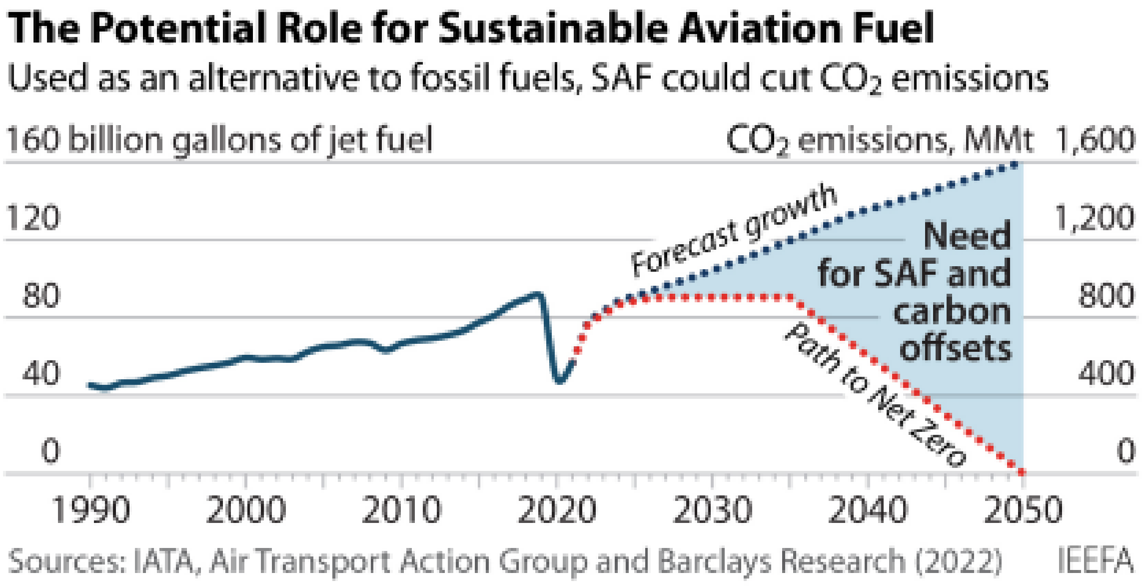
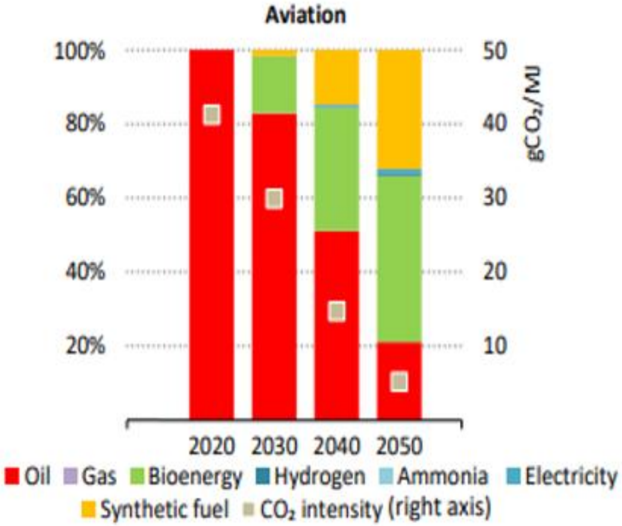
A Springboard Toward the SAFs of the Future

Maxime VASSIEU

Axens
Powering integrated solutions

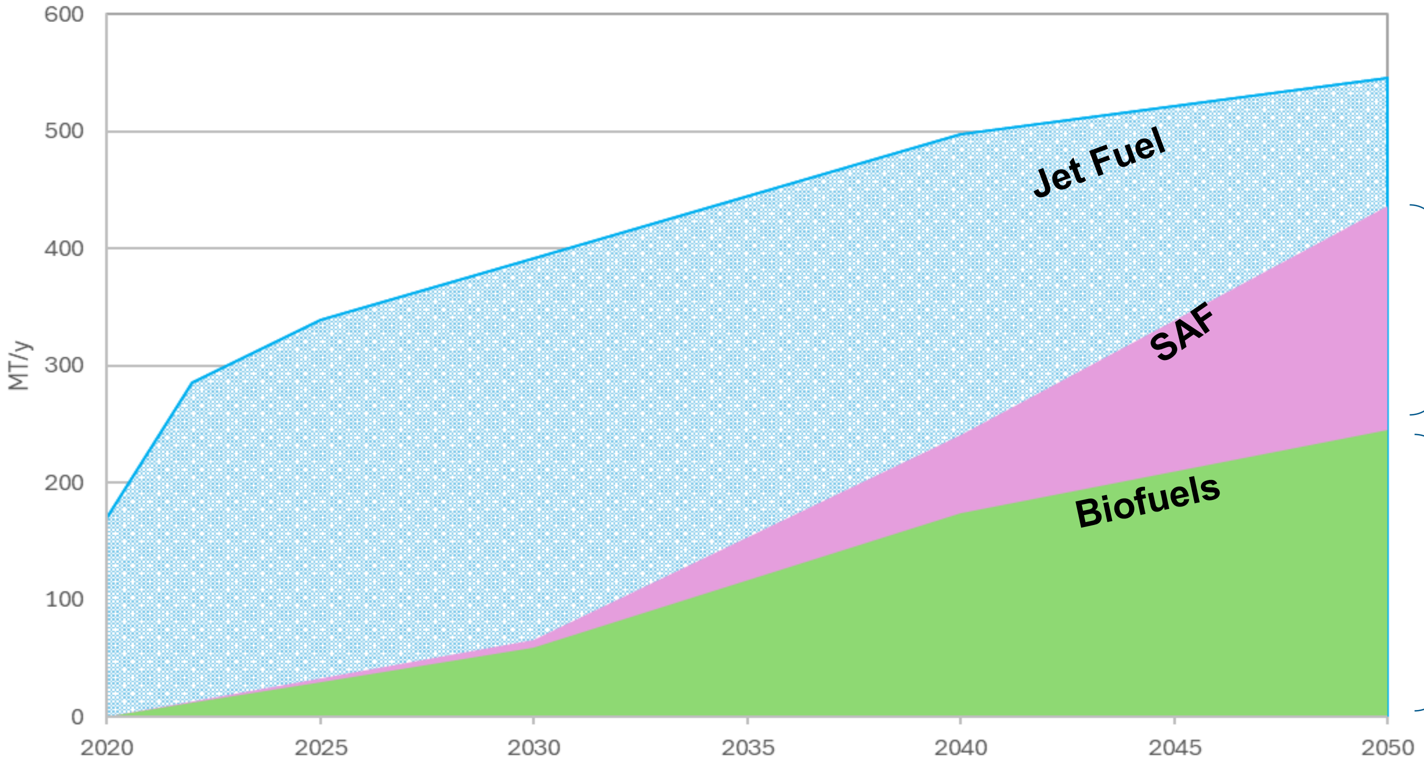
NZE Scenario and Aviation Fuel





IEA –NETZERO BY 2050

NZE Scenario and Aviation Fuel



35% efuel

190 MT/y

45% Biofuels

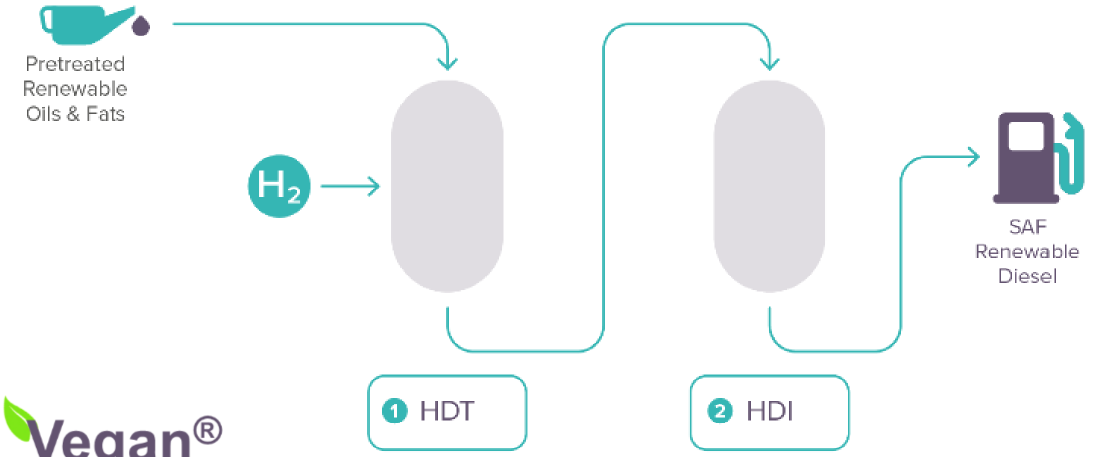
245 MT/y

Axens Portfolio – on Biofuels

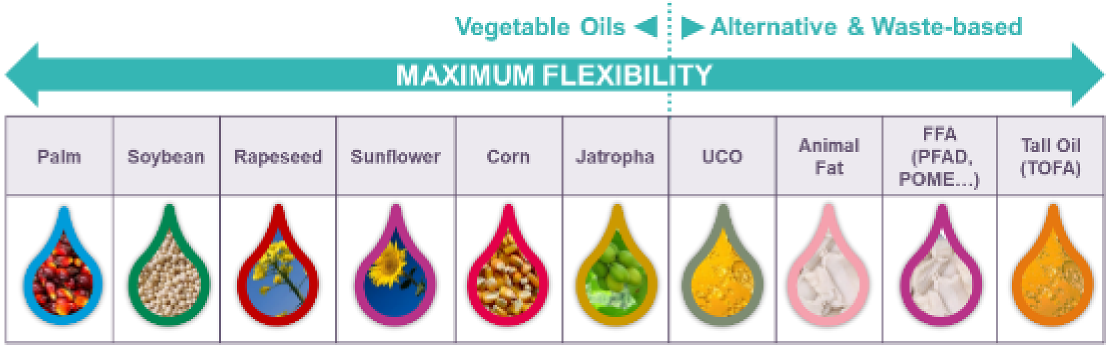
		CATEGORY (*)	ASTM
Renewable Oil & Fats	Co-processing Hydrotreatment	SAF	A1 D1655
	Vegan® Hydrotreatment	SAF	HEFA-SPK A2 D7566
Lignocellulosic Biomass	Futurol® + Jetanol™ Enzymatic Conversion & Ethanol to Jet	SAF	ATJ-SPK A5 D7566
	BioTfueL® Gasification, FT and Upgrading	SAF	FT-SPK A1 D7566

Renewable Fuels via Vegetable Oil

Vegan® from Vegetable Oil to Renewable Fuels



Vegan®



- **Best economical scheme**
  - Industry leading catalyst
  - Simple once-through scheme
  - Highest yield for SAF
  - Feed flexibility
- **Products quality**
  - Renewable Diesel cold flow property flexibility
  - SAF production without process scheme change
  - ASTM D7566 compliance
- **References**
  - 24 awards incl 13 basic engineering
  - 4 operating plants
  - 3 start-up scheduled in 2025-2026
  - 40 references in lipid co-processing
  - 500+ references in hydrotreatment applications

Commercial experience : Repsol

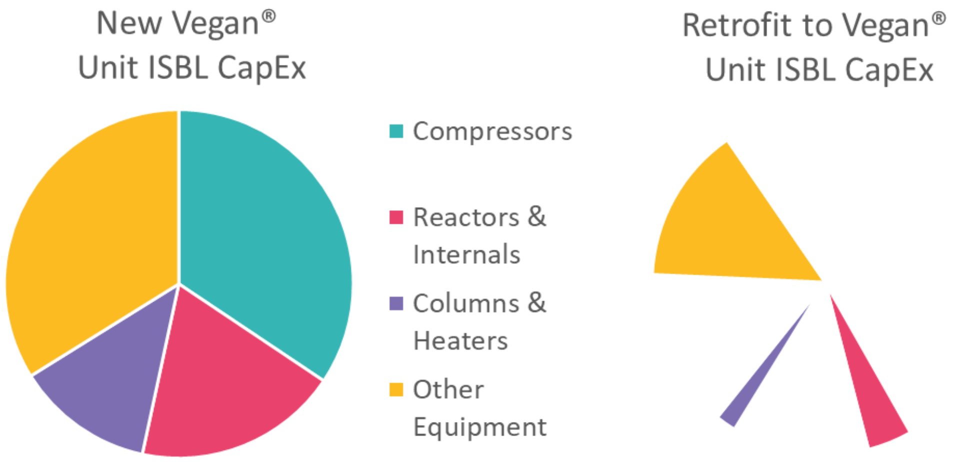
The new unit makes both diesel and jet fuel from used cooking oil. Emilio Parra Doiztua for The New York Times

Customer	**Repsol Cartegena**
Location	Spain
Feedstock	Mainly Used cooking oils
Capacity	300 KTA (feed)
Timeline	Started-up March 2024
Scheme	Grassroot Vegan®, RD, SAF or both at the same time

REPSOL

Commercial Experience : Haike

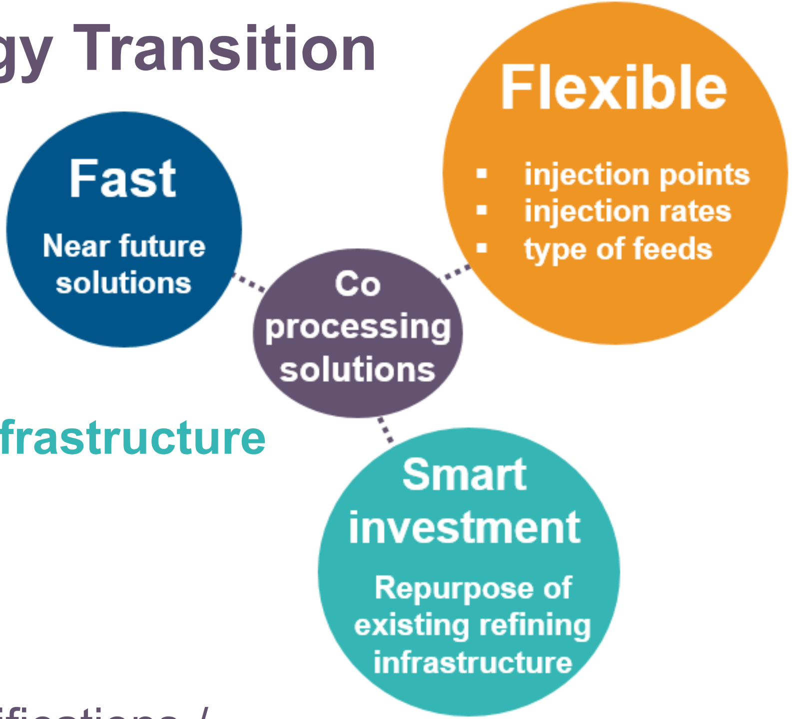
Retrofit of Fossil Hydroprocessing Unit
→ Major CapEx & Timeline Reduction



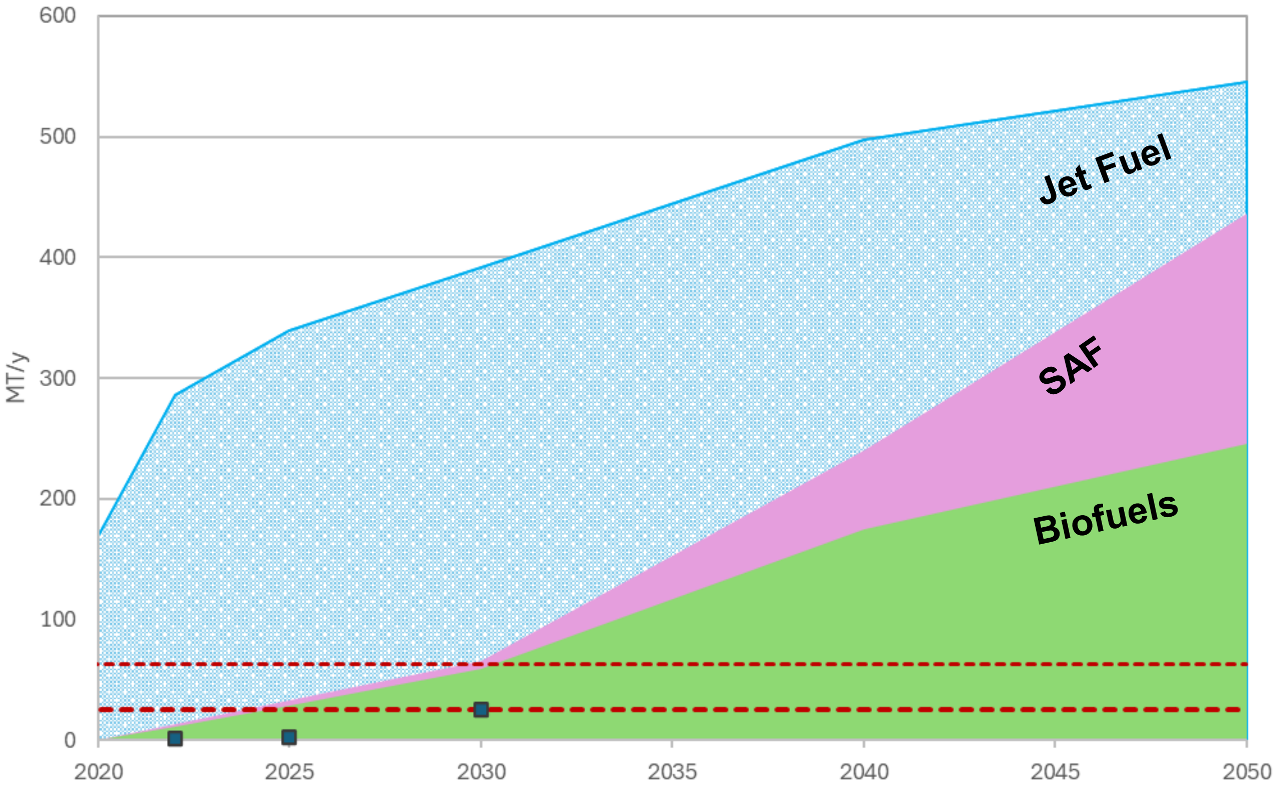
Customer	**Shandong Haike Chemical Co. Ltd**
Location	China (Dongying)
Feedstock	Lipid wastes from food industry (UCO, POME, animal fats, etc.)
Capacity	230 KTA of SAF
Timeline	- Basic engineering May 2023 - Start-up mid 2025
Scheme	Retrofit to Vegan®

Co-Processing to Accelerate Energy Transition

- **Fast** implementation
- **Low CAPEX** ⟺ Leveraging **existing infrastructure**
  True **drop-in**
- Feasible on **all refinery configurations**
- **Market driven** by policies / evolving specifications / companies net-zero goals
- **Reversible**, for an uncertain context



NZE Scenario and Aviation Fuel



- Max HEFA potential 25-65MT/y
- HEFA production
  2024 : 1.5MT
  2025 : 2.5 MT
  2030 : 25MT
- Timing challenge 2030/35
- Biomass and other feedstock to contribute

Sustainable Aviation Fuel From Biomass

BioTfueL® Solution

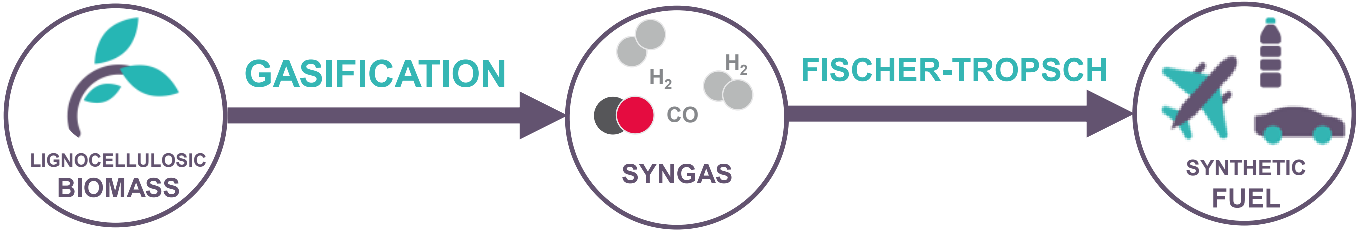
BioTfueL® in 60s

ID — BioTfueL®

STATUS — Commercial Technology

LICENSORS — Axens & thyssenkrupp

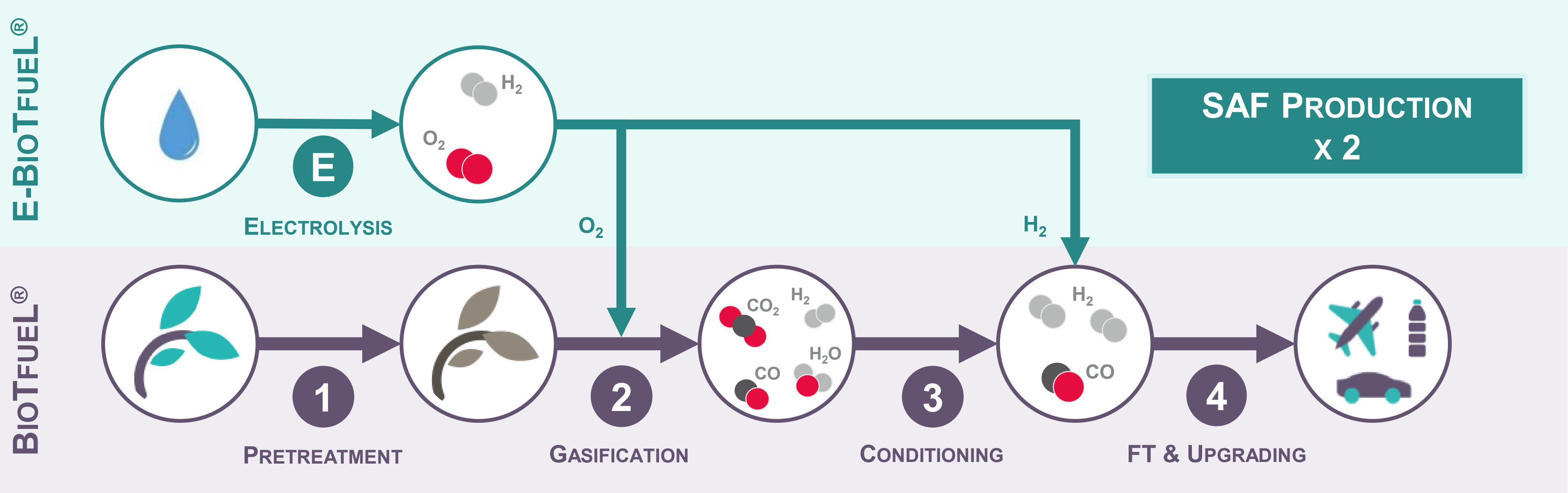
PATHWAY



FEATURES

1. **De-risked** — > 12 years of development, large scale demonstrators
2. **Versatile** — Feedstock and Product flexibility
3. **Integrated** — Global Licensor providing end-to-end guarantees

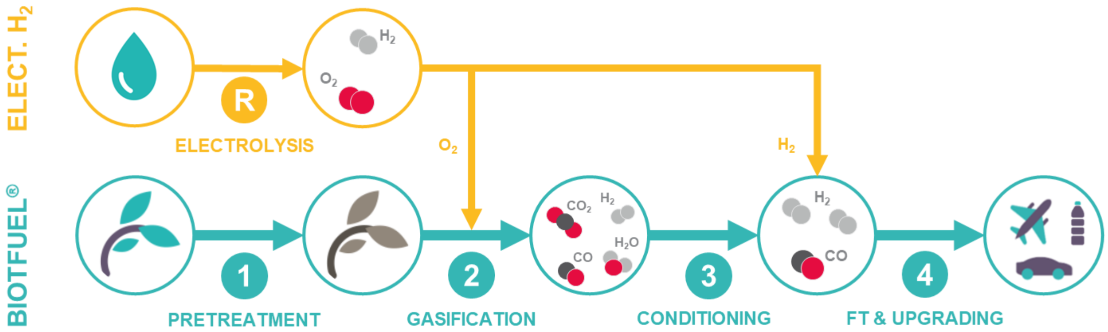
From BioTfueL® to E-BioTfueL®



MAXIMUM H_2 BLENDING

NO WATER GAS SHIFT

Commercial experience: BioTJet



BioTJet

Customer	**Elyse Energy**
Location	South of France (Lacq)
Feedstock	Biomass (local residues) Green H_2 (French grid)
Capacity	Feed: 300 KTA dry biomass Product: 110 KTA liquid (SAF + Renewable naphtha)
Timeline	Basic Engineering 2024 S/U Plant 2028
Scheme	BioTfueL® + AdvAmine™ - Gasel®

Axens Elyse Avril IFP Energies nouvelles BioTfueL

Axens Technologies

- **AdvAmine™ Syngas**
  - ➢**Acid Gas Removal**
  - ➢Over 200 References
- **SulShine®** Catalyst & **AxTrap™** Adsorbent
  - ➢**Syngas cleaning**
  - ➢Over 100 References
- **Gasel®**
  - ➢**Fischer-Tropsch & Upgrading**
  - ➢Over 400 references (upgrading)
  - ➢Over 25 bubbling bed reactors references
  - ➢Large demo plant (Fischer-Tropsch)
  - ➢Several plants under design

Hengli Crude to Chemical complex with 10 Axens licenses including Upgrading units

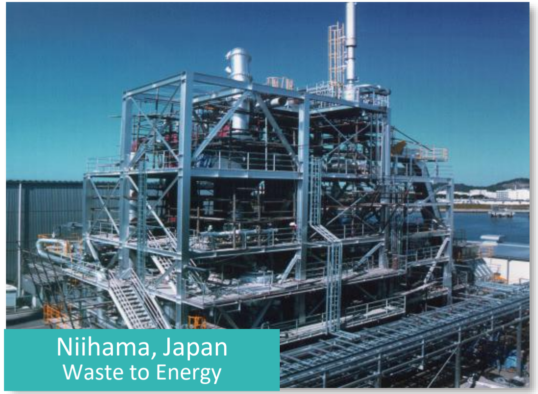
Gasification Experience

Modderfontein, South Africa
Coal to Ammonia/Fertilizers

Berrenrath, Germany
Lignite to Methanol

Oberhausen, Germany
Coal to H_2 and Oxo-Syngas

Over 100 Gasifiers designed, built and put into successful operation by Uhde



Niihama, Japan
Waste to Energy

Puertollano, Spain
Petcoke, Coal & Biomass to Power & H_2

Dunkirk, France
Biomass to Jetfuel

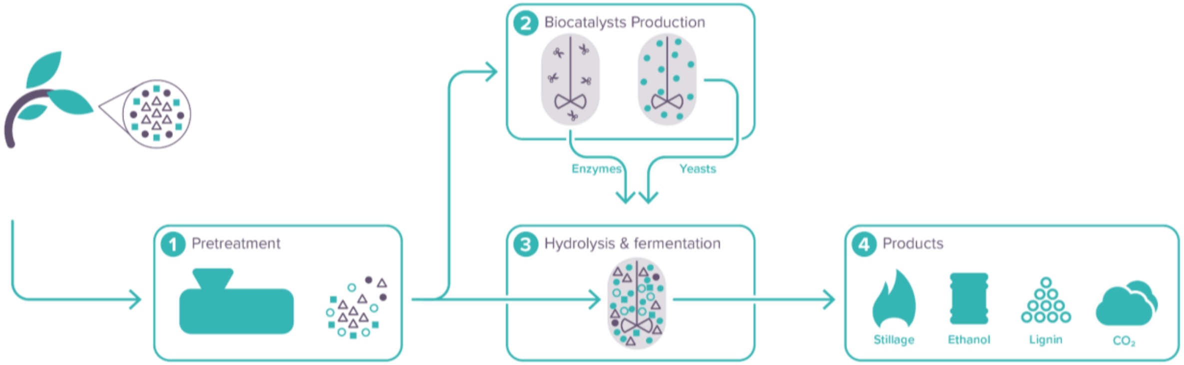
Full Chain Pre-Commercial Plant

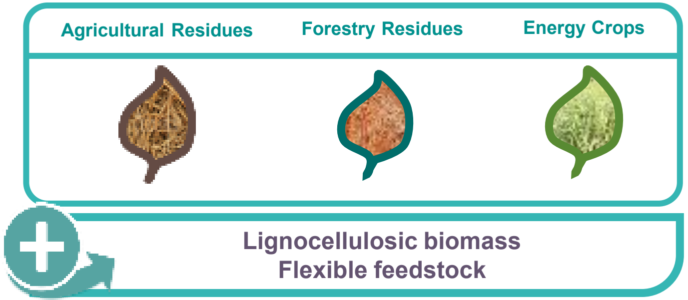
BioTfueL

Sustainable Aviation Fuel From Biomass

Futurol^{TM} Jetanol Combination

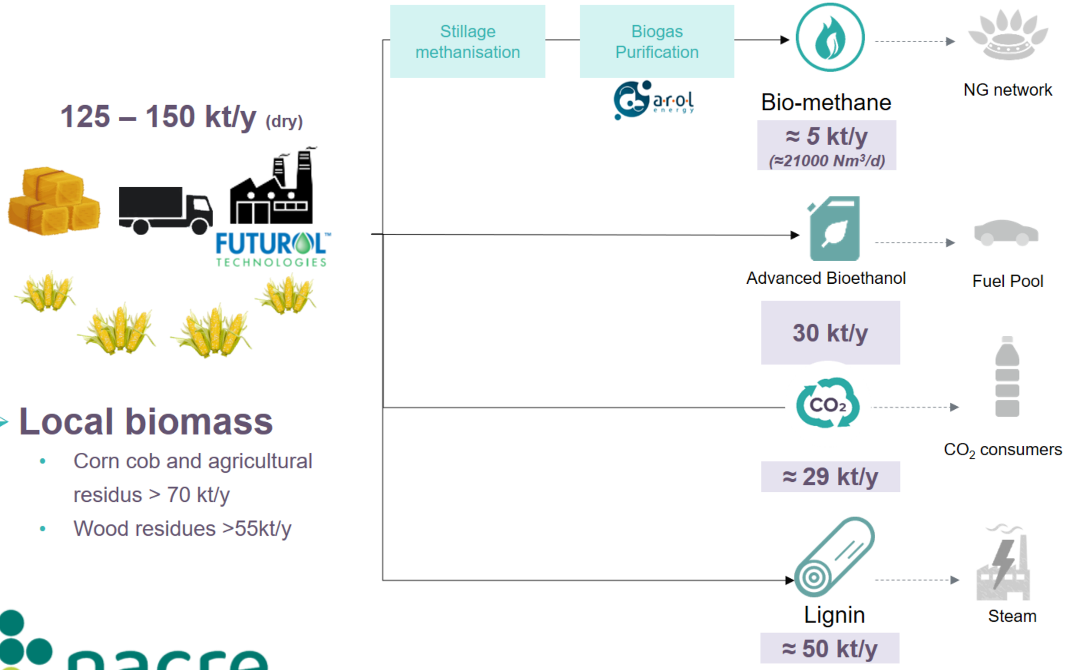
Futurol® from Biomass to Advanced Ethanol





- **Technology key features**
  - Robust biomass pretreatment technology
  - On-site production of tailor-made biocatalysts
    - → Full control of operating cost
    - → Less logistic, not relying on external supplier
  - One-pot enzymatic hydrolysis & fermentation
    - → CAPEX and OPEX minimization, high ethanol yield
- **Products quality**
  - Advanced / Drop-in Advanced Ethanol
  - First gate to bio-molecules platform: Ethylene, Renewable fuels / SAF, 2G Sugars
- **Commercial technology**
  - 2 references
  - 9+ years of operation of pre-commercial plant
  - 2 years of industrial pretreatment plant operation

Commercial Experience : NACRE



➢ Local biomass

- Corn cob and agricultural residus > 70 kt/y
- Wood residues >55kt/y

nacre

Customer	**NACRE**
Location	France (Lacq)
Feedstock	Corn cob / Forestry residues / Bamboo
Capacity	30 KTA of advanced bioethanol
Timeline	Basic engineering package starts Sept 2023 Start-up 2027
Scheme	Futurol®

Pre-Commercial Plant

Diverse Feedstock

Jetanol™ from Ethanol to Renewable Fuels

Sustainable Aviation Fuel
Renewable Diesel
Renewable Naphtha

9 references alcohol dehydration

44/35 references oligomerization

82references hydrogenation

- **Technology key features**
  - Products & feedstock flexibility
  - Superior yields → Market leading catalyst
  - High selectivity → easier separation/purification
  - Near zero carbon conversion loss
  - Single point licensor from biomass to biofuels
    - For Catalysts and Process Design Package execution
    - End to end guarantees
- **Products quality**
  - ASTM D7566 compliance
- **Commercial technology**
  - Long track record of references
  - Catalyst already used in the industry
  - 7 references

Conclusion

Biomass Summary – Key Parameters

	BioTfueL	Futurol +Jetanol
Capacity	Medium –High	Small – Medium
Yields	Equivalent SAF yield	Equivalent SAF yield
Byproduct	Naphtha - CO2	Lignin - CO2 – naphtha - Biogas
Flexibility	Feedstock - Product	Feedstock - Product
Configuration	Multiple Pre.Treatment H2 injection	Multiple Futurol 2G EtOH prod.
TRL	8	8

Take Aways

HEFA pathway launch SAF production **up to 2030-2035** then **alternatives feedstocks** needed

Technology selection for **Biomass to SAF** is **project dependant**

Axens is a **unique partner** to provide **integrated solutions** and **services** on the entire lifetime of the plant

Axens

Powering integrated solutions

axens.net

Thank you

Axens.net

a new digital journey