XFuel tech: keeping the oil underground with affordable and low carbon drop-in fuel for transport today.

# Content of the presentation

- Challenges to address
- XFuel Technology Overview
  - Chemical Liquid Refining (CLR)
  - Mechanical Carbon Conversion (MECC)
- Competitive advantages/ where we are

# The **problem**

**Transportation**, responsible for a staggering **21% of global emissions**[1], remains stubbornly **reliant on oil for 91%** of its energy[2], and this trajectory **is not on course for meaningful change.** Our planet's future demand sustainable solutions now.

Oil consumption in shipping and aviation is projected to **increase over 80% by 2050** with current policies,

and only **reduce 4%** should we meet <u>all</u> announced pledges fully and on time

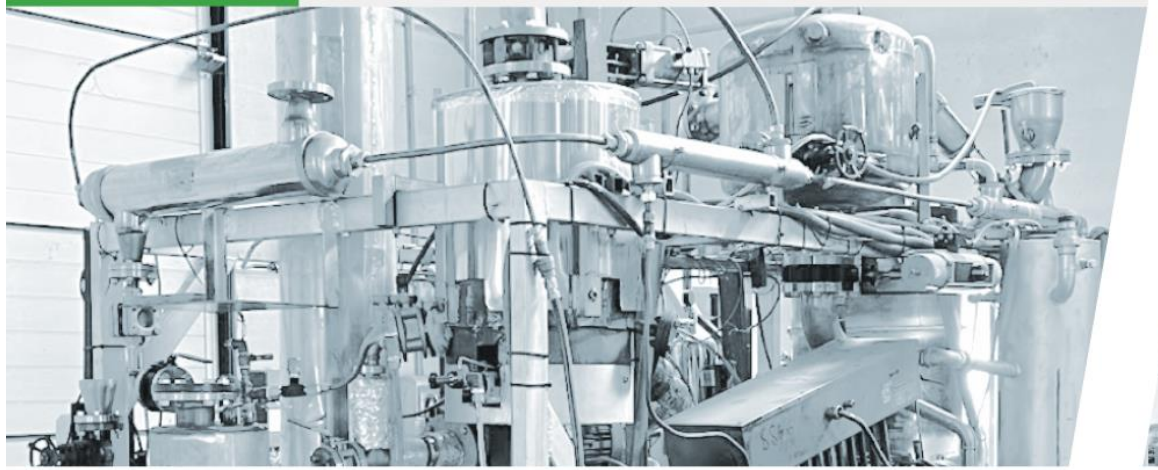
IEA International Energy Agency

[1] https://www.dnv.com/Publications/transport-in-transition-242808 [2] Data from the IEA (iea.org)

# Two **innovative** and **patented** technologies

Impact **NOW** with CLR while developing MECC for bigger **FUTURE** impact

**OPERATIONAL** **CLR Demo Plant** 50-100 litres per batch



## Chemical Liquid Refining (CLR)

One-step refining and valorization of waste hydrocarbon liquids into ultra clean drop-in fuels

**Ready for commercialisation**

**85%** GHG Savings (at fossil fuel prices)

**OPERATIONAL** **M1 Demo Plant** <1,000 tons MGO pa capacity

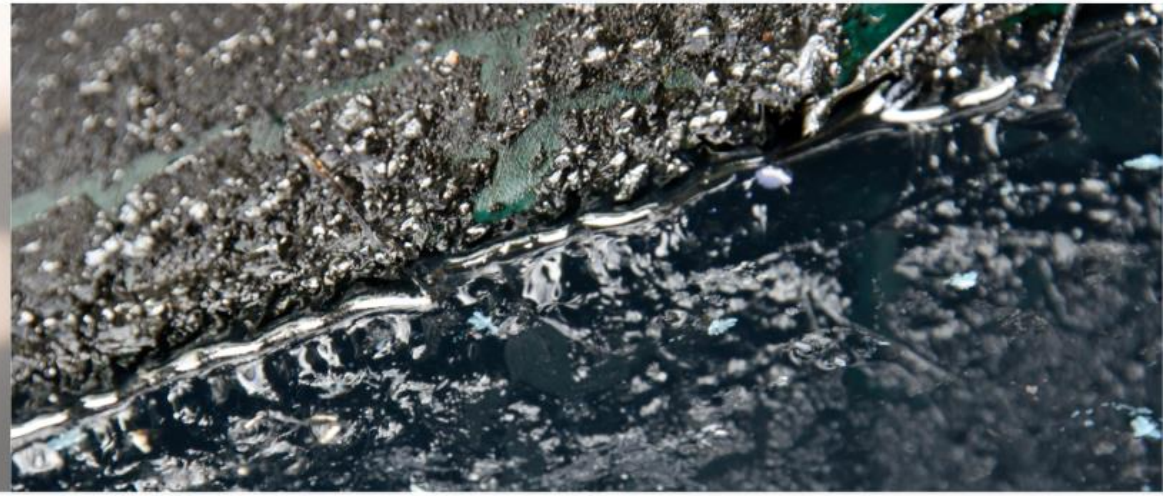

## Mechanical Carbon Conversion (MECC)

Low-cost co-processing of waste solid biomass and oils into drop-in fuels and biochar

**Under development**

**95-145%+** GHG Savings

# We are able to use a wide range of **biogenic** and **fossil** **waste** material across our technologies



## Lignocellulosic **biomass** **waste**

Agricultural Residues
Construction & Manufacturing Residues
Forestry Residues

## Industrial **waste**

Waste Lubricants
Shipping Waste (MARPOL Annex I)
Industrial Oils & Petroleum Waste

# Chemical Liquid Refining
(CLR)

FUEL

# Initial focus on **residual marine oil** feedstocks

First CLR projects will convert marine oil residues (MARPOL Annex I sludge) into the highest quality marine gas oil (MGO)

**330 million tons** of marine fuel consumed per year, generating **5-10 million tons** of MARPOL hazardous sludge

- Marine fuel tank oil residues (sludge) is generated from the filtering of bunker fuel oil prior to use in ship's engines (MARPOL Annex I, Reg 12)
- Comes from wax, asphalt, tars, and water in the fuel, and can amount **up to 3% of the volume of bunker fuel used by ships**
- Considered hazardous waste that is expensive to treat on board (if permitted), and needs to be offloaded at port facilities.
- Major environmental consequences when illegally dumped.

# **CLR** is an innovative low cost process, turning **waste** hydrocarbons into **ultra clean** drop-in fuels

INPUTS

## Impure Hydrocarbons

**Contaminated** and **waste** fossil and biogenic hydrocarbon liquids e.g. high density, high sulphur, heavy metals, high oxygen, etc.

Versatile with possible inputs including:
- Contaminated bio & fossil liquids
- Marine oil residues (MARPOL Annex I sludge)
- Waste lubricants
- Oil & Gas residues

## Chemical Reactant

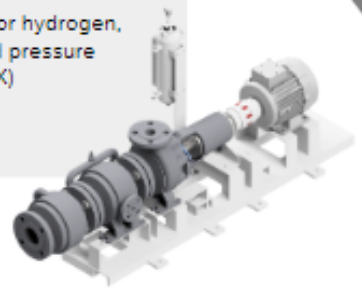
Widely available solid reactant which is easy to handle and transport

**CLR** refines and cracks contaminated hydrocarbon liquids into ultra clean high quality transport fuels

Proprietary turbine design through which mixture circulated

Single step process to both refine and lighten hydrocarbons increasing efficiency and reducing OPEX and CAPEX

Chemical reactant removes need for hydrogen, catalysts, high temperatures and pressure (lower OPEX and CAPEX)



## Ultra clean transport fuels

Depending on input, fuels meet:
- Marine Gas Oil (MGO) DMA
- EN590 road diesel (ULSD)
- Aviation standards

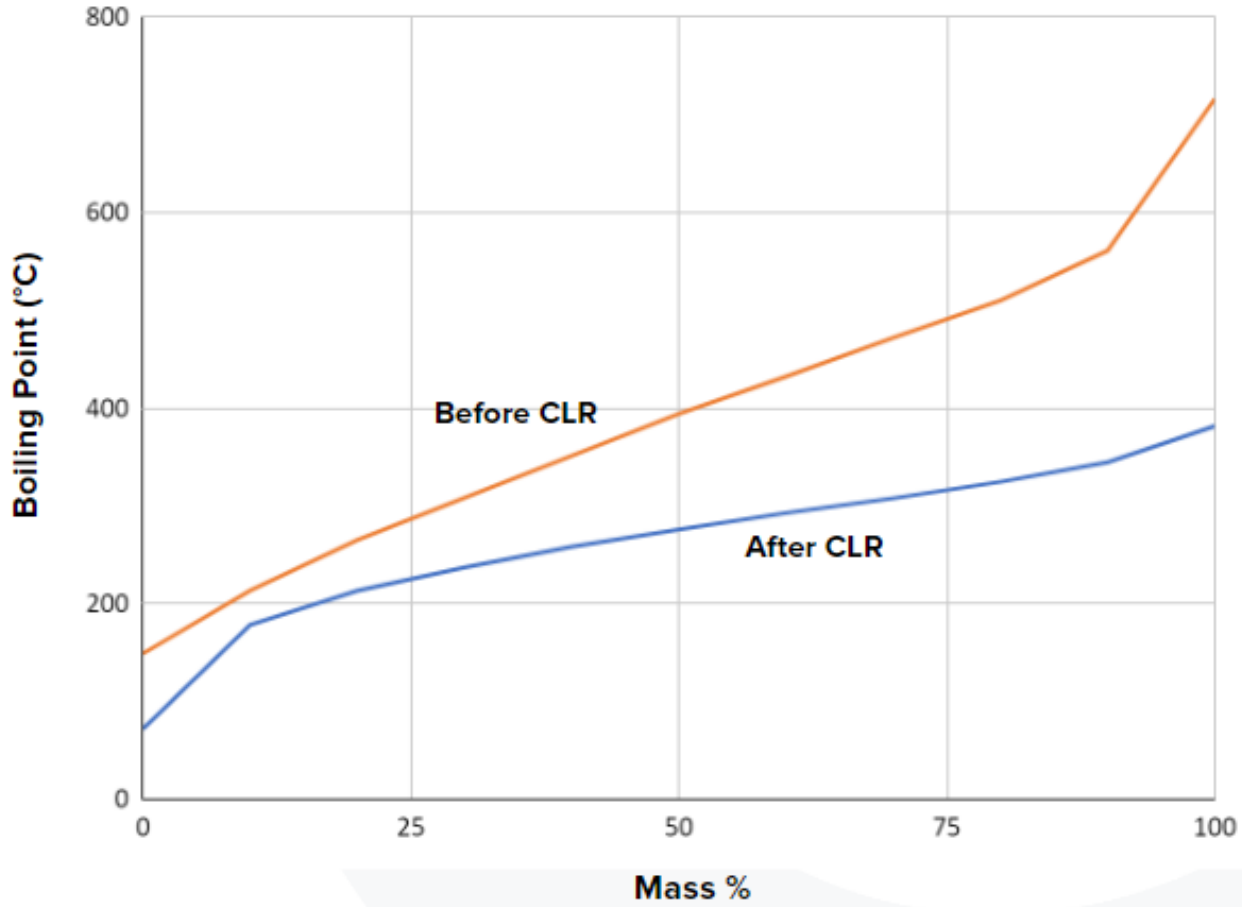
GHG savings will depend on input being a waste, type of waste and regulation targeted e.g. EU RED II

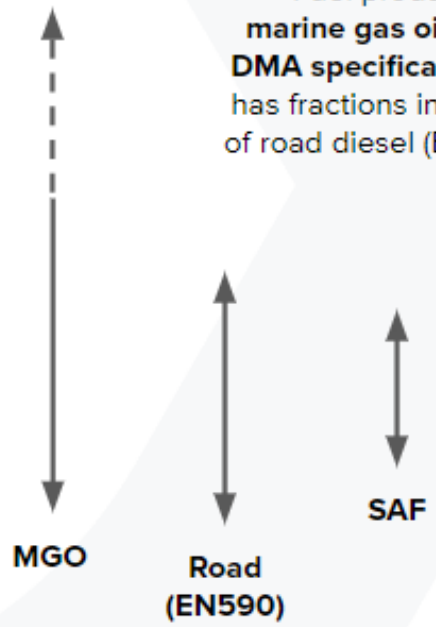
## Residues

Impurities are concentrated into a small amount of solids with consumed reactant, alongside water vapour

OUTPUTS

# CLR **fuel distribution** from marine oil residues




Fuel produced though **CLR** meets **marine gas oil (MGO) ISO 8217:2017 DMA specification** for marine fuel and has fractions in the boiling point range of road diesel (EN590) and sustainable aviation fuel (SAF)

# CLR fuel meets **ISO 8217 MGO DMA** specification

Marine oil residue from Hamburg port recycled into MGO

GREEN PORTS HAMBURG

Key properties

- Calorific value (42.5 MJ/kg)
- Low Sulphur (<1000 ppm) and can be optimised (1000-5 ppm)

**Report No.: 3103671-1**

Sample : Marine Destillates
Container : metal - Box 1000 ml
ASG-ID : 3103671_002

Date of order : 22.05.2023
Sample receipt : 22.05.2023
Sampling : Customer
Start of test period : 22.05.2023
End of test period : 30.05.2023
Report date : 01.06.2023

ASG Analytik-Service

| Parameter | Method | Result | Specification ISO 8217 :2018 min. | Specification ISO 8217 :2018 max. | Unit |
|---|---|---|---|---|---|
| Kin. viscosity (40 °C) | DIN EN ISO 3104 :2021 | 2,741 | 1,400 | 5,500 | mm²/s |
| Density (15 °C) | DIN EN ISO 12185 :1997 | 852,5 | - | - | kg/m³ |
| Cetane Index | DIN EN ISO 4264 :2018 | 47,2 | 45 | - | - |
| Sulfur content | DIN EN ISO 14596 | 0,036 | - | 1,00 | % (m/m) |
| Flash point | DIN EN ISO 2719 :2021 | 82,0 | 43 | - | °C |
| hydrogen sulfide | UOP 163 :2010 | -* | - | 2,00 | mg/kg |
| Acid value | ASTM D664 :2018 | 0,002 | - | 0,5 | mg KOH/g |
| Sediment content | ISO 10307-1 :2009 | 0,48 | - | - | % (m/m) |
| Oxidation stability | DIN EN ISO 12205 :1996 | 3 | - | 25 | g/m³ |
| Carbon residue | DIN EN ISO 10370 :2015 | <0,10 | - | (0,30)** | % (m/m) |
| Pour point | DIN EN ISO 3016 :2017 | -27 | - | - | °C |
| Water content | DIN ISO 3733 | 0,011 | - | - | % (V/V) |
| Ash content (775 °C) | DIN EN ISO 6245 :2003 | 0,004 | - | 0,010 | % (m/m) |
| HFRR (Lubricity at 60 °C) | DIN EN ISO 12156-1 :2019 | 520 | - | 520 | µm |
| 10 % (V/V) recovery | DIN EN ISO 3405 :2019 | 250,7 | - | - | °C |
| 50 % (V/V) recovery | | 263,8 | - | - | °C |
| 90 % (V/V) recovery | | 290,2 | - | - | °C |
| Cloud point | DIN EN 23015 :1994 | -28 | - | -16 | °C |

# Mechanical Carbon Conversion
(MECC)

FUEL

# **MECC** produces sustainable drop-in fuel and biochar from waste biomass and oils for **bigger impact**

INPUTS

**Waste Solid Biomass**

Lignocellulosic residues from the agriculture, forestry, and manufacturing industries

**Waste Oils**

Waste fossil and biogenic oils e.g. waste lubricant oils and Cashew Nut Shell Liquid (CNSL)

**Reactants**

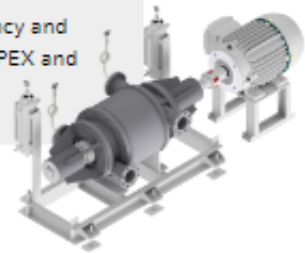
Chemical reactants used to improve process conditions

**MECC** efficiently converts waste solid biomass and waste oils into a range of sustainable products

100% friction and cavitation driven localised heating (no external heating), allowing for high efficiency (<360 celsius only and low energy overhead)

Use of carrier oil improves heat transfer, avoids oxygen and reduces unproductive decomposition (better products)

Low energy input, high energy efficiency and atmospheric pressures provides low OPEX and CAPEX needs



OUTPUTS

**Sustainable drop-in fuels**

Sustainable drop-in bio & recycled fuels for marine, road and aviation sectors with blended certified 95-145%+ GHG savings

**Biochar & Wood Vinegar**

Biochar used in agriculture and industrial applications such as a concrete additive, avoiding its release into the atmosphere

**Carbon Removal credits**

High quality carbon credits from an engineering sequestration solution (biochar) with high permanence

# MECC fuel meets **ISO 8217 MGO DMA** specification

LSMGO 70% / MECC Wood fuel from Eucalyptus 30%

BORAL®

Key properties

- Hydrogen Sulfide (<0.60ppm)
- Stable and compatible in blends with fossil MGO

**ANALYSIS REPORT**

BUREAU VERITAS

**Inspectorate (Singapore) Pte Ltd**
**2 Toh Tuck Link #03-01**
**596225, Singapore**
**E:**
**DL_SingaporeLabOps@inspectorate.com**
**T: +65 68663019**
**F: +65 64661312**

| | | | |
|---|---|---|---|
| **Job Type :** | LAB | **Client :** | TOYOTA TSUSHO PETROLEUM PTE LTD |
| **Job No :** | SGLSGJ21051179 | **Client Reference No :** | RYAN HOO |
| **Sample No :** | SGLSGJ21051179-007 | | 600 NORTH BRIDGE ROAD, |
| **Job Asset :** | NOT APPLICABLE | **Address :** | #16-08/09/10 PARKVIEW SQUARE, |
| **Product :** | Biodiesel | | SINGAPORE 188778. |
| **Terminal / Location :** | SINGAPORE | **Date Sample :** | |
| **Sample Asset :** | Handblend | **Date Received :** | 12-Oct-2021 |
| **Sample Summary :** | Handblend | **Date Tested :** | 12-Oct-2021 |
| | | **Date Reported :** | 13-Oct-2021 |

**Handblend Composite Analysis**

| | SGLSGJ21051179-007 | | | Specification |
|---|---|---|---|---|
| **Test** | **Method** | **Unit** | **Result** | **Min - Max** |
| Density @ 15°C | ISO 12185 :1996 | kg/L | 0.8576 | 0.8900 Max |
| Kinematic Viscosity 40°C | ISO 3104 :1994 | mm²/s | 4.199 | 2.000 - 6.000 |
| Flash Point, PMCC | ISO 2719:2016(Proc.A) | °C | 80.0 | 60.0 Min |
| Hydrogen Sulfide | IP 570/15(Proc.A) | mg/kg | <0.60 | 2.00 Max |
| Total Acid Number | ASTM D664A -18e2 | mg KOH/g | <0.10 | 0.5 Max |
| Pour Point | ISO 3016 : 1994 | °C | -12 | -6 Max |
| Sulfur Content | ISO 8754 :2003 | % (m/m) | 0.065 | 1.00 Max |
| Calculated Cetane Index | ISO 4264 : 2013 | - | 51.4 | 40 Min |
| Micro Carbon Residue on 10% (V/V) Distillation Residue | ISO 10370 :2014 | % (m/m) | <0.10 | 0.30 Max |
| Cloud Point | ISO 3015 :1992 | °C | -1 | Report |
| Cold Filter Plugging Point (CFPP) | IP 309 /16 | °C | -6 | Report |
| Ash | ISO 6245 :2001 | % (m/m) | <0.001 | 0.010 Max |
| Appearance | Visual ** | - | Clear & Bright | Clear & Bright |
| Oxidation Stability | EN ISO 12205 : 1996 | g/m³ | 5 | Report |
| Lubricity - method HFRR | ISO 12156-1 A :2018 | µm | 340 | 520 Max |
| Stability Test | ASTM D4740 -20 | - | 1 | Report |
| Compatibility Rating | ASTM D4740 -20 | - | 1 | Report |

**Remarks**

**LSMGO (51179-003-006) - 70%**
**Wood Oil (51179-002) - 30%**

# Our fuels comply with existing fuel standards and have been extensively **tested** and **certified**

Fuels have **low oxygen, high calorific value** and are true drop-in replacements

| | | |
|---|---|---|
| **Marine** | **Producing** ISO 8217 MGO (DMA) fuel | Analysis, blending studies, in-engine testing |
| **Road** | **Producing** EN 590 (EU) fuel | Analysis, blending studies |
| **Aviation** (SAF) | **Under development** aiming for Fast Track approval (B10) | Advanced analysis |

DLR · GoodFuels · MAERSK · ASG Analytik-Service Gesellschaft · ElbOil · bp · University of Sheffield Energy Institute | SAF-IC

# **MECC** also **sequesters** carbon and produces **biochar**

We produce high quality biochar that is being developed with partners for use in agricultural and industrial applications

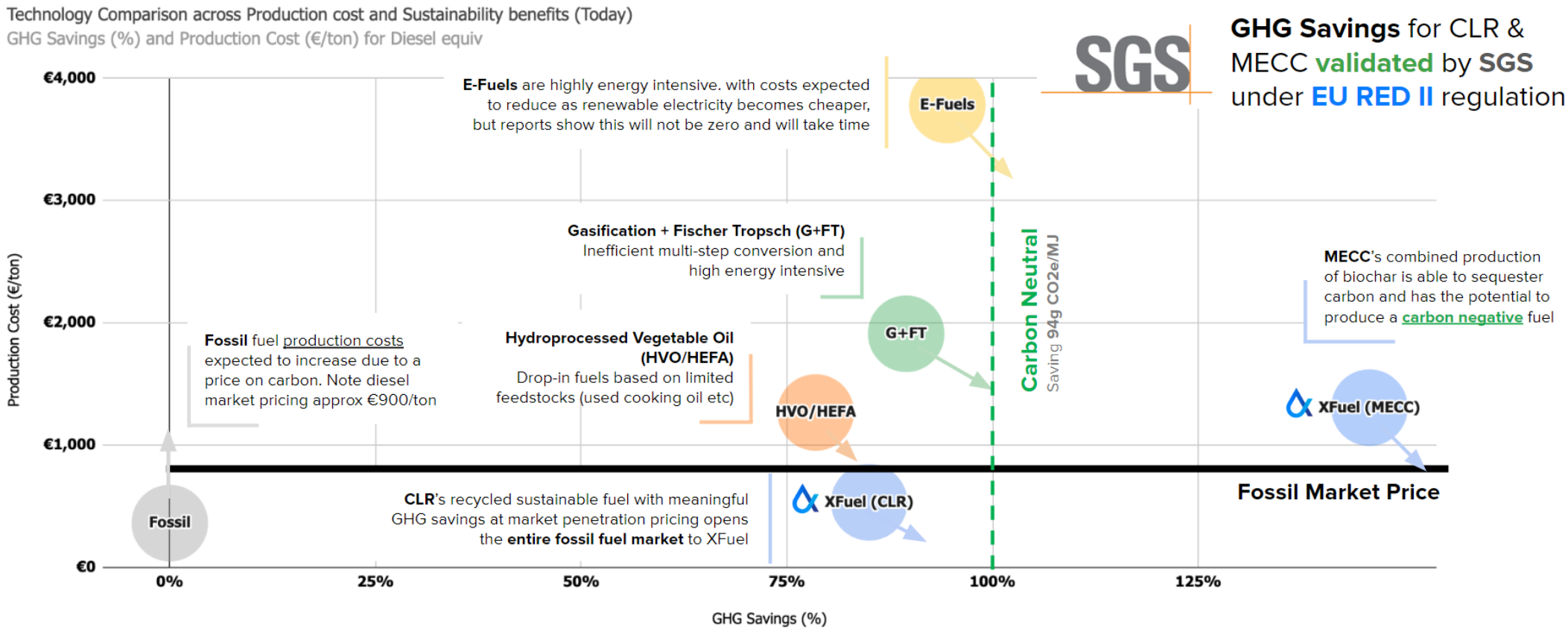
- **Agriculture** – soil amendment and enhancer
- **Concrete** – replacing % cement and improving properties
- **Asphalt** – improving properties and elasticity with blending
- **Steel** – substituting % coke in production

This avoids the need for higher carbon intense materials used in their production

Unlocking **carbon negative** fuels or producing carbon credits for voluntary market

# Competitive Advantage

# We can produce the **cheapest** low carbon fuel **today** and pioneering the **most** sustainable fuel **next**






References: McKinsey, WEF, Credit Suisse, Concawe, Aramco Reports. GHG saving calculations for CLR with marine oil residue (sludge) and MECC are under review with independent consultants.

# We've **demonstrated** our tech and now **scaling** production with a modular & decentralised approach

## CLR

ZEAN
De Dietrich

**OPERATIONAL**

Modular design and optional MECC add-on

### **CLR** Demo

**Batch runs**
100 litres MGO per run

### **C2** Plant

**1x module**
14,000 tons MGO pa

### **C10** Plant

**5x modules**
70,000 tons MGO pa

## MECC

DORIS
WE ENABLE CHANGE

**OPERATIONAL**

Modular design with multiple MECC reactors


### **M1** Demo

**1x reactor**
< 1,000 tons MGO pa
ISCC EU+Plus certified

### **M4** Plant

**4x reactors**
4,000 tons MGO pa
Pre-feed stage

### **M16** Plant

**16x reactors**
16,000 tons MGO pa

# **XFuel** produces liquid fuel replacements to **reduce emissions** in transport **today** with **zero added cost**

**sustainable** — 80-100% GHG saving with route to carbon-negative (>100%) fuels

**drop-in** — fully interchangeable with existing fuels, engines and infrastructure, saving time & cost

**scalable** — widely available waste lignocellulosic biomass and oils (biogenic & recycled)

**low cost** — production cost lower or competitive with fossil and alt. fuels & CAPEX 5x lower

Sergio Rios, R&D Engineer

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# Thank you