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Sustainable Aviation Fuel: Necessity and Path Forward as Clean Energy

Presentation by Pankaj Garg
General Manager - Sales and Business Development Technip Energies

Agenda

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01 Technip Energies Global View

Technip Energies at a glance

Listed on
Euronext Paris
Stock Exchange

Headquartered in
Paris

65+
Years of operations

€6B
Full year 2023 adjusted revenue

A leading Engineering & Technology company for the Energy Transition

€15.7B
Backlog at end 2023

~15,000
Employees in 34 countries

25+
Leading proprietary technologies

450 projects
Under execution

Our Technologies Portfolio

Delivering Excellence through our experience from diverse portfolio

Gas & Low Carbon Energies

- LNG: SnapLNG, CRYOMAX® NGL recovery
- Blue H_2: ATR & POx Technologies (with CASALE)

Sustainable Fuels, Chemicals & Circularity

- Ethylene
- Hydrogen
- FCC: PropyleneMax™, Resid2Propylene
- Fertilizers: Phosphoric Acid, UCEGO filter
- Petrochemicals: Acetic Acid, Bisphenol, Cumene, IPA, PET, PTA
- Epicerol, **Hummingbird (Ethanol to Ethylene)**

Decarbonization Solutions

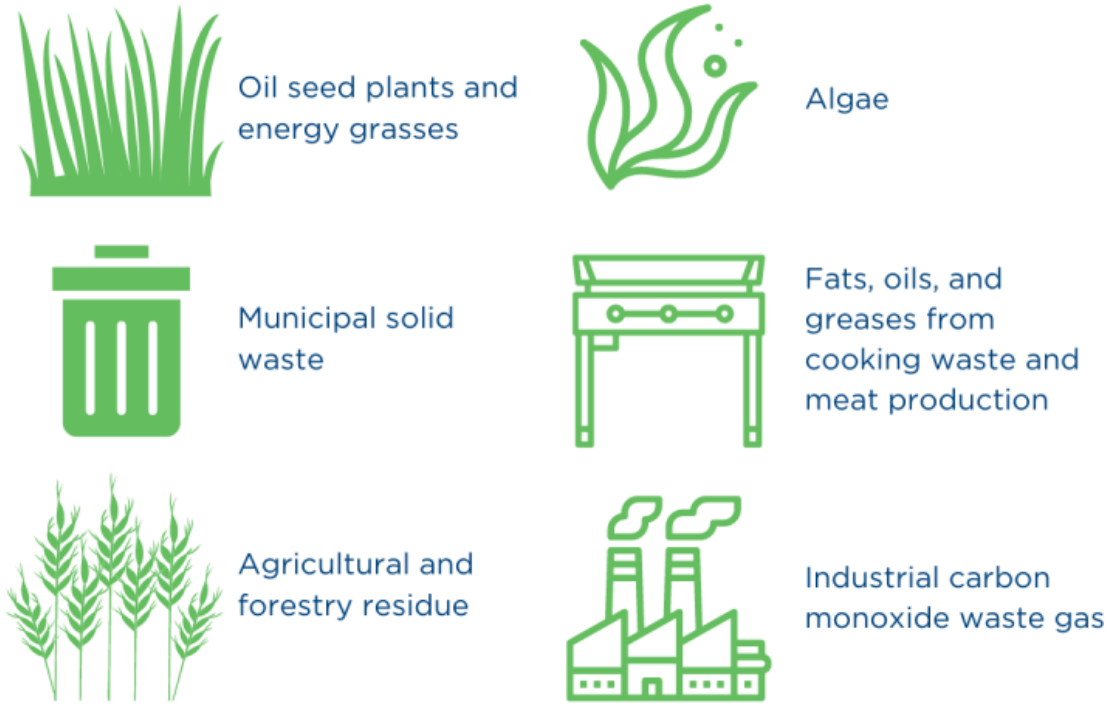
- CO_2 Canopy Solution- Capture.Now
- Green H2 & Power-to-X : RELY

We offer more than 65 technologies (In-house & Alliances)

02 About Sustainable Aviation Fuel (SAF)

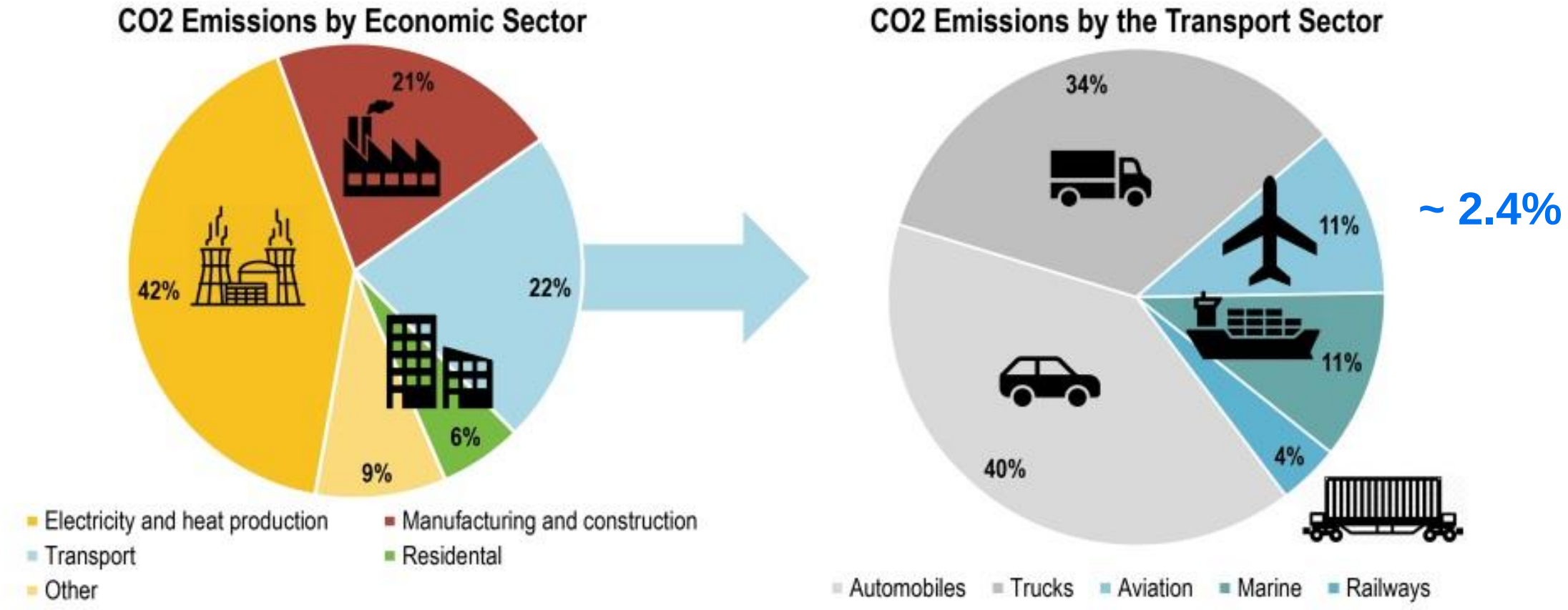
Sustainable Aviation Fuel

SAF, often known as jet biofuel or aviation bio-kerosene, closely **resembles** the characteristics of **conventional jet fuel**. However, SAF is **derived** from diverse and **renewable biomass sources**, including oil seeds, corn grain, animal fats, greases, algae, agricultural and forestry residues, wood mill by-products, municipal solid waste, and more



Source: https://www.envirotrec.ca/2022/saf-and-its-role-in-aerospace/

CO_2 Emissions



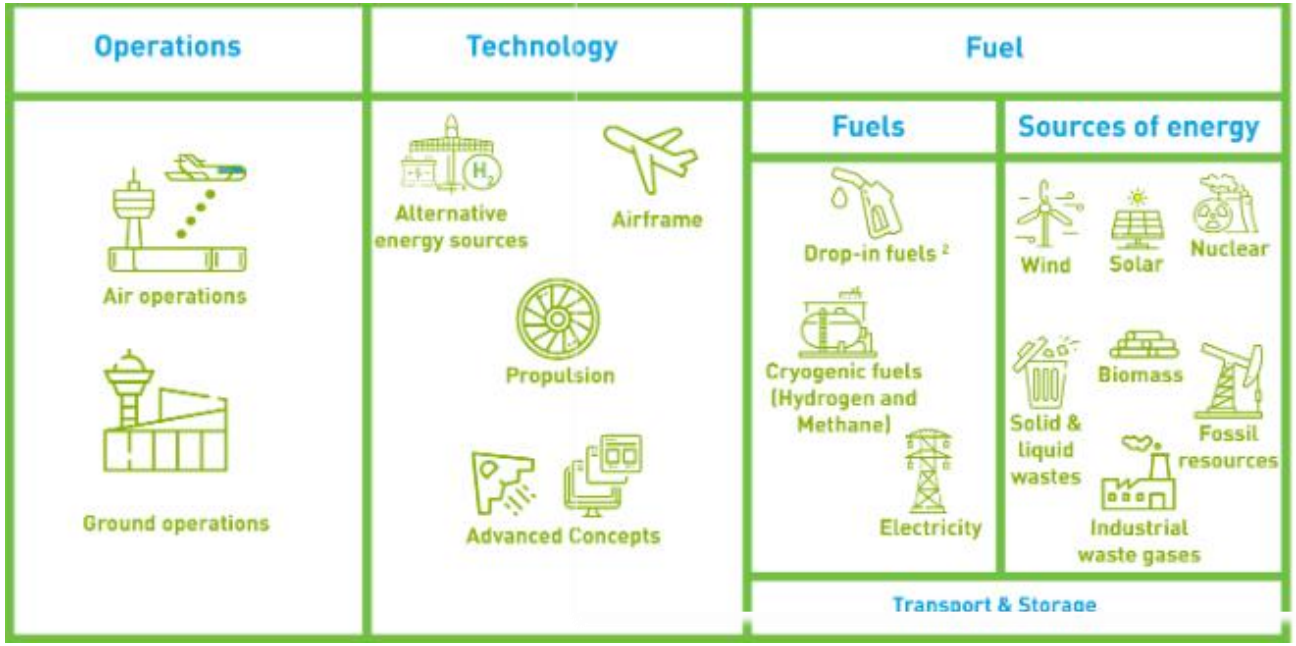
~ 2.4%

Source: https://transportgeography.org/contents/chapter4/transportation-and-environment/greenhouse-gas-emissions-transportation/

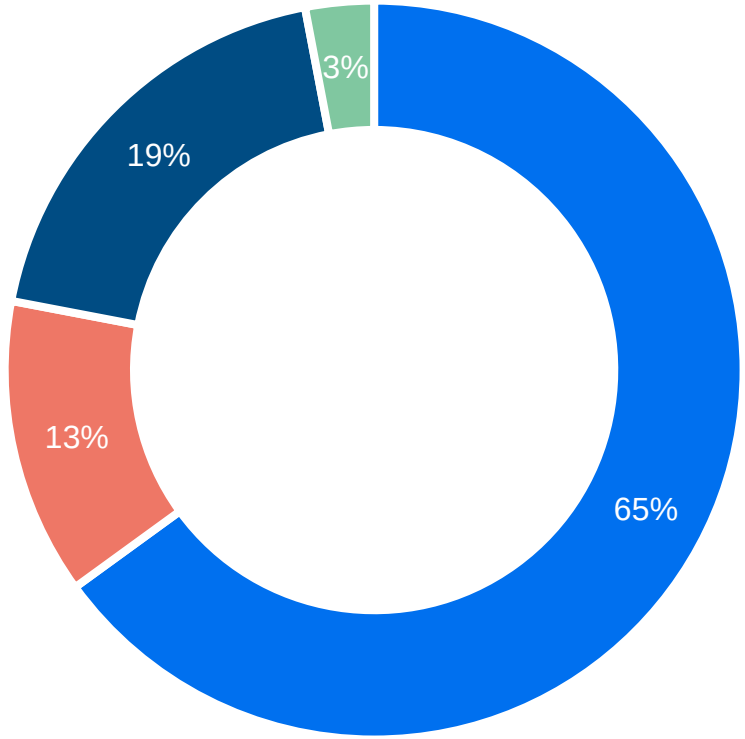
TECHNIP ENERGIES

Approach to Net Zero Carbon by 2050

- Aircraft-related technology development.
- Alternative fuels.
- Air traffic management and infrastructure improvement.
- Economic/market-based measures.

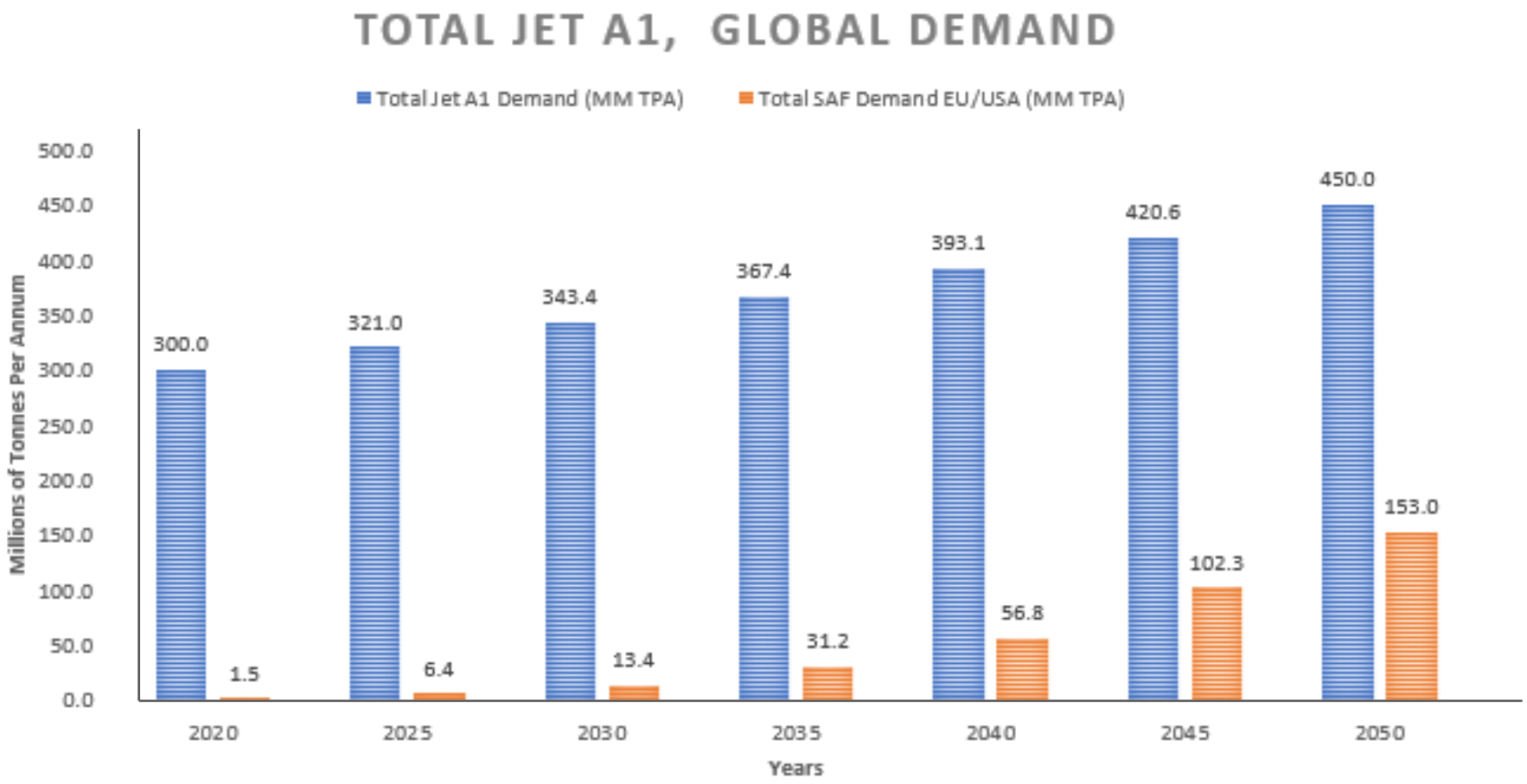


Source: ICAO Environmental Reginal Seminars, Apr-May 2023



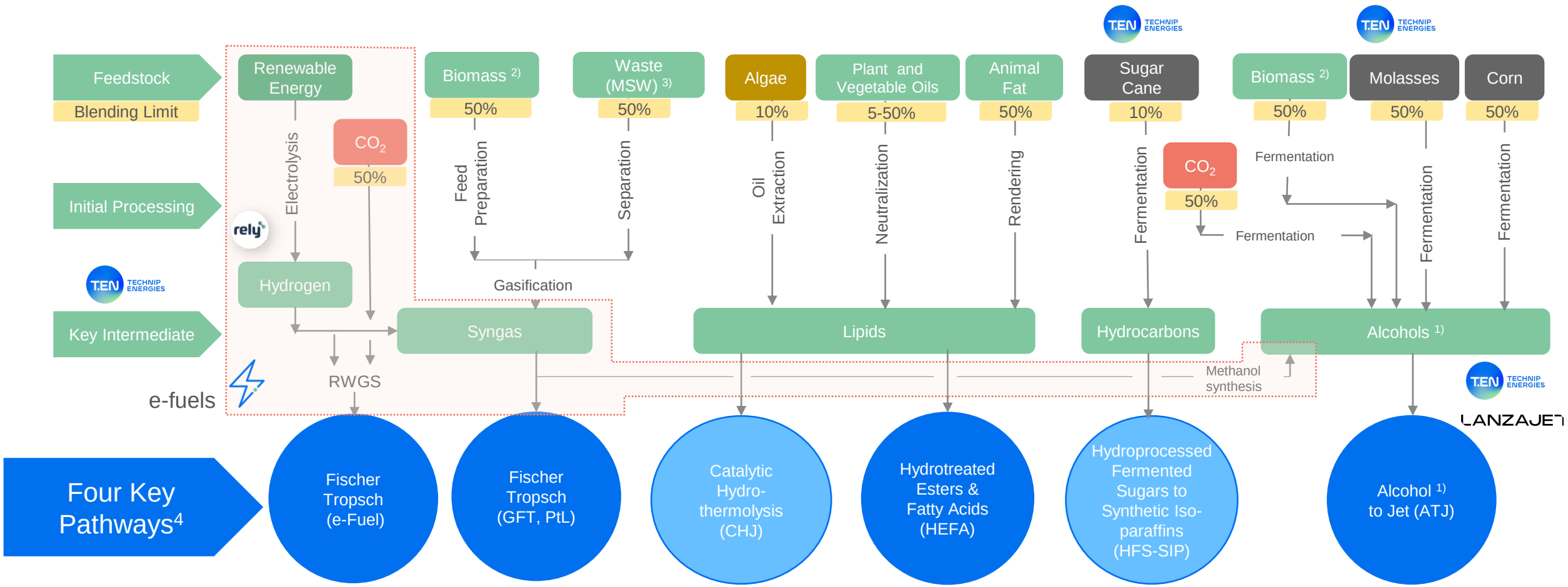
- SAF
- New Technology (e.g. Electric and Hydrogen)
- Offsets and Carbon Capture
- Infrastructure and operational efficiencies

Global Jet Fuel Demand to 2050



Key Process Pathways for SAF

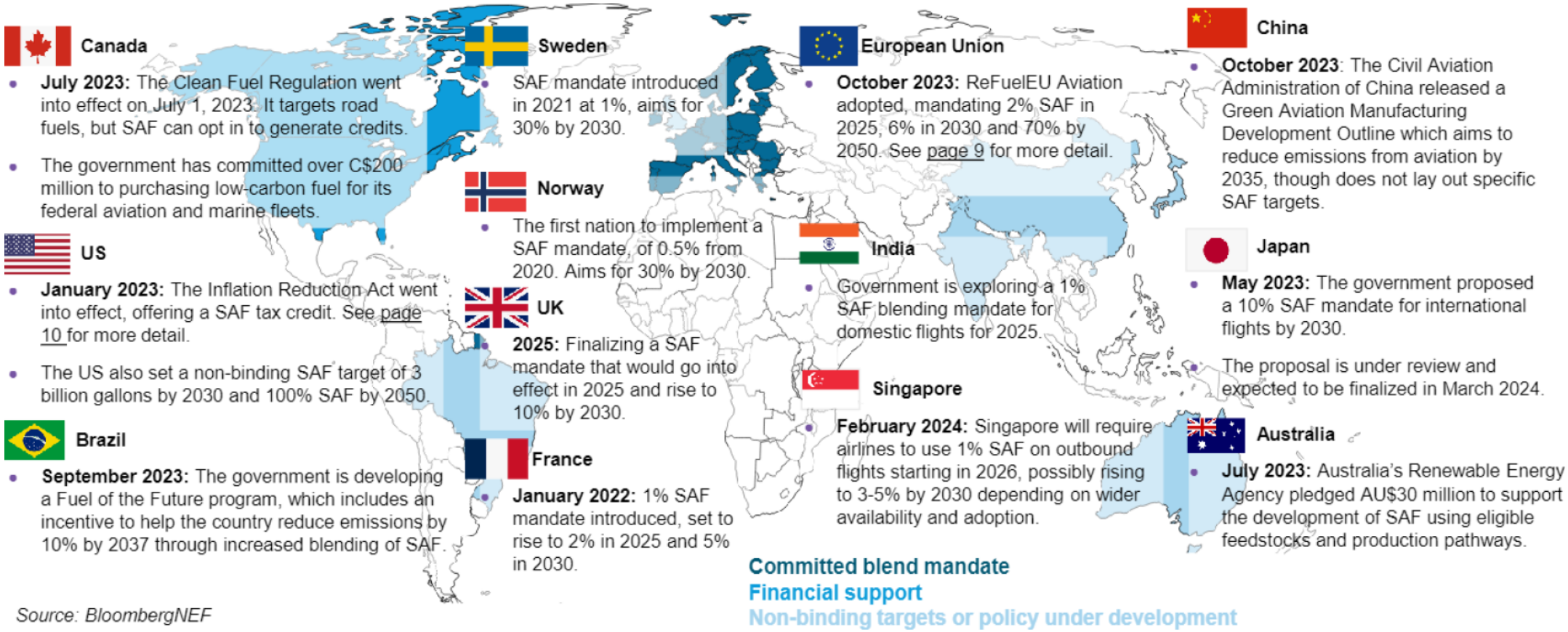
Innovation driven by access to novel feedstocks



1) Alcohols currently include Ethanol and Isobutanol. Work on-going to include Methanol in future
2) Biomass includes agricultural residues, forestry waste and energy crops
3) MSW = Municipal Solid Waste
4) Certified pathways: PtL (Power-to-Liquid), GFT, CHJ, HEFA, Ethanol / Isobutanol-to-Jet

1G Feedstock | 2G Feedstock | 3G Feedstock | Other

SAF Policy Highlights

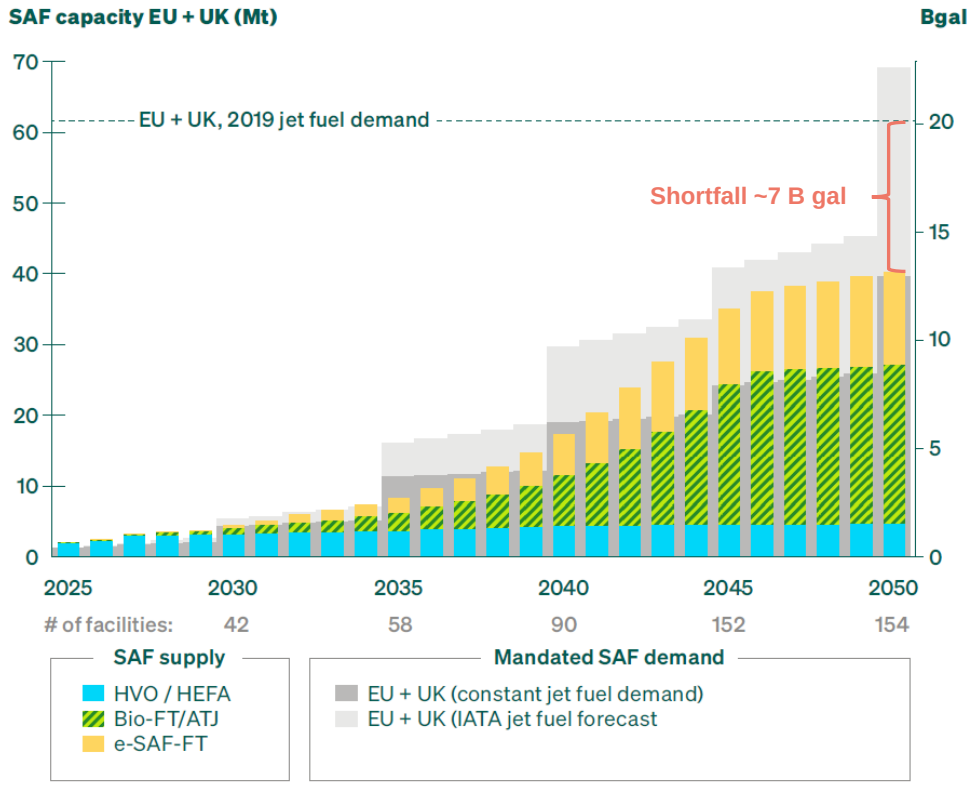


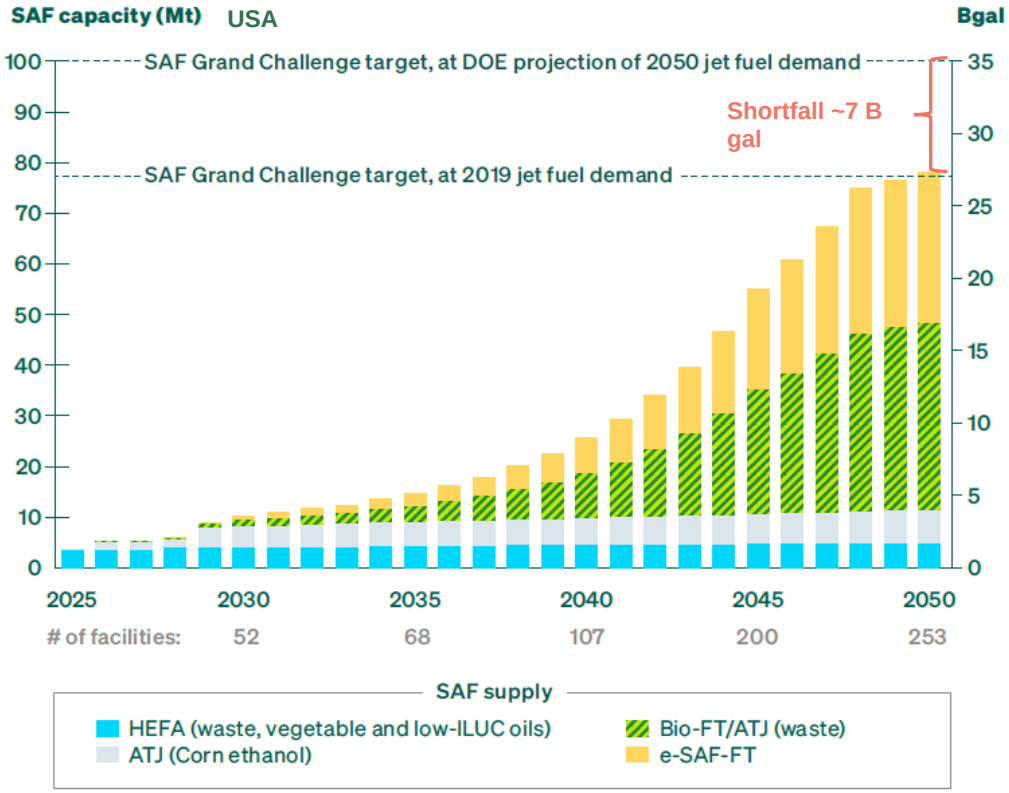
Source: BloombergNEF

Most Bio-fuel policies favor road fuels. SAF has start to gain formal policy support, usually in form of blending mandates. Firm commitments are still rate, primarily concentrated in Europe. Above highlights some key developments, region wise

Booming demand for SAF (ATJ) in coming years

Alcohol-to-Jet and Power-to-Liquids capacity increase after 2035





Risk OR Opportunities for Early Mover

03 SAF at Technip Energies

Sustainable fuels

Experience with flexibility to adapt and integrate established & innovative technologies

Differentiators

- Proven experience in large refinery and biofuels projects execution worldwide
- Skills to work on innovative advanced 2nd Gen biofuels projects
- Expertise in main SAF production pathways (**HVO/ HEFA**, **AtJ** & **FT**).
- Experience in **e-fuels** domain including technology blocks on **Carbon Capture**, **Low Carbon H_2** coupled with **Syngas expertise**
- In-house technologies for **bioethanol** and **ethanol-to-ethylene** (Hummingbird) – co-operation with LanzaJet on **AtJ SAF**
- Licensing btg-bioliquids **fast pyrolysis oil** technology
- **Sustainable methanol** from MSW relationship with Enerkem
- Vast experience of (bio)fuels projects with different techno solutions incl. 3rd party technologies / integration

Select references

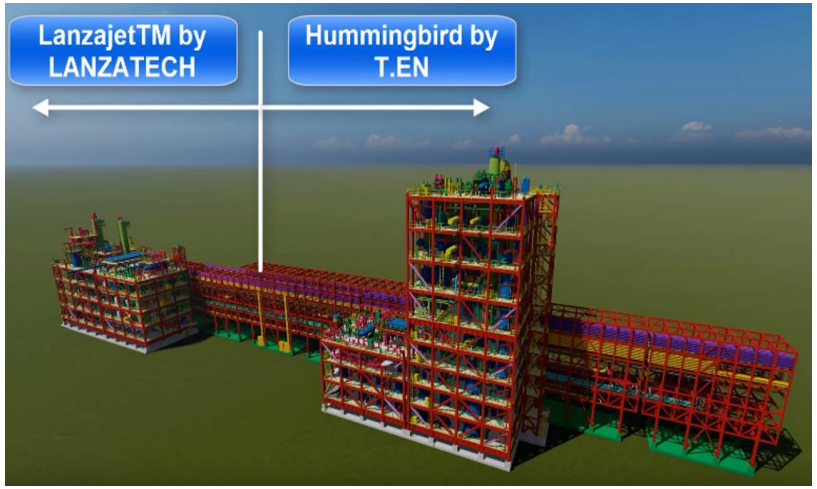
- **NESTE Biofuels plants** (incl. on-going expansions) based upon NexBTL technology, Singapore and Rotterdam
- **TOTAL La Mède biofuels** plant based on Axens Vegan technology, France
- Proprietary Hummingbird® technology deployed for **LanzaJet's Biorefinery projects**, USA, UK and other locations
- **TOTAL Grandpuits biofuels** plant based on UOP technology, France
- **SkyNRG biofuels** plant based on Topsoe technology, Netherlands
- **GALP biofuels** plant FEED, Portugal
- **Arcadia eFuels** FEED, Denmark
- **ENI biofuels** plant FEED, Malaysia

04 Focus on AtJ

Relationship with LanzaJet

- Technip Energies together with LanzaJet Inc. (since 2019) for SAF projects via Alcohol to Jet (AtJ) pathway (ASTM D7566).
- Combination of T.EN's Hummingbird® ethanol dehydration technology with LanzaJet's oligomerization / hydrogenation technology.
- First commercial AtJ SAF unit (30 kTA) due to start at Freedom Pines, Georgia.
- Activities include engineering for the complete SAF unit, together with value engineering, energy optimization and modularization.
- Other Projects in execution/ feasibility stage totalling ~ 2 M tonnes /annum SAF through this partnership.

Freedom Pines Grand Opening, January 2024



Modular designed 90 kTA SAF Unit

Technip Energies - Capabilities

- Pilot testing via T.EN's Weymouth Laboratory:
  - Third party R&D services for pilot scale technology development.
  - Complete Hummingbird® pilot to produce polymer grade ethylene from ethanol.
  - Collaboration with On Shoes and Borealis for Proof of concept for 'CleanCoud®' fossil free shoes.
  - Catalyst Performance testing and development.
- Engineering development – flowsheet development from pilot to demonstration unit and then to commercial scale.
- Scale-up (30 kTA > 90 kTA > 500+ kTA ongoing).
- Value Engineering – cost reduction/standardization opportunities.
- Economic evaluation – client project economics.
- Carbon Intensity Lifetime analysis for SAF

Weymouth Pilot Facilities – outside Boston, MA.

On shoes – CleanCloud® concept shoe made from recycled or renewable carbon (picture courtesy 'On Shoes')

LanzaJet/T.EN AtJ offering

Wheat, corn,
or sugar beet
as feedstock

~155 kTA
Ethanol
(1G, 2G, 3G)

Waste gases
CO2, H2…

Capture.Now

LanzaTech

rely

Combination of two technologies

SAF solution (for 90kTA Sustainable Products)

Block 1

Hummingbird ® Technology

- Ethanol Clean-Up
- Dehydration Reaction
- Separation

~ 88 kTA
Ethylene

Block 2

LanzaJet Technology

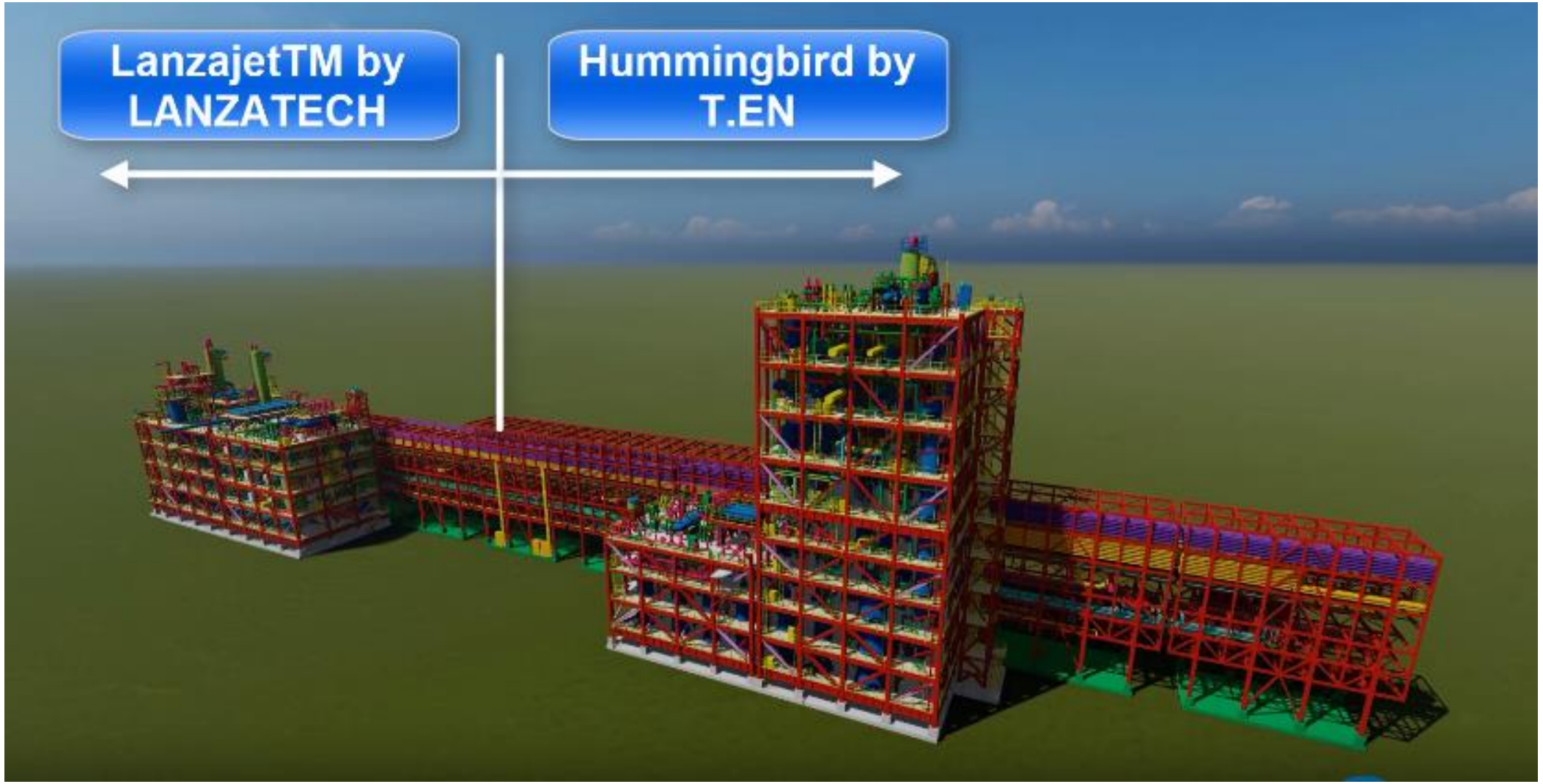
- Oligomerization
- Hydrogenation
- Fractionation

~ 80 kTA SAF

~10 kTA Renewable Diesel

kTA = thousands tonnes per annum

Model Snapshot



Ongoing SAF Projects (AtJ) with LanzaJet

PROJECT	LOCATION	CAPACITY *(KTA)*	COMMENT
LanzaJet Freedom Pines	USA	30	Start-up – Q2 2024
LanzaTech DRAGON	UK	90	FEED complete Q4 2023
Project FLITE	Netherlands (EU)	90	FEED completed Q3 2022
JetZero	Australia	90	BEDP ongoing
Project Speedbird	UK	90	BEDP ongoing
CONFIDENTIAL	India	90	BEDP ongoing
CONFIDENTIAL	USA	900	Scaling Studies ongoing
CONFIDENTIAL	USA	90	Studies completed
CONFIDENTIAL	Japan	90	Early engagement
CONFIDENTIAL	Sweden (EU)	90	Early engagement
Misc. Opportunities	Global	450	Early engagement
TOTAL		**2100**	

05 SAF Projects

References

SAF Projects to Date

	Sr. No.	Project Name	T.EN Projects SAF Capacity, KTA	Scope & Status	Technology/ Route
Operating references	1	Neste, Singapore	1,000	EPsCm: Completed	HEFA – Neste
	2	Total Energies [Phoenix Project], FR	500* (EPsCm)	EPsCm: Completed	HEFA – Axens
Active Projects	3	Freedom Pines, Georgia USA	27	PDP/L/Catalyst: Commercial demo S/U in Q2 2024	AtJ- (LanzaJet)
	4	ENI Phoenix Bio-refinery, MY	452	FEED: Completed	HEFA - ENI/UOP
	5	DRAGON, UK	80	FEED/License: Completed in Q4, 2023	AtJ- LanzaJet
	6	Project Flite, NL	80	FEED: Completed in Q3, 2022	AtJ- LanzaJet
	7	Jet Zero, AUS	80	PDP/License Ongoing.	AtJ- LanzaJet
	8	Speedbird, UK	80	PDP/License: Ongoing.	AtJ- LanzaJet
	9	Confidential, India	80	PDP/License: Ongoing.	AtJ- LanzaJet
	10	Confidential, USA	80	Study: Completed.	AtJ- LanzaJet
	11	Confidential, USA	80	Study: Completed.	AtJ- LanzaJet
	12	Confidential, USA	900	Study Ongoing.	AtJ- LanzaJet
	13	Confidential	80 x 5	Prospects under development.	AtJ- LanzaJet
	14	Neste Rotterdam, NL	500	EPsCm: Ongoing.	HEFA - Neste
	15	TotalEnergies [Galaxie Project], FR	210	EPsCa: Ongoing.	HEFA - UOP
	16	GALP HVO Unit, POR	270*	FEED/EPsCm: Ongoing.	HEFA - Axens
	17	SkyNRG DSL01, NL	100	Re-FEED: Ongoing.	HEFA - Topsoe
	18	Arcadia, DEN	2000 bbl/day**	FEED: Ongoing.	eFuels - SASOL + Topsoe
	19	SkyNRG PNW (2), USA	80	Study: Ongoing.	G+FT (as alternate for 11)
	20	Fulcrum, UK	84 (PMC service)	PMC services: Ongoing	G+FT
	21	SASOL Lighthouse	125	EDP – PDP	G+FT (Air Liquide + SASOL + Topsoe)
	22	BP Castellon	~200	Study completed	HEFA - UOP
	23	Repsol Bilbao eFuels Demo	~3	OSBL FEED	eFuels
	24	Total Energies HDT2	TBC	Pre-FEED Ongoing	HEFA
	25	HPCL Ethanol to Jet DFR	TBC	Study Ongoing	AtJ
	26	Tallgrass Ethanol to SAF	TBC	Advisory Study	AtJ
	27	Blue Blade Energy	387	Advisory Study	AtJ

- Bio-refinery feed capacity rather than SAF production
** - FT Products

LanzaJet

Project: Freedom Pines (AtJ)

Project

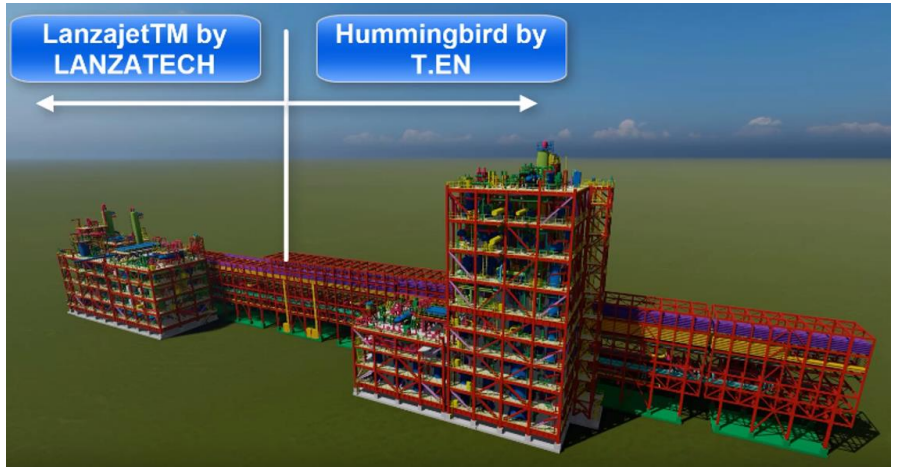
Contract: PDP
Award: 2019
Delivery: s/u June 2024
Client: LanzaJet
Location: Freedom Pines, GA.

Key figures

- Capacity: 30 kTA
- AtJ Licensor: LanzaJet/T.EN
- Package providers: Modular by Zeton

LANZAJET

World's first commercial scale AtJ SAF Unit – located in Freedom Pines, Georgia, USA.



LanzaTech

Project DRAGON (AtJ)

Contract: License, PDP, FEED (Completed)

EPF+Cm (Award expected in 2024 / 2025)

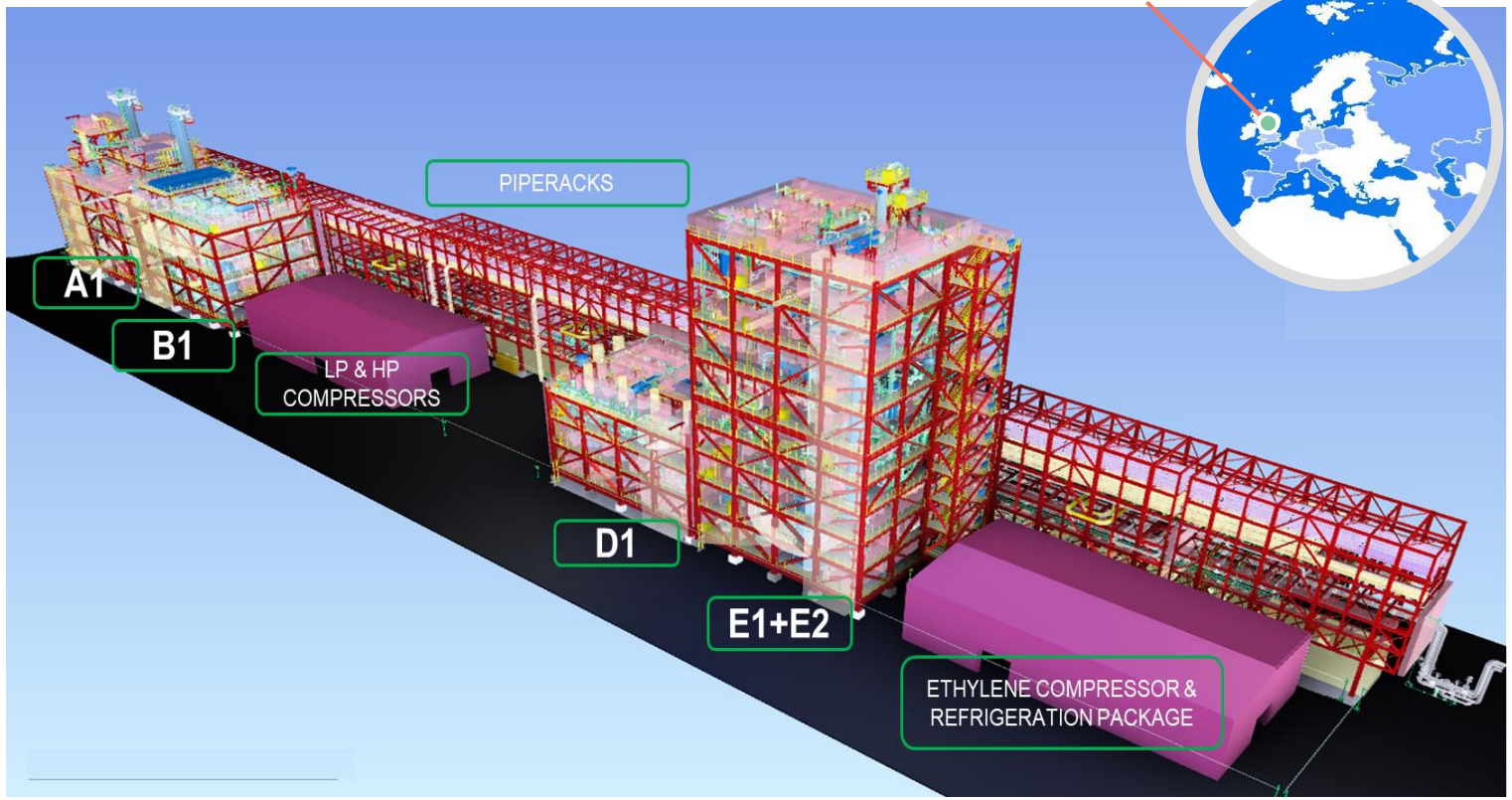
Client: LanzaTech UK Ltd.

Location: Port Talbot, South Wales (United Kingdom)

Key figures

New AtJ Unit (SAF) to produce 90kTPA renewable-diesel and SAF based on 2nd generation bioethanol feedstock in Port Talbot, UK

Project



First Commercial AtJ SAF Unit in Europe. FEED funded by the Clean Fuels Fund from UK DoT to produce 81 kTPA SAF and 9 kTPA renewable-diesel.

LanzaJet

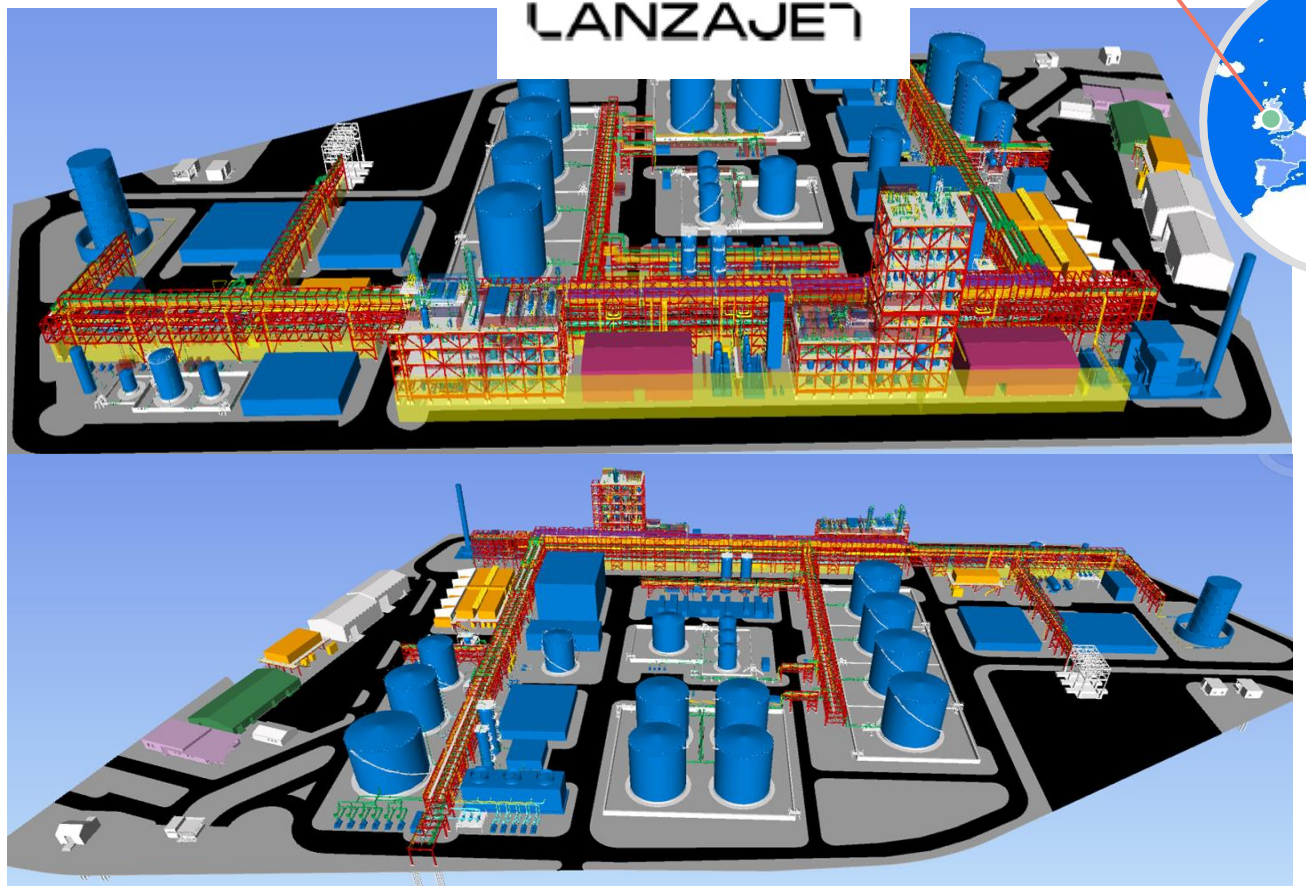
Project: Speedbird (AtJ)

Contract: PDP (ISBL+OSBL)
Award: 2023
Delivery: Jun 2024
Client: LanzaJet
Location: Teesside, UK

Key figures

- Capacity: 90 kTA
- AtJ Licensor: LanzaJet/T.EN
- Package providers: Complete modular ISBL Design by T.EN

Project



LanzaJet Build, Own Operate with British Airways as off-taker.

Jet Zero

Project: Ulysses (AtJ)

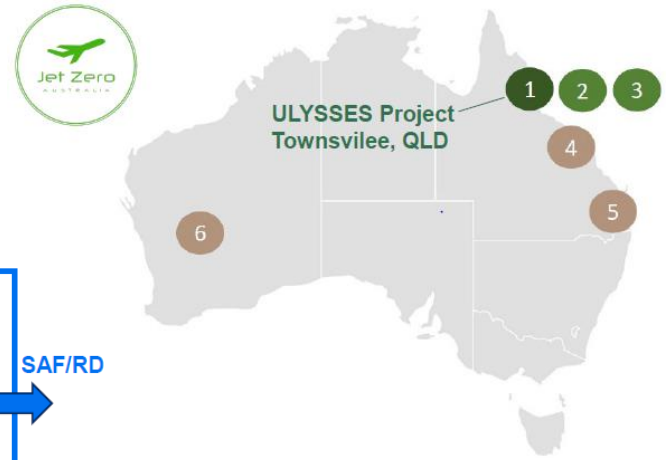
LANZAJET

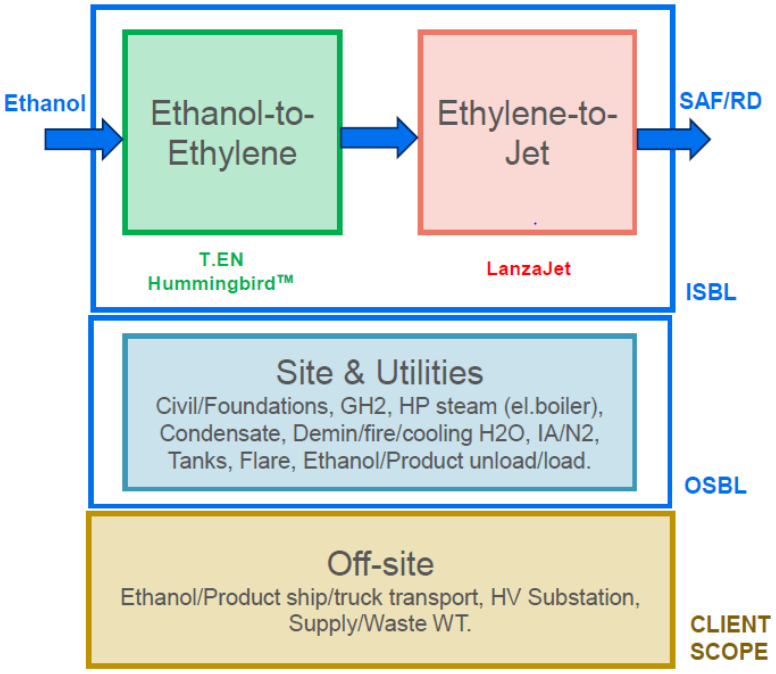
Project

Contract: PDP (ISBL+OSBL)
Award: 2024
Delivery: Jul 2024
Client: LanzaJet
Location: Queensland, Australia

Key figures

- Capacity: 90 kTA unit (30 MM GPY)
- AtJ Licensor: LanzaJet/T.EN
- Package Provider: Complete modular ISBL Design by T.EN





T.EN TECHNIP ENERGIES

TotalEnergies

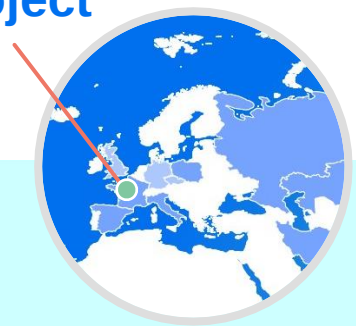
Galaxie Biojet (HVO)

Contract: EPsCa
Award: 2022
Delivery: 2025
Client: TotalEnergies
Location: France

Key figures

- Capacity: HVO 210 kty Biojet & 51 kty biodiesel
- HEFA Licensor: UOP
- Package providers: PTT Desmet Ballestra and Callidus for Thermal Oxidizer

Project



First biorefinery in France from Animal Fat and used cooking oils to renewable fuel

Galp

New HVO Unit (Biofuels)

Contract: FEED
Award: 2021
Delivery: 2022
Client: Galp
Location: Portugal

Key figures

Capacity: 270kTPA Bio-diesel and Bio-jet

Project

Based on renewable feedstock (animal fat, vegetable oils, etc.) in Galp's Sines refinery

T.EN TECHNIP ENERGIES

Arcadia e-Fuels Endor FEED Project

Sasol-TEN-Topsoe collaboration (unique proposition for Power to Liquid)

Contract: FEED

Award: 2022

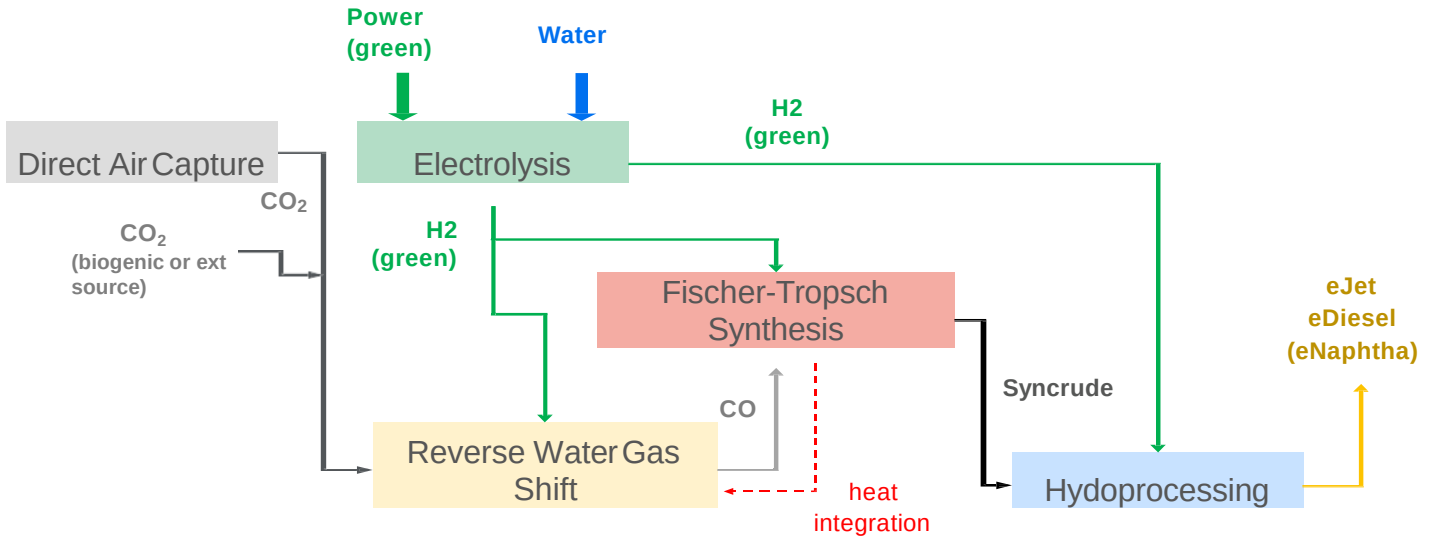
Completion: 2023

Client: Arcadia e-Fuels ApS

Location: Vordingborg, Denmark

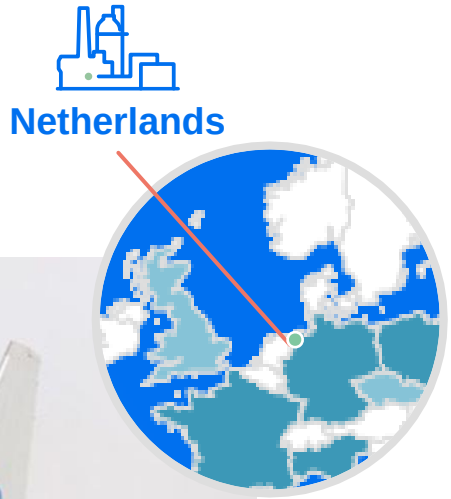
Key figures

- 2kbpd equivalent FT products (eJet and eDiesel)
- ~280MW Electrolyzer capacity



DSL-01

Sustainable Aviation Fuel plant (HEFA)



Contract: LS FEED with Class 2+4 Open Book estimate

Award: 2018

Delivery: 2020

Client: SkyNRG

Location: Delfzijl, The Netherlands

Key figures

- Capacity: 100 kTA SAF

Used Cooking Oil, animal fat & waste oils as feedstock.

T.EN TECHNIP ENERGIES

TotalEnergies

Phoenix Project

Contract: pre-FEED / FEED EPsCm

Award: 2015

Delivery: 2019

Client: TotalEnergies

Location: France

Key figures

Reconversion of refinery in La Mède, to produce 500 KTA of Hydrotreated Vegetable Oil (HVO) from Crude palm oil (CPO), Used cooking oil (UCO), animal fat and palm fatty acids distillates (PFAD) as feedstock.

Project

First biorefinery in France from vegetable and used cooked oils to renewable oils

TECHNIP ENERGIES

TECHNIP ENERGIES

Thank you