H·C·S GROUP

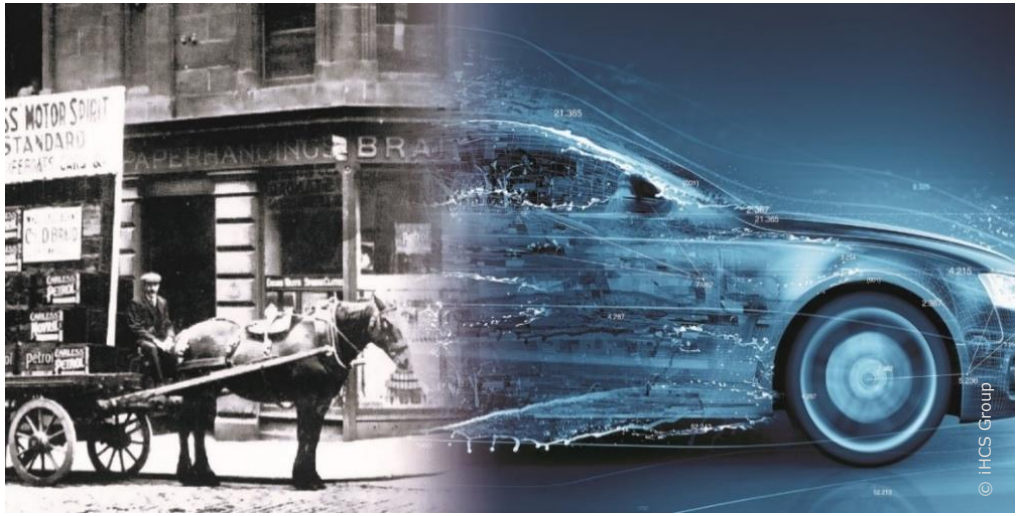
Alcohol to Jet (ATJ) – a future-proof route for SAF production

aireg | Dr. Harald Dialer | 12.12.2023

HCS Group – a pioneer in sustainable hydrocarbons

Breakthrough developments for more than 160 years

- A pioneer and leading global provider of high-value hydrocarbon solutions for Mobility, Life Science, Industrial and Energy
- Front-runner in defossilization – up to 100% renewable product offerings and circular solutions
- ISCC EU & ISCC PLUS certified; EcoVadis Gold-Status
- Long-term expertise in specialty chemicals, petrochemicals and biorefineries, combined with customized product developments
- Strong brands and products with leading market positions, serving local and global blue chip customers
- Decades of experience in large scale production (>500,000 mtpa) under audited quality standards



1859 - 2023

Haltermann Carless

ETS RACING FUELS

eos TRUSTED PURITY

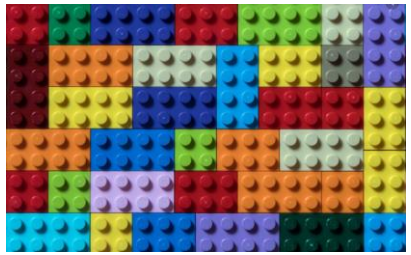
GOLD 2023 ecovadis Sustainability Rating

ISCC International Sustainability & Carbon Certification

Defossilization = Playing with renewable bricks

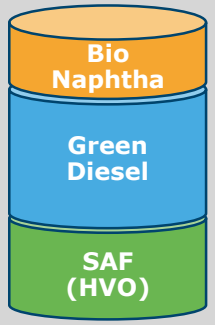
Examples in the world of SAF

- **HVO/HEFA Route – breaking down molecules, similarities with refining**



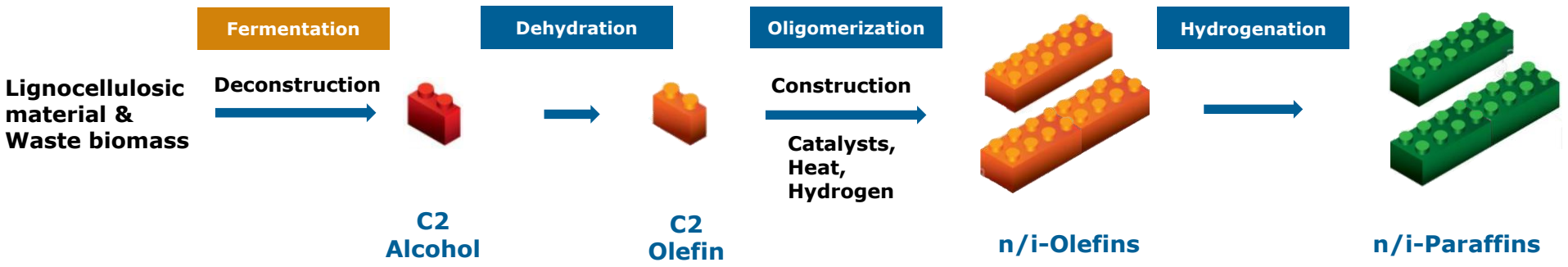
Deconstruction

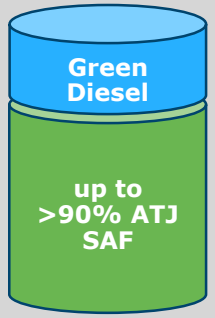
Catalysts, Heat, Hydrogen



Illustrative product spectrum

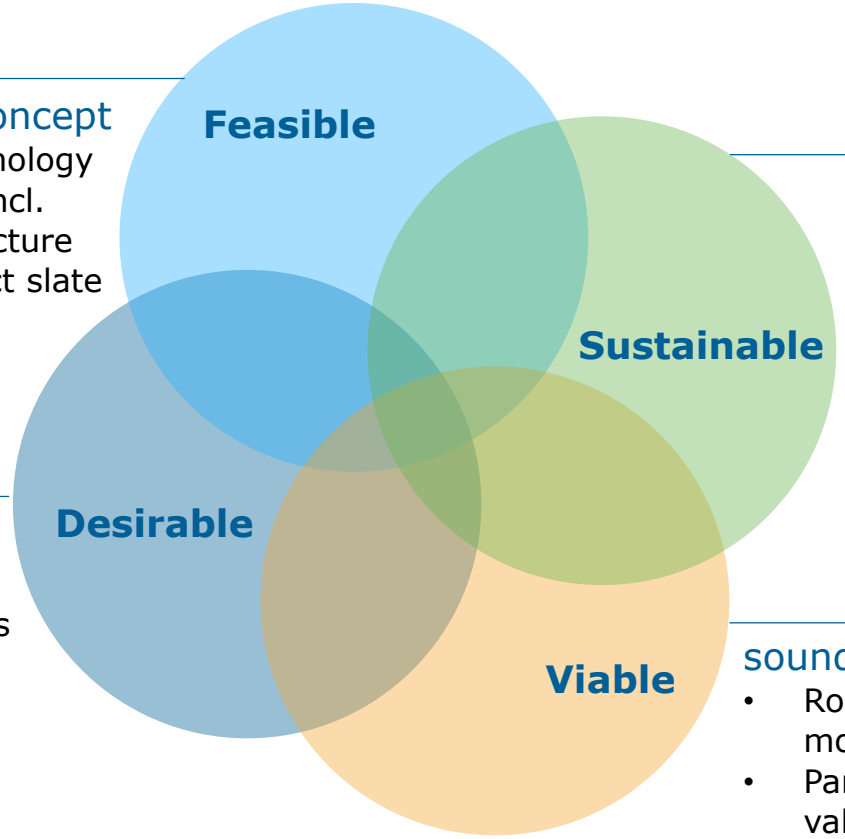
- **ATJ Route (example ETJ) – building up molecules selectively**





Illustrative product spectrum

ATJ SAF – key success factors



suitable technical concept
- Bankability of technology
- Strategic location incl. permits & infrastructure
- Flexibility of product slate

future-proof & right to play
- HEFA feedstock limitation will drive ATJ and other routes
- Access to advanced biomass feedstock (Annex IX) is key
- Minimization of CI
- Certified supply chains
- Strategic fit

actual demand / proof of market need
- Firm off-take commitments
- Demand signals across archetypes (commercial airlines, cargo, business aviation, fuel suppliers)

sound business model
- Robust commercial model
- Partnerships along value chain
- Financing
- Public funding

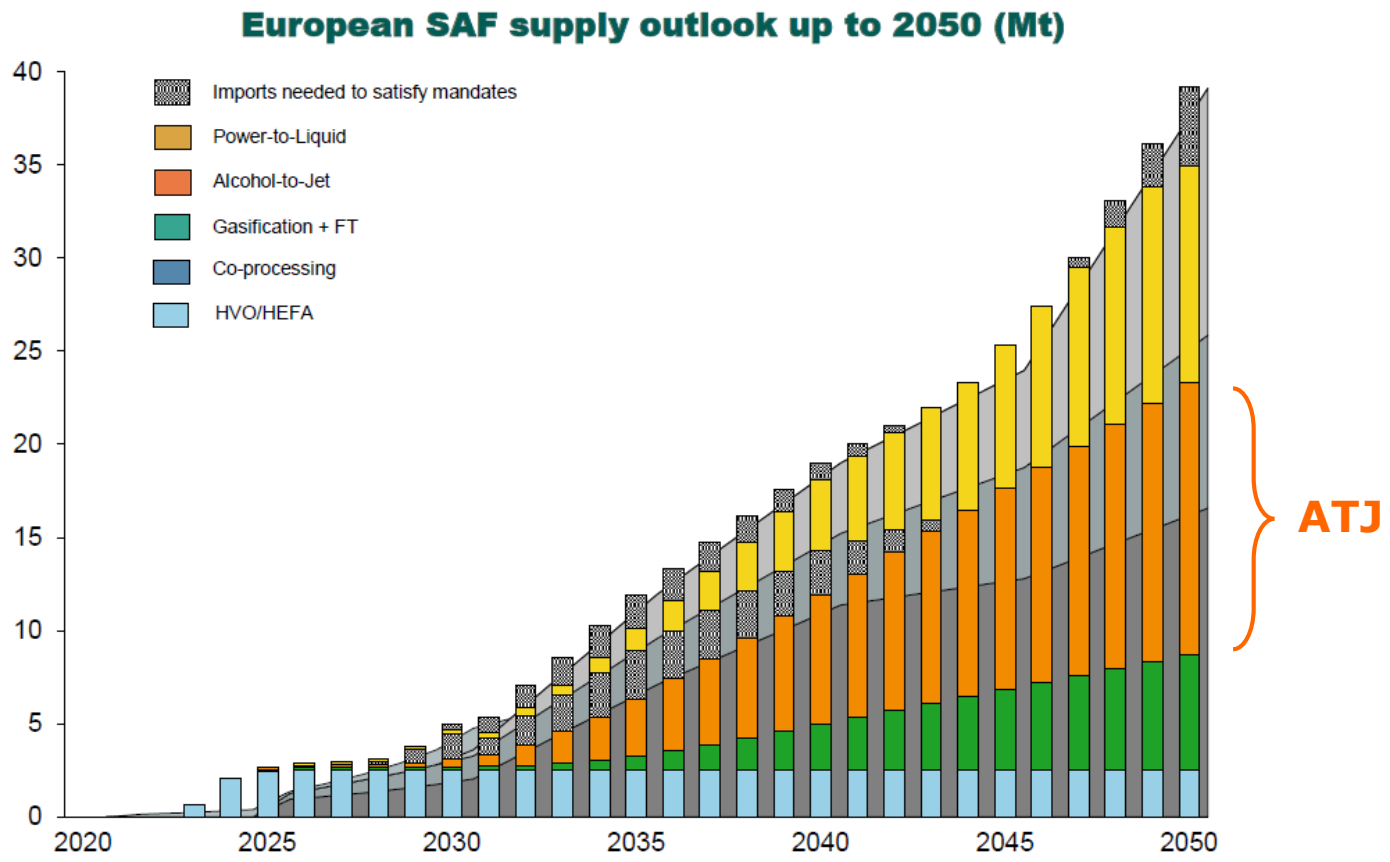
D SAF Desirability

D

Successful scale-up of SAF will require several technologies – ATJ is key

- EU Targets under Fit-for-55 and mandates for SAF blending translate to required European production of
  - 4.2 Mio. tons of SAF in 2030 for EU/UK
  - 40 Mio. tons of SAF in 2050 for EU/UK

- Openness for all key technologies HVO/HEFA, Alcohol-to-Jet, Gasification/FT and Power-to-Liquid is indispensable to ensure scale-up
- **Attractiveness of individual technologies varies significantly** dependent on regional factors like feedstock availability and access to low cost green hydrogen; HVO is limited to availability of UCO (Used Cooking Oil)
- Relevant volumes of **drop-in SAF before 2030** will only be possible from ASTM certified routes and primarily utilizing brownfield sites

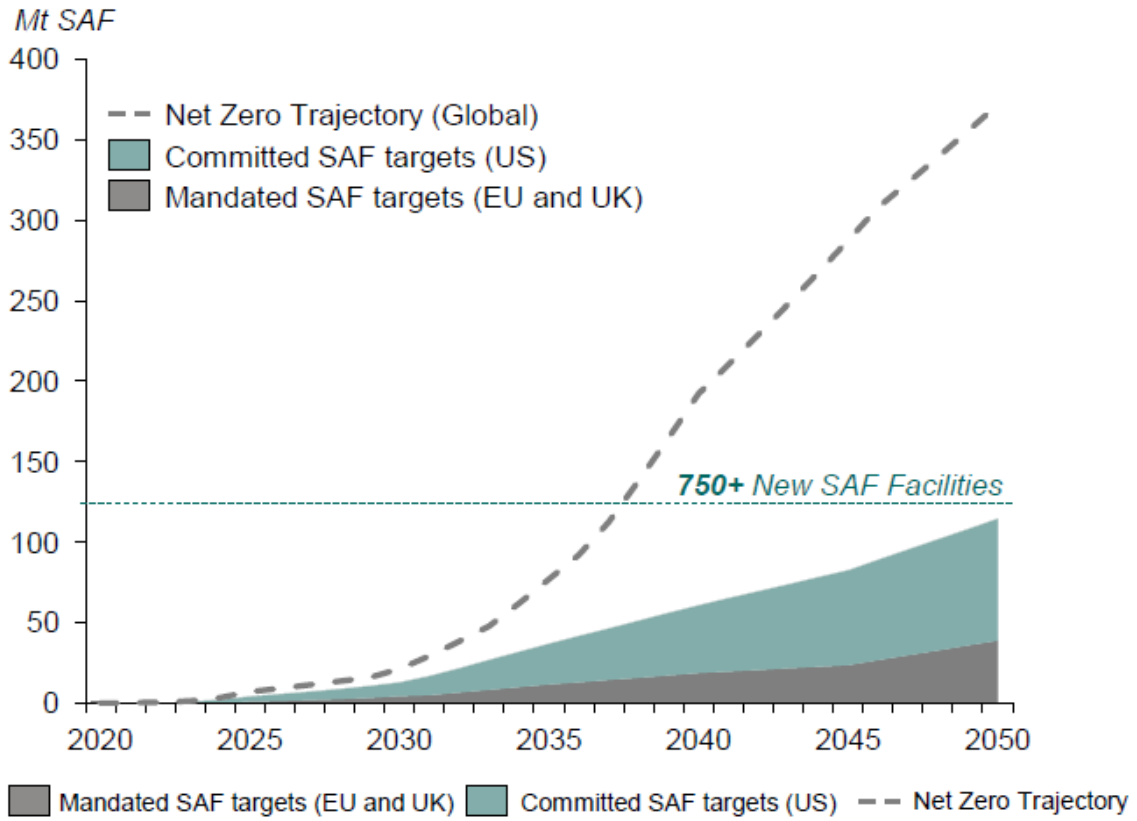


Source: SkyNRG SAF Forecast May 2023

D

Massive investments require entrepreneurial spirit, regulatory clarity and clear incentives

- **SkyNRG**
  - Projected 150 SAF refineries across Europe at a cost of $250 billion, or an annual average of $10 billion between 2025-2050
  - Projects that ~750 SAF plants are required until 2050 – only to meet Mandates and voluntary commitment in EU, UK and US
- **Shell**
  - Estimates globally required investment at $1.45 trillion over 30 years ($50bn y-o-y) for over 5,000 SAF production plants by 2050
  - Additional annual fuel costs of $38bn projected for a 10% SAF blend (fuel costs increasing from $192bn to $230bn) – compared to an overall total profit of the global aviation industry of $40bn in 2018
  - SAF cost projected for Germany in 2030: ~3.5bn EURO
  - SAF cost estm. for UK in 2030: ~3.0bn GBP



Source: Presentation Jan Toschka / Shell Aviation, December 6, 2022; SkyNRG SAF Forecast December 2022; ATAG Waypoint 2050

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Major investments are required to fulfill SAF targets

Putting things into perspective – how many new plants are required?

Annual production of 5 million tons of SAF in Europe 2030 would require

Atmosfair
Werlte, Germany
365 mtpa PTL
(existing)

x 13700

Nordic Electrofuel
Porsgrunn, Norway
8000 mtpa PTL
(in planning)

x 640

Published CAPEX estimate 175m€

HCS Group
Speyer, Germany
60,000 mtpa ATJ
(in planning)

x 80

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Neste
Porvoo, Finland
100,000 mtpa HEFA
(existing)

x 50

Gevo
Lake Preston, US
158,000 mtpa ATJ
(advanced stage)

x 30

Published CAPEX estimate $800m

HCS Group

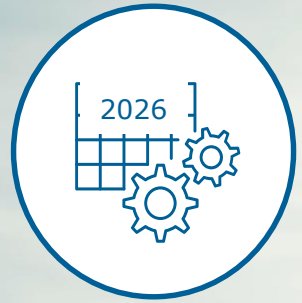
Source: Company websites; HCS analysis; Nordic Electrofuel announced 10 million Liters Syncrude ~ 8000 mt; Gevo announced 55 MGPY SAF ~ 158 ktpa,
Note: EU anticipated SAF mandate translates to ~40 Mt SAF in 2050

HCS Group is ready to contribute to defossilization in aviation

Project „Amelia“

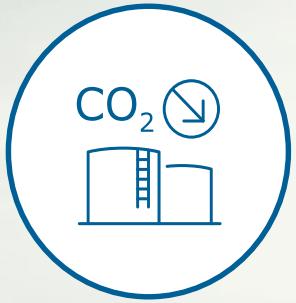
Objective: First large scale production of ATJ SAF in Germany with targeted output of 60,000 mt of ATJ SAF and renewable hydrocarbons by 2026

Timely



2026
Start of production

Effective



60,000 tons
Low Carbon Products

Local

Low carbon logistics
from the center of Europe

Future-proof

EU RED II/III
compliant

F

ATJ Feasibility

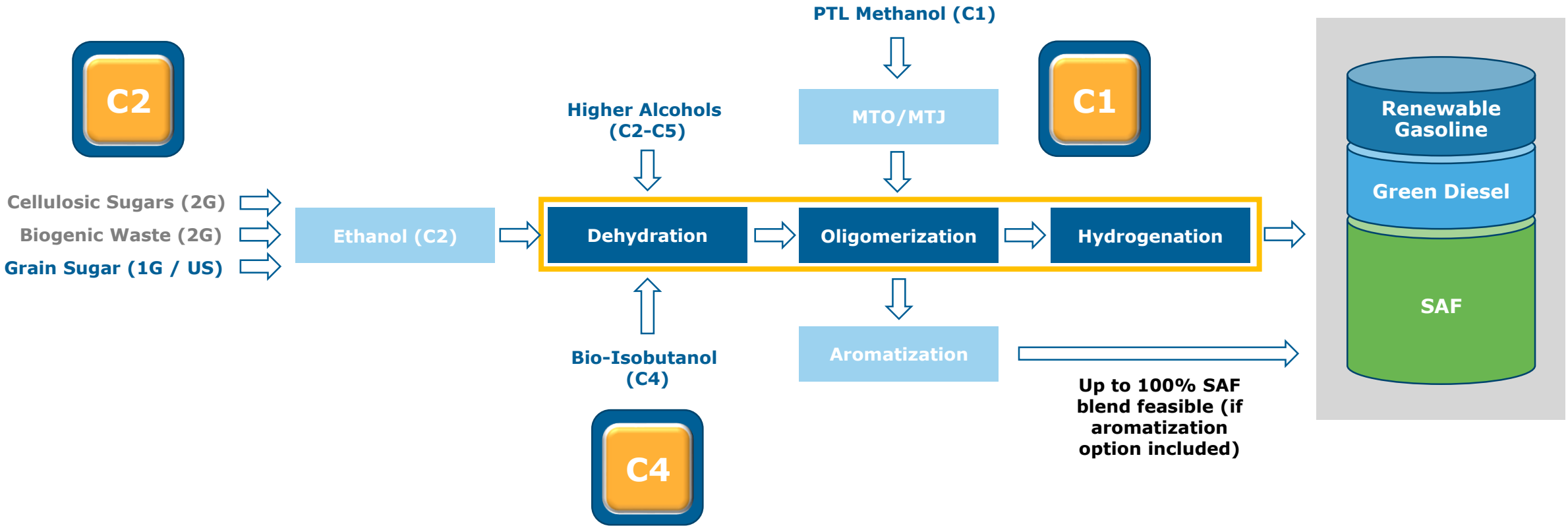
F

ATJ is a truly flexible platform technology

Future-proof route allowing conversion of biogenic alcohols and PTL methanol

Alcohol-to-Jet (ATJ) Process

Products



HCS Group

Source: HCS analysis

F

ATJ – a versatile route to high-value renewable hydrocarbons

C1

Licensors
- Topsoe
- UOP
- ExxonMobil
- CAC

Advantages/Challenges
- 80 renewable MeOH projects announced by 2030
- MTO type – high % of iso-paraffines
- MTG type – access to aromatic compounds
- Cost of PTL Methanol production in Europe
- ASTM pending

C2

Licensors
- Lanzajet
- Axens
- KBR/SB
- Lummus

Advantages/Challenges
- High SAF yield
- Bankability / Combination of proven unit operations
- Growing feedstock supply
- Competing applications of advanced ethanol

C4

Licensors
- Gevo
- GBE

Advantages/Challenges
- High isomeric purity of paraffines advantageous for specialty applications
- No IBA production in Europe
- Compatibility with Annex IX raw materials tbc

Source: HCS analysis

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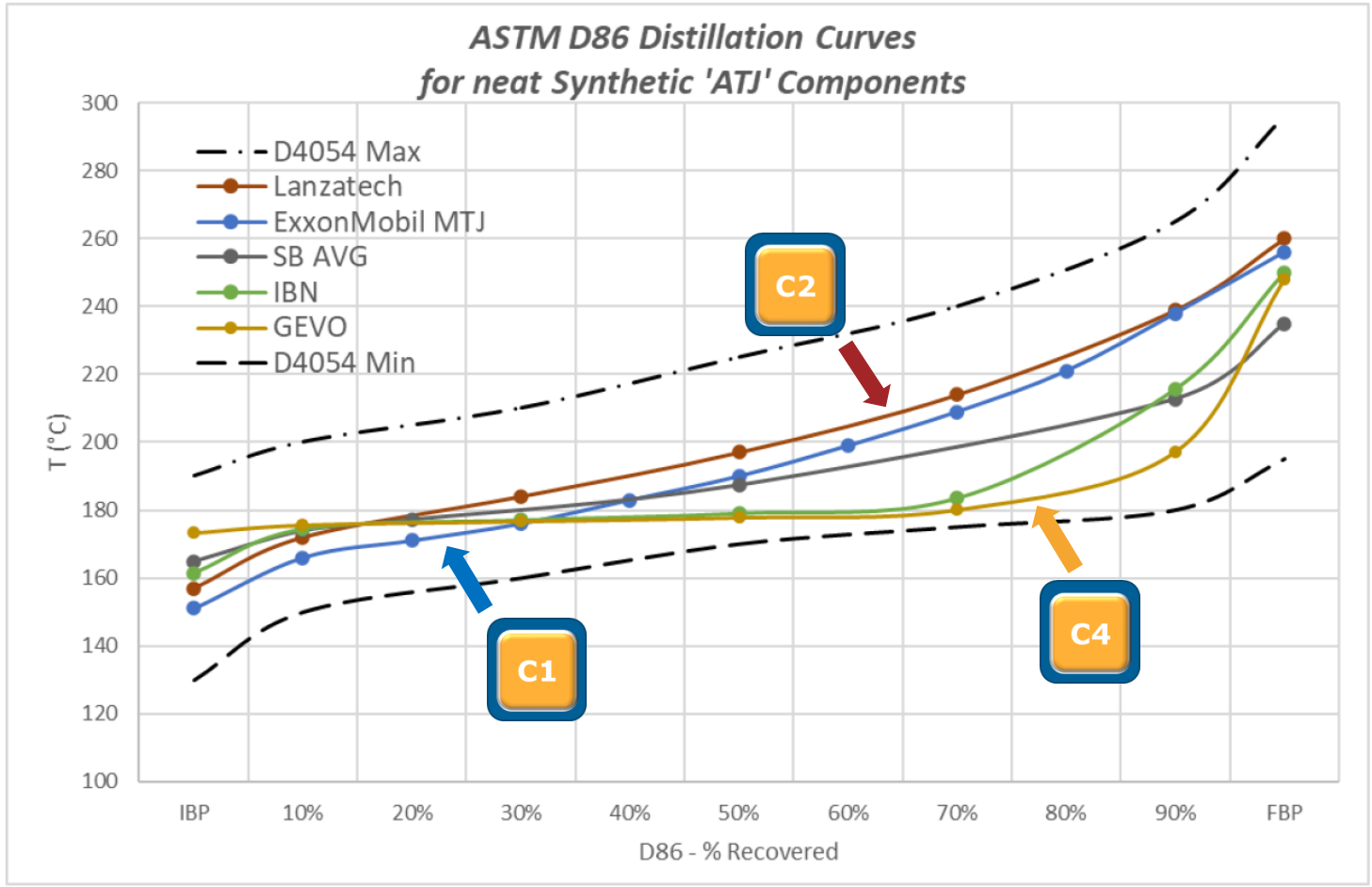
MTJ and ETJ can yield similar desirable product spectrum – more synergies to combine ATJ and PTL?

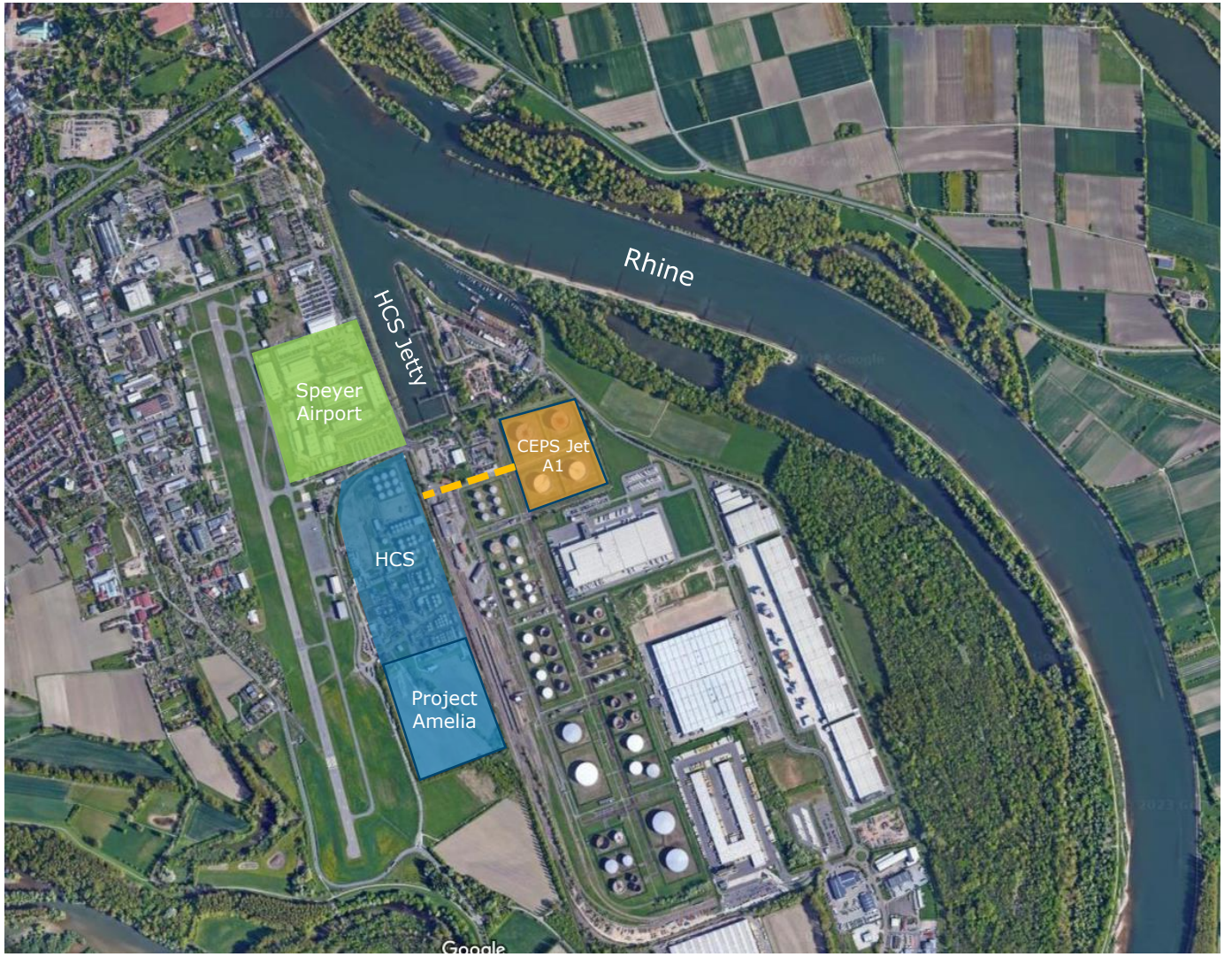


- ASTM Task Force AC724 report shows very comparable distillation curves for "MTO type" MTJ and ETJ, owing to selective oligomerization processes (low cyclo-paraffines, low n-paraffines, no aromatics)

Source: ExxonMobil CAAFI presentation July 25, 2023

F HCS Group's Speyer site is ideally positioned to supply SAF „Made in Germany"

Speyer cathedral, consecrated in 1061 it is the world's largest Romanesque church and an UNESCO World Heritage Site



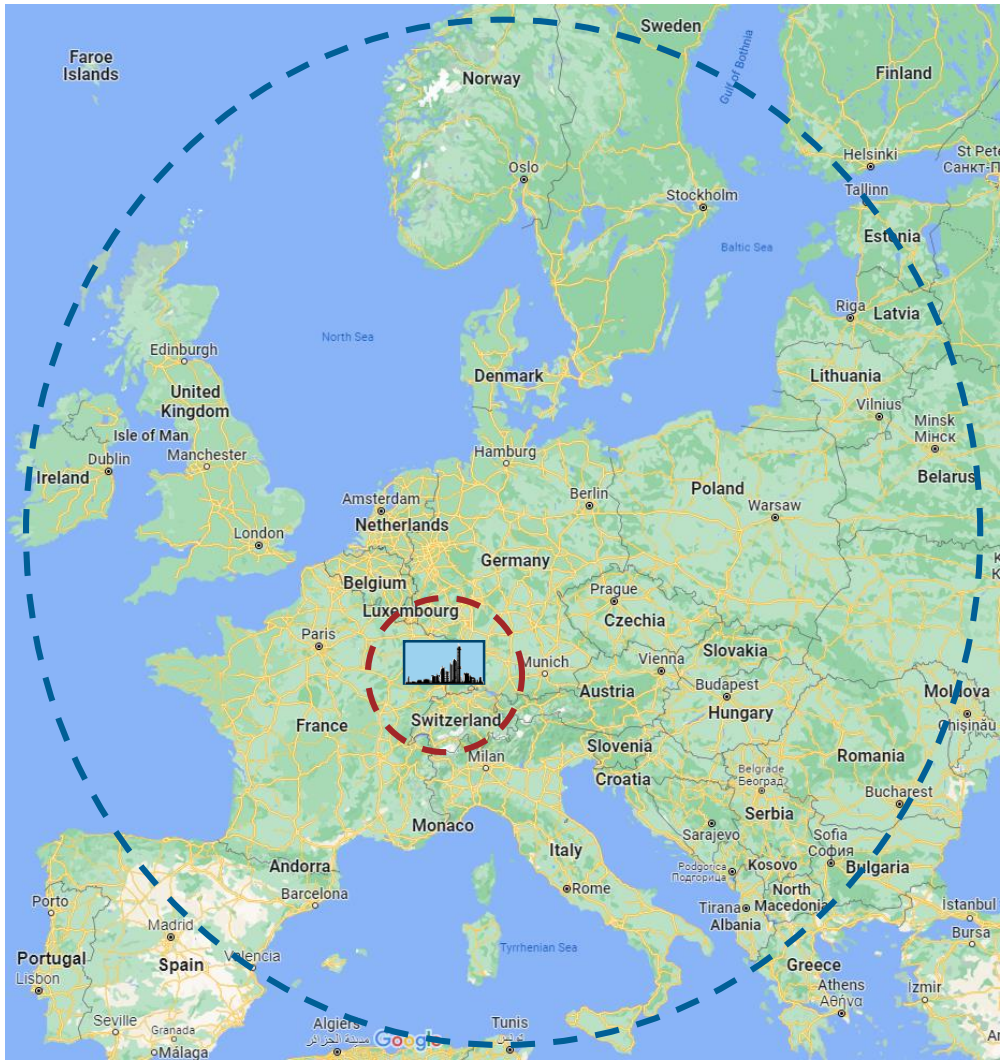
- **Strategically preferred location** directly on the Rhine, close to Frankfurt Airport & other key airports
- Permitted site with existing production of broad range of hydrocarbons Successful start up of new 100 ktpa hydrogenation plant in 2022 **Existing infrastructure and logistics** for raw materials and products (tanker trucks, railcars, barges)
- Significant advantage to lower overall investment cost and accelerate time-to-market

Goal: Certified supply chain from biomass to "tip-of-the-wing" to minimize emissions

S Sustainability

Focus on European waste biomass meeting Annex IX

Objective to certify entire European SAF supply chain from waste to tip-of-wing



Waste Feedstock for advanced biofuels already listed in RED II Annex IX:

- Biomass fractions of industrial waste not fit for use in food or feed chain
- Straw
- Biomass fractions of wastes and residues from forestry and forest based industries
- Other non food cellulosic material
- Other ligno-cellulosic material except saw logs and veneer logs
- Bagasse

Additional Waste Feedstocks considered by the EU to be added to RED II Annex IX (provisional):

- Fusel Oils
- Damaged crops not fit for food and feed
- Intermediate crops (contingent of no additional land use & other factors)
- Starchy waste effluents
- Bakery and confectionary residues
- Dextrose ultrafiltration retentate
- Vinasse

While ensuring ATJ feedstocks are in full **compliance with waste based raw materials approved under Annex IX**, HCS will utilize the additional **flexibility from potential new additions to Annex IX to minimize the radius of the supply chain** from biomass to tip-of-the wing

Haltermann Carless
Production Site Speyer

Target Radius (200 km) of biomass sourcing to minimize supply chain footprint

Total Radius of potential biomass sourcing (certified European raw material)

v Viability

v SAF Economics

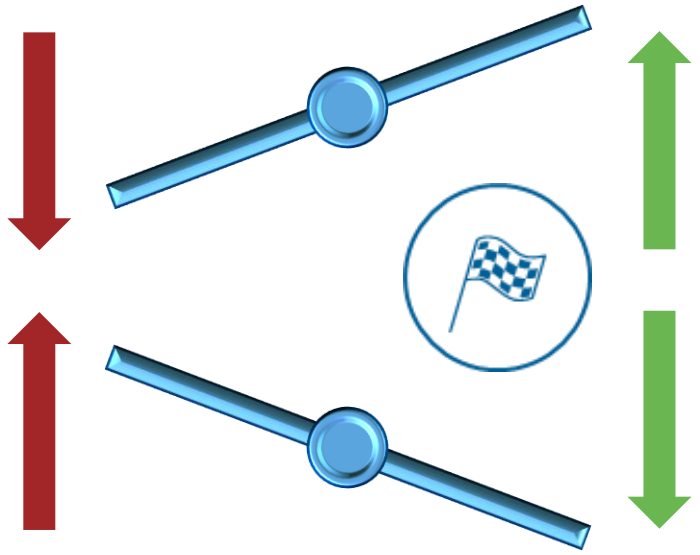
Key drivers for SAF Price and ATJ Feedstock Cost in Europe

Detractors

Regulatory
- Incomplete harmonization of regulations across Europe
- Incentives like double-counting favor advanced biofuels for road transportation over SAF

SAF Market
- Overcapacity for SAF due to faster project execution
- Significant imports of SAF compliant with RefuelEU Aviation and Annex IX
- Aviation stakeholders pay penalties for missing SAF quotas – and use excuse of insufficient SAF in market

Feedstock Supply
- Increased import of UCO from Asia
- Strong demand growth for advanced bio-alcohols from road transportation or other alternative uses
- Slow growth of Advanced Ethanol capacity



Promoters

Regulatory
- Regulatory clarity (e.g. REDII/III)
- Penalties for quotas implemented
- Book & Claim mechanism and certification EU measures to fight carbon leakage
- Public Funding

SAF Market
- Aviation stakeholders avoid penalties due to ESG and public perception issues
- HEFA SAF at maximum capacity, limited UCO
- Public-Private-Partnerships for SAF Production

Feedstock supply
- New global capacity for advanced feedstocks
- UCO from Asia stable with strict anti-fraud policies
- 1G Ethanol blending volumes unaffected and continued decline of gasoline usage

Commercial
- Long-term sales & supply agreements
- E2E index pricing formulas – decoupled from Jet
- Product mix of high value renewable hydrocarbons besides SAF
- Potential of bio-commodities hedging

Source: HCS analysis

Summary & Conclusion

SAF – Sustainable Aviation Fuel

Success factors to scale-up SAF in Europe

S
Security of investment

- Investor confidence requires **regulatory clarity** & coordinated approach in the EU
  - Stable framework (min. 10 y)
  - Regulatory clarity (RefuelEU, ETD, national laws)
  - Only one blending mandate
- Simplification and acceleration of SAF ramp-up via **book & claim** system
- Level Playing Field - instruments to **prevent distortions of competition and carbon leakage** e.g.
  - SAF levy for passenger flights in the EU
  - CO2 offsetting levy anchored in the European CBAM to prevent circumvention of the SAF quota obligations through non-EU hubs
  - Anti-tankering provisions

A
Access to feedstocks

- **Revision of RED II Annex IX** – the industry is waiting for clarity on provisional deal for Annex IX to additional waste feedstocks to support investments & volumes
- **ATJ is part of the solution** – "Lived" technology openness in policy making with stronger backing of advanced biofuels besides PTL is essential (sub-mandates for "Part A" biogenic SAF)
- **Clear sustainability criteria and independent certification** – customers demand high transparency re feedstock origin and GHG reduction
- **Strategic partnerships**
- Avoid cannibalization of raw materials with sectors that can be electrfied

F
Financing

- **Solve financing paradigm – EU mandates alone will not lead to sufficient investments**
- Business models to **increase "bankability" of off-take agreements**
  - Consortia and public-private partnerships
  - Long-term "take-or-pay"
  - De-coupling of pricing mechanisms from fossil Jet A1
- **Funding of breakthrough projects** to mitigate first mover disadvantage (ETS Innovation Fund, BMDV etc.)
- Government incentives to **generate a liquid SAF market** e.g. CfDs, double auction model like "H2Global"
- Reduce barriers to investment e.g. via low-interest subordinated loans and indemnity bonds

Lufthansa supports ATJ SAF “made in Germany”

LUFTHANSA GROUP

PRESS RELEASE

Frankfurt, August 01, 2023

Lufthansa Group and HCS Group sign Letter of Intent on the production and supply of Sustainable Aviation Fuel (SAF) ‘Made in Germany’

- **Lufthansa Group drives forward the market ramp-up and use of SAF as a core element of its sustainability strategy**
- **Production at the Haltermann Carless site in Speyer to start in 2026 with a volume of 60,000 tons per year**
- **SAF is a decisive technological key for more sustainable flying**

The Lufthansa Group and the HCS Group have signed a Letter of Intent (LoI) to partner on the production and supply of Sustainable Aviation Fuel (SAF). From the beginning of 2026, the HCS Group could supply the Lufthansa Group with SAF produced in the so-called Alcohol-to-Jet (AtJ) technology. The SAF, made from biogenic residues from agriculture and forestry, will be produced at the HCS Group production site in Speyer, operated by Haltermann Carless. SAF is a key element for more sustainable flying and thus for decarbonization in aviation.

H·C·S GROUP

Media Release

Lufthansa Group and HCS Group sign LOI to partner on the production and supply of Sustainable Aviation Fuel “Made in Germany”

The long-term cooperation on Sustainable Aviation Fuel (SAF) could enable Lufthansa Group and HCS Group to reduce carbon emissions in aviation as of early 2026. The fuel will be produced at the Haltermann Carless manufacturing site in Germany. SAF represents an important pillar on the path to decarbonisation in aviation.

Frankfurt a.M., Germany, 1. August 2023 – HCS Group and Lufthansa Group announced today that they have signed a Letter of Intent (LoI) on the production and supply of Sustainable Aviation Fuel (SAF), planned to start in early 2026. The SAF will be produced based on waste biomass from the agricultural and forestry sector at the HCS Group manufacturing site in Speyer, Germany, operated by Haltermann Carless. SAF is a key element for more sustainable flying and thus for decarbonisation in aviation.

Katja Kleffmann, Head of Fuel Management Supply Lufthansa Group: “We are very pleased to support SAF ‘Made in Germany’, produced near the Lufthansa Group’s main hub Frankfurt. Sustainable Aviation Fuels are a core element of our sustainability strategy. The LoI with HCS Group reflects our commitment to develop new SAF markets and to increase the availability of SAF – in this case in a logistically particularly favorable location close to the airport.”


Pioneering solutions
for a fossil free world.

H·C·S GROUP

PASSION PRAGMATISM PARTNERSHIP

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