

Highly Efficient Pathway to Sustainable Aviation Fuel

[Start presentation](#)

Energy & Materials Transition for Industry
Sustainable Fuels & Chemicals

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The Netherlands as a SAF Hotspot



The Netherlands is well-positioned to become the Hotspot for SAF



Underground storage potential (up to 500 TWh)



Top-notch petrochem & aviation industry



Well-connected industrial clusters to top European harbors and airports. CEPS pipeline



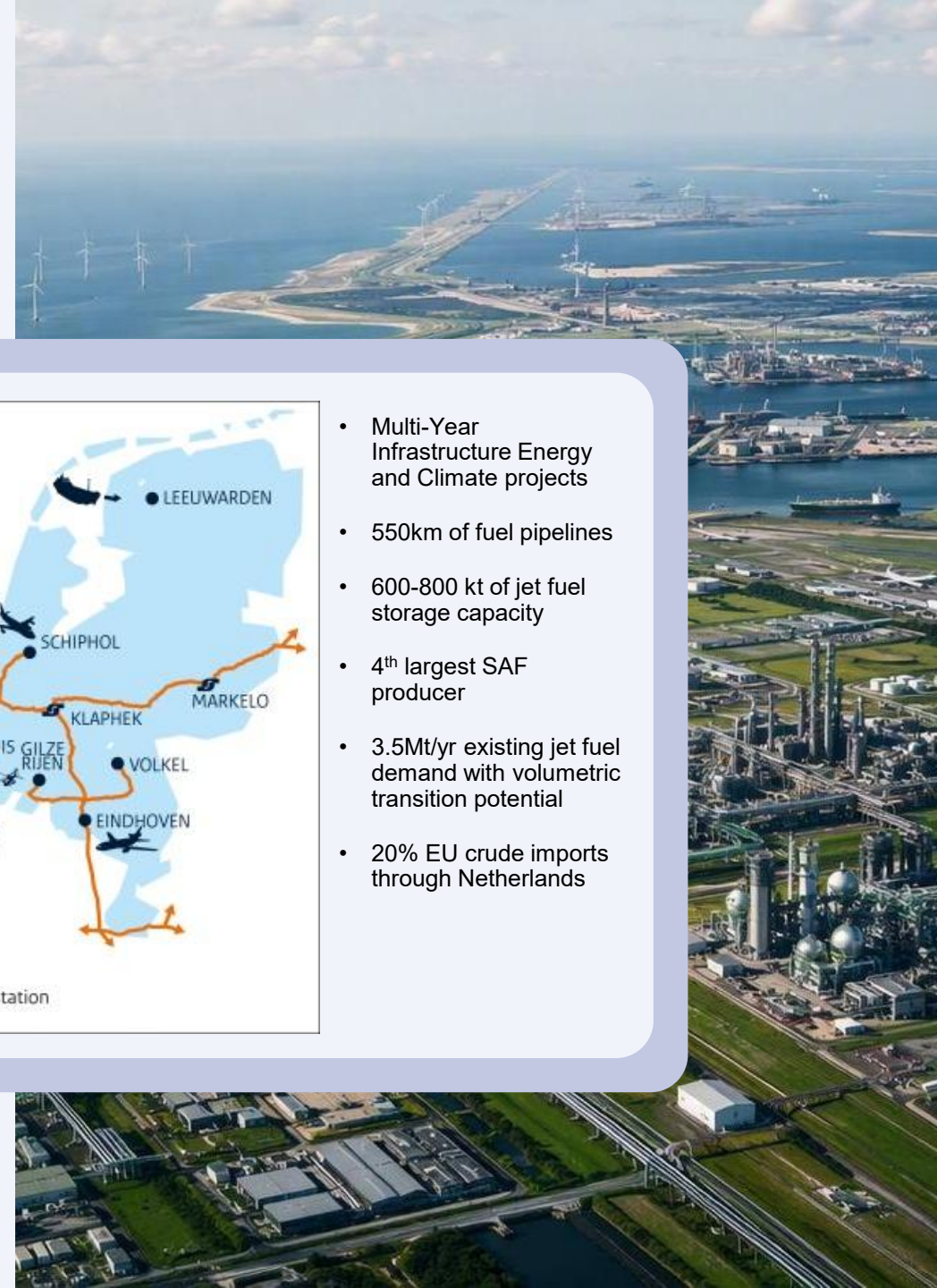
Extensive gas T&D infrastructure combined with world-class gas know-how



Strong carbon-reduction-driven policies



- Multi-Year Infrastructure Energy and Climate projects
- 550km of fuel pipelines
- 600-800 kt of jet fuel storage capacity
- 4th largest SAF producer
- 3.5Mt/yr existing jet fuel demand with volumetric transition potential
- 20% EU crude imports through Netherlands



Policy & Demand Signals

2%

Share of SAF in EU airports
from 2025

70%

Share of SAF in all EU airports
from 2050

1.2%

Share of synthetic aviation
fuels in all EU airports from
2030

35%

Share of synthetic aviation
fuels in all EU airports from
2050



Contribution to the
EU's climate targets



Creating a level playing
field for EU air
transport services



Boosting SAF
innovation and
investments



Creating new jobs
across the EU



Incentivising the
development of global
SAF value chains

Global policy-driven SAF demand

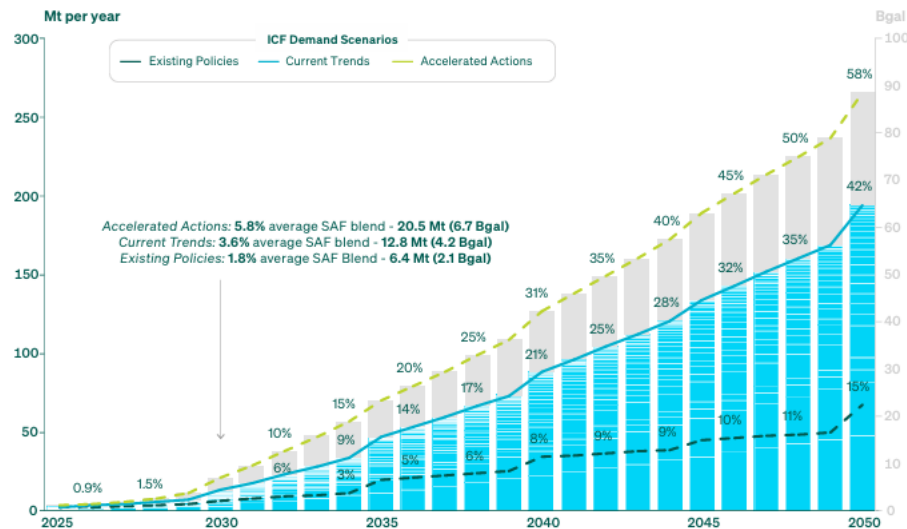
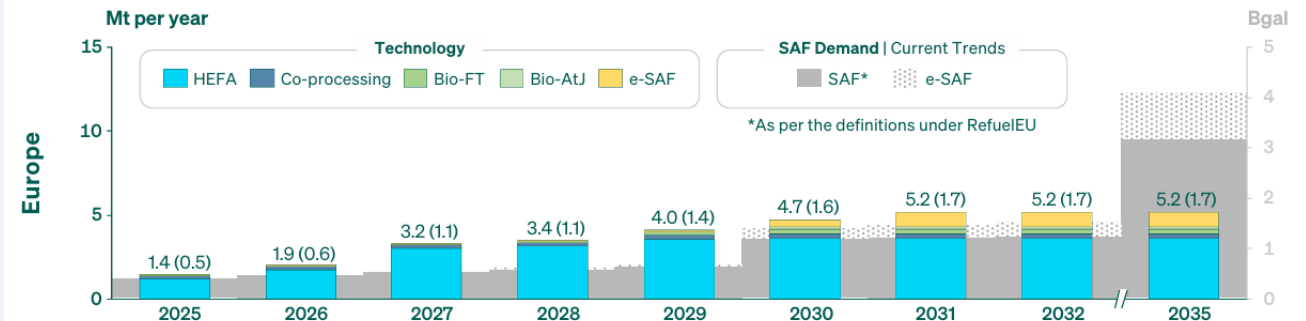


Figure 2: SAF demand is expected to reach 12.8 Mt (4.2 Bgal) by 2030 under the Current Trends demand scenario

Global SAF capacity by Region



SAF Production Platforms



Bio-FT
Residue-to-Jet
Leader



MtJ
Emerging
Flexible bio & e-
Fuel Route



PtL (e-SAF)
Future-Proof
Champion



**Co-
processing**
Quickest Route
to Compliance



HEFA
Today's Market
Leader



AtJ
Flexible
feedstock and
low CI

PROS

✓ Converts wastes & residues

✓ Produces high-quality SAF

✓ Potential CCS integration

✓ Compatible with bio/e-methanol ecosystem

✓ Strong logistics advantages

✓ Flexible carbon feedstock sources

✓ Unlimited feedstock potential

✓ Highest scalability of all routes

✓ Deepest decarbonization value

✓ Minimal investment required

✓ Uses existing refinery assets

✓ Fast deployment timeline

✓ Largest commercial volumes today

✓ Lowest technology risk

✓ Proven, bankable deployment pathway

✓ Existing alcohol and fermentation infra

✓ Flexible biogenic feedstock

✓ Strong global scale potential

CONS

⚠ High capital expenditure

⚠ Complex gasification supply chain

⚠ Early-stage deployment

⚠ Cost tied to methanol price

⚠ High cost today

⚠ Massive renewable power demand

⚠ Limited SAF contribution per barrel

⚠ Long-term decarbonization impact is limited

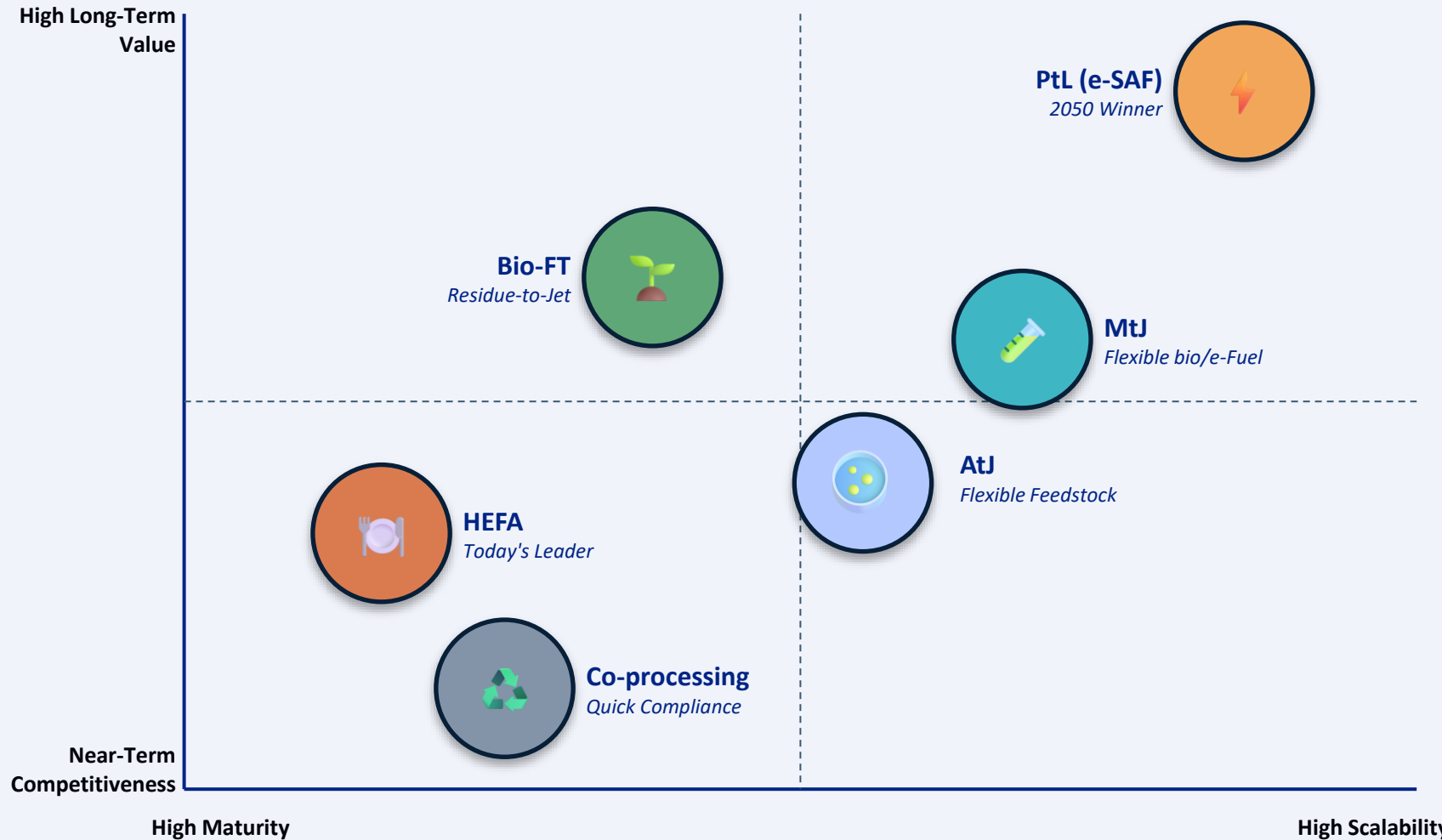
⚠ Feedstock supply is constrained

⚠ Competes with renewable diesel for fats & oils

⚠ Multiple steps & low efficiency

⚠ Economics depend on alcohol cost

SAF Production Platforms



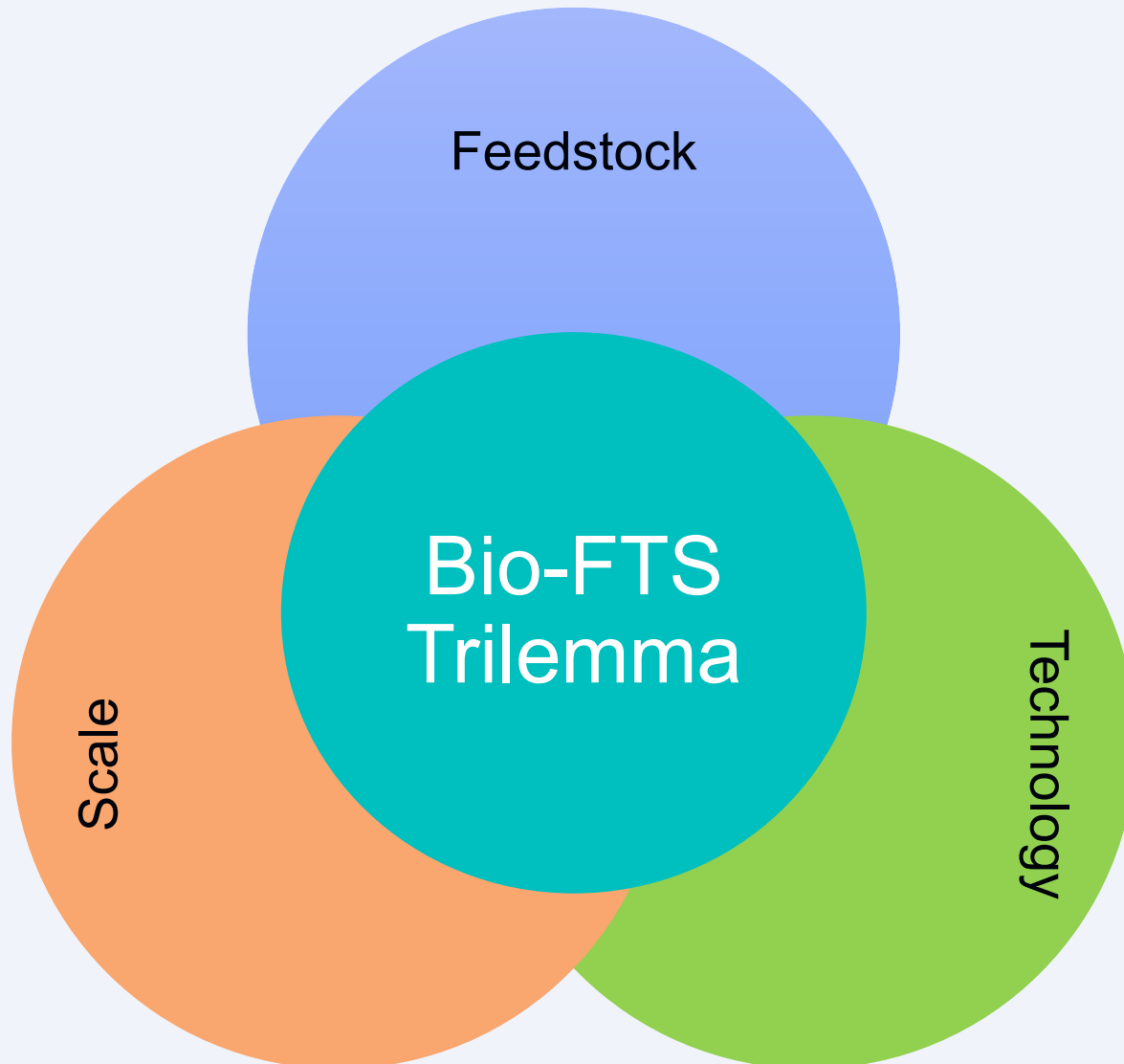
READING THE MAP

Six commercial SAF production pathways plotted by how mature and scalable the technology is today, against the long-term decarbonization value it can deliver.

-  Co-processing
-  HEFA
-  Bio-FT
-  MtJ
-  PtL (e-SAF)
-  AtJ

Technology Maturity → Scalability Potential

Struggling with Bio-FTS



Feedstock for FTS is based on fossil fuels. Abundant, standard quality, predictable, cheap. Biomass residues are mostly decentralized, less standard and more costly



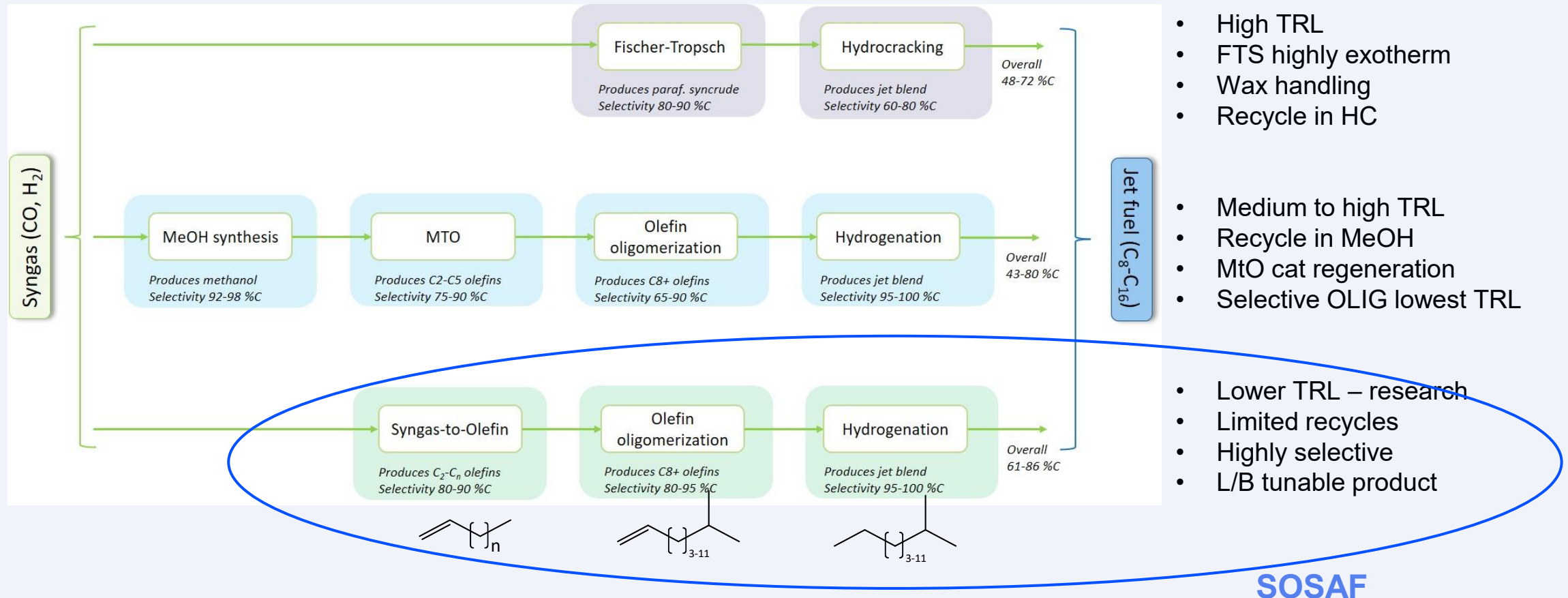
With large volumes of coal and gas to process, technology development centered around this. This resulted in design choices not matching biomass/waste gasification



With large volumes of coal and gas available, the economy of scale is working in your favour. Shell Pearl is 140.000 bpd and Sasol Secunda is 160.000 bpd. DG Fuels (~600 MWth + electrolser) has a 13.000 bpd capacity. This is 1.000.000 tons of biomass per year



Syngas-to-SAF: Production routes

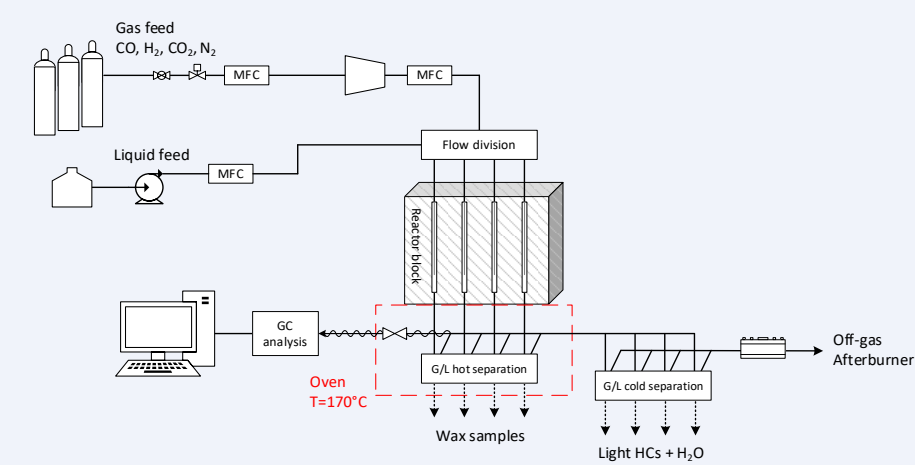


- High TRL
- FTS highly exotherm
- Wax handling
- Recycle in HC
- Medium to high TRL
- Recycle in MeOH
- MtO cat regeneration
- Selective OLIG lowest TRL
- Lower TRL – research
- Limited recycles
- Highly selective
- L/B tunable product

- SOSAF offers high SAF selectivity with highly tunable products. Potentially more cost efficient relevant for small scale application.

Solving by adapting scale

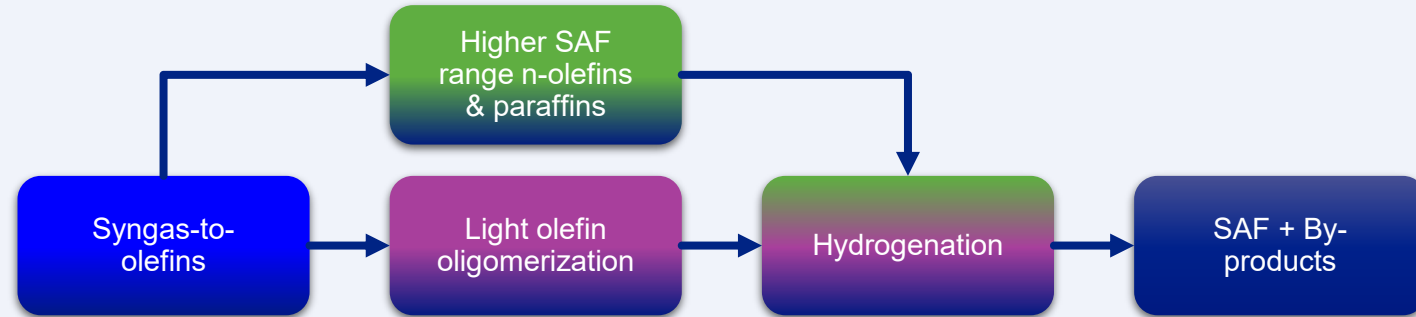
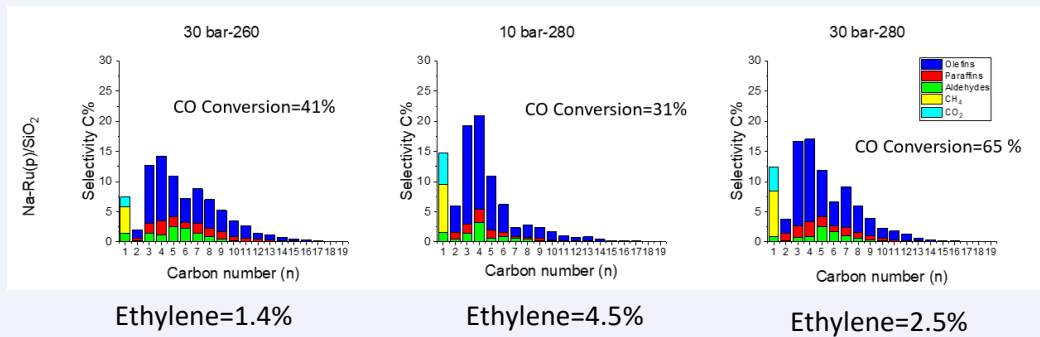
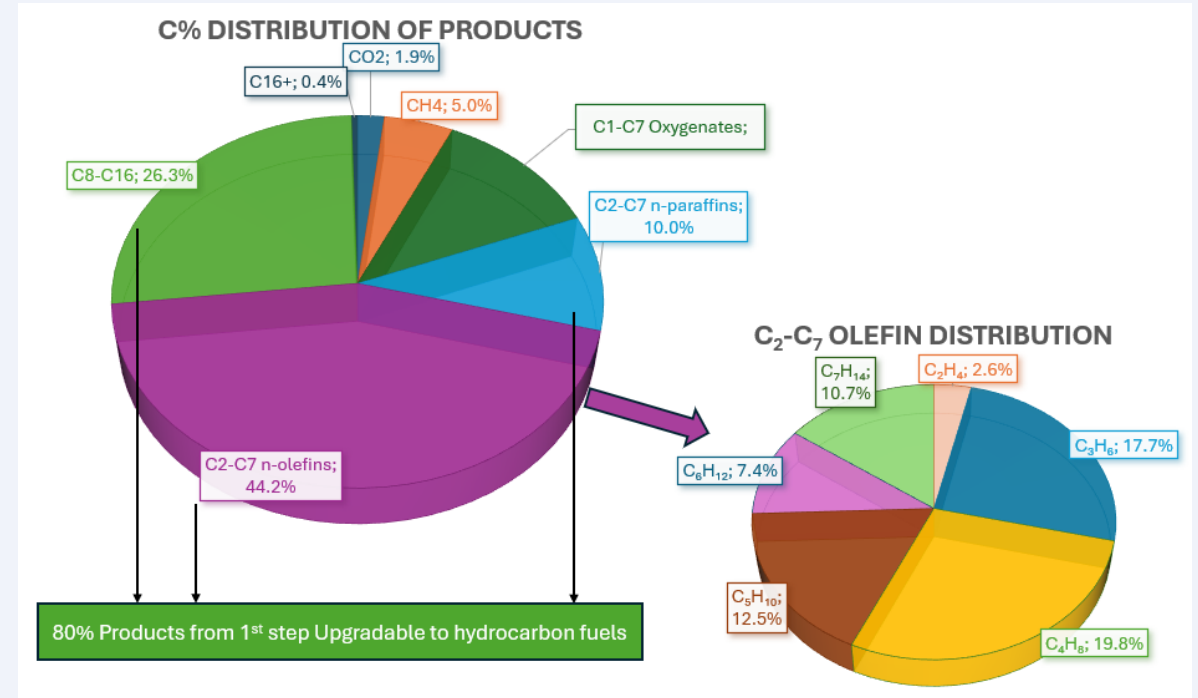
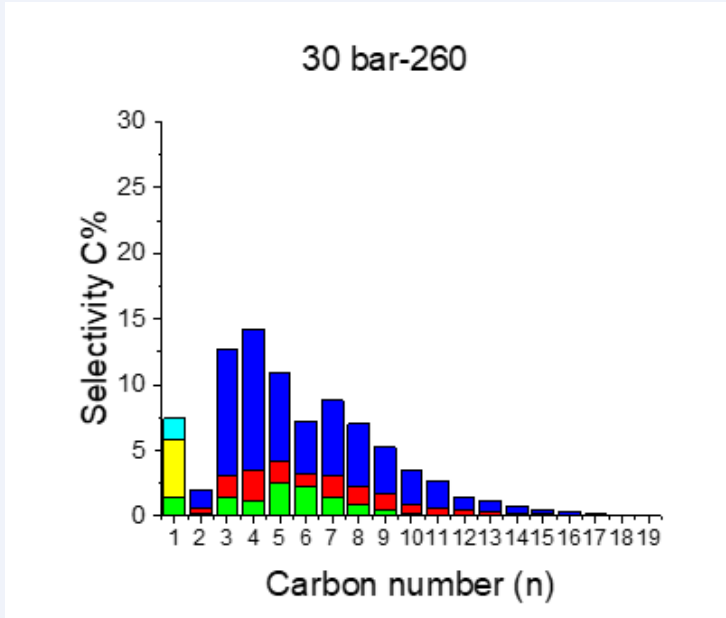
Reactor	Materials loaded	CO Conv. [%] at 220 °C , 20 Barg, baseline gas composition
1	10% Co/SiO2 (Evert/GLAMOUR)	<5%
2	15% Co/SiO2 (ICA-B2-EHU, 4h)	<5%
3	15% Co/SiO2 (ICA-B3-EHU, 2h)	<5%
4	15% Co/SiO2 (ICA-B2-EHU) + BEA (CP814C)	<5%



Catalyst	Cond.	CO Conv. [%]	H2 / CO Consumption	Selectivity [%C], CO ₂ -free basis		CO ₂
				CH ₄	O/P	
Na-Ru/SiO ₂	a	<3%	Unreliable	Unreliable	Unreliable	Unreliable
	b	3,81	2,23	3,83	pure	0.0
	c	8,61	2,34	4,00	5,39	4,16
Na-Ru/SiO ₂ + Ru-Co/Al ₂ O ₃	a	15,12	2,24	11,46	1,61	0,0
	b	26,28	2,25	16,84	1,25	0,0
	c	57,08	2,32	28,31	0,47	1,56
ZnCrO//SAPO-34	1	19.3	1.0	26.3	0.3	44.4
	2	12.5	0.6	24.3	0.5	43.5
	3	6.1	0.9	28.9	1.7	48.2
	4	3.7	1.1	28.7	2.8	50.1
	5	9.1	0.9	30.7	0.5	45.3
	6	2.1	0.6	26.1	2.1	58.2
ZnZrO//SAPO-34	1	24.6	2.2	85.8	0.0	54.9
	4	5.7	1.8	11.9	0.3	23.3

Gas comp baseline: 32% CO, 63% H₂, and 5% N₂ at a flow rate of 3.8 g/h (WHSV of 2.5 h⁻¹)
Cond a: Baseline composition at 220 °C and 10 barg.
Cond b: Baseline composition at 240 °C and 10 barg.
Cond c: Baseline composition at 260 °C and 10 barg.
Cond. 1: Baseline at 400 °C and 20 barg.
Cond. 2: 40% CO, 55% H₂, and 5% N₂ (H₂/CO at 1.4)
Cond. 3: 40% CO, 55% H₂, and 5% N₂ (H₂/CO at 1.4), 10 barg
Cond. 4: 40% CO, 55% H₂, and 5% N₂ (H₂/CO at 1.4), 10 barg, 7.6 g/h
Cond. 5: Baseline at 400 °C and 20 barg.
Cond. 6: 375 °C, 5 barg.

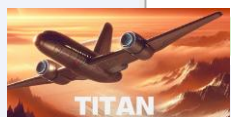
Iterative & Validative Testing



DoE – based on ICARUS results

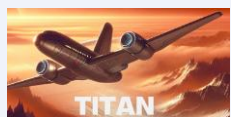
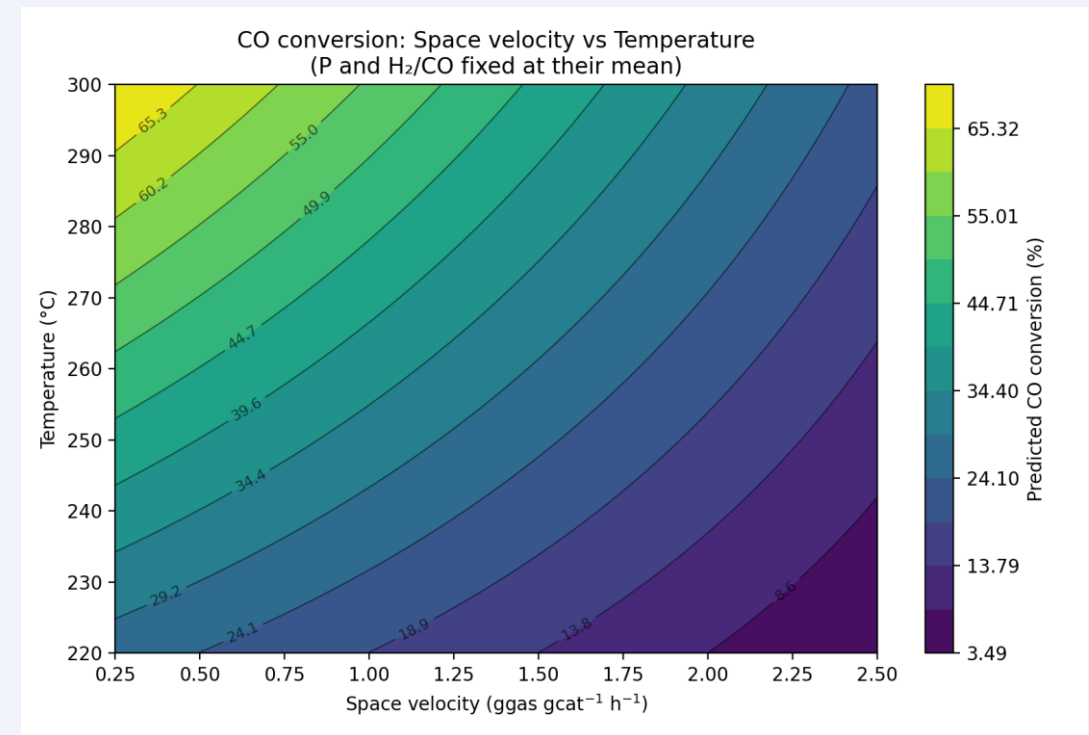
- Based on GC results under pseudo-stable conditions (3x stable injections)

EXPERIMENT SETTINGS			EXPERIMENT RESULTS																
	Variable	Variable	Variable	Variable															
	Setting	T set	P set	Space velocity	H ₂ /CO ratio	Gas composition [Vol%]						CO conversion	Carbon selectivity, [%C]						
		[°C]	[barg]	[g _{gas} g _{cat} ⁻¹ h ⁻¹]			CO	H ₂	CO ₂	N ₂	Sum (dry)	[%]		CH4	CO2	C2-C6 olefin	C2-C6 paraffin	C8+	
Productivity	Baseline	260	30	1.0	2.0		32	63	0	5	100		40.80		12.74	1.23	34.46	11.56	30.99
	1	220	10	2.5	1.0		47.5	47.5	0.0	5.0	100		0.19		84.51	0.00	0.92	0.00	14.57
	2	220	50	2.5	1.0		47.5	47.5	0.0	5.0	100		2.06		15.09	0.00	15.69	5.28	54.48
	3	220	50	0.3	1.0		47.5	47.5	0.0	5.0	100		23.06		7.62	1.00	15.21	7.39	60.42
	4	220	10	0.3	1.0		47.5	47.5	0.0	5.0	100		8.63		9.62	0.00	22.67	6.42	53.52
	Baseline	260	30	1.0	2.0		31.7	63.3	0.0	5.0	100		40.88		11.46	1.16	35.88	11.53	37.45
	5	220	10	0.3	4.0		19.0	76.0	0.0	5.0	100		14.03		13.96	0.00	28.51	10.99	37.82
	6	220	10	2.5	4.0		19.0	76.0	0.0	5.0	100		12.83		17.99	0.00	26.04	9.98	38.02
	7	220	50	0.3	4.0		19.0	76.0	0.0	5.0	100		72.83		11.15	0.02	23.68	14.71	41.65
	8	220	50	2.5	4.0		19.0	76.0	0.0	5.0	100		3.35		17.57	0.00	14.67	9.71	48.80
	Baseline	260	30	1.0	2.0		31.7	63.3	0.0	5.0	100		39.34		12.14	1.22	35.92	11.88	29.28
	9	300	10	2.5	4.0		19.0	76.0	0.0	5.0	100		25.98		36.76	4.92	33.53	10.99	11.96
	10	300	10	0.3	4.0		19.0	76.0	0.0	5.0	100		99.99		81.50	1.98	0.45	15.31	0.60
	11	300	50	2.5	4.0		19.0	76.0	0.0	5.0	100		43.62		28.23	5.16	28.11	12.42	20.41
	12	300	50	0.3	4.0		19.0	76.0	0.0	5.0	100		99.27		81.28	0.00	0.26	15.56	2.91
	Baseline	260	30	1.0	2.0		31.7	63.3	0.0	5.0	100		15.54		7.74	0.00	34.91	9.07	36.97
	13	300	50	2.5	1.0		47.5	47.5	0.0	5.0	100		24.95		7.26	3.55	38.43	7.80	32.49
	14	300	50	0.3	1.0		47.5	47.5	0.0	5.0	100		68.84		4.96	12.10	31.12	5.74	39.08
	15	300	10	0.3	1.0		47.5	47.5	0.0	5.0	100		28.95		7.55	18.44	44.29	5.39	18.53
	16	300	10	2.5	1.0		47.5	47.5	0.0	5.0	100		1.99		9.09	23.55	41.06	0.00	17.52
	Baseline	260	30	1.0	2.0		31.7	63.3	0.0	5.0	100		4.71		7.85	0.00	34.18	7.46	36.75



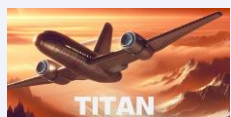
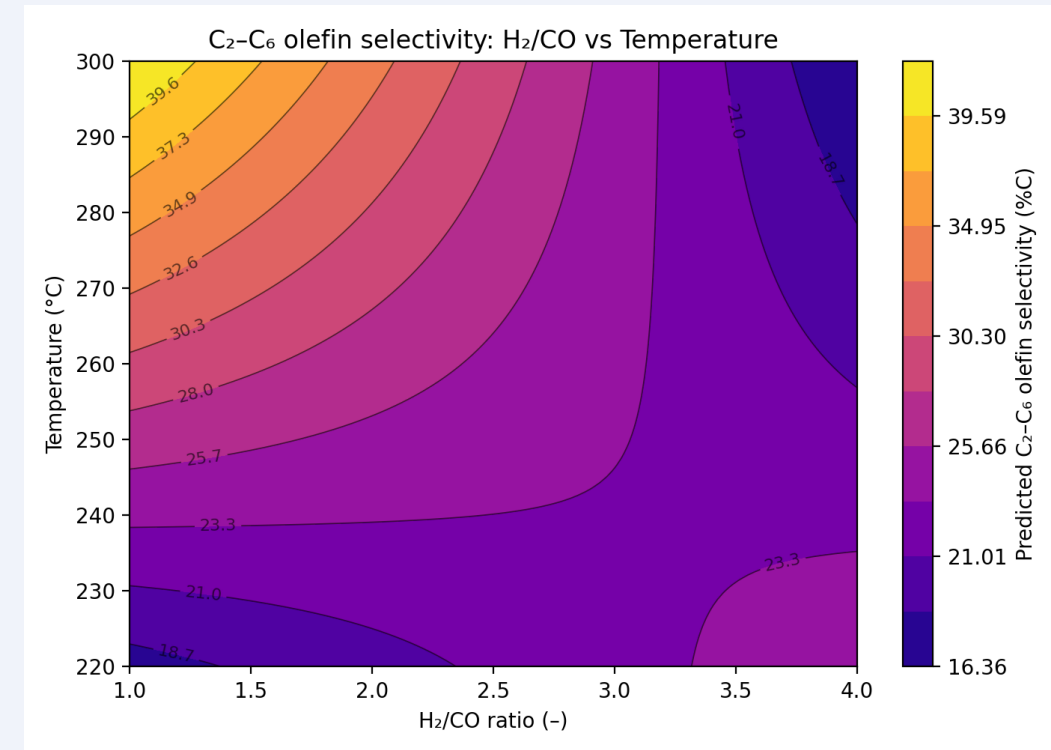
DoE output – CO conversion

- Output CO conversion: $T \uparrow$, $P \uparrow$, $H_2/CO \uparrow$, $SV \downarrow$ for higher conversion
- Relations
 - Space velocity (SV) — strong negative effect (lower SV $\rightarrow$ higher conversion)
 - Temperature (T) — strong positive effect
 - H_2/CO ratio — clear positive effect
 - Pressure (P) — moderate positive effect
 - No two-way term crosses typical 0.05 significance



DoE output – olefin selectivity

- O/P ratio (or C2-C6 olefin)
 - Largest effects: H_2/CO ratio — strong negative main effect (higher H_2/CO → lower O/P)
 - $T \times H_2/CO$ interaction — negative and significant (higher T boosts olefins primarily at lower H_2/CO ; the benefit weakens/reverses as H_2/CO increases))
 - Temperature — positive effect
 - Pressure — negative (smaller magnitude; borderline significant)
 - SV — small positive, not significant
- Overall no shocking results
 - Baseline conditions represent good conv/select tradeoff under stable conditions
 - Activation/de-activation patterns in time more workable for cat improvements.



Integrated FT Technology (from powder to pellet)

 **CO Conversion**
60% per pass

intensified reactor | Target: >90% with recycle

 **SAF Selectivity**
>85% in liquid product

*jet range HCs | SoA 40%(FT-SPK) 70% (ATJ) |
Tuning of linear/branched*

 **Wax Yield (C20+)**
<1%

eliminates hydrocracking step | Target: <1 wt%

 **Syngas Flexibility**
H₂/CO = 1-2.5

*Gasification tuning | DAC & SOE integ. | Resilient
to feedstock*

 **Catalyst Lifetime**
>300 h

No observed degradation | Pilot: 3,000 h target

 **Carbon Efficiency**
>75%

*C-atoms in syngas → liquid product | vs. 45-55%
SoA*

 **Unwanted By-Products**
<6% CH₄ | <2% CO₂

High value oxygenates | System-level target

 **Simpler Reactor and Process Design**
10-20% lower exotherm

*Simpler reactor design for heat and wax
management*

 **Cost Initial Estimate**
~ €1300-1700

20-25% cost savings | FOAK to nth improvements



**15 g/h
syngas**

TRL3 → TRL5

**200 g/h
syngas**



**2
Liter
SAF**

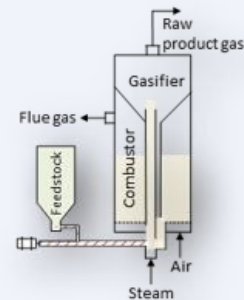
TNO – Technology development



Activities:

- 500 kW_{th} Downdraft gasifier for coal modified for biomass
- Developed in 1980

TRL3



Activities:

- 25 kW_{th} intensified circulating fluidized bed gasifier for testing renewable feedstock gasification to syngas
- Developed in 2004

Patents:

- US11214529B2
- ES2719611T3
- US20210155861A1/NL2018906 B1
- BR112015002693B1
- NL2031869B1

TRL4

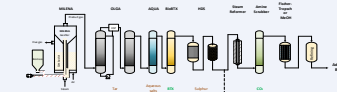


*Other partners confidential

Activities:

- 500 kW_{th} indirect gasifier CFB for renewable natural gas production
- Tested for various biomass, plastics, MSW and renewable feedstocks
- Connected to downstream upgradation units for methanation, Fischer Tropsch and methanol production units

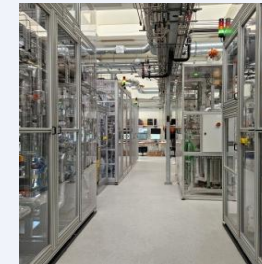
TRL5



Activities:

- Gasification to fuels and chemicals end-to-end GtL pilot setup for campaigning
- FEED Design package for a 30MW gasifier for RNG production
- Various campaigns for contract R&D
- Horizon project – BUTTERFLY for biomass and auto shredder waste conversion to SNG and DME

TRL6



Technology Transfer

Vision:

- FOAK-Demo
- Licensing
- SAF Production
- EPC + Project Developer + Traders

TRL8 Plant for plastics recycling under operation by collaborator via license offering

TNO – Development for Syngas to SAF



Patent Pending: Syngas to SAF range olefins technology (Fischer tropesch alternative)

Findings:

- 75% selectivity to olefins
- 60% conversion
- Targeted higher SAF range olefins
- Catalyst stable
- Little to no side formation of CO₂ and CH₄

Horizon Project – Icarus

- SAF development frameworks
- Innovation mapping in Europe and Mission Innovation countries (Brazil, India, USA)
- Cost effectiveness and sustainability
- Catalyst development for novel syngas to SAF route

TRL3



Findings:

- Syngas to light olefins towards SAF less viable than higher olefins
- >25% carbon and hydrogen efficiencies
- No sulfur
- <20% total emissions
- <36% cost compared to other PtL technologies

Activities:

- Horizon Project – TakeOff
- Economic evaluation and opportunities for cost reduction
 - Environmental impact assessment
 - CO₂ conversion to SAF via catalyst development and value chain demonstration

TRL4



Activities:

- TKI Industry Project for Scale-up to TRL5
- Syngas to SAF range olefins technology (syngas to light olefins technology developed separately and not here)
- Waste gasification and electrolysis to SAF modelling, testing and campaign
- Active material development
- Process engineering
- Comparative study for e-SAF vs bio-SAF

TRL5

Demonstration Prototype in Test or Industrial Environment

Vision:

- End-end Pilot Build
- Updated TEA
- SAF Clearing house validation
- EPC + O&G + Strategic feedstock supply, end-use and trading partnerships

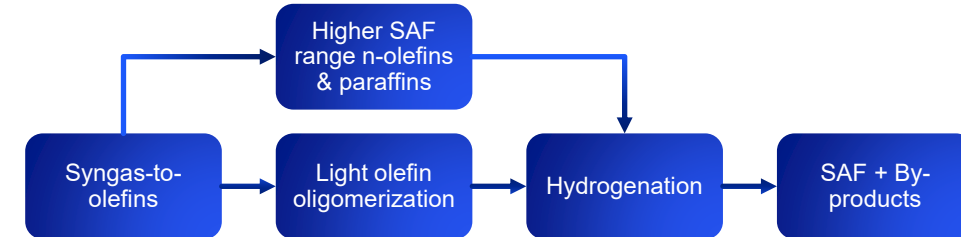
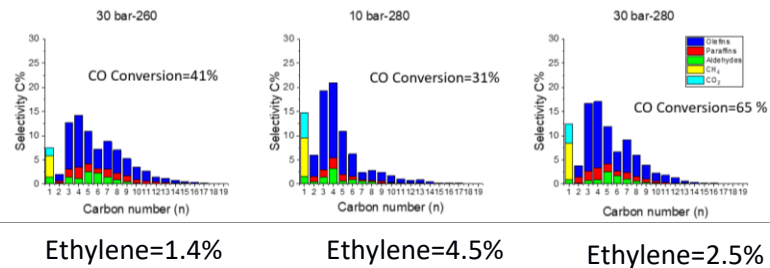
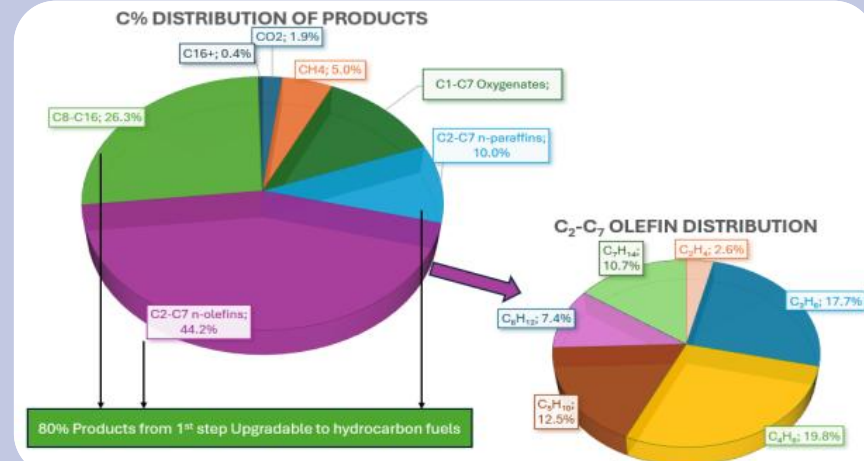
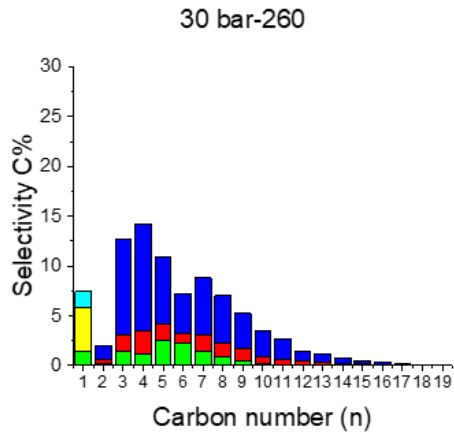
TRL6

Technology Transfer

Vision:

- FOAK-Demo
- Licensing
- SAF Production
- EPC + Project Developer + Traders

Syngas to Olefins what are the options



The performance is there. Now let's scale—together.

SOSAF points to a selective, carbon-efficient and simpler route from flexible syngas to SAF.

>85%

SAF SELECTIVITY

in liquid product

>75%

CARBON EFFICIENCY

syngas carbon to liquids

<1%

WAX

simplifies downstream processing

NEXT MILESTONE

Partner with TNO to move SOSAF from catalyst to reactor to pilot.

We are looking for partners in catalyst development, reactor engineering and scale-up.

Thank you for your attention

Innovation for life

 TNO Energy & Materials Transition

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