

# Alcohol to SAF from the perspective of a European producer



# 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



# Famous Danish brands



MAERSK

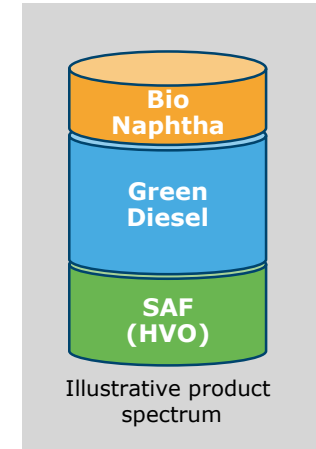
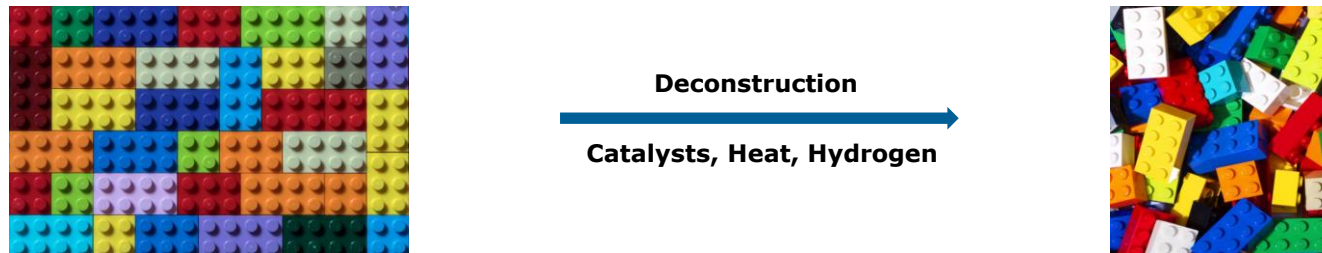


CARL HANSEN & SØN

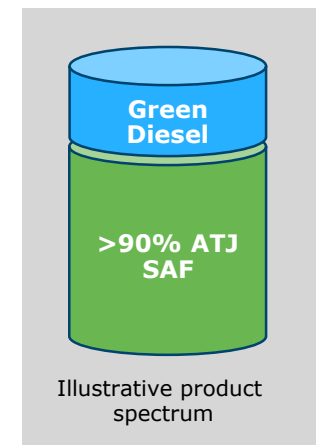
# Defossilization = Playing with renewable bricks

## Examples

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

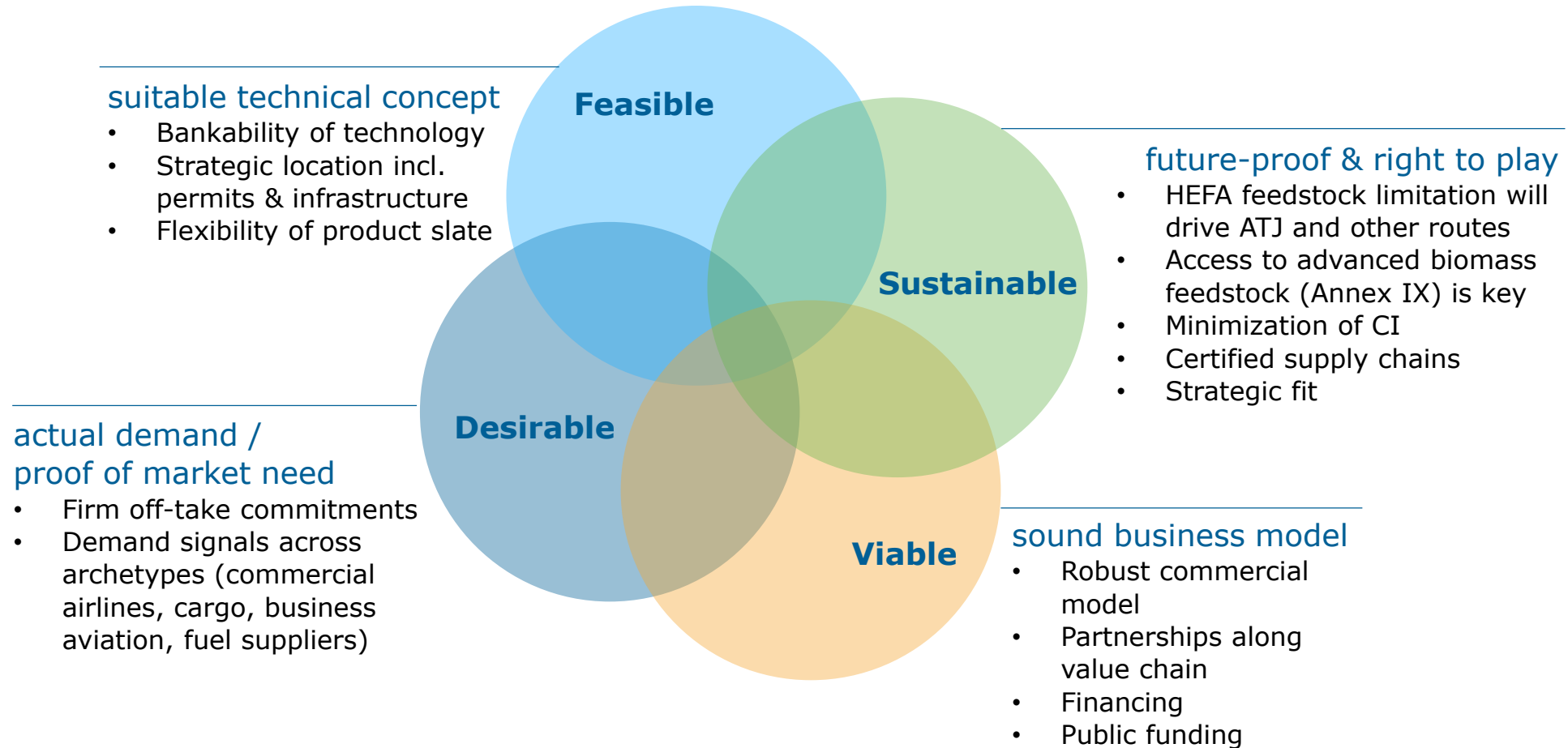


- ATJ Route (example ETJ) – building up molecules selectively



# Success factors for ATJ SAF in Europe

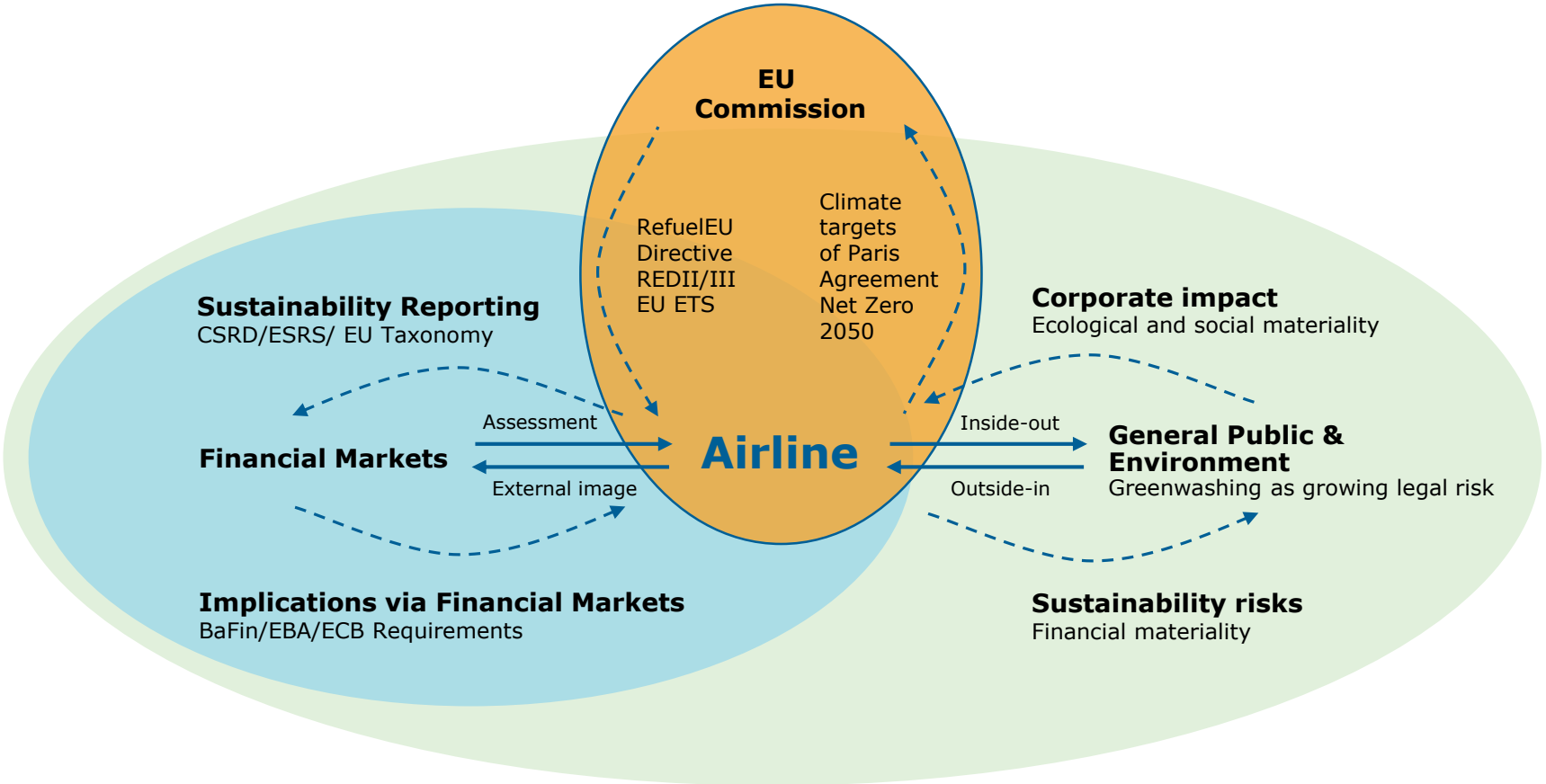
# ATJ SAF in Europe – key success factors



# **D** Desirability

D

# Airlines are under pressure...SAF is a key solution...





D

# ...and many carriers announced blending level above SAF mandates by 2030 and net zero by 2050

## Carriers to use 10% of SAF by 2030

Logos of carriers including: virgin atlantic, RYANAIR (12,5% of SAF by 2030), QANTAS, Lufthansa, IAG, Aer Lingus, BRITISH AIRWAYS, IBERIA, vueling, LEVEL, DELTA, ANA, ANA WINGS, CATHAY PACIFIC, SriLankan AIRLINES, Alaska AIRLINES, malaysia airlines, jetBlue (8% of SAF by 2030), S7 Airlines, American Airlines, FIJI AIRWAYS, ANA, JAL, JAPAN AIRLINES, ROYAL AIR MAROC, and ROYAL JORDANIAN.

## Carriers to become net zero by 2050

Logos of carriers including: IAG, Aer Lingus, BRITISH AIRWAYS, Lufthansa, UPS, IBERIA, vueling, LEVEL, DHL, scoot, American Airlines, DELTA, CATHAY PACIFIC, ROYAL AIR MAROC, S7 Airlines, SriLankan Airlines, SINGAPORE AIRLINES, FIJI AIRWAYS, RYANAIR, ANA, ANA WINGS, QANTAS, malaysia airlines, ANA, JAPAN AIRLINES, Southwest, ROYAL JORDANIAN, QATAR, Alaska AIRLINES, virgin atlantic, and norwegian.

## Carriers to use 2 billion gallons by 2030

Logos of carriers: Southwest and UNITED.

## Carriers to use 30% of SAF by 2030

Logos of carriers: FedEx Express, norwegian (16%-28% SAF by 2030), and DHL.



D

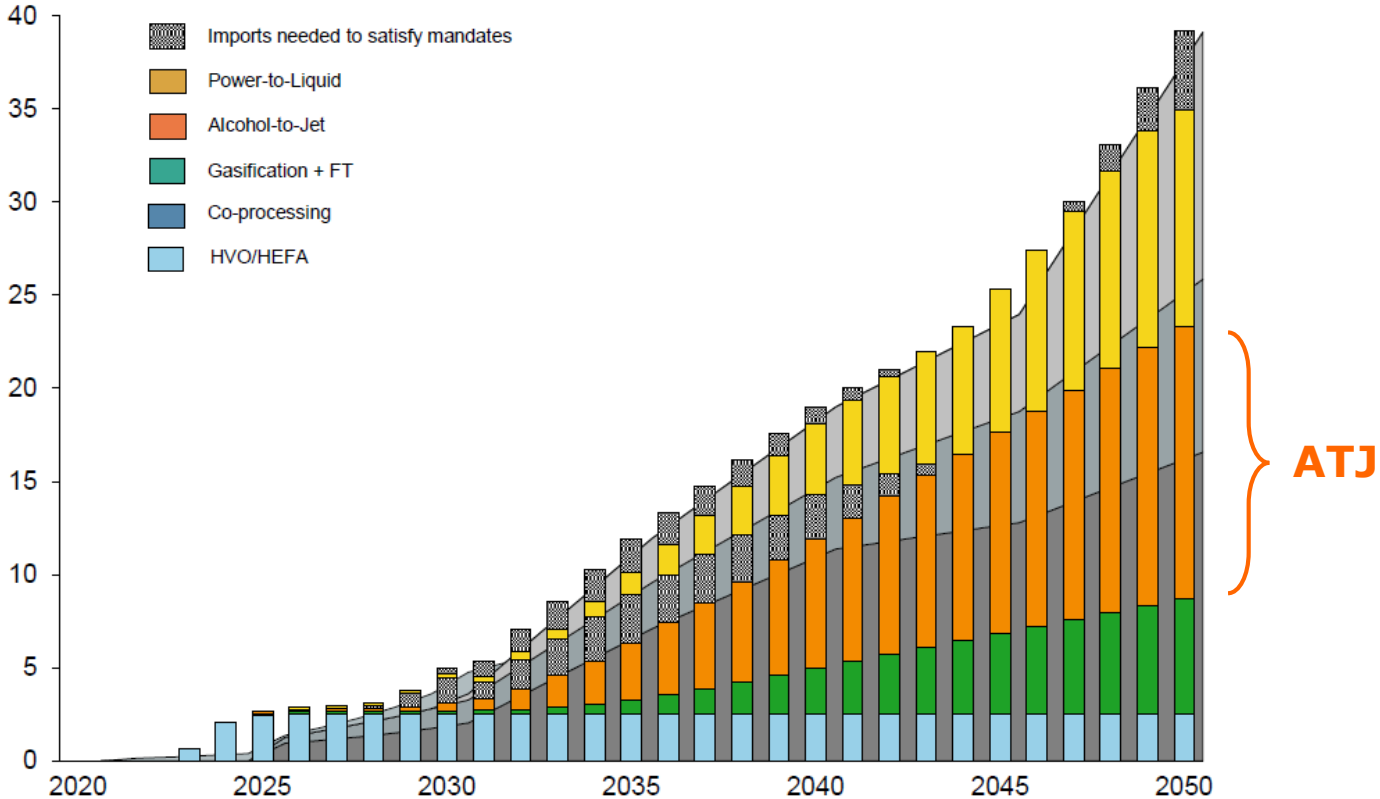
# Successful scale-up of SAF will require several technologies – ATJ is key

- 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



### European SAF supply outlook up to 2050 (Mt)



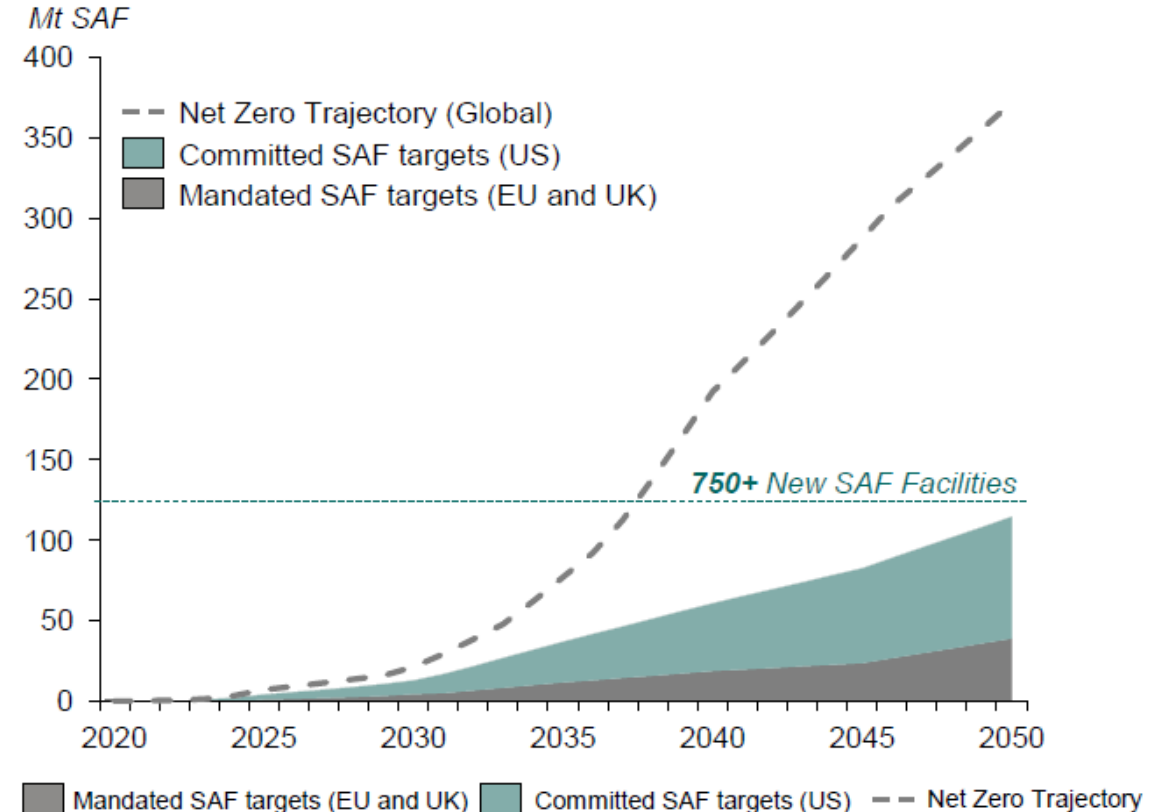
# Massive investments require entrepreneurial spirit, regulatory clarity and clear incentives

## ▪ 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





# 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)



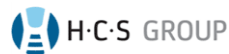
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Published  
CAPEX  
estimate  
175m€

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



**x 80**



**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

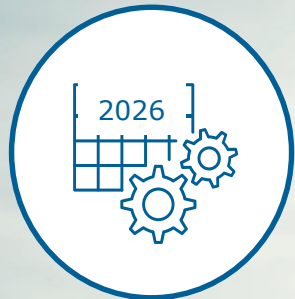
# HCS Group is ready to contribute to defossilization in aviation

## 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

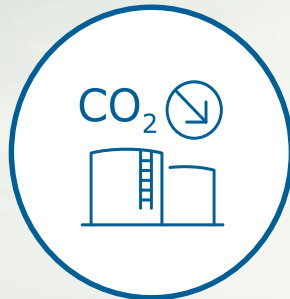


### Timely



**2026**  
Start of production

### Effective



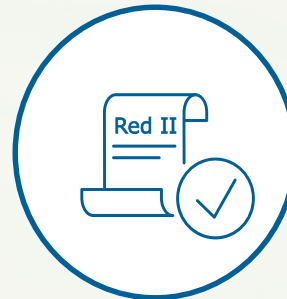
**60,000 tons**  
Low Carbon  
Products

### Local



**Low carbon logistics**  
from the center of Europe

### Future-proof



**EU RED II/III**  
compliant

# F Feasibility

# 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

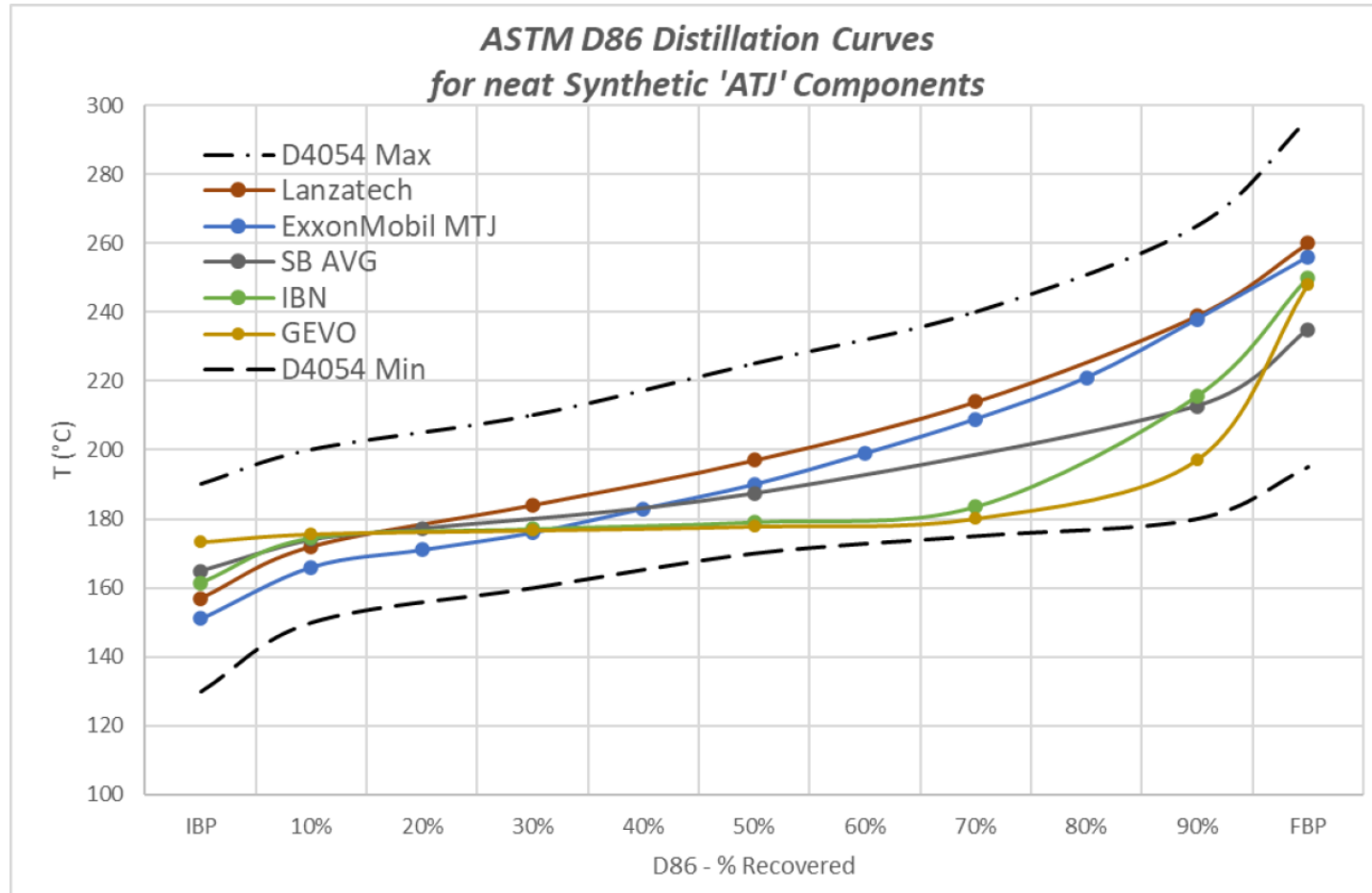
## Licensors

- 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

# 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)

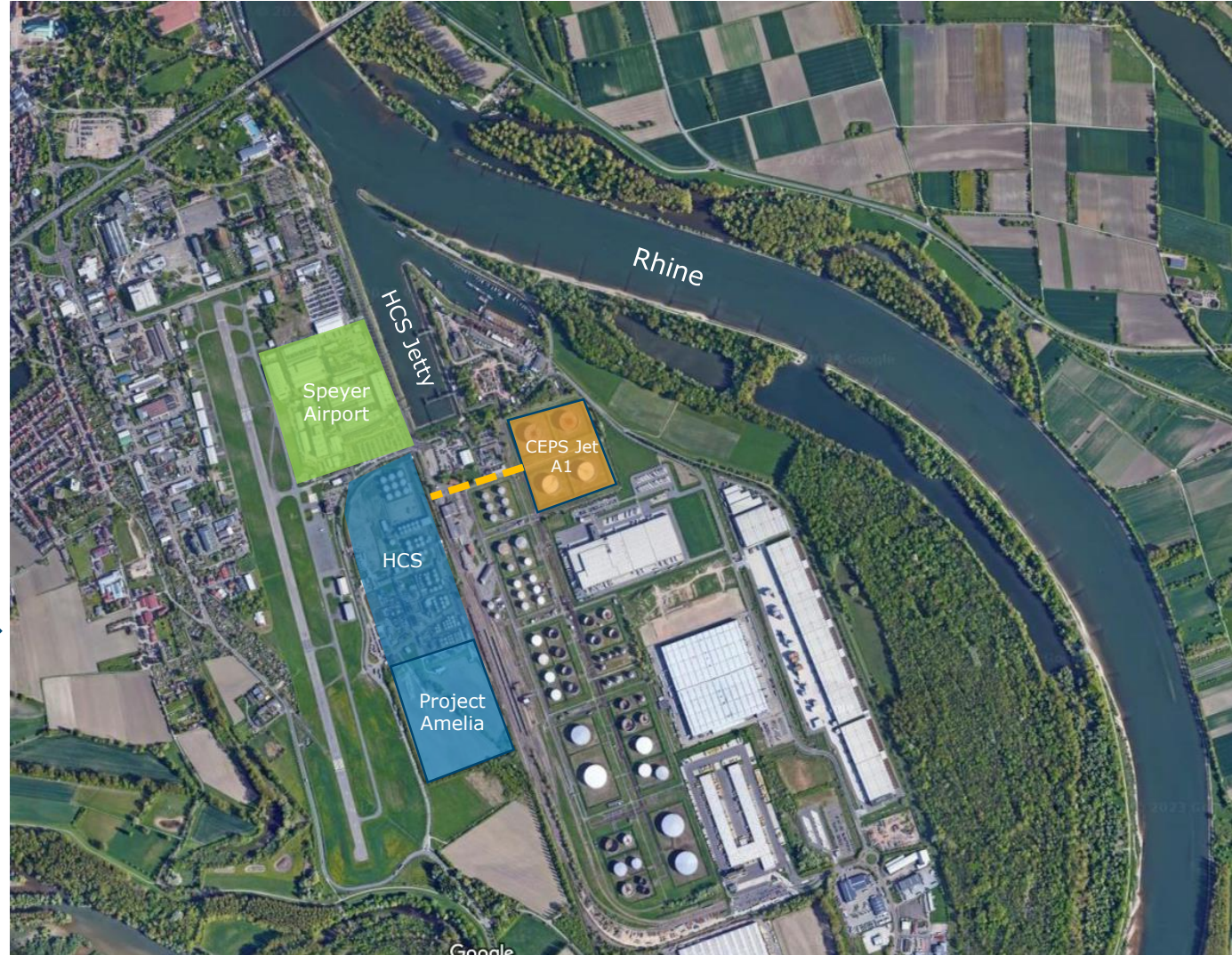


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# HCS Group's Speyer site is ideally positioned to supply SAF „Made in Germany“



**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



F

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





# **Sustainability**

# Alcohol-to-Jet: the future-proof SAF technology

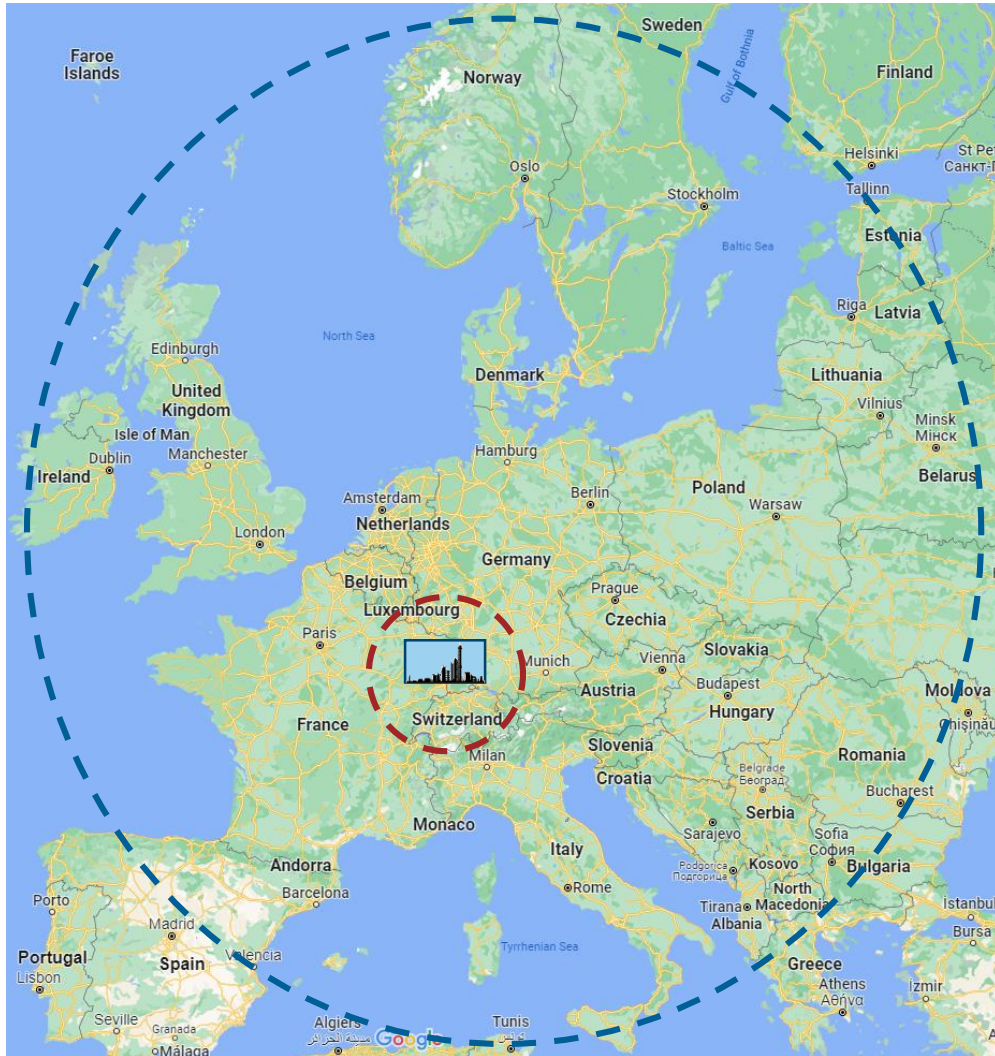
HCS Group utilizes ATJ technology offering multiple benefits

- ATJ is a **demonstrated and future-proof SAF technology**
- Allows **feedstock flexibility** (2G, waste and residue feedstock acc. to EU RED II Annex IX)
- **Sustainable availability for biofuel feedstocks in Europe** (lignocellulosic biomass, agricultural and forestry waste, cover crops)
- **Simple drop-in fuel solution** for existing aircraft utilizing airport infrastructure
- Immediate and significant carbon reduction with **demonstrated/certified Life Cycle Analysis (LCA)**
- Haltermann Carless has been **awarded ISCC EU and ISCC Plus Certifications**



# 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):

- Starch waste effluents
- Starch slurry
- Wheat and Corn residues
- Dry starch from fractionation
- Sugar production residues
  - Dextrose retentate
  - Dextrose raffinate
  - Sugar beet pulp
- 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

- — — Target Radius (200 km) of biomass sourcing to minimize supply chain footprint
- — — Total Radius of potential biomass sourcing (certified European raw material)





# SAF in the EU – many targets, no final clarity

Regulation	Status	Descriptions	2025	2030
ReFuelEU Aviation		<ul style="list-style-type: none"> <li>Mandate SAF blend target: at least 2% in 2025, 6% in 2030, 20% in 2035, 34% in 2040, 42% in 2045 and 70% in 2050<sup>1</sup></li> <li>Synfuel target: 1.2% in 2030, 2% in 2032, 5% in 2035, 15% in 2040, 20% in 2045, 35% in 2050</li> <li>To comply with SAF mandate fuels must (in general) be produced from feedstocks listed in Annex IX, Part A or Part B.</li> </ul>	<ul style="list-style-type: none"> <li>2% SAF</li> <li>1 million MT of SAF</li> </ul>	<ul style="list-style-type: none"> <li>6% SAF</li> <li>1.2% synfuel</li> <li>4.1 million MT of SAF</li> </ul>
RED II		<ul style="list-style-type: none"> <li>SAF must achieve 65% of GHG reduction and can not be produced from raw materials originating from high biodiversity land, high carbon stock land and land that was peatland in January 2008</li> <li>Minimum share of 14% renewables in transport (bio-fuels from Annex IX A&amp;B will be double counted for road use and 1.2x for aviation but be limited to a maximum of 1.7% from Part B and a minimum of at least: 1% by 2025 &amp; 3.5% by 2030 of Part A.</li> </ul>	<ul style="list-style-type: none"> <li>Constrains types of feedstocks used in SAF production</li> <li>Draft Revision of RED II Annex IX has been published with additional feedstocks proposed though most additions in Part B. No associated change has been made to maximum share of Part B though discussions are ongoing to provide member state discretion (double flexibility).</li> </ul>	
RED III (revision of RED II as part of <i>Fit for 55</i> )		<ul style="list-style-type: none"> <li>Requires 14.5% GHG emissions intensity reduction in transport</li> <li>Member states may increase the limit of 1.7% from Part B taking into account the availability of feedstock.</li> <li>Double counting for road use is maintained for parts A&amp;B, but for aviation only Part A is at a 1.2x Multiplier</li> </ul>	<ul style="list-style-type: none"> <li>Widens feedstock availability – particularly with new feedstocks appearing in Part B.</li> </ul>	
EU Emission Trading System (ETS)		<ul style="list-style-type: none"> <li>Total allowance for aviation was about 24.5 million in 2021, the total number will be reduced by 25% in 2025, by 50% in 2025 and to be completely removed in 2026</li> </ul>	<ul style="list-style-type: none"> <li>~€160-240/ton ETS cost for using A1 jet fuel<sup>2</sup></li> </ul>	<ul style="list-style-type: none"> <li>~€220-320/ton ETS cost for using A1 jet fuel<sup>3</sup></li> </ul>
Energy Taxation Directive (ETD)		<ul style="list-style-type: none"> <li>Tax for aviation jet fuel assessed to be introduced gradually to reach at least €10.75/GigaJoule by 2030 for intra-EU flights</li> </ul>	<ul style="list-style-type: none"> <li>~€230/ton ETD cost for using A1 jet fuel</li> </ul>	<ul style="list-style-type: none"> <li>~€470/ton ETD cost for using A1 jet fuel</li> </ul>

Renewable Energies Directive (RED)

Passed Proposal



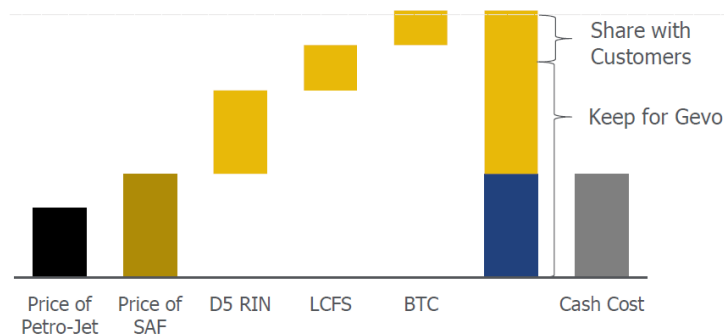
# SAF in the US – large carrots, small stick

CLARITY<sup>ST</sup>



## Clear Value of Sustainability „Value Stack“

- Renewable Fuel Standards (RFS)
- Low Carbon Fuel Standards (LCFS)
- SAF Tax Credits
- Can be shared partially with customers



## Sustainable Aviation Fuel Grand Challenge

- **Target of 9 million tons of SAF (3 bn gallon) in 2030** (20% lower emissions from aviation)
- **Target of 100 Mt SAF (35 bn gallon) SAF in 2050** - equivalent to 100% SAF use
- US Congress passed "Sustainable Skies Act" and "**US Inflation Reduction Act**" to accelerate scaling of SAF production through tax incentives (**\$1.25- \$1.75 per gallon tax credit dependent on lifecycle GHG emissions**)
- No imports accepted
- **IRA represents major challenge for Europe, but Life Cycle Analysis discussion, i.e. GREET vs. CORSIA**, adopted by the International Civil Aviation Organization (ICAO), could put pressure on existing crop based feedstocks
- Large SAF projects currently primarily in USA (Shell, World Energy, Gevo, Lanzajet, etc.)

# **Viability**





# 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

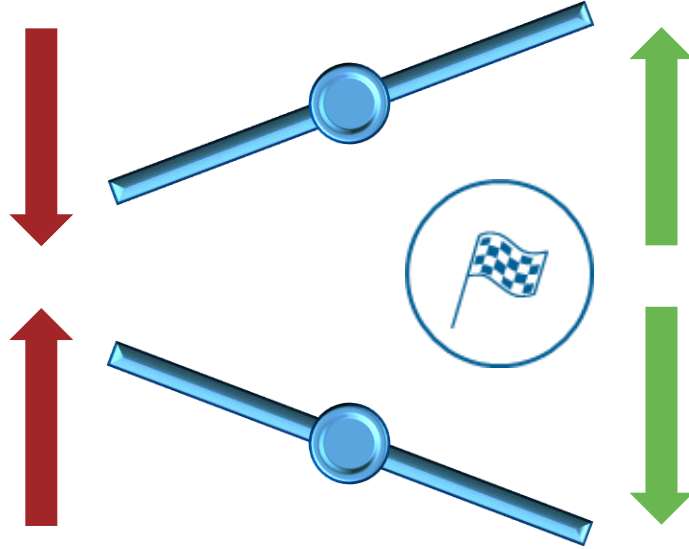
#### SAF Market

- 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

### SAF Price



### Feedstock Cost

### 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

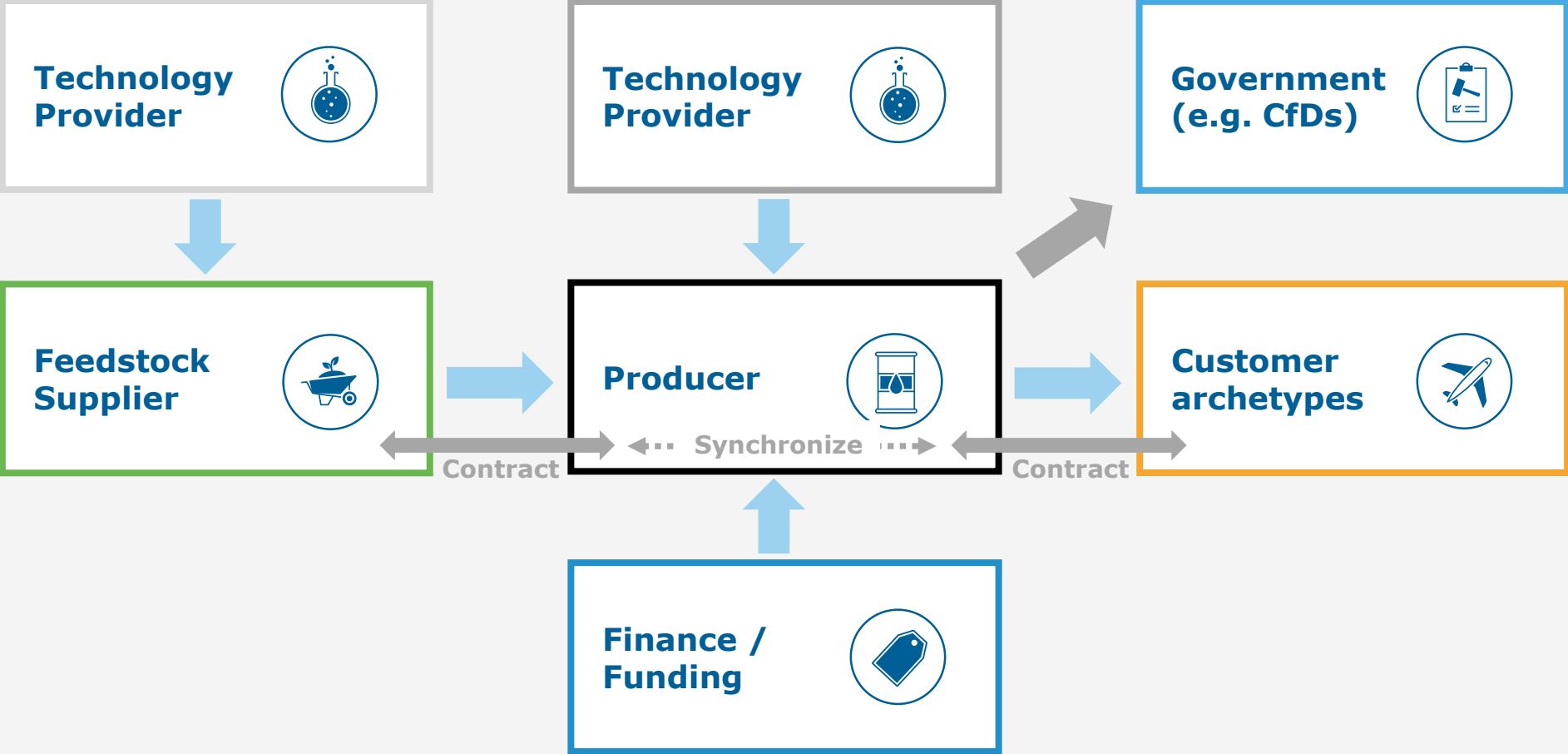
#### Commercial

- 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



# New business models and consortia can help drive SAF ramp-up

Large stakeholder space allows for **different business models, commercial arrangements and consortia** along the value chain to de-risk investment and accelerate time-to-market



# 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 (new sub-mandates for “Part A” biogenic SAF right step)
- **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 electrified

### 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

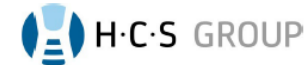
Frankfurt, August 01, 2023



### 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.



## 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.”



H·C·S GROUP

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**PASSION PRAGMATISM PARTNERSHIP**

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