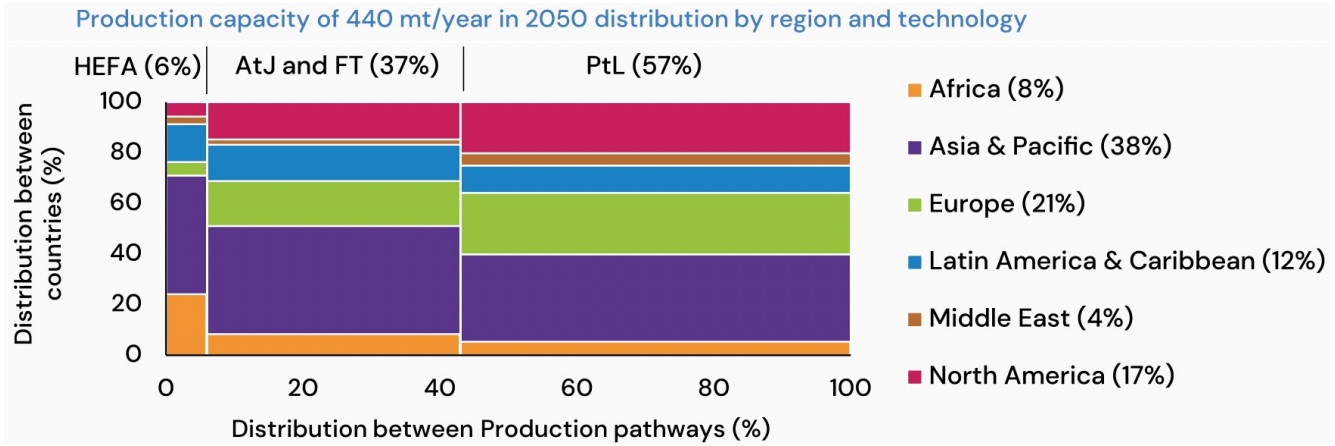
PtL-SAF to contribute around 60% to Global Ramp-up, Europe with 20% share







Source: ATAG Waypoint 2021, World Economic Forum, „Clean Skies of Tomorrow“

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PtL requires Green Hydrogen and a Renewable Carbon Source

If SOEC[3] is used

If PEM or alkaline is used

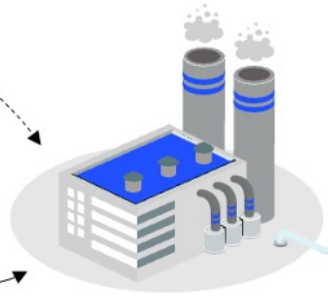
Renewable energy

Constraining factor for PtL production at scale:

- At least 36 MWh[1] needed to produce one ton of jet fuel and associated byproducts, depending on pathway

Hydrogen[2]

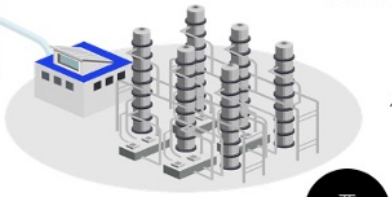
Only required if reverse water gas shift reaction is used for syngas production



Fuel synthesis and feedstock production preferably co-located due to high transport cost of H2 and CO2

Fuel synthesis

Multiple chemical processes such as co-electrolysis, reverse water gas shift reaction, methanol synthesis, Fischer-Tropsch synthesis, hydrocracking



End products

Byproducts

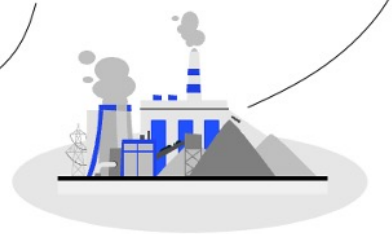
Naphtha[4] (20%)

Diesel (20%)

Jet fuel (60%)

Alternative uses

Such as HVO, fossil jet refining



Carbon capture

Industrial point-source capture (Ind-PSC), Biogenic point-source capture (Bio-PSC), Direct air capture (DAC)

1. Up to 45-52 MWh if using direct air capture
2. Blue hydrogen likely required until sufficient renewable energy is available to produce necessary amounts of green hydrogen
3. Solid oxide electrolyzer cell
4. Gasoline or chemical feedstock

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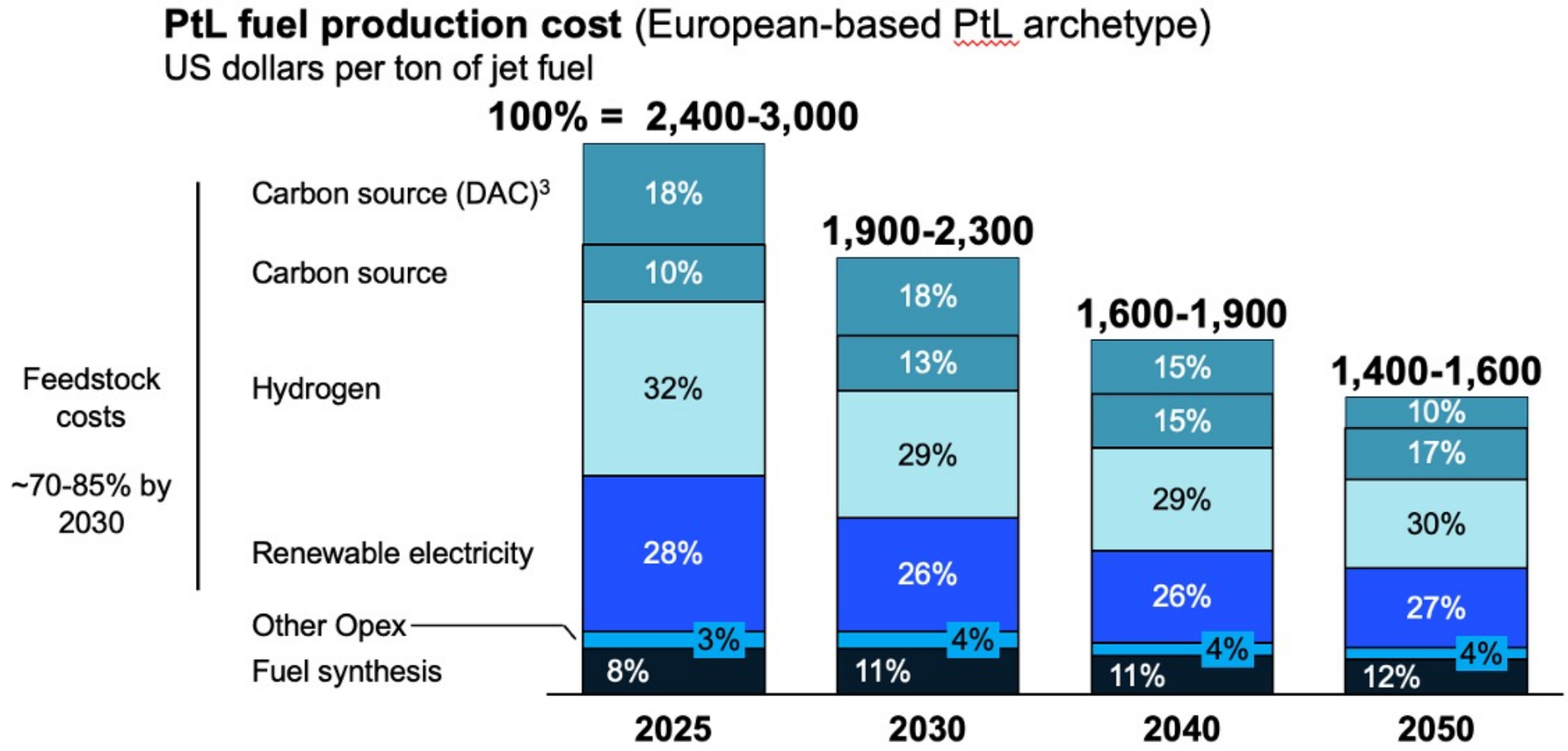
PtL Production cost largely driven by cost of renewable energy

- PtL is – different to waste-based fuels – **unlimited in supply**
- PtL cost in low cost power location may **break even mid 2030s**



1. Assuming offshore wind-based renewables and H2 produced in Europe and the US for $2.7/kg H2 in 2030, declining to $1.8/kg by 2050; Additional $0.2/kg H2 included for storage; Carbon cost based on industrial point source at $95/t CO2 capture with $5/t CO2 intermediate storage; DAC cost assumed $220/t CO2 in 2030 declining to $135/t CO2 by 2050; Reverse water gas shift + Fischer Tropsch technology configuration

Source: McKinsey Sustainable Fuel Cost Model

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PtL Production requires high Amounts of Energy and Space

A large scale PtL plant could produce...

30,000 tonnes jet fuel

+

10,000 tonnes diesel fuel

+

10,000 tonnes naphtha

... which yields

3,000 Airbus A320 or Boeing 737 for four to five hours

+

7,000+ roundtrips from Berlin to Madrid in a heavy-duty truck

+

1.5 million plastic bottles and other high value add petrochemicals

... and requires

1.8 terawatt hours of electricity

or

4,500 acres of solar park

+

270 kilotons of CO_2

=

Enough to power 2 million American homes for a month

or

3,500 football fields of solar arrays

=

The annual emissions of 60,000 cars

Assumptions: Average fuel economy of A320 of 2.4t/hr, heavy duty diesel truck of 6.5 mpg, 20 grams of PET per bottle, an average U.S. residential home consumes 893kWh/month, an average solar park produces 95,000MWh/km² per year, an average passenger vehicle emits 4.6t CO2 per year; one ton of jet fuel (and by-products) requires 36.2MWh energy and 5.4t CO2

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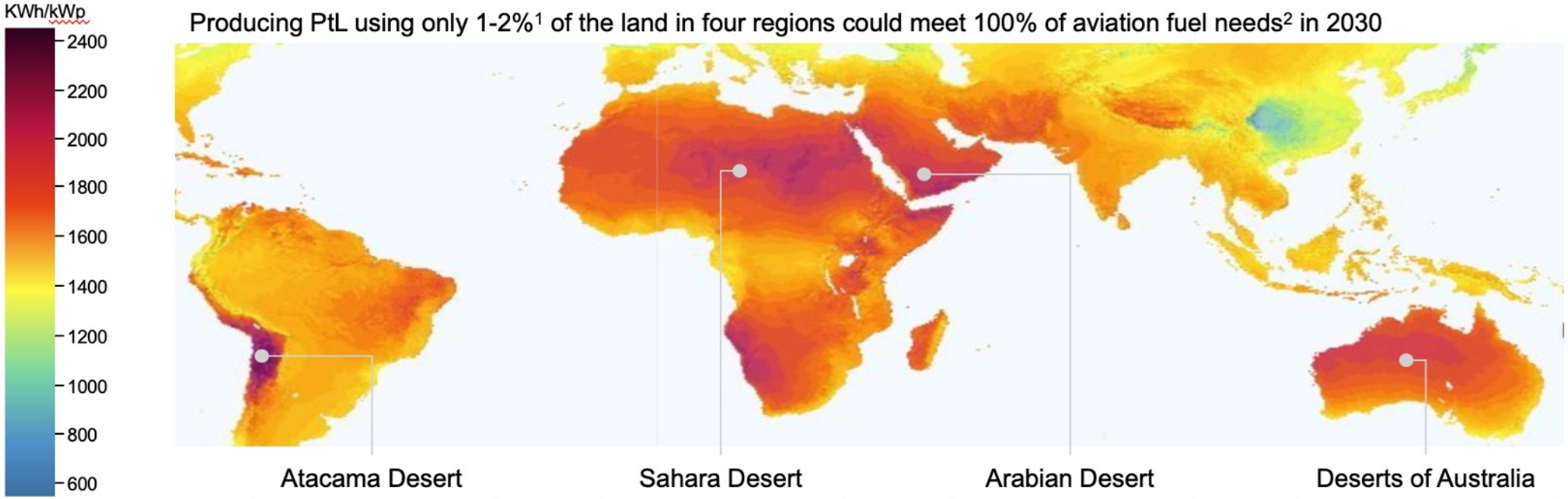
Four deserts can supply Global Aviation industry, Carbon Source and Port Access required



	Atacama Desert	Sahara Desert	Arabian Desert	Deserts of Australia
Total Land[3], km²	**95,000**	**8,300,000**	**1,650,000**	**2,050,000**
Capacity Factor[4] %	**30-34%**	**27-31%**	**26-30%**	**25-29%**

1. Includes land required for direct air capture
2. Includes an additional ~800-900 MtonCO2/y emissions avoided from PtL by products (Naphtha and Diesel) by 2030
3. Estimated land available for renewables development
4. Considers bifacial, single-axis tracking technology in 2030 at 33 MW/km2; includes land required for direct air capture

Source: Map obtained from the "Global Solar Atlas 2.0, a free, web-based application is developed and operated by the company Solargis s.r.o. on behalf of the World Bank Group, utilizing Solargis data, with funding provided by the Energy Sector Management Assistance Program (ESMAP). For additional information: https://globalsolaratlas.info

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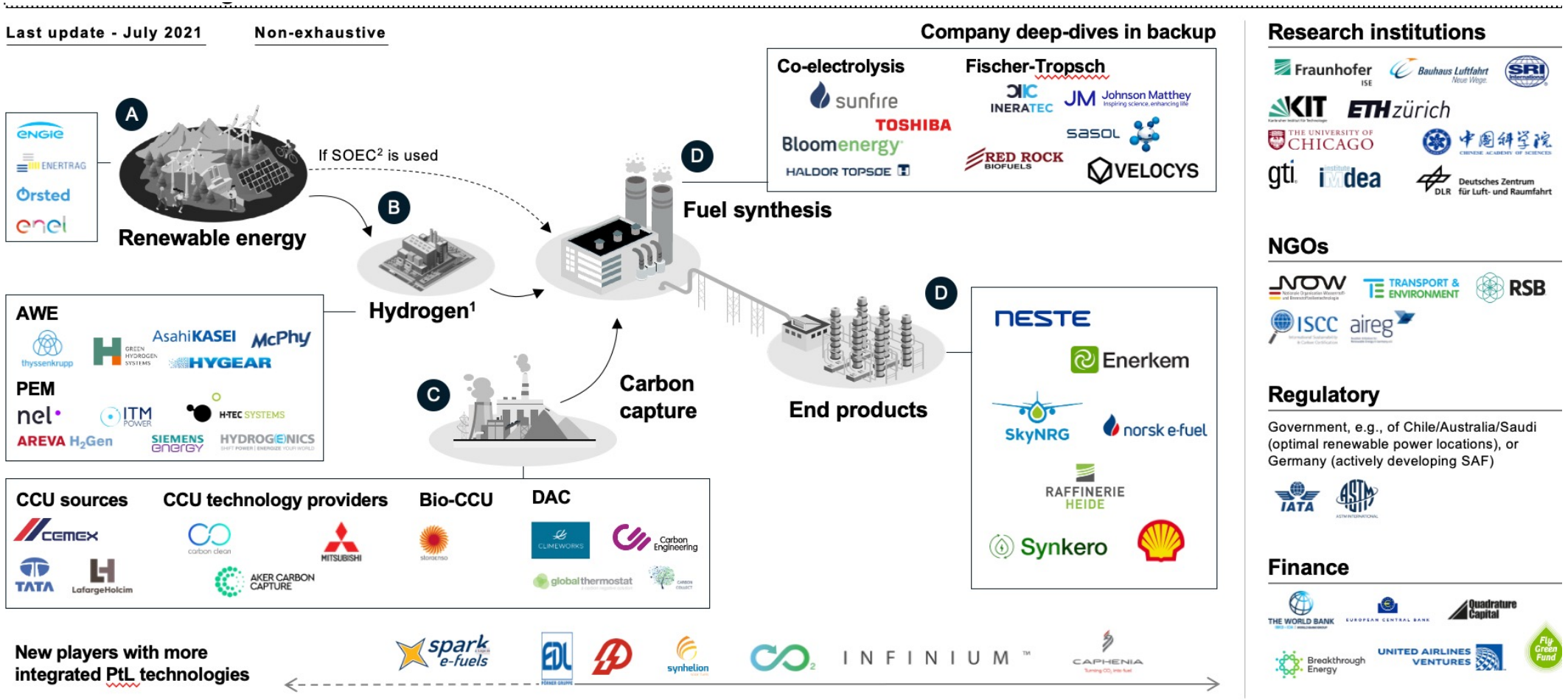
Vibrant Global Innovation Ecosystem in PtL maturing…



1. Blue hydrogen likely required until sufficient renewable energy is available to produce necessary amounts of green hydrogen
2. Solid oxide electrolyzer cell

Source: Company websites, Expert interviews, Press releases, Web search

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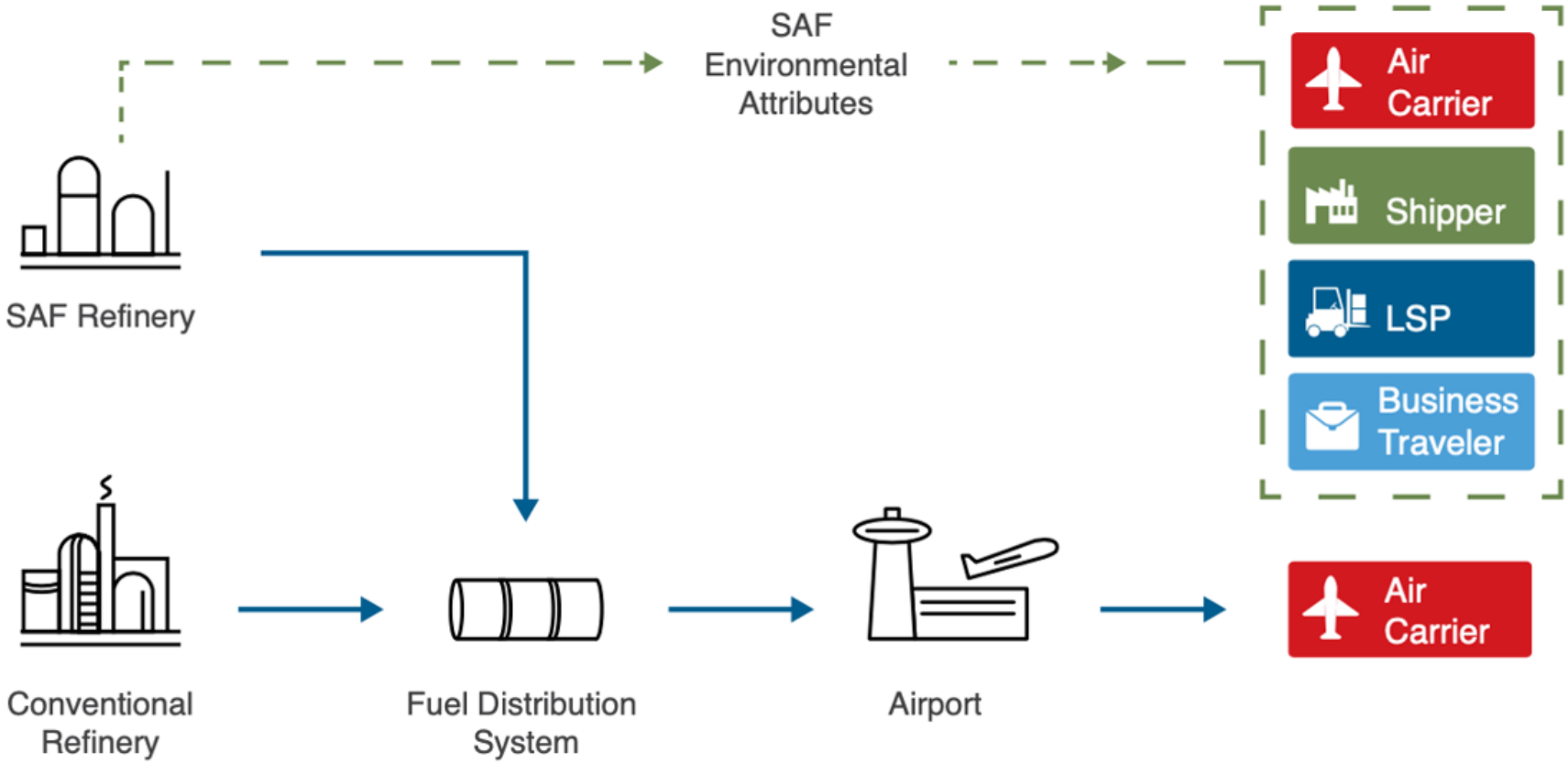
Book & Claim – Chain of Custody System (simplified)



Why Book & Claim?

- **Book & Claim works like „Green Electricity“** –Utilities supply (book)/ Consumers buy green power (claim)

- Avoids bureaucracy, logistics and costs through **efficient supply chain**

- Stimulates fuel suppliers and customers to **supply more SAF** into system

- Eliminates exemption/**transition period for smaller airports**

- enables decentral producers at low cost locations to enter SAF closeby **(i.e. emerging markets**)

..but…

- requires additional accounting tools (i.e. **central SAF registry**) to avoid double counting

- requires in situ **checks of fuel quality compliance** with RED 2 or other e.g. ICAO sustainability criteria

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ReFuel EU creates a European SAF market – with Opportunity for Expansion

ReFuel EU Aviation 2022

- Mandate for Fuel Suppliers to provide a blended aviation fuel with SAF Quota for ALL flights departing from ALL EU Airports (transition period for small airports)
- Environmental Integrity following RED 2 annexes, monetary incentives via EU-ETS
- SAF Quota ramps up over time (from 6% 2030 towards 63% in 2050)
- Sub-basket for SAF-PtL to support early ramp up, as mid term SAF Perspective relies on PtL
- Will allow import of SAF from e.g. emerging markets, as long as take up at European airports
- Member States can go beyond EU Quota (plans in Scandinavia, Holland etc.)

But….

- „Book and Claim“ (or Mass balancing“) not actively endorsed yet in ReFuel EU because of concerns on environmental integrity and quality assurance outside EU
- SAF Quota ramp up conservative with European production in mind – review after 2025

Corporate Purchases on top:

- Selected Aviation Customers want to go beyond ReFuel EU Quota
- „Science-Based Targets“ specifically endorses „Book & Claim“ (alignment with GHG Protocol outstanding)
- i.e. Corporates can „claim“ abatement of Scope 3 emissions through SAF purchases using „Book & Claim“ processes under SBTi

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Key Takeaways „PtL – SAF and „Book & Claim“

1.) A first step in creating a pan-European SAF market is taken with ReFuel EU as part of „Green Deal“ – time to raise ambition will come….

2.) „PtL – SAF“ will be the major contributor to aviation decarbonization – majority of supply will come from emerging economies with renewable ressources because of cost and space considerations

3.) A global „Book & Claim“ System should be enacted as soon as possible (and added to ReFuel EU to: a) accelerate the global ramp up of PtL-SAF; b) build confidence in Emerging Economies that they can participate; c) reduce the costs of the transition

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