Innovation in Sustainable Fuels Webinar Series

Session 2 – Advanced Renewable Diesel

Document prepared by Zemo Partnership

Thursday 25th March 2021

Gloria Esposito, Head of Sustainability
Zemo Partnership

Gaynor Hartnell, CEO, RTFA

Zemo Partnership
Accelerating Transport to Zero Emissions

Renewable Transport Fuel Association

Today's Agenda

10:30am	Welcome and house keeping	Gloria Esposito, Head of Sustainability, Zemo Partnership Gaynor Hartnell, CEO, RTFA
	Session 1 Chair	Gaynor Hartnell, CEO, RTFA
10:35 am	Greenergy Thames development fuel project	Chris Brookhouse, Director of Infrastructure, Greenergy
10.50 am	Co-processing and the production of low carbon liquid fuels	Simon Holt, Manager, Value Chain Optimisation Europe, Phillips 66
11:05 am	Beyond the blend wall: Integrated solutions for a low carbon fuel offer	Olivier Mace, Principal, Broadmanor Consulting Limited
11:20 am	Converting biomass to drop-in renewable diesel	Green Lizard Technologies Ltd,CEO Martin Atkins
11:35 am	Panel Discussion	
12:00 pm	Session wrap up and next session	Gloria Esposito, Head of Sustainability Zemo Partnership

All attendees on mute, camera off, please enter your questions in the chat function

PROVIDING ENERGY. IMPROVING LIVES.

Co-processing and the production of Low Carbon Liquid Fuels

Zemo-RTFA webinar
March 2021

Simon Holt

Manager, European Value Chain Strategy & Optimisation

Phillips 66 Overview

A Diversified Manufacturing & Logistics Company

Zemo Partnership

Midstream

22,000 Miles

Of U.S. Pipelines

Chemicals

28 Facilities

U.S Gulf Coast & Middle East

Refining

12 Refineries

2.2 million BPD Total Capacity

Marketing & Specialties

7,500

Branded U.S. Outlets

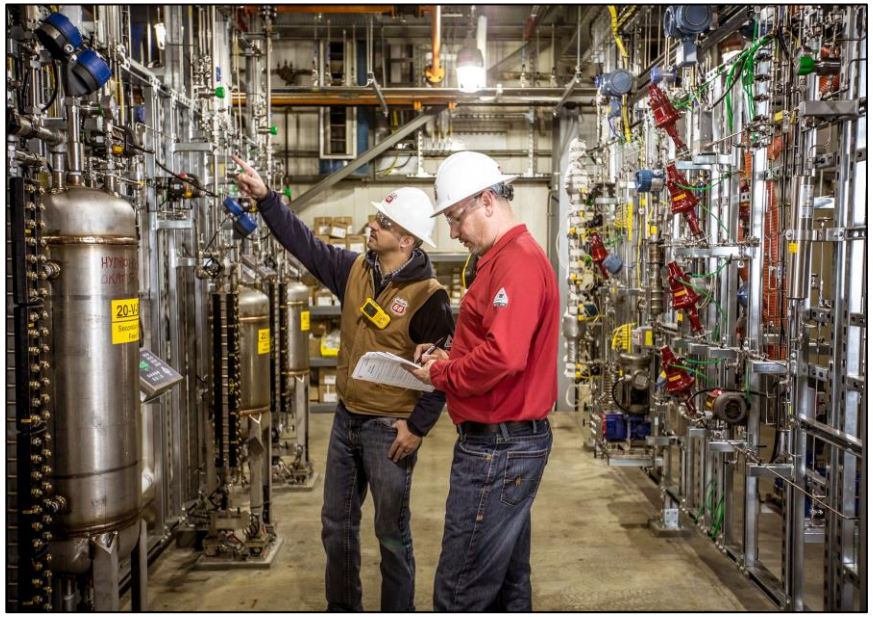
1,600

Branded International Outlets

JET

Energy Research & Innovation

- 440-acre Phillips 66 Energy Research & Innovation Center in Bartlesville, Oklahoma
- Team of researchers focused on sustainability technologies to address climate change:
  - Carbon capture
  - Hydrogen
  - Renewable transportation fuels
  - Batteries
  - Organic photovoltaic cells
  - Solid oxide fuel cell technologies



- Phillips 66 has developed patented technologies to produce renewable fuels from fats and oils, carbohydrates, and cellulosic biomass
- As the transportation energy market evolves, we are advancing new opportunities in sustainable fuels
- Research includes: drop-in liquid fuels from solid biomass or solid waste streams, renewable hydrogen and alternative high-octane fuel blend stocks

Co-processing

- The Humber Refinery, one of the most energy efficient refineries in Europe is leading the way in low-carbon fuels production
- The refinery was the first in the UK to produce high-performing, second-generation biofuels, at scale, from waste when Used Cooking Oil (UCO) was introduced in 2017
- In 2020, Phillips 66 invested significant capital trebling UCO processing capacity, with the addition of a new low carbon fuel module
- We have plans to increase co-processing further in 2021 including production of our first development fuel

Our Journey

Challenges

- Feedstock availability
- Supply chain variability
- Impact on refinery processes
- Investment for waste to liquids processes

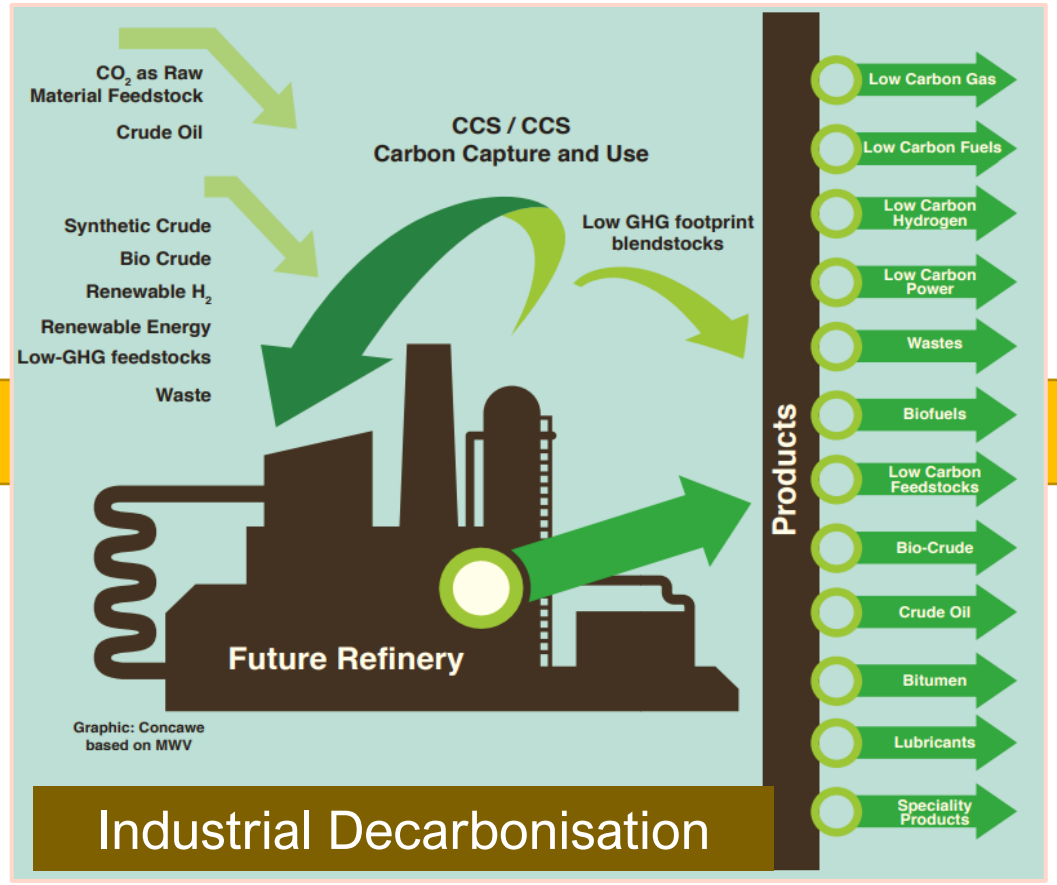
Opportunities

- Significant waste problems to be solved
- Process multiple waste streams in refinery
- Utilise existing infrastructure
- Shift renewable product from road fuels to other sectors

Refinery of the Future Concept

Concawe 2050 Vision of European Refining

Low and Zero Carbon Feedstocks



Decarbonised Energy Products

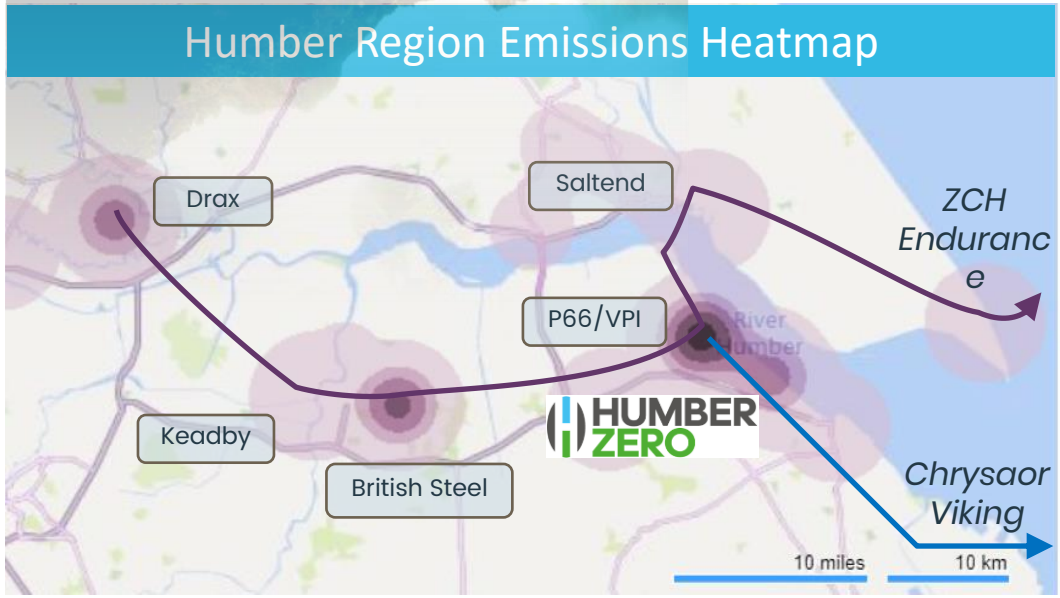
Humber Refinery: Refinery of the Future

Zemo Partnership

"A core building block on the road to building a UK-based EV battery manufacturing capability"

UK's Advanced Propulsion Centre

Waste Oils Processing



BROADMANOR
CONSULTING

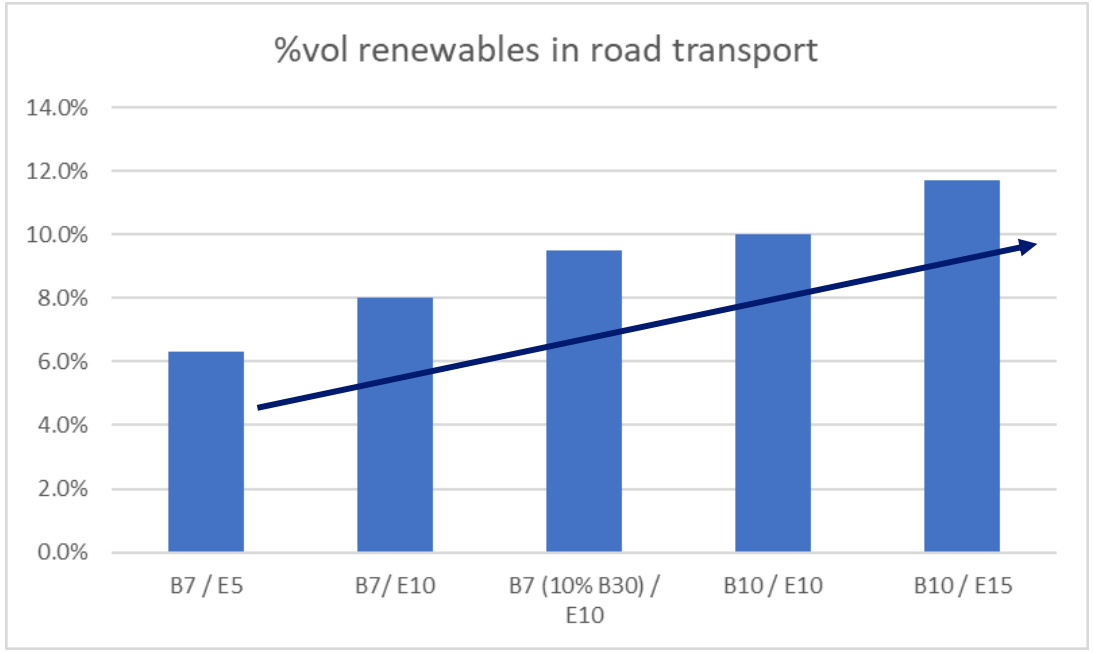
Beyond the blend wall: integrated solutions for a low carbon fuel offer

OLIVIER MACÉ – 25 MARCH 2021

INNOVATIONS IN FUELS WEBINAR PROGRAMME

Beyond the blend wall?

- **Blend wall** is the maximum blend of conventional biofuels (ethanol & FAME) allowed by the fuels specifications (BS EN228 / EN590)
- Modelling the UK blend wall (without double-counting):
  - 16bn.l petrol
  - 30bn.l diesel
- Solutions to the blend wall:
  - Double-counting!
  - High blends (B30 / B100 / E95)
  - **Drop-in fuels**



Most countries in Europe have already crossed the blend wall with their biofuels mandate.

Drop-in fuels

- Essentially hydrocarbon-based fuels, full compatibility with fossil hydrocarbons
- Various manufacturing pathways, e.g.
  - Hydrogenation of fats & oils – “HVO”
  - Gasification of biomass then re-assembling of syngas (H2 & CO) into hydrocarbons: Fischer-Tropsch reaction
  - Power-to-fuels (aka eFuels)
- Can be blended into petrol and diesel without limit, subject to their quality as a blendstock
- GHG savings depend primarily on the type of biogenic feedstock used; to a lesser extent, on the manufacturing process
- Most likely applications to be middle distillates (jet & diesel)

HVO as a diesel blendstock

Property		Implications
Cold flow	Poor*	Harder to meet winter-spec diesel
Cetane	High	Good cetane enhancer
Density	Low	Needs to be blended with higher density components
Sulphur	Low	Easier to meet ULSD specification

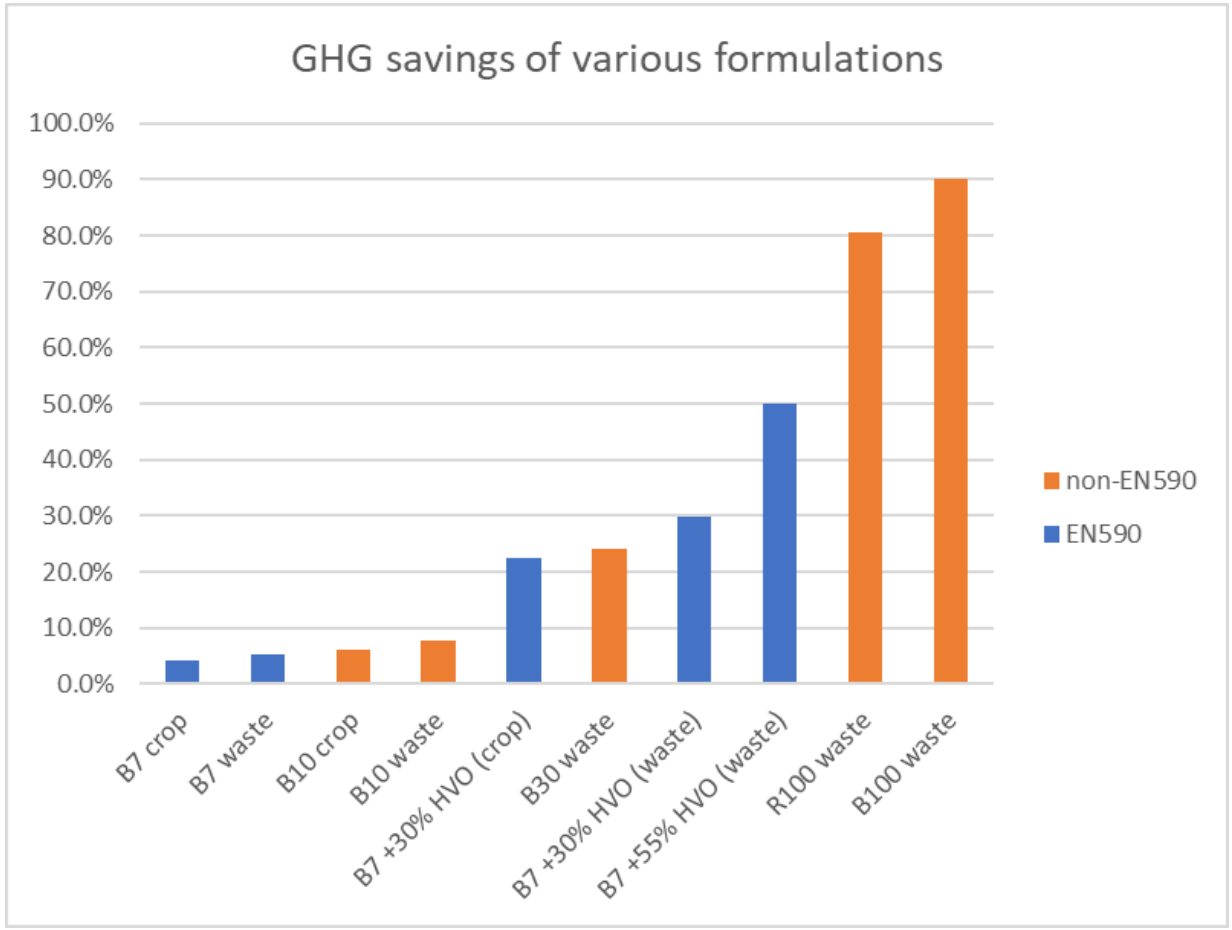
* unless isomerized

The exam question…
Really low carbon diesel – how to?

- Today: **6%** (more or less) carbon intensity (CI) reduction in road transport fuels
- By 2030: **15%**? **22%***?
- How to create a "ULCD" diesel offer with **30%** CI reduction? with **50%**?
- Modelling options:
  - Crop biodiesel @ 70% GHG savings
  - Waste biodiesel @ 90% GHG savings
  - Crop HVO @ 60% GHG savings
  - Waste HVO @ 80% GHG savings

* Germany draft legislation

Ultra Low Carbon Diesel



Other options (not modelled):

- non-fuel carbon savings (eg UERs, carbon offsets)
- Renewable fuels with negative CI (CCUS, waste avoidance)

HVO / FAME co-blending

- HVO is a hydrocarbon hence largely behaves like fossil diesel in blending with FAME biodiesel.
- Paraffinic - reduces aromatic content from the HC portion of the finished diesel.
- Following points to note:
  - Low density vs diesel spec → FAME helps (high density) ✔
  - Low lubricity (paraffins) → FAME helps (high lubricity) ✔
  - Low polarity (paraffins) → reduces solubility of SMGs (impact cold start operability) ✗
  - Cold flow properties (CFPP/CP): depends on both HVO type (isom/non-isom) and FAME type; response to CP additive needs monitoring

Overall **No Show Stopper**. Synergistic attributes in blend in some respects.

Conclusions

- As transport fuel renewable mandates increase, **drop-in fuels like HVO are needed** to provide lower-carbon liquid fuels compatible with the existing vehicle park.
- HVO and other Renewable Diesel products are hydrocarbons however they **don't necessarily meet the diesel specification**.
- Creating "Ultra Low Carbon Diesel" offers for the retail market (EN590-compliant) is likely to involve **significant amounts of Renewable Diesel**.
- Biodiesel (FAME) and Renewable Diesel are **complementary in delivering CI reductions** and, with some care in the blending recipe, can blend well to optimise finished grade quality.
- Other issues – for another day…
  - Feedstock availability for Renewable Diesel, in particular waste Fats, Oils & Greases (FOGs)
  - Scalability and price of ULCD

Breakthrough technology: Non-food crop biomass to Renewable Fuels (Diesel/ Jet)

Martin Atkins
25.03.21

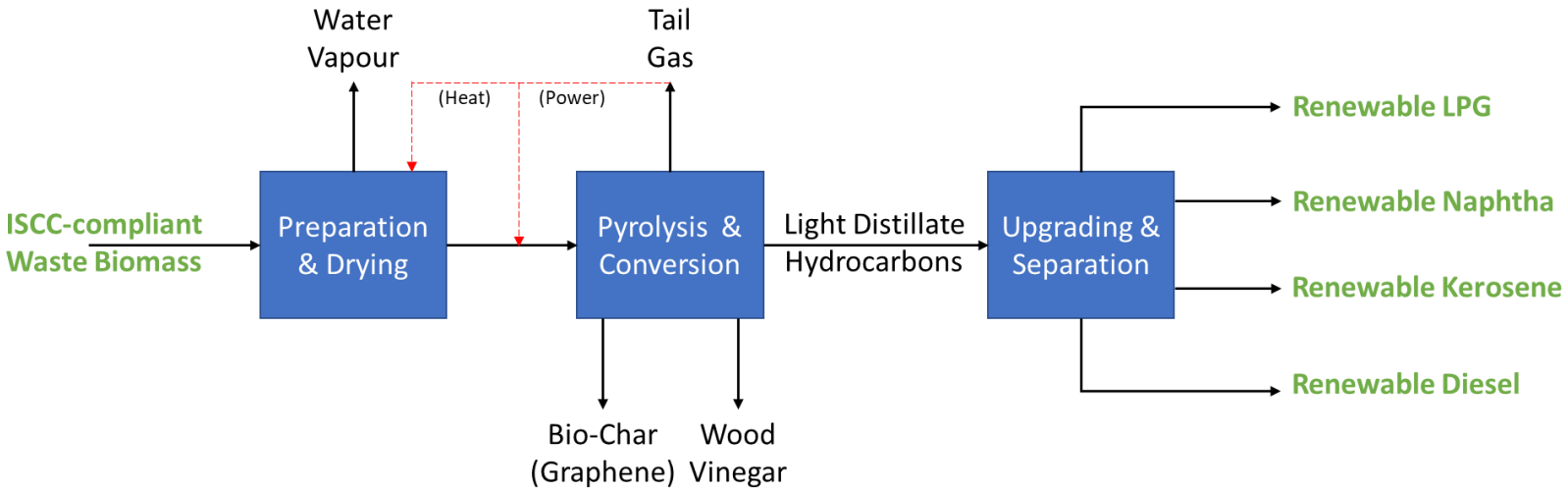
Introduction

A partnership between Green Lizard Technologies (GLT) and Abundia Global Impact Group (AGIG) has developed a novel and exciting technology converting non-food crop biomass into bio-jet, kerosene and related hydrocarbon products in a competitive unit operation.

- Approx. $750 billion global collective market
- Fossil fuels & chemical markets are in need of alternatives
- Industry recognition of a need for change, however no viable alternatives
- Growing public sentiment and awareness demanding change
- Varying world wide regulation increasing the requirement for green fuels and energy
- Bioenergy accounts for roughly one-tenth of the world total primary energy today and is expected to grow significantly in the next few years
- Adoption of biofuels in transport, domestic heating applications, aviation and marine sectors has struggled to meet envisaged global targets due partly to performance but mainly due to cost and availability

Breakthrough technology

PROCESS OVERVIEW



- ***Pyrolysis*** - lignin and cellulosic materials in the biomass are completely ***de-oxygenated***, forming a mixture of ***Renewable Hydrocarbons***, Organic Acids, ***Graphene-rich Biochar*** solids and tail gases containing CH_4, H_2, CO and CO_2.
- ***Renewable Hydrocarbon Upgrading*** via Hydro-processing and isomerization Technologies.
- ***Fractionation*** yields a range of ***Oxygen-free Bio-derived Renewable Hydrocarbon*** products.

Feedstocks tested include;

Miscanthus, Switchgrass, Railroad Ties, Borate, Creosote & QNAP Coatings, Green Urban Waste (yard trimmings), Cotton Gin Trash, Municipal Solid waste – compost & autoclave, Palm Fronds, Palm Kernel Shells, Hickory, Bagasse, Pine Bark, Virginia Pine, Cedar, Grass Hay, Mesquite, Red Oak, White Oak, Flooring Waste – hardwood floor & nylon carpet, Spruce, Poplar, Lint, Bamboo, Mixed Paper, Corn Stover, Wood Pellets.

Commercially operational 2017 US for diesel at 7.2m gal. UK plant will be 20m gal. capacity.

Crude & filtered products prior to hydrotreatment

Product Data

Renewable Kerosene

Approvals underway through ASTM D4054 Evaluation Process for use as a Sustainable Aviation Fuel blend-stock.

Key Properties

PROPERTY	UNITS	TEST METHOD	SPEC.	VALUE
Flash Point	°C	IP170	>38	49.5
Freeze Point	°C	IP529	<-47	-47.8
Trace Metals	mg/kg	ASTM D7111	all <0.1	all <0.1
Total Nitrogen	mg/kg	ASTM D4629	<2	1.1
Total Sulphur	mg/kg	ASTM D5453	<15	<1.0
Total Halides	mg/kg	ASTM D7359	<1	<1.0
Total Oxygenates	% wt.	ASTM D5622	n/a	<0.04

Renewable Diesel

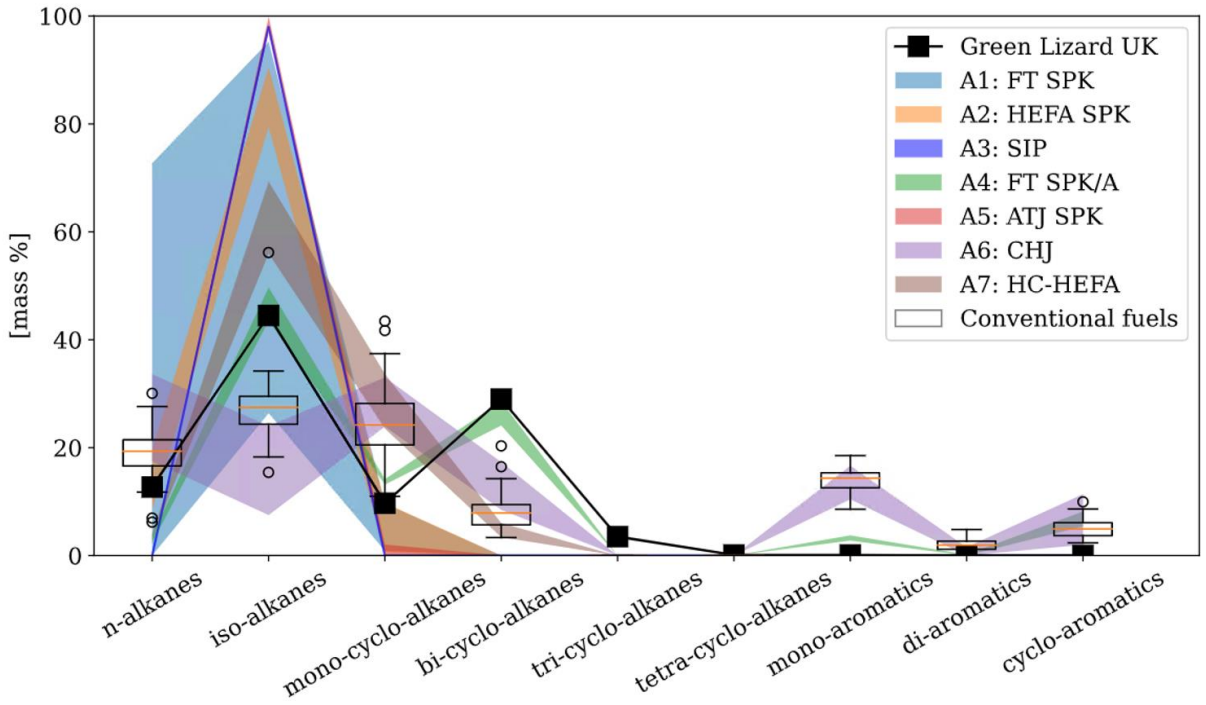
Complies with EN 15940 Standard for Hydrotreated Paraffinic Renewable Diesel Fuel.

Key Properties

PROPERTY	UNITS	TEST METHOD	SPEC.	VALUE
Flash Point	°C	EN ISO2719	>55	75
CFPP	°C	EN 116	<-15	-18
Cetane Number		EN 15295	>60	86.3
Cetane Index		EN ISO 4264	>60	92.6
Total Sulphur	mg/kg	EN ISO 20846	<10	1.5
FAME	% vol.	EN 14078	<7	NIL
Total Oxygenates	% wt.	ASTM D5622	n/a	<0.04

Tier alpha: Part 1 Compositional analysis

Tier alpha: Part 1 Compositional analysis



Tri/tetra-cyclo-alkanes are unusual and have not been detected for other fuels.

High similarity to FT SPK/A from fuel family mass-fraction perspective.

Further similarity analysis can be performed.

Recommendation for Next Steps

- Tier alpha results look promising.
- Fuel looks reasonable and similar to already approved fuels and indicates high fast track potential.
- Property predictions are being verified by experimental measurements.
- Trace metals are less than 0.1ppm.
- Looking to partners/investors to facilitate further development and offtakes running out globally. Large land areas where waste biomass is focussed e.g. Brazil (Bagasse) Malaysia/Indonesia (EFB)....is prime target.
- First UK plant, Teesside - operational Q1 2023

Acknowledgements

- Bastian Rouche, JetScreen
- Chris Lewis Fuels Consultancy Ltd.
- David Richardson, Coryton
- Intertek

- Thank you for Listening, Any Questions?

Thank you

Renewable Transport Fuel Association

Zemo Partnership
Accelerating Transport to Zero Emissions

Any questions? Please get in touch

Gloria Esposito
Head of Sustainability
E: Gloria.esposito@zemo.org.uk
T: 020 7304 6038

Interested in joining the Partnership?

E: Carolyn.webb@zemo.org.uk
T: 0207 304 6880

Next Webinars

Session 3: Advanced Renewable Gaseous Fuels

31st March, 10:30am – 12pm

Session 4: Sustainable Aviation Fuels

1st April 10:30am – 12pm

Zemo Partnership, 3 Birdcage Walk, London SW1H 9JJ
T: +44 (0)20 7304 6880 | E: hello@zemo.org.uk @Zemo_Org | www.zemo.org.uk

Interested in joining Zemo

Zemo Partnership

Our work covers six areas related to accelerating the transition to a zero transport future.

Buses & Coaches

Action programmes to speed the introduction of zero emission buses in the UK by working with passenger transport companies and local authorities

Cars

Working with manufacturers, fleet operators, environment and consumer groups to accelerate the adoption of zero emission cars.

Fuels

We explore measures to increase the adoption of sustainable low carbon fuels such as biofuels and renewable hydrogen.

Commercial Vehicles

For manufacturers, freight transport operators, technology suppliers, technical expert and others interested in accelerating the transition to cleaner, greener road freight.

Energy Infrastructure

Formed to make suggestions to Government and industry to ensure that the GB energy system is ready for and able to facilitate and exploit the mass take up of electric vehicles.

Collaborative Initiatives

Joint working group projects where content crosses over, overseen by the members' council.

Renewable Transport Fuel Association

Zemo Partnership

- Established end of August 2020, with 12 founder members
- Membership now exceeds 30 (and includes all UK bioethanol and biodiesel producers, all companies dispensing biomethane to transport, along with prospective SAF and development fuel producers)
- Formed to champion the contribution that renewable and low carbon fuels can make towards the decarbonisation of UK transport
- www.rtfa.org.uk
- Contact: Gaynor Hartnell, CEO

  gaynor@rtfa.org.uk