TRENDS IN BIOFUELS:
RECAP OF 2025 ACROSS REGIONS AND TECHNOLOGIES

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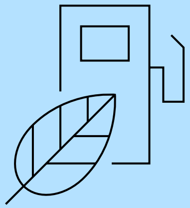
Future of Biofuels 2025, Gothenburg

TOPSOE

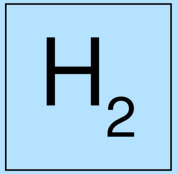
TOPSOE AT A GLANCE: OVER 80 YEARS OF INNOVATION AND LEADERSHIP

For more than 80 years, we have been guided by our purpose, **'Perfecting chemistry for a better world'**. We work to deliver solutions that will leave the world in better shape for future generations.

Today, it is our ambition to lead the global transition of hard-to-abate sectors to a net zero future.



Renewable fuels



Low carbon hydrogen

2,800

Employees

$1B

In revenue

(USD)

8.6%

Of revenues invested in R&D

+500

Patent families

PROJECTS DEFINING ENERGY TRANSITION

WITH INDUSTRY LEADING CARBON EMISSION REDUCTION TECHNOLOGIES FROM TOPSOE

Topsoe will support HOLBORN Europa Raffinerie GmbH in production of Sustainable Aviation Fuel (SAF) and renewable diesel at its plant in Hamburg.

Aramco will produce low-carbon hydrogen using Topsoe's ground-breaking eREACT™ technology in Aramco's Shaybah NGL facility.

Topsoe will support Preem, Sweden's largest fuel company, with production of Sustainable Aviation Fuel (SAF) and renewable diesel, using Topsoe's HydroFlex™ technology.

First Ammonia will be using Topsoe's Solid Oxide Electrolyzer Cell technology (SOEC) to produce green ammonia in the U.S.

ExxonMobil is building the world's largest low-carbon hydrogen facility in the U.S., running on Topsoe technology.

GUANGXI HONGKUN BIOMASS

Topsoe will deliver HydroFlex™ technology to Guangxi Hongkun Biomass for the production of Sustainable Aviation Fuel (SAF) and renewable diesel at its plant in the Qinzhou Port Area Free Trade Pilot Zone of Guangxi, China.

OUR AREAS OF EXPERTISE ARE THE ELEMENTS OF OUR OFFERING

TECHNOLOGY

PROPRIETARY EQUIPMENT

PROCESS DESIGN, ENGINEERING AND LICENSING

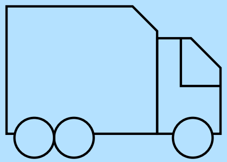
BUSINESS AND TECHNICAL SERVICE

HIGH-PERFORMANCE CATALYSTS

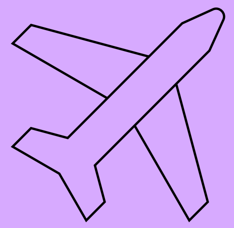
AGENDA

1	BIOFUELS - A COMPLIANCE MARKET
2	SAF – THE ‘HYPE’ PERSISTS
3	TRENDS: FEEDSTOCK EVOLUTION AND CO-PROCESSING
4	BEYOND SAF & BIOFUELS

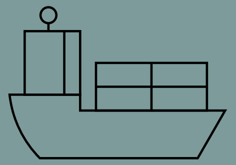
REGULATIONS SUPPORTING THE PRODUCTION OF ALTERNATIVE FUELS ARE DEPLOYING GLOBALLY FOR ROAD, AVIATION AND SHIPPING FUELS



- 60 countries have **ethanol** blending mandates.
- 49 countries have **biodiesel** blending mandates
- Several regions are supporting production and/or use of **renewable diesel/HVO** (**EU, US, Brazil, Canada, UK**)



- Several regions have implemented regulations for production or use of SAF (**EU, UK, US, Brazil, British Columbia**)
- Many countries are planning to have **SAF regulations** (Japan, Turkey, UAE, New Zealand, Singapore, South Korea, India, Australia, China, Chile, Colombia, Thailand, Malaysia, Indonesia, etc.)



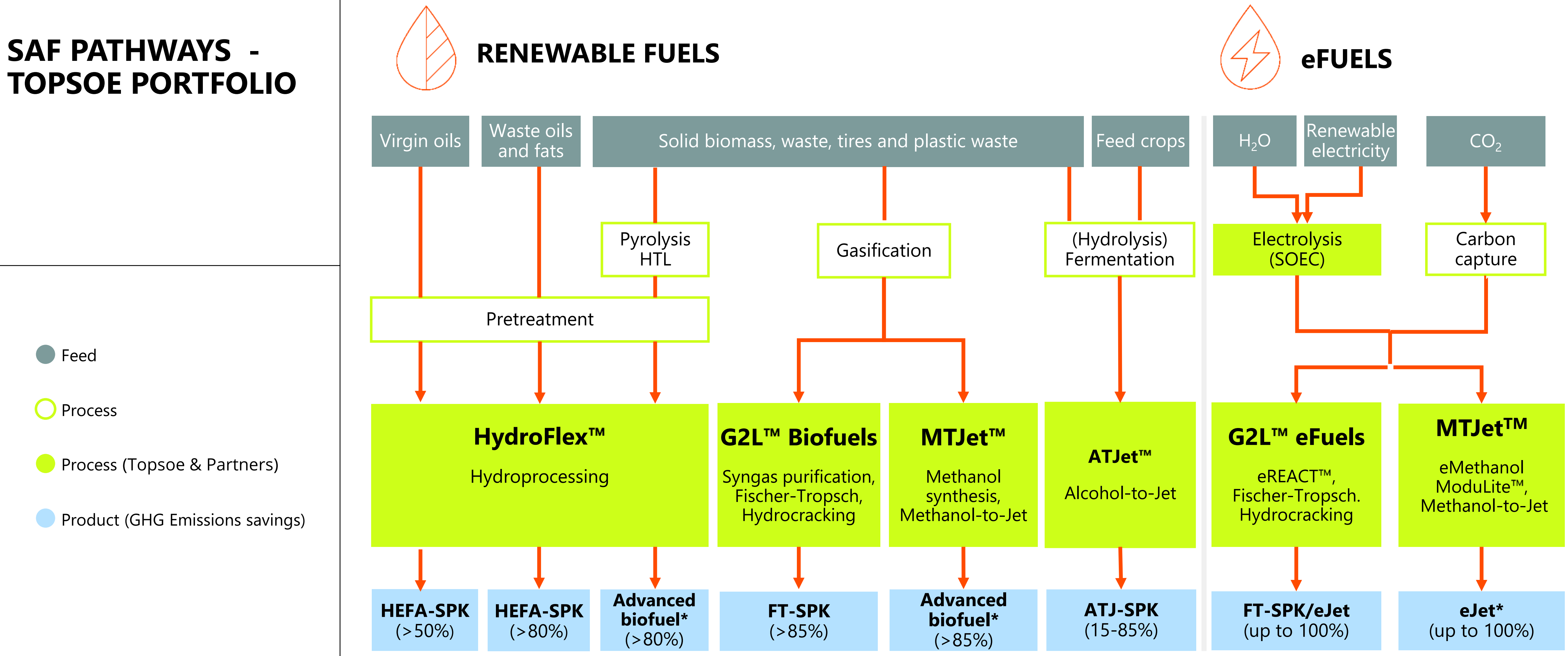
- Only the **EU** has implemented a regulation to minimize GHG emissions of shipping (FuelEU Maritime)
- **IMO** has Net zero Aspirational goal close to 2050 and issued **ambitious draft mid-term measures** (2027-2040) which is disappointingly delayed

DIFFERENT APPROACHES ARE POSSIBLE WHEN IT COMES TO POLICIES SUPPORTING DEPLOYMENT OF RENEWABLE FUELS

Stick	**Blending mandates imposed that are creating the market** **Non-compliance penalties** **Examples**: EU-27, US (RFS2)
Carrot	**Incentives for the production or offtake of renewable fuels** **Examples:** US (OB3, LCFS), EU-27 (ETS SAF allowances, CAPEX funding), UK (revenue certainty mechanism)
Stick and carrot	**Mixture of incentives, mandates, and penalties** **Example:** UK (blending mandate with tradeable certificates for SAF)
Happy-go-lucky	**Voluntary market** **Examples:** CORSIA, airlines commitment, corporate programs, cargo, passengers' willingness to pay

AGENDA

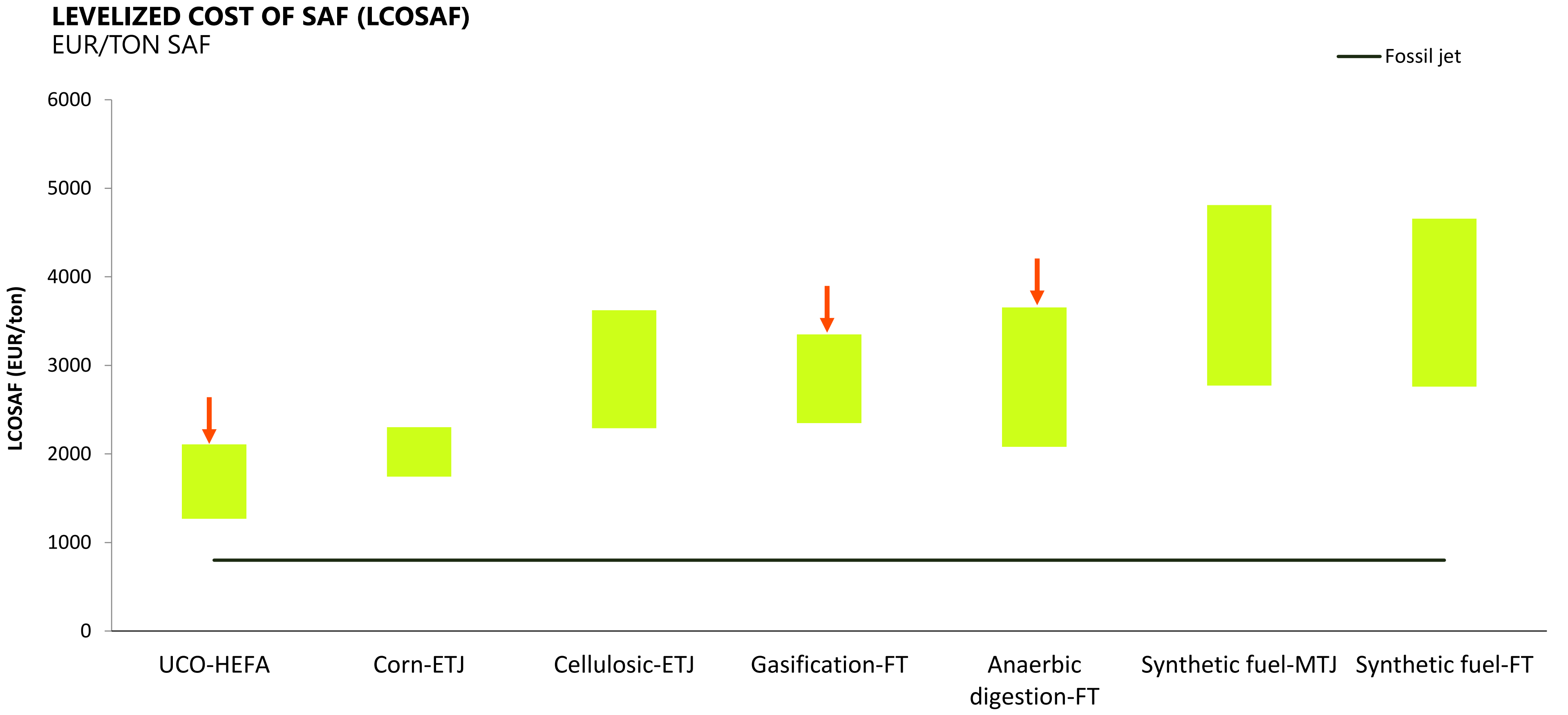
SAF PATHWAYS - TOPSOE PORTFOLIO



*Not approved ASTM pathways yet

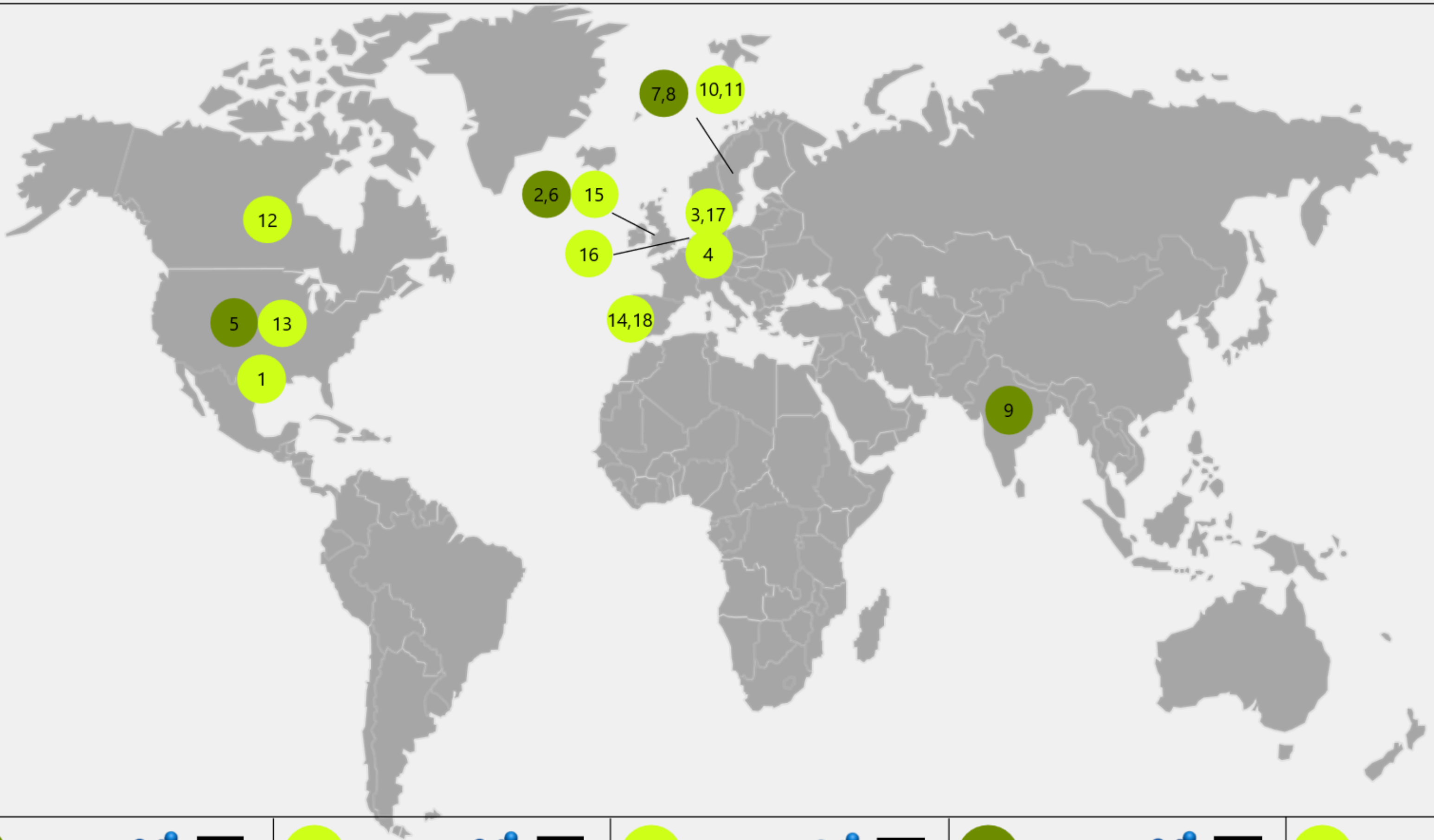
Source: CORSIA, ICCT paper 2021-11, WEF+McKinsey 2020-11

ESTIMATED LEVELIZED COST OF SAF



Assumptions
WACC: 10%, UCO: 900-1600 EUR/ton, Corn ethanol: 800-1100 EUR/ton, Cellulosic ethanol: 1100-1800 EUR/ton, Forrest residue: 50-150 EUR/MWh, Biogas: 15-25 EUR/MJ, eMeOH: 900-1450 EUR/ton, Electricity: 30-60 EUR/MWh

PLANNED* FT-BASED XTL PLANTS



Solid waste / biomass

Captured CO_2

Demo size projects taking **FID**

Biogas gains traction – derisking the pathway

2	1-3	4	5-9	10-25+
Undisclosed UK 4,000 bbl/day (FEED)	Arcadia eFuels, DK Undisclosed , USA 2,000 bbl/day (FEED)	DLR Germany 80 bbl/day (FEED)	USA, UK, Sweden, India 2,000-5,000 bbl/day (4 feasibility/pre-FEED)	Canada, USA, Portugal, UK, Holland, Denmark, Sweden, 1,000-3,000 bbl/day (9 feasibility/pre-FEED)

*Limited list of projects at various planning stages

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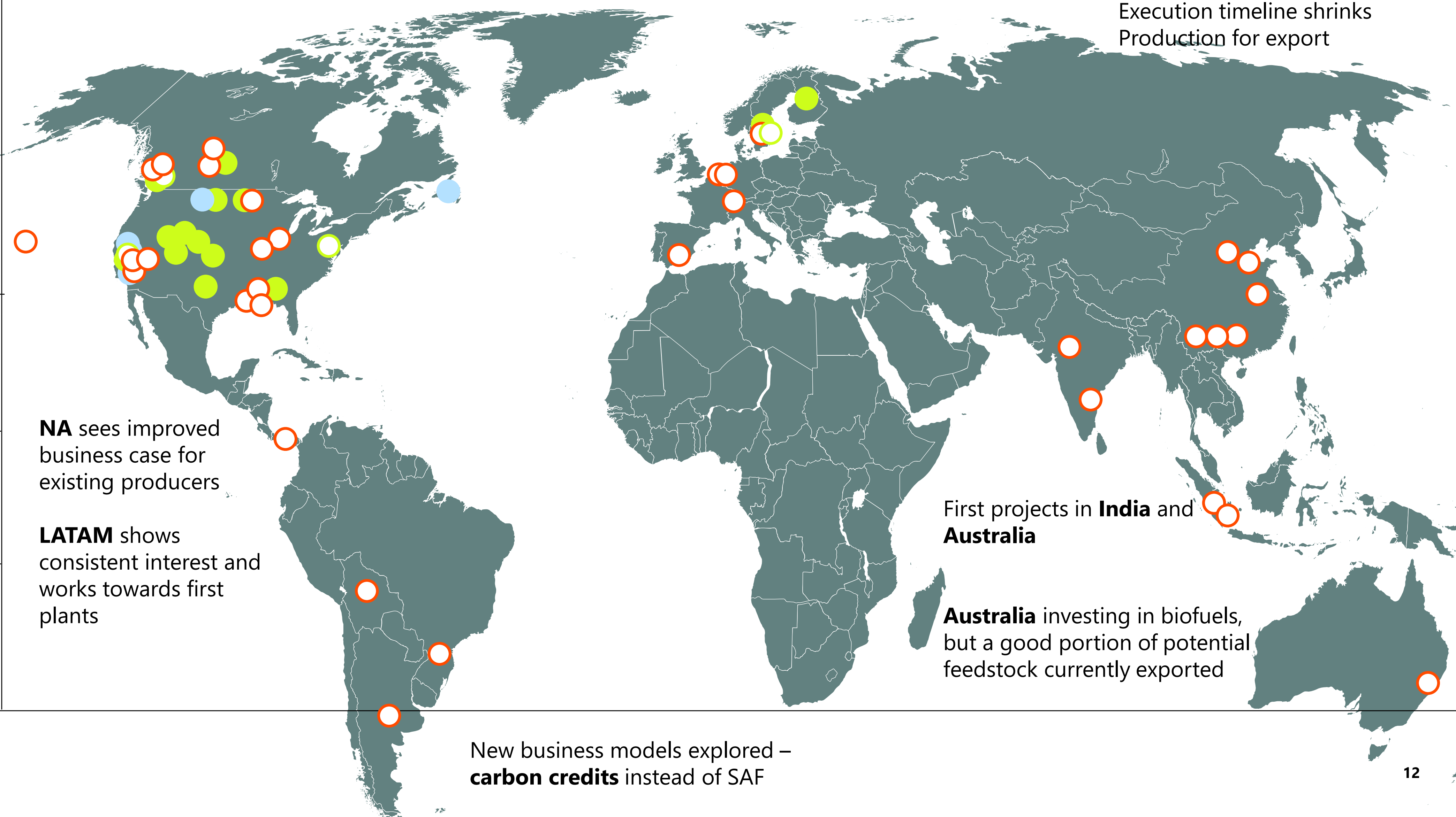
HYDROFLEX -100% RENEWABLE REFERENCES AROUND THE WORLD

- HVO – Operating (16)
- HVO and SAF – Operating (6)
- HVO – Engineering (5)
- Fully flexible/Jet only – Construction/Engineering (47)

2010
Start-up of first reference

22
Operating plants

>1/3
Of the renewable fuels operating capacity volume



China – '300KTA, UCO' prototype
Execution timeline shrinks
Production for export

NA sees improved business case for existing producers

LATAM shows consistent interest and works towards first plants

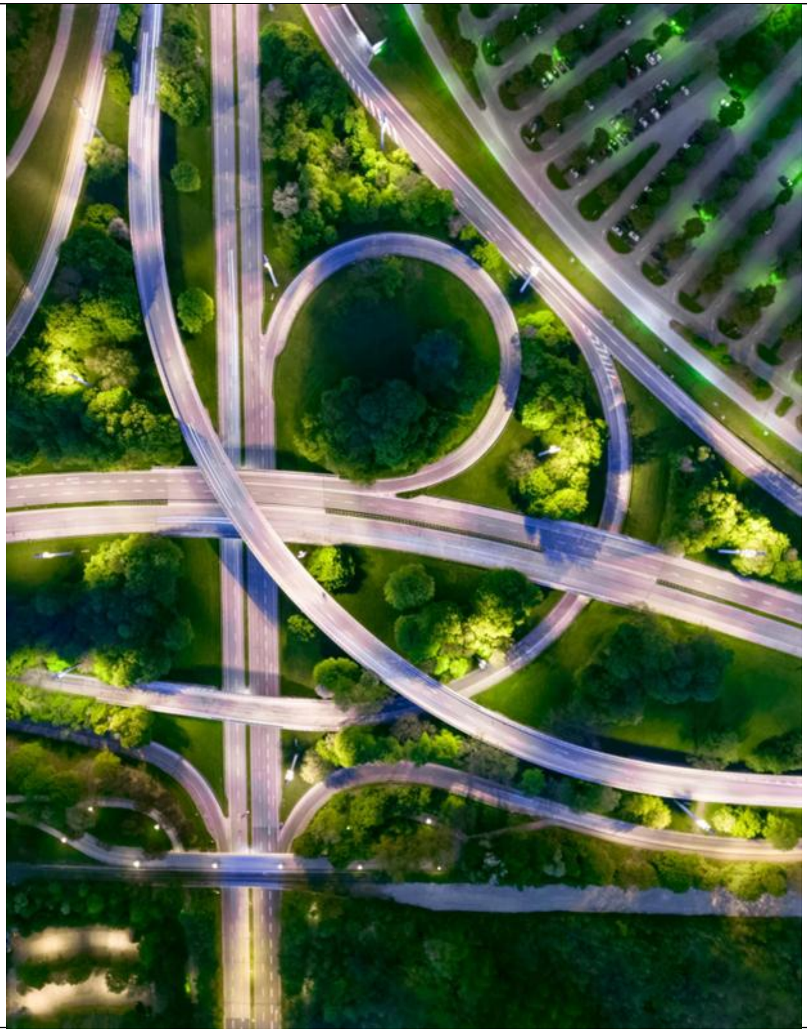
First projects in **India** and **Australia**

Australia investing in biofuels, but a good portion of potential feedstock currently exported

New business models explored – **carbon credits** instead of SAF

AS PROJECTS BY MAJORS IN EUROPE GET CANCELLED A NUMBER OF OTHER THINGS HAPPEN…

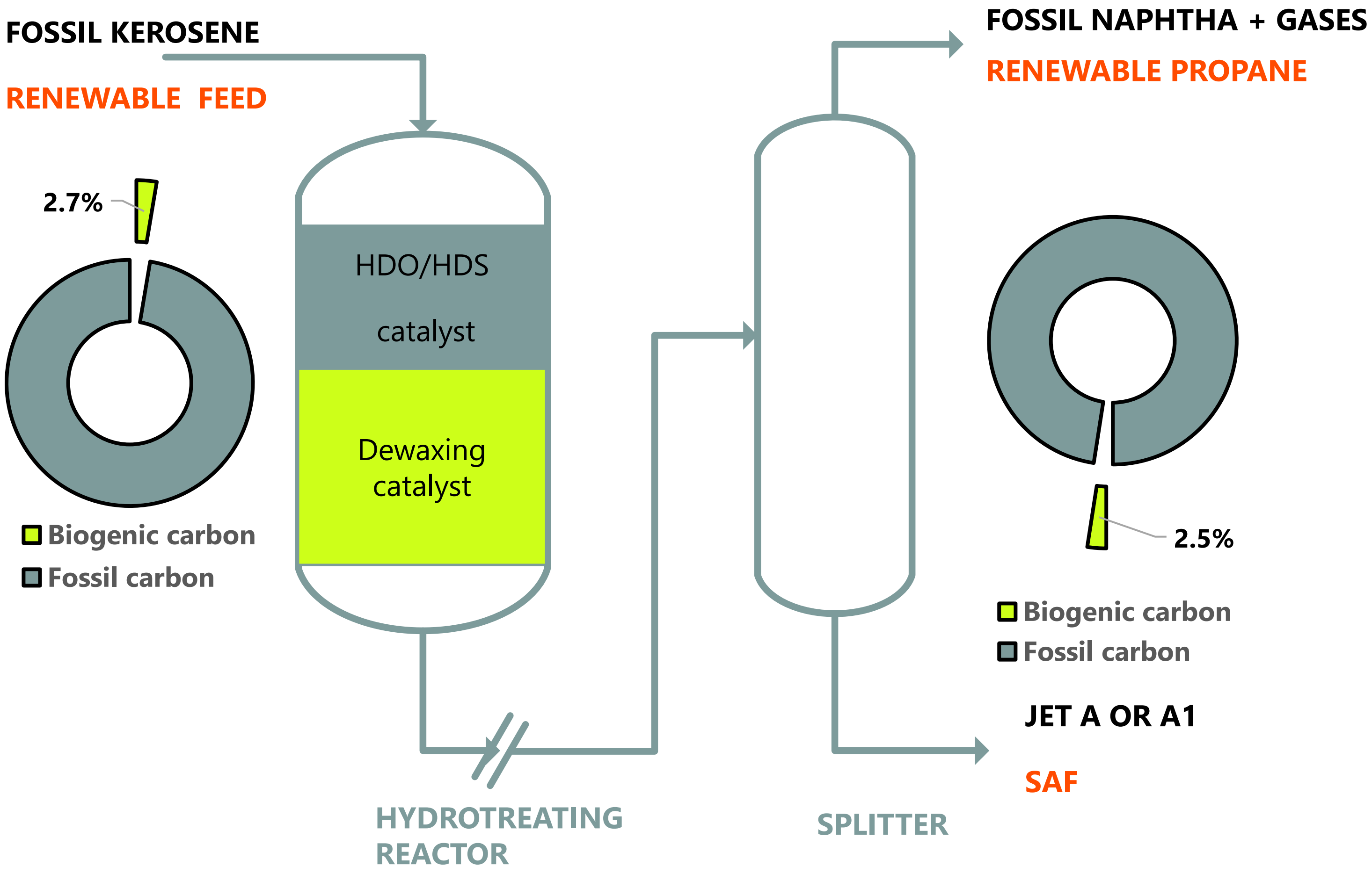
- Execution strategies vary but smaller grassroots, revamps seem to win
  - CAPEX investment vs business case
  - Easier to secure feedstock & offtake for smaller projects
- Re-scoping: to smaller size, to revamps
- The ‘invisibility’ of co-processing
- Biofuels enter the energy security agenda
- Region digging deep for new feedstock sources

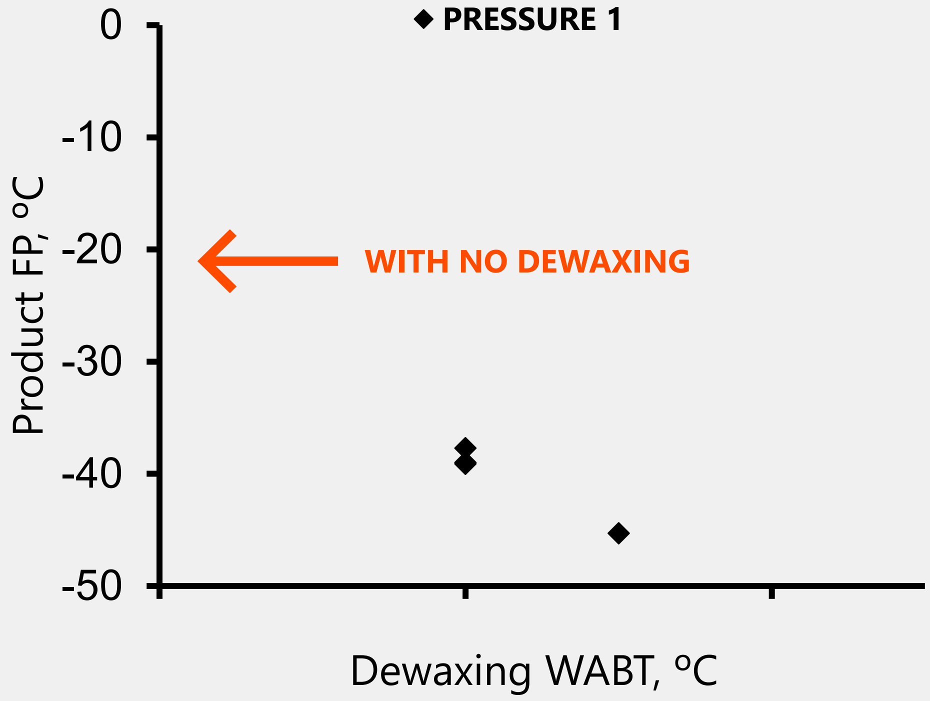


AGENDA

HEFA CO-PROCESSING IN HYDROTREATERS: FATE OF BIOGENIC CARBON IS CRITICAL

DRIVEN BY SPEED OF CHANGE AND LIMITED INVESTMENT





3vol% co-processing

LOWEST PRODUCTION COST OF HEFA IS A STRONG MOTIVATION TO EXPAND THE FEEDSTOCK POOL

AVAILABILITY IMPACTS THE SCALABILITY, SUSTAINABILITY, AND COST-EFFECTIVENESS OF RENEWABLE FUELS

VIRGIN OILS

Rapeseed Oil

Palm Oil

Soybean Oil

Sunflower Oil

WASTE OILS AND FATS

Used Coking Oil (UCO)

Animal fats and Edible Tallow

Distillers Corn Oil (DCO)

Crude Tall Oil (CTO)

Tall Oil Fatty Acid (TOFA)

Palm Oil Mill Effluent (POME)

LOW ILUC/ROTATIONAL CROPS

Carinata Oil

Castor Oil

Micro and macro-algae

Synthetic fatty acids

SOLID WASTE BIOMASS

Agricultural/forestry residue

Sewage sludge

Organic fraction of MSW

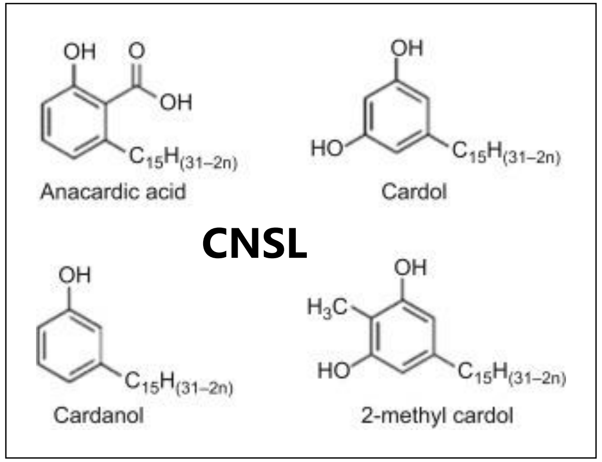
RECYCLED CARBON

Non-recyclable mixed plastic waste

End of life tires

AVAILABILITY

ONE OF THE CO-PRO STARS: CASHEW NUT SHELL LIQUID (CNSL) - LIMITED AMOUNT, LARGE INTEREST



- Phenols with long side chains
- High concentration of olefins

WHAT DOES THIS MEAN FOR PROCESSING TO FUEL?

- Oxygen is easy to remove with high HDO selectivity
- Less isomerization needed (vs triglycerides)
- Design needs to address potential plugging due to olefins

- **Miscible** with fossil crude/renewable oils
  - Co-processing with renewable oils and/or fossil feedstocks for renewable diesel
  - SAF production possible but requires ASTM certification

HDO – Hydrodeoxygenation

AGENDA

BEYOND SAF: HVO AND MARINE FUELS LANDSCAPE

Demand for **HVO** expected to increase

RVO increase from 2026, matching the current supply much better

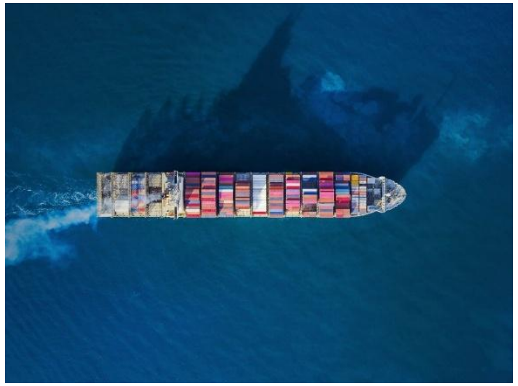
45Z and overall federal level credits stack: HVO slightly better positioned than SAF

Regional feedstocks preferred

RED III comes with increased ambition for road transport

Biodiesel and ethanol blending walls being reached

Double counting slowly phased out



What now for **sustainable marine fuels** after the IMO framework delay?

- FuelEU Maritime still on – for lessons learnt
- Biodiesel demand seeing a boost
- Ethanol another fuel to join the solutions portfolio
- China again plays a supplier role

RVO – Renewable Volume Obligation

BIOFUELS COMPLICATED RELATIONSHIP WITH RFNBO AND RCF

- Are biofuels **RFNBO** in diguise?
  - Battle between majors and minors for what really counts as RFNBO
- Can Sustainable Transport Investment Plan (STIP) help deliver eFuels in Europe?
  - Bankability, risk and wrap are the buzz words
  - Nordics and Iberia have the lowest barrier

- **Recycled Carbon Fuels** (or just fuels from plastic waste and end of life tires) getting more traction globally
- Problem statement: No oxygen challenge but nitrogen and aromatics (in TDO) or a myriad of contaminants (in PPO) to be tackled
- Similarities to fossil feedstocks make plant design a familiar task and co-processing an option

RFNBO – Renewable Fuels of Non-Biological Origin
TDO – Tire-Derived oils
PPO – Plastic Pyrolysis oils

TAKE HOME MESSAGE
A COMMUNITY OF BELIEVERS – FOR GOOD AND FOR BAD

The interest is undisputably global but is the market? Most of the customers count on export to the same region.

Difficult to rely on aspirational goals. Regulatory drivers are needed.

First movers should be helped: we need to deploy for the cost to go down.

Co-processing with lipids or fossil is a good first step for new liquid feedstocks.

Some feedstocks are best suited for applications other than SAF (marine fuel, diesel or naphtha). Products should be matched with market the best way possible.

STOP. SCAN. LISTEN.
A TOPSOE PODCAST FOCUSING ON RENEWABLE FUELS.

THE FUEL FOR THOUGHT PODCAST SERIES

- Key industry players, experts, and influencers discuss industry challenges.
- What is driving our industry and where is it heading?
- Get new perspectives, inspiration, and knowledge.

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