Ketjen

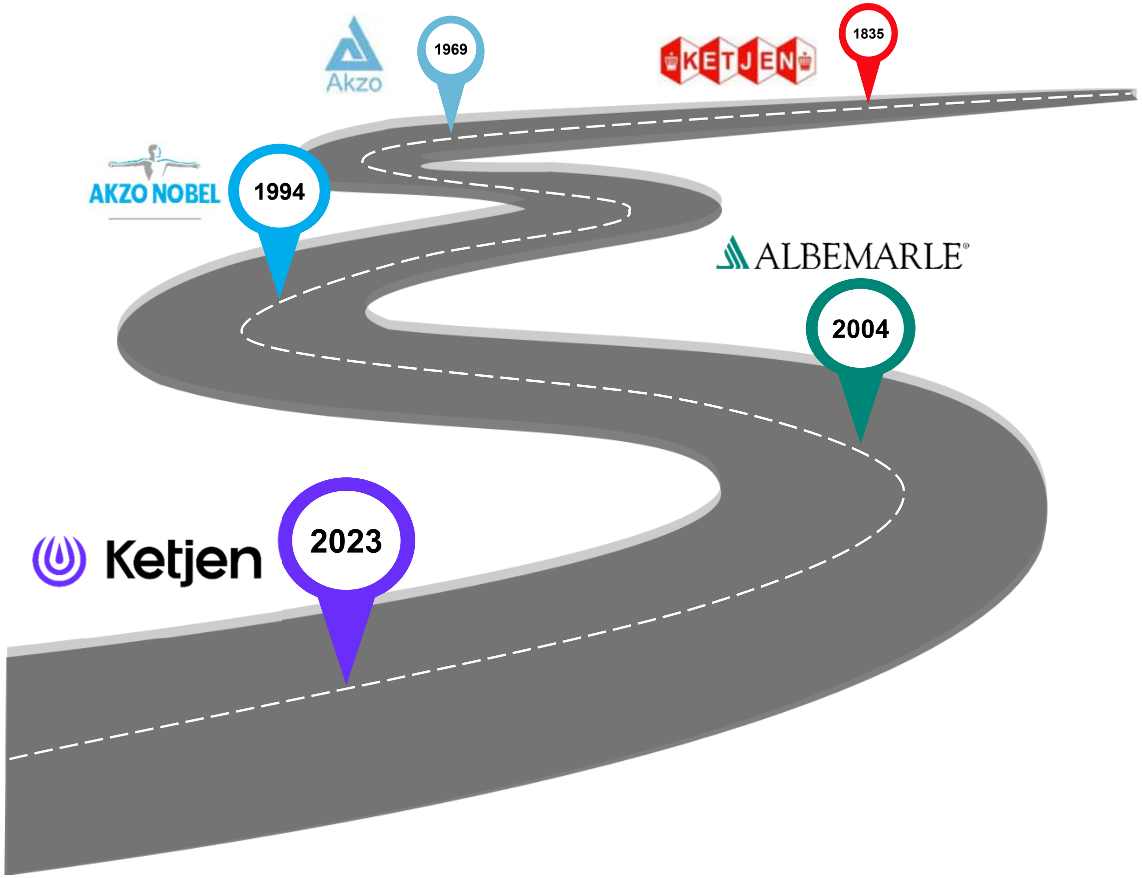
About | Solutions | Careers | Investors

SPARKING SUCCESS

Ketjen unleashes the potential of advanced chemistry for industries that power the world.

Ketjen: the future of catalysts is here

- Started in 1835
  - 1947, Ketjen starts refinery catalysts business
  - 1953, Ketjen starts FCC catalyst production
  - Through mergers, acquisitions and divestitures, in 2004, Albemarle catalyst global business unit formed
- 2022, Albemarle strategic decision
  - Ketjen as a wholly owned subsidiary
- Reaffirm commitment to Refining & Petrochemical industries
  - Enhanced focus on three business segments; Fluidized Catalytic Cracking, Clean Fuels Solutions, Performance Catalyst Solutions
- Independent catalyst supplier with decades of experience and expertise
  - Refining and Petrochemical catalysts
  - Energy transition, renewables, and sustainability



Innovation and partnerships for high impact

Ketjen collaborates with customers throughout their energy transition journey, offering tailor-made catalyst solutions that support their sustainability objectives while optimizing their business returns.

We create **DEE PARTN RSHIPS** with industry leaders and **ADVA CE ESILIE CE** in their unique energy transition journeys

We deliver, **HIG PAC, T R-** solutions to complex challenges that increase business value

The **RELENTLESS PUR** to tackling intricate problems while delivering value energizes us to **ATE** our offerings

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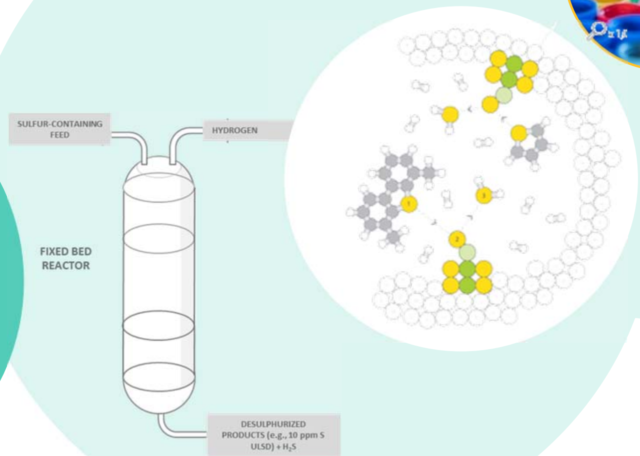
Ketjen offers a comprehensive portfolio of solutions for various feedstocks and processes.

Renewables processing

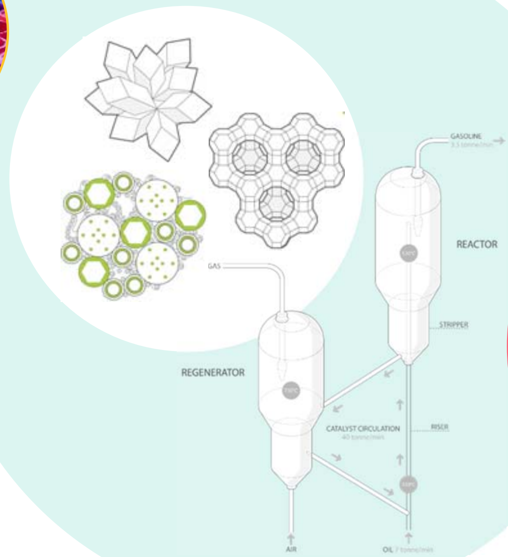
NEXBTL
Co-development and suppling catalysts for 1st commercial process for producing advanced Renewable Diesel

First to facilitate co-processing of Vegetable oils in hydroprocessing
ReNewFine

Hydroprocessing



Fluid Catalytic Cracking



ReNewFCC
Dedicated catalyst line for Renewables co-processing in FCC

Catalyst solutions for processing py-oils from waste plastics and biomass
ReNewFine

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Biofuels and regulations
HVO process and feedstock

Masoud Zabeti

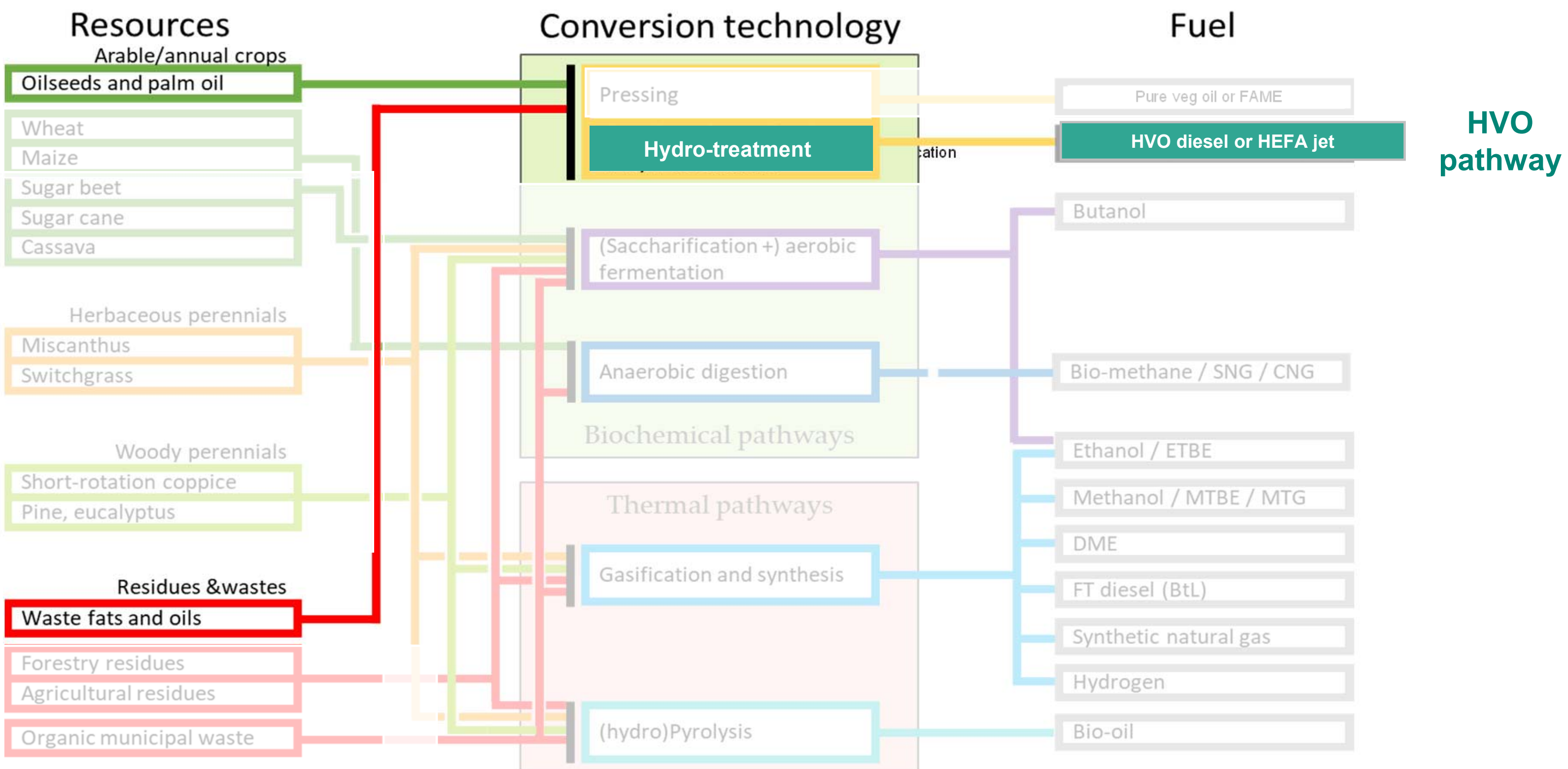
Zoetermeer 13th April 2023

Many technology pathways could lead to renewable fuels

HVO is commercially available for production of drop-in renewable diesel and jet

Many technology pathways have been developed for renewable fuels production

- **HVO** (Hydrotreated Vegetable Oils) is **currently** the **only commercial technology for production of drop-in diesel and jet fuels**



Global HVO project developments

Location of the major existing/future HVO plants

- New refiners
- Traditional refiners
- Traditional refiner, co-processing
- Operational
- Under construction/planned

Total production (MMt in 2022)
Global: 16.4
- Traditional refiners: 10
  - Co-processing: 0.4
- New refiners: 6

Data source: Ketjen's in-house database **Traditional refiners:** Petroleum refiners who have divested/invested in renewable fuels; both on green and brown fields
New refiners: Tech companies and initiatives who have invested in renewable fuels on green fields; they have no records in petroleum business

HVO supply is growing globally, NA and the EU being the main markets

- Global supply will grow rapidly by 2026
  - Stimulated mainly by regulations/policy
  - Growth is limited by feedstock availability
- There is a **growing interest in NA** market, mainly due to policy incentives
- The **largest HVO plants are in NA and the EU**
- **Traditional refiners lead the market (>62% of the market) globally**

Per region

Region	2022 Capacity (MMt)	2022 # Units	2022 Avg. Unit size (MMt)	2026 Capacity (MMt)	2026 # Units	2026 Avg. Unit size (MMt)	2030 Capacity (MMt)	2030 # Units	2030 Avg. Unit size (MMt)
NA	11	18	0.6	16	28	0.6	23	47	0.6
EU	4	8	0.4	11	22	0.5	13	29	0.5
Asia	1	5	0.2	4	7	0.5	7	20	0.3
RoW	0.0	0	0	1	3	0.3	2	4	0.5

Data source: Ketjen's in-house database NA: North America; EU: European Union; RoW: Rest of World; EEA: The European Economic Area
Assumptions: All the announced projects start up by 2026; all the units will remain operational with full capacity by 2030

Most supportive policies and regulations for HVO fuels are in US and the EU

Country level
- Volume obligation similar to the US RFS

Province level: British Columbia
- Follows California LCFS

Federal level
- Renewable Fuel Standard (RFS)
  - Volume obligations
  - RIN credits 520 – 750 USD/MT for renewable (or HVO) diesel
- Federal Blenders Tax Credit (BTC)
  - 340 USD/Mt for HVO diesel
- Sustainable Aviation Fuel Act
  - Sets 30% GHG emission reduction target

State level (California, Oregon & Washington)
- Low Carbon Fuel Standard (LCFS)
  - Credit of CO_{2e} avoided: 180 – 200 USD/Mt

RED II
- Sets blending mandates for renewable fuels (14% by 2030)
  - Incentivizes HVO diesel and other advanced fuels by double counting

RED III proposal
- Proposes GHG emission reduction mandates for transport (13% by 2030)
  - HVO diesel from “advanced feedstock” deliver >85% emissions reduction

ReFuelEU Aviation proposal
- Proposes Blending mandates for sustainable aviation fuel (SAF)
  - 5% by 2030 → 63% by 2050 (SAF from HVO will play an important role)

FuelEU Maritime Proposal
- Proposes GHG emission reduction mandates for shipping sector
  - 6% by 2030 → 75% by 2050

Indonesia

Current biodiesel blending mandate at 30%
- Raising to 35% or 40% in 2023

Achieving this through both FAME and HVO diesel
- Main feedstocks will be palm oil and used cooking oil

South Korea

Supporting use of domestic biofuels through adopting
- Marine biofuels by 2025
- SAF by 2026
- Raising biodiesel blending mandate from 5 to 8% (5% from FAME and 3% from HVO diesel (co-processing or 100%)

The energy ministry boosting domestic biofuels production

CORSIA

CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION

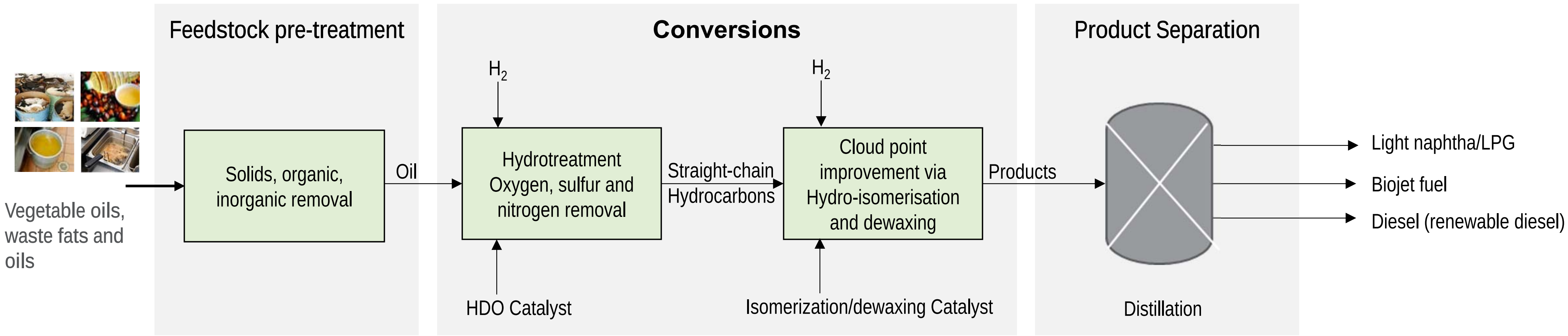
- Global scale carbon offsetting measures for the aviation industry

RIN: Renewable identification number HVO: Hydrotreated vegetable oil HDO: hydro-deoxygenation SAF: sustainable aviation fuels

Advanced biofuels: biofuels that are produced from challenging feedstocks (in the context of the EU policies, these feedstocks are so called “Annex IX” feedstocks, i.e., certain feedstocks that are listed under Annex IX of the Renewable Energy Directive

HVO process and feedstock compatibility

HVO is a refinery process that turns vegetable oils/fats and their derivatives into drop-in diesel and jet fuels via hydroprocessing



- The conversion process typically involves two stages
    1. Hydro-deoxygenation/denitrogenating
    2. Hydro-isomerization
- Feedstock quality varies depending on type and sources of feedstock
- The quality of final diesel or jet products is similar to that of fossil fuel and can be used as drop-in fuels

HVO diesel

Properties [3]	Unit	Value
Elemental composition		
– C:	wt.%	85
– H:	wt.%	15
– O:	wt.%	0.0
– N:	wt.%	<1.5
Cetane number		75 – 99
Energy content	MJ/kg	44
Viscosity	Mm²/s	2.3 – 3.5
Density	kg/m³	785
Cloud point	°C	-5 – -25
Flash point	°C	>61

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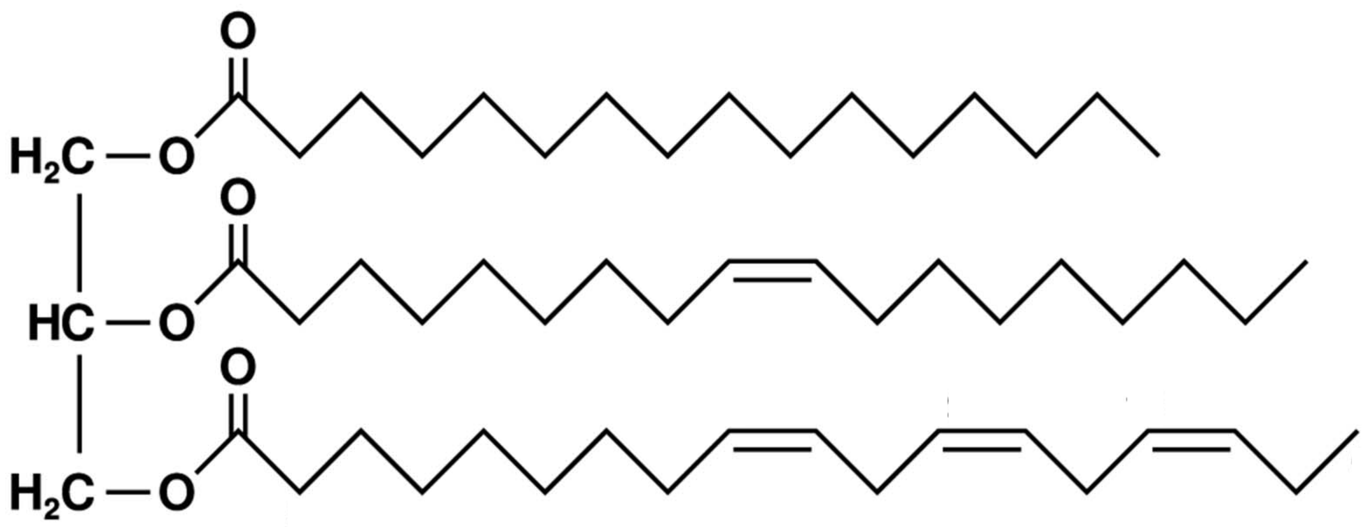
Molecular structure of vegetable oils and fats

Vegetable oils are mainly composed of triglycerides and their basic constituents, fatty acids.

Triglycerides are the main components of vegetable oils and fats. They are constituted by 3 fatty acids bound by a propane molecule.



Fatty acid compositions of vegetable oils and fats

	Rapeseed	Palm	Soybean	Sunflower	Beef Tallow	Chicken Fat
C12:0s	0.0			0.1	0.2	
C14:0	0.1	1.0		0.2	3.2	1
C16:0 C16:1	4.7 0.3	43.8 0.5	10.0 0.2	6.8 0.1	26.3 3.8	25 8
C18:0 C18:1 C18:2 C18:3	1.7 59.0 21.4 9.9	5.0 38.5 10.5 0.3	3.5 21.0 55.3 9.2	4.7 18.6 68.6 0.5	21.2 38.5 2.8	6 41 18
C20:0 C20:1	0.6 1.4	0.4	0.5	0.4	0.2	
C22:0 C22:1	0.4 0.3		0.3		0.2	
C24:0	0.2					

C18 and C16 are dominant fatty acid chains in most of vegetable oils and fats

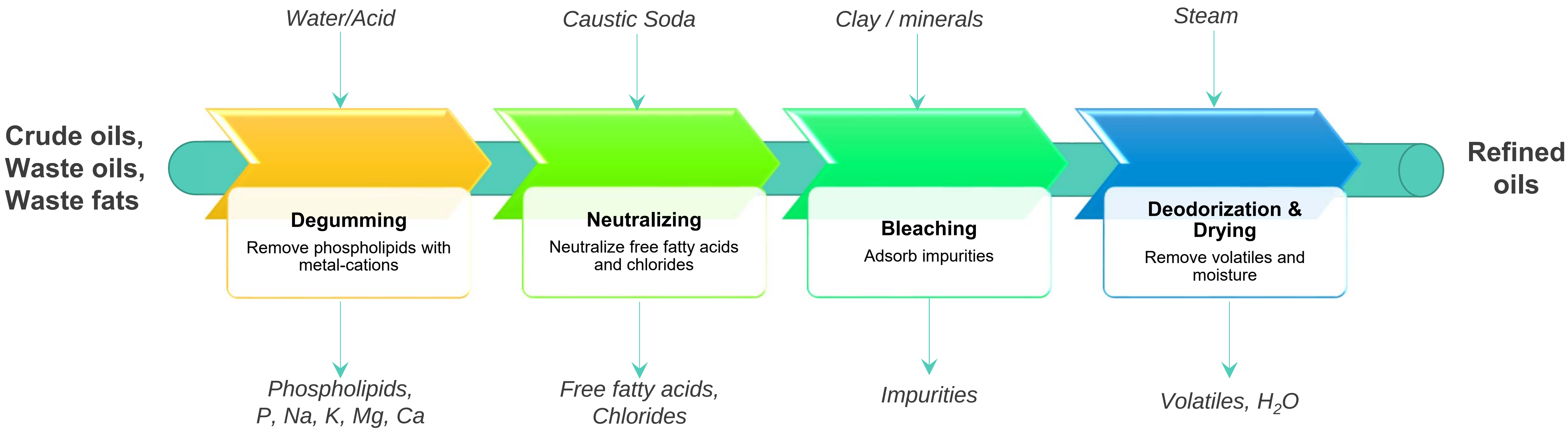
- Diesel molecular range: C10 – C18

Impurities and contaminants in vegetable oils and fats

- Vegetable oils and fats typically contain **elemental (such P, N, S, Cl), metals (such as Fe, Na, Ca, Mg) and unsaponifiables (such as sterols) impurities**.
- The **level of impurities depends on the type and source of oils/fats**
  - Virgin vegetable oils have typically less impurities as compared to most of waste oils and fats
- These impurities **are detrimental to the catalyst activities** and must be removed before the feed enters the reactor.
  - Partially removed through feedstock pre-treatment process
  - The remaining are removed by catalyst guard-beds and traps (example: metal and phosphorous traps)

Parameter	Typical values	
	Crude veg.le Oils	Waste Oils and Fats
Chlorides, ppmwt	<30	<500
FFA, %wt.	<10	<35
Phosphorous, ppmwt	<300	<1000
Total Metals, ppmwt	<300	<2000
Nitrogen, ppmwt	<200	<2500
Polyethylene, ppmwt	<200	<1000
Insoluble impurities, ppmwt	-	-
Unsaponifiable, %wt	<15	<15

Crude oils and fats Pretreatment



- In general for waste oils and fats more steps are required (further filtration, deacidification and adsorption)
- The intensity of the pretreatment varies from feed to feed and it depends on the targets and objectives on the final product.

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Biofeed properties before and after pretreatment

Parameter	Before	After	LICENSOR SPECIFICATIONS FOR PRETREATED			
	Waste Oils and Fats	Waste Oils and Fats	LICENSOR A	LICENSOR B	LICENSOR C	LICENSOR D
Chlorides, ppmwt	<500	<50	10	50	5	50
FFA, %wt.	<35	<5	5	20	20	95
Phosphorous, ppmwt	<1000	<150	3	1	2	3
Total Metals, ppmwt	<2000	<80	10	5	5	10
Nitrogen, ppmwt	<2500	<400	50	350	100	350
Polyethylene, ppmwt	<1000	<50	50	50	10	50
Insoluble impurities, ppmwt	-	-	500	500	100	500
Unsaponifiable, %wt	-	-	-	1	1	-

- To meet the unit tolerances, the remaining of contaminants after feedstock pretreatment process can be removed using a combination of high performance traps, catalyst guard-beds and active catalysts

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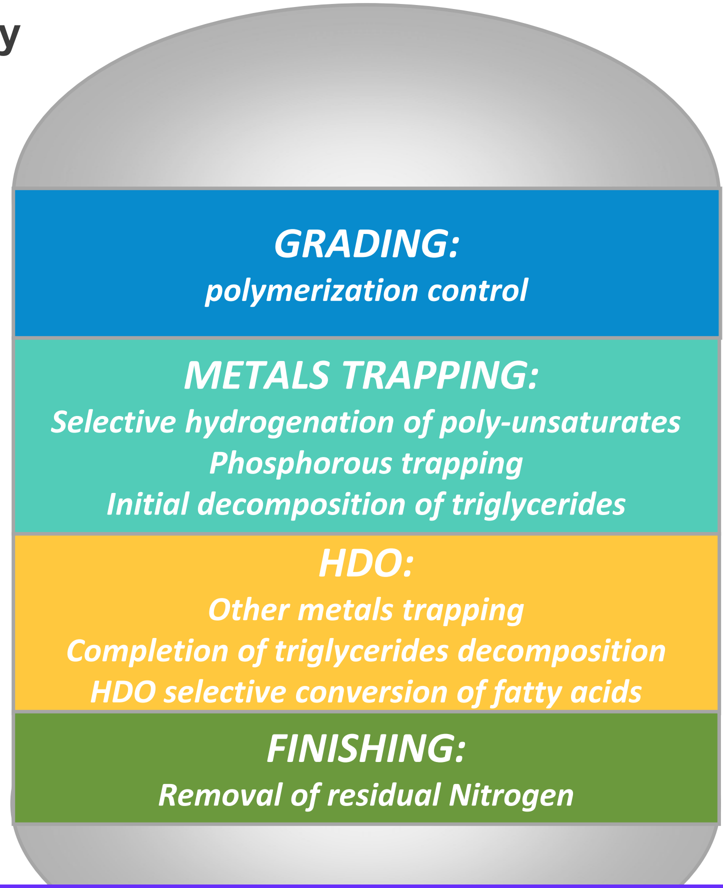
Removal of remaining feed contaminants via catalyst loading systems

Ketjen's ReNewSTAX loading strategy

- **Inert disks for control of polymerization and initial metal trapping**
- **Selective hydrogenation is combined with Phosphorous and further metal trapping (mainly Fe)**
- **Other metals present (Ni, V, alkali, etc) and possible metals slipping out from previous layer are picked up.**
- **Hydro-denitogentation (HDN) catalysts with large pore size to ensure removal of residual nitrogen**



High performance catalyst guard-beds and catalyst loading strategy are crucial in removing feedstock contaminants and extending the catalyst lifetime

Why bothering using waste oils/fats if virgin vegetable oils have better qualities?

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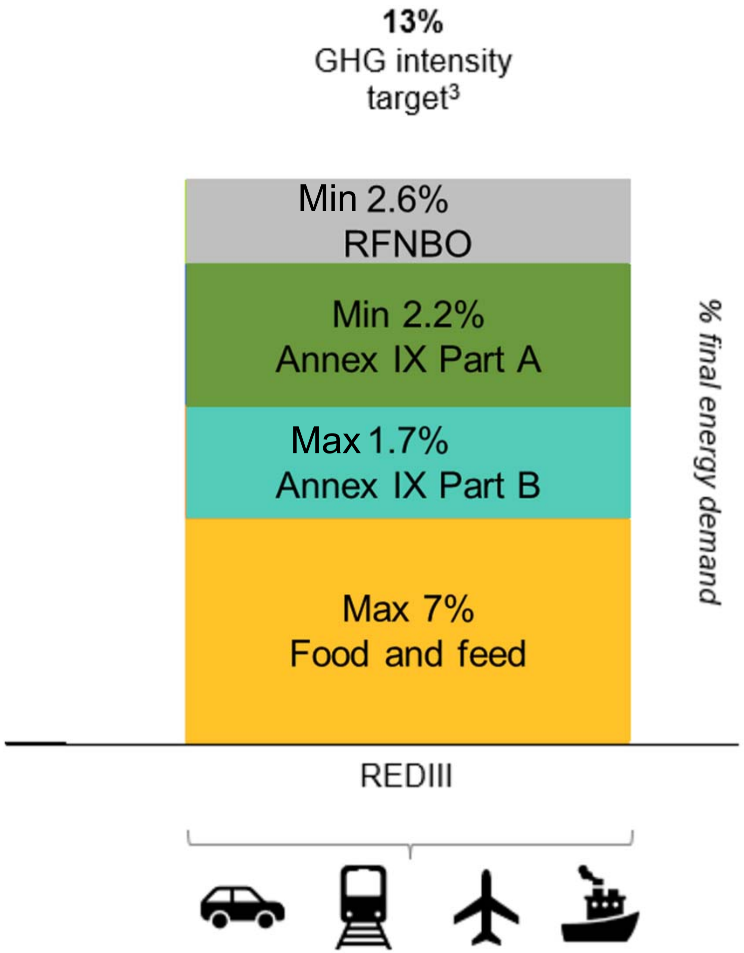
EU regulations is pushing for use of bio waste oils and fats for production of biofuels

- The use of **crop-based feedstocks** for the production of biofuels for transport will be **limited** by the proposed RED III
    - Max 7% of the final transport **fuel consumption (on the energy basis**)
- Annex IX Part B feedstocks (UCO and animal fat) will also be **limited** to max 1.7 %
- Annex IX Part A feedstocks will be promoted by getting a **minimum value**
    - 2.2% of the final transport fuel consumption shall come from Annex IXA feedstock
- Non-biological origin feedstocks are also promoted by getting a **minimum value** (2.6%)

Note: RED III will be in place from 2025 - 2030



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Proposed EU regulations for sustainable aviation fuels is also pushing for use of bio waste oils and fats as feedstocks

- ReFuelEU Aviation is a comprehensive policy proposal targeting sustainable aviation fuels (SAF) under the ‘Fit for 55’ package
- It includes a first ever SAF blending obligation for fuel suppliers, union airports and flight operators to blend a minimum volume percentage of SAF in the aviation fuel supply, with a separate **minimum** for synthetic aviation fuel from 2030:

2025	2030	2035	2040	2045	2050
2% SAF	5% SAF, > 0.7% synthetic	32% SAF, > 8% synthetic	32% SAF, > 8% synthetic	38% SAF, > 11% synthetic	63% SAF, > 28% synthetic

- Where
  - Sustainable aviation fuel (SAF) is defined as: Fuels that are produced from **bio-origin waste and residue** feedstocks (feedstock listed under Annex IX of the EC Renewable Energy Directive, such as animal fat, used cooking oils, algae etc.)
  - Synthetic aviation fuel is defined as: fuels that are renewable fuels of **non-biological origin**, i.e.: means liquid fuels other than biofuels, the energy content of which is derived from renewable sources other than biomass

Feedstock categories under EU Renewable Energy Directive (RED)

Crop-based

Vegetable oils and fats
- Rapeseed oil
- Palm oil
- Soybean oil
- Sunflower oil

Sugars and starches
- Sugar beet
- Sugar cane
- Corn
- Wheat
- Sweet sorghum

Waste and residue

Annex IXB
(a) Used cooking oil
(b) Animal fat
(category i & ii)

Annex IXA
(a) Algae
(b) Biomass fraction of MSW
(c) Bio-waste from private households
(d) Biomass from industrial waste
(d) Fish fats
(e) Straw
(f) Animal manure & sewage sludge
(g) Palm oil mill effluent
(h) Tall oil and tall oil pitch
(i) Crude glycerine
(j) Bagasse
(k) Grape marcs and wine lees
(n) Nut shells
(m) Husks
(n) Cobs cleaned from corn kernels
(o) Forestry residues and forestry industry residues
(p) Other non-food cellulosic materials
(q) Other Ligno-cellulose material

Non-biological origin

Plastic wastes
- PVC
- PET
- PS
- PP
- PE
- Rubber waste

End of life tire
Captured carbon dioxide
Hydrogen

No sustainability criteria defined yet

Less — Sustainability measure — More

Feedstock quality is one of the biggest challenges in biofuels production

Waste and residues

Other Annex IXA
- Municipal Solid Waste
- Algae
- Sewage sludge
- Forest residues

Annex IXA oils & fats
- Fish fats
- Tall oil
- Acid oils
- Palm oil mill effluent

Annex IXB oils & fats
- Used cooking oil
- Animal fat

Vegetable oils and fats
- Sunflower oil
- Rapeseed oil
- Palm oil
- Soybean oil

Increasing feedstock price →

← **Increasing technical efforts for processing**

Extremely high contaminant levels
- High P (2000 – 12000)
- High Cl (30 – 2000 ppm)
- High Metals (500 - 5000 ppm)
- High N and Si

Higher contaminant levels
- High P (30 – 800)
- High Cl (50 – 1000 ppm)
- High Metals (30 – 500 ppm)
- High N (100 – 500 ppm)
- High Si

Contaminant level typically < 100 ppm
- Low P
- Low Cl
- Low Metals
- Low N and Si

US feedstock regulations
RFS sets fuel obligations for fossil refiners and importers, incentivizing certain feedstocks

- EPA approved fuel pathways under RFS, that lead to HVO diesel (renewable diesel) and jet production
- Approved only for Chevron El Segundo

Fuel Type	**Renewable diesel, jet fuel**			**Renewable diesel, jet fuel**
Feedstock	Soybean oil, Oil from cover crop, **separated food waste** (e.g. used cooking oil, animal fat), algae	**Other vegetable oils** (edible oils e.g. palm, canola) than soybean oil and separated food waste	Soybean oil, Oil from cover crop, **separated food waste** (e.g. used cooking oil, animal fat), algae	Soybean oil
Production process	**100% (HVO)-** Hydrotreating, excludes co-processing		**HT co-processing** Hydrotreating, includes only co-processing	**FCC co-processing** of soybean oil and petroleum
RIN type	D4, biomass-based diesel	D6, Renewable fuel	D5, advanced	D6, Renewable fuel
RIN price: benefit for the producer	**1.70 $/RIN**	**1.15 $/RIN**	**1.85 $/RIN**	**1.15 $/RIN**

RIN: Renewable identification number
RFS: US Renewable Fuel Standard
HVO: Hydrotreated vegetable oil HT: hydrotreatment
EPA: US Environment Protection Agency
FCC: fluidized catalytic reaction
Source for RIN prices: EPA website

Thank you

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