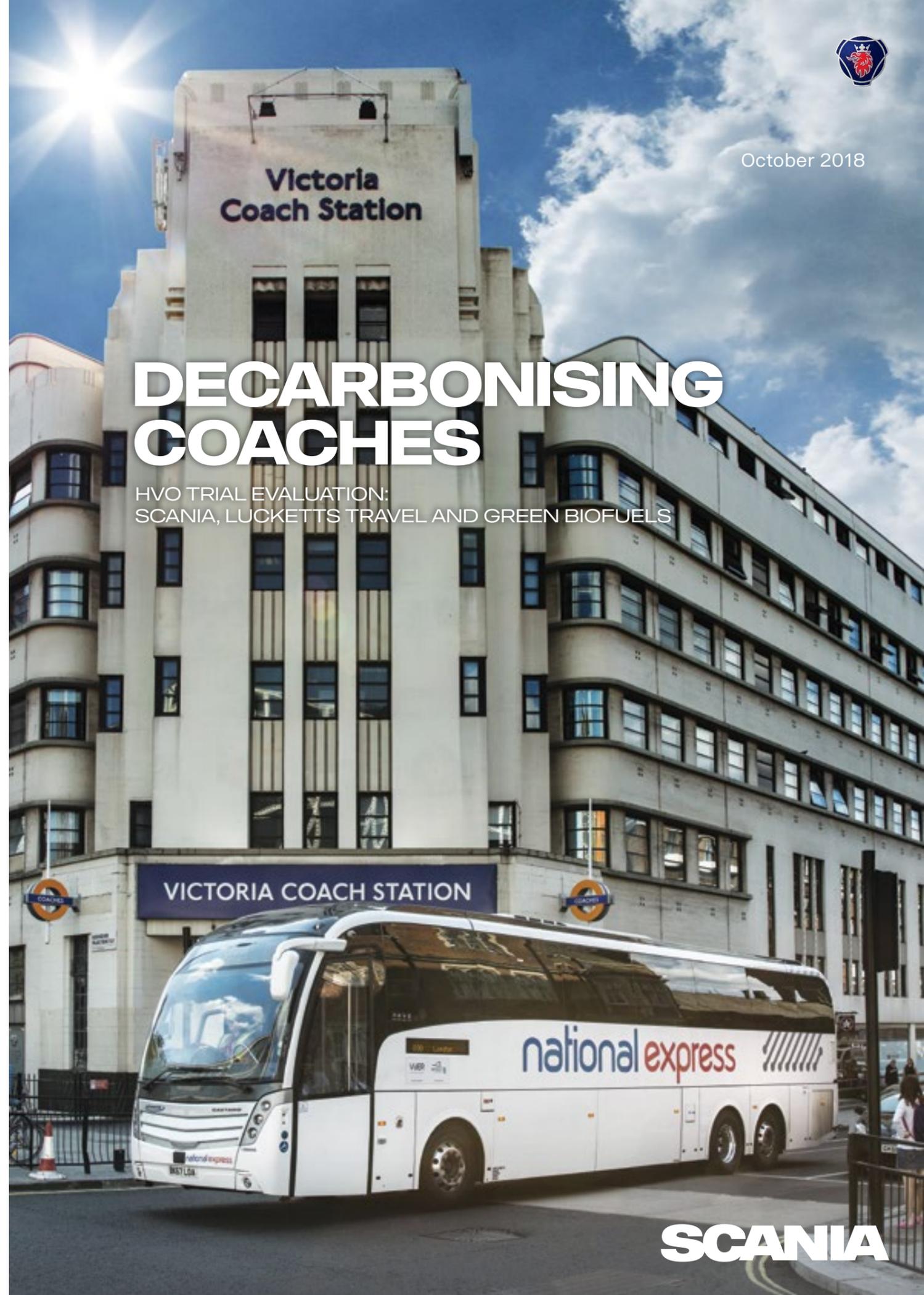




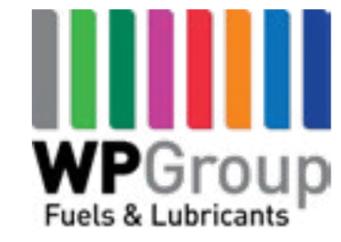
October 2018

DECARBONISING COACHES

HVO TRIAL EVALUATION:
SCANIA, LUCKETTS TRAVEL AND GREEN BIOFUELS



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FOREWORD

As we progress on our low carbon journey and cement Scania's position as a leader in sustainable transport, we are constantly looking at potential opportunities for our customers to shift to a low carbon sustainable solution.

Just as we worked closely with stakeholders to promote the use of bio-gas in the bus industry, we identified such an opportunity in the form of Hydrotreated Vegetable Oil (HVO).

All our engines from Euro IV onwards are able to run without modification on HVO. While the fuel is widely used across the European market, it hasn't had the same level of adoption in the UK.

There are a few myths which may have prevented its uptake in our market, which we have looked at objectively as part of our trial, such as the supply and availability of the fuel. Although the fuel cannot be purchased through the mainstream network, this wouldn't be an issue for a 'back to base' or 'captive fleet'.

All the stakeholders entered into this trial with a number of aims, which this document will cover in more detail.

Our aims included: creating awareness of HVO as an alternative fuel option in coach sector, outlining the benefits as well gaining customer and government acceptance of the fuel and its performance with real-life tangible results.

We sincerely hope that the trial will see government and policy support to encourage HVO use within the coach sector.

The engagement and contributions from all involved with this trial have been great and the commitment they have shown illustrates that we have a real opportunity to drive the shift to a future of sustainable transport.



Martin West,
Sales Director, New Bus & Coach

BACKGROUND AND AIMS

THE TRIAL

As Scania has been developing its Sustainable Solutions portfolio, a potential solution for customers who operate long haul/intercity/scheduled coach services and require a low carbon solution was identified.

Unlike the bus sector, which has seen years of funding support and adoption of clean technology, the only low carbon offer currently available in the coach sector is Euro VI diesel.

This represents a challenge for the coach industry and Scania believed that by highlighting HVO, a plug and play alternative could be introduced demonstrating that coaches can too be part of the solution and can contribute towards the UK's carbon emission targets.

The trial took place from June to September 2018 using Lockett's National Express operations. Two routes were chosen – Portsmouth to London and Portsmouth to Brighton. This was done for comparability.

The routes routinely use 14 vehicles. These were split with seven of the vehicles running on HVO and seven on regular diesel so that a direct comparison can be drawn between the two.

A temporary infrastructure was located at Lockett's Fareham depot, where the HVO vehicles were fuelled.

PROJECT AIMS

The trial had a number of aims, including:

- Decarbonising coaches by using a renewable and sustainable fuel option.
- Creating awareness of low carbon solutions, engaging the coach sector and stakeholders.
- Educating the industry and the wider audience of the existence of HVO and its benefits.
- Gaining acceptance of the fuel and its performance among the industry with real-life data.
- Encouraging the coach sector to look at and adopt a commercially viable alternative to fossil fuels.
- Using the findings to work with government so the fuel can receive support to encourage its use within this segment.
- Offering an alternative to retrofit technology, if proven benefits are realised.

THE VEHICLES

Scania K410 EB 6x2*4 with Caetano Levante II bodywork

- Scania K410 6X2*4
- Caetano Levante II bodywork
- Scania opticruise gearbox and rear axle
- 14.1 Metre
- 56 Passenger Seats

No modifications had to be made to the vehicles ahead of the trial for them to be compatible with HVO.

Before the trial period began, information was gathered to create baseline readings to compare the data taken at the end of the period.



THE FUEL

SCANIA SAYS:

Scania approves HVO EN 15940 as a fuel in its Euro IV, Euro V and Euro VI diesel engines for trucks and buses.

The exception is DC07 101. This is not approved for other mixtures of HVO 15940 than those in accordance with EN 590.

Get in touch with your local Scania representative to talk to them about the alternative fuels suitable for your application.

HVO – A SUSTAINABLE ALTERNATIVE

Hydrotreated Vegetable Oil (HVO) is widely available today throughout Europe, but has not so far been adopted to the same degree within the UK.

The HVO used in the Lockett's National Express trial is produced from used cooking oil (UCO) and is certified palm oil free.

The fuel is being supplied by Green Biofuels, the UK's sole importer of HVO produced by Finland-based Neste.

What is HVO?

The common acronym 'HVO' comes from Hydrogenated Vegetable Oil or Hydrotreated Vegetable Oil – in the case of Neste, the fuel supplier for this trial, it is Hydrotreated. Neste Corporation calls its own product 'Neste Renewable Diesel' and in the case of Green Biofuels, 'Green D'.

The chemical composition is comparable to fossil fuel, meaning it behaves just like conventional diesel. It also offers a 'well-to-wheel' reduction in carbon dioxide of up to 90%. It's often described as a 'splash and go' fuel.

What is Hydrotreatment?

The hydrotreating of vegetable oils as well as suitable waste and residue fat fractions to produce HVO is a quite new but already mature commercial scale manufacturing process. It is based on oil refining know-how and is used for the production of biofuels for diesel engines.

In the process, hydrogen is used to remove oxygen from the triglyceride vegetable oil molecules and to split the triglyceride into three separate

chains, thus creating hydrocarbons which are similar to existing diesel fuel components. This allows blending in any desired ratio without any concerns regarding fuel quality.

It is this manufacturing process that makes HVO a sustainable fuel in the tanks of vehicles as it doesn't clog up the tank or rot any rubber engine components.

CEO of Green Biofuels, Magnus Hammick, simplifies the process of manufacturing HVO: "Essentially it's a big soup made of organic matter which is bombarded with hydrogen, this splits the soup. The top part is HVO and the rest is made up of waste streams, which is put back into the organic soup to be hydrotreated again."

What is it made of?

- Animal fat from food industry waste
- Fish fat from fish processing waste
- Residues from vegetable oil processing
- UCO - Used Cooking Oil
- Technical Corn Oil
- Tall Oil Pitch

But I heard Palm Oil was bad?

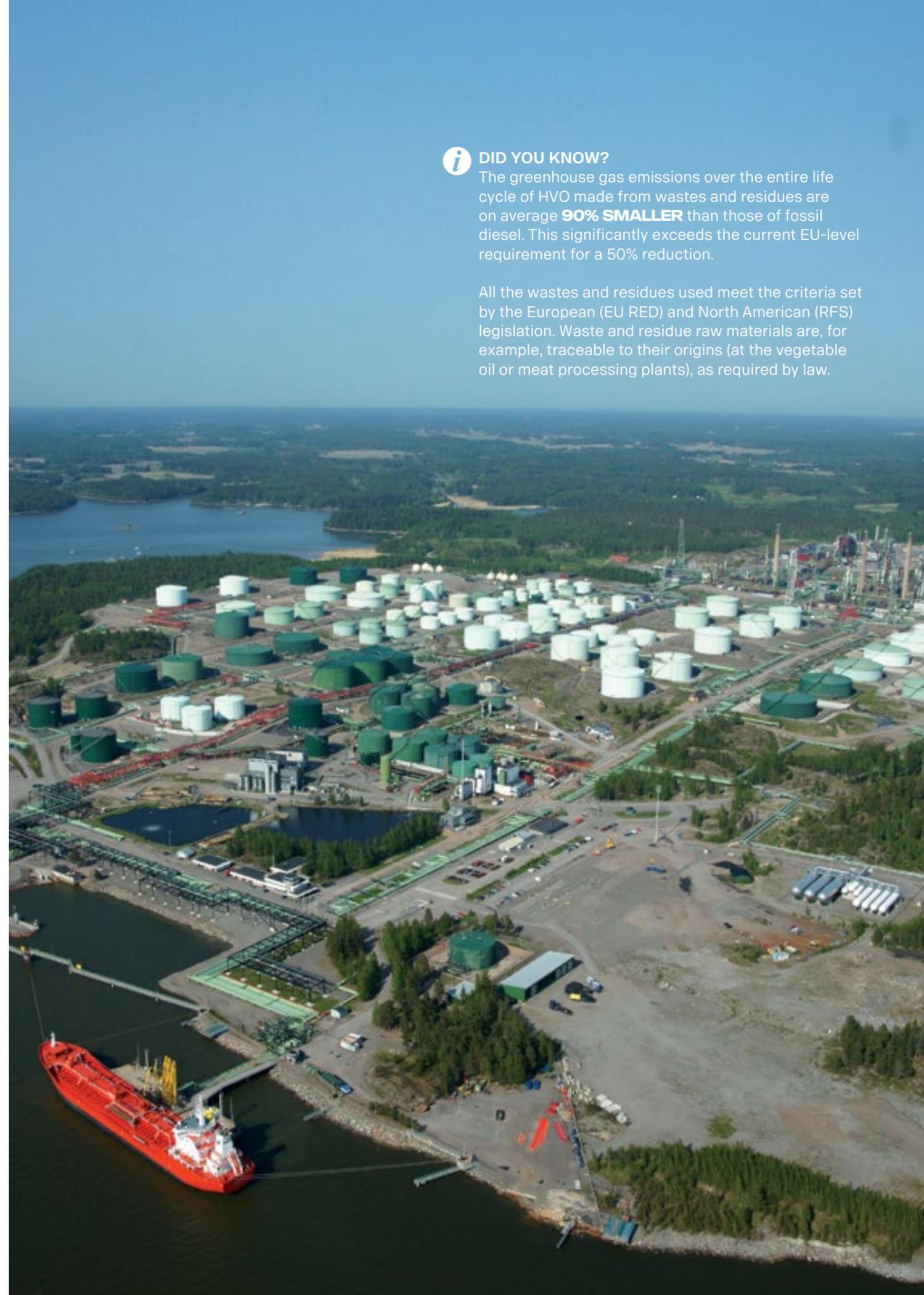
The role of palm oil in Neste raw material portfolio has become less significant in recent years. In 2017, it accounted for approximately 20% of the raw material usage. All the palm oil used in this trial has been fully traceable to the plantation level since 2007, and 100% certified since 2013.

The amount of certified palm oil Neste uses represents less than 1% of the global consumption of palm oil, and 6% of the biofuel industry's usage. All the oils used are on the RED II preferable list.

DID YOU KNOW?

The greenhouse gas emissions over the entire life cycle of HVO made from wastes and residues are on average **90% SMALLER** than those of fossil diesel. This significantly exceeds the current EU-level requirement for a 50% reduction.

All the wastes and residues used meet the criteria set by the European (EU RED) and North American (RFS) legislation. Waste and residue raw materials are, for example, traceable to their origins (at the vegetable oil or meat processing plants), as required by law.





SO WHAT WAS THE OPINION ON HVO FUEL?

We talked to a customer, a vehicle manufacturer and a fuel supplier for their thoughts . . .

MARKET POSITION AND OPPORTUNITIES

Global

Over the last five years, Hydrotreated Vegetable Oil (HVO) production has been developing rapidly on a global scale with more oil majors and dedicated renewable fuel producers investing in HVO production units. The acceptance of HVO is especially prevalent in Europe and the US, but there is growing interest from the Asian market.

According to the greenea.com website, 'Europe will remain, by far, the leader on the HVO market with 3,870,000 MT of installed capacity by 2020'.

Sweden is one of the pioneers in using HVO in Europe. The fuel is available at the pump and accounts for the third largest transportation fuel type in the country.

With further areas of growth on a global scale identified, the trend points toward HVO becoming even more of a popular choice.

United Kingdom

In the UK, the use of HVO is less prevalent to the rest of Europe.

“There has been strong uptake. Typical customers are centrally fuelled users with large capacity diesel engines fleets, on-road, off-road and marine.”

CEO of Green Biofuels, Magnus Hammick, explains more: “The current market for HVO in the UK is small but growing. We have in total

approximately 15 customers who we have supplied approximately 2.5 million litres of fuel to.

“Our conservative estimates, based on these customers moving from trial quantities to full contracted quantities, is for 100–150 million litres during 2019. This is a figure we expect will grow as adoption is more widely known about.

“There has been strong uptake. Typical customers are centrally fuelled users with large capacity diesel engines fleets, on-road, off-road and marine. Those that operate in Low Emission Zones and where air quality and Greenhouse Gas saving is either a regulatory or social issue.”

Green Biofuels has been working to get trials running all over the United Kingdom to raise the profile of HVO as a viable alternative fuel in the UK. They have contracts with organisations such as Red Funnel and Hackney Council.



PERSPECTIVE: VEHICLE MANUFACTURER

PAUL CHAPMAN, PRODUCT DEVELOPMENT MANAGER FOR SCANIA BUS & COACH

What had to be done to the vehicles to make them compatible?

Paul Chapman, explains: "That's the beauty of HVO – nothing! All our Scania engines from Euro IV onwards can run on HVO straight away with no modifications or maintenance changes. It's fully mixable too so can be used in conjunction with regular diesel, from a 'splash and go' perspective, it is ideal!"

How were the vehicles prepared?

"While no changes had to be made to the coaches for the trial to begin, we did perform a number of tasks so that the data from the trial was comparable and we had a baseline to work from. The fuel tanks were checked for contamination and the fuel filters were changed.

"We also took a download from the vehicle's software to get readings for elements including – but not limited to:

fuel consumption, AdBlue usage, mpg of fuel per injector, idling time, average speed and any fault codes that were stored."

What was measured and why?

"We worked alongside the factory in Sweden on data gathered from engine tests in a controlled environment; however the importance of real-life data is also important which is why we wanted to carry out this trial to see how it would perform.

"Put simply, there were three main quantitative measurements:

- Oil – Oil samples were taken from all the vehicles at the beginning of the trial and sent for analysis – these formed the basis of what the oil samples taken at the end of the trial would be compared to.

- HVO – HVO vehicles should in theory be better – would see less wear – expecting, less copper and carbon.

- Vehicle software downloads – Again, a baseline was taken at the start of the trial so that the download at the end of the trial could be compared.

"An independent test was carried out under controlled circumstances at Millbrook Proving Ground."

What's the maintenance of the vehicles like on HVO?

"There has been no additional maintenance to the vehicles which are running on HVO. In theory, there is no additional maintenance required when vehicles are running on HVO and it should be possible, to extend oil change periods.

"This is due to HVO having a higher cetane rating to diesel, meaning it burns cleaner than diesel and produces less soot – this in turn keeps the engine components cleaner."

Paul says: "To give you an idea on cetane rating, diesel has a cetane number of around 53 and in comparison; HVO is around 80-99."

PERSPECTIVE: CUSTOMER

IAN LUCKETT, MANAGING DIRECTOR, LUCKETTS TRAVEL

"We have worked in partnership with Scania for many years so have a strong working relationship.

alternative fuels and solutions at the forefront of our minds.

that are viable for our individual industries.

"When we were first approached about the possibility of taking part in this trial, I asked a few key questions – 'Will we have to make any changes to the vehicles? Will there be any detriment to the vehicles and their maintenance? And is this a commercially viable option for coach operators?'

"What made HVO stand out for me was that there were no changes that needed to be made to the vehicles and the possibility to mix it with regular diesel should the need arise with no negative impact."

"What made HVO stand out for me was that there were no changes that needed to be made to the vehicles and the possibility to mix it with regular diesel should the need arise with no negative impact.

"With the introduction of clean air zones around particular towns and cities, the pressure is on to find a commercially viable option so that operators can keep doing their job.

"When I found out that we wouldn't have to change anything on the vehicles, there could potentially be savings on the maintenance of the vehicles running on HVO and the fuel efficiency would at least be on parity with regular diesel, what's not to like?

"It's been a pleasure to be part of trialling HVO as a potential solution and I sincerely hope that the findings help start conversation within the industry about low carbon and sustainable fuel options."

"It's great to be able to take part in something which can help our industry as a whole. It's important to keep

"When it comes to environmental matters, it's a team effort as we all need to work together to find solutions



Paul Chapman, Product Development Manager for Scania Bus & Coach

i DID YOU KNOW?
Did you know? At the dedicated Scania demo centre in Sweden, all of the demonstration vehicles run on HVO.



WHAT'S NEXT?

Following the trial, it is even more evident that HVO is a viable alternative to regular diesel.

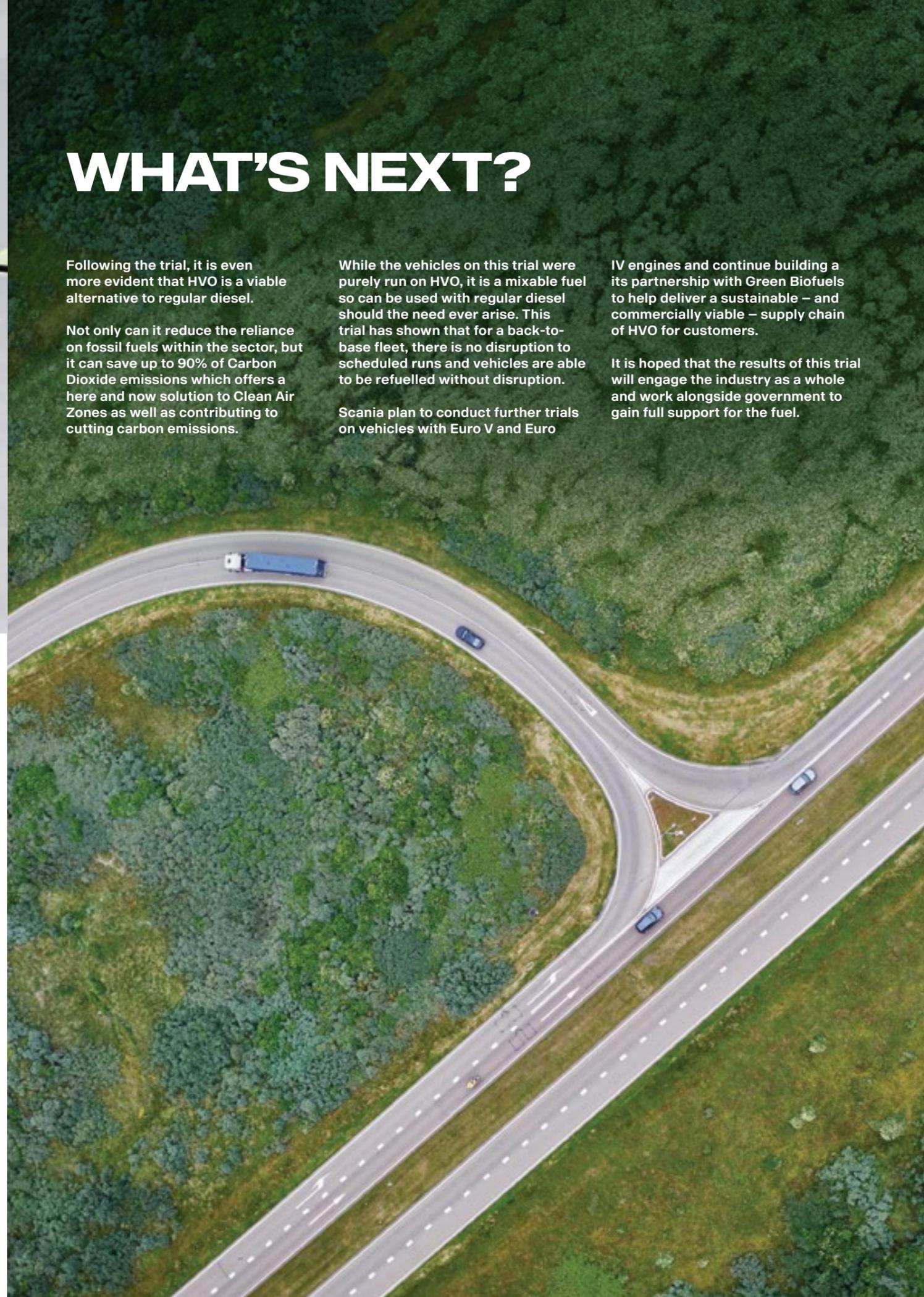
Not only can it reduce the reliance on fossil fuels within the sector, but it can save up to 90% of Carbon Dioxide emissions which offers a here and now solution to Clean Air Zones as well as contributing to cutting carbon emissions.

While the vehicles on this trial were purely run on HVO, it is a mixable fuel so can be used with regular diesel should the need ever arise. This trial has shown that for a back-to-base fleet, there is no disruption to scheduled runs and vehicles are able to be refuelled without disruption.

Scania plan to conduct further trials on vehicles with Euro V and Euro

IV engines and continue building a its partnership with Green Biofuels to help deliver a sustainable – and commercially viable – supply chain of HVO for customers.

It is hoped that the results of this trial will engage the industry as a whole and work alongside government to gain full support for the fuel.



PERSPECTIVE: FUEL SUPPLIER

MAGNUS HAMMICK, COO OF GREEN BIOFUELS ANSWERS YOUR QUESTIONS . . .

How does the infrastructure currently work in the UK?

“Green Biofuels currently have one storage unit in the UK. However, if there is an increase in demand then this would change.”

How much does it cost?

“Direct cost is approximately 5-10% more expensive; but other savings such as CO₂, Greenhouse gases and reduced maintenance and operational costs have very significant benefits.

“Due to the fuel being ‘clean burn’, for a ferry operator, their cleaning costs would be reduced as there would be no smoke from exhaust. Therefore, while the cost of the fuel may be marginally more, the savings could be gained in other ways.

Customers are able to obtain a long-term fixed price contract if they were to sign up for a year.”

How much of the fuel is available?

“We would estimate the UK addressable market to be approximately 10 billion litres and we are targeting 1-2 billion litres. This will require additional capacity outside of Neste, which we are securing now. The available product for UK market is estimated at up to four billion litres.”

What's the RTFO?

“The Renewable Transport Fuel Obligation (RTFO) supports the government's policy on reducing greenhouse gas emissions from vehicles by encouraging the

production of biofuels that don't damage the environment. It is the regulator of the biofuels industry used for transport and non-road mobile machinery.”

What makes it such a good alternative?

“Green D is a low emission, total drop-in replacement for standard diesel. It requires no modification whatsoever – in the case of most engines. It's a splash and go fuel and can be mixed with regular diesel with no detrimental effect.

“In comparison to red diesel, it also lasts longer in the tank and gives better fuel stability. We care about human health and have seen that Green D has the potential to make a significant difference to air pollution today. We want to make that difference happen.”

TEST PROCEDURE AND RESULTS

Scania Euro VI Coach
 Vehicle Engine Testing on Chassis dynamometer
 Comparison of Emissions with Two Fuels: Diesel and Green D



THE VEHICLE

- Scania Coach
- Vehicle No: YN18SSX
- Engine: DC13 115 410hp EuroVI
- Transmission: Scania Opticruise GR875R

Tests were conducted at Millbrook Proving Ground on a Scania Euro VI coach with two fuels which were tested on a chassis dynamometer using the 2017 LowCVP UK Coach (LUC) cycle.

The comparative results are summarised in the Figure below

CO, PM PN: despite the very low limits for the Euro VI engine CO and PM show further reductions with the GD fuel.

'NOx e': This refers to the NOx equivalent. The engine management system ensures that the tail pipe emissions of NOx are kept within the set limits for Euro VI by scrubbing the exhaust gasses with AdBlue.

Therefore, the reduction in NOx due to the fuel change register as a reduction in Adblue consumption. Generally, the GD fuel has shown NOx reduction of around 10 to 29% in various engines.

Flue Efficiency: The volumetric fuel consumption shows the expected increase of 3% over diesel. However, the CO₂ emissions are 6% lower.

This apparent paradox simply reflects the fact that GD has a lower density (by 9%) relative to diesel. On this basis

the theoretical increase in fuel volume consumption ought to be 9% and not the 3% (as observed).

The difference of 6% is due to an improvement in fuel efficiency (higher power output per unit of fuel) which is confirmed by the 6% reduction in CO₂ emissions between the fuels (for doing the same amount of work).

Greenhouse gas (GHG) CO₂ equivalent ('CO₂ e'): GD is based on a sustainable fuel – the hydrocarbon is derived from atmospheric CO₂ through photosynthesis.

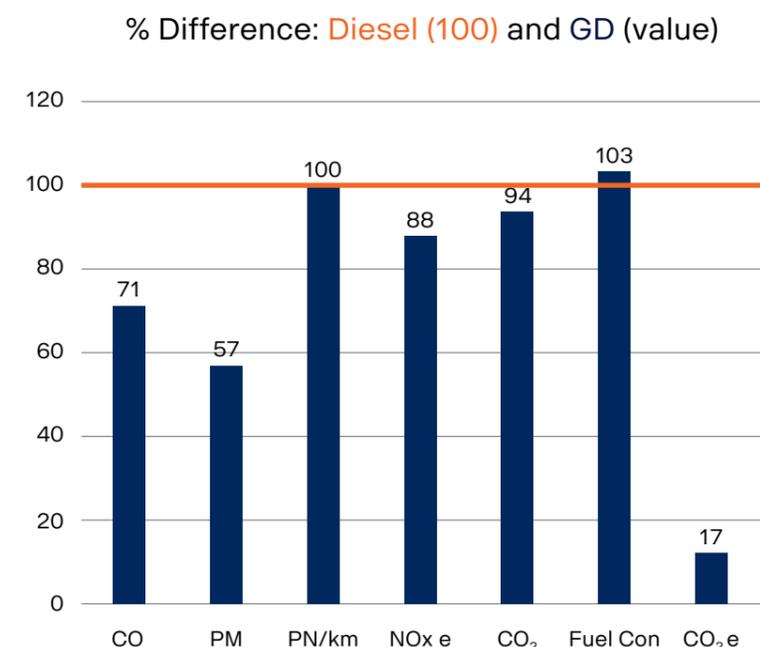
The fatty acid glycerides are hydrotreated and isomerised to give a saturated paraffinic hydrocarbon, devoid of the problems associated with biodiesel, a fuel which relies on the same raw material oils.

Various calculations have concluded that the reduction in Greenhouse gas CO₂ equivalent emissions relative fossil fuels are in the region of 90%. Typically, a coach does 250,000 km per annum.

With a fuel consumption of 4km per litre (i.e. 62,500 litres of fuel), the GHG saving is estimated to be 180 tonnes of CO₂ e per annum per coach.

NOTES

- This work was undertaken at Millbrook Proving Ground to a specialised 2017 LowCVP UK Coach (LUC) cycle.
- Values obtained from the latest DBEIS site: <https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting>.
- WTT = Wheel to Tank (Scope 1)
- TTW = Tank to Wheel (Scope 3)
- WTW – Well to Wheel



Saving of 1 coach = 180 tonnes of CO₂ e per annum



This represents a reduction of over 90% of CO₂ e over use of diesel

SCANIA'S SUSTAINABILITY PORTFOLIO

Driving the shift to a fossil free future has never been more important, the targets being set both locally in the UK and globally are challenging but not impossible.

At Scania we want to part of the solution not part of the problem we have the broadest range of solutions available to help.

We can offer support and guide you to find the most appropriate solution for your business. Different vehicles operating in differing environments demand bespoke solutions.

Our green toolbox has everything required to help you, whether its efficiency in your operation, driver training, alternative fuels or a complete transformation of your operation we are here to help.

As we move forward on this journey together, Scania are redefining the way we do business.

The landscape is changing, our network of partners and knowledge is evolving and the partnerships we are creating will help us to innovate to find more sustainable solutions for the industry and our customers.



Tanya Neech,
Sustainable Solutions Manager

