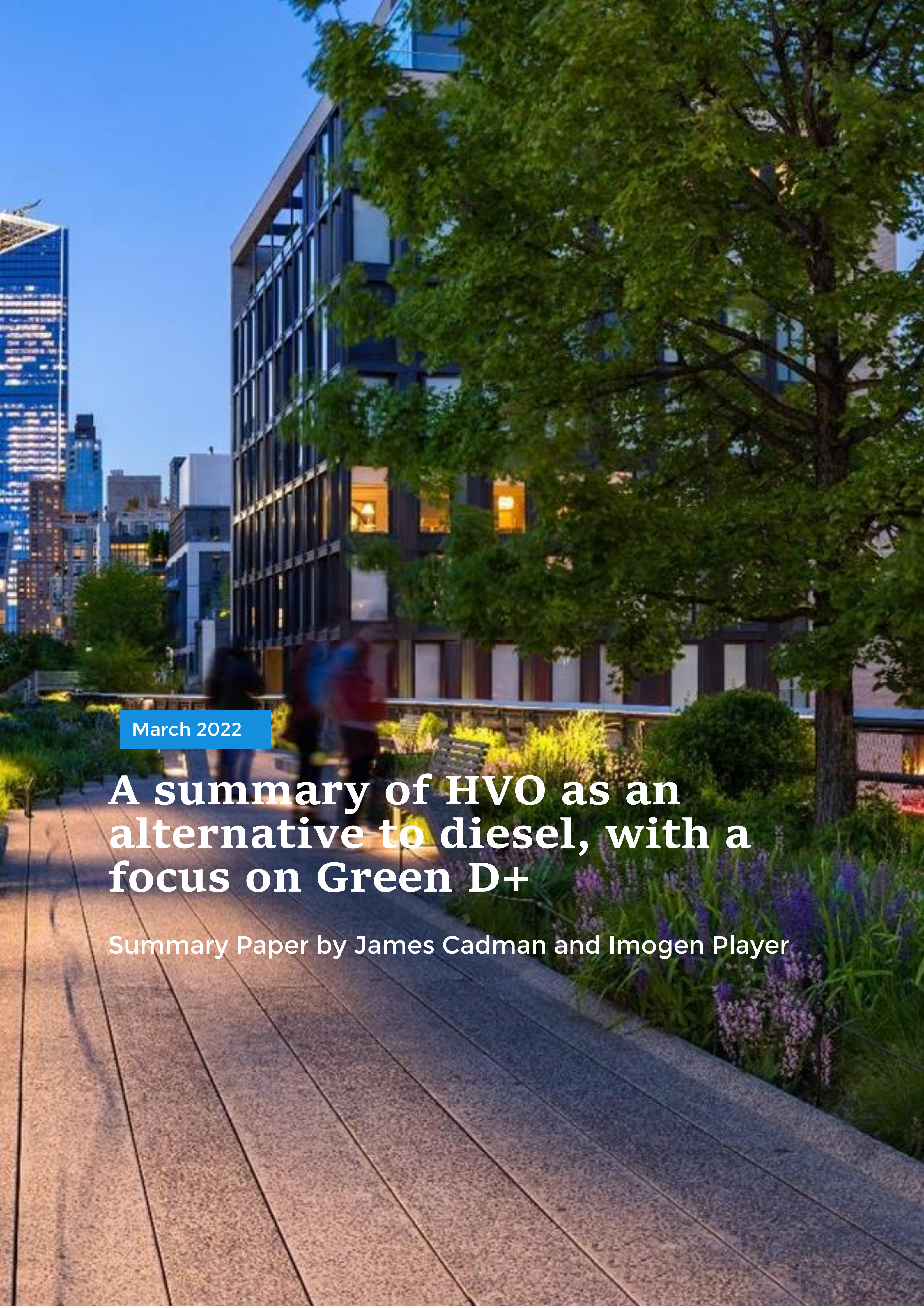


March 2022

A summary of HVO as an alternative to diesel, with a focus on Green D+

Summary Paper by James Cadman and Imogen Player

Contents

Executive Summary

Hydrotreated Vegetable Oil (HVO) has gained a lot of attention recently as an alternative fuel to conventional diesel due to the fact that it claims to have lower sustainability impacts through its life cycle, from production to use. It is seen by many as a 'stepping stone' between standard fossil fuels and zero emission fuels.

This report into the impacts of HVO, when compared to diesel, was originally commissioned by Barratt Developments Plc who have kindly agreed to share its findings through the Supply Chain Sustainability School for everyone's benefit. The information and recommendations expressed in this report are those of Action Sustainability, who undertook the research.

The scope of this report was to review one particular brand of HVO, namely **Green D+ HVO**, in terms of its sustainability impacts and viability as an alternative fuel option to conventional diesel. While this report focused on one brand of HVO, the findings and recommendations are relevant to all brands of HVO fuel. The report provides detail on composition process, the environmental, social and ethical impacts of its production and use, as well as relevant certifications.

Key Learning Points

- HVO has significant benefits when compared to conventional diesel, which include:
    - Life cycle CO_2e emissions reduced by up to 90%, including well-to-tank and in use;
    - Improved local air quality from a reduction in nitrogen oxides (NOx) and particulate (PM) emissions;
    - A greater start-up efficiency at colder temperatures when compared to other biodiesels;
    - Being a 'drop-in' fuel so there is no need to change infrastructure;
    - Longer shelf life compared with FAME (Fatty Acid Methyl Ester) biodiesels as it is less prone to bacterial growth; and
    - Use of waste oils as feedstock, such as waste vegetable oils and waste animal and fish fats.

- Green D+ HVO is just one brand of HVO. The report's conclusions apply across other sources of HVO. Therefore, consider the benefits of using any type of HVO, so long as it meets your requirements for supply chain due diligence, provenance of feedstock and performance of the fuel in use.

- While you can use HVO as an alternative 'drop-in' fuel to conventional diesel in the medium-term, it needs to be part of a wider long-term strategy to transition to other alternative, low carbon power sources, such as hybrid, electric and/or hydrogen, depending on your use of plant, available infrastructure and market availability. The use of alternative fuels should be clearly aligned with efficient operator behaviour to get optimised productivity and reduced emissions.

- HVO should be sourced from a reputable supplier, who has good quality procurement and due diligence checks in place. As such, the fuel should meet the standards for diesel fuel: EN 15940; EN 590 and ASTM D975.

- Moreover, ensure that any HVO sourced comes with certification from the ISCC (International Sustainability & Carbon Certification) and RFAS (Renewable Fuels Assurance Scheme). Avoid palm oil wastes within the feedstock where possible. If that is not possible, ensure it meets the Renewable Energy Directive and is RSPO (Roundtable on Sustainable Palm Oil) certified.

What is HVO Fuel?

Hydrotreated Vegetable Oil (HVO) is a fossil-free, paraffinic biofuel. It is typically made by reacting waste vegetable oils and animal fats with hydrogen at high temperature and pressure to create fuel suitable for use in diesel engines.

It is considered a sustainable alternative to conventional diesel on the journey to zero emissions power. When compared with diesel combustion it leads to reduced GHG emissions over its life-cycle, coming from renewable feedstocks, and can reduce emissions of NOx and PM.

HVO is certified against the standards for diesel: EN 15940, EN 590 and ASTM D975, more of which below.

HVO is a paraffinic, renewable fuel that can be used as a drop-in alternative to fossil diesel - you don't have to flush or clean the engine before use, and many engine manufacturers now warrant its use. It's a second generation, synthetic, advanced renewable diesel alternative; second generation biofuels are attractive as the raw materials can be composed completely of 'left-over' waste oils and fats that don't interfere with the human food chain.

HVO has a higher cetane number and a higher energy density than diesel and other biodiesels, which means it burns more efficiently.[1]

[1] Greenea: Is HVO the Holy Grail of the world biodiesel market?

HVO has better user performance than both conventional diesel and Fatty Acid Methyl Esters (FAME) biodiesel as it starts better at colder temperatures, due to reduced oxygen content.

This aspect of its chemical structure also means that it is much less hygroscopic (absorption of water) leading to a much lower likelihood of mould growth whilst it is in tanks; in other words, the product can be stored for longer.

Green D+ specifically is undetectable in water immediately, and in soil after 51 days. However, the Environment Agency still class Green D+ as a fuel and must therefore be treated as such after a spill and cleaned up according to protocols for diesel spills.

The process for making HVO is provided in Appendix 1.

Green D+ HVO is one specific brand of HVO, manufactured by Green Biofuels, and sold by distributors such as New Era Fuels and Speedy Services. There are other types of HVO, e.g. Neste's MY Renewable Diesel™. All tend to draw their raw material feedstock from the same sources, and in many cases from the same supplier: Neste.

Green D+ HVO is the same as other HVO fuels, the only difference being the inclusion of an additive – cerium oxide – which works to further reduce emissions of NOx to N_2 in the exhaust gases, whilst oxidising incomplete combustion products (hydrocarbons, PM (Particulate Matter) and carbon monoxide).

Sustainability
Carbon and Air Quality

HVO has been tested by several organisations for its carbon and air quality emissions. Defra/ BEIS have emissions factors for HVO in their annual update.

HVO, and Green D+ HVO specifically, can reduce CO_2 emissions by up to 90% over the life cycle in comparison with conventional diesel. The largest reduction is at the exhaust (98%), but there are still reductions in production (50%). ***NB***: out of scopes emissions still need to be accounted for.

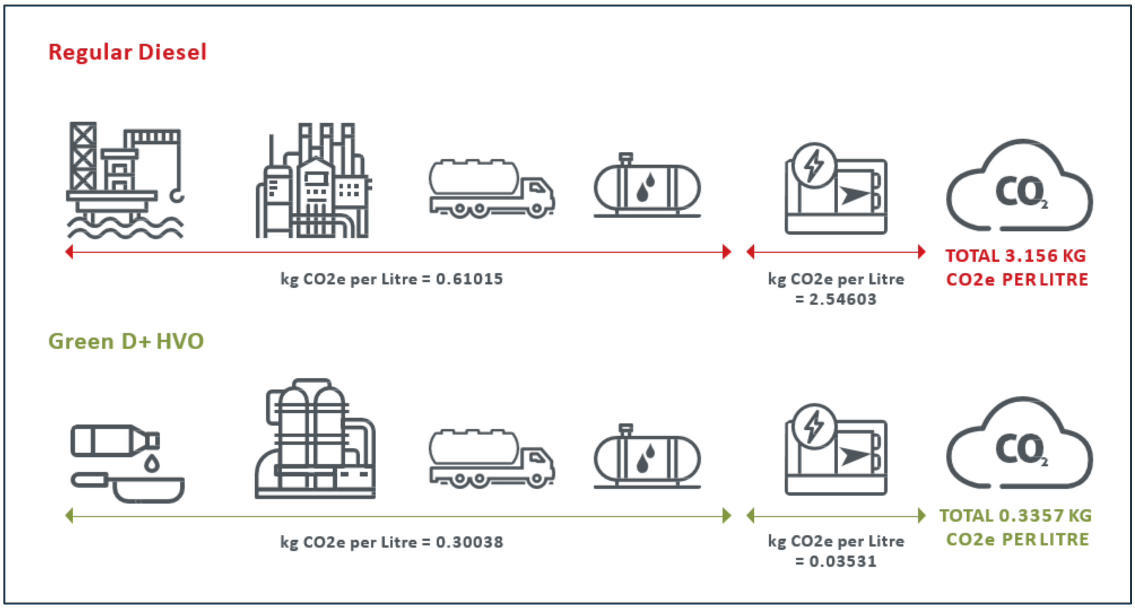


Figure 1. CO2 emissions associated with the production and use of diesel [2]

When using HVO, local air quality emissions can be dramatically improved, with reductions in NO_x and PM emissions of 19% and 65% respectively when compared to standard diesel. Manufacturers of Green D+ claim that these emissions can be reduced by 30% and 85% respectively.

[2] Source: Conversations with Speedy Hire Services

Sustainability

Raw Materials

HVO is used from waste products, such as vegetable oil and animal and fish fats. By purchasing ISCC-certified HVO – more of which below - you can ensure that waste feedstocks are used, and virgin materials are not. Moreover, it certifies the protection of land with high biodiversity value or high carbon stock, as well as deforestation-free supply chains.

Waste palm oil – oil that is waste to the palm refining process – is used in some HVO blends. Palm oil is allowed under the EU Renewables Energy Directive II, at least until 2030, like other waste oil products from cooking, etc.

To meet EU Legislation on biofuels, palm oil has to come from plantations that have been in operation since 2007 or earlier, i.e. 2008 is the cut-off date.

But there are reputational concerns about it being derived from other activities that have caused deforestation, even if it is a waste (virgin palm should not be considered).

Moreover, any palm oil content should have chain of custody and traceability to a sustainable origin. The RSPO (Roundtable on Sustainable Palm Oil) criteria and certification is the most widely accepted method for independent 3rd party certification. As such proceed with caution if an HVO product contains palm oil. Consider any with existing policies on palm oil. If possible, avoid the use of any palm oil at all.

Using verifiably 100% certified sustainable palm oil from organisations such as the Roundtable on Sustainable Palm Oil is the first step on this journey, but given the severity of the supply risk, the goal should be to eliminate its use altogether.
CIPS, 2021

Sustainability
Ethical Labour Standards

Purchasing HVO from reputable suppliers with ISCC-certified HVO and enacting due diligence can reduce the risk of poor labour standards and modern slavery.

Modern slavery is prevalent across the world, and Neste, the main HVO producer globally, state that there is a risk of modern slavery in the countries in which they operate. They identify there to be an extreme risk in India and Cambodia, a high risk in countries such as China, Indonesia, Mexico and Brazil, and a medium risk in countries such as USA, Russia, Italy, South Africa and Saudi Arabia. [3]

As such, undertaking good sustainable procurement practices, with due diligence, traceability and supply chain management are the key steps towards reducing the risk of modern slavery and improving labour rights associated with the production of HVO. Using systems such as ISCC are a key part of this.

[3] Neste Modern Slavery Statement 2020

Certifications

ISCC

The International Sustainability & Carbon Certification (ISCC) is a sustainability certification system covering the entire supply chain and all kinds of biobased feedstocks and other materials. ISCC certification provides full traceability along the supply chain and details the provenance of the feedstock, and its composition. The ISCC certification assures the production, processing and transportation processes of the fuel.

ISCC EU is a certification system to demonstrate compliance with the legal sustainability requirements specified in the Renewable Energy Directive (RED) of the European Commission and the Fuel Quality Directive (FQD). ISCC is a partner of the Food Security Standard (FSS) which can be integrated into existing sustainability standards like ISCC.

ISCC certified 96% of all UK renewable fuel in 2019, with other Renewable Transport Fuel obligation (RFTO) voluntary schemes including: RSB, 2BSVS, Redcert EU and HVO Renewable Diesel Scheme 1.

Palm oil, and waste palm oil, can be present within ISCC certified feedstock. It is recommended however that the use of any palm oil is avoided within ISCC certified fuels.

HVO, and Green D+ HVO, should be certified against ISCC.

RFAS

The Department for Transport's Renewable Fuels Assurance Scheme (RFAS) is an initiative designed and managed by Zemo partnership. The voluntary scheme enables suppliers to be a certified 'renewable fuel supplier' and so operators purchasing the fuel receive renewable fuel declarations, detailing the types and volumes of renewable fuel purchased, the GHG emissions intensity and savings as well as details of the types of raw material feedstocks and certification.

The scheme's focus is on enabling operators to obtain supply chain specific GHG emissions data, thereby ensuring accurate and representative information for company scope 3 carbon reporting.

RFAS works alongside the UK Government's Renewable Transport Fuel Obligation (RTFO).

As with ISCC, palm oil, and waste palm oil, can also be present within RFAS certified product. It is recommended however that the use of any palm oil is avoided within RFAS certified products.

HVO, and Green D+ HVO, should be certified against RFAS.

ISCC or RFAS: Should fuel be certified to both?

Whilst the schemes may seem similar, they are different, and fuel should be certified to both.

ISCC is an international scheme that guarantees feedstock through the entire supply chain from collection to delivery to end users. This is fully auditable where the supplier has full chain of custody for the product.

RFAS is a new UK based scheme for the DFT, to verify claims that companies supplying renewable fuels make about the GHG savings and raw material feedstocks. Carbon certificates can be issued to end users so, if for instance, a company buys carbon credits under the UK Emissions Trading Scheme, they can produce certificates to prove the reduction in CO_2e emissions and buy less credits.

Certified Sustainable Palm Oil Standard

The RSPO has developed a set of environmental and social criteria which companies must comply with in order to produce Certified Sustainable Palm Oil. This standard does not specifically apply to waste palm oil and is relevant instead for raw palm oil.

Diesel Standards

HVO, and Green D+ HVO, align with the following standards for diesel

- EN 15940 Standard for Paraffinic Diesel Fuel;
- EN 590 Standard for Diesel Fuel;
- ASTM D975 Standard Specification for Diesel Fuel.

These standards do not take into consideration whether the origin is sustainable (i.e. whether it is a fossil or renewable source) since that part of the fuel supply chain is regulated only in fuel and feedstock directives. The only requirement is that the final fuel meets the defined technical requirements.

So, the HVO you use could be meeting EN 15940 standard, but may be sourced unsustainably – therefore it is recommended that you source from a provider who is certified against ISCC and the RFAS, as detailed above.

Red-marked fuels for off-road use are currently taxed at 11.14p per litre. This applies to both “red diesel” and “red HVO”.
From April 2022, the construction sector will no longer be able to get this rebate and will have to use conventional “white diesel” or “white HVO”, both of which are taxed at 57.95p per litre.
Whilst HVO currently has a price premium compared to diesel, the benefit it brings is in lower GHG, NOx and PM10 emissions and can be seen as a route to more sustainable operations.

EN 15940 has two main fuel grades: high cetane class A (70 minimum) and normal cetane class B (minimum 51). It’s recommended that you purchase HVO that is of class A standard.

Ester type biodiesel (FAME) standard EN 14214 is not valid for HVO, since they consist of hydrocarbons only and not esters, so this standard is not relevant.

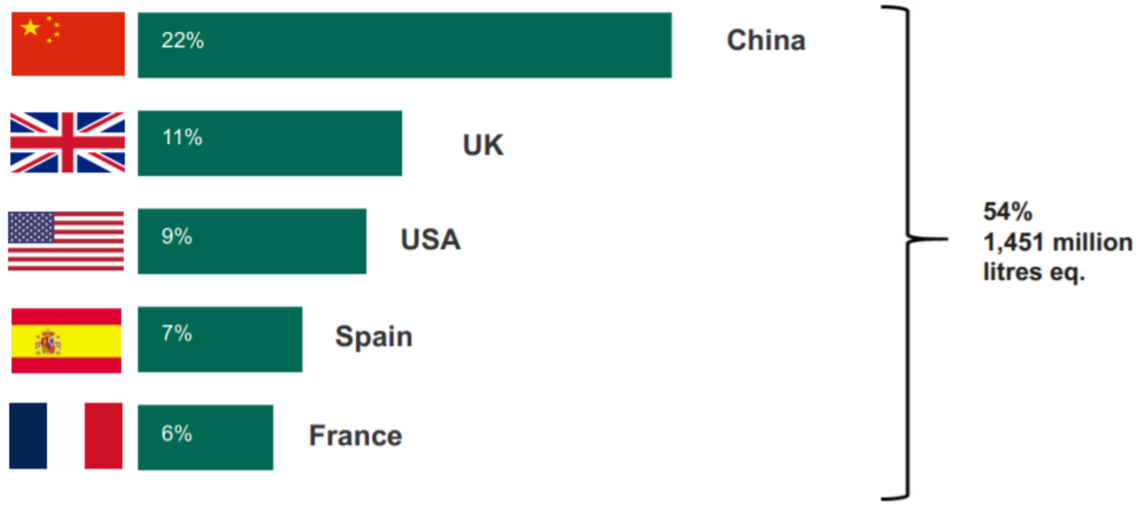
HVO can be blended with diesel, however it is recommended that you use 100% HVO to reduce emissions as much as possible. There is no need to slowly transition over as HVO is a drop in fuel so can be used immediately.

Are there any other risks to switching to HVO?

There was an increase in the proportion of renewable fuel from Asia from 23% in 2018 to 34% in 2019. This was driven largely by an increase in biodiesel from used cooking oil from China and Malaysia. The proportion of renewable fuel from the UK decreased from 16% in 2018 to 11% in 2019.

Supply and demand of HVO, and Green D+ HVO specifically, may prove to be the biggest risk. As demand goes up there might be a drive in the sector to produce more and cut corners. As long as HVO is sourced from a reputable supplier and due diligence is in place, the risk of modern slavery and environmental degradation for feedstocks is reduced.

Figure 2. CO2 emissions associated with the production and use of diesel [4]



Should there be supply and demand issues, options to overcome this could include committing to volumes with the supplier, or blending with diesel. A reminder again that HVO is seen as the transitional solution whilst hydrogen and electricity technologies are improved.

[4] Department for Transport, Renewable Fuel Statistics 2019 Final Report

Checklist of Sustainability Credentials

Make the following checks to ensure that you are purchasing HVO from a sustainable source:

- Ensure that you are purchasing from a reputable supplier who can prove supply chain traceability for the feedstocks.
- Undertake your due diligence checks.
- Ensure that fuels are ISCC and RFAS certified; this accounts for the feedstock production, processing and transportation of the fuel.
- Avoid the use of palm oil in the composition of the feedstock.
- Ensure that fuels meet the diesel standards: EN 15940; EN 590 and ASTM D975; this accounts for the fuel in use.

Other Power Sources

HVO is seen as a transitional replacement for diesel, whilst the technology and market availability of electric and hydrogen sources progress.

For handheld tools and smaller equipment, battery powered sources, or those with a flex to connect to the grid, already exist and are common. These should be used in place of diesel sources.

For larger equipment, where direct connections to the mains are possible, these are favoured. Renewable sources, such as solar, are appropriate for some items such as lighting towers.

Where direct connections are not possible, consider hybrid engines, and as a last resort, Stage V diesel engines could be used.

HVO is very much seen as a short to medium term solution. Development and roll-out of low emission, alternatively powered plant, such as hybrid, electric and hydrogen, is seen as the long-term replacement for diesel. Hydrogen especially is seen as the long-term goal and replacement for conventional fuels.

Other HVO sources:

Neste's MY Renewable Diesel:

- Meets EN 15940 requirements for paraffinic diesel fuels, and ASTM D975 requirements. [5]
- This is the most common HVO, as Neste are the biggest producer of HVO.
- Many different distributors will provide HVO.

Hydrogen

Hydrogen fuel cells are now being used and are seen as a clear alternative to fossil fuels. But they are still an emerging technology and are expensive in comparison with more conventional fuels. Be careful as not all sources of hydrogen gas are the same. It can be produced from cracking fossil fuels – so called 'blue hydrogen'. While you have no local air quality emissions when consumed in a fuel cell, overall it does not reduce the impact on the climate as fossil fuels are still being consumed. Much better is 'green' hydrogen, which is manufactured using renewable energy to electrolyse water to produce the hydrogen. Prices are currently high compared to other forms of fuel and the

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[5] Neste MY Renewable Diesel

necessary infrastructure and availability of suitable kit is still nascent. However, this is truly zero carbon with no GHG emissions or local air quality pollutants, especially at the larger, heavier end of NRMM.

Electric

Electric battery power has many advantages to fossil fuel use. It significantly reduces carbon emissions when charged from a sustainable source, such as a direct electricity mains connection to the grid or even better from a renewable source such as solar panels. Possibly more importantly, when compared to a petrol- or diesel-powered alternative, they reduce air quality emissions for the user and local neighbourhood. Furthermore, without a combustion motor, they also reduce noise, helping to maintain productive relationships with local communities. It is important that green tariffs are used; this means that some or all of the electricity that you buy is 'matched' by purchases of renewable energy that your energy supplier makes on your behalf – typically from wind farms and hydroelectric power stations. Hand tools and indoor access plant all have the capability and market availability to be used via electricity.

Hybrid

Hybrid power sources are readily available for lighting, small plant, access equipment and power and welfare accommodation. Stage V hybrid engines can be combined with a variety of other power sources, such as solar and battery.

Biogas

This is a renewable fuel produced by the anaerobic digestion (without oxygen) of organic matter such as animal manure, municipal rubbish/ waste, plant material, food waste or sewage. Once compressed, it can be used as a fuel for vehicles, and if cleaned up and upgraded to natural gas standards it can be used as biomethane for cooking and heating.

Appendix 1:
Production of HVO

HVO is synthesised from vegetable oils or animal fats using hydrogen as a catalyst. Its purity allows it to significantly reduce harmful emissions when used in diesel vehicles, by improved burning efficiency. Hydrogenation removes all oxygen from the vegetable oils which gives an advantage to the HVO production as it helps to avoid oxidation. The feedstock for HVO can be the same or much lower quality than for producing biodiesel. Paraffin is the main HVO output product which is a synthetic, clean liquid fuel, and propane is the by-product. They have low aromatic and naphthenic hydrocarbon content and zero sulphur.

HVO production differs to biodiesel production: whilst the feedstock is similar, biodiesel is produced by the transesterification of methanol, producing FAMEs (Fatty Acid Methyl Esters), which contain more oxygen. Glycerine is the by-product in the production of biodiesel. FAME biodiesels are likely to hold a higher water content than HVO, which can often lead to microbial growth and fuel contamination.

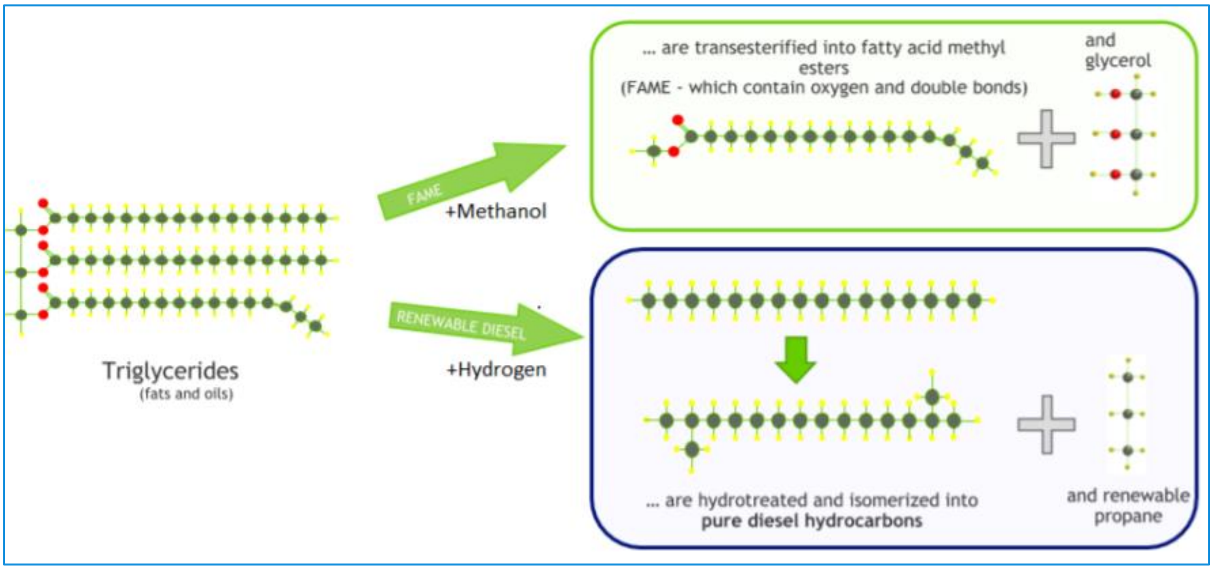

Figure 3. Simplified version of biodiesel process (top) vs HVO process (bottom) [6]

[6] Neste [Renewable Diesel Handbook]

Typical feedstocks for both biodiesel and HVO:
- Vegetable oils (preferred).
- Animal and fish fats - from food industry waste and fish processing waste.
- Waste cooking oils (palm, rapeseed and sunflower).
- Residues from vegetable oil processing.
- Technical corn oil.
- Tail oil pitch.

Vegetable oils have high concentrations of unsaturated fatty acids, and animal fats have higher concentrations of saturated fatty acids.

Typically, the process to produce HVO is already a mature commercial scale manufacturing process, as it is based on oil refining processes and is used for the production of biofuels for diesel engines. Hydrogen is used to remove oxygen from the feedstock, for example, triglyceride vegetable oil molecules, and splits the triglyceride into three separate chains, thus creating hydrocarbons that are similar to diesel fuel components. The hydrotreating process consists of 3 main reactions: hydrodeoxygenation, decarbonylation and decarboxylation. The fully saturated paraffinic hydrocarbon is the main product (HVO) that is then used as fuel (shown in the figure 2 as 'R-CH2-CH3). Triglycerides are contained in the biomass lipids, and H2 saturates the double bonds of the triglyceride at mild temperatures (280-450C) and mild pressures (1-5MPa) and solid catalysts of mild acidity.

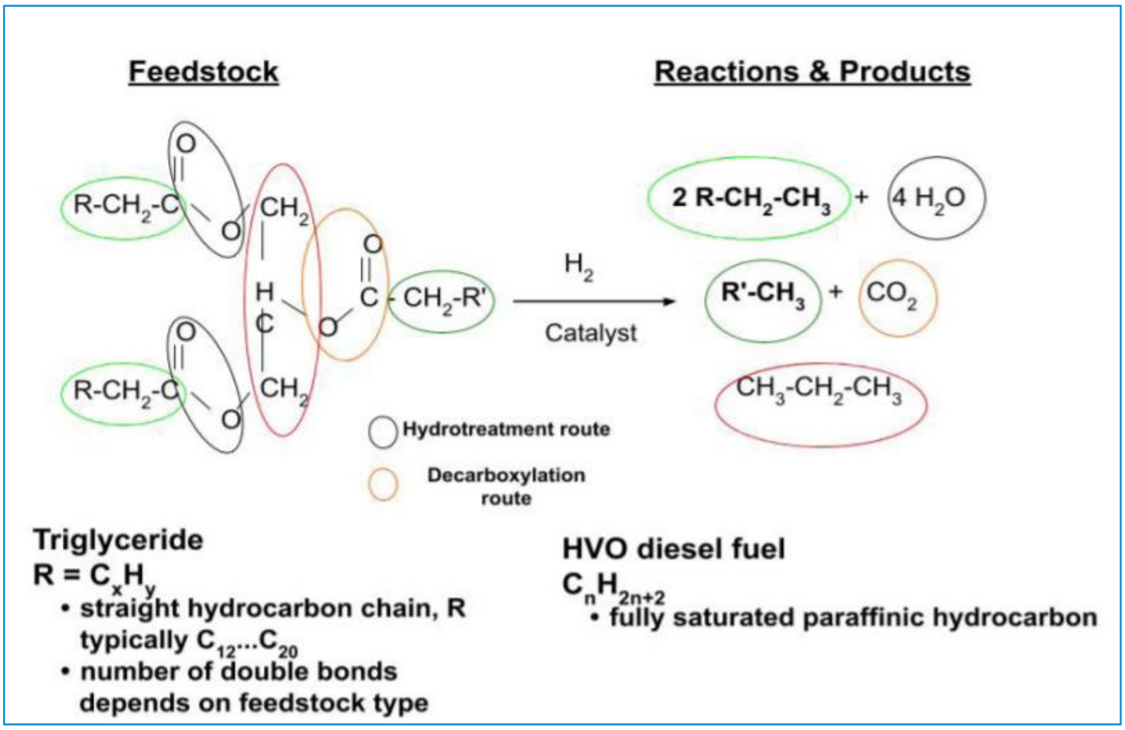

Figure 4. Chemical reaction to demonstrate the most common method by which HVO is produced - hydro-processing. NiMo is most commonly used as the catalyst.

By-products in the production of HVO:

1. Water
2. Carbon dioxide
3. Propane

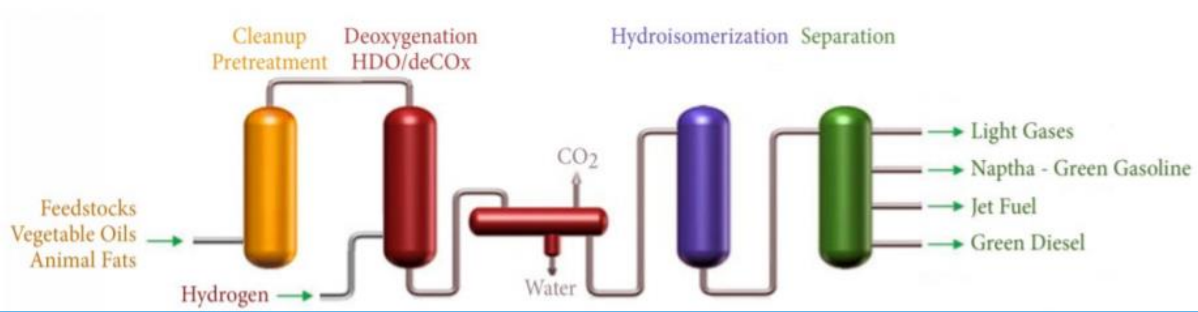

Figure 5. Schematic representation of a standalone biomass hydroprocessing plant, where 'Green diesel' is HVO [7]

Company Name	Location	Feedstocks	Capacity	Technology
Neste	The Netherlands	Vegetable oil and waste animal fat	1,000,000 tn/year	NExBTL
Neste	Singapore	Vegetable oil and waste animal fat	1,000,000 tn/year	NExBTL
Diamond Green Diesel	USA	Non-edible vegetable oils and animal fats	900,000 tn/year	Ecofining™
UOP/Eni	Italy	Vegetable oils, animal fats and used cooking oils	780,000 tn/year	Ecofining™
Neste	Finland	Vegetable oil and waste animal fat	380,000 tn/year	NExBTL
Renewable Energy Group (REG) Inc.	USA	High and low free fatty acid feedstocks	250,000 tn/year	Dynamic Fuels LLC
AltAir Fuels	USA	Non-edible natural oils and agricultural waste	130,000 tn/year	Ecofining™
UPM Biofuels	Finland	Crude tall oil	100,000 tn/year	UPM BioVerno

Figure 6. The main HVO producers currently in operation globally [7]

[7] Douvartzides et al., 2019, Green Diesel: Biomass Feedstocks, Production Technologies, Catalytic Research, Fuel Properties and Performance in Compression Ignition Internal Combustion Engines, Energies.

Green D+ HVO is an enhanced HVO, achieved by the addition of an additive to HVO. This additive reduces NOx and PM emissions even more than HVO.

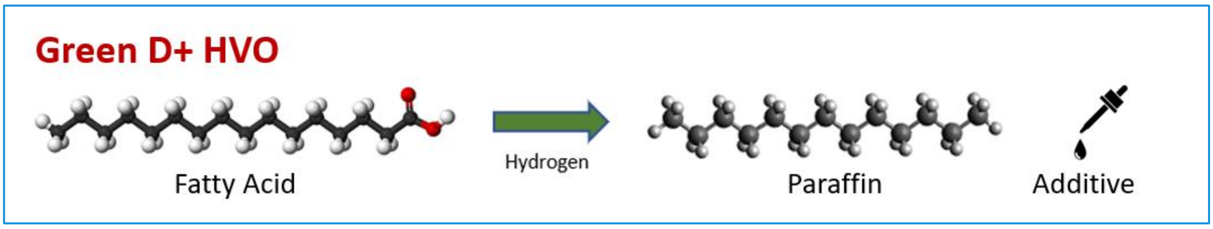

Figure 7. Simplified diagram of Green D+ HVO production. The paraffin is HVO, and an additive is added to produce Green D+ HVO [8]

MILLBROOK TRIAL ON EURO VI WASTE TRUCK		
	GREEN D+ HVO	HVO
CO_2e	↓ 90%	↓ 90%
NO_x	↓ 30%	↓ 19%
PM	↓ 85%	↓ 65%

Figure 8. CO2e, NOx and PM emissions reductions when comparing Green D+ HVO and HVO with conventional diesel [8]

[8] Conversations with Speedy Hire Services

Appendix 2:
Fuel Specification

						Green D+	
Properties	Unit	Test Method	EN 590	EN 15940	ASTM D975	Min	Max
Cetane number	-	EN 15195	> 51	> 70	> 40	70	-
Density at 15ºC	kg/m³	EN ISO 12185	820 – 845	765 – 800	-	770	790
Sulphur content	mg/kg	EN ISO 20846	< 10.0	> 5.0	< 15.0	-	5.0
Flash point	ºC	EN ISO 2719	> 55	> 55	> 52	61	-
Carbon residue (on 10% distillation residue)	% (m/m)	EN ISO 10370	< 0.30	< 0.30	< 0.35	-	0.10
Ash content	% (m/m)	EN ISO 6245	< 0.010	< 0.010	< 0.010	-	0.001
Water content	mg/kg	EN ISO 12937	< 200	< 200	-	-	100
Total contamination	mg/kg	EN ISO 12662	< 24	< 24	-	-	10
Copper strip corrosion (3h at 50ºC)	Rating	EN ISO 2160	Class 1	Class 1	Class 3	Class 1	
Oxidation stability	g/m³	EN ISO 12205	< 25	< 25	-	-	25
Lubricity, corrected wear scar diameter (wsd 1.4) at 60ºC	mm	EN ISO 12156-1	< 460	< 460	< 520	-	400
Viscosity at 40ºC	mm²/s	EN ISO 3104	2.0 - 4.5	2.0 - 4.5	1.9 – 4.1	2.0	4.0
Distallation IBP % (V/V) recovered at 250ºC % (V/V) recovered at 350ºC 95% (V/V) revocered at	 ºC % (V/V) % (V/V) ºC	EN ISO 3405	 - < 65 > 85 < 360	 - < 65 85 < 360	 - - - -	 180 - 85 -	 - < 65 - 320
Cloud Point (Summer/Winter) and CFPP	ºC	EN 23015 / EN 116	Down to -34	-	-	-15/-32 CFPP reported	
Appearance	-	Visual	-	-	-	Clear and bright	
Total aromatics content	% (m/m)	EN 12916	-	< 1.1	< 35	-	1.0
Electrical Conductivity	pS/m	ISO 6297	-	-	-	100	-
Acidity total (TAN)	mgKOH/g	ASTM D3242	-	-	-	-	00.1
Sediment, particulate matter	g/kg	EN 12662	-	10	-	-	< 1
Net heat of combustion, measured	MJ/kg	ASTM D4809	-	42	-	-	44

Figure 9. Green D+ HVO Fuel Specification

Benefits of HVO, and Green D+ HVO, over diesel and biodiesel[9]:

- High cetane number (above 70).
- Good cold operability due to reduced oxygen content (better than biodiesel).

[9] Conversations with Speedy Hire Services

- Free of aromatics or naphthenes (as in diesel) so provides a cleaner combustion.
- Through an isomerisation process, severe winter and arctic grades are available.
- Stable so don't need to apply a 'use before' date.
- Long-term oxidation stability means that there are no risks if vehicles or stationary engines with HVO in their fuel tanks are out of use for extended periods.
- Sulphur and ash contents are low – low ash means that it doesn't cause excess burden for modern exhaust aftertreatment systems.
- Low water solubility (similar to diesel) (especially compared with FAME biodiesel) so less water content enables less microbial growth.

Appendix 3:
Case Studies

Carnell: Green D+ HVO
Highway maintenance contractor Carnell piloted the use of Green D+ HVO fuel with plant hire firm Speedy. They replaced their regular diesel usage with the HVO fuel to power lighting equipment and the site compound for a Highways England central barrier upgrade on the M6. The scheme, which spans six kilometres, has used more than 4,300 litres of the renewable fuel and confirmed a 90% reduction in CO_2e emissions compared to diesel fuel use.

Learn More

Sir Robert McAlpine: Green D+ HVO
Working on 21 Moorfields in London, Sir Robert McAlpine wanted to trial the use of Green D+ HVO to minimise their carbon footprint and reduce disturbance to the local community. 21 Moorfields is a major commercial development covering approximately 564,000ft^2. Two 500kva generators were used, along with Green D+ fuel, and it is estimated that 118 tonnes of CO_2e was saved when comparing with conventional red diesel. Additionally, NOx emissions were reduced by 29%, and airborne particulates were reduced by 77%.

Learn More

Vinci: HVO
Vinci completed a successful trial of HVO in 2020. Their trial used two brand-new 40kva generators running continually for 4 hours whilst connected to exactly the same load to ensure a consistent data set. They found that it eliminated up to 90% of net CO_2 emissions, and significantly reduced NOx, PM and CO emissions.

Learn More

BAM: HVO

BAM construct and BAM Nuttall are switching to HVO instead of diesel, which they state will be 15% more expensive, but worth it to meet the decarbonisation aspirations of their clients. They have signed a supply deal with Crown Oil, and the transition will be phased.

Learn More

Skanska: Green D+ HVO

Skanska is switching to Green D+ HVO to power all of its site plant and equipment, in its drive to become net zero carbon by 2045. The Green D+ HVO is supplied by Green Biofuels Ltd. Their ambition longer term is to move to hydrogen or electrification, so whilst this technology is not currently available at the scale and pace that Skanska require, they are using Green D+ HVO.

Learn More

John Sisk & Sons: HVO

John Sisk & Son delivered a scheme in Cambridgeshire that successfully used over 1.5 million litres of HVO as an alternative to gasoil to fuel the earthworks plant and equipment needed to build the 5km of highway and create future development areas. This approach saved over 4550 tonnes of CO2e, a 91% reduction on what would have been generated otherwise. The approach also resulted in an 80% reduction in harmful particulate matter and a 50% reduction in sulphur oxide emissions.

Learn More

Appendix 4:
Sustainability Issue Scope

Sustainability Issue	Relevant to HVO	Scope within report
Air quality	Yes	Reduction in pollutant emissions when using HVO (and Green D+ HVO specifically) in comparison with diesel
Biodiversity	Yes	Palm oil and land use associated with feedstocks
Carbon and energy	Yes	Reduction in carbon emissions when using HVO (and Green D+ HVO specifically) in comparison with diesel
Environmental management	Yes	Pollution and spills
Equality, Diversity and Inclusion	No	Lower priority compared to labour standards and BDW has less influence with supply chain
Labour standards	Yes	Including modern slavery. Due diligence and transparency of supply chains is key to sustainable HVO use
Materials	Yes	Using waste materials as feedstock to reduce raw material use
Waste and resource efficiency	Yes	Using waste materials as feedstock to reduce raw material use and waste produced
Water	No	Less of an impact in comparison to GHG and AQ

Appendix 5:
Glossary

Term	Abbreviation	Definition
Air Quality	AQ	The degree to which the air in a particular place is pollution-free.
ASTM D975 Standard		Standard specification for diesel fuels
Biodegradable		Capable of being decomposed by bacteria or other living organisms
Biodiesel	Also known as FAME (Fatty Acid Methyl Ester)	This is different to HVO – it is produced by the transesterification of triglycerides contained in biomass matter such as vegetable oils (e.g. rapeseed, soybean, palm, corn, sunflower, coconut, peanut, camelina) animal fats, used cooking oils. The biomass lipids are combined with methanol, and the triglycerides are transformed into FAME/biodiesel.
BS EN 15940 Standard		Standard specification for paraffinic diesel fuels
Cetane number		Number used to indicate the combustion speed of diesel fuel and compression needed for ignition. A higher cetane number indicates a shorter ignition delay and a better performance of the fuel. It is the equivalent of the octane number to gasoline.
Greenhouse Gases	GHG	A gas that contributes to the greenhouse effect by absorbing infrared radiation. Carbon dioxide and chlorofluorocarbons are examples of greenhouse gases.
Gas-to-Liquid	GTL	A refinery process that converts natural gas or other gaseous hydrocarbons into longer-chain hydrocarbons, such as gasoline or diesel fuel.
Hydrotreated Vegetable Oil	HVO	HVO is the main name within the industry, as well as in the fuel standards and European regulations Can often also be referred to as 'green diesel', 'renewable diesel', 'second generation diesel', 'bio-hydrogenated diesel', 'hydrogenated esters and fatty acids (HEFA)', 'hydrogenated vegetable oil'

Term	Abbreviation	Definition
International Sustainability and Carbon Certification	ISCC	A sustainability certification system covering the entire supply chain and all kinds of biobased feedstocks and renewables
Lipid		Substance that is insoluble in water and soluble in non-polar solvents such as alcohol, ester, chloroform. Lipids are one of the main constituents of plant and animal cells (along with carbohydrates and proteins). Cholesterol and triglycerides are lipids.
Nitrogen Oxides	NOx	Any of several oxides of nitrogen, most of which are produced in combustion and considered to be atmospheric pollutants, such as: nitric oxide, nitrogen dioxide and nitrous oxide.
Non-Road Mobile Machinery	NRMM	A broad category which includes mobile machines, and transportable industrial equipment or vehicles which are fitted with an internal combustion engine and not intended for transporting goods or passengers on roads.
Original Equipment Manufacturer	OEM	An organisation that makes devices from component parts bought from other organisations
Particulate matter with diameters that are 10 micrometres and smaller	PM_{10}	A mixture of solid particles and liquid droplets found in the air.
Particulate matter with diameters that are 2.5 micrometres and smaller	$PM_{2.5}$	A mixture of solid particles and liquid droplets found in the air.
Roundtable on Sustainable Palm Oil	RSPO	Established in 2004 with the objective of promoting the growth and use of sustainable palm oil products through global standards and multistakeholder governance.
Renewable Transport Fuel Obligation	RTFO	Supports the UK Government's policy on reducing GHG emissions from vehicles by encouraging the production of biofuels that don't damage the environment.
Renewable Fuels Assurance Scheme	RFAS	Initiative designed and managed by Zemo partnership. The scheme aims to verify claims made by companies supplying renewable fuels to heavy-duty vehicle and equipment operators regarding their product's GHG emission savings and provenance of raw material feedstocks.

Appendix 5:
Research Method

Desk-based research was undertaken to assess the sustainability credentials of Green D+ HVO, and HOV more widely.

All information was found through publicly available information online. Key search terms were used, such as 'HVO', 'Green D+ HVO', 'feedstock', 'sustainability', 'composition', 'certification', etc.

The research was combined with conversations with key subject matter experts, known to Action Sustainability from our work leading the Plant Category Group within the Supply Chain Sustainability School.

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