Scaling up the SAF supply base

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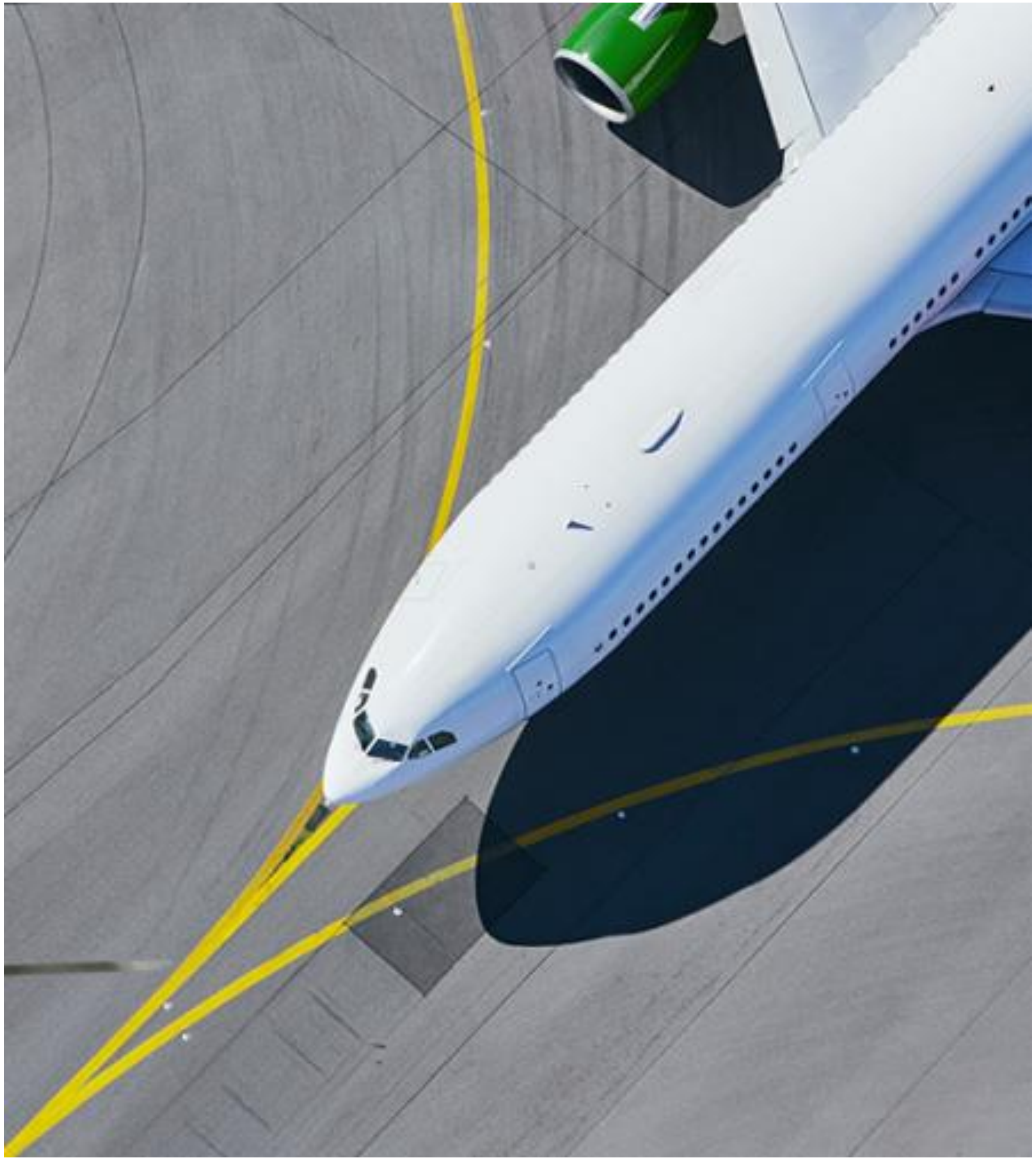


Agenda

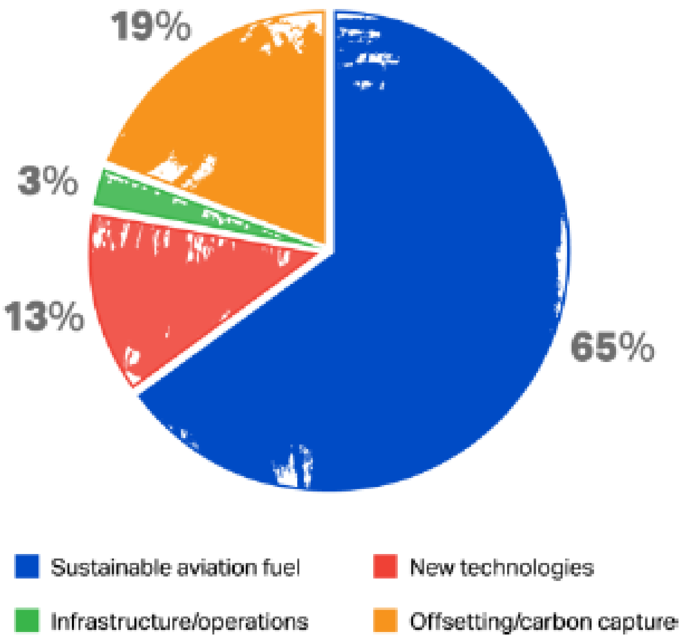
- Energy transition across sectors
- SAF pathways
- Scaling up SAF

Energy transition across sectors

Driven by IATA, aviation has ambitious but necessary targets – to achieve Net Zero Carbon emissions by 2050.

The plan

Contribution to achieving Net Zero Carbon in 2050



Net Zero 2050 is achievable through:

Combination of measures

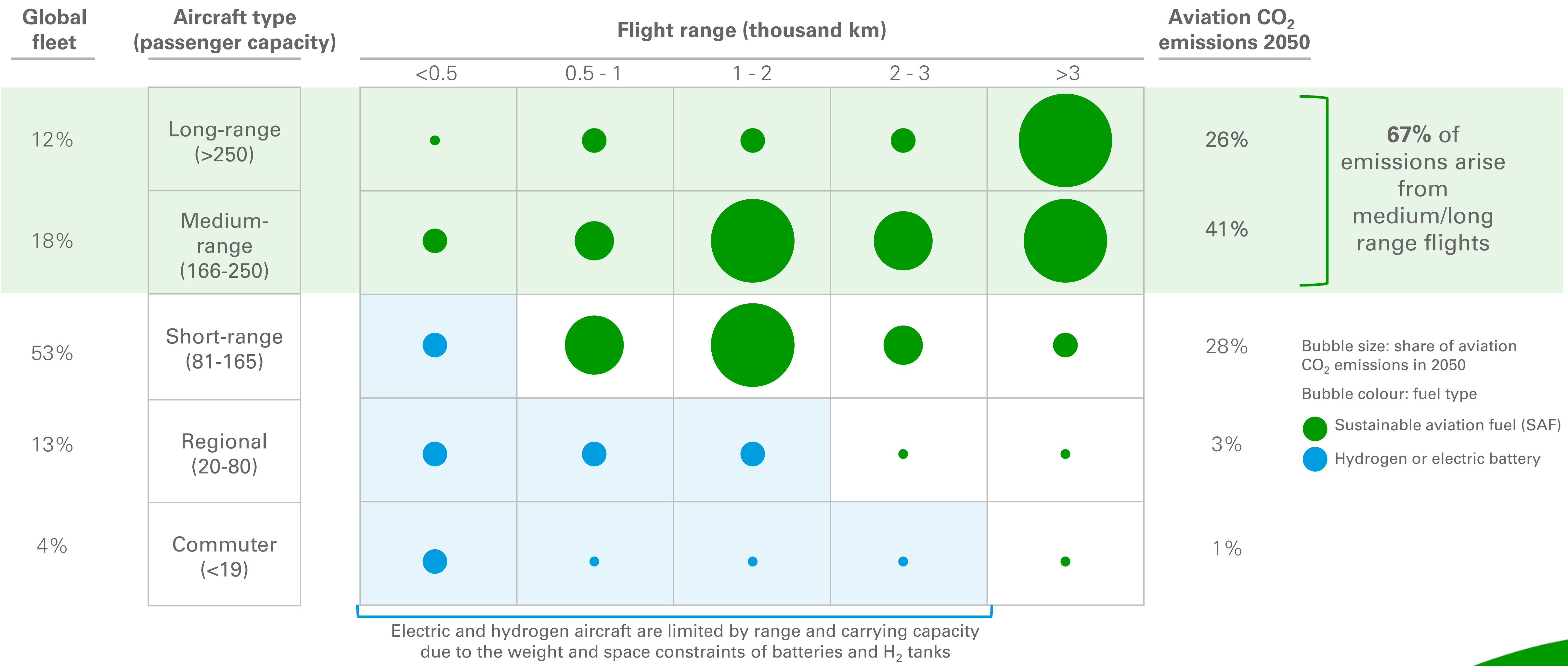
- Sustainable Aviation Fuel, new , technologies, operational and infrastructure improvements, and offsetting/carbon capture

Collective effort

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

Source: IATA, Press release No: 66. October 2021

Two-thirds of emissions come from medium/long range flights where only SAF can be used – H_2 and electric can abate ~5% of emissions in the short/regional range



Source: European hydrogen aviation report, ATAG waypoint 2050

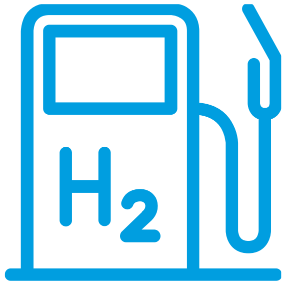
Options to decarbonise fuels are based on four key technologies

Biofuels

Sustainable fuels from abundant feedstocks including: waste oils, wood and agricultural residue and conventional sugar.

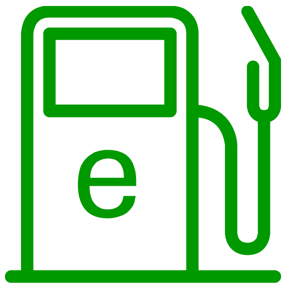
Electricity

Produced from renewable sources including wind and solar, or using low carbon sources such as gas with CCS and nuclear.



Hydrogen

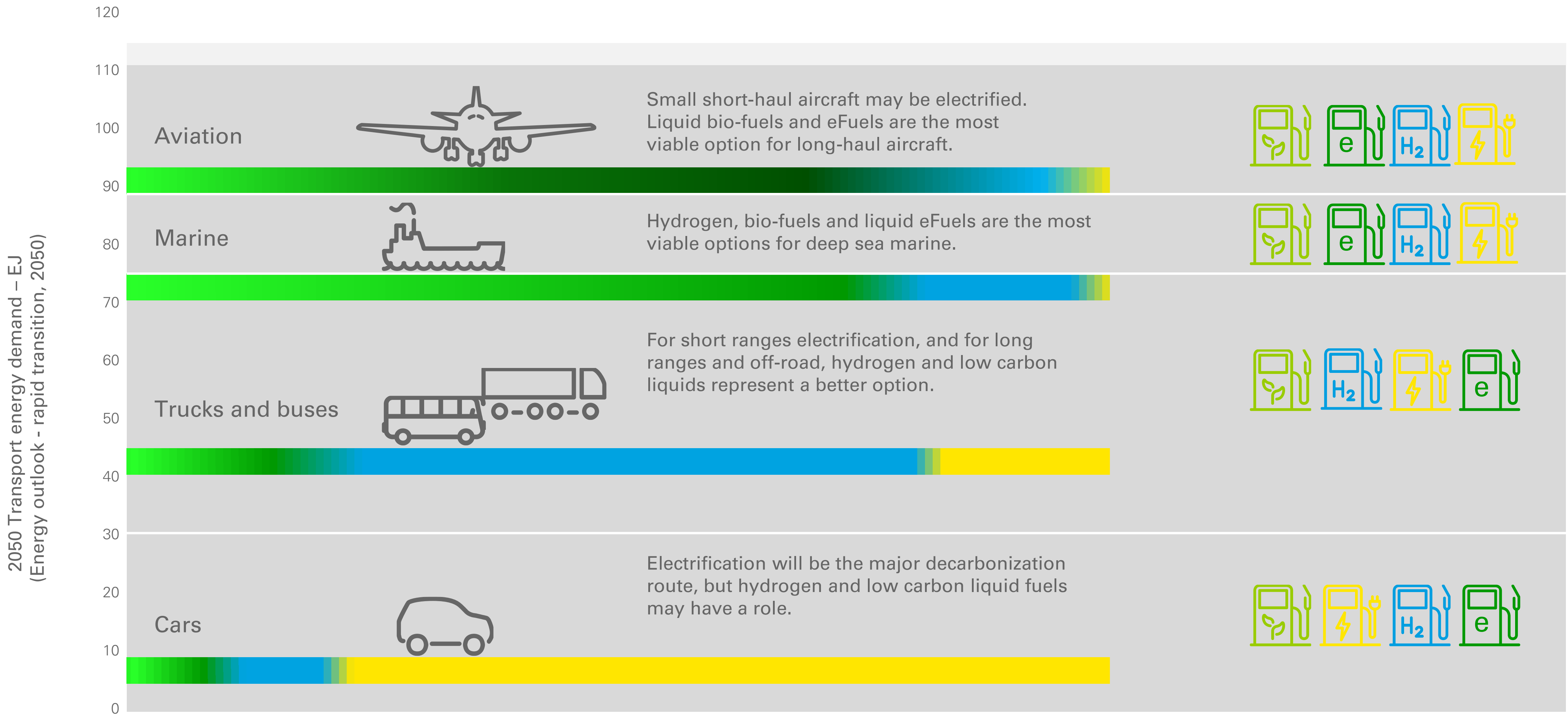
Produced from natural gas with CCS or from electrolysis of water using renewable electricity. Transported as compressed gas, liquid or converted to ammonia (NH_3), it can be combusted or used in fuel cells.



eFuels

Liquid or gaseous fuels produced from renewable electricity (via hydrogen) and CO_2 from air, a biomass source or sustainable industrial source such as cement.

Certain transportation sectors are considered best suited to specific low carbon fuels. Integrated energy companies are evaluating refinery optimization options.



Size of color bars is illustrative only to give an idea of scale

SAF pathways

There exists several SAF technology pathways

	HEFA (waste oil)*	FT (MSW)	1G Ethanol to jet	2nd Generation Biomass***	eFuel****
Time to market & current scale	**2020s** **Currently commercial.**	**2025-2030** **Commercial demo.**	**2025-2035** 1G ethanol is mature. Dehydration to ethylene commercial. Ethylene to jet not yet commercial.	**2030-2035** Pyrolysis commercial demo. Pyrolysis oil to jet not yet commercial.	**2030-2040** rWGS not yet commercial. FT demonstrated. Electrolysis is commercial.
Key opportunities	**Fungible feedstock, scaleable technology** Back-integration to refineries. Capital Lite.	**Negative cost feedstock** FT technology integrates to eFuels	Capital lite process **Attractive in areas with existing ethanol capacity (US/Brazil)**	**Significant feedstock availability** long-term **low-cost potential**	**Progress at pace of renewables societal preference** Highest sustainability credentials
Near term constraints	**Competition with renewable diesel** (HVO) for a highly limited feedstock	**Investment risk**	**Opportunity cost to sell ethanol** for road transport is high	**Costs and technology readiness** Investment risk	**Costs and technology readiness** Improvements required in multiple areas of technology
Long term constraints	**Feedstock supply is limited** to <1-5% jet demand unless oilseed energy crops emerge post 2035. [rent may migrate to feedstock]	**High capital intensity** MSW access **GHG reduction is dependent on avoided landfill emissions**	**Opportunity cost to** sell as chemicals may be high **sustainability concerns**	**Build rates biomass aggregation**	**Capital costs build rates for eFuel and power/H_2**
Estimated GHG reduction vs. fossil jet	65-79%	82-94%**	60-70% sugarcane; <20-30% corn	76-94%	100%
Key take away	HEFA is a near term option that uses fungible feedstock and back-integrates to refineries.	FT MSW provides near-mid term potential in urban areas with tipping fees for waste.	First generation ATJ is capital lite and produces SAF from existing ethanol markets.	Second generation biomass technologies have long term, low cost potential.	eFuels potential is increasing due to the pace of renewables and green H_2.

*1G food crop vegetable oils could also be used as a feedstock for HEFA
**assumes avoided landfill emissions are counted as part of analysis; landfill practice changes pose a risk to this accounting
***multiple other technology routes from 2nd generation biomass to SAF should also be considered including alternate catalytic/fermentative conversions, LC ethanol to jet, etc.
****alternate routes to eFuels also exist including a route through methanol and others at R&D stage

Achieving the net zero scenario in the bp outlook is possible (though not easy) and likely requires a mix of different technology pathways which vary by region

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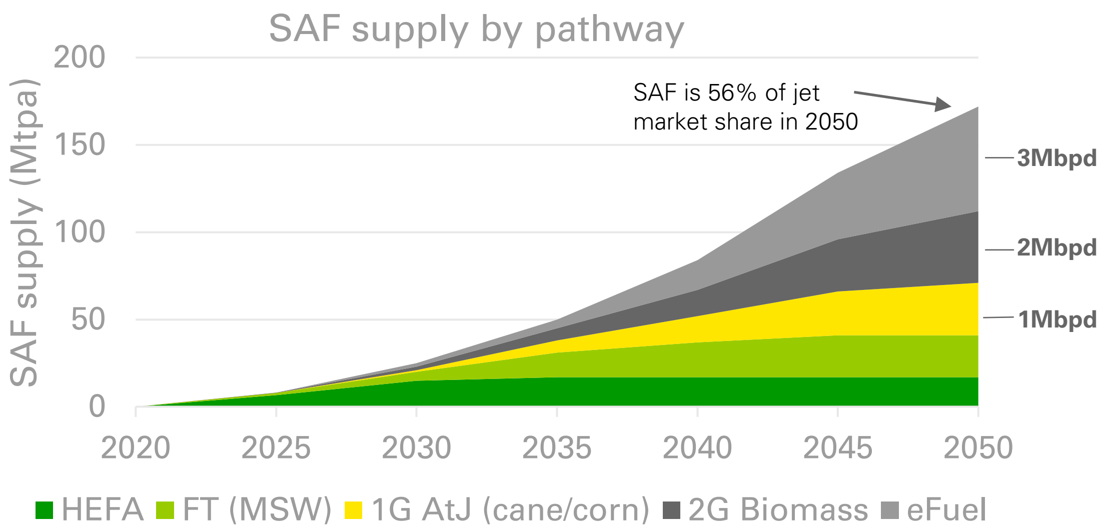
Net zero scenario (aligned with IATA targets) – SAF supply



Key conclusions:

Multiple pathways required

- The low-cost solution will be obtained i) investing in technology development for **multiple pathways today** and ii) scaling those technologies in various waves as they become competitive with other types of SAF (at <$2500/te).
- The required investment, build rates, or subsidies are not unprecedented on their own if compared to other sizeable transitions, but the combination of these factors will be the primary challenge for achieving net zero in aviation.

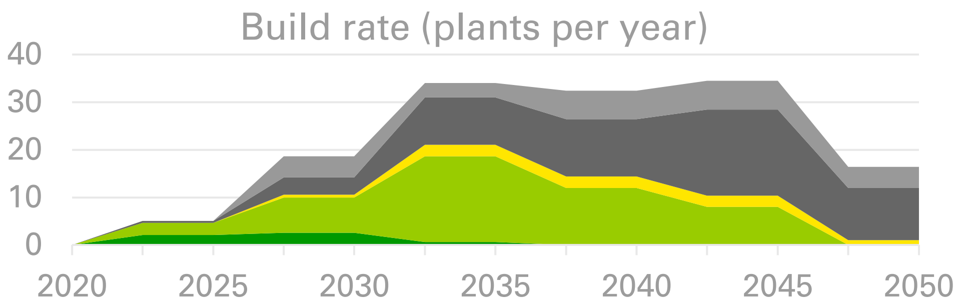
Regional variations:

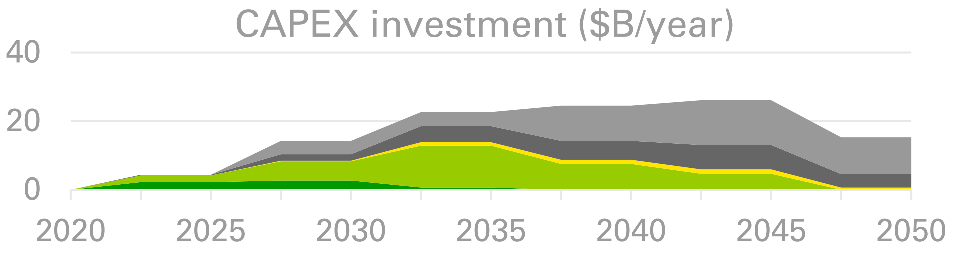
- Some regions will **prioritize specific pathways** with a strong focus on land use and sustainability resulting in growth of **eFuels** and **2G biomass.**
- Other regions could favour **domestic supply** resulting in production of **ATJ** from ethanol or biojet from MSW.

Source: Statista. IRENA

Achieving the net zero scenario in the bp outlook is possible (though not easy) and likely requires a mix of different technology pathways which vary by region

Slide 2 of 2





Transition scenario for aviation decarbonization is similar to historical precedents

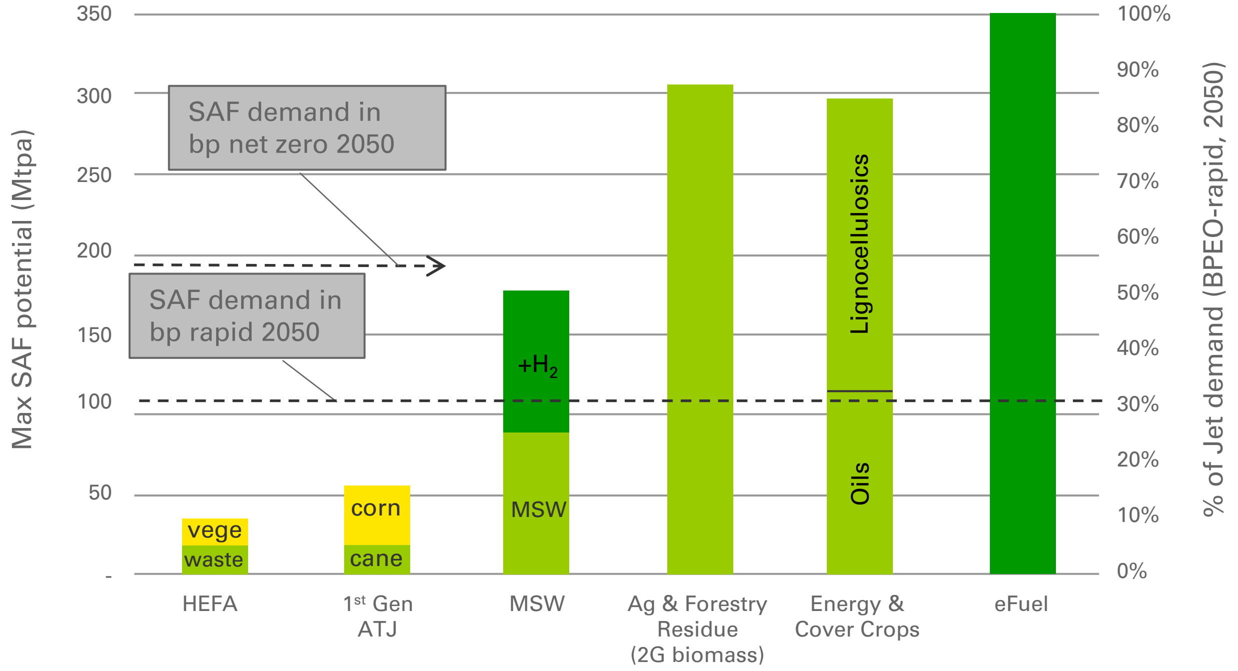
705 plants built (23/year average)
equivalent to the **US/Brazilian bioethanol** sector (~680 plants)

$535B capital invested over 30 years (~$17B/year average)
new refinery investment was ~$45B/year the last 5 years (Statista)

Source: Statista. IRENA

Sustainable and available feedstock in 2050 defines the maximum supply of SAF

Feedstock availability and land use constraints were used to define the maximum SAF potential by feedstock and technology pathway. Sustainable land use and the ability to aggregate feedstock was considered.



Feedstock availability may limit some pathways (e.g. HEFA). However, in aggregate, there is more than enough non-food bioenergy feedstock potential to meet the demand for jet fuel. eFuel potential could be layered on top of that.

Sources: ATK, S2Biome, FAO

2050 Rapid demand (conversion): 350Mtpa~8Mbd~15 Exojoules~115B gallons

How does an integrated energy company look at SAF production?

Co-processing:

- Accepted by OEMs / Industry
- Successful for
  - HEFA (waste oils and greases, first generation vegetable oil)
  - FT synthetic wax derived from many feedstocks: municipal solid waste, ag and wood waste, coal, natural gas;
- FCC processing of pyrolysis oil (biomass, tires, plastic) – if approved
- Current approval limited to 5% of feedstock concentration – bp is leading coprocessing ASTM task force to review potential to increase limit to 30%
- Advocacy: financial incentives to be equalized with ground fuels with no disproportionate treatment (C14 testing)
- Sustainability: ensured via current certification schemes, feedstock with no ILUC risk/s

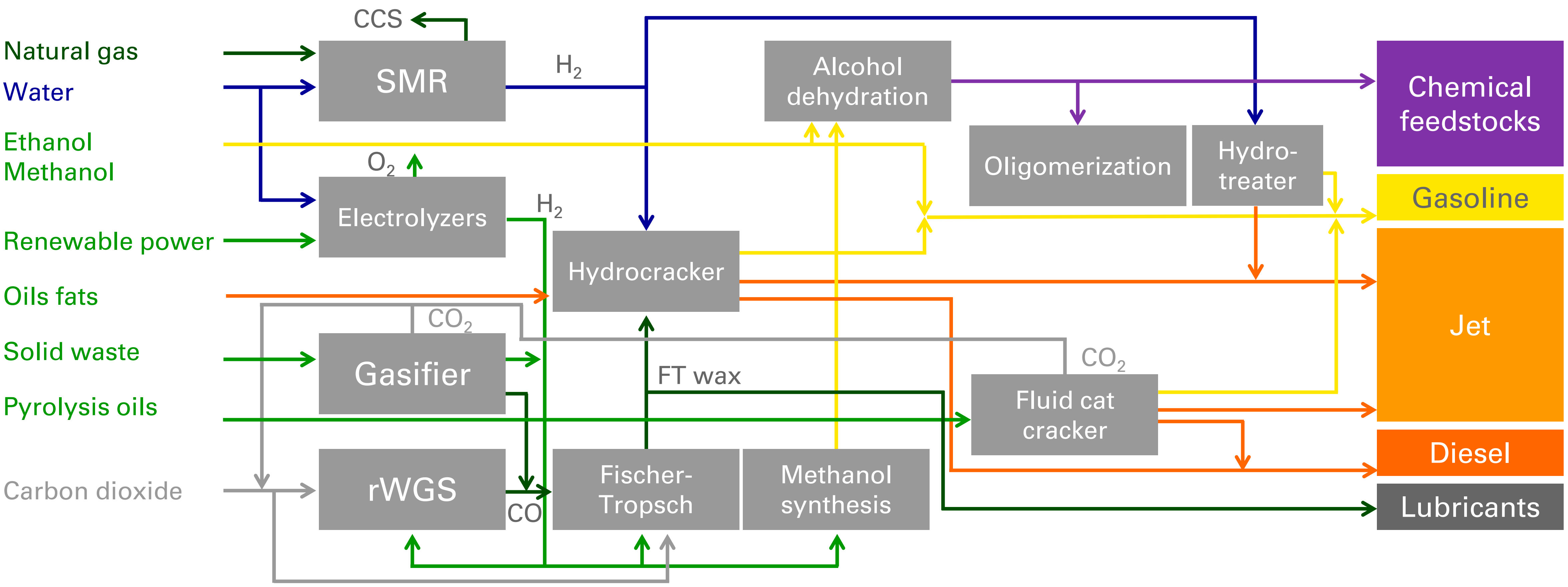
Stand-alone units:

- Project competitiveness assessment
- Secure and develop feedstocks
- Production flexibility between aviation and ground fuels
- Develop technology to diversify beyond HEFA
  - Options to diversify ATJ as ground fuels shifts to electricity (technology is ready, will SAF margins overcome high intermediary value in petrochemicals)
  - FT (developing better catalysts, better utilization of CO_2 through integration with green H_2 and eFuels, alternative products, integration and upgrading of feedstocks and process steps
  - Pyrolysis oils are difficult to upgrade and require research and development

Beyond bio:

- eFuels development; reverse water gas shift, direct air carbon capture

A net zero refinery



Scaling up SAF

Scaling up SAF

What are important elements to consider as SAF production and access grows

Logistics and technical aspects

- Feedstock – most move globally, some are local. Key to recognize the role for energy crops (when not competing with food/feed markets)
- Feedstock / fuel sustainability credentials should be ensured via proven certification schemes, like ISCC system
- Blending, storage and transportation infrastructure/certification - Physical delivery versus book and claim – transitional tool to ease SAF ramp -up?

Support and compliance

- Regulatory compliance mechanisms – understanding access to incentives/subsidies.
- Proper design of mechanisms ETS, CORSIA, EU Refuel, etc (who has the obligation, where the fuel qualify, etc.) and with its coexistence with other segments (ground fuel, marine, petchems) that compete for same feedstocks

Commercial aspects

- Recognize different value proposal for same supply chain: supplier, airlines, airports and consumers; which are green attributes for them? what is the value, how its related and how can be the demand connected?
- Carbon reduction claims: accounting integrity, transparency and third party assurance
- Risk – SAF index, feedstock exposure, etc

bp drives a focused advocacy strategy to promote SAF availability, accessibility and affordability at pace in order to help deliver the aviation sector ambitions

Overview of bp's "5As" advocacy position for decarbonizing aviation:

Availability
Multiple SAF pathways are required, and all should be allowed to compete on their own merits within societal preference

Accessibility
Promote a global market with global logistics movements of SAF to ensure access and affordability

Accountability
Support feedstocks that avoid the creation of additional demand for food and feed crops or with high risk of ILUC

Affordability
Support economy-wide carbon pricing and recognizing that aviation needs disproportionate price support because cost per ton of carbon abated is higher than other sectors

Acceleration
Pace of policy and collective action must be prompt in order to deliver the industry ambitions