ICAO ENVIRONMENT

ACT-SAF #15 SERIES

Co-processing and revamping: how to use existing refineries to produce SAF

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ACT SAF

ACT SAF

Assistance, Capacity-building and Training for SAF

Opening remarks by ICAO

Objectives

ACT-SAF #15 SERIES

Provide participants with knowledge on co-processing and revamping refineries.

ACT-SAF Series #15 Speakers

Ole Frej Alkilde

Lead Technology Manager

Topsoe

Sylvain Verdier

Senior Strategy Manager

Topsoe

Tamara Galindo

Renewable fuels Project Manager

Repsol

Bruce Fleming

CEO

Montana Renewables

Agenda

- Opening remarks by ICAO
- ICAO update on ACT-SAF activities
- Presentation by Topsoe
- ICAO presentation on CORSIA-related aspects of co-processing
- Presentation by Repsol
- Presentation by Montana Renewables
- Questions and answers with the audience
- Closing remarks by ICAO

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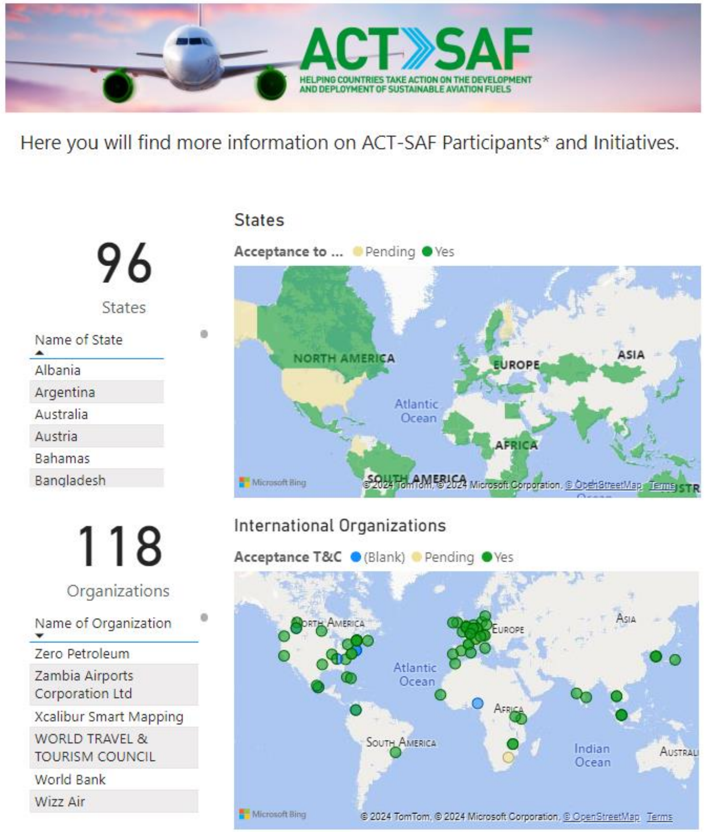
ACT SAF

ACT SAF Assistance, Capacity-building and Training for SAF

ICAO update on ACT-SAF programme

Marked increase in number of ACT-SAF partner States/Organizations

- **Increased opportunities for expert contributions towards training, feasibility studies, etc.**
  - More than 200 ACT-SAF Partner States and Organizations
  - Supports further outreach of SAF development and deployment initiatives
  - Upcoming survey to Partner Organizations to enquire how best they can support States

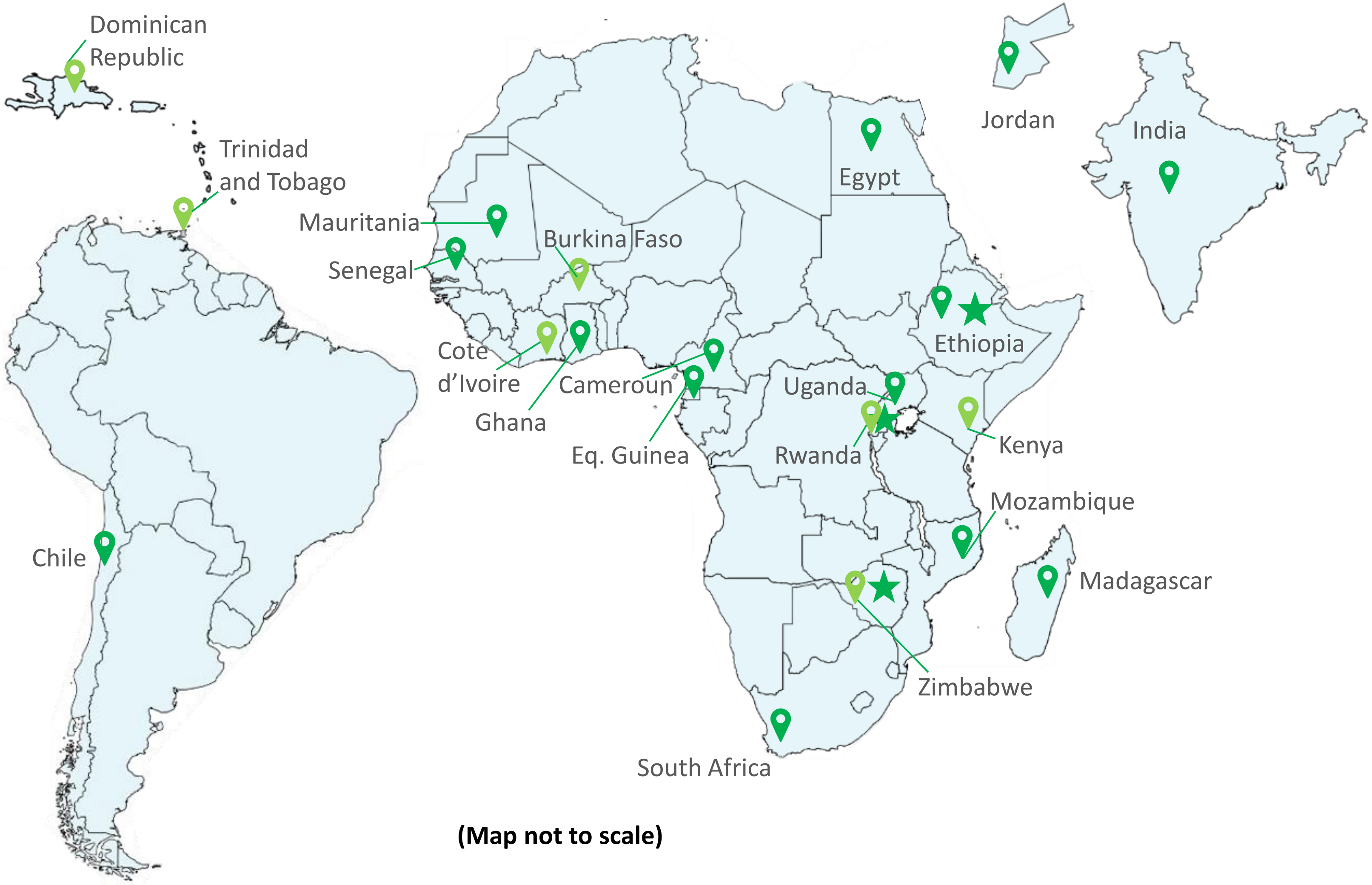


Planning of ACT-SAF studies coordinated by ICAO

- Already completed: Burkina Faso (FS/EU), Cote d'Ivoire (FS/EU), Dominican Rep. (FS/EU), Kenya (FS/EU), Rwanda (FS/EU), Trinidad and Tobago (FS/EU), Zimbabwe (FS/EU)
- 2024: Ethiopia (FS/EU), India (FS/EU), South Africa (FS/EU), Jordan (FS/NL), Chile (FS/NL), Rwanda (BI/FR), Zimbabwe (BI/UK) + 3 States TBC (FS/Airbus)
- 2025 - 2026 : Cameroun (FS/EU), Egypt (FS/EU), Ethiopia (BI/FR), Equatorial Guinea (FS/EU), Ghana (FS/UK), Madagascar (FS/EU), Mauritania (FS/EU), Mozambique (FS/EU), Senegal (FS/EU), Uganda (FS/UK), + 1 State TBC (FS/NL)

Feasibility study (FS)

Business Implementation study (BI)



(Map not to scale)

Close coordination with EASA in other EU funded ACT-SAF projects

- Additional Feasibility Studies done by EASA : **Nigeria, Morocco**

ACT-SAF EU-Africa India Project (Part-II)

Regional Workshop on SAF Direct Supply Lines

Mombasa, Kenya, 30.09 – 02.10.2024

Project Funded by the EU

Project Status

Projects already initiated for: Chile (NL), Ethiopia (EU), Rwanda (FR), India (EU), Jordan (NL), South Africa (EU) and Zimbabwe (UK)

- Kick-off discussions with States ✓
- Recruitment of consultants ✓ → Finalizing recruitment
- Kick-off meetings in each partner State ✓ → National kick-off workshops in preparation
- Pre-feasibility study "Waypoint Meeting" → In progress
- Follow-up activities

Other initiatives

- ✓ **Mexico** – ACT-SAF workshop held in November.
- ✓ **Airbus** – contract signed, coordination ongoing to define States.
- ✓ **Cote d'Ivoire** – support provided on development of national code on bioenergy. Further support on regulatory framework being evaluated.
- ✓ **Kenya** – resources announced by the Netherlands to study conversion of Mombasa refinery

Presentation by Topsoe

ASTM HAS APPROVED 8 + 3 PATHWAYS TO PRODUCE SAF SO FAR

Pathway	ASTM	Annex	Year	Feedstock options	Current blending limit
Fischer-Tropsch Synthetic Paraffinic Kerosene (FT-SPK)	D7566	A1	2009	Coal, natural gas, biomass (syngas)	50%
Hydroprocessed Esters and Fatty Acids Synthetic Paraffinic Kerosene (HEFA-SPK)		A2	2011	Vegetable oils and fats, animal fat, recycled oils	50%
Hydroprocessed Fermented Sugars to Synthetic Isoparaffins (HFS-SIP)		A3	2014	Biomass used for sugar production	10%
Fischer-Tropsch Synthetic Paraffinic Kerosene with Aromatics (FT-SPK/A)		A4	2015	Coal, natural gas, biomass	50%
Alcohol to Jet Synthetic Paraffinic Kerosene (ATJ-SPK)		A5	2016	Ethanol or isobutanol	50%
Catalytic Hydrothermolysis Synthesized Kerosene (CH-SK, or CHJ)		A6	2020	Triglyceride-based feedstocks	50%
Hydroprocessed Hydrocarbons, Esters and Fatty Acids Synthetic Paraffinic Kerosene (HHC-SPK or HC-HEFA-SPK)		A7	2020	Triterpenes produced by the Botryococcus braunii species of algae	10%
Alcohol-to-jet synthetic paraffinic kerosene with aromatics (ATJ-SKA)		A8	2023	C2 to C5 Alcohol	50%
Co-processing of mono-, di-, and triglycerides, free fatty acids, and fatty acid esters	**D1655**	A1.2.2.1	2018	Mono-, di-, and triglycerides, free fatty acids, and fatty acid esters	5vol% (feed & product)
Co-processing of hydrocarbons derived from synthesis gas via the Fischer-Tropsch process using iron or cobalt catalyst		A1.2.2.2	2020	Fischer-Tropsch hydrocarbons	
Co-processing of hydrocarbons derived from HYDROPROCESSED mono-,di-tryglycerides.	**D1655/23**	A1.2.2.3	2023	Hydroprocessed mono-, di-, and triglycerides, free fatty acids, and fatty acid esters	24vol% feed & 10vol% product

WHAT ARE THE OPTIONS TO PRODUCE RENEWABLE FUELS?

FOSSIL HDP UNIT

↓

RENEWABLE HDP UNIT

HDP= hydroprocessing

< 5 VOL % RENEWABLE FEEDSTOCKS	Catalyst system and operational adjustments. Revamp typically not required
< 10 VOL % RENEWABLE FEEDSTOCKS	Study recommended. Revamp typically not necessary
> 10 VOL % RENEWABLE FEEDSTOCKS	Some type of revamp is typically required
100 VOL % RENEWABLE FEEDSTOCKS	Grassroot unit or extensive revamp required

WHAT ARE THE OPTIONS FOR HEFA-SPK?

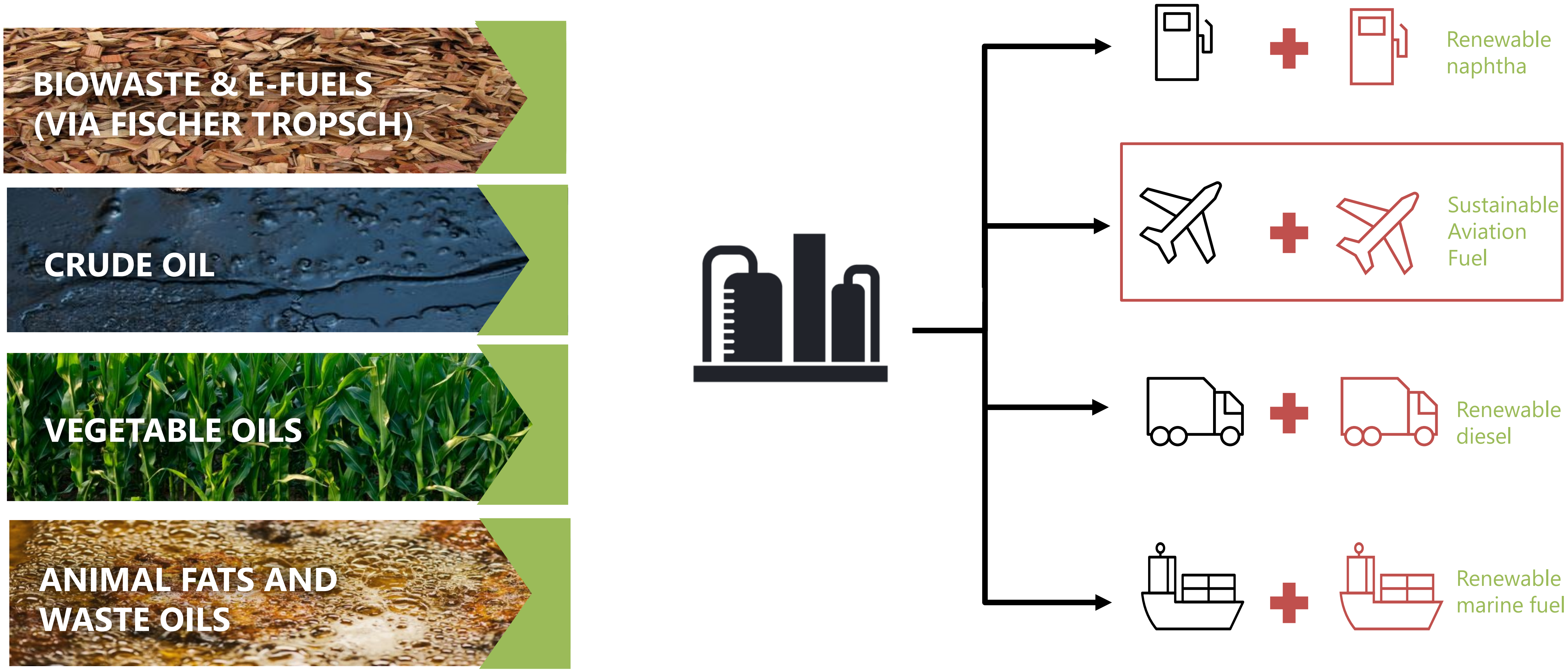
FOSSIL HDP UNIT

RENEWABLE HDP UNIT

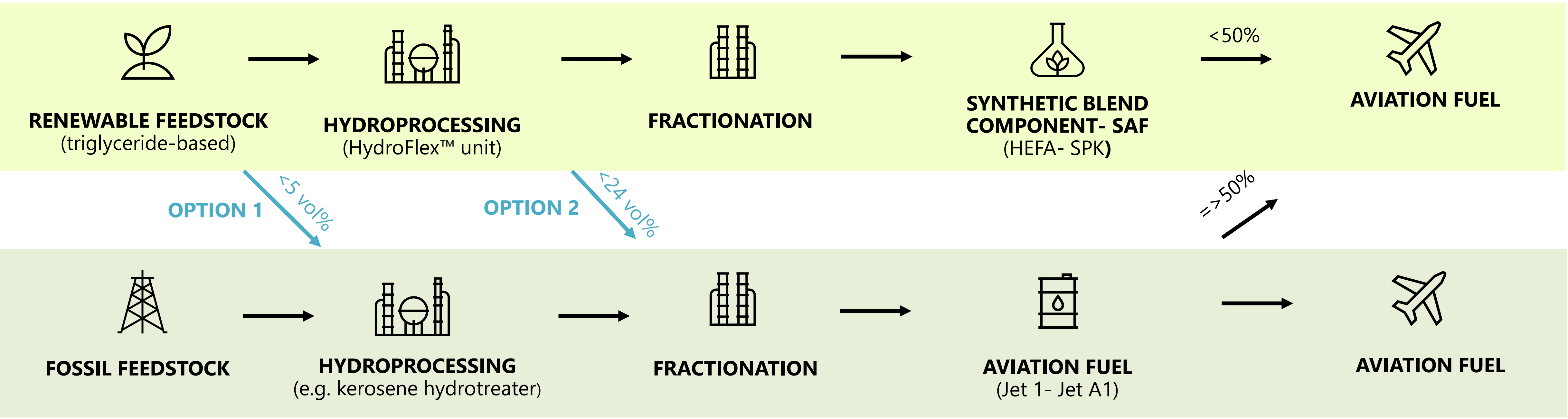
HDP= hydroprocessing

up to 5 VOL % CO-PROCESSING		**CO-HYDROPROCESSING**
up to 24 VOL % CO-PROCESSING		**CO-FRACTIONATION**
100 VOL % STAND-ALONE		**100% STAND ALONE UNIT (HEFA- SPK)**

WHAT IS CO-PROCESSING?



POSSIBILITIES TO INTEGRATE WITH REFINERY ASSETS



OPTION 1- **ASTM 1655/23 A1.2.2.1** Co-processing as co-hydroprocessing

OPTION 2- **ASTM 1655/23 A1.2.2.3** Co-processing as co-fractionation

WHY TO CO-PROCESS TO SAF?

>90

TOPSOE CATALYST REFERENCES

Industrial cycles co-processing renewable feedstocks in hydroprocessing units (includes RD, SAF, etc.)

>20

ADAPTABILITY STUDIES

Hydroprocessing units to produce SAF by co-processing

>15

PILOT TESTS FOR SAF

At different rates and conditions to evaluate biogenic carbon distribution

2

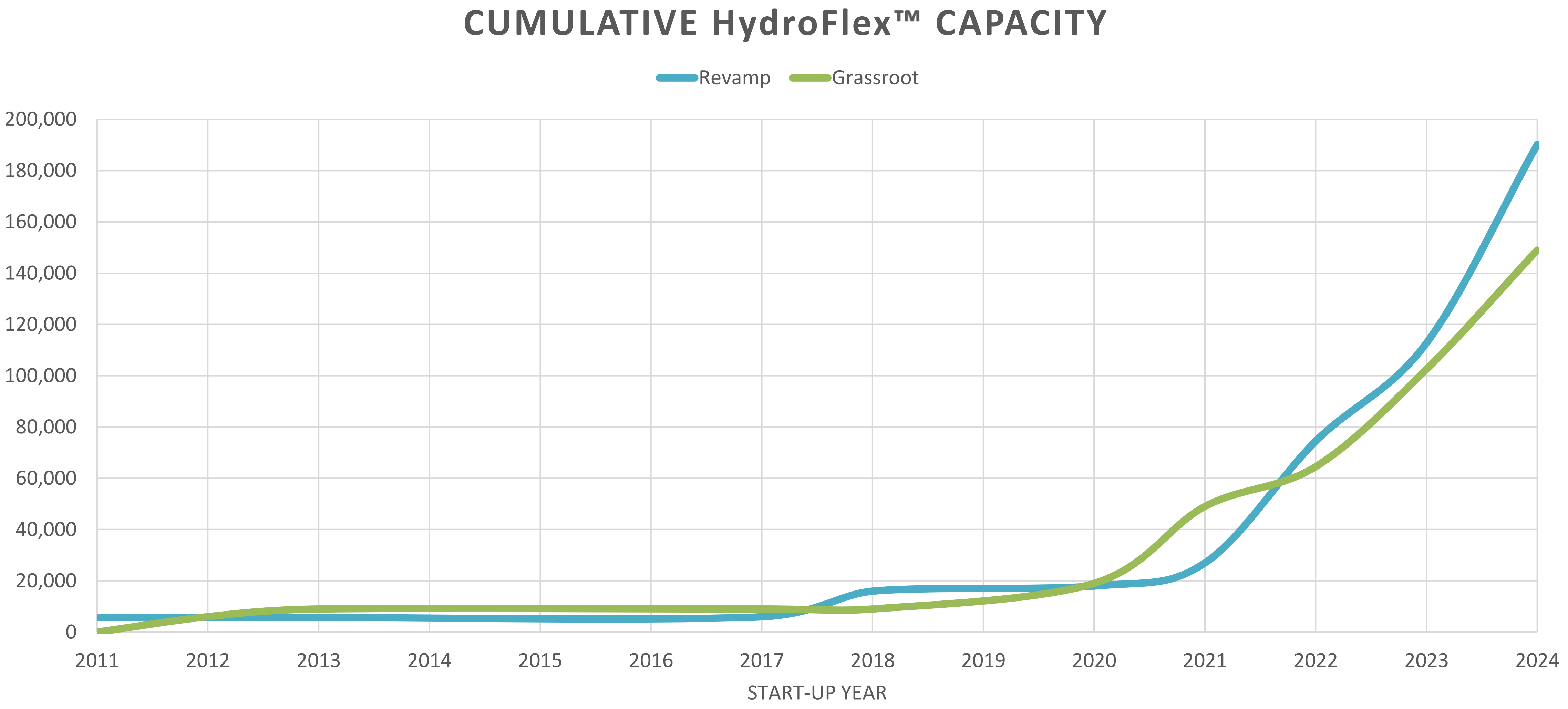
CATALYST ORDERS

For producing SAF via co-processing in kerosene hydrotreating units.

CO-PROCESSING IS A LOW CAPEX FAST TRACK SOLUTION FOR SAF

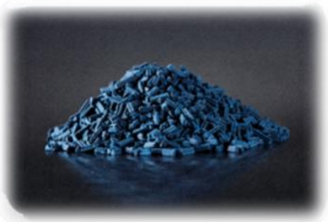
- → Fastest way to add SAF to the market
- → Co-processing in hydrotreaters is a well-proven procedure
- → Existing assets are evaluated and reused while new components may be added
- → Up to 2 years construction time can be gained
- → Implementation possible both with hydrotreaters and hydrocrackers
- → CAPEX savings start at 30%

50% of the capacity is revamps



HEFA-SPK production

Feedstock

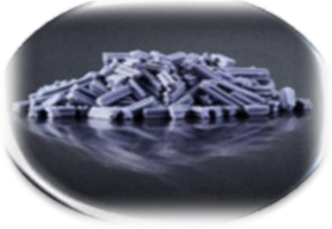


Hydrodeoxygenation (HDO)

Removal of Oxygen and olefins

Dewaxing (DW, isom)

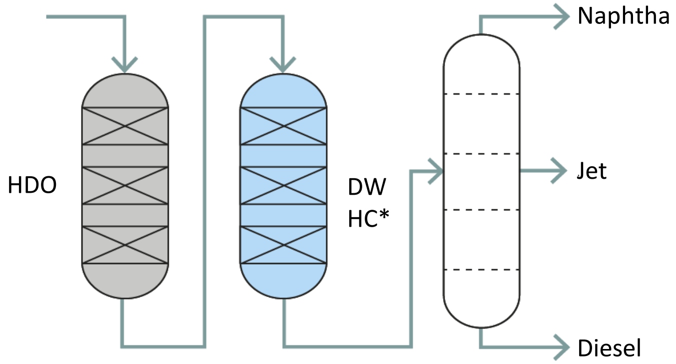
Freeze point reduction



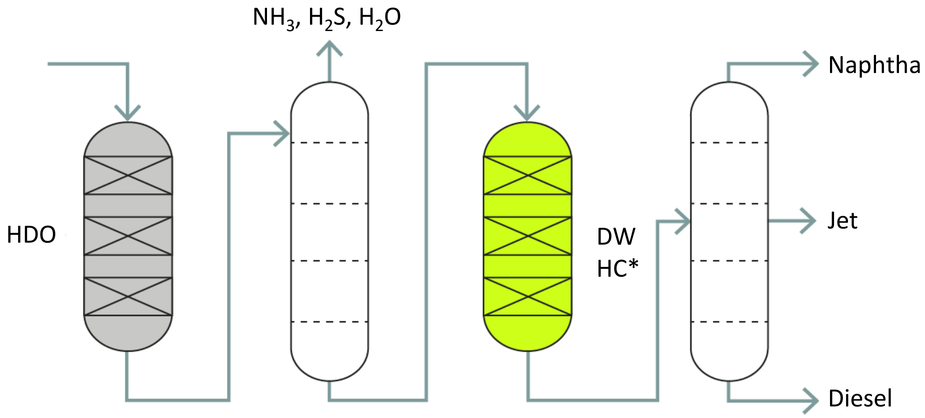
Hydrocracking (HC)

Adjustment of distillation profile

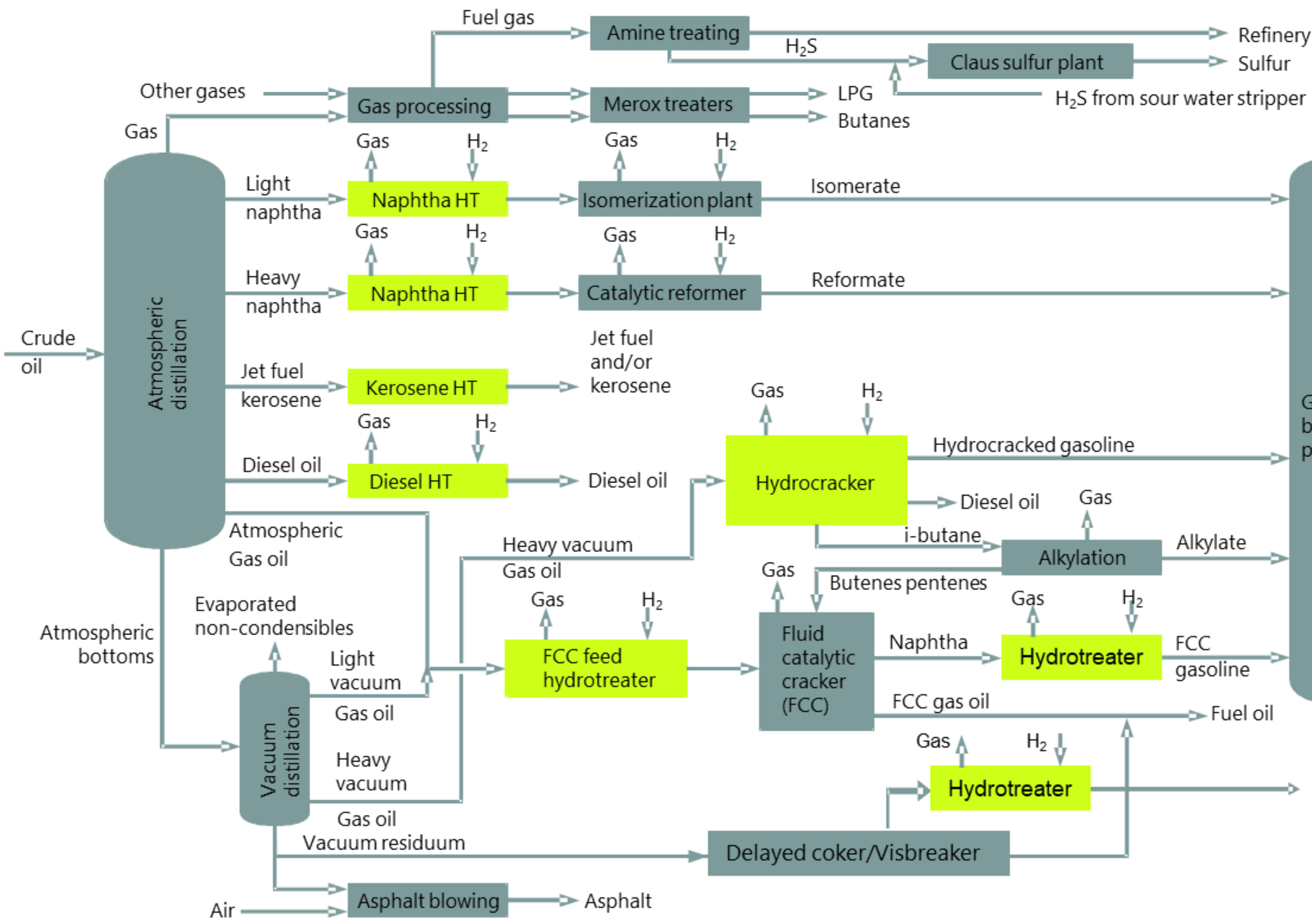
HydroFlex™ – sour mode



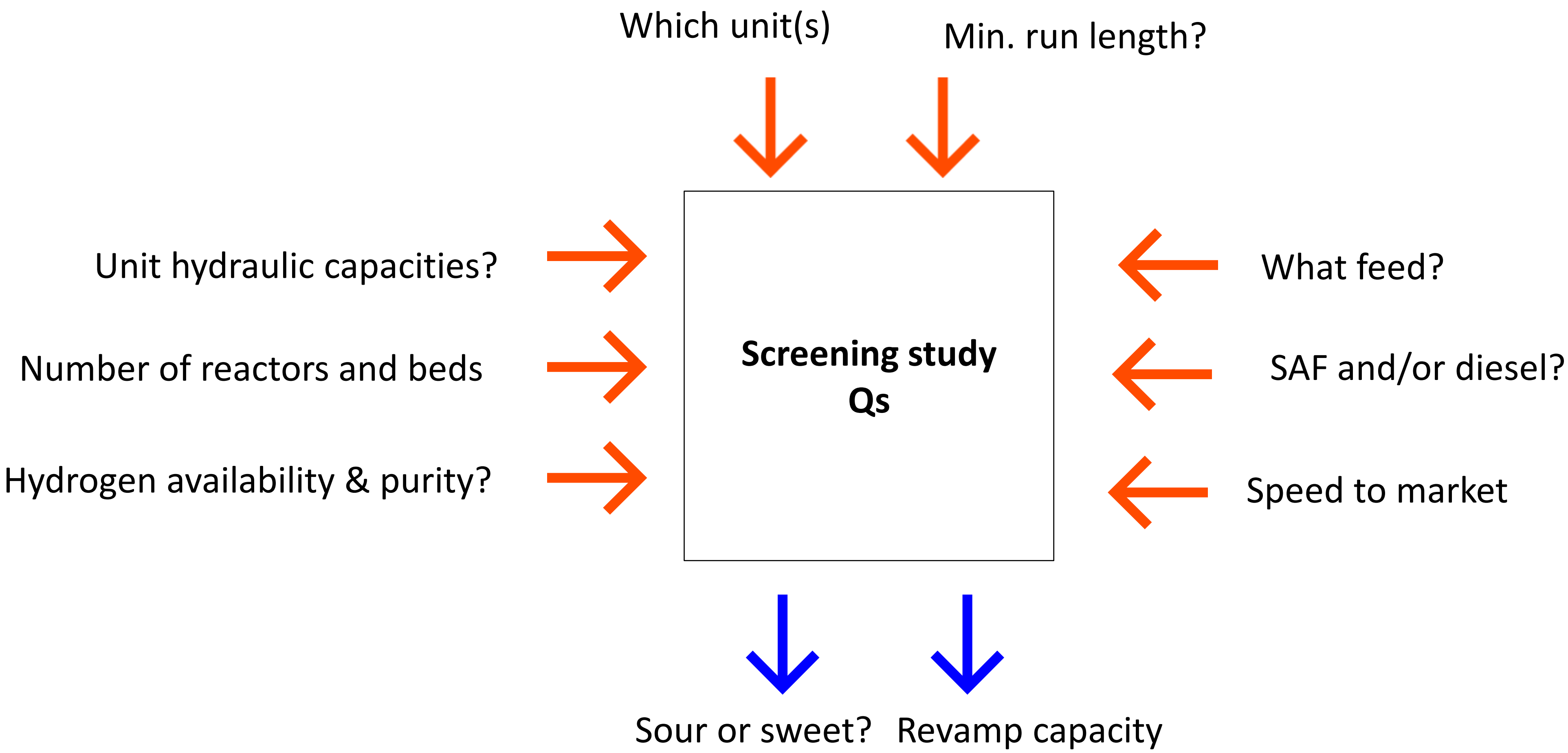
HydroFlex™ – sweet mode



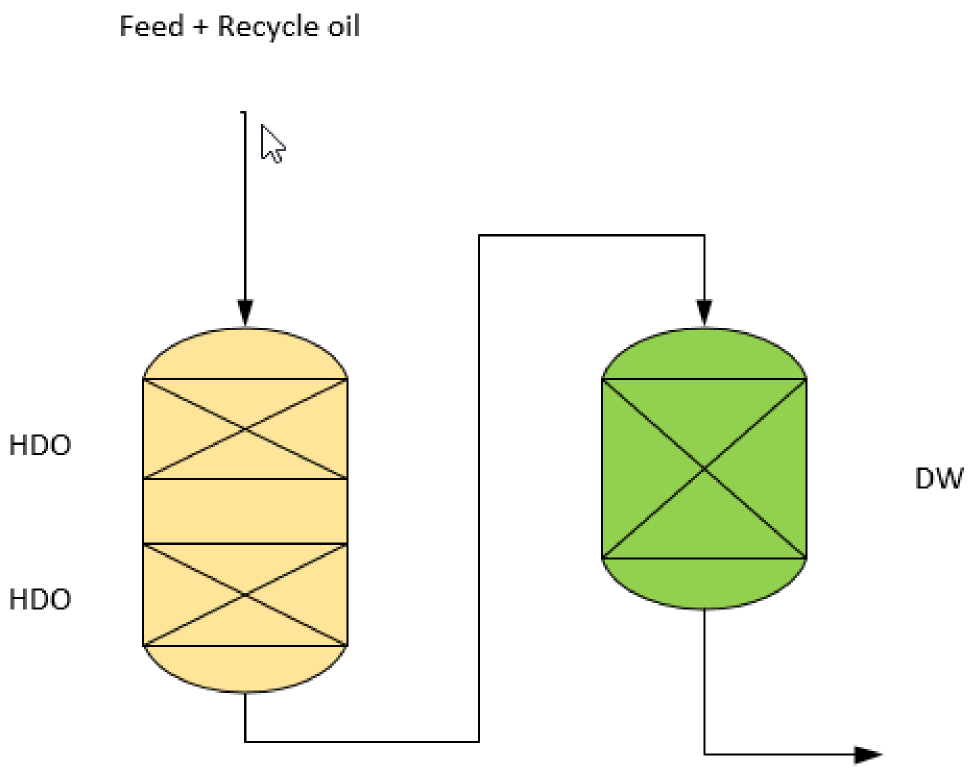
Many options for HEFA-SPK production in a refinery



Option screening

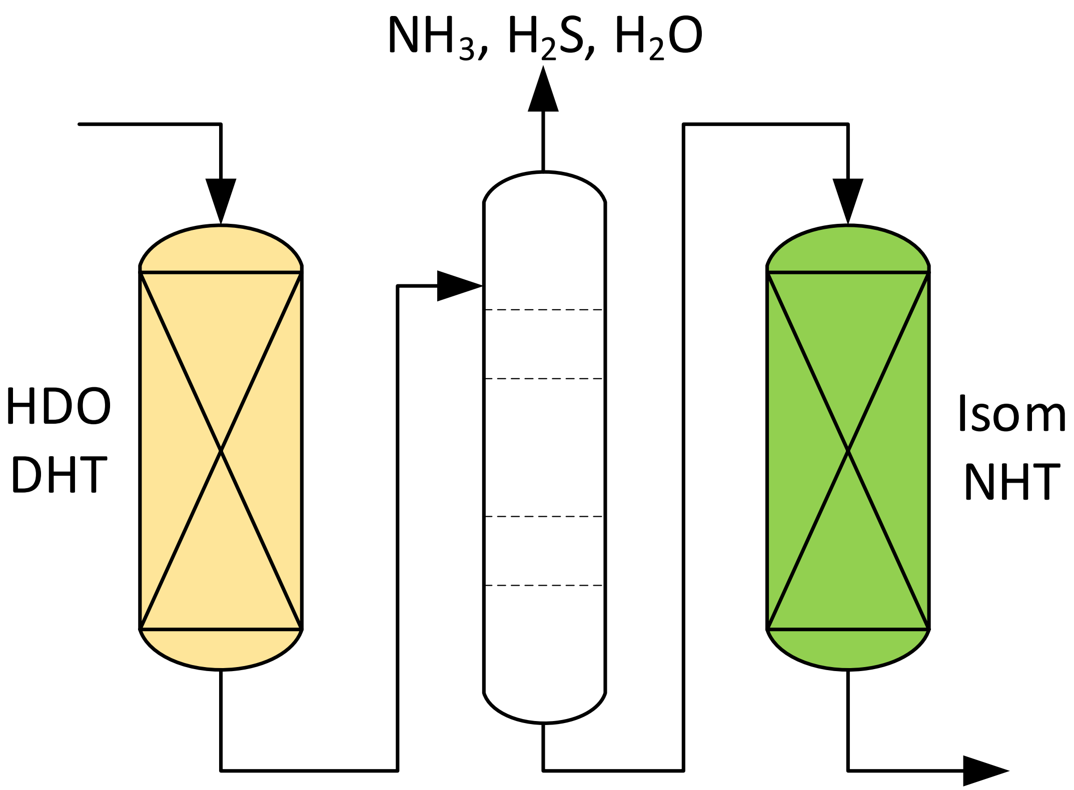


Case story A



- Conversion of diesel hydrotreater
- 20 months from project kick-off to unit start-up
- Unit capacity limited by make-up and recycle compressors
- Revamp capacity is 25% of original

Case story B



- Conversion of diesel and naphtha hydrotreaters to a sweet mode unit.
- 23 months from project kick-off to unit start-up
- Unit capacity limited by Hydrogen availability in refinery
- Revamp capacity is 12% of original

TOPSOE HAS LICENSED THE HIGHEST NUMBER OF RUNNING UNITS PRODUCING HVO AND SAF

RD - Operating (14)

RD and SAF - Operating (5)

RD – Engineering (5)

Fully flexible/Jet only – Construction/Engineering (38)

2010

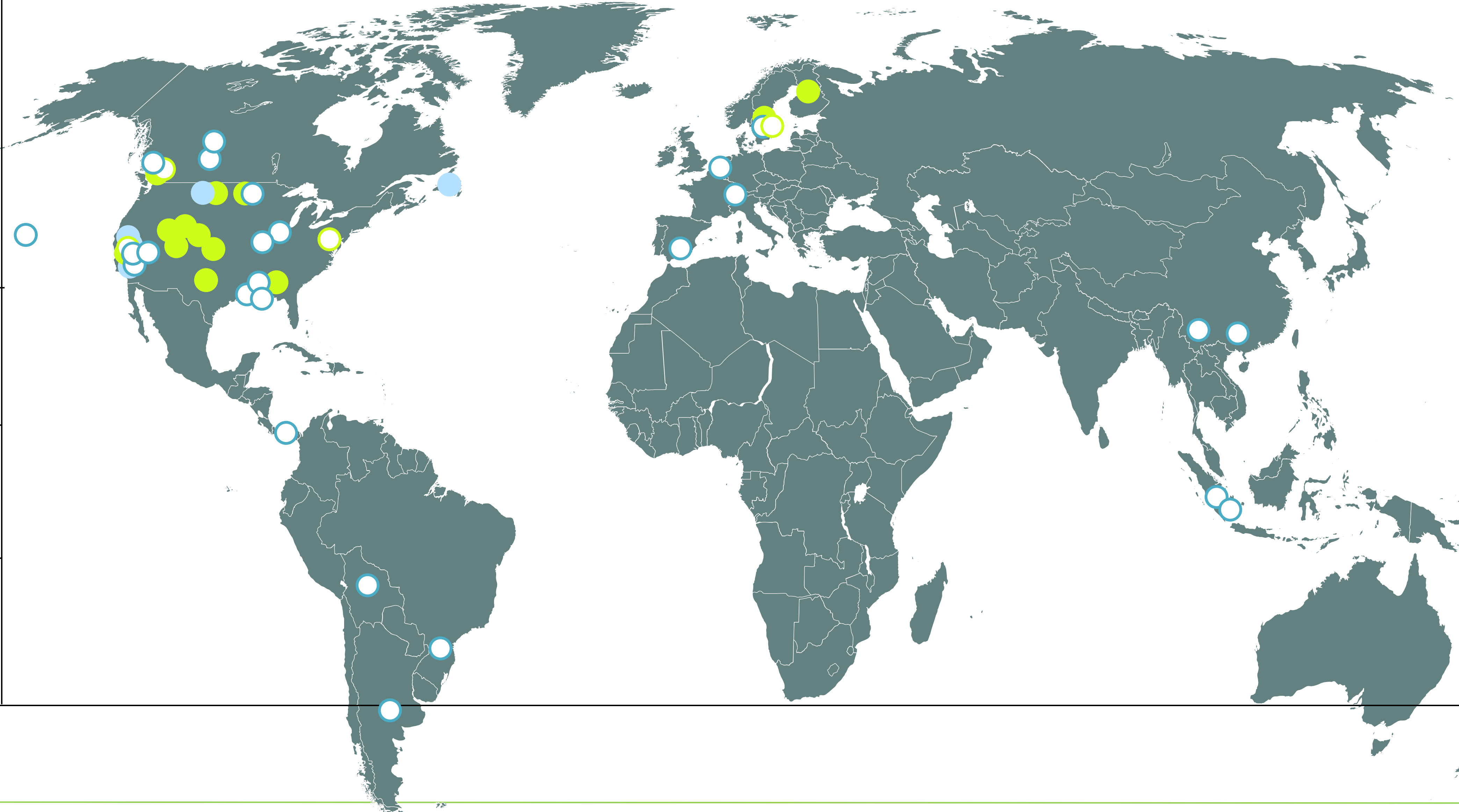
Start-up of first reference

19

Operating plants

>1/3

Of the renewable fuels operating capacity



ICAO ENVIRONMENT

ACT SAF

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Assistance, Capacity-building and Training for SAF

ICAO presentation on CORSIA-related aspects of co-processing

CORSIA rules on co-processing

- Two ICAO supporting documents were updated in October 2024
  - CORSIA Default Life Cycle Emissions Values for CORSIA Eligible Fuels
  - CORSIA Methodology For Calculating Actual Life Cycle Emissions Values

LCA and ILUC default values

The **default core LCA values** for co-processed fuels and the **default ILUC values** refer only to the **biogenic fraction of the fuel**.

Fuel Feedstock	Pathway Specifications	Default Core LCA Value*
Tallow	Maximum of 5% of tallow in volume Feedstock inserted at either the hydrotreater (HDT) or hydrocracker (HYK) points	27.2
Used cooking oil	Maximum of 5% of used cooking oil in volume Feedstock inserted at either the hydrotreater (HDT) or hydrocracker (HYK) points	16.7
Soybean oilseed	Maximum of 5% of soybean oil in volume Feedstock inserted at either the hydrotreater (HDT) or hydrocracker (HYK) points	40.7

Region	Fuel Feedstock	Pathway Specifications	Default ILUC value
USA	Soybean oilseed	Maximum of 5% of soybean oil in volume Feedstock inserted at either the hydrotreater (HDT) or hydrocracker (HYK) points	24.5
Brazil	Soybean oilseed	Maximum of 5% of soybean oil in volume Feedstock inserted at either the hydrotreater (HDT) or hydrocracker (HYK) points	27.0
Global	Soybean oilseed	Maximum of 5% of soybean oil in volume Feedstock inserted at either the hydrotreater (HDT) or hydrocracker (HYK) points	25.8

Formula to define L_{CEF}

The L_{CEF} of a finished co-processed fuel needs to be calculated as the **sum of the L_{CEF} of the two components**, weighted by their energy contributions.

$$L_{CEF,CoPro} = \frac{89 * \%Mass_{fossil} * LHV_{fossil} + L_{CEF\ bio} * \%Mass_{bio} * LHV_{bio}}{\%Mass_{fossil} * LHV_{fossil} + \%Mass_{bio} * LHV_{bio}}$$

Where:

$\%Mass_{fossil}$ *percentage of the final co-processed fuel derived from petroleum, in mass*

$\%Mass_{bio}$ *percentage of the final co-processed fuel derived from SAF feedstocks, in mass*

LHV_{fossil} *lower heating value of the fossil* fraction of the fuel.

LHV_{fossil} *lower heating value of the biogenic* fraction of the fuel.

$L_{CEF\ bio}$ *lifecycle emission value of the* biogenic fraction of the fuel (core LCA value from Table 6 + default ILUC value from Table 12).

Formula to define L_{CEF}

Due to the difficulties and the approximations related to the definition of the lower heating value (LHV) and %mass for each fuel component, a practical solution for operators and the SCS to calculate L_{CEF} of the finished co-processed jet fuel:

$$L_{CEF,CoPro} = 89 * \%vol_{fossil} + L_{CEF\ bio} * \%vol_{bio}$$

This equation allows the calculation of L_{CEF} with the information from:

- the process simulation (%vol.); and/or
- from measurements (for instance with 14C techniques)

The L_{CEF}, bio value will be used for the purposes of assessing compliance with Sustainability Criteria 1.1

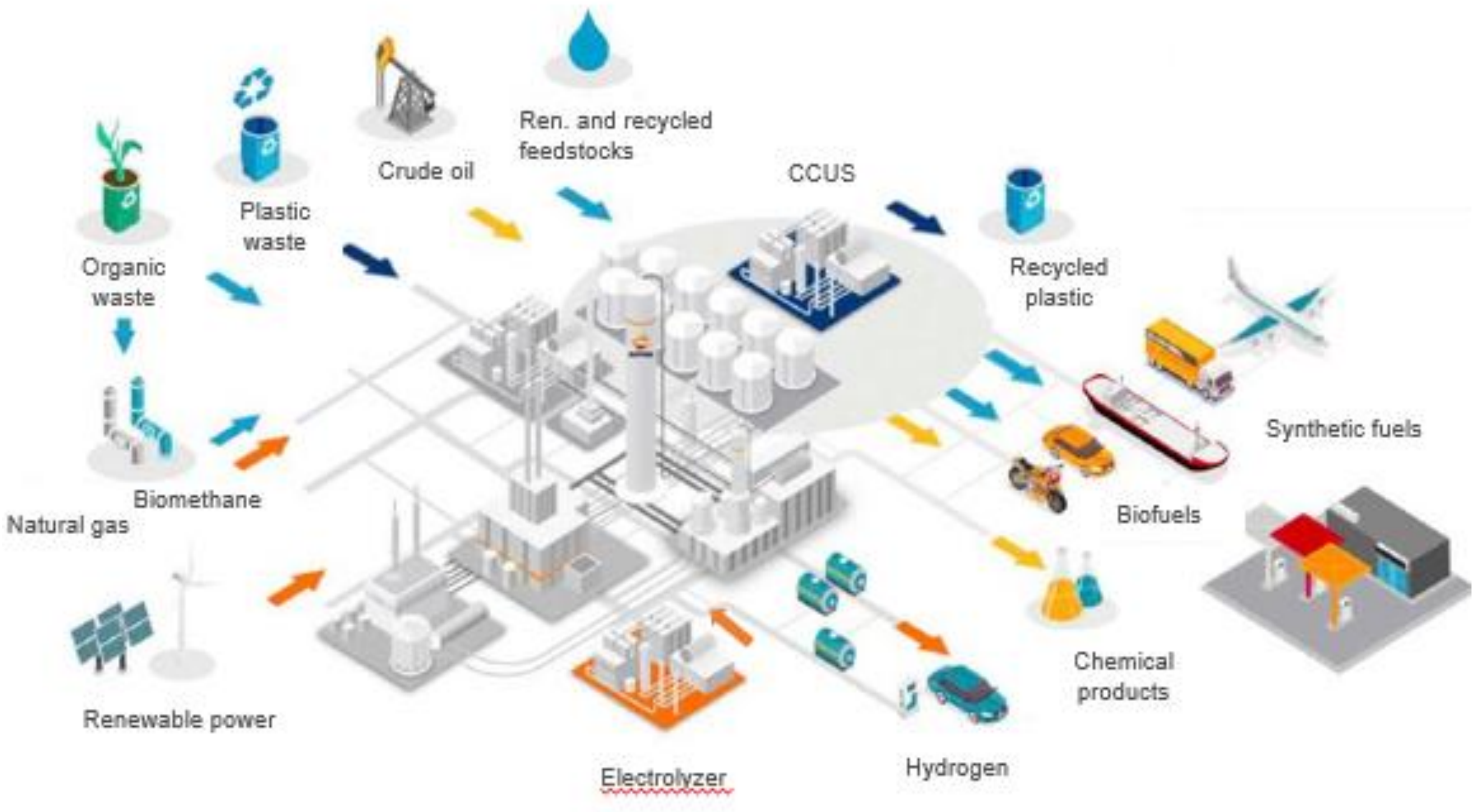
Theme	Principle	Criteria
1. Greenhouse Gases (GHG)	Principle: CORSIA SAF should generate lower carbon emissions on a life cycle basis.	Criterion 1.1: CORSIA SAF will achieve net greenhouse gas emissions reductions of at least 10% compared to the baseline life cycle emissions values for aviation fuel on a life cycle basis.

ICAO document - CORSIA Sustainability Criteria for CORSIA Eligible Fuels

Presentation by Repsol

Strategic Targets 2030

Repsol Compromiso
Cero Emisiones Netas
2050



2,4 GWeq Renewable H2

CH_4 2,3 TWh Biomethane

2,7 Mton Renewable fuels

200 kta Recycled polyolefins

Integration with the industrial complexes

ACT SAF

Waste and raw materials	Primary Conversion	Secondary Conversion	Products	Final Uses

New units

Current refinery

Renewable Liquid Fuels and Gases

Raw Material for the petrochemical industry

- Sustainable vegetable oils
- UCO
- Lipidic Wastes
- Municipal and Industrial Solid Waste
- Plastic Waste
- Forestry, agricultural, livestock and food industry wastes
- CO_2

Waste conversion to synthetic oils
+
Pretreatment

Delocalized (National & International)
Distributed
Integrated

Energy Efficiency
Renewable energy and gas
Carbon Capture

Renewable Fuels for road transport

Renewable Fuels for aviation

Renewable Fuels for marine

Renewable and Circular Materials

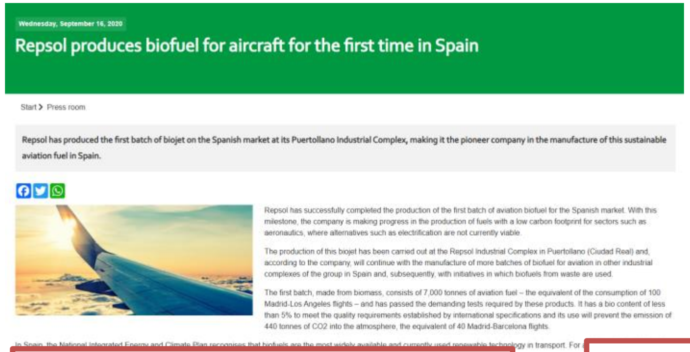
Power generation, Heating, industry, residential

H_2

H_2

The Repsol Commitment Net Zero Emissions by 2050

REPSOL SAF Projects pipeline



Wednesday, September 16, 2020

Repsol produces biofuel for aircraft for the first time in Spain

Start > Press room

Repsol has produced the first batch of biojet on the Spanish market at its Puertollano Industrial Complex, making it the pioneer company in the manufacture of this sustainable aviation fuel in Spain.

Repsol has successfully completed the production of the first batch of aviation biofuel for the Spanish market. With this milestone, the company is making progress in the production of fuels with a low carbon footprint for sectors such as aeronautics, where alternatives such as electrification are not currently viable.

The production of this biojet has been carried out at the Repsol Industrial Complex in Puertollano (Ciudad Real) and, according to the company, will continue with the manufacture of more batches of biofuel for aviation in other industrial complexes of the group in Spain and, subsequently, with initiatives in which biofuels from waste are used.

The first batch, made from biomass, consists of 7,000 tonnes of aviation fuel – the equivalent of the consumption of 100 Madrid-Los Angeles flights – and has passed the demanding tests required by these products. It has a bio content of less than 5% to meet the quality requirements established by international specifications and its use will prevent the emission of 440 tonnes of CO2 into the atmosphere, the equivalent of 40 Madrid-Barcelona flights.

Repsol produce por primera vez en España biocombustible para aviación a partir de residuos

25/08/2021 · Redacción

Consolidated SAFcoprocessing production in Puertollano, Tarragona, Petronor and Coruña

Repsol invertirá 200 millones en Cartagena en la primera planta de biocombustibles avanzados

First SAF batch in Puertollano (Co-processing)

First batch co-processed biojet fuel **from waste** in Spain **(Petronor's Complex)**

E Fuels Demo Plant Under construction (Petronor)

2020 → 2021 → 2022 → 2023 → 2024 → 2025 → 2026 → 2030+

Repsol produce en Tarragona biocombustible para aviones

22/01/2021 en Transporte

SAF batch in Tarragona (Co-processing)

Columbus Day Parade in Spain (October 2022).

ENERGY TRANSITION

Repsol's Cartagena refinery starts up Spain's first industrial-scale biofuels plant

Repsol SA has commissioned the Iberian Peninsula's first plant exclusively dedicated to 100% industrial-scale production of renewable fuels at the operator's 220,000-b/d Cartagena refinery in the country's southeastern province of Murcia.

Robert Brelsford

April 3, 2024

Repsol SA has commissioned the Iberian Peninsula's first plant exclusively dedicated to 100% industrial-scale production of renewable fuels at its Cartagena refinery in the country's southeastern province of Murcia.

C-43 Plant (HEFA technology)

Other routes (TBD):

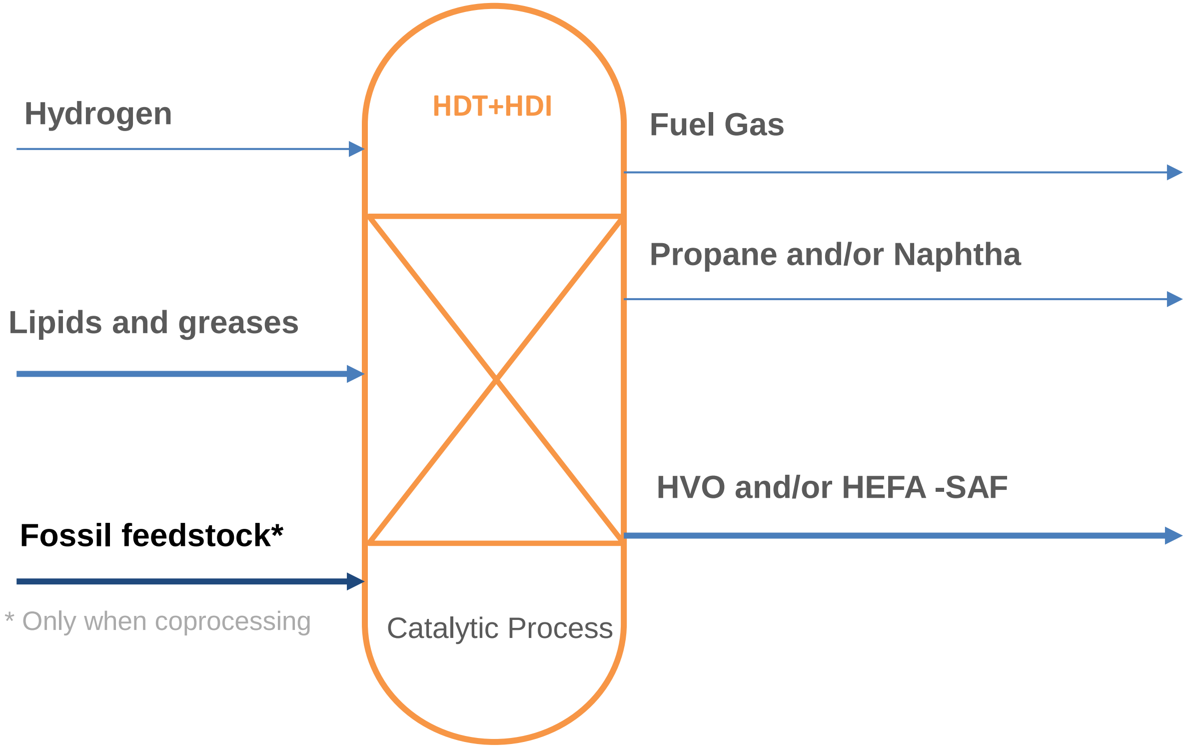
- Gasification + FT (FT- SPK route)
- Alcohol to Jet (AtJ- SPK route)
- E Fuels industrial Plant

Repsol SAF production overview

- **The HEFA route** is the **most mature technology and most of SAF projects announced worldwide up to 2028 correspond to this route.**
- **The limitation of raw materials** for this route makes it necessary to **boost the development of new technologies such as gasification + FT or Alcohol to Jet or eFuels**.
- **This innovative technologies** are capable of transforming other types of waste such as **MSW, forest or agricultural biomass,** etc but **require technological development**. For these new technologies to be cost competitive, **financial support and a clear and stable regulatory framework are necessary**.
- **Repsol has projects in its portfolio with the potential to significantly increase the capacity to produce SAF.** Post 2030 if technological maturity allows it, projects to produce synthetic SAF by new technologies will be considered.
- **Refuel Aviation targets** are **a positive step toward increasing demand**, but they are **insufficient to encourage short-term investment.** Despite its significant potential to reduce carbon emissions**, SAF adoption remains too low to support large-scale production.**
- **Renewable road fuels, with an established market, can support demand and investment for SAF. Synergies between aviation and road transport can speed up the adoption of sustainable fuels.**
- **Collaborative efforts reduce costs and improve production efficiency, aiding the transition towards a sustainable future for all transport modes.**

Lipidic Route - HEFA

- **Most similar to refining technology and more mature technology**
- Our refining system integration allows us to maximize hydrogenation capacity and transform it to renewable fuels (HVO and SAF)



+ FLEXIBILITY &CAPEX −

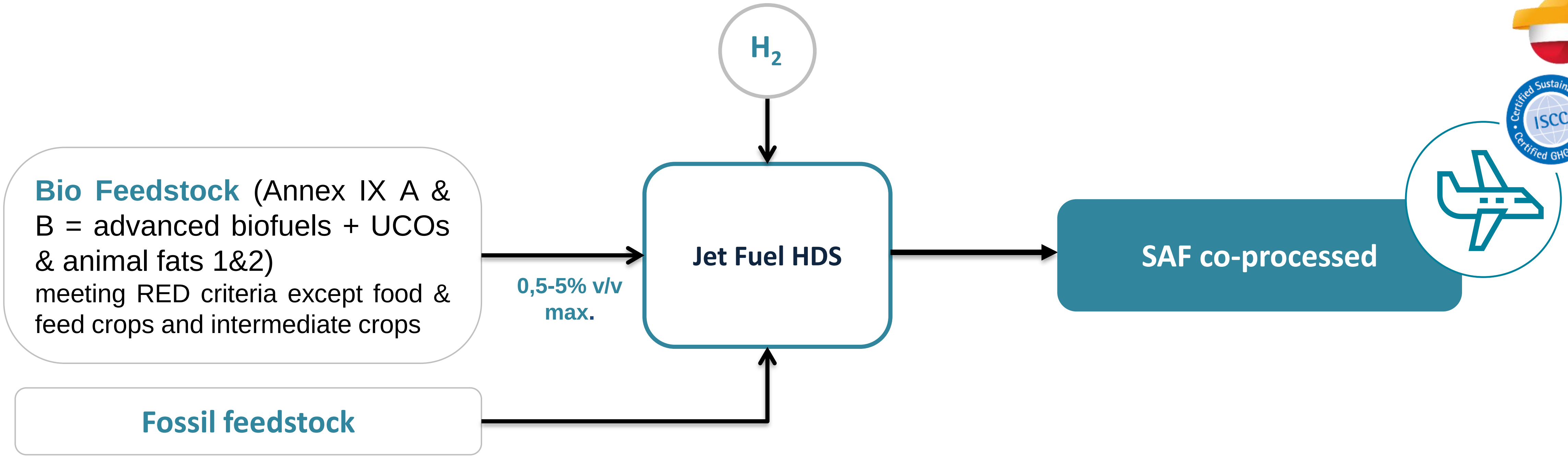
		New unit (Cartagena´s unit)	Retrofitting (TBD)	Coprocessing
CAPEX intensive		Moderate	Low	Not needed
Feedstock	Flexibility	Moderate	Low	Low
	Availability	Limited	Limited	Limited
	Cost	High	High	High
Product flexibilty		Good	Low	Very low
Product volume production		High	Moderate	Very low
CO2 abatement		High	High	High
Technology readiness		Ready	Ready	Ready
Integration with existing assets		Infrastructure	Existing units + infra	Existing units + infra
Profitability		High	High	High

The optimum mix of standalone units, co-processing and retrofitting will give us the more competitive scheme.
Co-processing is a low CAPEX fast track solution to produce SAF

SAF. Co-processed

- **ASTM D1655 and Def Stan 91-091 allow** the production of aviation fuel by co-processing with **up to 5%v/v alternative feedstocks along with the fossil feed**.
- The materials approved for co-processing in the production of aviation fuels are:
  - Mono-, di- and triglycerides, free fatty acids and fatty acid esters.
  - Hydrocarbons derived from synthesis gas via Fischer-Tropsch using cobalt or iron catalysts.
  - Hydrocarbons from hydroprocessed mono-, di, and tryglycerides, free fatty acids and fatty acid esters.
- **Only one type of raw material can be used to produce a specific batch of kerosene** and the Product Quality Certificate must indicate that it can contain up to 5% by volume of co-processed synthetic kerosene.
- **Co-processing of hydrocarbons** from hydroprocessed mono-, di-, and triglycerides, free fatty acids, and fatty acid esters must include fractionation and **may involve other conventional fuel manufacturing processes**. **The final fractionation unit for jet production should not exceed 24%** by volume of these hydrocarbons, with the remaining 76% from conventional sources, and the final jet batch is limited to 10% by volume of co-processed synthesized kerosene.
- **ASTM has included in Def Stan 91-091 Issue 18 (currently for public commentis) the possibility of increasing the amount of sustainable raw material in co-processing in conventional processes up to 30% v/v. This is key to increase the volume of SAF produced at a lower cost**

Repsol Co-processing



- **SAF by co-processing is a viable and scalable approach with mínimum operational adjustments**
- **Freezing point limits the bio incorporation rate**
- **Yield: ~97%v/v. The product must meet additional quality requirements compare to conventional jet**
- **Delegated act “Co-processing“ 2023/1640/EC is aplicable since September 2023**
    - Measurements with 14C is required (as verification method at least each 4 months).
- **Product under ISCC EU certification for national market**
- **Challenges in recognizing co-processed products for export: using Spain's logistics pipeline network complicates compliance with C14 import requirements in some countries**

SAF Co-processed quality

- Def Stan 91-091 recognize this route as "conventional" drop-in jet fuel
- However, the regulations require **additional and stricter quality requirements** for this type of fuel, focusing on **thermal stability**, **fluidity and unconverted fatty acids**.

Table 3: Extended Requirements of Aviation Turbine Fuels Containing Co-processed Synthesized Kerosene[1,2]

Test	Property	Units	Limits	Method
1	Thermal Stability			IP 323 / ASTM D3241
1.1	Test Temperature for 2.5hr	°C	Min 280	[3]
1.2	Tube Rating (one of the following requirements shall be met):			
1.2.1 or	Annex B VTR	-	Less than 3. No Peacock (P) or Abnormal (A)	
1.2.2	Annex C ITR or Annex D ETR, average over area of $2.5mm^2$	nm	Max 85	
1.3	Pressure differential	mm	Max 25	
2	Fluidity			
2.1	Freezing Point	°C	Max minus 47.0	IP 435 / ASTM D5972[4] IP 529 / ASTM D7153 ASTM D7154
2.2	Viscosity at minus 40°C[6]	mm^2/s	Max 12.0	IP 71 Section 1[4,6] or ASTM D445[6], ASTM D7042[7], ASTM D7945
3	Composition			
3.1	Aromatics: One of the following requirements shall be met[8,9]			
3.1.1 or	Aromatics	% v/v	Min 8	IP 156[4,10] or ASTM D1319[10], ASTM D8267, ASTM D8305[11]

Table 3: Extended Requirements of Aviation Turbine Fuels Containing Co-processed Synthesized Kerosene[1,2]

Test	Property	Units	Limits	Method
3.1.2	Aromatics	% v/v	Min 8.4	IP 436 / ASTM D6379
4	Volatility			
4.1	Distillation[8]	°C		IP 123[4, 12] or ASTM D86[12], IP 406 or ASTM D2887[13], ASTM D7345[14]
4.2	T50-T10		Min 15	
4.3	T90-T10		Min 40	
5	Lubricity			
5.1	Lubricity[8]	mm	Max 0.85	ASTM D5001
6	Process Control			
	Unconverted fatty acid esters and fatty acids	mg/kg	Max 15	IP583 / ASTM D7797[16]

Sustainability requirements & Spanish certification system

Fuente: AOP

- **ISCC EU certification for Repsol's 5 refineries**
- **Certification of Exolum facilities (ISCC EU).** Exolum is the operator of the Spanish logistics pipeline network.
- **Within Exolum's main network**, we can perform **mass balance for the delivery of sustainability documentation.**
- **To comply with RefuelEU legislation**, the **weighted average system** will be used.
- **Certificates are associated with outputs from the refinery connected to the relevant Exolum facility.**
- Other certifications:
  - Cartagena and Puertollano Refineries are also certified under **ISCC CORSIA**, but there's **no production expected under this scheme until its entry into force.**
  - Repsol Sales is certified under **RBS Book and Claim Scheme**, not for regulatory compliance but to **voluntary overseas markets**

Conclusions

- Synergies between aviation and road transport has sped up the adoption of sustainable fuels in the past and continue doing in the future
- Currently, 99% of the SAF on the market is produced using the HEFA pathway, a mature technology with numerous commercial applications. It uses lipid waste as feedstock, but the availability of this type of raw material is limited.
- Co-processing is a low CAPEX fast track solution to produce SAF.
- Increasing the amount of bio feedstock that can be co-processed up to 30% is essential to increase the volume of SAF produced at a lower cost
- A clear & stable regulatory framework is essential to drive investments and meet demand, integrating both mandatory and voluntary requirements to create a liquid market.
- A universal definition of SAF is critical for harmonizing market rules, optimizing global production, and ensuring scalability. This definition should include not only feedstocks but also emission reduction targets, sustainability conditions, and other criteria.
- Regulatory signals and feedstock acceptance for SAF must be consistent globally to avoid market distortions. Regional disparities, such as uncertainty in European flexibility mechanisms, may impact compliance, investment strategies, and competitiveness.
- Continued support from government policies and incentives is crucial for the widespread adoption of SAF
- **Ongoing research and** technological advancements **will play a key role** in making SAF more accessible and cost-effective.
- **To ensure SAF availability,** production routes for renewable aviation fuels should be rapidly validated in line with technological developments and the quality requirements need to be simplified.
- Collaboration **among all the players in the value chain is key for the SAF deployment**

Together, we can look forward to a cleaner and greener sky.

ACT SAF

Assistance, Capacity-building and Training for SAF

Presentation by Montana Renewables


MONTANA
RENEWABLES™

CALUMET: Celebrating 100 Years of Innovation and Growth

1919
Calumet Refining Company is Formed (Burnham, IL)

1925
Koshiro begins to buy petrolatums from now-Calumet Karns City

1995
Enter Aliphatic Solvent Business (Cotton Valley, LA)

2006
Public Listing NASDAQ ticker CLMT (New York, NY)

2012
Enter Automotive, Industrial, & Racing Use Synthetic Lubricants (Porter, TX)

2013
Enter High Tech Industrial, Power Sports, Mining, & Marine Lubricants (Farmingdale, NJ)

2021
Montana Renewables ("MRL") carved out as unrestricted subsidiary (Great Falls, MT)

1953
Enter Naphthenic Base Oil Business (Princeton, LA)

1990
Calumet Corporate Headquarters Moved (Indianapolis, IN)

2001
Enter Paraffinic Base Oil & Wax Business (Shreveport, LA)

2008
Enter White Oil, Petrolatum, & Gel Business (Karns City, PA)

2012
Enter Ready-to-Use Fuels for Outdoor Power Equipment (Shreveport, LA)

2017
Expand R&D Capabilities with "The Center" (Indianapolis, IN)

MONTANA RENEWABLES COMMISSIONED 2022

2022 Commissioned
2023 Expanded
2024 Reached 45MM gpy SPK runrate at mid year

- 175MM gpy total renewable products
  - **SPK**—under term contract since 2022
  - Renewable hydrogen
  - Renewable diesel
  - Renewable naphtha (gasoline today, renewable plastics tomorrow)

- **SAF Pioneers – North America**
  - World Energy—first domestic SAF producer
  - Montana Renewables—currently largest (2024)
  - Diamond Green (sales expected 4Q24)
  - P66 (sales expected 4Q24)

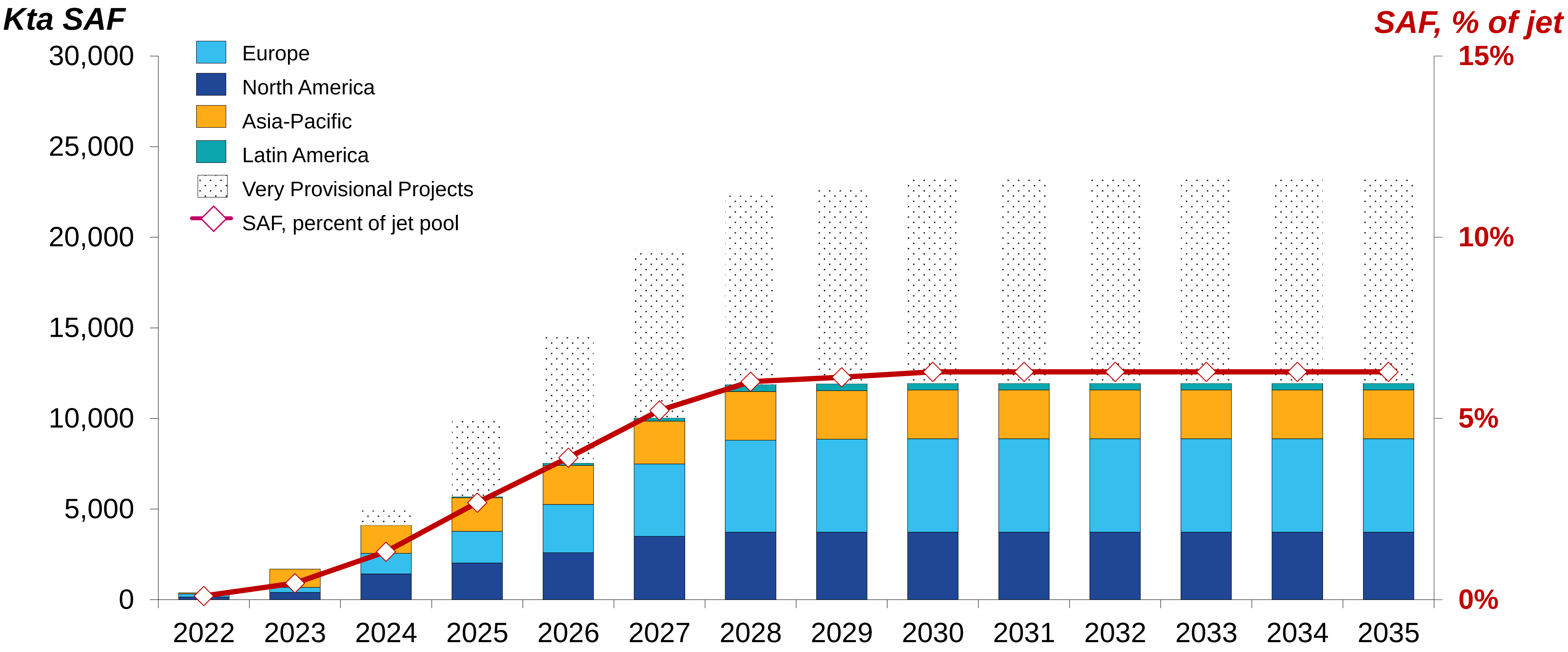
SAF PRODUCERS—NORTH AMERICA

Legacy Refining Company?	Pending	Running
YES	DIAMOND GREEN DIESEL; PHILLIPS 66 → 2024	world energy; MONTANA RENEWABLES™
Other	**Potential supply:** **~ 3 dozen provisional projects *not* under construction (mostly HEFA, ATJ)**	

Difficult for startup proposals to attract risk capital for construction

IS THE WORLD ON TRACK FOR 10% SAF BY 2030?

ONLY IF THE PROVISIONAL PROJECTS CAN MOVE



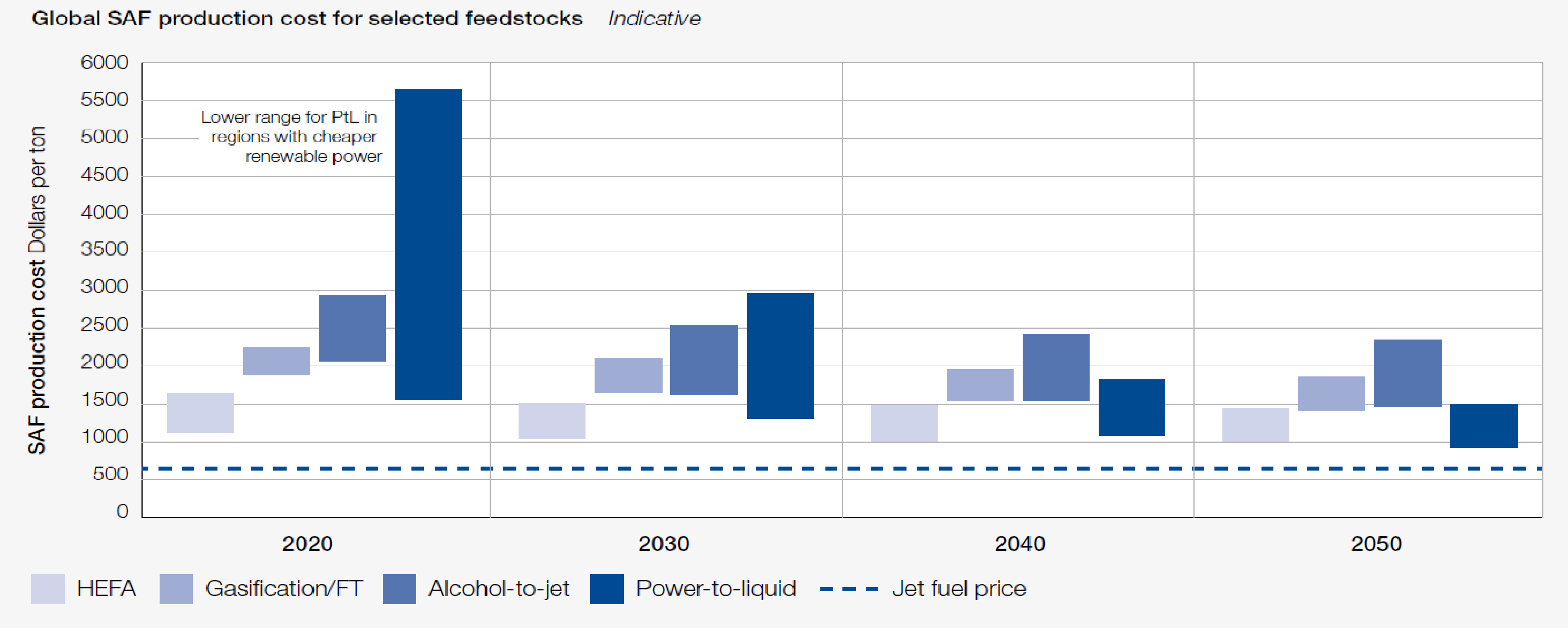
Source: Argus Consulting (supply)
DOE and aviation trade groups (jet demand)

HOW TO MOVE PROJECTS FORWARD?

1. Last year ~600 million gpy SAF was left in the North American renewable diesel pool, where it will stay
   - ***Unless SAF is priced above Renewable Diesel***
2. Is capital available for RD/SAF capacity expansion?
   - ***If lenders and investors believe they will receive a risk-adjusted return on investment***
3. Investor risk focus?
   - Technology risk
   - Sponsor’s operational competencies
   - Value chain and “last mile” into wing
   - Stability of regulatory policy

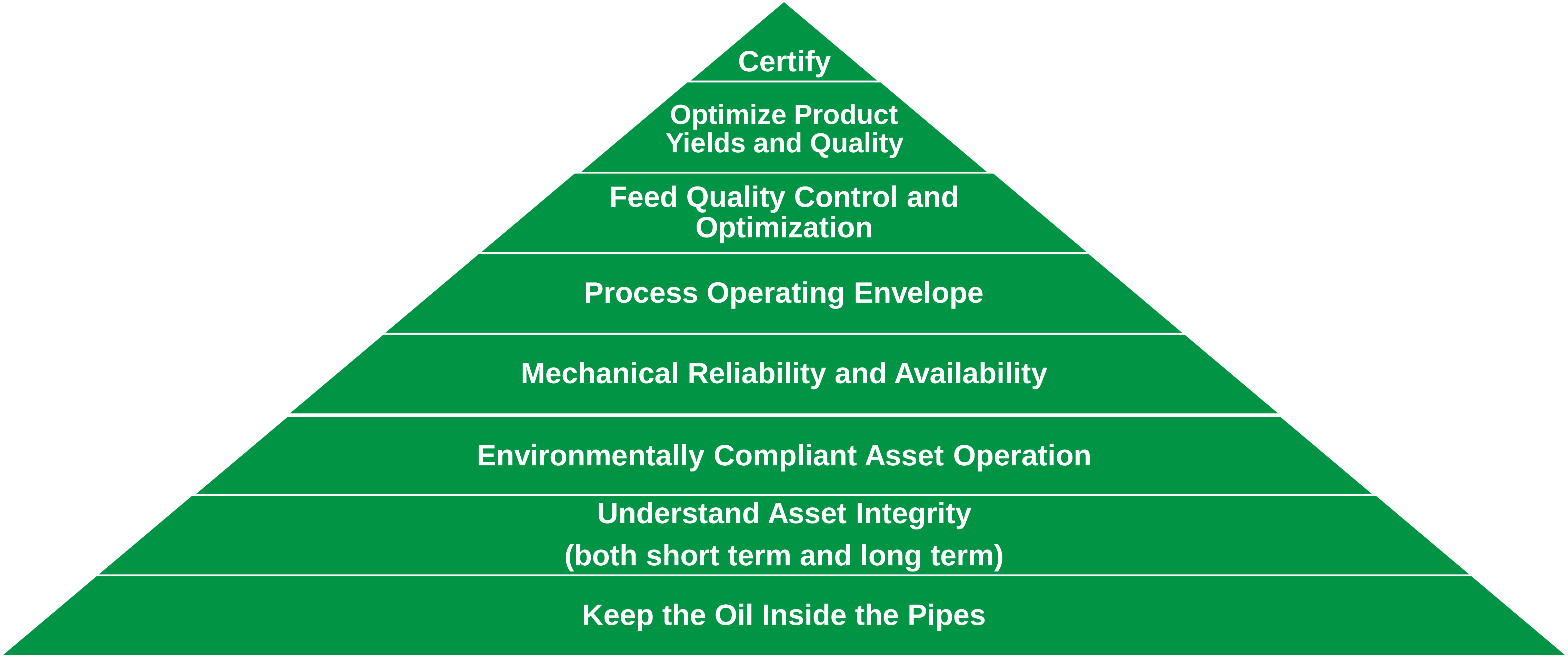
TECHNOLOGY RISK

- The world's SAF is currently from HEFA technology, which offers the lowest cost



In Collaboration with McKinsey & Company: Clean Skies for Tomorrow, Sustainable Aviation Fuels as a Pathway to Net-Zero Aviation, Insight Report Nov 2020 World Economic Forum

SPONSOR’S OPERATIONAL COMPETENCIES



VALUE CHAIN AND “LAST MILE” RISK – VOLATILITY

- Value chain is lengthy and crosses otherwise-unrelated industry boundaries
  - Chain length and complexity causes significant price volatility
  - **And each step is generally under a different regulatory incentive structure**

1. FARM & RANCH FEEDSTOCK CHAIN:

1. Farm & ranch primary output
2. Transport
3. Seed crusher or food processor
4. Transport oil or waste to SAF producer

2. FEEDSTOCK HANDOFF TO SPK - SAF CHAIN:

1. SPK production incl. optimization
2. Transport SPK ASTM D7566
3. Blend w JetA to finished SAF ASTM D1655
4. Last mile into airfield

REGULATORY UNCERTAINTY

The biggest challenge and the biggest opportunity?

- Alignment, but….
  - Positive policy support from a tapestry of incentives and requirements among States and Provinces, Federal Canada, and Federal US (EPA, Dept Ag, DOE, FAA)
  - But details can be materially at odds across jurisdictions, e.g. vegetable oil feedstock "yes/no"
  - Result is 'balkanized' value chain

- Predictability, but…
  - The regulatory tapestry is changing faster than 10-year investor capital recovery model
  - Worse: disincentives from 2023-25 RVO; BTC/PTC "donut hole"; broken permitting process; etc.

- Global…not yet
  - Compliance and certification mechanics for SAF will uniquely require international alignment
  - Including workable chain of custody accounting and book & claim approach e.g. Shell Avelia[(1)]

- Like the Club of Rome, forecasts will be wrong—sometimes dramatically so—and the Law of Unintended Consequences has not been repealed

(1) https://aviation.shell.com/avelia-panel-interactive

lo·ca·vore

/ˈlōkəˌvôr/

noun

NORTH AMERICAN

1. a person whose diet consists only or principally of locally grown or produced food.

A MODEST PROPOSAL

- EU volume mandate or North American incentives?
  - A trick question, since N.A. incentives are just complicated volume mandates of which the U.S. Renewable Volume Obligation is the largest

- Policy incentives must be *perceived by investors* as predictable if risk capital is to be affordable
  - Historically the RVO had predictability: when additional renewable production capacity appeared in the market EPA added it to the following year's RVO
  - The 2023-25 RVO departed from this practice and "The Renewable Volume Obligations for biomass-based diesel…were set significantly lower than production…"[1]

- While North American risk pioneers are succeeding locally…
  - LCFS geographies
  - Illinois and Minnesota state SAF incentives

- …the Grand SAF Challenge seeks to launch a national industry
  - Which requires that EPA increase biobased distillate RVO to a level that matches production

[1] Senators Klobuchar and Grassley, along with 16 others, urging EPA to fix the error, letter to Michael Regan on June 11, 2024

LOCAVORE EXAMPLE: THE GREATER MSP SAF HUB[1]

"FIRST SUSTAINABLE AVIATION FUEL ARRIVES AT MSP AIRPORT"

Business Wire, Tue, September 24, 2024 at 6:17 AM MDT

MN and ND Farms
Camelina seed crop

Truck transport

Cargill
Seed crusher

BNSF Rail
Camelina oil to MRL

Montana Renewables
SAF production

Montana Renewables
Blend to Jet A

Shell Aviation
delivery to MSP

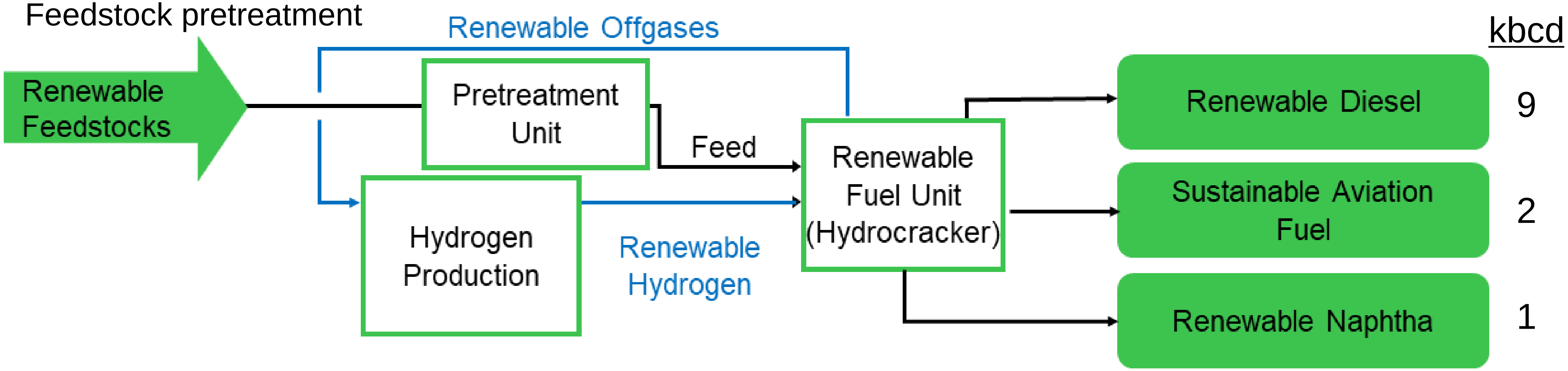
Delta Airlines
DL 2732 from MSP to LGA

[1] https://www.mnsafhub.org/

MRL CONVERSION OF AN EXISTING REFINERY ASSET

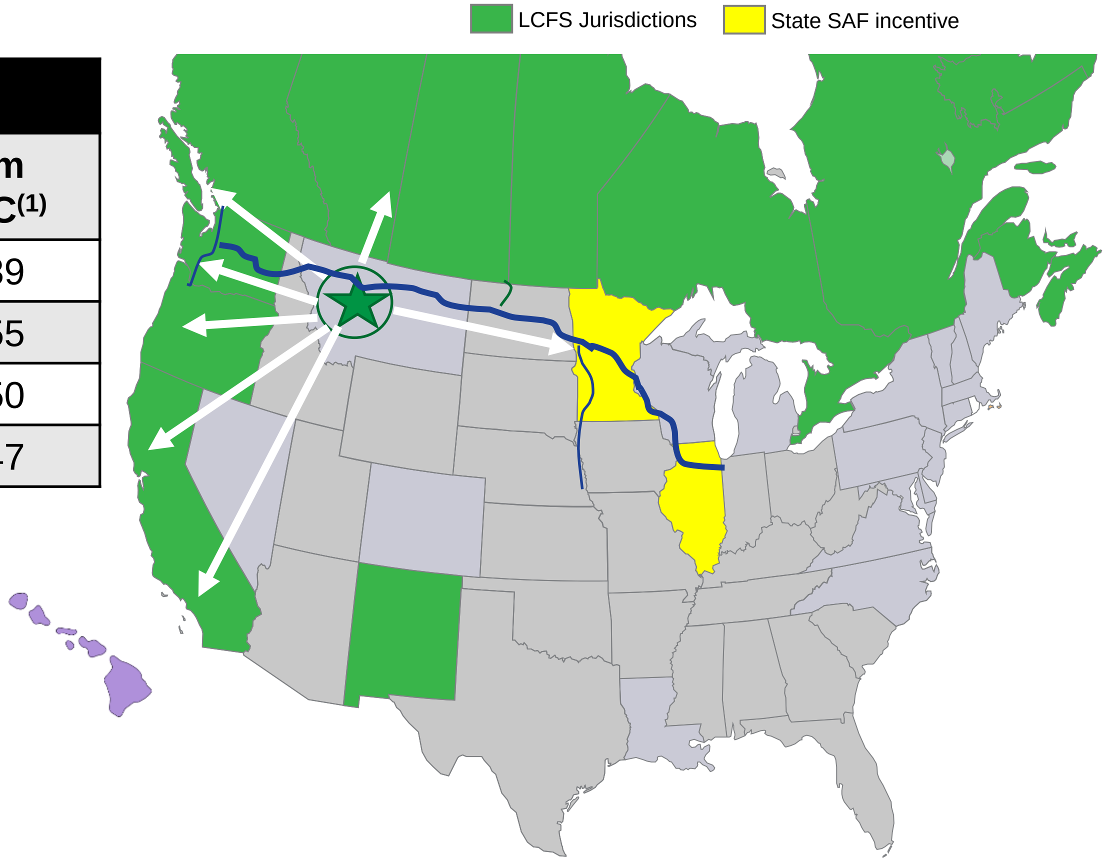
2022 Conversion of existing oversized hydrocracker and hydrogen supply (new in 2016)
- 317L metallurgy for renewable feedstock—critical element of fast, low-cost conversion vs. industry
- Reactor suitable as-is
  - 5 catalyst beds
  - Recycle capability
  - Quench capability
- Mechanically the best conversion in North America

2023 Added growth projects
- Renewable Hydrogen
- Feedstock pretreatment



LOCAL LCFS MARKETS FOR MRL PRODUCT

Product Rail Costs to LCFS Markets		
$/gallon	**From Great Falls**	**From USGC[(1)]**
To Vancouver, BC	$0.27	$0.39
To Calgary, AB	$0.26	$0.55
To Seattle	$0.25	$0.50
To Los Angeles	$0.37	$0.47



But product pipelines dramatically cheaper, e.g. ~$0.07/gallon USGC to NY on Colonial PL[(2)]

(1) Average of two renewable diesel plant sites
(2) Beaumont TX to Linden NJ https://colpipe.s3-us-west-1.amazonaws.com/media/Colonial-FERC-99.88.0-Index-Increase-4861-1278-4579.1.pdf?mtime=20240531054825&focal=none

NEXT: MAX SAF EXPANSION

- MaxSAF™ includes a series of discrete, modular projects to enhance MRL capability and reduce emissions
  A. ***Increase SAF capacity to ~150mm gallons/year within ~2 years***
    - First step is to install the previously-acquired second reactor
    - Early estimate capex of $150-250MM
  B. ***Increase SAF capacity to ~300mm gallons/year within ~3 to 4 years***
    - Sequential steps: execution of other project modules including Renewable hydrogen production, expansion of existing Renewable Fuels Unit and Feedstock Pretreatment Unit, wastewater treatment, renewable electricity and steam via cogeneration, SAF truck rack capability, other efficiency projects

- Tranche 2 funding will be drawn during MaxSAF™ construction subject to satisfaction of other customary conditions precedent, and MRL maintaining DOE at 55% debt to total capitalization

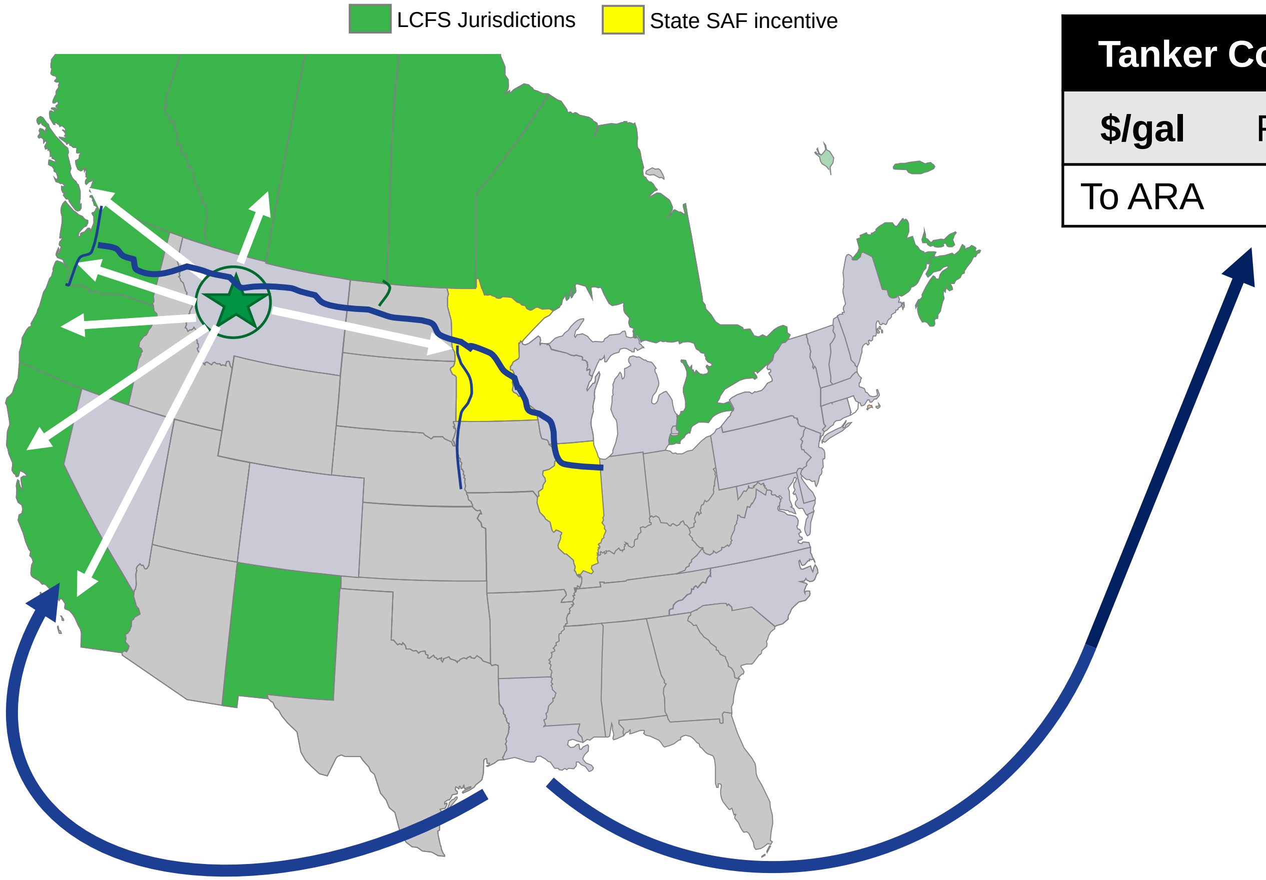
Estimated Yields, kbcd	Runrate[1] 2024	Second Reactor ~2026	MAX SAF ~2027/8
Renewable Diesel	9	4	2-4
Renewable Jet (100%)[2]	2	10	15-20
Renewable Naphtha	1	1.5	2-3

[1] Demonstrated midyear 2024
[2] 100% Renewable SPK, ASTM D-7566 (the Into-wing volumes are double the above after blending)

SAF TO EU ?

Rail Costs to LCFS Markets		
$/gallon	**From Great Falls**	**From USGC(1)**
To Vancouver, BC	$0.27	$0.39
To Calgary, AB	$0.26	$0.55
To Seattle	$0.25	$0.50
To Los Angeles	$0.37	$0.47

Tanker Cost to USWC via Panama Canal	
$/gal	From USGC
To LA	$0.25-0.40



Tanker Cost to EU (2)	
$/gal	From USGC
To ARA	$0.10-0.15

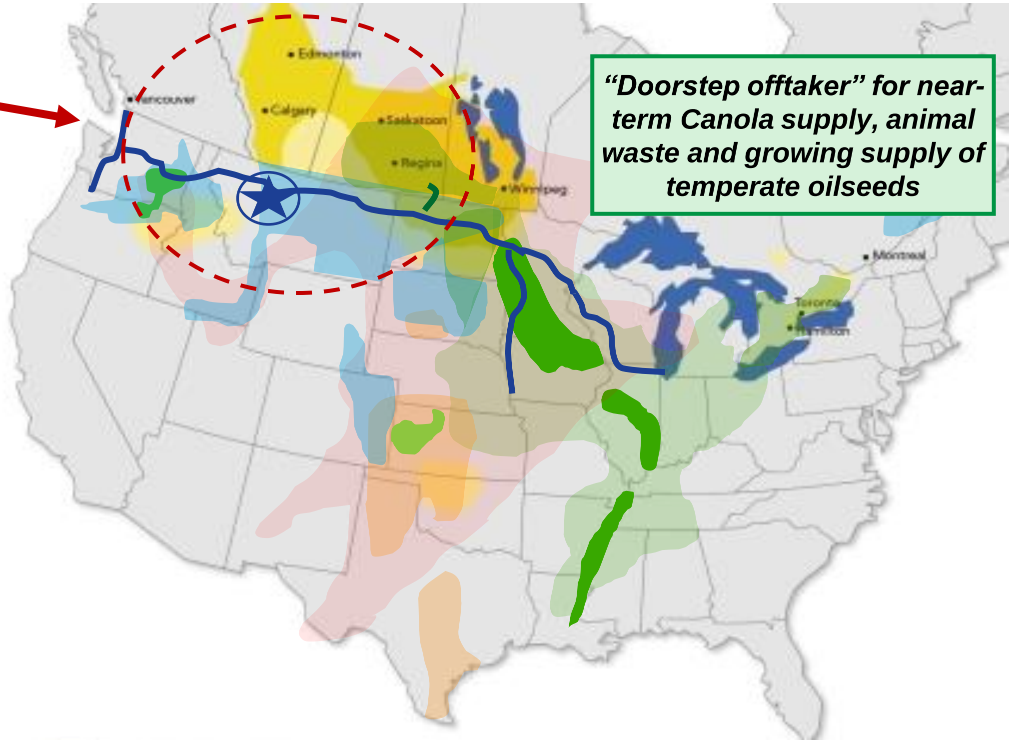
SAF will seek its highest netback price

(1) Average of two renewable diesel plant sites
(2) Foreign flag Houston to Rotterdam, McQuilling

LOCAL GATHERING OF MRL FEEDSTOCK

Located within the temperate oil seed belt for immediate feedstock access and lower-cost logistics

- 125,000+ barrels per day of feedstock within advantaged logistics range—10X MRL needs
- Burlington Northern ag commodities heavy duty rail



Great Falls, MT
Canola Growing Density
Soybean Growing Density
Cattle Ranching Density
Camelina Growing Density
BNSF High Line (partial)

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Questions and Answers

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Closing Remarks

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THANK YOU