A decorative graphic consisting of a thin black crosshair with a vertical line extending upwards and a horizontal line extending to the left, positioned to the left of the title.

Low-Cost Production of Renewable Diesel and SAF with BioFlux Hydrotreating Technology

Sashikant Madgula
Business Segment Leader – Renewables
Clean Fuels & Chemicals Licensing



Sulzer offers products, services and know-how for a wide range of fluid processing applications in many different markets



Flow Equipment

From standard pumps to highly engineered pumps and other specialized equipment, for water, industry and energy



Chemtech

Separation and process technology and associated services for the chemical and refining industries, with a strong position in emerging biopolymers and recycling



Services

Parts, service and refurbishment for pumps, turbines, compressors, motors and drives, etc.

+ Technology licensing

GTC Technology into Sulzer since May 2019 as part of Clean Fuels & Chemical Licensing Business Unit

Offer more than 25 licensed technologies across multiple value chains that provide for increased capacity, improved efficiency, and maximized production

Refining & PX Complex

- GT-BTXSM
- GT-BTX PluSSM
- GT-DWCSM
- MaxFlux[®]
- CrystPX
- GT-TransAlkSM

Petrochemicals

- GT-BTXSM
- GT-StyreneSM
- C5 Processing
- PGO Processing

Sustainable Technologies

- BioFlux for Renewable Diesel/SAF
- Mixed Plastics Pyrolysis Upgrading

Licensed Technology Scope of Supply

R&D

Technology

Licensing

Engineering

Technical
Services

Chemicals
& Catalysts

Proprietary
Equipment



The industry is transforming



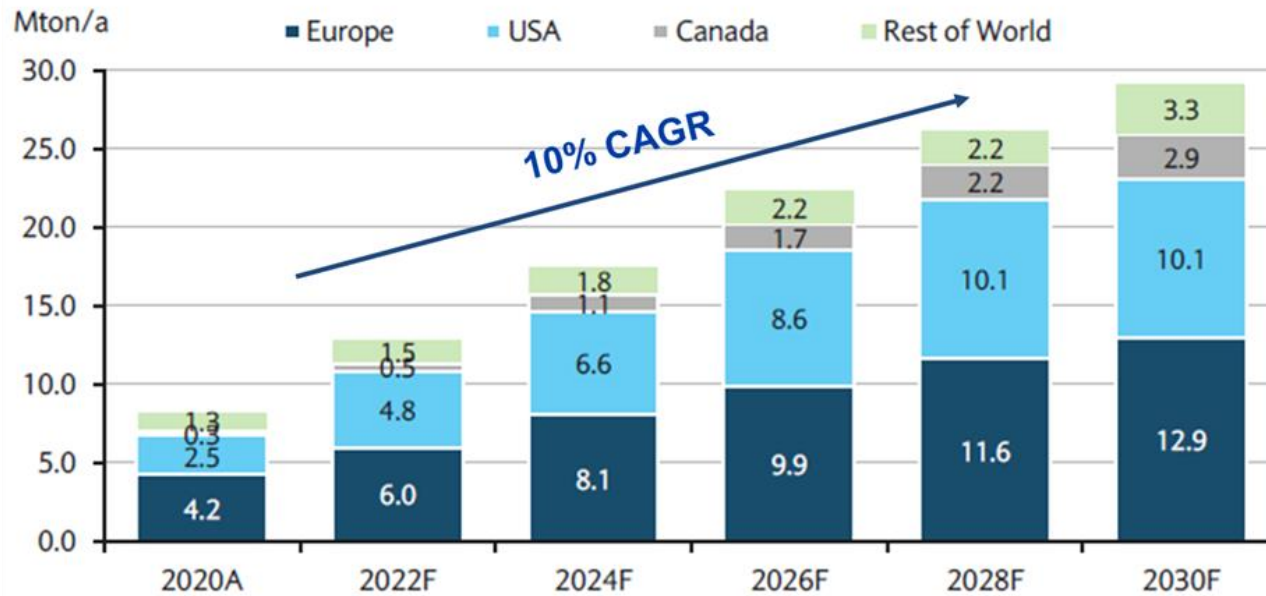
- Our customers are increasingly driving refining and petrochemical integration as well as diversifying their feedstocks, i.e., using bio-based resources and recycled waste plastics & polymers in addition to, or replacing, crude and gas
- The industry transformation requires innovation and development of new processing technologies and key equipment, which is at the core of the Sulzer Chemtech business



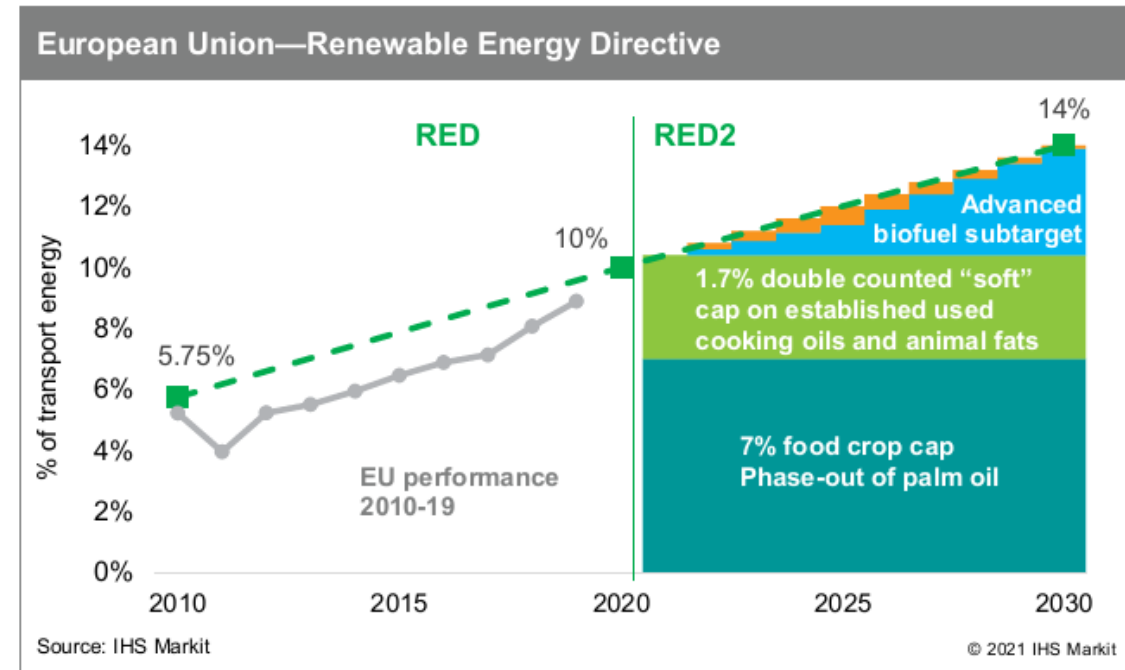
Renewable Fuels Markets – Driven by Government Policy

Demand growth for renewable fuels driven by US and Europe government policy

RD base case demand projections by region, Mton/a



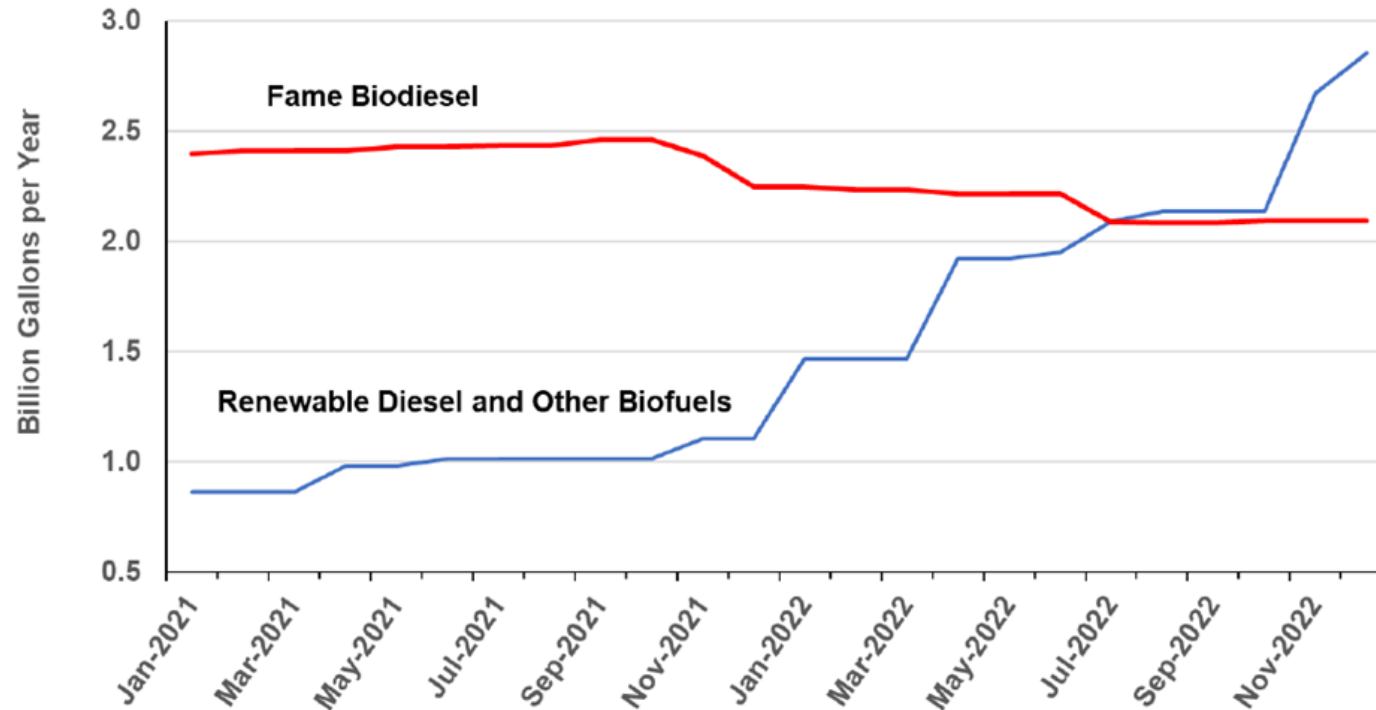
Source: Barclays Research Estimates based on policy and mandates



- Demand growth for renewable fuels driven by US and Europe government policy
- US market is driven by Renewable Fuels Standard (RFS) with RINs and California LCFS Scheme
 - Produce Biofuels or pay for RINs and credit scheme for producing biofuels with low carbon intensity
- European market growth is driven by its Renewable Energy Directive (RED II) – Fit for 55 proposal
- RED II requires member states meet a minimum supply of 14% of the energy consumed in transport as renewable energy by 2030

+ US Renewable Diesel has surpassed Biodiesel (FAME)

US Production Capacity - Renewable Diesel (HVO) vs Biodiesel (FAME)



Source: EIA

Historic switch in the dominant production role between renewable diesel and FAME biodiesel in the US thanks to RFS and LCFS schemes

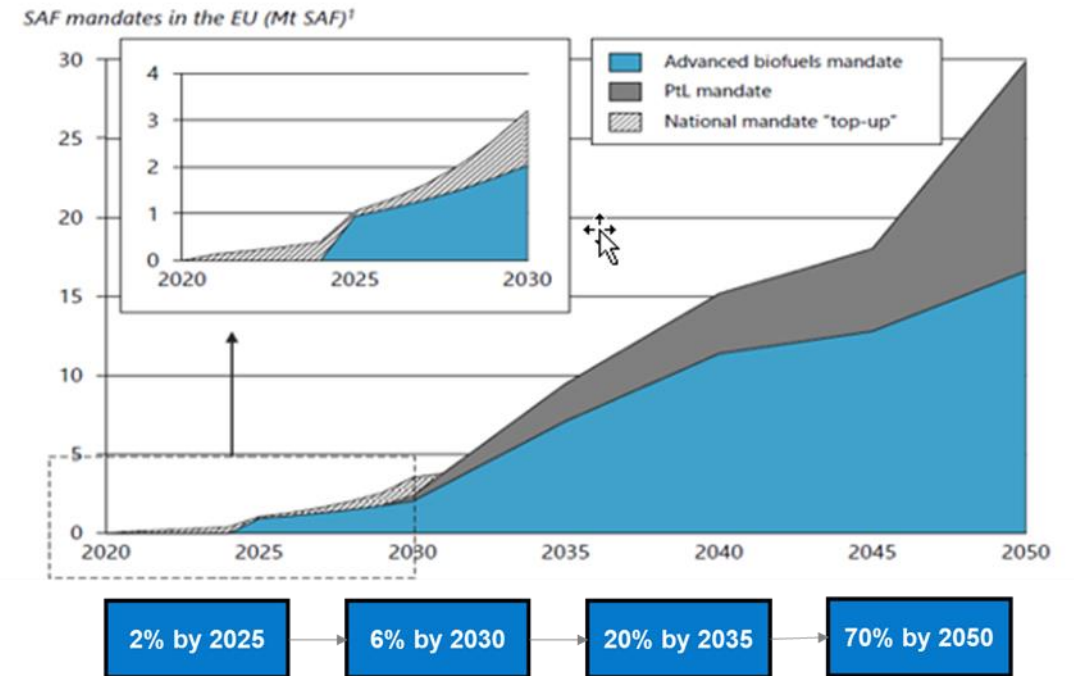
+ Sustainable Aviation Fuel – Fast Growing Global Phenomenon

Aviation produces about 3% of total CO₂ and 12% of transport emissions globally



Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)

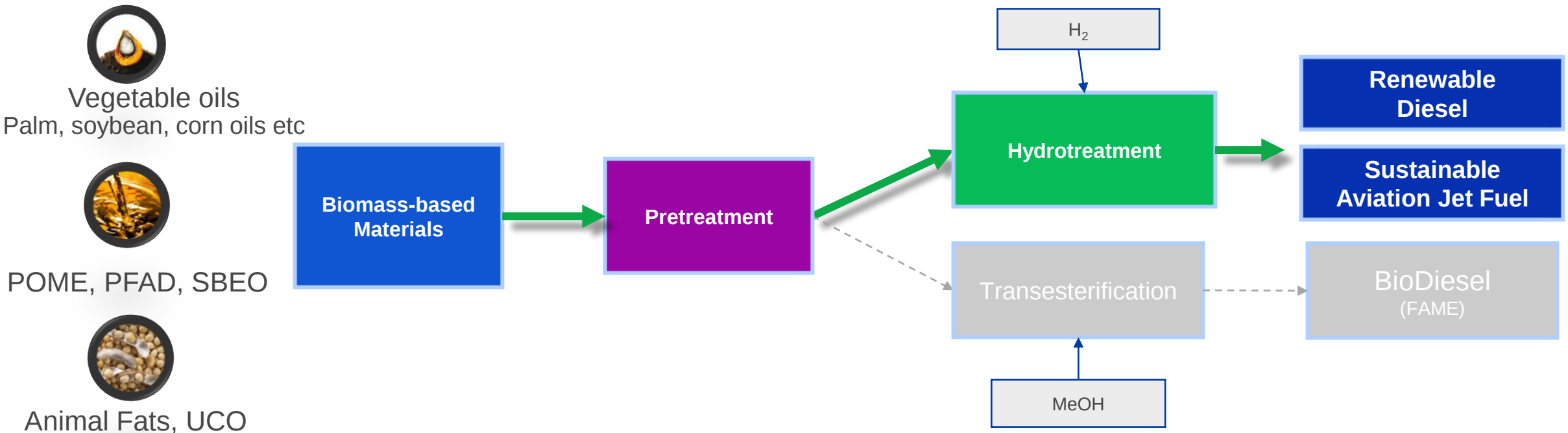
- US Aviation SAF Grand Challenge - Supply to at least three billion gallons of SAF per year by 2030 – reduce emissions by 20%
- Eventual goal of meeting 100% of U.S. aviation fuel demand with SAF by 2050.
- SAF mandates as CORSIA aims to increase the share of sustainable fuels at EU airports
- **EU agreed to binding targets for SAF usage - minimum of 2% share of Jet Fuel in 2025, 20% in 2035 and to 70% by 2050.**



+ Renewable Diesel (HVO) & Sustainable Aviation Fuel (SAF)

Hydrotreated Esters and Fatty Acids (HEFA) from Fats, Oils and Greases

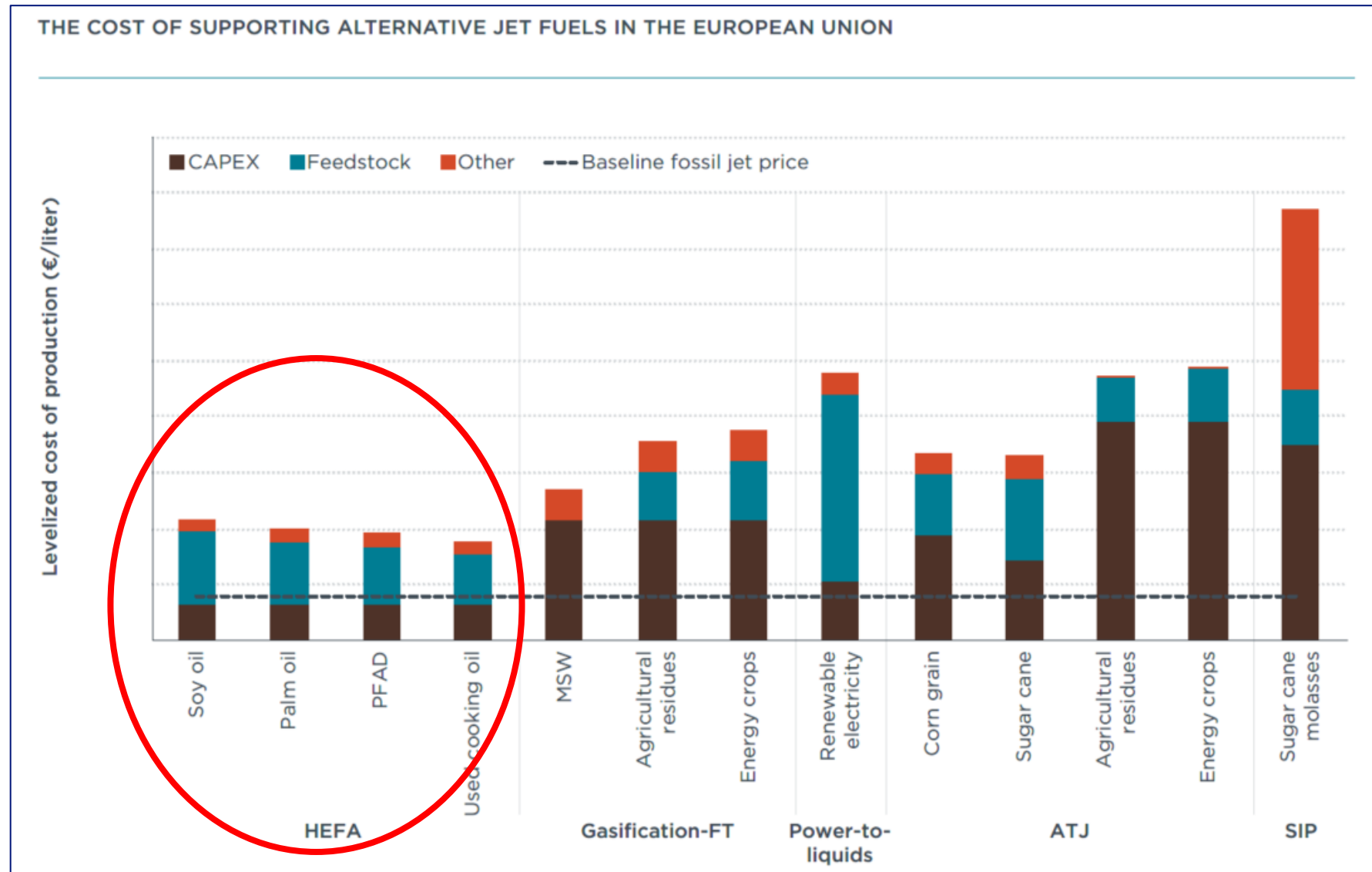
Renewable diesel, or HVO (hydrotreated vegetable oil) is a non-petroleum hydrocarbon fuel made up of 100% renewable raw materials and is **chemically identical to conventional petroleum derived road diesel**



HVO or renewable diesel can be used as total substitute for conventional diesel



HEFA is still the most economic pathway to produce SAF and Renewable Diesel

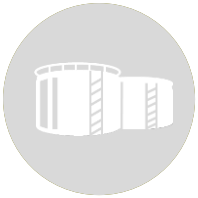




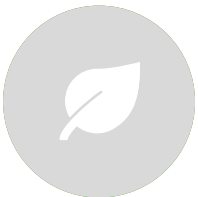
The challenges with fats, oils, and greases (FOGs)



Processability



Availability



Sustainability

Property	Typical Value
Total Fatty Acids, Mass wt%	90
Free Fatty Acids, wt%	3 – 85
Moisture, Mass % (no free water)	< 0.5
Insoluble Impurities, Mass %	< 0.5
Unsaponifiable Matter, Mass %	< 0.5
Total MIU, Mass %	< 3
Iodine Value	60 – 130
Total Metals	75 – 2,500
Phosphorus	5 – 1,000
Chlorides	20 – 2,000
Sulfur	0 – 50
Nitrogen	0 – 170
Polyethylene	0 – 1,000

- Contaminant removal is critical to maintain catalyst activity, prevent corrosion, and ensure operational stability
- Pretreatment unit must be designed to match the feedstock
- Unit flexibility required as feedstocks supply is volatile



The challenges with fats, oils, and greases



Processability

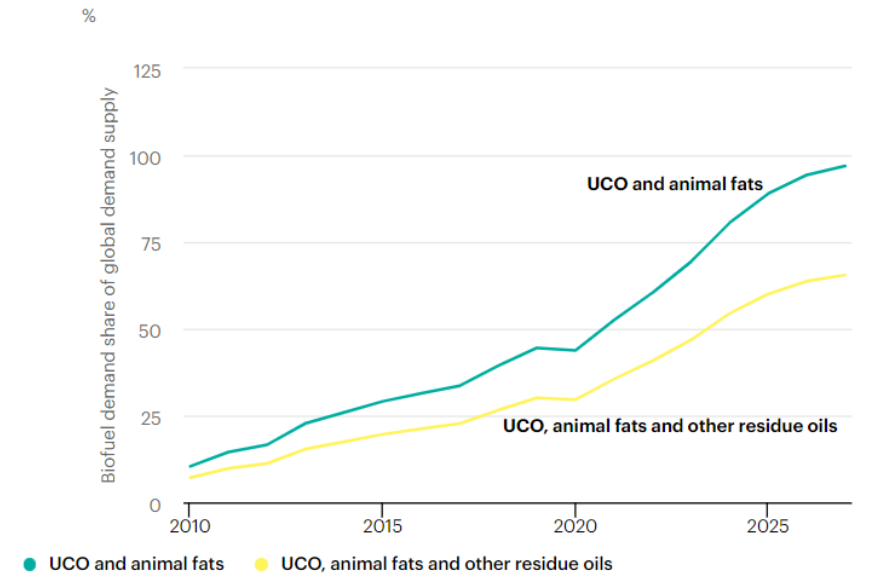
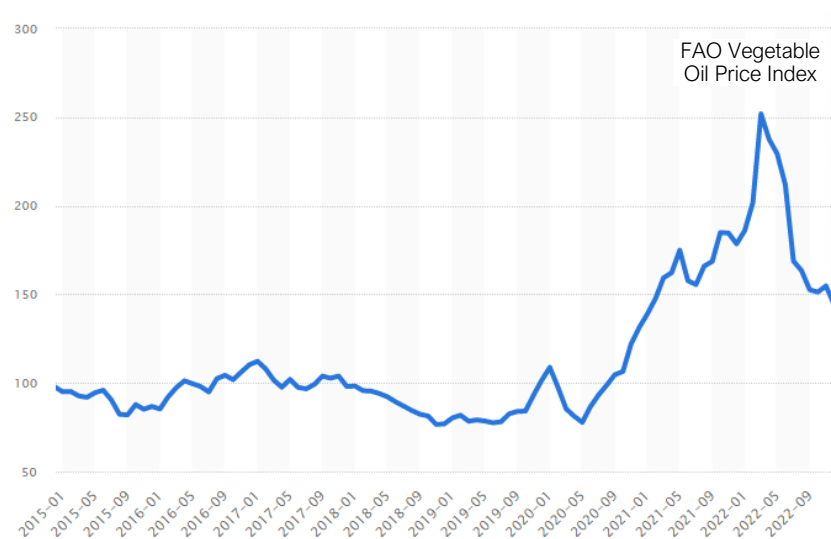


Availability



Sustainability

- Rapid expansion of HVO & HEFA processes have raised feedstock prices and created supply shortage
- Increasing partnerships and/or co-location between feedstock supply and fuel production (e.g., Valero & Darling Ingredients or Bunge & Chevron)



Source: IEA



The challenges with fats, oils, and greases



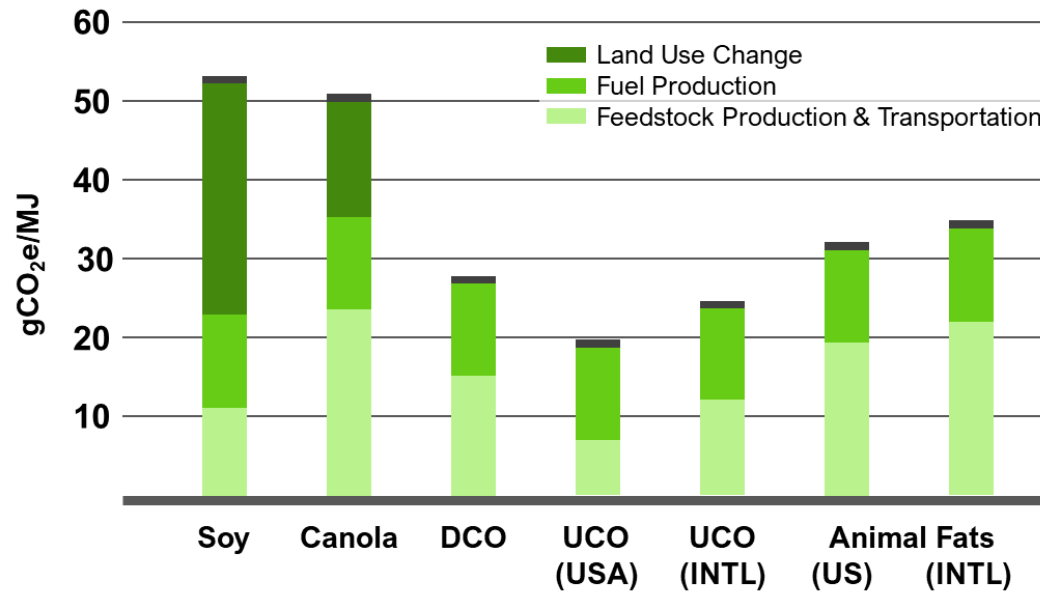
Processability



Availability



Sustainability

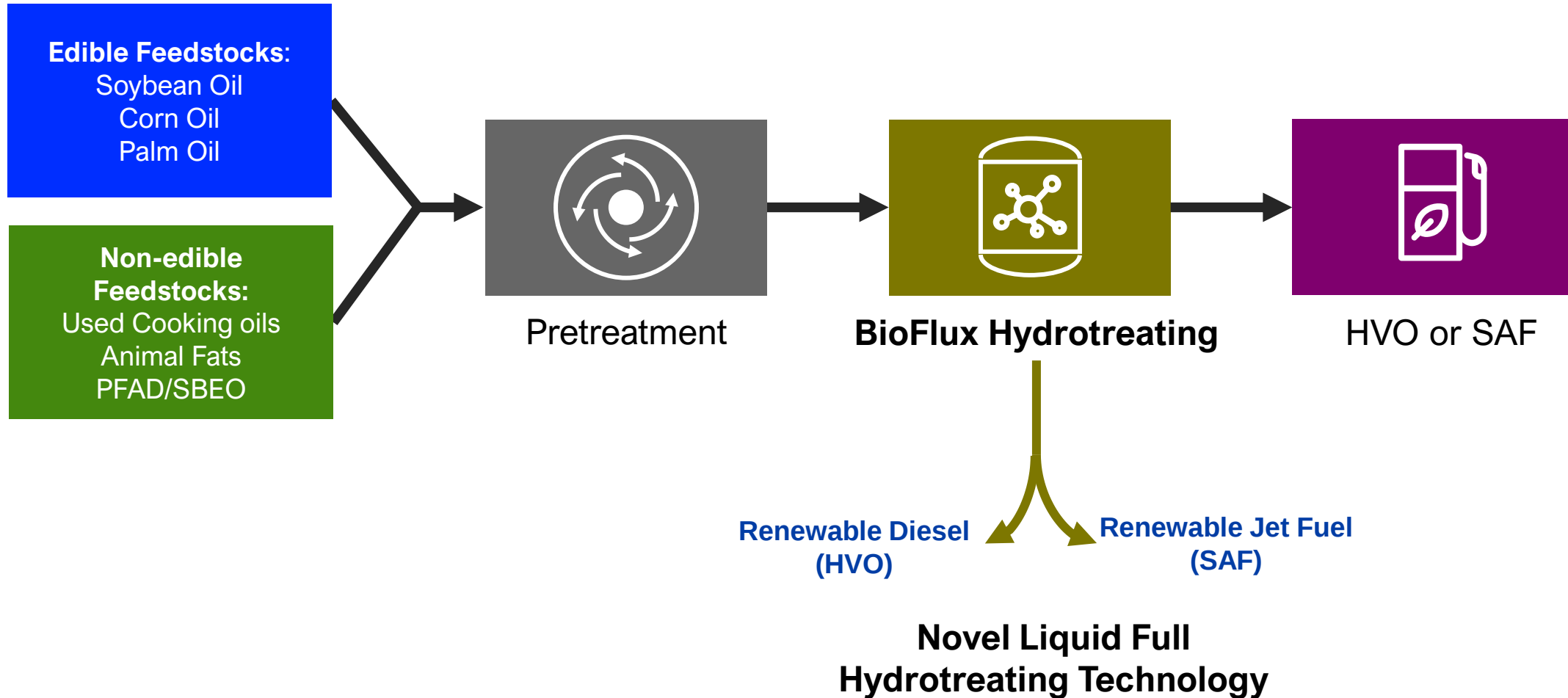


Source: CARB / Stratas Advisors

- Land use change and impact on carbon intensity
- Edible vs. non-edible sources, virgin vs. waste feedstocks
- Government regulations incentivize producing fuels with lower carbon intensity (CI)

+ Hydrotreatment – Renewable Diesel (HVO) and SAF

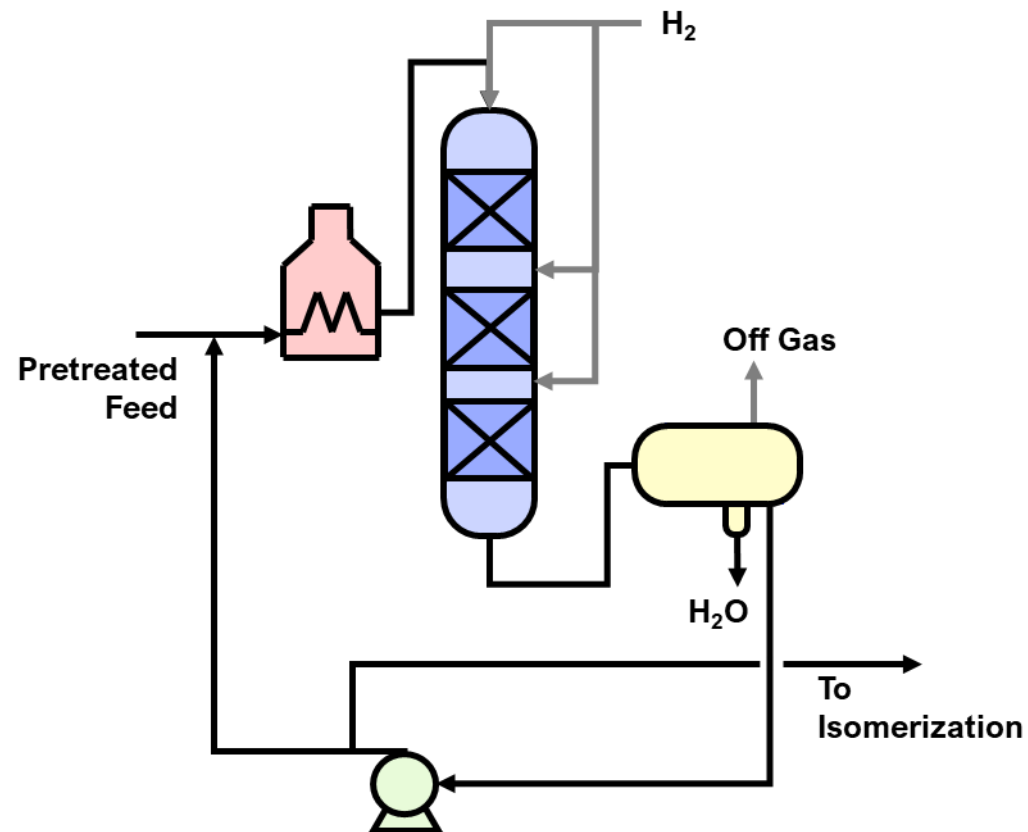
Licensed by Sulzer Chemtech globally in co-operation with Duke Technologies, LLC





BioFlux Hydrotreating

HDO Reactor Loop



BioFlux Technology has:

Hydrogen fully dissolved into the liquid feed, improving availability

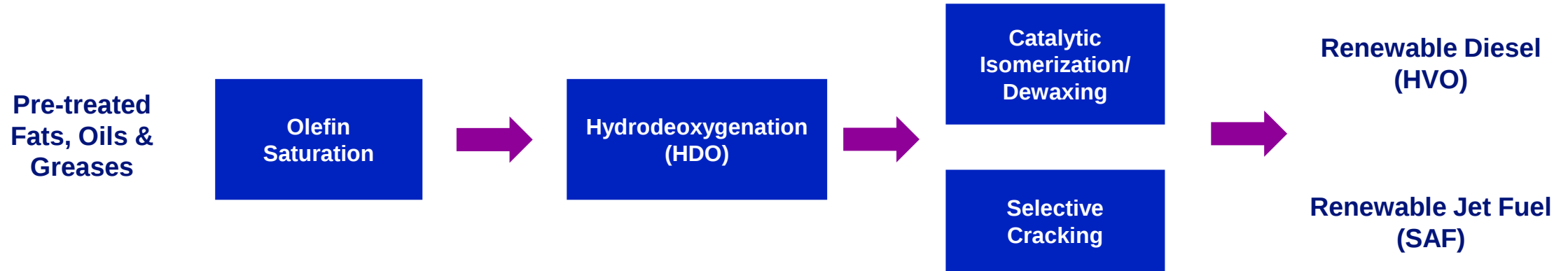
High volume flux, which eliminates mass transfer limits

Liquid recycle; **no gas recycle**

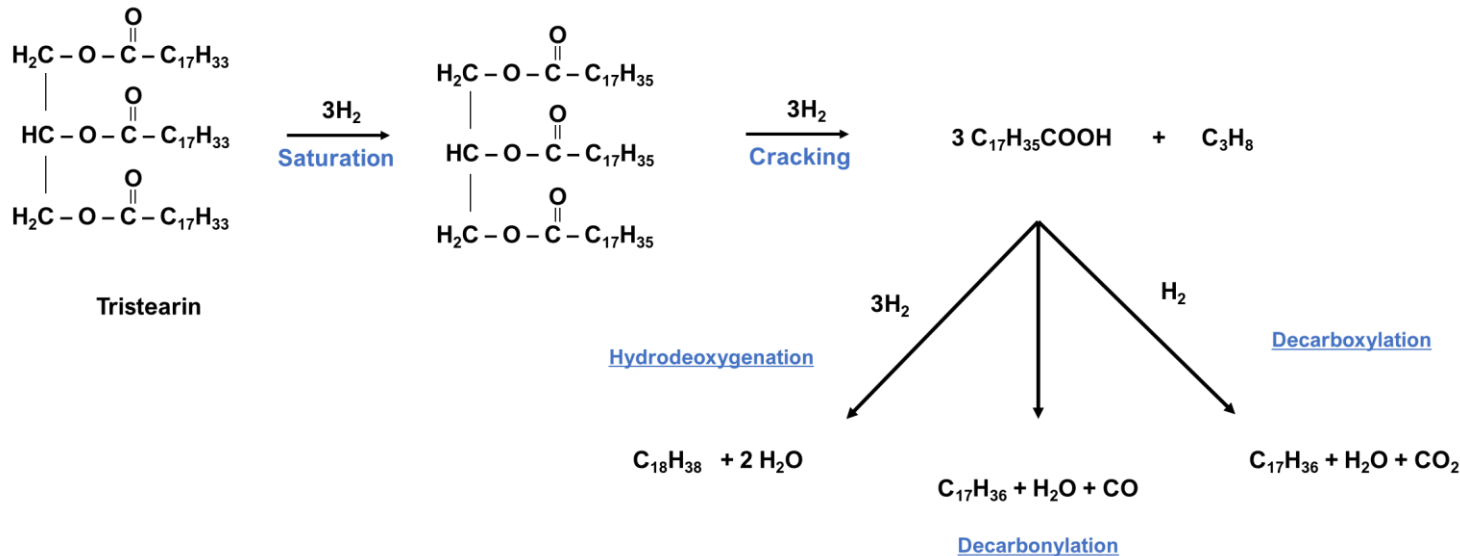
Improved thermal management; higher yield; lower utility consumption

Lower Capital & Operating Expense

+ The Chemistry of Hydrotreating Fats, Oils & Greases



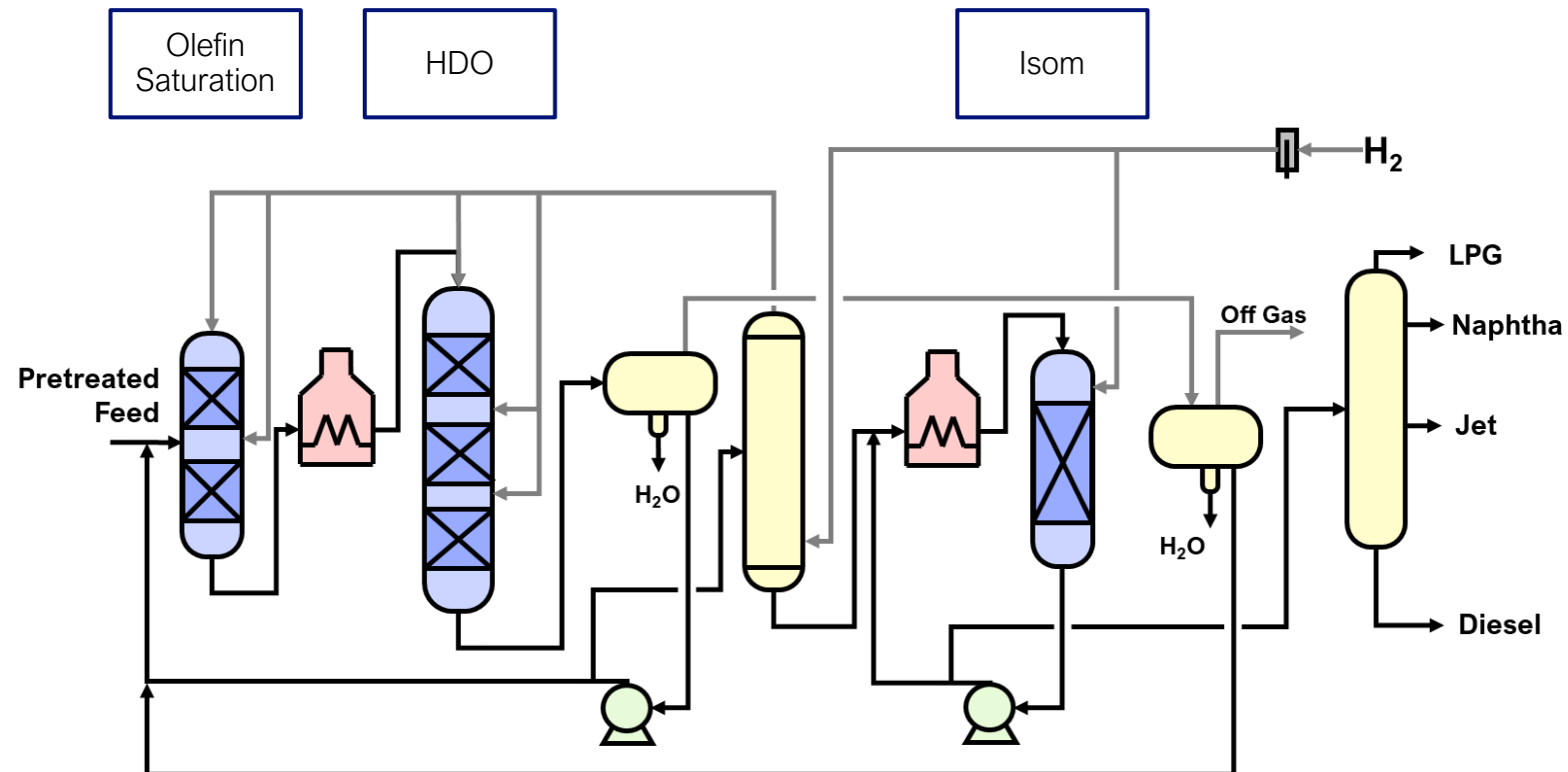
Reaction Pathways in the Hydroprocessing of FOGs



- Objective is to maximize HDO reactions – decarboxylation reduces produce by one carbon
- Olefin saturation and HDO require up to 2,100 scf/bbl; Isomerization requires 300 – 500 scf/bbl
- HDO product then undergoes isomerization to improve cloud point & selective cracking to produce jet fuel product for SAF



BioFlux process flow scheme



- Separate HDO and ISOM stages with independent liquid recycle
- Product distribution can be tuned via catalyst selection in the second stage – isomerization vs selective cracking



Liquid recycle dilutes increased feed contaminant levels



Higher sensitivity to feed contaminants



Typical BioFlux yields

	Flexible Unit		Jet Only (wt%)
	Max Diesel (wt%)	Max Jet (wt%)	
Feed			
Pretreated FOG	100	100	100
Hydrogen	2 – 4	2 – 5	2 – 5
Products			
Off gas	1 – 3	1 – 3	3 – 5
Naphtha	0 – 2	16 - 20	18 – 22
Jet	0	66 – 70	70 – 74
Diesel	83 – 86	0	0
Aqueous Waste	Balance	Balance	Balance

- BioFlux units will be designed for multiple modes of operation:
 - Flexible unit: Max diesel, max jet, or mix of products
 - Jet only: designed specifically to maximize jet fuel production and minimize/avoid producing diesel
- Design changes include:
 - Operating conditions
 - Catalyst selection
 - Additional fractionation



BioFlux - lowest cost of production

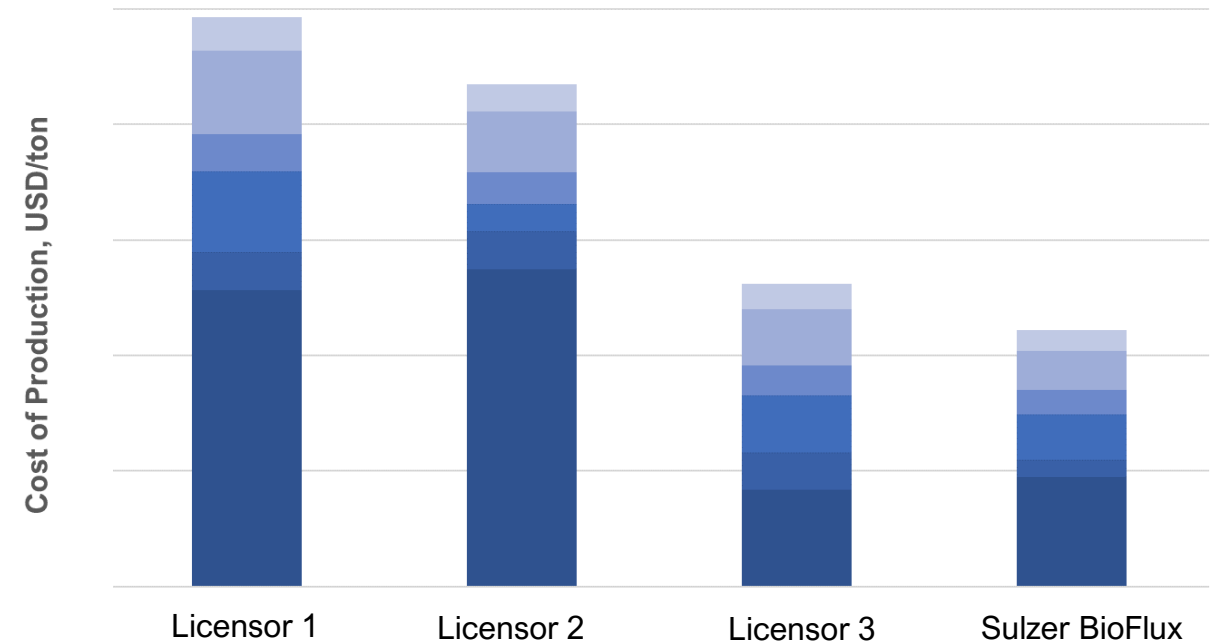
BioFlux Technology has:

Lower net feedstock cost through higher yield of preferred products

Lower CAPEX by up to 30%

Lowest total cost of production

Lower hydrogen demand



Source: NexantECA BioRenewable Insights Report 2022



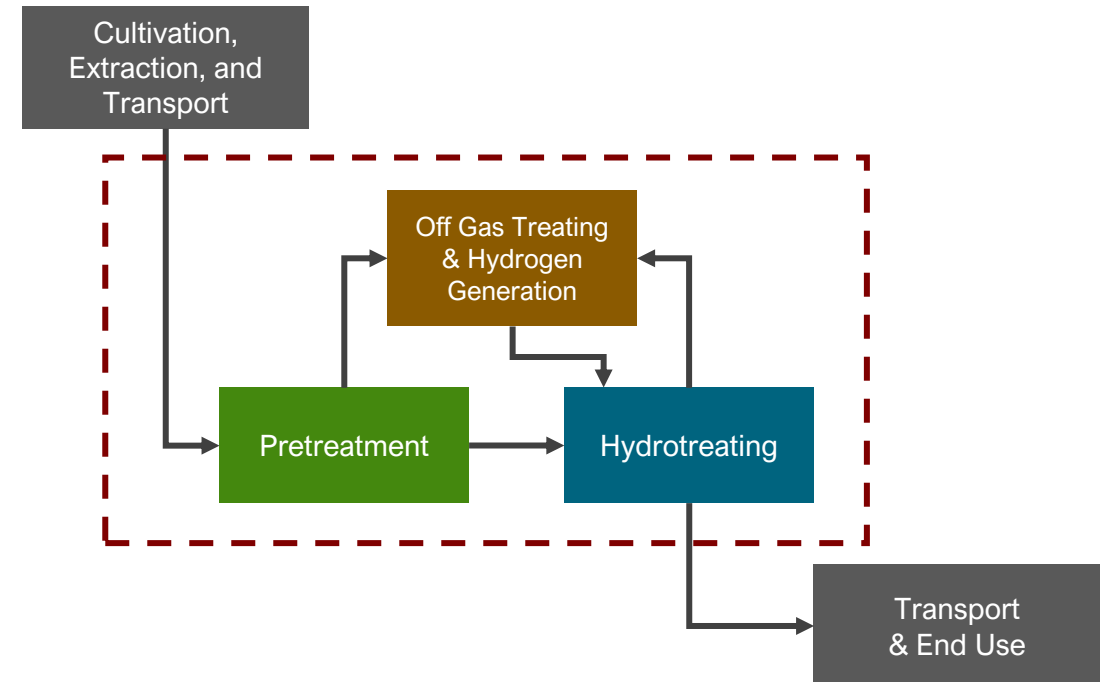
Carbon intensity

■ Incentives for HVO Producers

- Capture the LCFS credits, which are additive with EPA RINs and Blenders Tax Credit (USA)
- Reduce carbon tax and meet requirements of REDII (EU)

■ BioFlux technologies reduce carbon intensity of the fuel production steps and generate economic value:

- US: one CI reduction = \$0.020 - \$0.027 per gallon
- EU: CO₂ is taxed at rates from 0.07 to 116.33 euros per metric ton





BioFlux - proven technology

- Sulzer GTC has experience designing many hydrotreating units in the refinery and petrochemical industry
- Liquid phase hydrotreating has been applied in refinery industry
- Now Sulzer GTC has applied the hydrotreating experience and liquid phase hydrotreating to biofuels

	Location	Capacity, bpd	Capacity, kTa	Feedstock
1	Jackson, MS, US	1,400	70	DCO, Tallow
2	Reno, NV, US	3,500	170	DCO
3	Rayong, Thailand	975	45	UCO/RBDPO
4	Sabah, Malaysia	7,500	360	UCO/POME/PAO





BioFlux Hydrotreating process

- **Innovation at the core – liquid-full reactor design**
 - Hydrogen fully dissolved into liquid feed, which eliminates any mass transfer limitations
 - Increased product yield and catalyst life due to elimination of hot spots and over cracking
 - Optimized process design with elimination of recycle gas separation and treating loop
- **Best economic value**
 - Lower CAPEX due to elimination of recycle gas separation and compression loop
 - Lower OPEX with increased catalyst life and product yield
 - Single source of supply for technology and engineering
- **Efficient & flexible**
 - Reactor internals designed to ensure optimum hydrogen utilization in the reactor
 - Flexible process to switch between HVO and SAF modes
 - Easily integrated with pretreatment and hydrogen production unit
- **Enables low GHG emissions & carbon intensity**
 - Lower CI due to higher yield, lower utility consumption, and improved hydrogen management
 - Integrated design with hydrogen production available to further reduce GHG emissions
 - Lowest carbon intensity enabled by integration with BioFlux® pretreatment





Contact



Sashikant Madgula
Business Segment Leader
Clean Fuels and Chemicals Licensing
Sashikant.madgula@sulzer.com



Sulzer Chemtech

Neuwiesenstrasse 15
8401 Winterthur
Switzerland

[sulzer.com](https://www.sulzer.com)





Disclaimer

This presentation may contain forward-looking statements, including but not limited to, projections of financial developments, market activities or future performance of products and solutions, containing risks and uncertainties.

These forward-looking statements are subject to change based on known or unknown risks and various other factors, which could cause the actual results or performance to differ materially from the statements made herein.

Copyright © Sulzer Ltd 2023