Sustainable Aviation Fuels

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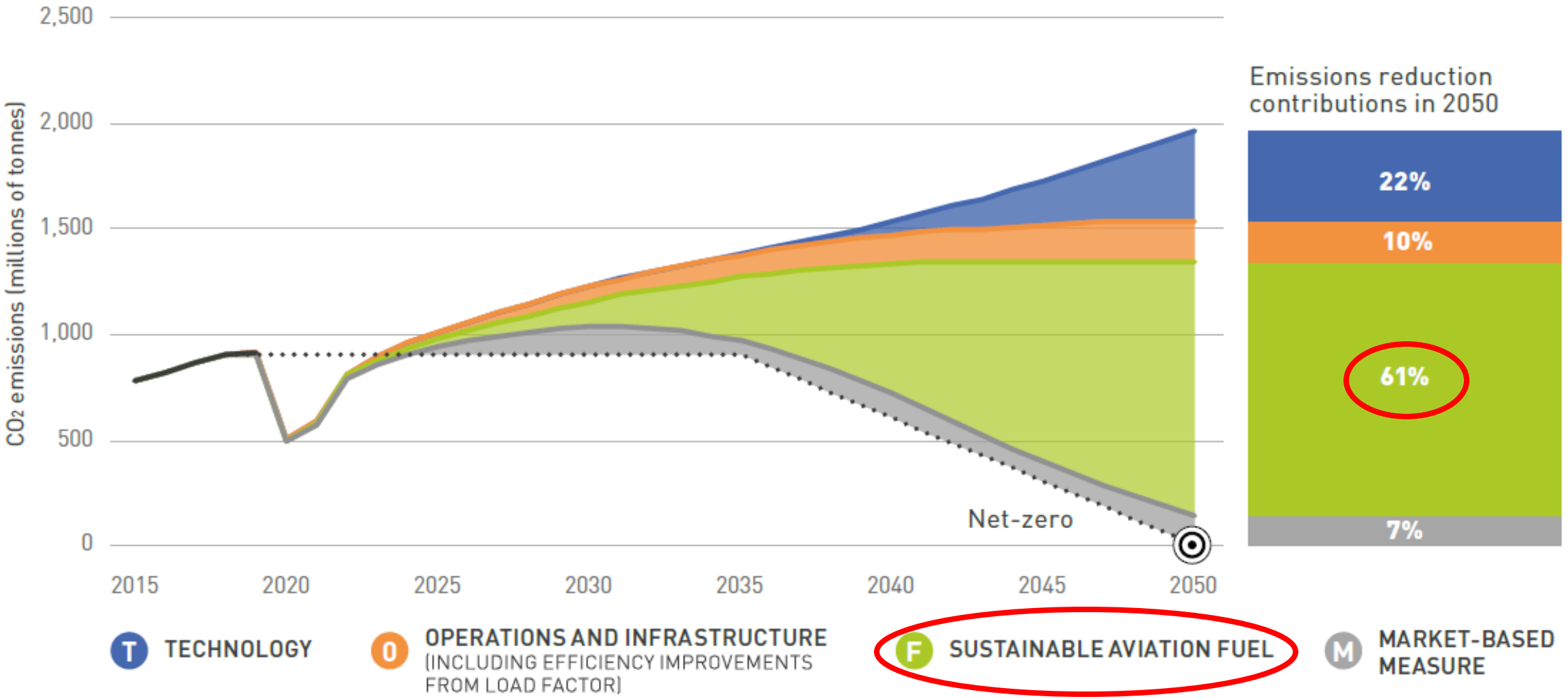
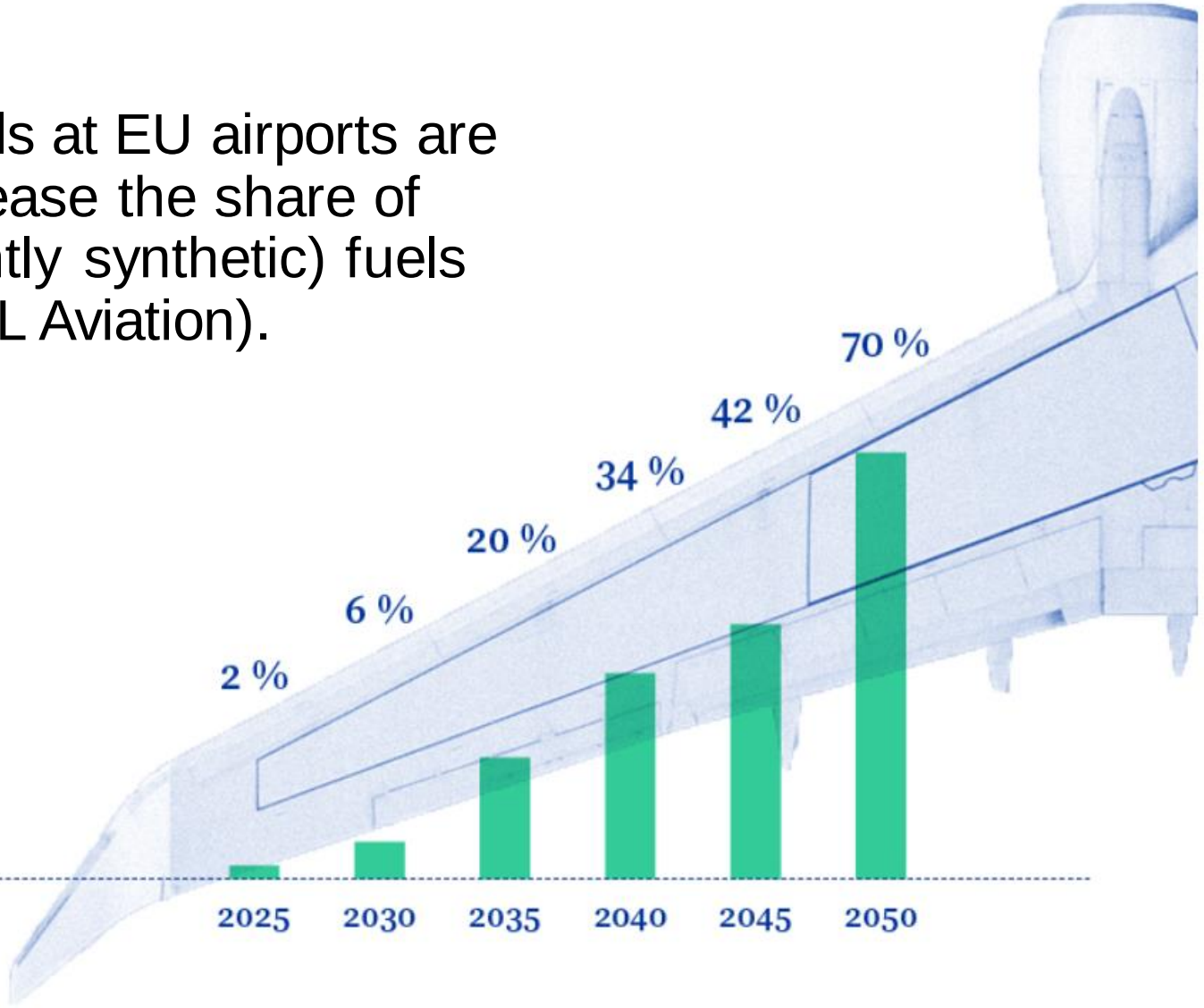
Civil Aviation: Net Zero Emission Target until 2050



Report Waypoint 2050 – Air Transport Action Group: https://aviationbenefits.org/media/167418/w2050_v2021_27sept_summary.pdf

Minimum SAF Share according to „ReFUEL Aviation“

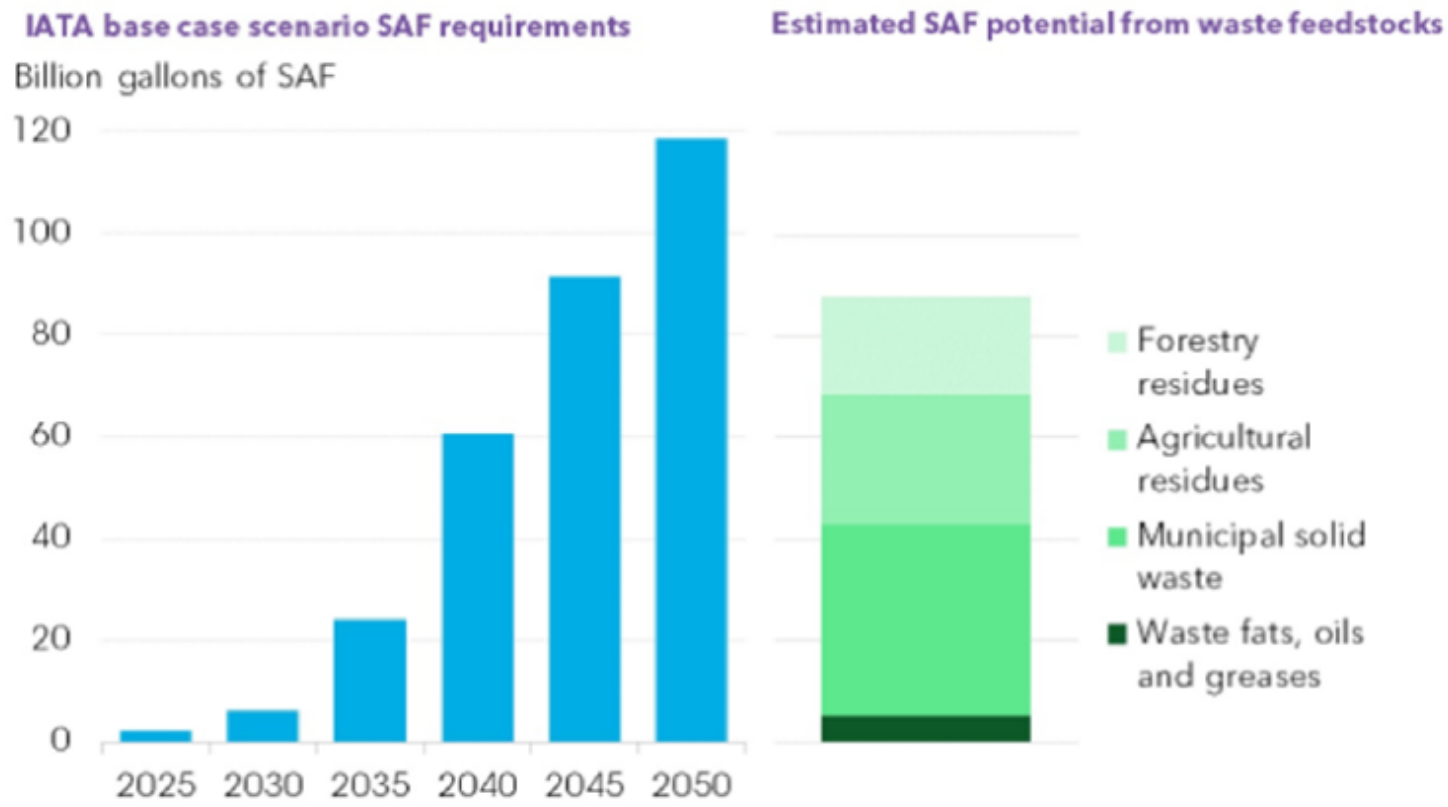
Suppliers of aviation fuels at EU airports are obliged to stepwise increase the share of sustainable (predominantly synthetic) fuels in their portfolio (ReFUEL Aviation).



Minimum share of sustainable aviation fuel [in %]

Sustainable Aviation Fuel (SAF) Demand Forecast

IATA SAF requirements and estimated SAF potential from waste feedstocks

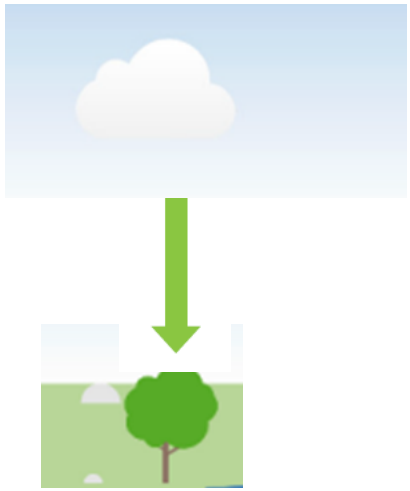


Source: BloombergNEF, IATA

Note: Feedstock estimates are conservative estimates of sustainable waste feedstocks, and do not include potential SAF supply from virgin vegetable oils.

Carbon Neutral SAF Production: Carbon Source

CO_2 Uptake



Direct Air Capture (DAC)

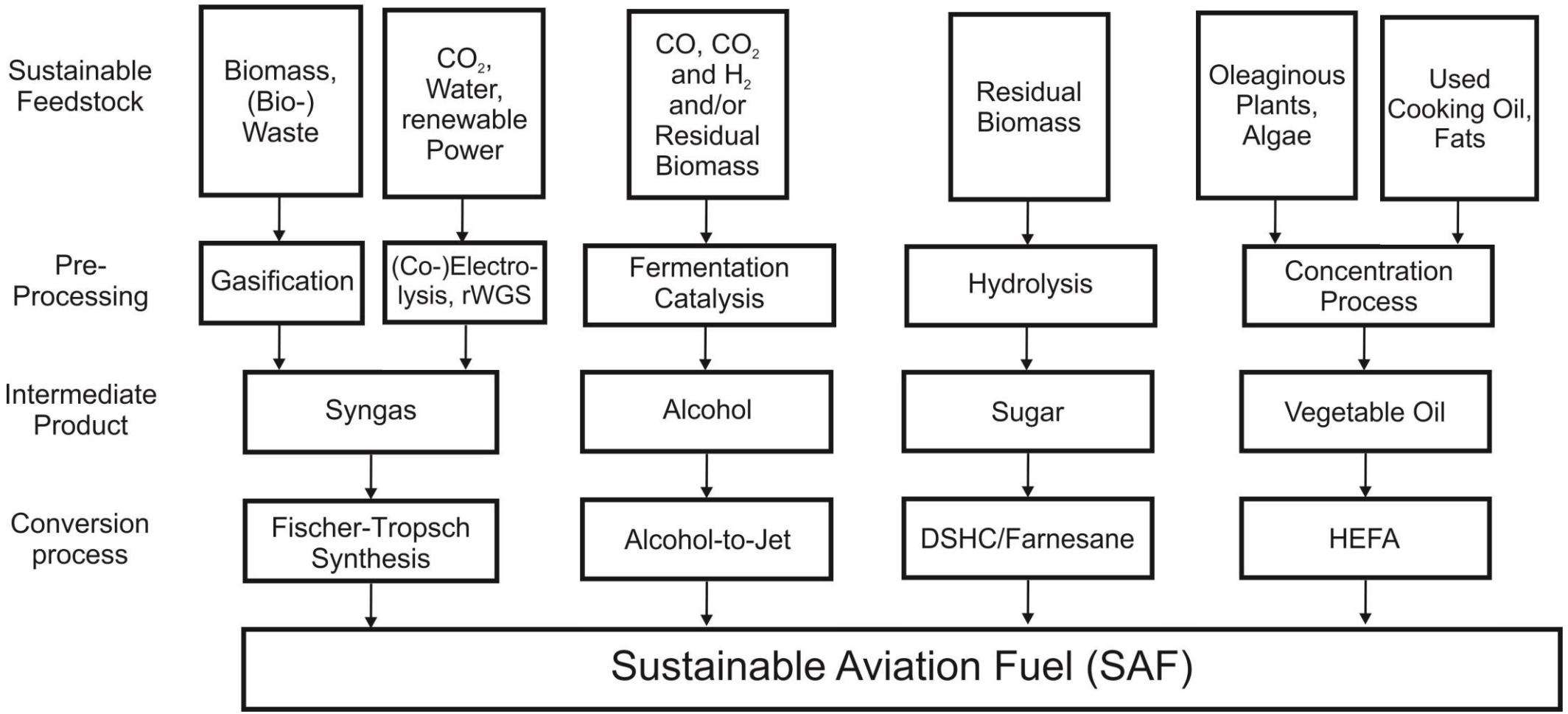
Utilization of Biomass

SAF Production

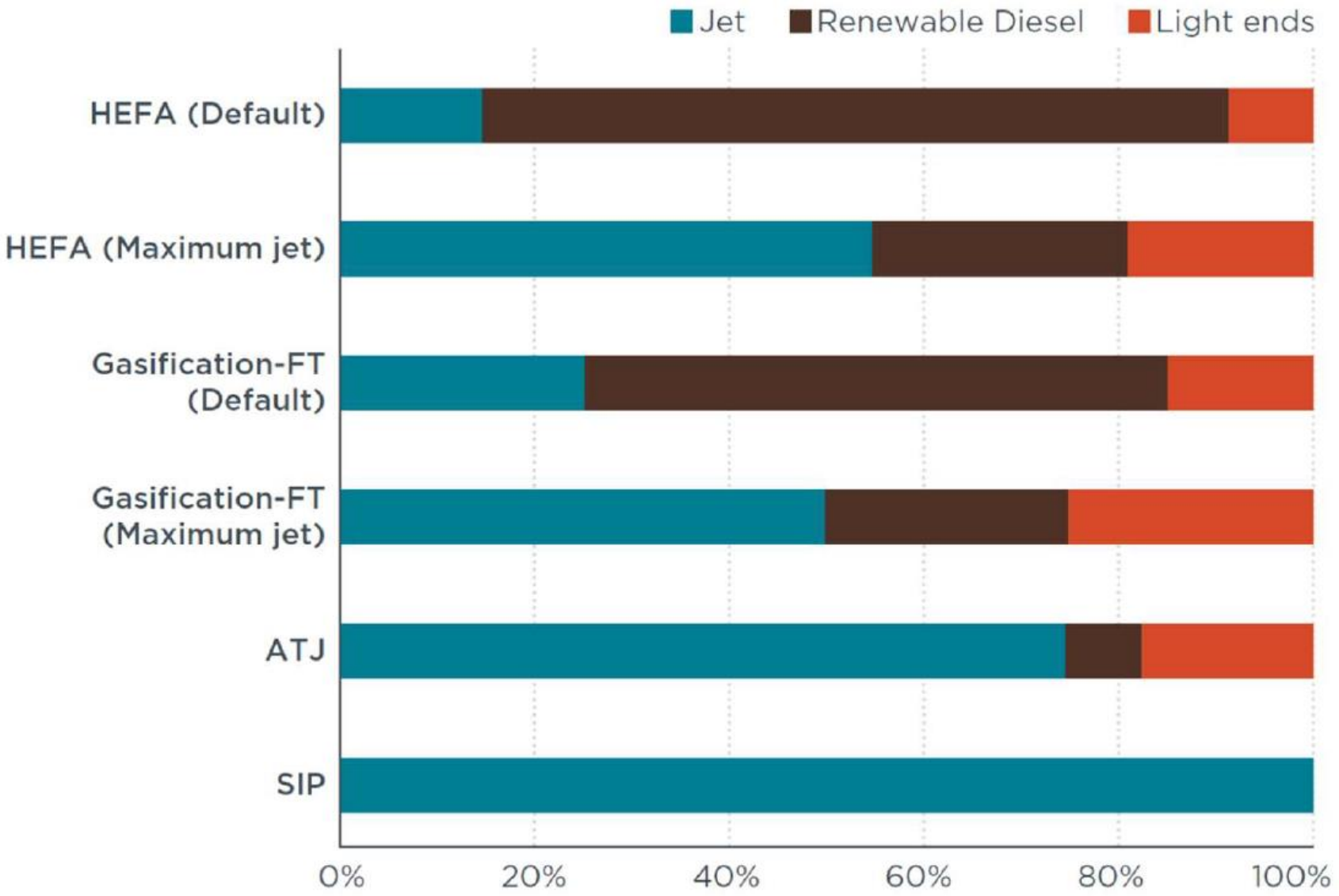
SAF Usage

CO_2 Release

SAF Production Options



Product composition of different SAF production routes

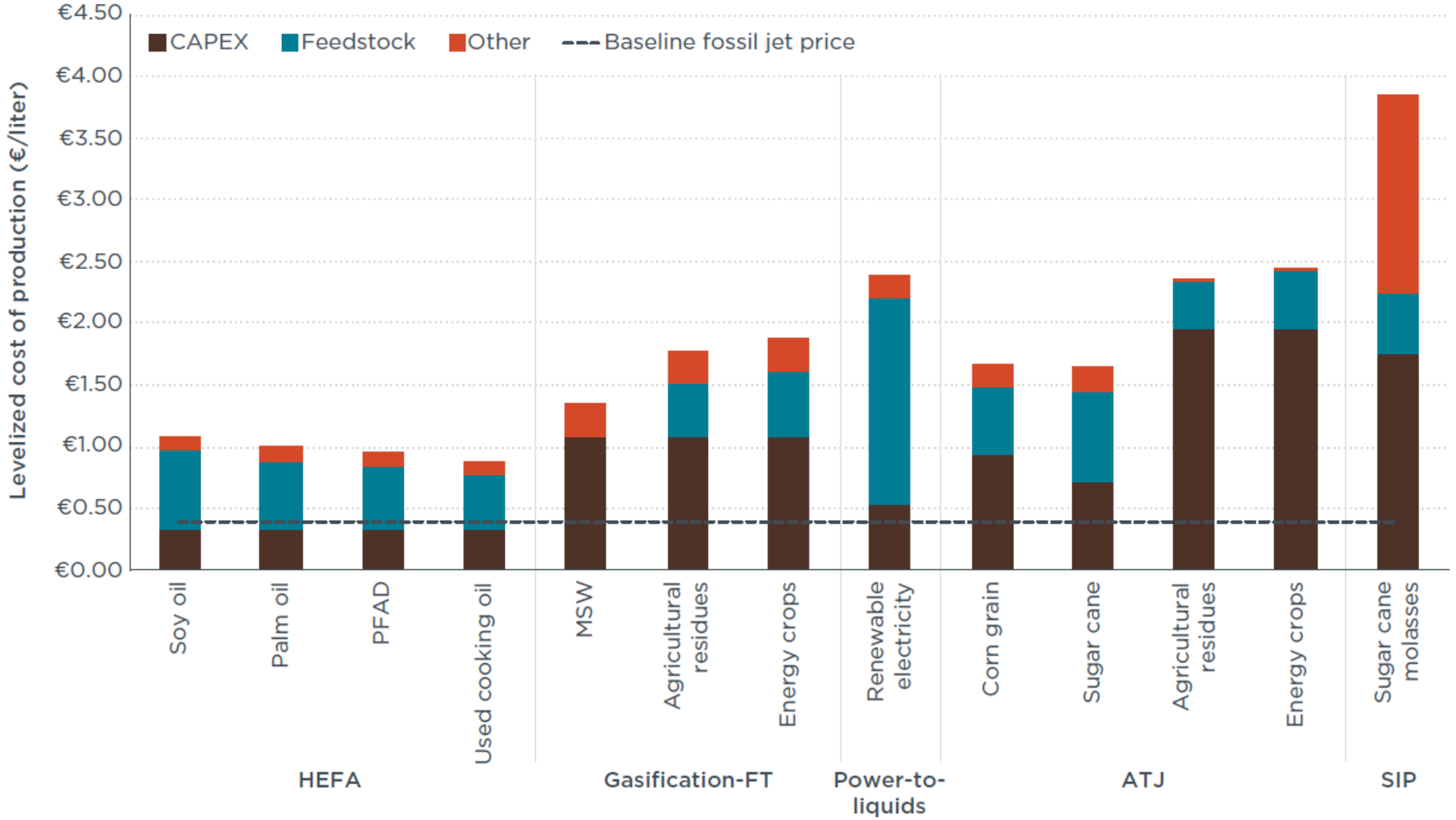


Source: IEA Energy Task 39, May 2021

ASTM D7566 Annex 1 – 8 certified SAF Fuels

Pathways and processes	Feedstock options	Producers (expl)	Date of approval	Blending limit
Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)	biomass (forestry residues, grasses, municipal solid waste)		2009	up to 50%
Hydroprocessed Esters and Fatty Acids (HEFA-SPK)	algae, jatropha, camelina	Alt Air	2011	up to 50%
Hydroprocessed Fermented Sugars to Synthetic Isoparaffins (HFS-SIP)	microbial conversion of sugars to hydrocarbon	Amyris	2014	up to 10%
FT-SPK with aromatics (FT-SPK/A)	renewable biomass such as municipal solid waste, agricultural wastes and forestry residues, wood and energy crops		2015	up to 50%
Alcohol-to-Jet Synthetic Paraffinic Kerosene (ATJ-SPK)	agricultural waste products (stover, grasses, forestry slash, crop straws) – feedstock: isobutanol and ethanol	Gevo LanzaTech	2016 2018	up to 30% up to 50%
Catalytic hydrothermolysis synthetic jet fuel (CHJ)	Triglyceride-based feedstocks (plant oils, waste oils, algal oils, soybean oil, jatropha oil, camelina oil, carinata oil and tung oil)	ARA and Euglena	2020	up to 50%
High Hydrogen Content Synthetic Paraffinic Kerosene (HHC-SPK)	biologically derived hydrocarbons such as algae	IHI World	2020	up to 10%
Alcohol-to-Jet Synthetic Kerosene and Aromatics (ATJ-SKA)	agricultural waste products (stover, grasses, forestry slash, crop straws) – feedstock: mixed alcohols	Swedish Biofuels	2023	up to 50% (target: 100%)

Costs of SAF Fuels



SAF cost relative to conventional at least twice the price of fossil jet fuel!

Source: International Council on Clean Transportation, Working Paper 2019-05

Current and announced SAF production facilities

Company	Technology pathway	Biojet vol MGPY (MLY)	Start-up date	
World Energy (Paramount)	HEFA	25 (95)	2020	
Neste (Porvoo)	HEFA	34 (128)	2020	
Gevo (Silsbee)	Isobutanol-to-jet	Demo	2020	→ Started in 2020
Total (La Mede)	HEFA	Not available	2020	→ Started in 2021
Fulcrum Bioenergy (Sierra)	Gasification/FT	7 (26)	2021	→ Started in 2022
Red Rock Biofuels (Lakeview)	Gasification/FT	6 (23)	2021	→ Testing in 2022
Neste (Singapore & Rotterdam)	HEFA	480 (1,816)	2022	→ Opened May 2023
SkYNRG (Delfzijl)	HEFA	33 (125)	2022	→ Still announcement
Lanzajet (Freedom Pines)	Ethanol-to-jet	10 (38)	2022	→ End of 2023
World Energy (Paramount)	HEFA	150 (568)	2022	→ 2024
Gevo (Luverne)	Isobutanol-to-jet	19 (72)	2023	
Go Sunshine (New Orleans)	HEFA	29 (110)	2023	
Fulcrum #2 (Indiana)	Gasification/FT	21 (80)	2023	
Readifuels	Catalytic hydrothermolysis	24 (91)	2023	
Phillips 66 (San Francisco)	HEFA	290 (1,098)	2024	
Total (Grandpuits)	HEFA	56 (212)	2024	
Preem (Gothenburg)	HEFA	~70 (265)	2024	
Lanzajet	Ethanol-to-jet	90 (340)	2024	
Velocys (Altalto, UK)	Gasification/FT	16 (60)	2025	

Source: IEA Energy Task 39, May 2021

Summary

- SAF is mandatory to achieve GHG emission reduction in civil aviation.
- Increasing SAF demand can only satisfied by application of different technologies and feedstock options.
- No production process yields only SAF.
- In view of limited resources and still high production costs, further process optimization and research is required.

Thank you for your attention!

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