

Next-Generation Sustainable Aviation Fuel Production Pathways

A technical analysis of emerging SAF production technologies, their process advantages, challenges and market readiness.

*M. Pourkashanian, OBE
Professor of Energy Engineering,
Head of Energy Innovation Centre
University of Sheffield, UK*



Technical Assessment of Novel SAF Pathways

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Current State of SAF

Brief overview of conventional HEFA and Fischer-Tropsch pathways dominating current production

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Alcohol-to-Jet (AtJ)

Technical analysis of catalytic alcohol oligomerization and conversion processes

3

Power-to-Liquid (PtL)

Assessment of electrolytic hydrogen and carbon capture technologies for e-fuel synthesis

4

Advanced Biological Pathways

Exploration of microbial conversion and advanced feedstock engineering innovations

5

Techno-Economic Analysis

Comparative assessment of production costs, carbon intensity, and scale-up potential

Current SAF Production: Limitations Driving Innovation

Today's commercial SAF production relies primarily on Hydroprocessed Esters and Fatty Acids (HEFA) from vegetable oils, animal fats and waste oils, plus some Fischer-Tropsch synthesis from gasified biomass.

These pathways face critical limitations:

- Feedstock availability constraints (~2.5% of jet fuel demand)
- High production costs (2-4× conventional jet fuel)
- Competition with food production
- Scaling challenges for carbon intensity goals

Current ASTM-approved pathways: HEFA-SPK, FT-SPK, SIP, ATJ-SPK, CHJ, HC-HEFA-SPK, HH-SPK, and catalytic hydrothermolysis jet (CHJ)



Alcohol-to-Jet (AtJ) Pathway: Technical Assessment

Process Fundamentals

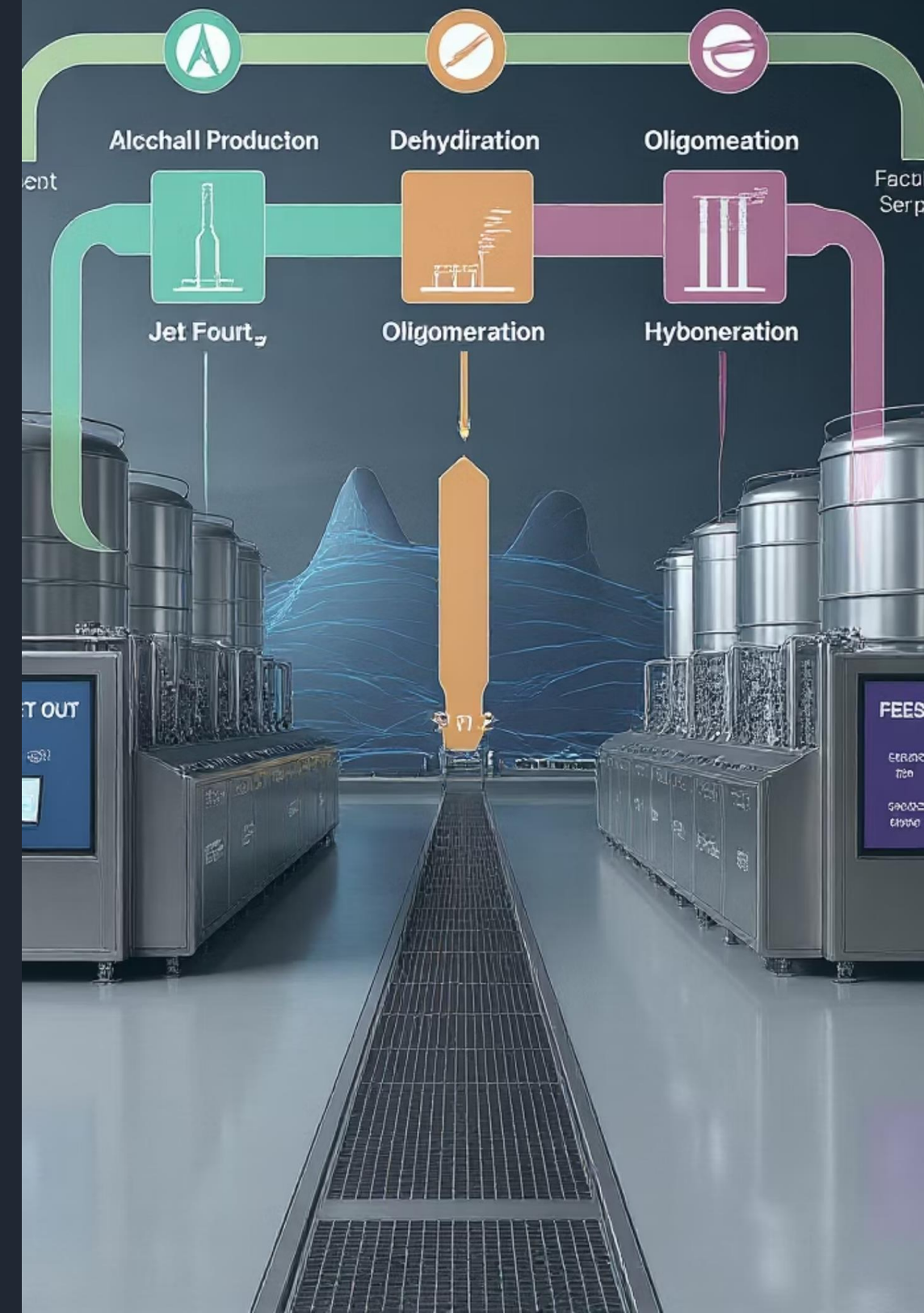
Conversion of alcohols (ethanol, butanol, isobutanol) to jet fuel through dehydration, oligomerization, hydrogenation and fractionation. Targeting C8-C16 hydrocarbons.

Technical Advantages

- Versatile feedstock compatibility (corn, sugarcane, cellulosic)
- Utilisation of existing ethanol infrastructure
- Superior cold-flow properties vs HEFA
- Lower aromatic content (reduced particulate emissions)

Key Challenges

- Multiple catalytic steps increase capital intensity
- Higher hydrogen requirements than conventional refining
- Energy-intensive distillation steps
- Catalyst deactivation issues in oligomerization



Power-to-Liquid (PtL) SAF: Technical Foundation



Renewable Electricity

Solar, wind or other renewable power sources provide zero-carbon electricity input



Water Electrolysis

PEM or alkaline electrolyzers split water into hydrogen and oxygen (30-50 kWh/kg H₂)



Carbon Capture

CO₂ sourced from industrial emissions, direct air capture, or biogenic sources



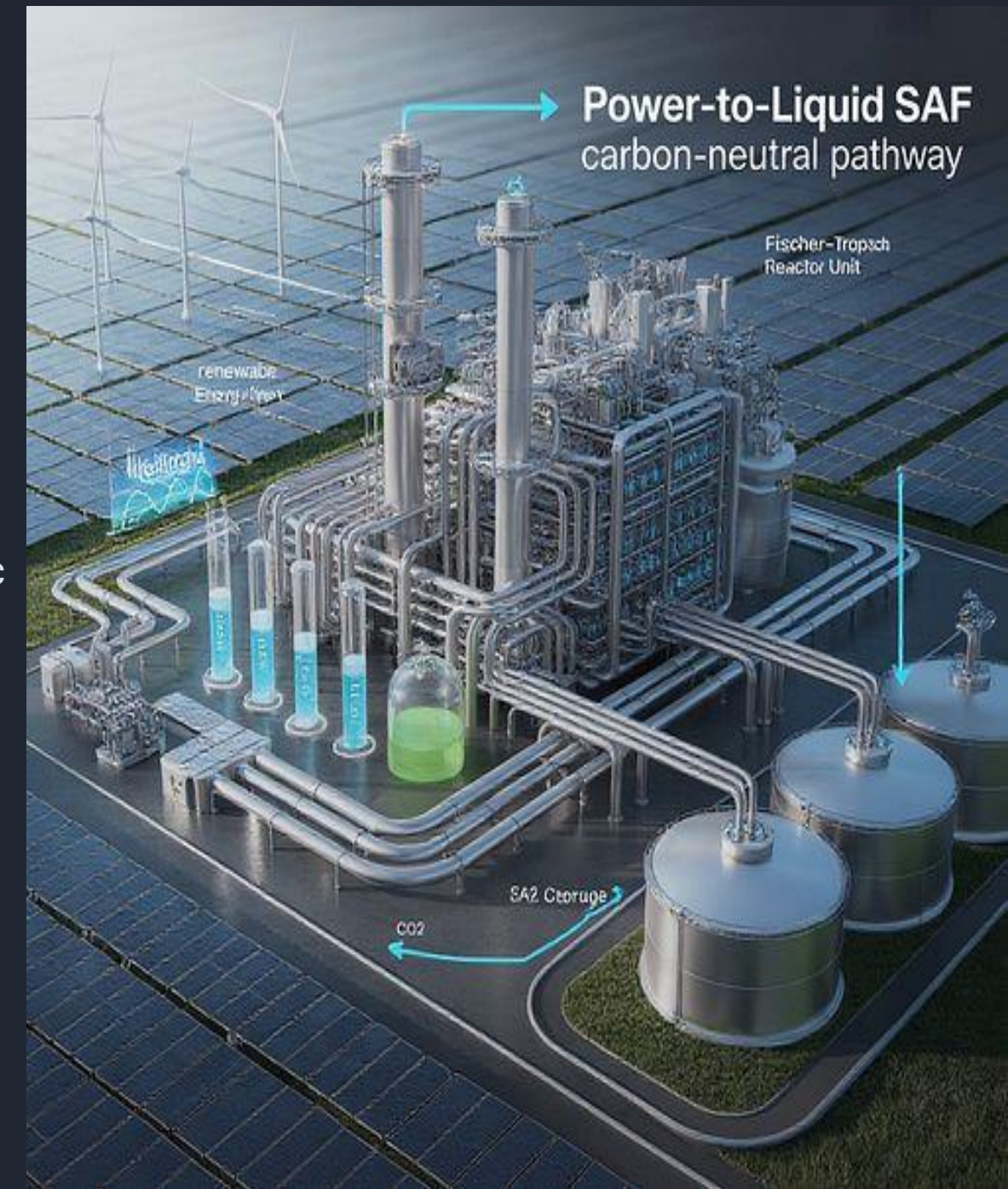
Syngas Production

Reverse water-gas shift reaction converts H₂ and CO₂ to CO and water



Fischer-Tropsch Synthesis

Catalytic conversion of syngas to hydrocarbon chains with iron or cobalt catalysts



PtL Technical Challenges and Recent Innovations

Critical Technical Challenges

- Extremely high electricity requirements (~55 kWh per litre of jet fuel)
- Low overall energy efficiency (~45% well-to-wake)
- High capital costs for electrolyser and Fischer-Tropsch units
- CO₂ capture energy penalty and cost, especially for direct air capture
- Scale-up challenges for catalyst manufacturing and reactor design

Breakthrough Technologies

Several promising innovations show potential to overcome key limitations:

High-Temperature Co-Electrolysis

Solid oxide electrolyzers simultaneously converting H₂O and CO₂ to syngas, reducing process steps and improving efficiency by ~20%

Structured Microchannel Reactors

Novel Fischer-Tropsch reactor designs enabling 30% higher throughput and improved heat management

Advanced Biological SAF Pathways

Microbial Production Systems

Engineered microorganisms are creating entirely new production routes:

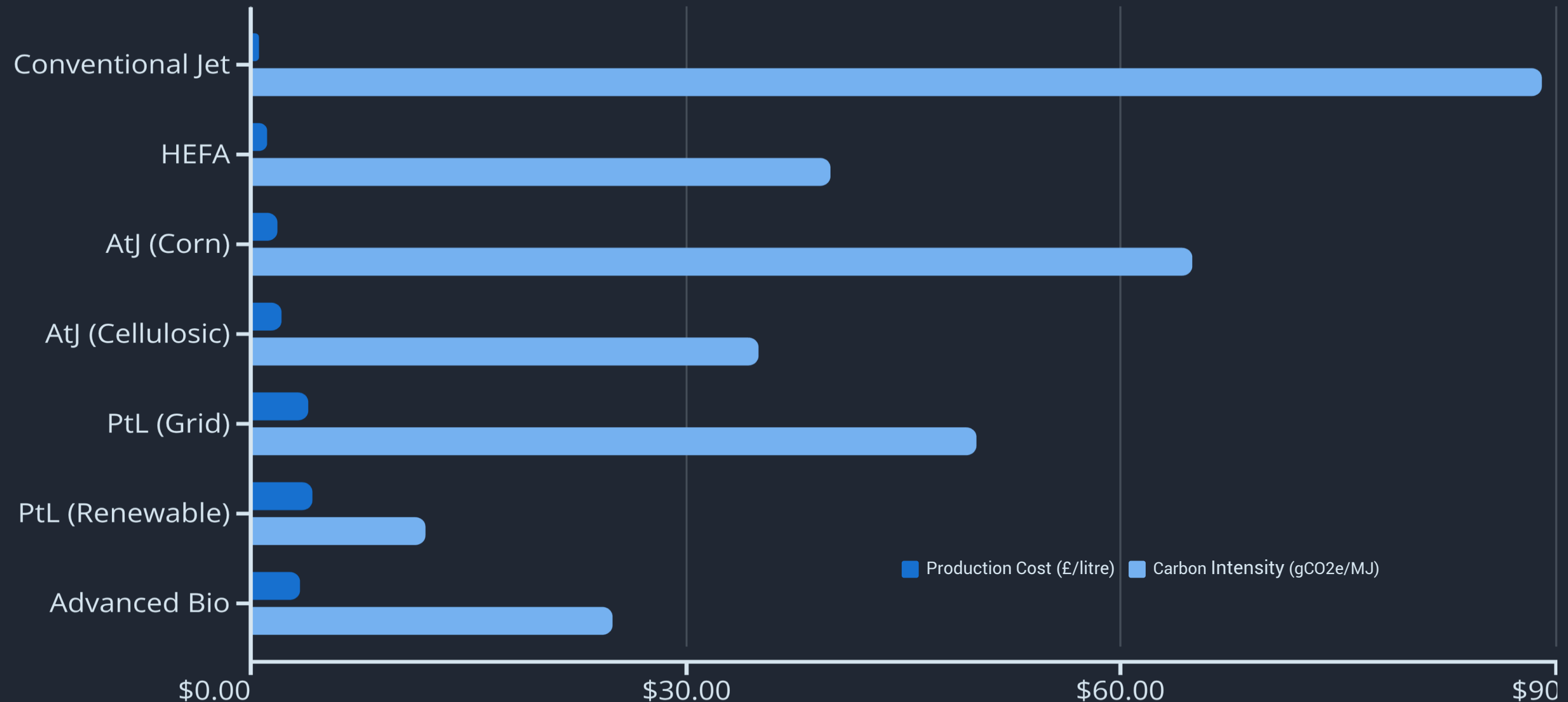
- Genetically modified *E. coli* strains producing medium-chain fatty acids directly from glucose
- Cyanobacteria engineered for direct photosynthetic production of hydrocarbons
- Oleaginous yeasts with lipid accumulation >70% of dry cell weight
- Cell-free enzymatic synthesis systems for targeted molecule production



Molecular Engineering for Jet Fuel: Synthetic biology platforms are being developed to engineer microbes that produce specific hydrocarbon structures not found in nature, enhancing energy density and cold-flow properties

Novel photobioreactor designs enable continuous cultivation of engineered cyanobacteria for direct hydrocarbon production with theoretical solar energy conversion efficiency of up to 5%.

Techno-Economic Comparison of Next-Gen SAF Pathways



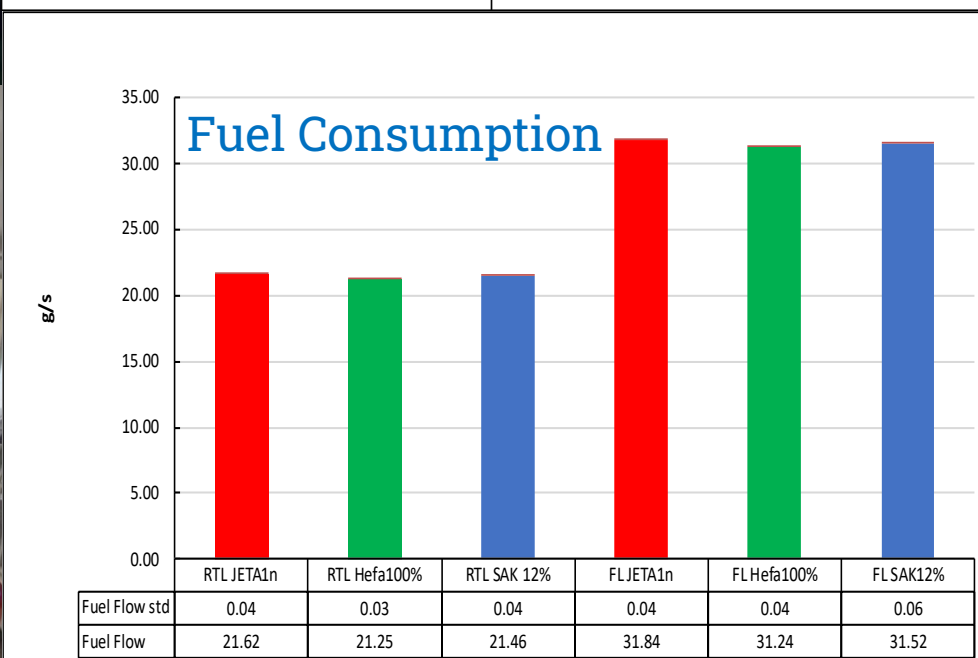
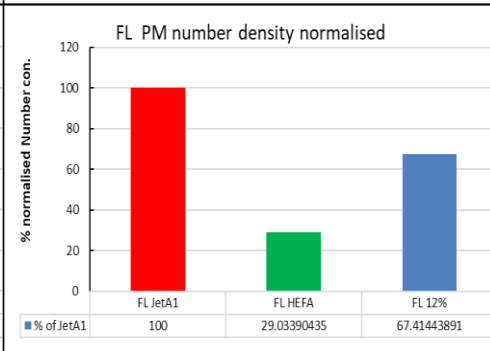
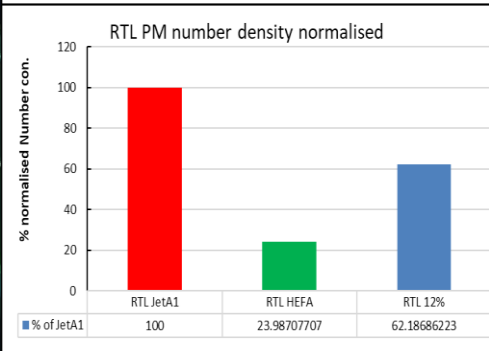
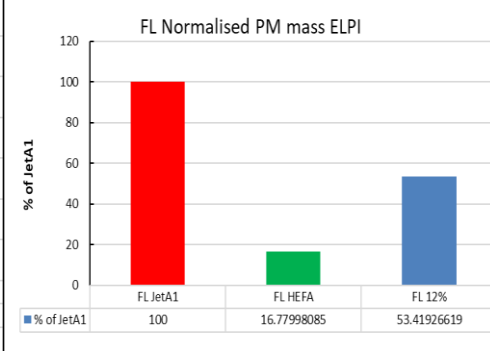
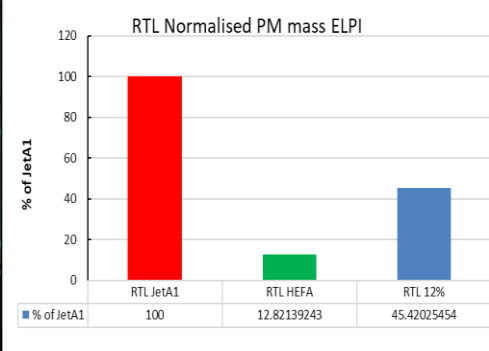
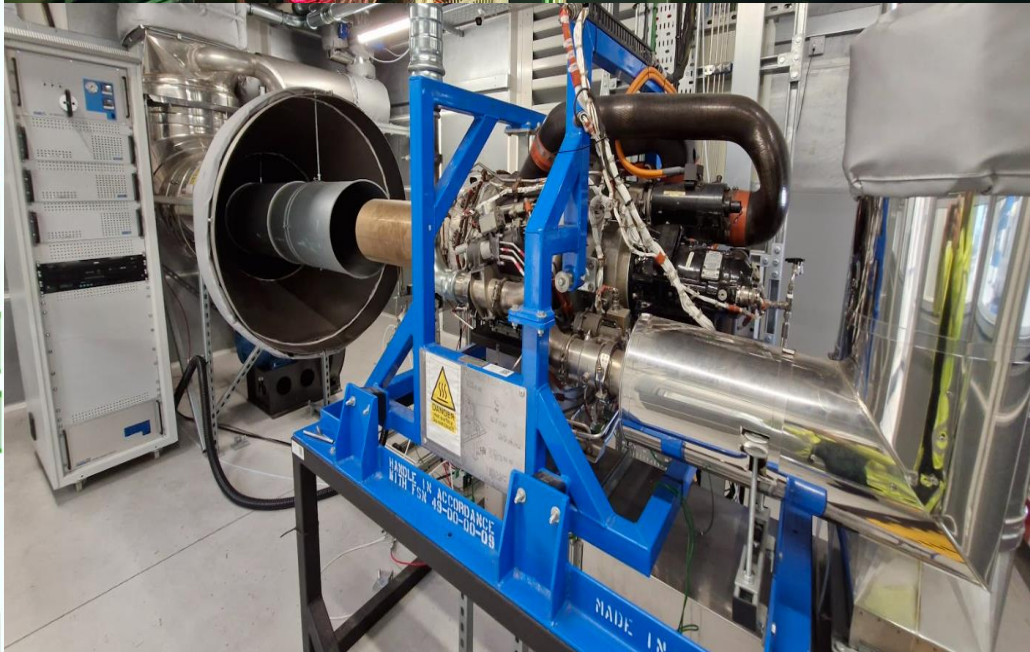
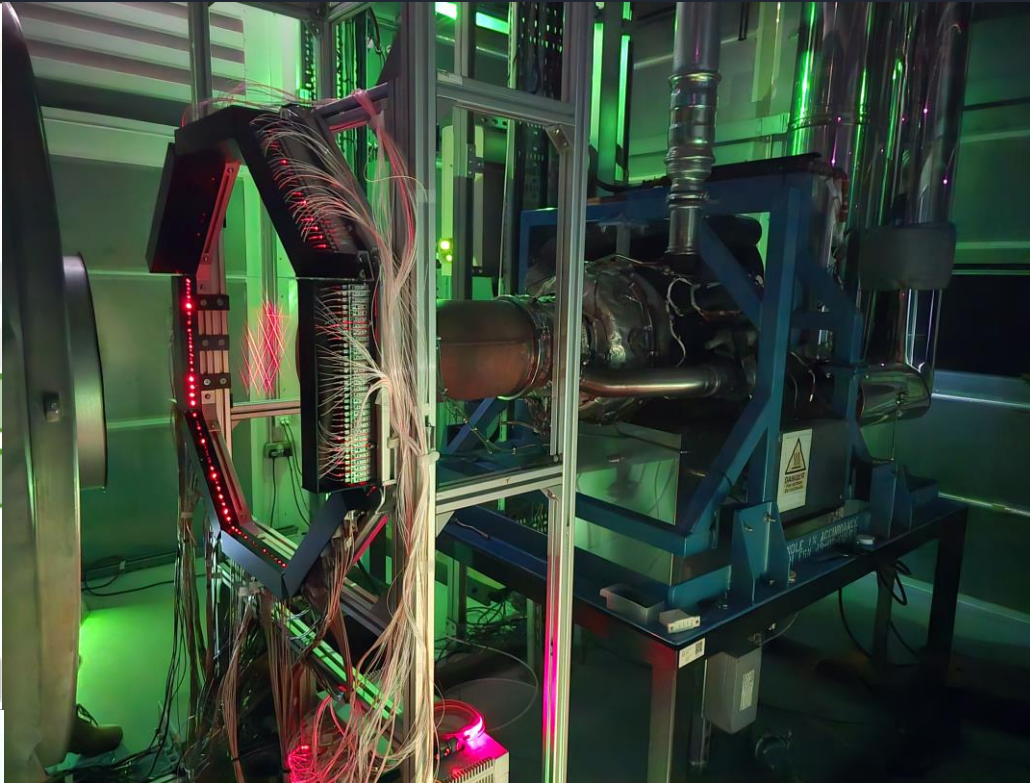
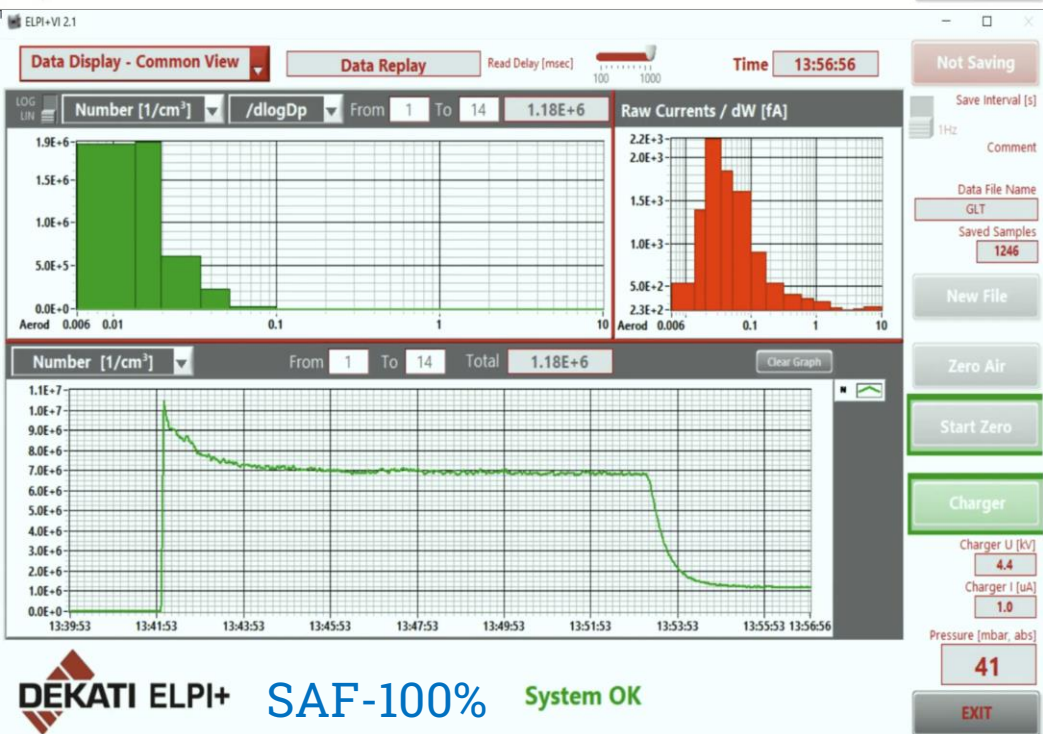
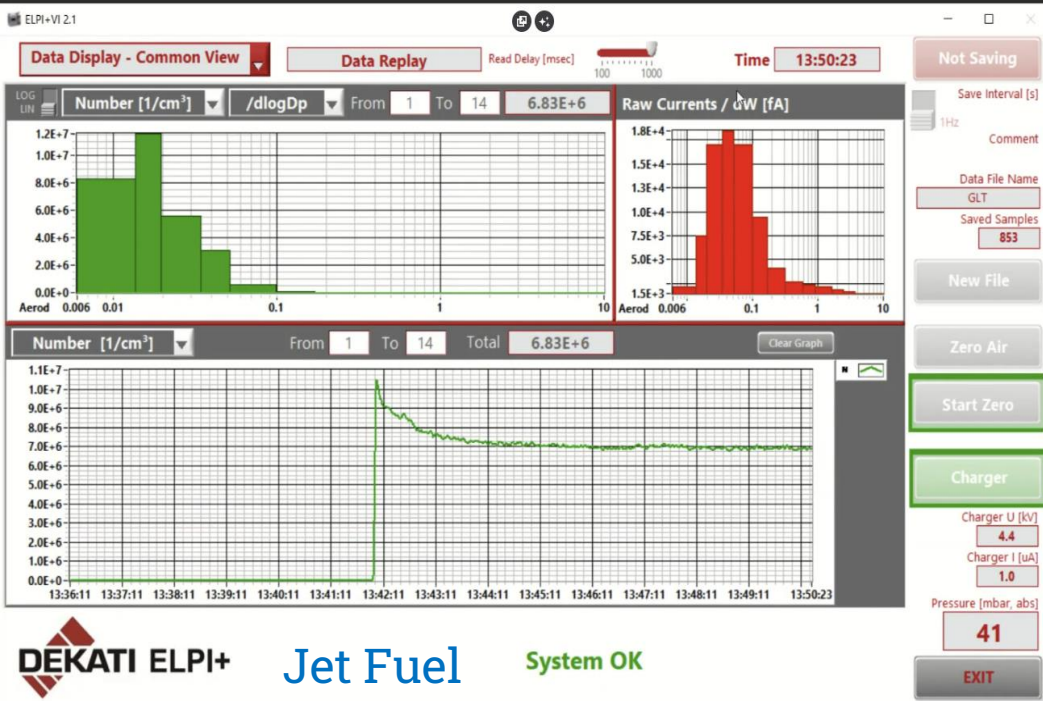
Production costs reflect 2023 technology readiness levels and are expected to decrease with scale. Carbon intensity values represent full lifecycle analysis from feedstock to combustion, including land-use change impacts where applicable.



'Sustainable flight is too difficult'
Challenge accepted

100% SUSTAINABLE AVIATION FUEL	
FLIGHT 100	28.11.23

Impact of SAF on Particulate Emission: Flight-100 APU Test



Research and Innovation Infrastructure At EIC

BIO/ENERGY



WTE/BIOMASS

Wood GASIFIER



BioGas Turbine



Bio/Diesel

Marine Engine



Combustion Test Furnace

CARBON CAPTURE

MCFC



ACP



RPB



DAC



HYDROGEN



CO₂

H₂

CO

CO₂

CO₂

CO₂

H₂

SUSTAINABLE FUELS PLANT

REWG

FT

UPGRADING



GAS

GASOLINE

NAPHTHA

SAF

DIESEL

FUEL OIL

HEAVIES



FUEL ANALYSIS

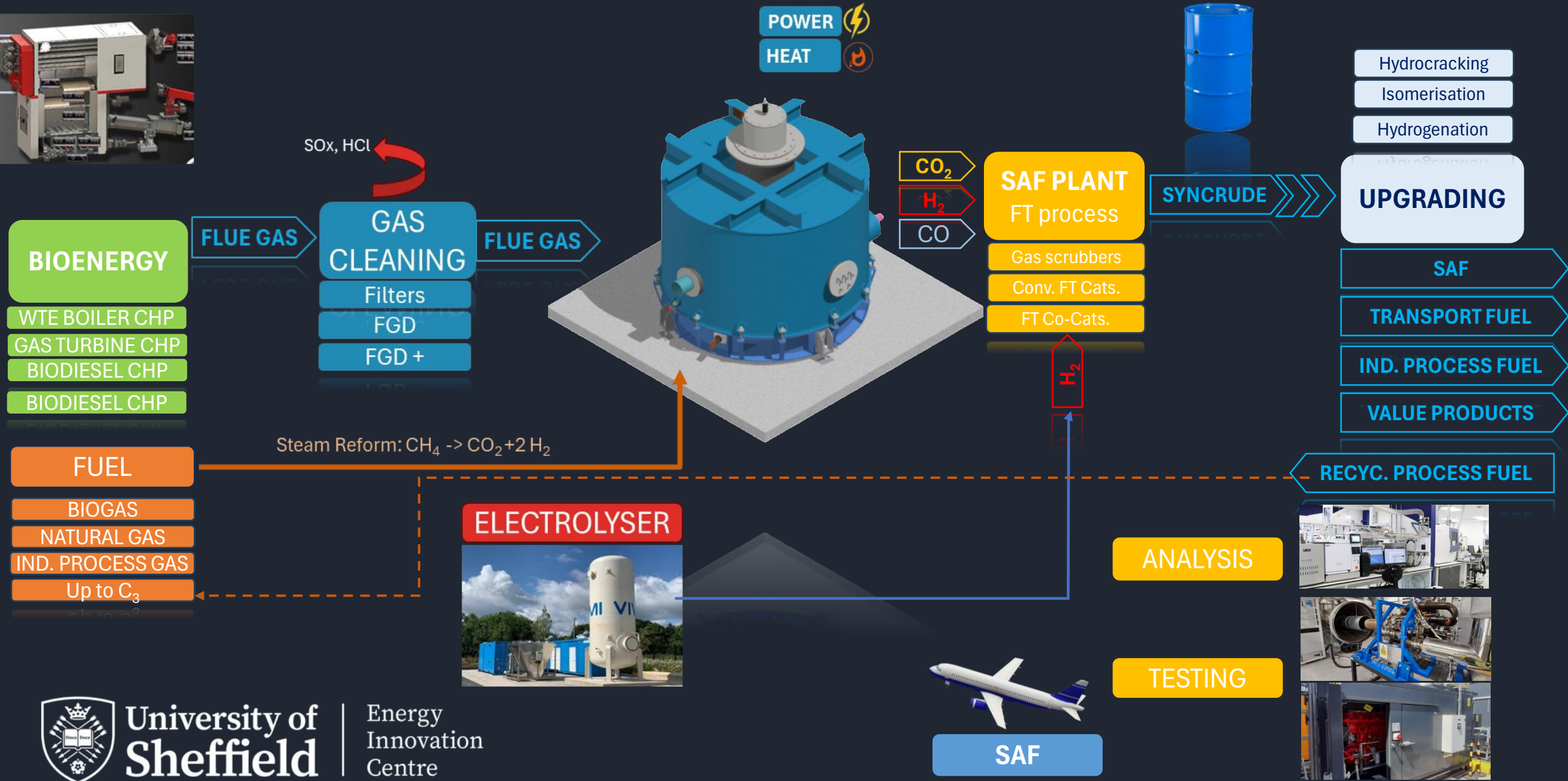


SAF TESTING



Sustainable transport fuel

Next Generation SAF production Pathway: NEXTGEN-SAF



Strategic Recommendations and Next Steps



Research Priorities

- Focus catalyst development on improved selectivity and lifetime
- Advance electrolyser efficiency and durability for PtL pathways
- Develop low-cost, scalable CO₂ capture technologies



Demonstration Projects

- Scale up integrated AtJ production to 10-50 million litres/year
- Establish 1-5 MW PtL demonstration facilities at industrial CO₂ sources
- Pilot advanced biological pathways at 1,000-10,000 litre scale



Policy and Industry Action

- Establish long-term carbon pricing mechanisms to improve economics
- Develop technology-specific support schemes for emerging pathways
- Create strategic partnerships across aviation, energy and biotech sectors
- Implement coordinated UK-EU research programmes to accelerate development

With focused research investment and supportive policy frameworks, next-generation SAF technologies could reach commercial viability by 2030-2035, potentially meeting 30% of UK aviation fuel demand by 2050.

Thank You

Any Question

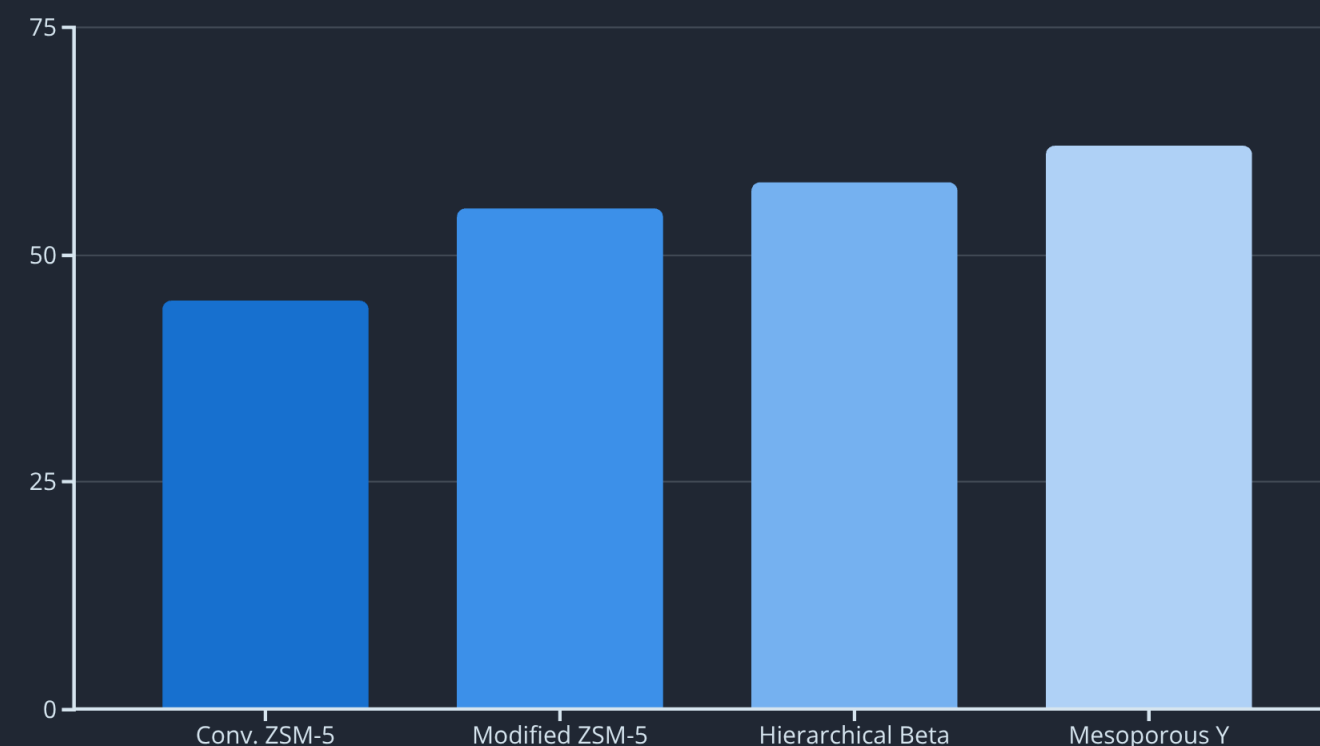
Contact: m.pourkashanian@sheffield.ac.uk

AtJ Catalyst Development: Recent Breakthroughs

Heterogeneous Catalysis Innovations

Recent advances in bifunctional zeolite catalysts have demonstrated significant improvements in selectivity and conversion efficiency:

- Modified ZSM-5 catalysts with tuned acidity profiles show 22% higher jet-range selectivity
- Novel Ru/Pt bimetallic catalysts reduce hydrogen consumption by up to 15%
- Hierarchical zeolites with mesoporous structures exhibit 3× longer catalyst lifetimes



Jet fraction yield comparison for various catalyst formulations in the dehydration-oligomerization step (based on 2023 laboratory data)