

# **Hydrotreated Vegetable Oil (HVO) and Gas to Liquid (GTL) : Renewable Diesel & Paraffinic Diesels**

## Year 1900 (119 Years ago)



Rudolph Diesel: 1858-1913



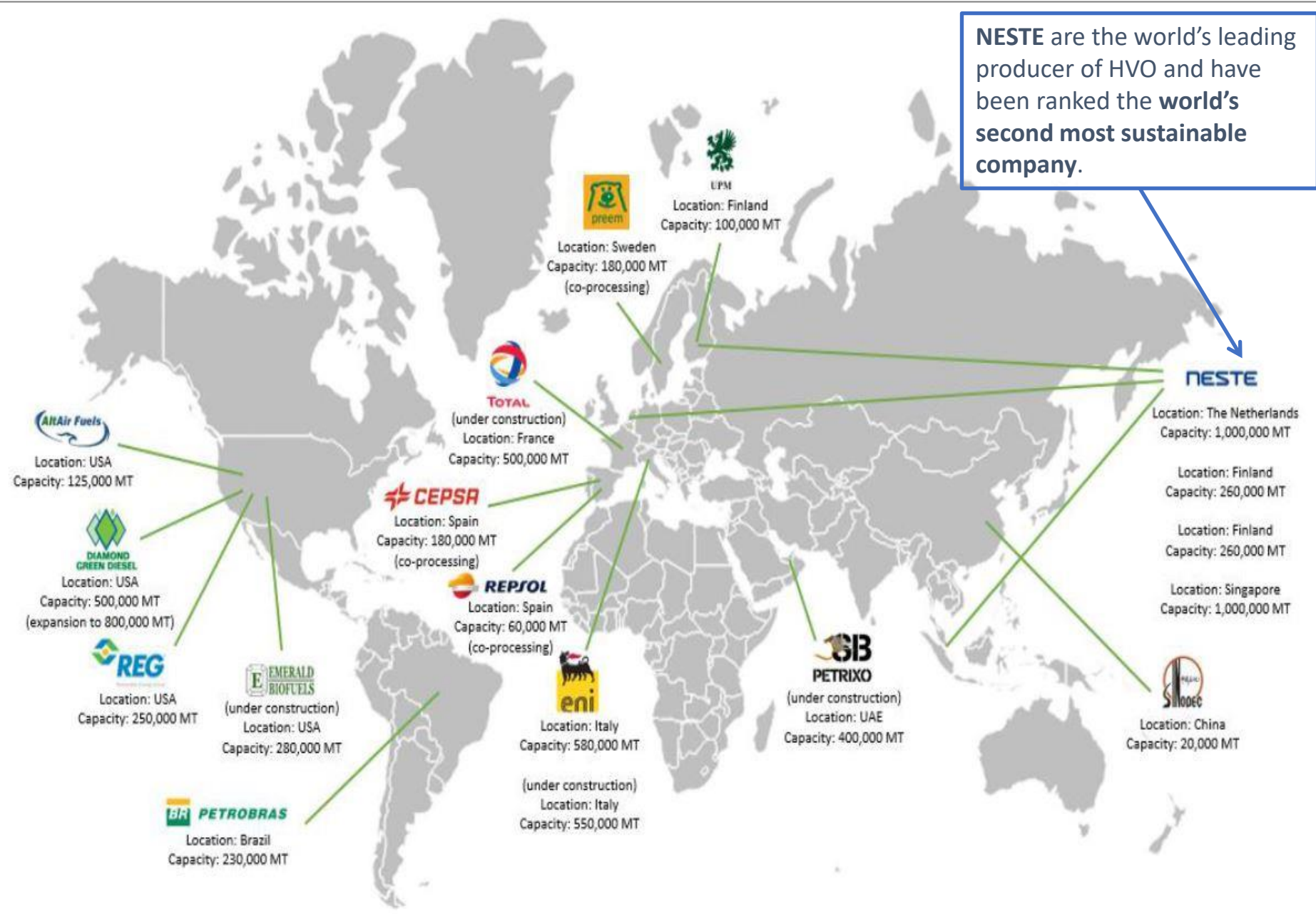
1900 World's Fair, Paris.

**Rudolph Diesel expected his engines to run on vegetable and seed oils. He wanted his engines to be widely available to independent artisans, craftsmen and farmers—“common folk”—without any hindrance from big oil monopolies or steam engine manufacturers. At the 1900 World's Fair in Paris, Diesel ran his engine on peanut oil and took home the Grand Prix, the most prestigious prize awarded.**

## What is Hydrotreated Vegetable Oil (HVO) – Renewable Diesel

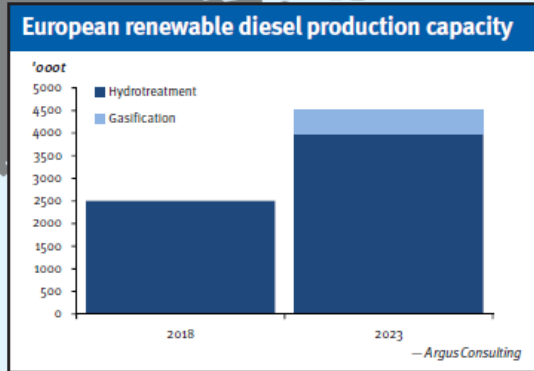
- Hydrotreated Vegetable Oil (HVO) is a form of renewable diesel that has been produced from used vegetable oils and waste animal fats.
- As a fuel, HVO is very similar to conventional fossil diesel, **though the name is somewhat misleading**. HVO can also be derived from animal fats, residual and waste fats, oils and greases including used cooking oil (UCO) and crude tall oil (“pine oil from trees”), although pure vegetable oils can also be used.
- Unlike regular biodiesel, hydrogen is used as a catalyst in the creation process instead of methanol. By doing this, the oxygen is removed from the fuel, making it more stable to temperature and storage.
- The product is sulphur, oxygen, nitrogen and aromatics free diesel which can be used without modification in diesel engines.
- The European EN 15940 standard uses a definition “Paraffinic Diesel Fuel from Hydrotreatment”.
- HVO is referred as a “drop-in-fuel” in that with the absence of oxygen, it can be blended into conventional diesel at any percentage.
- The Renewable Transport Fuels Obligation (RTFO) has increased the bio-content of conventional diesel for road vehicles from 4.75% currently to 9.75% in 2020 and then 12.4% by 2032.

NESTE are the world's leading producer of HVO and have been ranked the **world's second most sustainable company**.



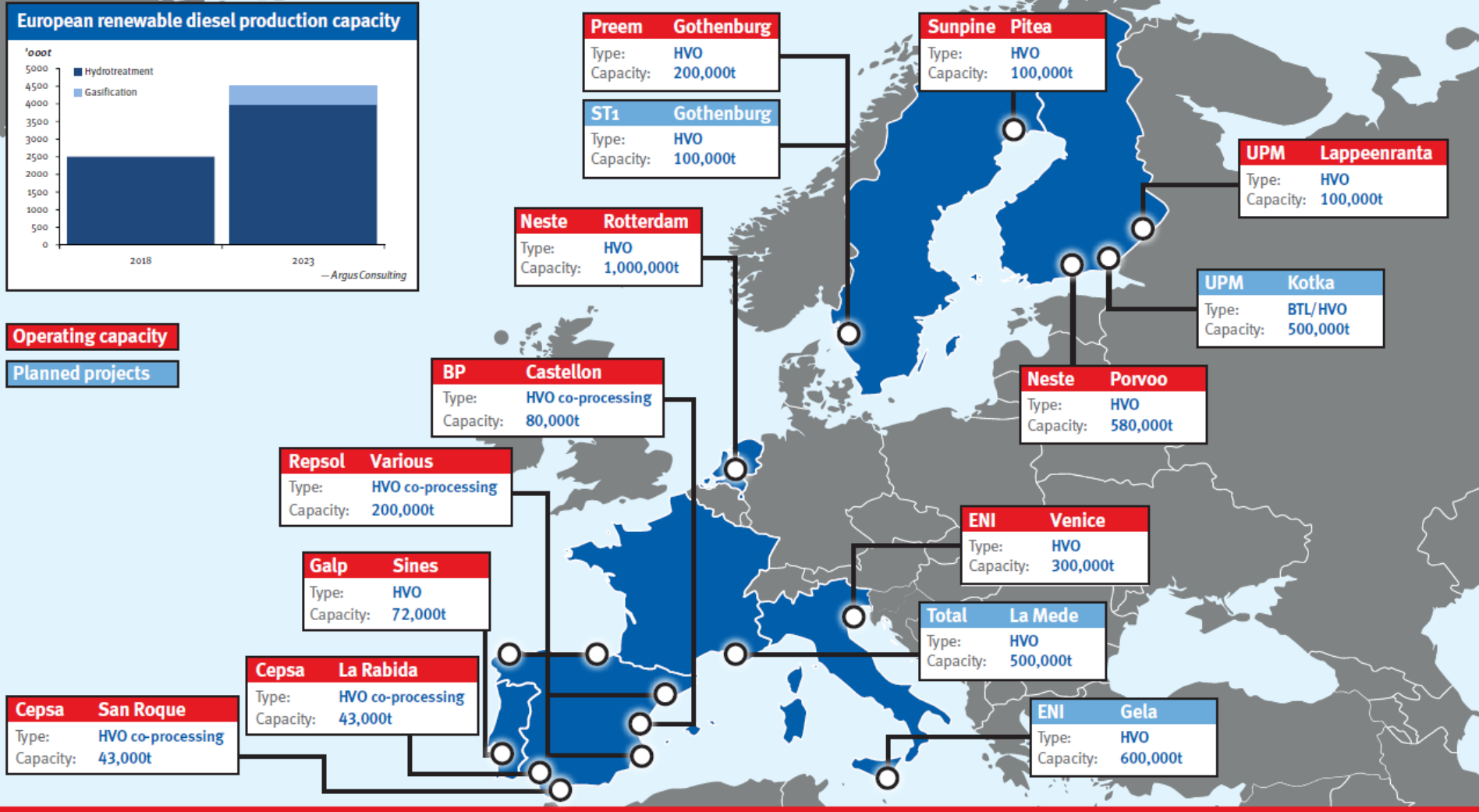
Exh. 1. Current and planned HVO production units

# HVO production and outlook 2019



**Operating capacity**

**Planned projects**



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# HVO production in Europe is expected to increase, with new plants opening this year and further projects planned for the next four years

<b>Company</b>	<b>Location</b>	<b>Capacity (tonne)</b>	<b>Expected completion</b>
Total	La Mede, France	500,000	Opened July 2019
ENI	Gela, Italy	750,000	Opened August 2019
ENI	Porto Marghera, Italy	240,000	2021
UPM	Kotka, Finland	500,000	Final decision pending
St1	Gothenburg, Sweden	200,000	2022
Preem	Lysekil and Gothenburg, Sweden	1,200,000	Increasing to 1.3m tonnes by 2023
PKN Orlen	Plock, Poland and Litvinov, Czech Republic	Not disclosed	Not disclosed

# UK PARAFFINIC DIESEL PROJECTS: TOTALLY DEPENDENT ON MUNICIPAL WASTE MOSTLY WASTE PLASTIC FEEDSTOCK

1. Velocys/BA/Shell: Avonmouth - 2022 – Aviation fuel
2. Neste/Renew/Licella: Teeside – 2022 – Aviation fuel
3. Recycling Technologies/Lodestar: Swindon and Scotland - Testing plants

**All relying on waste plastic receiving either RTFC or Development fuel status?**

In Europe, some 27 million tons of post-consumer plastic is generated annually. Only about one-third of this amount is currently collected for recycling.

18 July 2018

## Neste aiming to use waste plastic as a raw material for fuels and plastics

Published in Releases and news under Renewable solutions, Circular economy, Climate change, Sustainability

Plastics, Waste plastics





# THE CONSTRUCTION INDUSTRY'S CONTRIBUTION TO CUTTING EMISSIONS IS VITAL TO THE ENVIRONMENT AND THE NATION'S HEALTH

- According to the most detailed air-quality study in the UK, the London Atmospheric Emissions Inventory, construction sites are responsible for approximately 7.5% of damaging nitrogen oxide (NOx) emissions, 8% of large particle emissions (PM10) and 14.5% of emissions of the most dangerous fine particles (PM2.5). The vast majority comes from the thousands of diesel diggers, generators and other machines operating on construction sites across the UK.
- Tests by Kings College London (2015) of an 8 kilowatt generator (smaller than many on construction sites) found it emitted roughly six times more nitrogen dioxide than the average London bus and 15 times more particulate matter per unit of work done.



# EU NRMM REGULATIONS FOR NEW MACHINES

## • KEY DATES AND STAGES

- **Stage II** implemented from 2001 to 2004, depending on engine power output.
- **Stage III/IV** adopted April 21, 2004.
- **Stage III** standards, further divided into Stages **IIIA and IIIB**, phased-in 2006 to 2013
- **Stage IV** entered into force in 2014
- Stage III/IV legislation applies only to new vehicles and equipment; replacement engines to be used in machinery already in use should comply with the limit values that the engine to be replaced had to meet when originally placed on the market.
- **Stage V** standards effective from 2019 for engines below 56 kW and above 130 kW, and from 2020 for engines of 56-130 kW.



# STRICT NEW REGULATION ENFORCES CONTRACTORS TO USE LESS POLLUTING EQUIPMENT ON CONSTRUCTION SITES

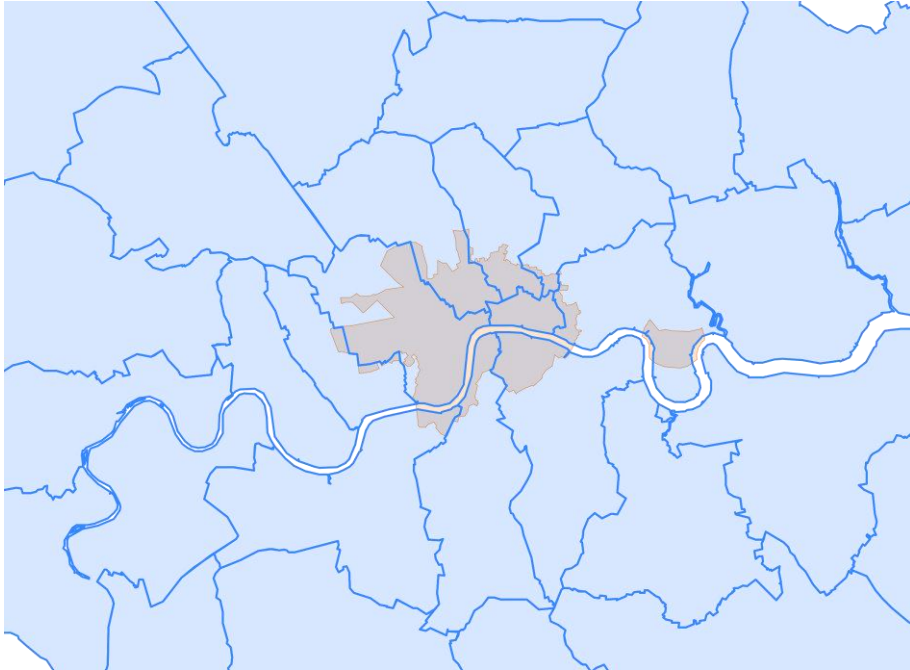
EU 2016/1628 extends the scope of the NRMM Directive 97/68/EC by additional power categories and reducing emissions even further by:

- setting stricter engine emission limits.
- introducing particulate number limits.

The regulation applies to engines of any power, any ignition system and any fuel, irrespective if they are variable or constant speed, which are installed or intended to be installed in non-road mobile machinery (unless excluded from the scope of the regulation).



# LONDON NRMM 'LOW EMISSION ZONE'



There are two zones - Greater London (shown in blue), and the Central Activity Zone (CAZ) and Canary Wharf (shown in grey). The Central London & Canary Wharf areas have a tighter emissions standard applied to them.

## EMISSION STANDARDS

### 1. Current standards:

- For 37-560 Kw engines
- Greater London -Stage IIIA standard
- Central London and Canary -stage IIIB standard.
- Generators excused until January 1<sup>st</sup> 2020

### 2. Proposed from 1 September 2020

- 37-560 Kw Engines
- Greater London Stage IIIB
- Central Activity Zone or Canary Wharf Stage IV

### 3. Final proposals out November 2018, some changes might be:

- All NRMM engines from 10-560 Kw (generators only 37 Kw+?)
- Mayor brings September 1<sup>st</sup> 2020 forwards

**UK GOV: Air quality: non-road mobile machinery and red diesel – call for evidence. Consultation finished July 24 2018. Outcome in November 2018 budget. In addition, Clean Air Zones for Leeds, Derby, Birmingham, Nottingham, & Southampton and 23 other Clean Air Zones are being proposed**

# PARAFFINIC FUELS ARE THE FUEL YOU NEED FOR A CLEANER AND HEALTHIER CONSTRUCTION SITE

- Fuel may only represent a small percentage of construction spend, but by making smarter procurement choices, contractors can meet current legislation on emissions which are harmful to our environment and care for the health and wellbeing of its workforce and neighbouring communities.
- They are drop-in fuels offers an immediate solution for the construction industry to reduce harmful nitrogen oxide (NOx) and particulate matter (PM) emissions without impacting efficiency.



# DEFRA LEGISLATION FOR COMBUSTION PLANT GENERATORS

from 1 January 2019

Achieve less than  $190\text{mg}/\text{nm}^3$  or  $0.576\text{ g}/\text{kwh}$  NOx emissions after 10 minutes:

Tranche A generators: operational before 31<sup>st</sup> October 2017

- 1<sup>st</sup> October 2025: between 5-50 MW, operates more than 50 hours pa and emits more than  $500\text{mg}/\text{nm}^3$
- 1<sup>st</sup> January 2025: between 5-50 MW, operates less than 51 hours and emissions less than  $500\text{mg}/\text{nm}^3$
- 1st January 2030: = and less than 5MW

New contracts entered into after 31<sup>st</sup> October 2017 become a Tranche B generator. Any non tranche A generator is Tranche B.

## DEFINITION OF A GENERATOR

Any single stationary electricity generating combustion plant; or any group of stationary electricity generating combustion plant located at the same site and providing electricity for the same purpose, with a rated thermal input of between 1MWth and 50MWth, including any MCP, but excluding any plant subject to the provisions of Chapter II or Chapter III of Directive 2010/75/EU (the Industrial Emissions Directive).



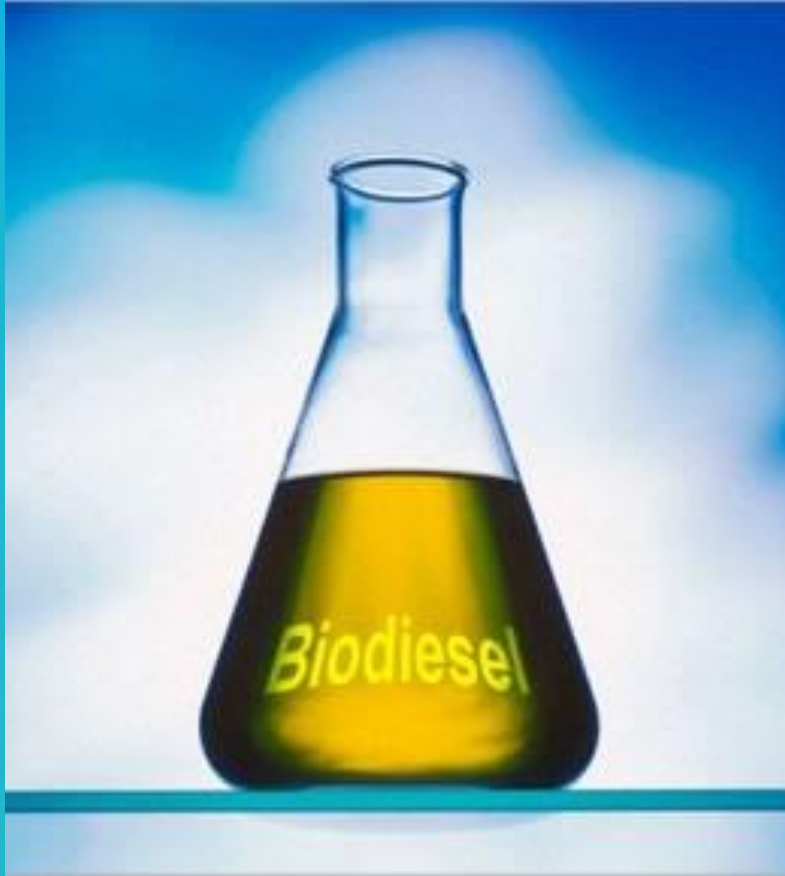
# GTL/HVO : CHEMICAL COMPOSITION

	Biodiesel (FAME / RME)	Red diesel 10 ppm Sulphur	Paraffinic diesel HVO/GTL	Fischer-Tropsch (BTL)
<b>Raw material</b>	Vegetable oils & animal fats (mainly rapeseed oil)	Crude oil (mineral oil)	Flexible mix of raw materials (vegetable oils & waste fats) or Gas	Biomass
<b>Technology</b>	Esterification	Traditional refining	Hydrotreating	Gasification & Fischer-Tropsch
<b>End product</b>	Ester-based, conventional biodiesel	Hydrocarbon (gasoline, jet fuel, diesel)	Hydrocarbon (renewable diesel, jet fuel, bionaphta, biopropane) Paraffinic Diesel	Bio-based hydrocarbon (renewable gasoline, jet fuel, diesel)
<b>Chemical composition</b>	$\text{O II}$ $\text{H}_3\text{C-O-C-R}$	$\text{C}_n\text{H}_{2n+2}$ + aromatics	$\text{C}_n\text{H}_{2n+2}$	$\text{C}_n\text{H}_{2n+2}$

FAME = Fatty Acid Methyl Ester, conventional biodiesel RME = Rapeseed Methyl Ester, conventional biodiesel BTL = Biomass to Liquid

**GTL/HVO** are paraffinic diesel / EN 15940 / US ASTM D975 2D fuels with very a high cetane number, no sulphur and no aromatics. Thus reducing emissions of toxic hydrocarbons, nitrous oxides and particulate matter (PM) with no unwanted impurities.

# UK'S HISTORIC SOLUTION: BIODIESEL



## BENEFIT VS GAS OIL

- Less Particulates and total hydro carbon emissions, and no Sulphur emissions
- GHG savings 45%+ to 87%

## PROBLEMS VS GAS OIL

- Up to 12% more NOx emissions especially at higher loadings/gears
- Low quality esterification\* leaves many impurities resulting in filter and fuel injection issues
- Impurities, water attraction and high O<sub>2</sub> content (10-12%) reduces storage life
- High distillation point and impurities results in more oil changes
- Freezing point influenced by feed stock characteristics: Palm oil: +10°C, Soya: -5° to +2°C, Tallow: +15°C, & Rape seed: -12° to -16°C

## RESULT

- In the UK, apart from the RTFC incentivising B7, little uptake.
- Engine warranties above 30% biodiesel (B30) in diesel, very difficult to obtain
- 15 years since arrival, biodiesel has not established a presence as a 100% fuel

*\* Esterification is the processing vegetable oil/animal waste with alcohol creating Methyl or Ethyl esters*



# HVO/GTL: THE CLEAN EFFICIENT DROP IN DIESEL CHOICE

	Fossil Diesel EN590/ASTM D975 2D	HVO EN15490/ ASTM D975 2D
AROMATICS	30% carbon deposits in fuel system & engine	NONE. CLEANS THE ENGINE. LESS MAINTENANCE.
CETANE VALUE	45 - 48	70-95 RAPID COLD START, LOWER EXHAUST EMISSIONS, LESS NOISE
ENGINE OIL	OK	NONE: NO SULPHUR, NO OXIDATION, NO POLYMERIC REACTION PRODUCTS
EFFICIENCY	OK	SAME AS OR BETTER THAN FOSSIL DIESEL AT NORMAL LOADS
EMISSIONS	Poor overall	REDUCES BY UP TO: NOX 69.6%, PM 2.5 84%, PM10 75%, GHG (GREEN D+) 90% (REDUCTION DEPENDENT ON FEEDSTOCK)
SULPHUR CONTENT	OK: 10 - 20PPM	NONE
STABILITY/STORAGE	OK	INDEFINITE
ASH/METALS	OK	NONE: NO EFFECT ON EXHAUST AFTER TREATMENT SYSTEMS
COLD PROPERTIES	-12c needs additive thereafter	SUITABLE FOR VERY COLD WEATHER CONDITIONS -22oC to -47°C; NO ADDITIVE NEEDED

# ENGINE TRUCK & POWER MANUFACTURE WARRANTIES



JOHN DEERE



Paraffinic Fuels/EN 15940 fuels are ASTM D975 2D Fuels.  
Over 90% of NRMM (and on road) engine manufacturers warrant these fuels 100%

# THE PEDIGREE OF EN 15940 FUELS / PARAFFINIC DIESELS

Used by:

- US Navy, Italian Navy, Scripps Institution of Technology, Dutch Waterways
- In the USA:
  - Cities of California & Oregon (e.g. San Francisco ,Oregon, Oakland etc) run their buses, fire engines, waste trucks and NRMMS on EN 15940 fuels
  - Google run their Science Park buses
  - UPS is switching their delivery vans to it (eventually across USA/Europe)
  - The 2016 Super Bowl's "Generator City" and Shuttle Buses powered by it
- Hamburg Airport switched from DERV to EN 15940 fuels in Nov 2016.
- Qatar airport runs on GTL
- Netherlands/Rotterdam Harbour mandate GTL on inland waterways.:
- EN 15940 fuels are 40% of the Swedish/Finnish on road markets
- Aggreko, 2016 - Eurovision Song Contest and UK festivals 2016-2019
- GLA and TfL: approved use in London buses



# Year 2019 (Sweden - 119 Years later)



- All diesel sold in Sweden in 2019 consists of up to 40% Hydrotreated Vegetable Oil (HVO) and 7% Rape Seed Oil (RME).
- Over 100 HVO100 (%) pumps and increasing.



**HVO100 – räddaren i  
dieselnöden**

**HVO100 – The rescuer in the diesel emergency**

December 2018 – Gothenburg

Volvo XC60 (2010) – Filled up with HVO during my one week stay.

No difference noticed in engine performance, although a noticeable increase in smiles per mile was experienced! 😊



*April 2019 - Volvo have announced that **ALL** of their engines, both heavy and personal car, new or old are now certified for HVO use. VW are being reported to be following this with the same.*

# THE PEDIGREE OF EN 15940 FUELS / PARAFFINIC DIESELS: LESS MAINTENANCE NEEDED

- DAF/Brake Bros, Aug 2018 GTL Test:
  - 40% less NOx and no DPF regeneration on Euro 6 trucks needed – less maintenance and better fuel efficiency
- Utrecht, Netherlands: Fleet of 142 Euro 5 and 166 Euro 6 Buses:
  - GTL is a drop in Fuels, Less Noise, Less Particulates and NOx & less fuel consumption
  - Far less maintenance of their after treatment systems needed – significant saved costs
- Hitachi Zaxis 5 excavators in Norway:
  - On GTL – as efficient as diesel, less emissions and no cold start issues even at -20°C
- D B Schenker, Netherlands, Locomotives:
  - GTL reduced local emissions and helped reduce operational and maintenance costs
- Eugene Water and Electric Board, Oregon, USA:
  - Discovered that renewable diesel (HVO) is much easier on vehicle engines and diesel particulate filter systems. After making the switch, a significant decrease in maintenance issues was noticed.
- San Diego, California:
  - “Renewable diesel is going to help a significant portion of our fleet run much cleaner with less wear and tear on the engines compared to petroleum diesel.”
- Oregon, California:
  - Renewable diesel can also be used in any diesel powered vehicle or equipment, even those where traditionally fleet managers have had no alternative fuel options such as off-road vehicles, construction equipment, auxiliary engines, generators, etc.
  - To summarize, it’s cleaner burning, displaces petroleum consumption and can be used in all existing diesel fuel tanks and vehicles at no additional cost, converting the entire diesel fleet to alternative fuel overnight. I know, it sounds too good to be true...but it is!

# GTL/HVO

## non-toxic, readily biodegradable and easier / safer to handle

- Under criteria recognised by the European Chemicals Agency (ECHA), GTL/HVO Fuel is classified as having health and environmental benefits when compared with regular diesel. This is because it is not harmful if inhaled, fumes pose less risk of eye irritation, there is less risk of skin irritation and it does not cause significant organ damage through prolonged or repeated exposure. In vitro tests also indicate that the fuel is not materially carcinogenic.
- GTL/HVO as such is practically insoluble in water.
- The odour of GTL/HVO is very weak and of a paraffinic nature.
- GTL/HVO Fuel is more biodegradable than conventional diesel. OECD 301 and 307 tests have shown that GTL/HVO Fuel can be classified as 'readily biodegradable', and was not detectable in soil 51 days after being introduced.



# Sustainability certification

## **Sustainable raw materials**

- HVO Renewable diesel produced from sustainably produced renewable raw materials.
- All the raw materials are sourced in compliance with the EU Renewable Energy Directive requirements.
- 100% of the renewable raw materials are traced back to their origin.
- Certification systems used include ISCC and HVO Scheme.

# HVO: RENEWABLE RAW MATERIALS SAVE GHG



**Used cooking Oil**



**Waste animal fat from the food industry**



**Waste fat from fish processing industry**



**Camelina oil**



**Jatropha oil**



**Soybean oil**



**Rapeseed oil**

All the renewable raw materials that are used in refining, offer the users of HVO an opportunity to reduce greenhouse gas emissions (GHG) by 52–93% compared to Gas oil.

Not over-reliant on any ONE feedstock

# HVO PROOF OF SUSTAINABILITY (POS) CERTIFICATION



An ISCC EU POS certificate re GHG saving up to 200 miles from UK store tank is supplied with every delivery / batch

- Every element of a supply chain for sustainable materials must provide evidence of compliance with the sustainability criteria of the Renewable Energy Directive 2009/28/EC amended through Directive (EU) 2015/1513 and the Fuel Quality Directive 2009/30/EC (FQD) amended through Directive (EU) 2015/15131. This is obtained through the individual certification of every supply chain element. To ensure that all of the relevant product properties and related sustainability characteristics are forwarded through the supply chain to the quota-obligated party (i.e. economic operators bringing sustainable biofuels or bioliquids onto the market), adequate traceability and chain of custody measures are required.
- According to the International Organization for Standardization (ISO) the term ‘traceability’ describes the ability to identify and trace the origin, distribution, location and application of products and materials through supply chains.
- ‘Chain of custody’ is a general term for making a connection between sustainability information or claims regarding raw materials, intermediate and final products. Different chain of custody methods are available for the handling of sustainable materials along the supply chain.
- The combination of both the traceability and chain of custody requirements ensure that the physical flow of materials can be traced back and forth throughout the supply chain, which guarantees the integrity of sustainability statements. This also ensures that sustainability characteristics can be assigned to individual consignments of material, and that the amount of sustainable material withdrawn at any stage of the supply chain does not exceed the amount of sustainable material supplied. The term consignment, or ‘batch’, describes a specific amount of material with the same sustainability characteristics. In the following the term ‘batch’ will be uniformly used.
- ISCC is a globally leading certification system covering the entire supply chain and all kinds of biobased feedstocks and renewables. Independent third party certification ensures compliance with high ecological and social sustainability requirements, greenhouse gas emissions savings and traceability throughout the supply chain. ISCC is officially recognised by the European Commission under the European Energy Directive (RED).

# CARBON ACCOUNTING WORKBOOK (CAW)

HVO has now become a separate fuel type listing in the Carbon Accounting Workbook (CAW) -Version 13 (February 2019):

HVO - EF: 0.042 KgCO<sub>2</sub>e/MJ

RED proposed average from crops: 1.53423 kgCO<sub>2</sub>e/litre

GTL:  
THROUGH  
REDD+ CARBON  
OFFSET  
CREDITS  
ACHIEVES 100%  
GHG SAVING

- Purchasing REDD+ credits from Code REDD projects ensure that you are contributing to protection of the world's remaining forests. The astounding fact is that deforestation, at roughly 15% of global annual greenhouse gas emissions, is pumping more CO<sub>2</sub> into our atmosphere than the *entire global transportation sector*. Addressing the perverse economic incentives driving deforestation is widely recognized as a critical element to advancing comprehensive climate strategies.
- That is why the United Nations created the REDD+ mechanism to quantify and value the carbon storage services that forests provide. By making forests more valuable standing than felled, REDD+ provides forest communities and developing countries with a NEW, sustainable, low-carbon pathway to economic growth.

# PURE GTL/ HVO: EN 15940 Diesels - less harmful



GTL/HVO Diesels

Conventional fossil diesel

Average emission reductions with 100% Paraffinic Diesels

NOx-emissions: -10 %

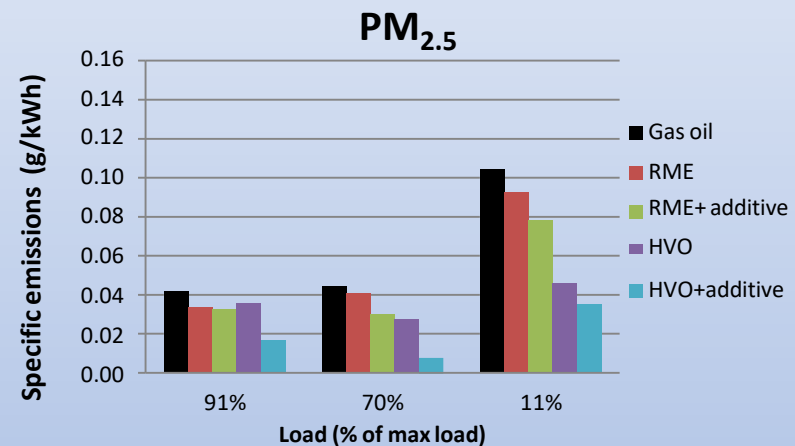
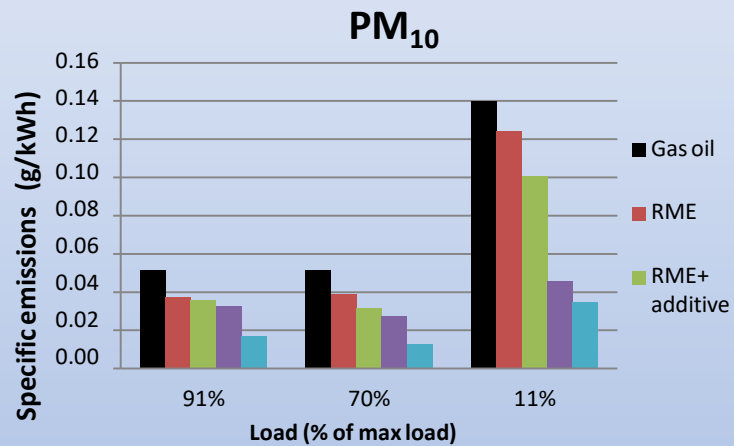
PM-emissions: -30 %

CO-emissions: -35 %

THC-emissions: -40 %

PAH compounds: reduced significantly

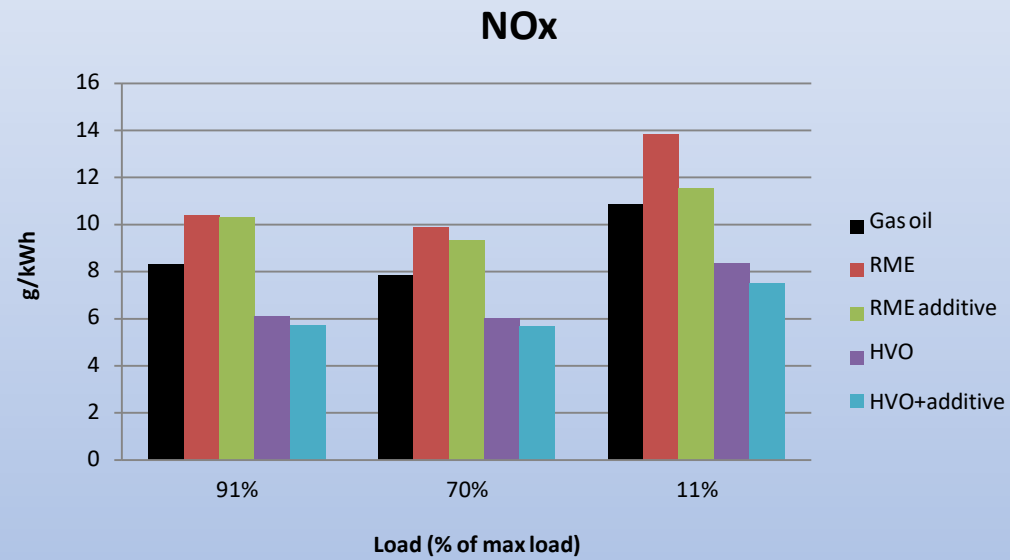
# HVO Renewable diesel



The genset used has a maximum capacity of 128 kW (160 KVA) at 50Hz and complies with EU stage II emission standard.



# HVO Renewable Diesel + Additive NOx test results



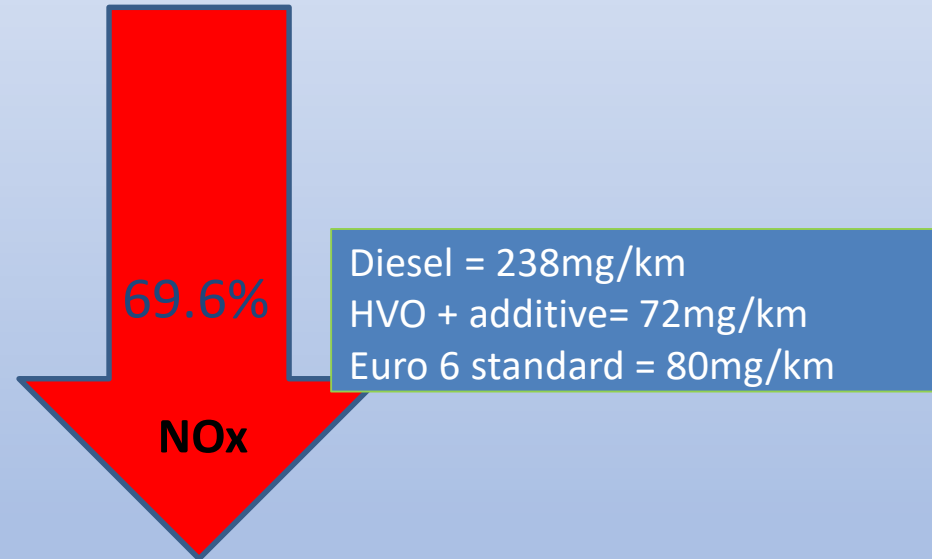
NOx concentrations in exhaust for five fuels at three engine load conditions



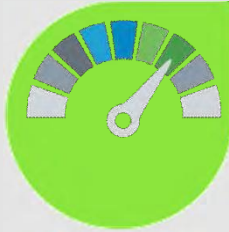
**HVO Renewable Diesel + Additive SLASHED NOx in Euro VI engine exhaust emissions in an urban cycle test by 69.6% allowing the engine to meet the legal Euro VI requirement of 80mg/km with 11% improved productivity**



Millbrook/TFL test: Dennis Eagle Elite 6 waste truck January 2017



# Clean Paraffinic Diesels are ideal for fleet Operations



## High performance

Free of sulphur, oxygen, and aromatics. Together with a high cetane number of 75-95 the fuel ensures an efficient and clean combustion.

## Smaller environmental footprint

Reduces greenhouse gas emissions by up to 90% in addition to sizable reductions in tailpipe emissions.



## Lower operating costs

Longer service and maintenance intervals than for other alternative fuels.

## Superior cold weather performance

Suitable for very cold weather conditions. No matter the raw material, Neste guarantees its fuel will exceed cold temperature requirements.



## Long shelf life

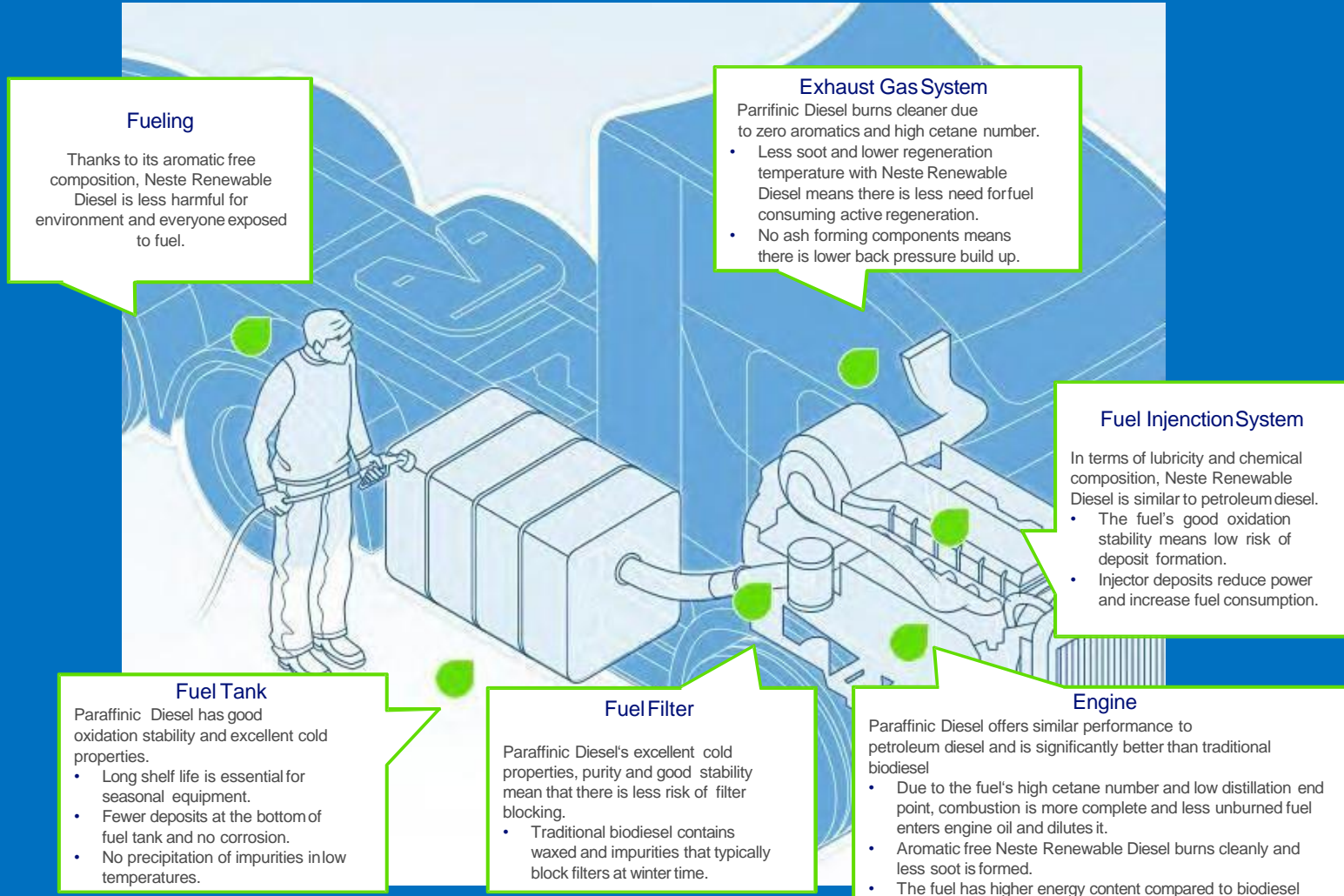
Can be stored over long periods of time with no deterioration in quality or water accumulation.

## Easy switch; no additional investments

Fleets can switch to HVO Renewable Diesel overnight without any conversion of vehicles or to logistics systems.



# Paraffinic Diesel effect on vehicles



# GTL/HVO: Paraffinic Diesel

- Summary of Emissions results on 2x 175 kVA generators at 70% load, compared to Gas Oil:
  - NO<sub>x</sub> reduced by 27%
  - PM<sub>10</sub> reduced by 75% and PM<sub>2.5</sub> reduced by 84%
  - A poorly performing Tier II engine achieved a Particulates emissions level of Tier V from just the drop in fuel
  - Productive output equivalent to Gas Oil
- No “sell by date” on the life of the fuel in the tank unlike Biodiesel
- Summary of results of tests run by Tfl/GLA in a Euro VI (Jan 2017) waste truck showed a 70% tailgate NO<sub>x</sub> reduction & a +11% improved productive output compared to DERV
- Effective Cold Filter Plugging Point (CFPP)
  - -22°C to -41°C engineered into the product (i.e. no Cold Flow additive needed)
- GTL allows 100% GHG saving thru Carbon offsetting
- High Cetane of 70+: very good cold starts
- Can be mixed in any percentage with any EN 15940 fuel or with DERV /Gas Oil
- Far less maintenance needed and prolongs machinery life – thus cheaper than Diesel
- UK Budget Oct/Nov 2018: Warning that Red diesel rebate duty will be raised. Paraffinic diesel’s left alone? Being Resurrected?



# HVO & BIODIESEL RTFC/GHG BENEFITS & PRICING

FUEL	DEFAULT GHG SAVING.	RTFCs	GHGs	GROSS ARA/LITRE	NET ARA/LITRE
UCOME (sg 0.878)	83%	2	2.5	£1	£0.2751
HVO (sg 0.78)	83%	2	2.5	£1.09	£0.3651
ULSD (sg 0.83)	0	0	0	£0.40	£0.40

## Assumptions re 03 01 2020:

£ = \$1.31

RTFC = £0.2975

GHG = £0.053

UCOME = \$1496 mt

HVO (UCO derived) = \$1830 mt

ULSD = \$631 mt

- Net price after RTFC/GHG credits but before Fuel duty and VAT
- sg = specific gravity

GHG Credit mandate needs to be reapplied for 01 01 2021 onwards by the RTFO

Neste HVO from UCO achieves a 92% GHG saving