Decarbonising Heavy Duty Vehicles and Machinery

Proposals for a UK Renewable Diesel Incentive

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Zemo Partnership
Accelerating Transport to Zero Emissions

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Executive Summary

The UK Government has introduced ambitious UK economy-wide targets to meet net zero greenhouse gas (GHG) emissions by 2050. These are a 65% reduction by 2030, and 72% reduction by 2035, relative to 1990 levels. Surface transport emissions will need to reduce by an estimated 73% to reach the levels of GHG emission abatement required to meet the 2030 target. The pace and scale of action to mitigate GHG emissions will need to increase substantially.

Whilst Government's vision for road transport decarbonisation is focused on replacing the internal combustion engine with electric propulsion technology, heavy duty vehicles such as trucks and coaches, and non-road mobile machinery (NRMM), have longer transition timelines than cars and vans. HGVs are responsible for approximately 18% of surface transport GHG emissions and identified as one of the 'hardest' to decarbonise sectors.

The phase-out dates for sales of non-zero emission HGVs have been identified as 2035 for HGVs under 26t and 2040 for all HGVs. In the case of NRMM, no such date has been set. This sector covers a broad range of equipment types with typically long operational lifetimes and demanding power requirements. It is not uncommon for NRMM to have operational lifetimes of up to thirty years. The full transition to electrification for this sector is likely to take significantly longer than for HGVs, with legacy diesel NRMM likely to remain in the transport fleet well beyond 2045. As a result of these lengthy timelines, a near-term solution is required for GHG emissions abatement from these heavy duty sectors, if we are to achieve Government's interim and long-term carbon reduction goals. Renewable liquid fuels, such as biodiesel and hydrotreated vegetable oil (HVO), offer an immediate solution for mitigating GHG emissions from the HDV and NRMM sectors.

Zemo undertook a study in 2021[1] which explored the market opportunities for decarbonising heavy duty vehicles using high blends of renewable fuels. This included biodiesel and HVO supplied at bio-blend percentages above the retail grade of B7 (7%). Currently several thousand heavy duty vehicles run on higher blends of renewable liquid fuels, mainly biodiesel B20 and 100% HVO. HVO is classed as a drop-in fuel, serving as a straight substitute for diesel, requiring no modification to vehicles or fuel storage and refuelling systems. The use of HVO is rising gradually in the NRMM sector, primarily in the construction industry, however deployment of low carbon liquid fuels in NRMM is generally limited.

Zemo's study identified that fleet operators are hindered from adopting higher blends of renewable diesel by economics. The business case is insufficient to motivate a change in purchasing behaviour. A second barrier precluding higher blends of biodiesel in HDV is that only a limited number of manufacturers warranty their vehicle engines to run on B20, B30 and B100. Zemo's engagement with HDV stakeholders as part of their 2021 study revealed that a fiscal incentive could help improve the business case for higher blends of renewable diesel and therefore stimulate wider demand and adoption. This was considered especially advantageous as HDV fleet operators typically operate their businesses on very tight financial margins, making it challenging to switch to low carbon solutions that are currently more expensive than diesel. A fiscal incentive linked to fuel duty and the GHG performance of renewable fuels was identified by stakeholders as the key mechanism to deliver a financial benefit, whilst simultaneously encouraging GHG emission savings.

It is important to highlight that higher blends of biodiesel and HVO supplied to heavy duty vehicles and NRMM can currently achieve between 85%-90% GHG emission[2] savings and are produced from biogenic waste feedstocks. Zemo has introduced a Renewable Fuels Assurance Scheme[3] (RFAS) which provides heavy duty vehicle and NRMM operators with independent verification of low carbon fuel supply chains in terms of GHG emission performance, renewable fuel blend composition and feedstock sustainability.

1 Market opportunities to decarbonise heavy duty vehicles using high blend renewable fuels, Zemo Partnership 2021: https://www.zemo.org.uk/assets/lowcvpreports/Market_opportunities_decarb_HDVs%20using%20HBRF_2021_.pdf

2 Renewable diesel supplier data from Zemo Renewable Fuels Assurance Scheme, 2021

3 Renewable Fuels Assurance Scheme, Zemo Partnership: https://www.zemo.org.uk/work-with-us/fuels/the-renewable-fuels-assurance-scheme.htm

Study aims

The overarching aim of this study is to help accelerate the decarbonisation of HDVs and NRMM using low carbon distillate liquid fuels through the introduction of a fiscal incentive. The study explores a pricing mechanism for a fuel duty discount and potential GHG emission benefits in the HDV and NRMM sectors. The objectives were:

- To determine the whole life costs (WLC) of a range of biodiesel and HVO blends compared to diesel, for HGV and NRMM fleets respectively.
- To determine a sufficient discount price (pence per litre) based on the blend and GHG saving potential of the renewable fuel (starting at blends above 7% renewable fuel content) to incentivise uptake. This included engagement with industry stakeholders to ascertain feedback on the incentive mechanisms.
- To estimate the change in diesel demand over the next three decades and the volume of renewable liquid fuel that could potentially be used to decarbonise the HDV and NRMM sectors, and the associated GHG emission savings.
- To illustrate the cost to Treasury of introducing a fiscal incentive for renewable diesel use in HDVs and NRMM over the next decade.

Study outcomes

Whole life cost analysis

The whole life costs (WLC) were determined for heavy duty applications running on diesel and a selection of biodiesel and HVO blends (20%, 30%, 50% and 100%). The HDV and NRMM applications were as follows: rigid HGV truck (18t), mini excavator (<5t) and wheel loader (>5t). The additional WLC of operating the HGV and NRMM equipment on the biodiesel or HVO blends, compared to diesel, was determined.

Biodiesel B100 reveals the highest additional costs, due to the maintenance requirements and vehicle/equipment and infrastructure adaptations needed. B20 shows the lowest additional whole life cost as no alterations are required to the vehicle/equipment or fuelling infrastructure, maintenance is comparable with diesel vehicle/equipment, and the fuel price is lower than that of HVO. For 100% HVO the impact of the higher fuel purchase price gives rise to additional WLC, which of course decrease as the proportion of HVO in the blend reduces.

Fiscal incentive linked to fuel duty

The study proposes a fuel duty discount is set for a 100% renewable diesel fuel and scaled according to the bio-content of renewable fuel blends. This would be the simplest mechanism for linking a fuel duty fiscal incentive to GHG emissions savings (the higher the blend of renewable diesel, the greater the GHG savings). Renewable diesel fuels would only qualify for the incentive if approved under the Renewable Transport Fuels Obligation (RTFO) and produced from waste-based biomass feedstocks. The fuel duty incentive would be received by the company supplying the higher blends of renewable diesel and paying fuel duty. The reduced price of low carbon liquid fuel should then cascade down to the vehicle fleet or NRMM operator, purchasing either a blend or 100% renewable diesel. It is proposed that the discount would apply to renewable diesel blends of 20% or more. Zemo's Renewable Fuels Assurance Scheme could serve as a useful mechanism to give fleet and NRMM operators confidence that they are purchasing RTFO approved low carbon liquid fuel and certainty of the bio-blend component.

For illustrative purposes the analysis explored a maximum fuel duty discount of 15 ppl for 100% FAME and HVO, which would be scaled down to 3 ppl discount for a 20% blend of FAME and HVO. The WLC of each renewable liquid fuel blend was re-calculated taking into consideration the renewable diesel fiscal incentive. The fiscal incentive was applied to the standard fuel duty (57.95 ppl) and apportioned relative to the bio-content of the renewable fuel blend.

- In general, although reduced by the proposed duty discount, there are still additional WLC for using higher renewable diesel blends. At the time the study was undertaken, engagement with various stakeholders indicated the discount proposed would be acceptable and sufficient to encourage a switch to higher blends of renewable diesel.
- B20 becomes more affordable for operators and might even reach price parity (or close to) for some HDV and NRMM applications and use cases.

Analysis on the future demand for diesel fuel in surface transport

- Between 2022 and 2032 many parts of the HGV and NRMM sectors will be in the very early stages of transitioning to electric propulsion technology. As a result of this, a significant volume of diesel will continue to be in used in ICE-powered vehicles and off-highway equipment. Renewable liquid fuels therefore offer an immediate near-term opportunity for significantly reducing GHG emissions in these sectors.
- As the demand for diesel reduces over time for the light duty vehicle sector (vans and cars), due to electrification, this will liberate both biodiesel and HVO which could be supplied to the HDV and NRMM sectors as high blends of renewable diesel. Additional supplies of drop-in renewable diesel fuel will also become available over the next decade if demand is stimulated.
- As the demand for diesel falls over time, the existing RTFO targets are likely to be met through E10 petrol and B7 forecourt diesel. Hence there is currently little or no incentive for the supply of higher blends of renewable diesel in the HDV and NRMM fleets, and an immediate and continuing decline in overall volumes of renewable diesel supply is expected.
- It is therefore imperative that RTFO targets should also be raised to support an increase in the overall supply of renewable diesel (HVO and biodiesel) into the UK HDV and NRMM sectors.

Analysis on the uptake of renewable diesel and GHG savings

- Average blend percentages of renewable diesel could increase to around 15-45% by 2035 across the HDV and NRMM sectors, or to around 20-65% within the HGV sector alone; this is predicated on the RTFO targets increasing to stimulate supply.
- The cumulative GHG savings could reach 20-40 million tonnes of CO_2e by 2035; for comparison, the UK HDV fleet is currently responsible for emitting about 20 million tonnes of CO_2e per annum.
- With an increase in the RTFO target and the adoption of higher blends of renewable fuels to achieve an average of 30% across the HGV fleet by 2035, it is estimated that around 25 million tonnes of CO_2e could be abated by 2035. This contribution is considered essential for meeting net zero by 2050.

Analysis on the carbon pricing and the indicative cost to Treasury from a fuel duty discount

- Renewable diesel fuel incentives of 15-25 pence per additional litre incentivised were shown to be cost effective in terms of carbon pricing to 2035.
- It is estimated that by incentivising higher blends of renewable diesel with a maximum fuel duty discount of 15 ppl, the income to Treasury from HDV diesel sales will reduce by about 1% in 2022, moving to 6% in 2032.

Acronyms and abbreviations

APC	Advanced Propulsion Centre
BAU	Business As Usual
B7 (B20, B30, B100)	Biodiesel with 7% (20%, 30%, 100%) renewable content
CapEx	Capital Expenditures
CCC	Climate Change Committee
E5 (E10)	Petrol with 5% (10%) bioethanol
FAME	Fatty Acid Methyl Ester
GHG	Greenhouse Gas Emissions
HDV	Heavy Duty Vehicle
HGV	Heavy Goods Vehicle
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
LCF	Low Carbon Fuel
MEL	Maximum Effective Life
Ml	Million litres
MT	Million Tonnes
NAEI	National Atmospheric Emissions Inventory
NPV	Net Present Value
NRMM	Non-Road Mobile Machinery
OEM	Original Equipment Manufacturer
OpEx	Operating Expenses
PHEV	Plug-in Hybrid Electric Vehicle
ppl	pence per litre
RFAS	Renewable Fuels Assurance Scheme
RTFO	Renewable Transport Fuel Obligation
WLC	Whole Life Costs
ZE	Zero Emissions
ZEV	Zero Emissions Vehicle

1. Introduction

In 2021 the UK Government announced ambitious UK economy-wide targets to meet net zero greenhouse gas (GHG) emissions in 2050. These are a 65% reduction by 2030, and 72% reduction by 2035, relative to 1990 levels. Surface transport emissions will need to reduce by an estimated 73% to reach the levels of GHG emission abatement required for the 2030 target. The pace and scale of action to mitigate GHG emissions will need to increase substantially.

Whilst Government's vision for road transport decarbonisation is focused on replacing the internal combustion engine with electric propulsion technology, heavy duty vehicles such as trucks and coaches, and non-road mobile machinery (NRMM), have much longer transition timelines than cars and vans. This is illustrated in **Figure 1**, the Advanced Propulsion Centre's (APC) technology roadmap for HGVs and off-highway vehicles to 2050. The phase out dates for sales of non-zero emissions HGVs for example, have been identified as 2035 for HGVs under 26t and 2040 for all HGVs. In the case of NRMM, this sector covers a broad range of equipment types with typically long operational lifetimes and demanding power requirements.

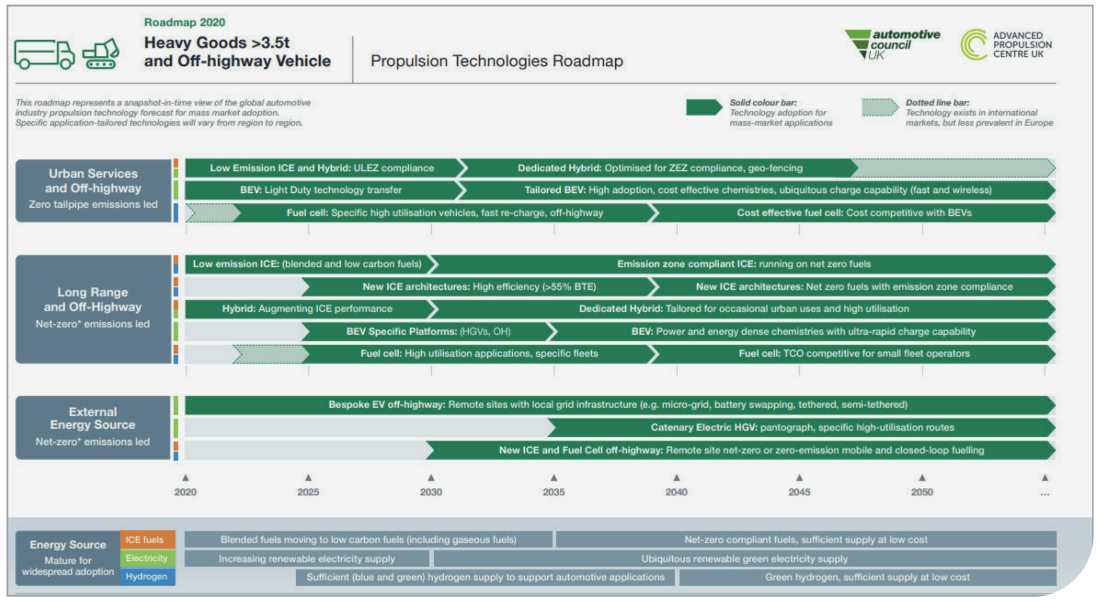


Figure 1. APC HGV and off-highway vehicles technology roadmap to 2050

The full transition to electrification or zero emissions for this sector is likely to take longer than HGVs. As a result of these lengthy timelines, a near term solution is required for GHG emissions abatement from these sectors, to help achieve Government's interim and long-term carbon reduction goals. Renewable liquid fuels, such as biodiesel and hydrotreated vegetable oil (HVO), offer an immediate solution for mitigating GHG emissions from the HDV and NRMM sectors.

It is important to highlight that while the demand for diesel will decrease over time, due to increasing electrification, lowering GHG emissions from the legacy diesel ICE HDV and NRMM fleet will be critical. Rigid HGVs, coaches and NRMM equipment can have operational lifetimes of 20 years or more.

1.1 High blend renewable diesel adoption and market barriers

Renewable diesel is currently deployed by some HDV and NRMM operators as biodiesel/FAME and HVO at blends above the retail grade of B7 (renewable fuel content of 7%): for example, blends of 20%, 30% and 100% pure renewable fuel. Market adoption rates are however in their infancy, with less than 1% of the UK HDV and NRMM fleet using higher blends of renewable diesel. Zemo Partnership undertook a study in 2021[4] which identified key market barriers and interventions to help accelerate the adoption of higher blends of renewable fuels. One of the main limiting factors preventing the wider scale adoption of renewable diesel supply chains is the increased whole life costs associated with running heavy duty vehicles and NRMM equipment on higher blends of biodiesel and HVO. This issue is especially acute for small businesses who operate on very tight financial margins and fail to see the commercial case for adopting lower carbon fuels.

In the case of biodiesel, blends above B30 can require vehicle adaptations and increased maintenance. In addition to this, the use of B100 requires modifications to the biodiesel storage and refuelling lines. A second barrier precluding higher blends of biodiesel in HDV is that only a limited number of manufacturers approve their vehicle engines to run on B20, B30 and B100. This subsequently impacts the fleet operator's vehicle warranty.

In the case of HVO, the commercial challenge relates to the much higher fuel price compared to diesel. HVO is classed as a drop-in fuel, serving as a straight substitute for diesel, requiring no modification to vehicles or fuel storage and refuelling systems.

At present there is an absence of any form of financial incentive for HDV and NRMM operators, to help support the business case for adopting higher blends of renewable diesel. Such an incentive could also leverage heavy duty vehicle manufacturers into providing warranties for use of higher blends of biodiesel.

Zemo's engagement with fleet operators revealed that a fiscal incentive, linked to fuel duty, would be highly advantageous, increasing the commercial case for running their vehicles on higher blends of low carbon liquid distillate fuels, such as biodiesel and HVO. In response to this, Zemo Partnership in collaboration with UKPIA and the RTFA, has undertaken this study to demonstrate how a fiscal incentive could be shaped, and the benefits this could deliver in terms GHG emission abatement.

[4] Market opportunities to decarbonise heavy duty vehicles using high blend renewable fuels, Zemo Partnership 2021: https://www.zemo.org.uk/assets/lowcvpreports/Market_opportunities_decarb_HDVs%20using%20HBRF_2021_.pdf

1.2 Study aims and objectives

The overarching aim of this study is to help accelerate the decarbonisation of HDVs and NRMM using renewable liquid fuels through the introduction of a fiscal incentive. The study explores a pricing mechanism for a fuel duty discount, focused on low carbon intensity liquid distillate fuels. The objectives are:

- **a.** To determine the whole life costs (WLC) of a range of biodiesel and HVO blends compared to diesel, for HGV and NRMM fleets respectively.
- **b.** To determine a sufficient discount price (pence per litre) based on the blend and GHG saving potential of the renewable fuel (starting at blends above 7% renewable fuel content) to incentivise uptake. This includes engagement with industry stakeholders to ascertain feedback on the incentive mechanisms.
- **c.** To estimate the change in diesel demand over the next three decades and the volume of renewable liquid fuel that could potentially be used to decarbonise the HDV and NRMM sectors, and the associated GHG emission savings.
- **d.** To illustrate the cost to Treasury of introducing a fiscal incentive for renewable diesel use in HDVs and NRMM over the next decade.

2. Whole life cost modelling

2.1 Methodology

This study entailed determining the whole life costs of three heavy duty applications running on diesel and a selection of biodiesel and HVO blends (20%, 30%, 50% and 100%). The HDV and NRMM applications were as follows:

- Rigid HGV truck (18t)
- NRMM equipment types - mini excavator (<5t) and wheel loader (>5t)

WLC data inputs and assumptions:

CapEx	Capital expenditure for higher blends of biodiesel (B30, B50, B100) include vehicle and fuel infrastructure adaptations, and new fuel storage tanks where required. Data was sourced from fleet operators, renewable fuel suppliers and Zemo's Renewable Fuels Guide (2021).
OpEx	Fuel consumption data was obtained from various sources. Operational cost data for any additional maintenance was sourced from fleet operators and renewable fuel suppliers. Diesel, biodiesel and HVO pricing data was obtained in Q4 of 2021 from a variety of sources including renewable diesel suppliers, fleet and NRMM operators and a fuel price forecasting company. A range of values were received, with Zemo taking the mid value for the WLC analysis.

Further details of the inputs and assumptions can be found in the Appendix.

The majority of NRMM OEMs approve their engines to run on B20 and up to 100% HVO.

The WLC analysis was carried out in two phases:

1. The additional WLC of operating the HGV and NRMM equipment on the biodiesel or HVO blends, compared to diesel, was determined.
2. The WLC of each renewable liquid fuel blend was then re-calculated, taking into consideration the renewable diesel fiscal incentive. The fiscal incentive was applied to the standard fuel duty (57.95 ppl) and apportioned relative to the bio-content of the renewable fuel blend. In some instances, a saving in WLC, compared to diesel, has been shown.

To demonstrate the impact of fluctuations in fuel prices, a sensitivity analysis was carried out. Two scenarios were considered: the first where the price of biodiesel and HVO increase by 20% (the price of fossil diesel being as per the base scenario), the second where the price of fossil diesel increases by 20% (the price of biodiesel and HVO being as per the base scenario).

2.2 Phase 1: whole life cost modelling results

Figures 2, 3 and 4 reveal similar trends in the additional WLC of the renewable diesel blend options, compared to diesel, for the three HDV and NRMM applications. The additional WLC increase as the bio-content of the renewable fuel blend rises.

Biodiesel B100 reveals the highest additional costs, due to the maintenance requirements and vehicle/equipment and infrastructure adaptations required. B20 shows the lowest additional whole life cost as no alterations are required to the vehicle/equipment or fuelling infrastructure, maintenance is comparable with diesel vehicle/equipment, and the fuel price is lower than that of HVO.

For HVO the impact of higher purchase fuel price is clearly evident from using 100% HVO, with the additional WLC decreasing as the proportion of HVO in the blend reduces.

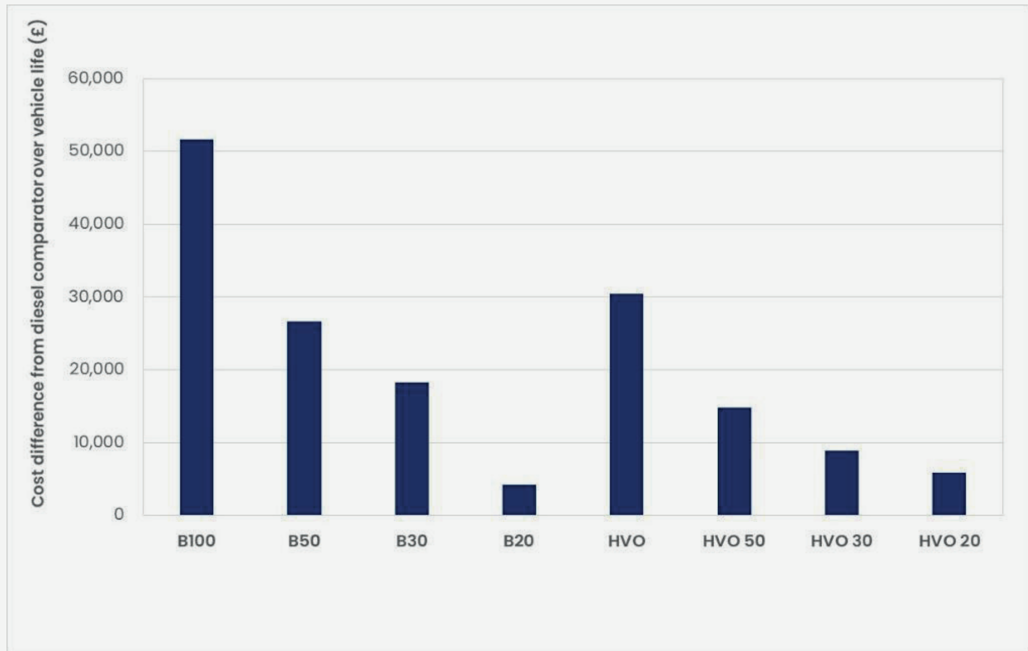


Figure 2. Additional cost of renewable diesel blends compared to diesel over HGV lifetime

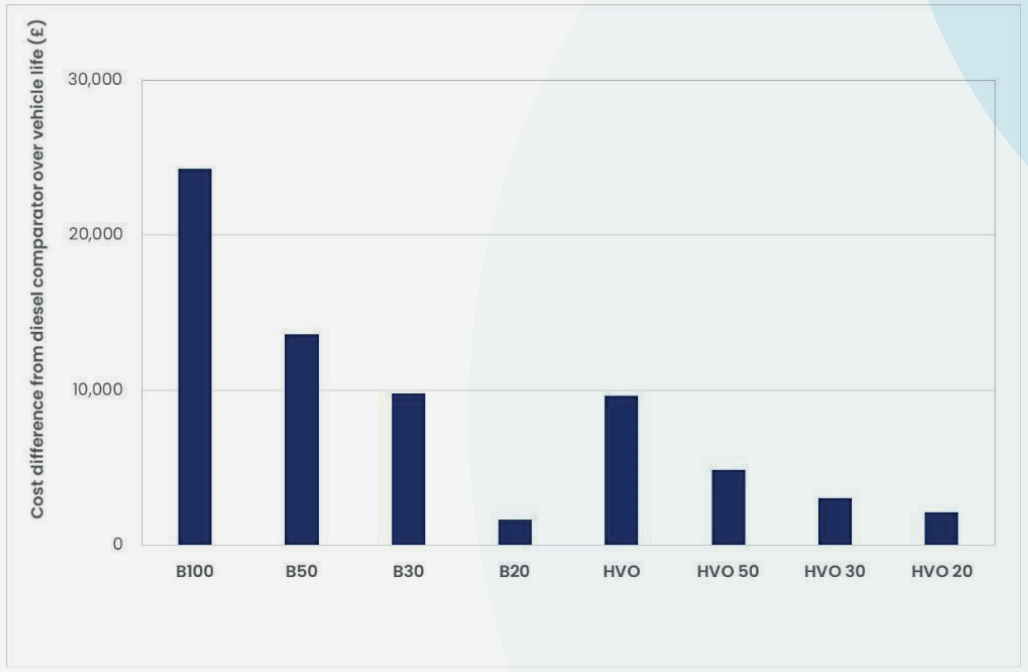


Figure 3. Additional cost of renewable diesel blends compared to diesel over mini-excavator lifetime

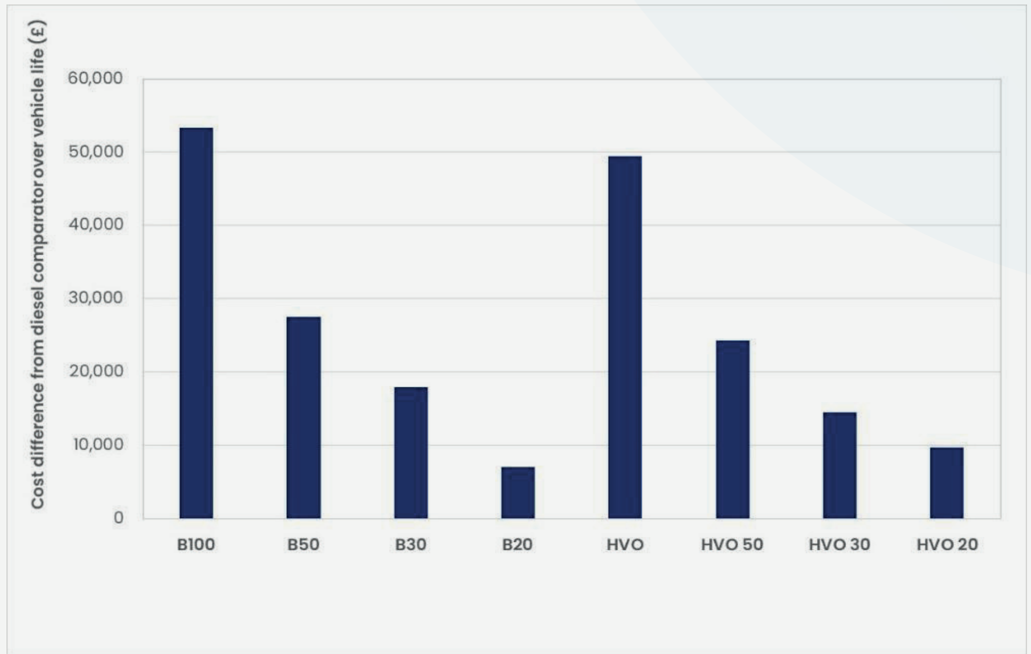


Figure 4. Additional cost of renewable diesel blends compared to diesel over wheel-loader lifetime

3. Renewable diesel fiscal incentive

3.1 Fuel duty discount design

Zemo proposes a fuel duty discount is set for a 100% renewable liquid fuel and scaled according to the bio-content of the renewable fuel blend. This would be the simplest mechanism for linking a fuel duty fiscal incentive to GHG emissions savings (the higher the blend of renewable diesel, the greater the GHG savings). Renewable diesel fuels would only qualify for the incentive if they achieved the RTFO GHG emissions savings threshold and sustainability standards. The fuel duty incentive would be received by the company supplying the higher blends of renewable diesel and paying fuel duty. The reduced price of low carbon liquid fuel would then cascade down to the vehicle fleet or NRMM operator, purchasing either a blend or 100% renewable diesel. It is proposed that the discount would apply to renewable diesel blends of 20% or more. Treasury would require evidence of RTFO approval to grant the discount to renewable diesel suppliers.

Zemo Partnership has introduced a Renewable Fuels Assurance Scheme[5] which provides independent assurance of claims made by renewable fuels suppliers of the GHG emission savings, and feedstock sustainability, of bulk low carbon fuels sold to their customers. This could include fuel distributors and/or HDV fleet and NRMM operators. The scheme enables Zemo to track the sale of renewable liquid and gaseous fuels, and blends of renewable fuels, across the UK market. We have 14 renewable fuel suppliers approved, including the majority of biodiesel and HVO suppliers. Zemo's scheme compliments the RTFO scheme and essentially enables the tracking of low carbon fuels after the point of duty. Approval under Zemo's scheme could help in providing evidence of bulk renewable diesel, including blends, sold to fleet and NRMM operators.

Fleet operator engagement carried out as part of Zemo's 2021 study on market opportunities for high blend renewable fuels, revealed a discount of 10 to 20 ppl (pence per litre) on fuel duty would incentivise a switch to 100% HVO, and a discount of 4 to 6 ppl would incentivise biodiesel B30.

[5] Renewable Fuels Assurance Scheme, Zemo Partnership: https://www.zemo.org.uk/work-with-us/fuels/the-renewable-fuels-assurance-scheme.htm

For this study a maximum fuel duty discount of 15 ppl has been selected and then scaled relative to the bio-content of renewable diesel blend. This would essentially be identical for HVO and biodiesel (and any other renewable diesel product that could enter the market). **Table 1** below illustrates the discount across the four renewable liquid fuel options.

Renewable Fuel Blend	20%	30%	50%	100%
Fuel Duty Discount	3 ppl	4.5 ppl	7.5 ppl	15 ppl

Table 1. Fuel duty discount based on the bio-content of the renewable fuel blend

The incentive proposal was then applied to the whole life cost analysis undertaken in Section 2 and discussed with a variety of stakeholders, as outlined in the next sections.

3.2 Phase 2: whole life cost modelling results

Figures 5, 6 and 7 illustrate the additional WLC of blends of HVO and biodiesel for the three HGV and NRMM applications, compared to diesel, with and without the fuel duty discount (maximum 15 ppl). With the fuel duty discount applied, the reduction in additional WLC for the HGV truck, ranges from almost 100% for B20 (meeting price parity), to around 70% for the HVO blends (HVO 20-100), to around 35-45% for the higher biodiesel blends (B30-B100).

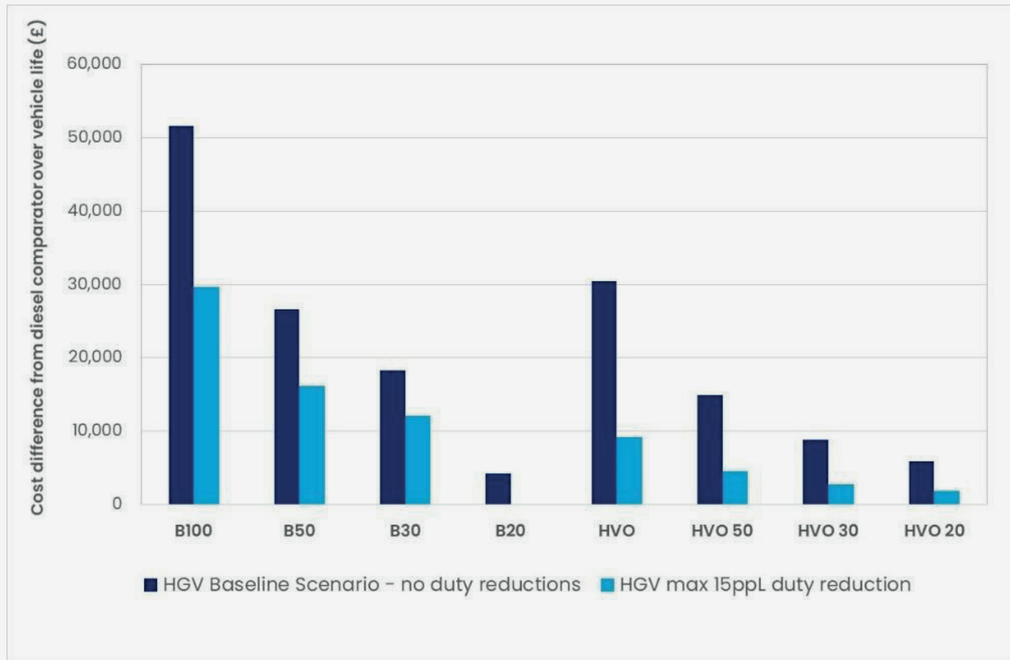


Figure 5. Impact of a fuel duty discount on HGV additional WLC

Similarly, for the mini-excavator, B20 shows the largest reduction in additional WLC (compared to diesel) at around 80%, with the HVO blends around 60-65% reduction, and the higher biodiesel blends (B30-B100) around 20-30% reduction.

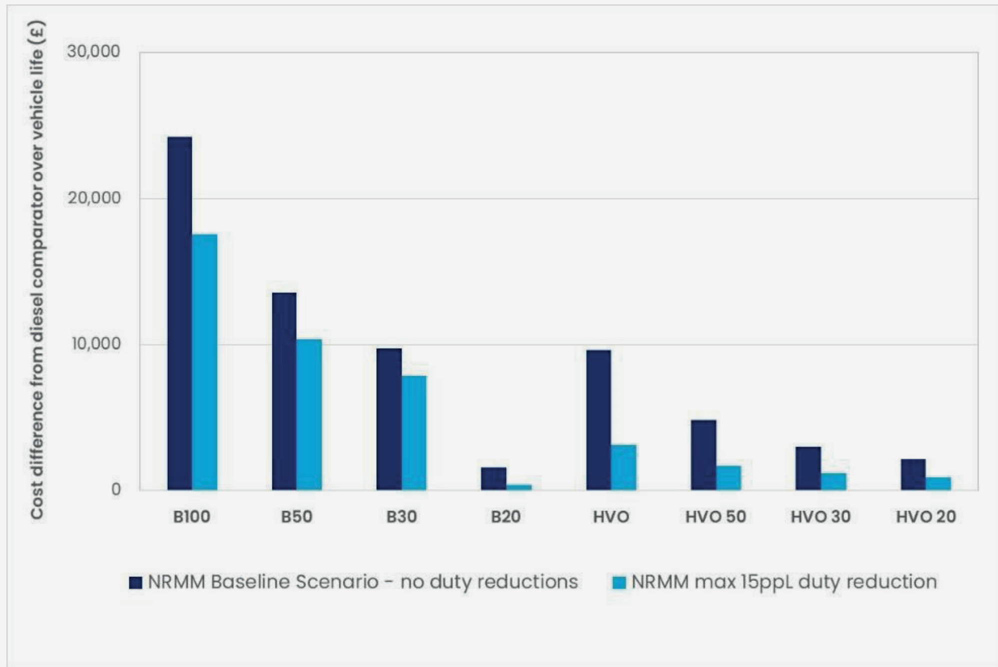


Figure 6. Impact of a fuel duty discount mini-excavator additional WLC

The benefits of the fuel duty discount are more pronounced for the wheel-loader, reducing additional WLC (compared to diesel) by around 95% for B20, around 70% for the HVO blends and B100, and around 55-60% for B30 and B50.

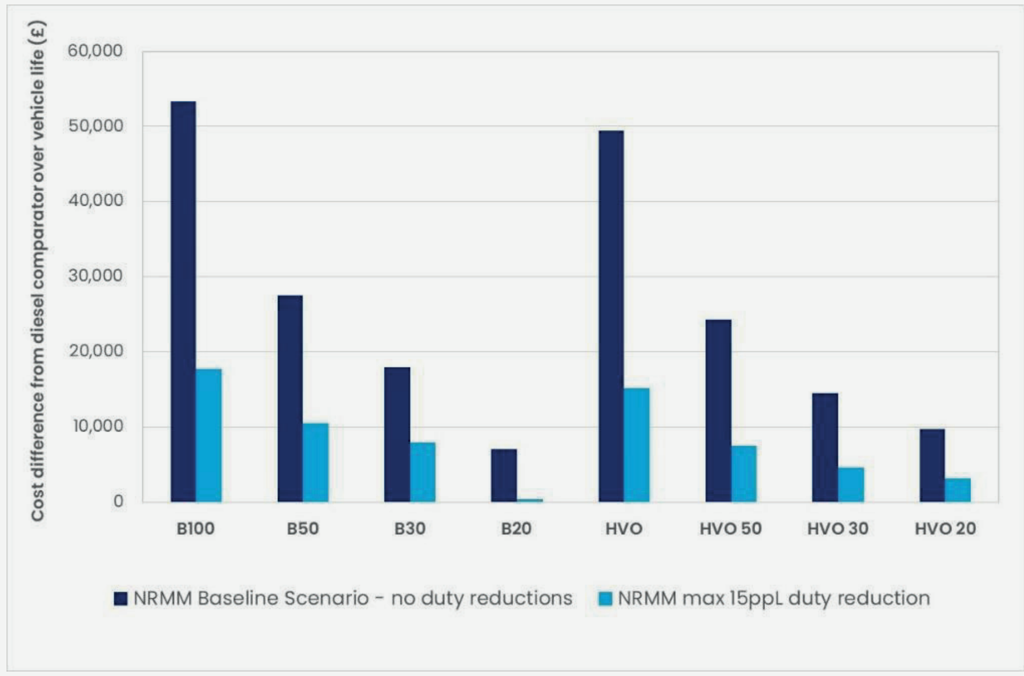


Figure 7. Impact of a fuel duty discount on wheel-loader additional WLC

Given the variations in fuel price data and the fluctuations in fuel prices over time, it was considered beneficial to perform a sensitivity analysis on fuel price, as shown in **Figure 8**. In the first scenario, the pre-duty price of biodiesel and HVO was increased by 20% (the price of fossil diesel being as per the base scenario). In the second scenario, the pre-duty price of fossil (mineral) diesel was increased by 20% (the price of biodiesel and HVO being as per the base scenario). In both scenarios the fuel duty discount and other assumptions remained unchanged. The results show that a 20% increase in the renewable fuel price (without a corresponding rise in fossil diesel) would erode most of the financial benefit from a fuel duty discount with a maximum of 15 ppl. A 20% increase in fossil diesel price would make the renewable fuels more affordable for operators, with B20 and the HVO blends offering WLC savings compared to diesel.

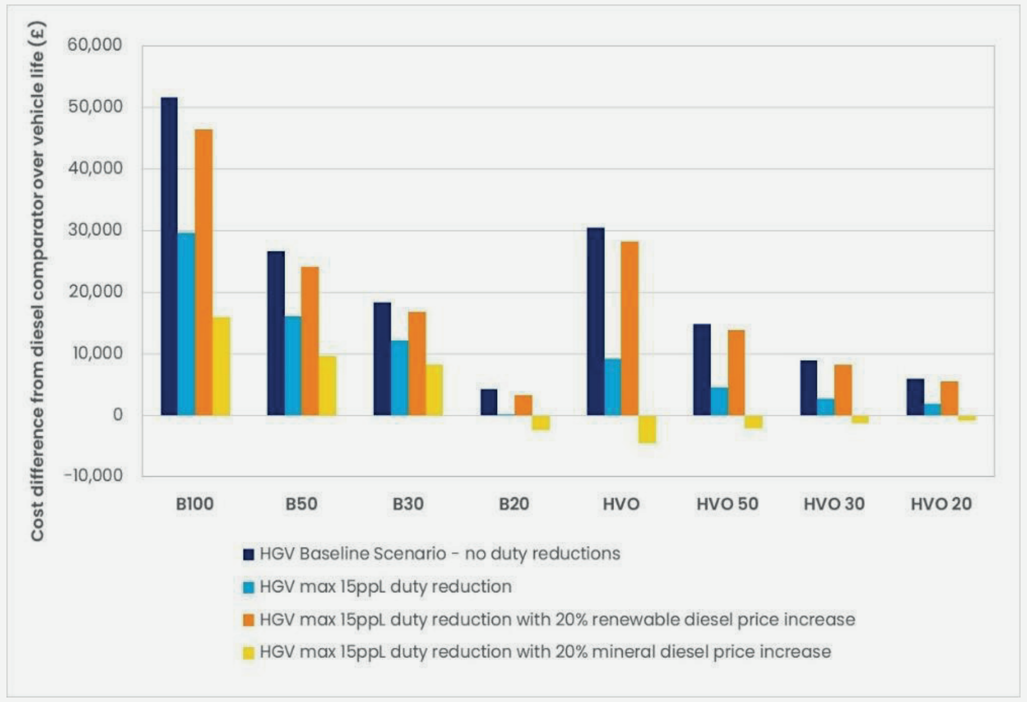


Figure 8. Sensitivity analysis for HGV additional WLC

3.3 Stakeholder engagement and feedback

Zemo engaged with a broad range of HDV and NRMM stakeholders to seek views on the fuel duty discount pricing mechanism for biodiesel and HVO blends. This involved one-to-one conversions and virtual group discussions through industry trade body meetings during January 2022. The WLC analysis undertaken by Zemo was presented, with and without the fuel duty discount applied. Organisations were asked questions about their fleet decarbonisation plans and the obstacles in adopting renewable liquid fuels. In total 45 organisations participated, including: Logistics UK, Sustainable Retail Logistics Forum, Road Haulage Association, SMMT, Confederation of Passenger Transport, Construction Plant Hire Associations, Renewable Transport Fuel Association, UKPIA and Zemo Partnership members. Vehicle and equipment operators included bus, coach, freight logistics, construction equipment, and local authority fleet operators. Fleet operators involved in the stakeholder engagement exercise used a mix of depot and public refuelling infrastructure. Key messages from the stakeholder engagement exercise were as follows:

- All HDV and NRMM operators saw great benefit in the introduction of a fuel duty discount for higher blends of renewable diesel, this was perceived to improve the business case, and commercial value, as a decarbonisation solution.
- Approximately 70% of stakeholders supported a fuel duty discount of 15 ppl (100% renewable diesel), with 30% suggesting the discount should increase 20 ppl.
- Scaling the discount according to the blend of renewable diesel was perceived as straight forward, a simple approach was recommended.
- There was a general preference for 'drop-in' renewable diesel (HVO) as this was considered easier to adopt, and a 'straight swap' with diesel. Some stakeholders highlighted historical concerns about higher blends of biodiesel causing engine filter blocking.
- Companies already using low carbon liquid fuels were willing to accept the higher WLC due to the GHG emission savings benefits, and the fact that their customers were requiring carbon reduction measures as part of the procurement process (e.g. construction sector). Other companies (e.g. logistics/hauliers) however, could not afford to adopt renewable fuels and their customers were not willing to pay more for a 'lower carbon' delivery contract. For these organisations, a fiscal intensive for renewable diesel was viewed as being highly advantageous.
- Stakeholders supported the proposal that only RTFO renewable diesel fuels should receive a fiscal incentive. Maintaining strong GHG emission savings compared to diesel, and use of waste based sustainable feedstocks, was considered imperative.
- The use of renewable liquid fuels was considered an immediate, and necessary bridging technology with regards to meeting net zero. A large proportion of stakeholders perceived battery electric and hydrogen fuel cell powertrain technologies as being challenging to adopt in the near or medium term – especially in the long-haul HGV and NRMM sectors.
- Companies who run small HGV fleets, and purchased second-hand vehicles, viewed renewable fuels as one of the only decarbonisation options available to them, as alternative low carbon technologies would be cost prohibitive and practically difficult. They would consider using renewable diesel if an incentive was in place, the proposal of a discount to fuel duty was seen as highly advantageous.
- The coach community mentioned a lack of Government funding for low carbon technologies and fuels, and intense financial challenges post-Covid. Renewable liquid fuels were considered one of the only solutions to decarbonising their fleets in the near term. Whilst their preference was for reaching price parity with diesel, a reduction in operational costs would certainly make the business case more attractive.
- A few fleet operators identified that installing new fuel storage infrastructure for higher blends of renewable fuels at numerous depots can be an expensive task, and therefore support for this was required. This was most frequently mentioned for HVO.
- Several fleet operators believed OEMs might consider extending vehicle warranty for a wider range of biodiesel blends if a fiscal incentive was in place. Many fleet operators were not willing to risk using higher blends of biodiesel without amendments to their vehicle warranty.

4. Diesel demand modelling methodology

The following sub-sections summarise how the potential future demand for diesel fuel in transport across the UK has been estimated. The modelling methodology applied is described and the key assumptions and scenarios explained. The resulting demand profile and how it falls (as sales and usage of zero emission technologies take over) is presented in Section 5. Against this baseline demand, various future scenarios are then described (Section 6) in which varying proportions of that residual diesel fuel demand are met by renewable fuels. The overall costs and benefits (in terms of greenhouse gas savings) are then presented (Section 7), against the baseline with only limited blending of renewable diesel fuel with predominantly fossil feedstocks.

The Excel spreadsheet model developed for this work starts with baseline published data from the National Atmospheric Emissions Inventory (NAEI) for the UK[6]. This data provides the most robust estimates of greenhouse gas (GHG) emissions from various land-transport sectors of interest. With the (completely reasonable) assumption that fuel use in such sectors is currently more or less exclusively diesel, these GHG emissions estimates have been used to generate estimates of overall diesel fuel demand in each sector, using standard GHG reporting factors[7].

The latest year for which NAEI estimates are available is 2019. We have assumed that the demand for diesel fuel in each sector calculated for 2019 applies also in 2021, which is the baseline year used in our model. While fuel demand in 2020 would inevitably have been significantly impacted by the SARS-cov2 pandemic, activity in 2021 is likely to have been close to pre-covid levels.

The second modelling step is to apportion each sector's overall fuel demand to the vehicles by age, i.e. what percentage of that fuel demand is consumed by new vehicles (up to one year old), by 1-2 year old vehicles, by 2-3 year old vehicles, etc. In the absence of published data, to do this, a mathematical construct has been developed that reflects, for each sector, how long vehicles tend to remain in service and, from that, how steeply annual fuel use, on average, declines as each vehicle ages.

This mathematical approach is based on a "Maximum Effective Life" (MEL) being assigned to each sector. The MEL for each sector is defined as the age of vehicles in that sector at which point 99.5% of that sector's overall fuel use is consumed by vehicles of that age and younger (i.e. just 0.5% of fuel is

6 https://naei.beis.gov.uk/data/data-selector
7 https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

consumed by vehicles older than the MEL). Furthermore, the model assumes an exponential decline in fuel use as vehicles age such that in year x, the percentage of overall fuel used by vehicles of that age is determined by an equation of the form:

$$F = Ae^{Bx}$$

Where F = fuel % for vehicles of age x and A and B are factors chosen to ensure the sum of all Fs from x = 1 to x = MEL is ≥ 99.5%[8].

The net effect is that, as one would expect, vehicles that typically remain in service for many years have a flatter MEL curve than those with a much higher fleet turnover rate (**Figure 9**).

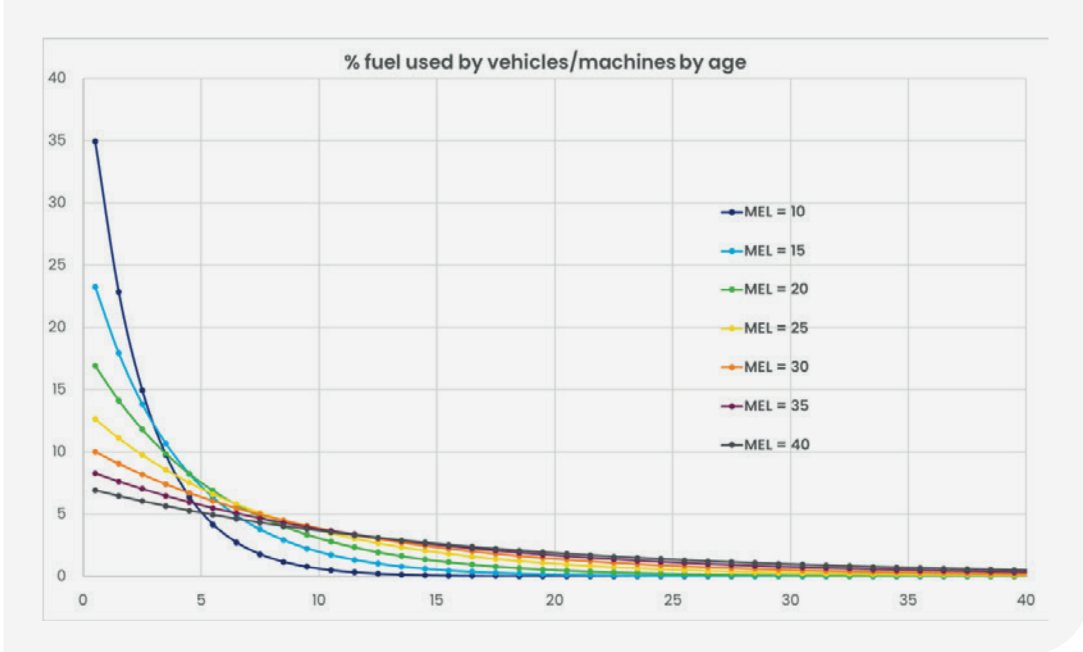


Figure 9. Variation of fuel use by Maximum Effective Life (MEL, ranging from 10 to 40 years)

As stated previously, more detailed estimates of how fuel use varies with vehicle age are largely absent from the published literature, but such information is essential for estimating how overall fuel use will change as new technologies take over from diesel.

The MEL curves used for this study are believed to be broadly accurate representations and, therefore, form a sound basis for making broad projections regarding overall fuel demand.

8 To properly represent all vehicles sold in any one year, the model uses x = 0.5 for vehicles up to 1 year old, x = 1.5 for those 1-2 years old, etc.

The third modelling step, again for each sector of interest, is to assign growth trajectories for zero emission technologies over the coming years/decades, to completely displace sales of new, non-zero combustion-engine vehicles and machinery. These "S curves" are inherently speculative but have been based on a combination of engineering knowledge and known regulatory frameworks (e.g. the UK Government's recently confirmed plans to end the sale of all new non-zero emission HGVs > 26 tonnes gross weight by 2040, and lighter ones by 2035).

The S curves used, again derived from exponential mathematical formulae, cover phase-out dates from 2025 to 2045, in five-year increments (**Figure 10**), from at or very close to zero in 2021 to 1.00 (i.e. 100% of sales) by the chosen date.

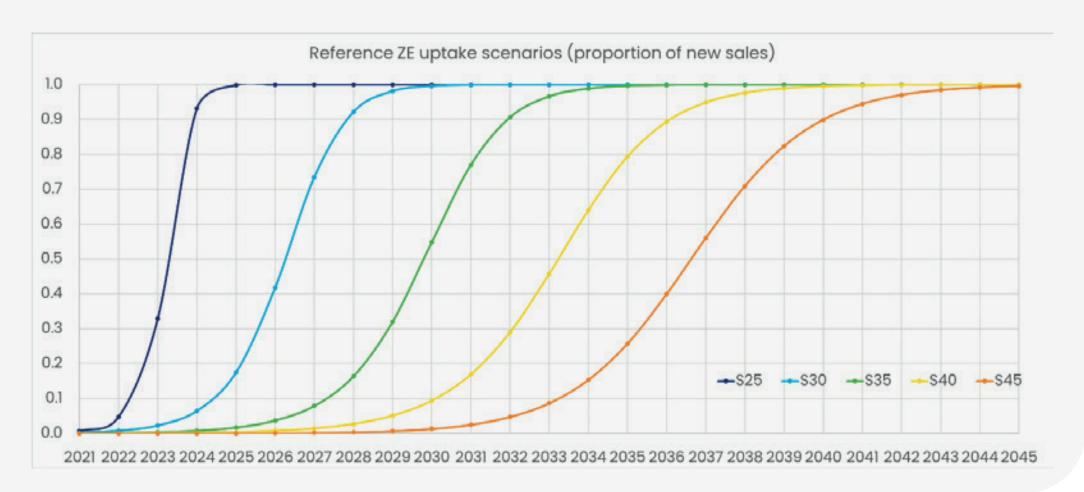


Figure 10. S curves to model uptake of zero emission technologies for new vehicle sales

4.1 Uptake of gas-powered (biomethane) vehicles

To displace what would otherwise be the purchase and usage of conventional diesel vehicles or machinery, gas-powered alternatives will need to be available. For most of the nine NAEI activity sectors used for the above diesel demand modelling, such alternatives do not exist and are, in our expert view, unlikely to become available in the timescales being considered here. Our assumption is that this applies to the Cars, Vans, NRMM, Air-Support Vehicles and Railway sectors.

Of the four remaining sectors (Artic and Rigid HGVs, Bus & Coach and Agriculture), we have further assumed that there would be negligible take-up of biomethane in the bus and coach sector. ZE technologies for buses, particularly battery-electric, are now well established with pressure increasing on bus operators to ensure any new vehicles they buy are fully zero emissions at the tailpipe. We are not aware either of any gas-powered coaches in current production for the UK market. We therefore consider it unlikely that the bus and coach sector would switch to new gas vehicles in significant quantities.

This leaves the two HGV sectors and agricultural mobile machinery (e.g. tractors) as the sectors we believe may have potential for some switching to biomethane. Even in these sectors, however, the take-up of gas vehicle technologies will inevitably be constrained, not least to only those OEMs with product available.

In the articulated HGV sector, three of the major OEMs have gas-powered vehicles available; Volvo, Scania and Iveco. In this specific case of articulated HGVs, our modelling has also assumed a modest further uptake in gas-powered vehicles, also assumed to run on biomethane. Much like the ZE technologies, further uptake of gas vehicles has been modelled via growth in the proportion of new, non-zero emission vehicle sales, such that new gas vehicles displace only what would otherwise have been new diesel vehicles (and are thus modelled to not in any way detract from the uptake of ZE vehicle sales). Our modelling assumes sales of gas-powered artics grow to 15% of all ICE tractor unit sales by 2032 and remain at that level thereafter. This is broadly equivalent to the existing gas vehicle OEMs achieving an overall 50% market share for those vehicles within their overall ICE sales volumes.

In the agricultural machinery sector, one OEM currently offers a dedicated gas vehicle option (CNH). Given that this sector will, after April 2022, also still be able to use duty-rebated red diesel (gas oil), it will be a potentially much more challenging sector to achieve a biomethane price that is attractive against diesel. Overall, however, we have assumed that there is no significant potential for new ICE agricultural mobile machinery sales to be gas-powered over the period modelled.

For clarity, in the model, an x% market share for gas of new vehicle sales means that x% of the "Business as Usual" (BAU) diesel demand for that sector, in that year, is displaced by gas usage. How much gas those vehicles use in subsequent years is then modelled in the same way as the diesel vehicles (using MEL curves).

4.2 Generating overall BAU projections of diesel demand

The above calculations and data have been combined to provide overall estimates of how demand for diesel fuel in each vehicle/machine sector of interest will fall as ZE technologies permeate into the fleet via increasing sales of new vehicles/machines. These thus represent BAU projections of overall diesel demand (with some growth in bio-methane usage) but with the full take-up of ZE technologies over appropriate timescales.

Furthermore, to reflect the inevitable uncertainties involved in forecasting future fuel demand and the sensitivities of our projections to the assumptions that underpin them, in addition to our "Central Scenarios", we have modelled two further scenarios. These have been named "ZE Market Enthusiasm" and "ZE Market Reluctance" and have been based on either shortening (ZE Market Enthusiasm) or lengthening (ZE Market Reluctance) the MEL estimates for each sector by 5 years. In effect, shortening the MEL simulates a scenario in which the cost savings and benefits of the new ZE technologies are so strong that owners/users of existing diesel machinery are motivated to bring forward their own fleet phase-out so that the incumbent diesel vehicles/machines are retired from significant service ahead of the historical norm. Conversely, the ZE +Market Reluctance scenario is relevant in the situation that the ZE technologies, despite mandates effecting new sales, are perceived to be more expensive and/or less effective than the existing diesel technologies and so owners/users are instead motivated to hold on to their old equipment for longer than the norm.

The sectors modelled, and the MEL's and phase-out date S curves assigned to each, across the three overall scenarios are shown in **Table 2.**

NAEI Activity sector	Non-Zero Phase-out Date*	Max Effective Lives (MELs, Years)		
		Central Scenarios	Market Enthusiasm	Market Reluctance
Articulated HGVs	2040	15	10	20
Rigid HGVs	2035	20	15	25
Bus & Coach	2030	20	15	25
Vans	2035	20	15	25
Diesel Cars	2025	20	15	25
NRMM	2040	20	15	25
Air-Support Vehicles	2035	20	15	25
Railways	2045	35	30	40
Agriculture	2045	25	20	30

Table 2. Sectors and scenarios modelled for overall diesel fuel demand projections

* **Note:** sales of new diesel cars are projected to reach effectively zero by 2025. This is ten years ahead of the official phase-out date but is in line with current market trends (diesel sales have fallen over recent years to just 8% of new car sales in 2021).

* **Note:** for NRMM, railways, air-support vehicles and agriculture a hypothetical phase-out date of 2040 has been chosen, no such non-zero phase-out dates have been proposed by Government.

5. Diesel demand modelling results

5.1 Diesel demand, all sectors of interest

The resulting diesel fuel demand projections are shown in the Figures that follow. The first (**Figure 11**) presents a detailed breakdown of how demand in each sector falls over time, in the Central Scenarios. The second (**Figure 12**) highlights the overall sensitivity/uncertainty of the central projections by framing them in relation to those generated by the ZE Market Enthusiasm and ZE Market Reluctance scenarios.

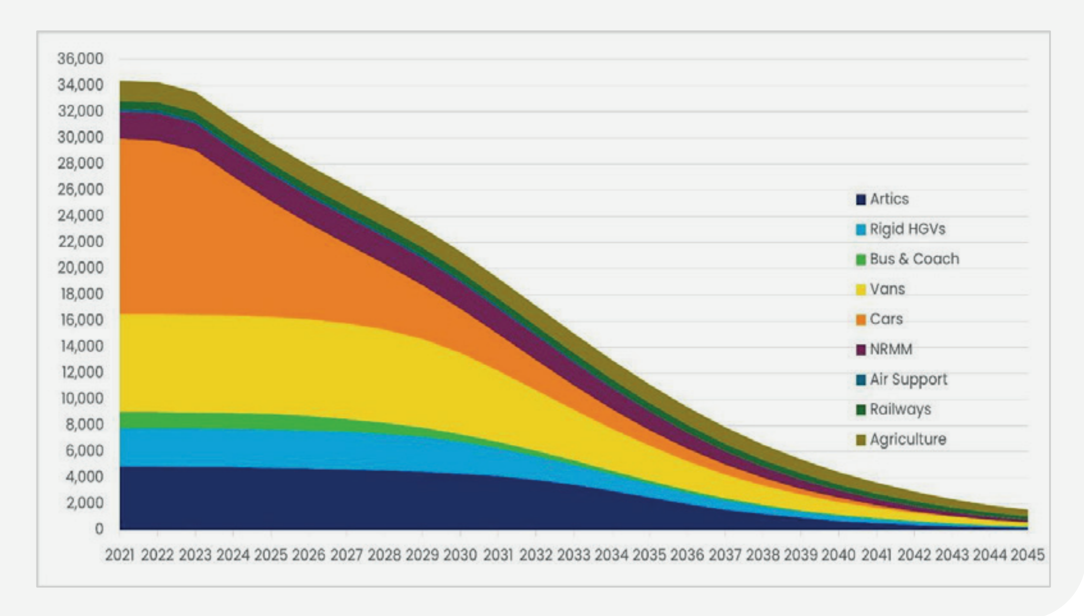


Figure 11. Annual BAU diesel fuel demand (Ml) by sector, Central Scenarios

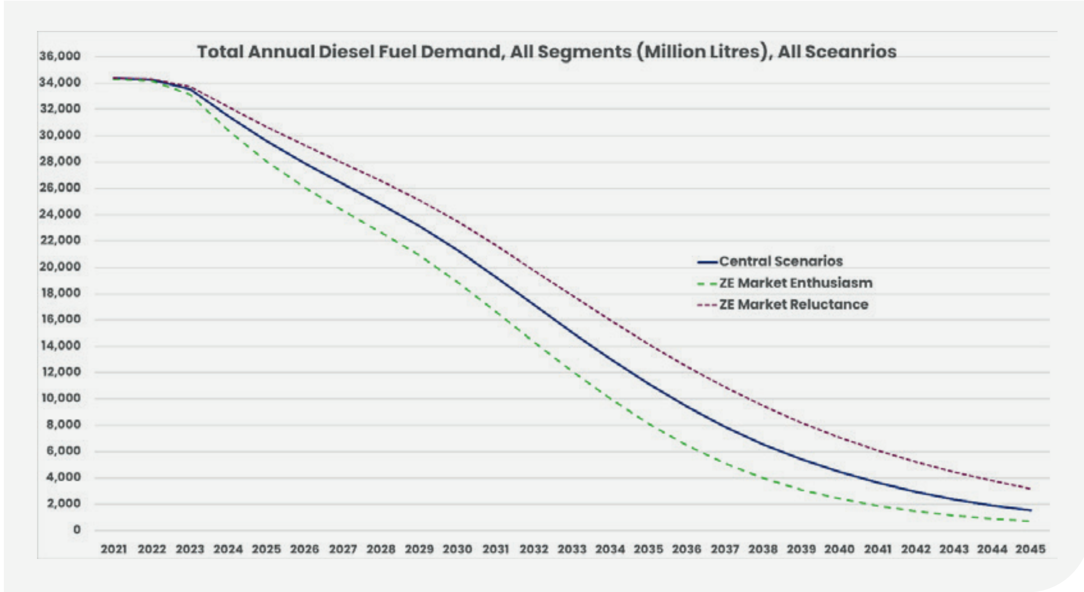


Figure 12. Projected diesel demand in three main scenarios

In total, annual diesel fuel demand across the nine sectors is projected to fall from its current 34 billion litres to between 20 and 24 billion litres in 2030 and then more steeply to around 8-14 billion litres by 2035 and just 2-7 billion litres by 2040 and 1-3 billion litres by 2045.

5.2 Biomethane demand, HGVs

This assumes 15% new sales proportions for articulated HGVs are achieved by 2032. Previous testing by Zemo of gas-powered vehicles indicates that a good general rule of thumb is that, in appropriate applications, each kg of gas displaces very roughly 1 litre of diesel fuel, so for every Ml of diesel displaced it can be estimated that 1 ktonne of biomethane would be needed. Overall, the modelling and associated assumptions described above generates a central estimate that demand for biomethane use in the UK fleet of HGVs could peak at around 430 ± 60 ktonne in the early 2030s. Thereafter, demand is projected to fall again as ZE technologies replace ICE vehicles, to around 50-150 ktonne by 2040 and 0-60 ktonne by 2045. Modelled projections of biomethane demand for articulated HGVs can be found in the Appendix.

6. Renewable diesel uptake scenarios

6.1 Baseline (current RTFO) scenario

The market for renewable (and sustainable) fuels in UK transport is governed by the provisions of the Renewable Transport Fuels Obligation (RTFO)[9]. In outline, this sets targets for the supply of renewable fuels and market-based economic instruments are then deployed to ensure those targets are met (but not exceeded) in the most cost-effective way.

Under the terms of the most recent revisions to the RTFO targets, the overall proportion of transport fuel that must be renewable is set to increase year-on-year from roughly 10% in 2021 to just under 15% by 2032 and remain at that level until 2035 and beyond (the current RTFO does not specify any increase in targets after 2035).

These targets will be achieved by a combination of renewable gasoline fuels (as blended into petrol), renewable diesel fuels, bio-methane and some other renewable fuels, with the targets applying across road and NRMM. There are no specific targets for the uptake of renewable diesel fuels within this overall framework.

The only significant market for renewable petrol is in the car sector. The maximum blend percentage (i.e. the proportion of total petrol fuel dispensed that is renewable, normally bio-ethanol) increased in 2021 from 5% to 10% (E5 to E10). In order to model the overall demand for renewable diesel fuel that the RTFO would dictate, it is first necessary to understand the contribution of renewable petrol to the RTFO targets. The modelling described above only covers diesel and biomethane fuel usage.

[9] https://www.gov.uk/guidance/renewable-transport-fuels-obligation

To fill this data gap, we have used a set of petrol demand projections recently published by the RAC Foundation[10]. These have been modelled in a more complex way than our approach but cater in a similar way for the growing uptake of new battery-electric cars (including plug-in petrol hybrids, PHEVs) between now and 2035 and the consequent reductions in overall demand for petrol. The RAC Foundation report describes three demand scenarios, labelled "Low", "Median" and "High"; we have used their Median scenario demand figures. To reflect the recent change in petrol specification, we have further made the assumption that overall bio-ethanol blends in petrol will gradually increase from 5% in 2021 (E5) in 1% annual increments to 10% (E10) by 2026; on average, forecourt fuel labelled as (up to) E10 is unlikely to be very far ahead of this timescale.

Achievement of the RTFO targets is further complicated by the ability to "double-count" some feedstocks. This, in effect, means the target can be achieved with only half the theoretical volumes of renewable fuel being needed, as each litre/kg of double-counted fuel contributes to the target as if it were 2 litres or 2kg of non-double-counted (i.e. single-counted) fuel.

To simplify our modelling, we have shown all bio-ethanol uptake in petrol as being single-counted and all renewable diesel as being double-counted.

Biomethane usage also counts towards RTFO targets, so for the articulated HGV sector we have further assumed all biomethane is also double-counted (reflecting expert advice and the existing market).

The modelling of this and the other scenarios (described in the following sections) is based on the assumption current retail blends are maintained by B7 and E10. The extent to which those blends contribute to the RTFO is then determined and any residual need for additional renewable fuel volumes (to meet that year's overall RTFO target) is then applied as a variable blend percentage across the other road transport and NRMM sectors. The railway and agriculture sectors are excluded as they will continue after April 2022 to be eligible for the red diesel duty rebate and thus will have a more limited economic incentive to make the switch to renewable diesel use.

[10] https://www.racfoundation.org/wp-content/uploads/Fuel_duty_decline_Lam_January_2022.pdf

Figure 13 suggests that the current RTFO targets, even as they gradually rise in percentage terms between now and 2032, are likely to lead to an immediate and gradual decline in overall volumes of renewable diesel supply. In effect, the rate at which cars will cease to need diesel fuel (as they rapidly transition to non-diesel alternatives) looks set to out-pace the quite modest increases in the RTFO target percentages. The figure also shows what demand remains for renewable diesel in the heavy duty vehicle and NRMM fleet (after allowing for E10 petrol and B7 diesel for all light duty vehicles and some growth in bio-methane usage for articulated HGVs) represents only around 6-7% average blend over the modelled period.

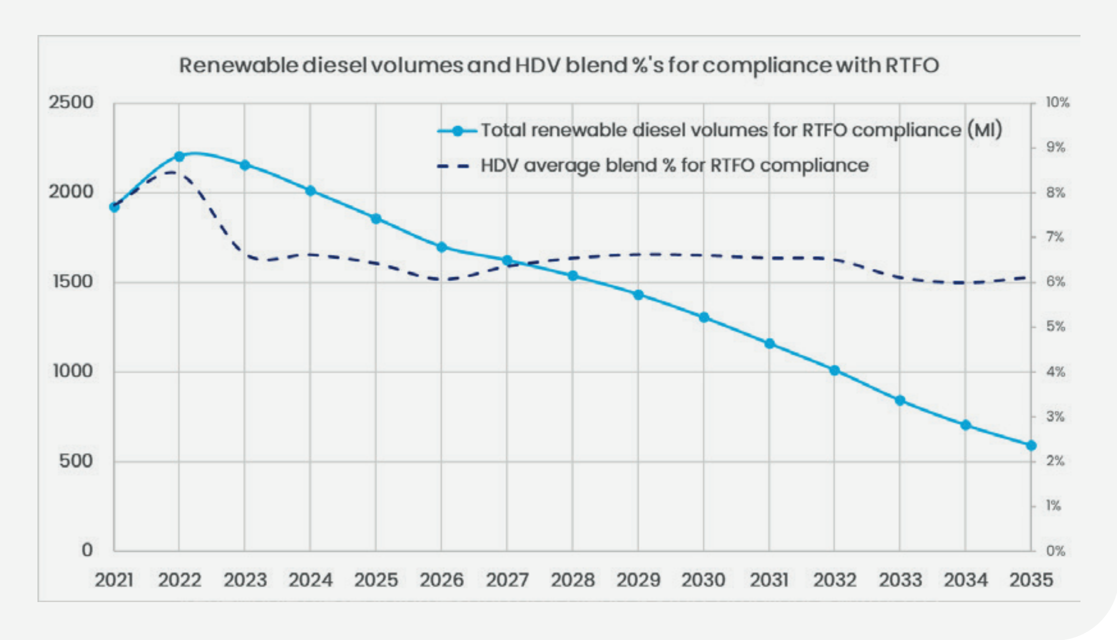


Figure 13. Renewable diesel demand projections under current RTFO and average HDV blend %.

The following sections describe modelling of a set of alternative scenarios whereby the overall supply of renewable diesel into the UK HDV and NRMM sectors is allowed to increase, over and above the levels projected under the existing baseline RTFO scenario, but not increasing to potentially unsustainable levels with regard to feedstock availability and competing demands for bio-energy resources.

6.2 Scenarios for increasing renewable diesel uptake

Zemo has modelled four alternative scenarios for increasing the uptake of renewable diesel in the HDV and NRMM fleets. The results are presented here in terms of both overall supply volumes (in millions of litres, Ml) and average blend percentages for HDV/NRMM fleets. It is important to note, however, that these average blend percentages do not necessarily mean all such vehicles would run on a blend of that percentage, i.e. for example a 20% average blend does not mean all vehicles would run on B20. The model simply presents the overall fleet average; individual fleets may use B20, B30, HVO, B100 or B7 or any combination of these, such that when all fleets are combined, they achieve this overall modelled average.

Furthermore, the average blend percentages for each scenario are presented in two ways. First, assuming the renewable fuel is used across all the modelled HDV and NRMM sectors (HGVs, Buses, Coaches, Air-Support Vehicles and NRMM) and second, assuming it is just used by HGVs (and the other HDV/NRMM sectors use pump-average B7 only).

The first two of these scenarios (labelled Scenarios 1A and 1B) are based on retaining or slightly increasing the overall supply volumes, largely by assuming the renewable fuel volumes no longer needed for light duty vehicles (as the B7 blend wall is reached and overall volumes needed by such vehicles decline) are re-assigned to the HDV and NRMM sectors. These scenarios effectively ignore any constraints imposed by the RTFO, other than using the existing RTFO to define a sustainable level of overall renewable diesel supply volumes.

For Scenario 1A, the peak volumes of renewable diesel to be supplied under the existing RTFO described in the preceding section (2,200 Ml in 2022) are then held constant throughout the remaining modelling period, to 2035. Any "spare" renewable diesel not needed for B7 compliance in the light-duty vehicle fleets (cars and vans) is then modelled in terms of its effective average blend percentage if fully used by the HDV and NRMM fleets.

Scenario 1B goes slightly further by assuming a gradually increasing supply of HVO into the UK market. There are already plans in place to increase the supply of HVO for the European market by 5 billion litres over the next five years or so. Scenario 1B assumes that the UK can ultimately capture up to 10% of this additional supply capacity. On top of the 2,200 Ml of renewable diesel assumed for Scenario 1A, Scenario 1B increases this in 100 Ml increments from 2023 to 2,700 Ml in 2027. Supply is then held constant at this level until 2035.

The second set of scenarios (labelled Scenarios 2A and 2B) assume that higher levels of renewable diesel fuel supply can be achieved through further modifications to the RTFO, i.e. increasing the targets. In Scenario 2A, we model the RTFO targets to increase from their current 11% in 2022, in 1% increments to 21% in 2032 (and then remain at 21% until 2035). Scenario 2B uses exactly the same RTFO targets out to 2032 but then assumes they continue to increase between then and 2035, and at a faster rate; 25% in 2033, 30% in 2034 and 35% in 2035. These Scenario 2B target values have been chosen to align with a trajectory that would ultimately mean full diesel fuel decarbonisation of the HDV and NRMM fleets by 2040 (the phase-out date for all new non-zero emission HGVs), i.e. sufficient renewable diesel supply to mean no fossil-derived diesel fuel would be needed for such vehicles/machines by that time. This would be a full decade ahead of the full fleet decarbonisation that would be achieved relying solely on the uptake of new zero emission equipment from 2040. The above four scenarios modelled are summarised in **Table 3**.

Scenario	Description
Scenario 1A	Peak supply volumes determined by current RTFO (2,200 Ml) held constant to 2035
Scenario 1B	As 1A but with additional 500 Ml of supply, based on 10% of new European HVO capacity
Scenario 2A	Increase RTFO targets, ultimately to 21% in 2032 (15% under current RTFO)
Scenario 2B	As 2A but increase targets further after 2032, ultimately to 35% in 2035

Table 3. Alternative scenarios for increasing uptake of renewable diesel fuel

6.2.1 Modelling results from alternative scenarios

The modelled volumes of renewable diesel to be supplied under each scenario (for all road transport not just the HDV and NRMM sectors) are shown in **Figure 14**.

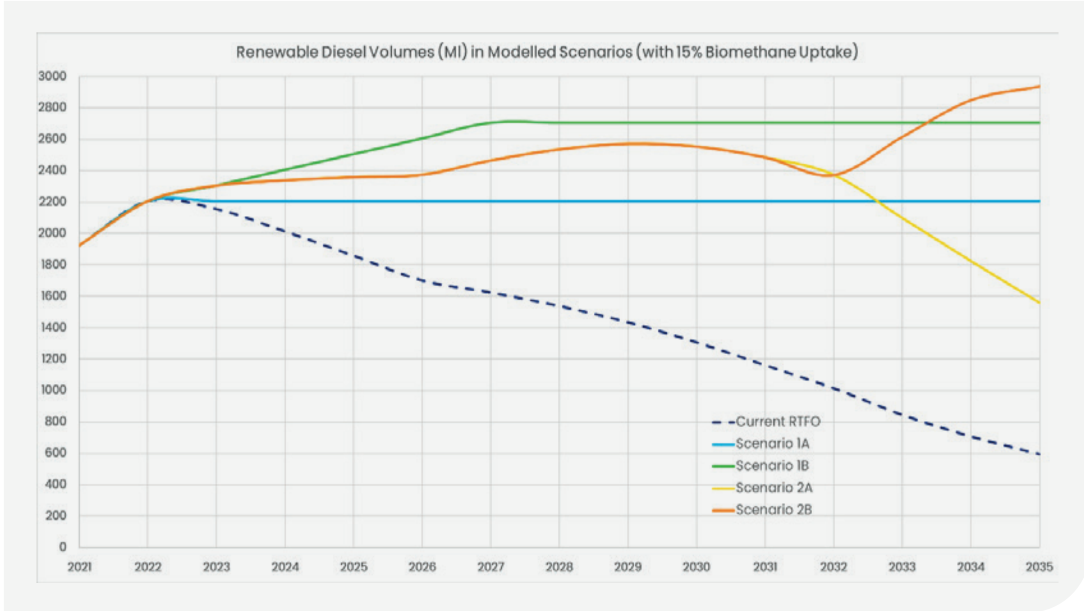


Figure 14. Overall renewable diesel supply volumes, modelled scenarios

Supply volumes under all the modelled scenarios do not exceed 3 billion litres in the period modelled to 2035, meaning even under the most ambitious scenario (2B) volumes in 2035 amount to no more than 50% above the volumes already being supplied to the UK in 2021/22. With the assumption that these current volumes are entirely sustainable and involve no major conflicts for bio-energy resources with alternative usage sectors, this modest level of increased supply, over a period of more than a decade, should, we believe, also be readily achievable sustainably. The highest growth rate for renewable diesel supply derives from Scenario 1B (rising by 100 Ml per year to 2.7 billion litres in 2027). This, too, is believed to be wholly achievable in a sustainable way; renewable diesel supplies, for example, are reported by the RTFO[11] to have grown by roughly double this amount in the five-year period from 2014 to 2019, so our modelling is not suggesting anything outside of the bounds of what has already recently been achieved.

[11] https://www.gov.uk/government/collections/renewable-fuel-statistics

The effects of these modelled overall supply volumes on average blend percentages within the HGV and/or HDV & NRMM sectors (with all other diesel-consuming sectors assumed to be fixed at B7) are shown in Figures 15 and 16.

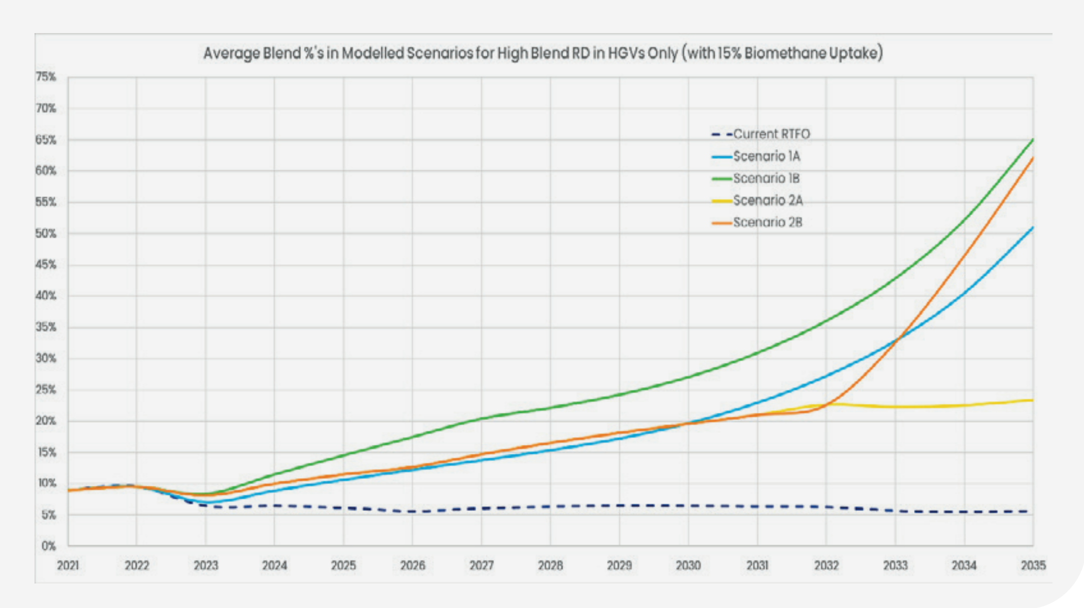


Figure 15. Modelled average blend percentages for increasing supplies of renewable diesel to HGVs only

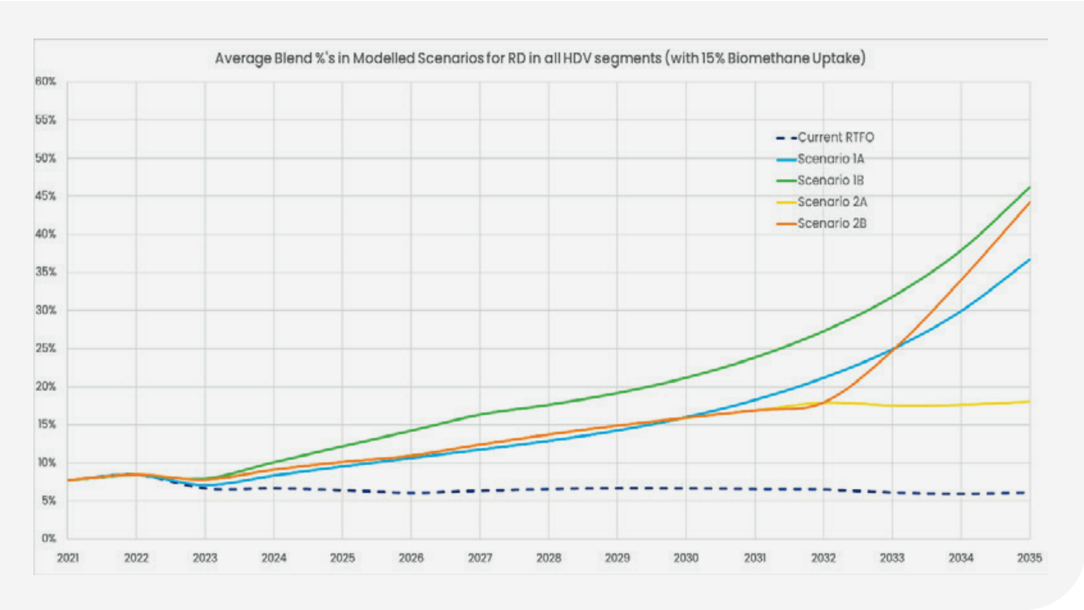


Figure 16. Modelled average blend percentages for increasing supplies of renewable diesel to HDV & NRMM

If all "spare" renewable diesel is directed specifically at the HGV sector (**Figure 15**), average blend percentages would increase under Scenarios 1A, 1B and 2B to somewhere in the range 50-65% by 2035. In Scenario 2A, which freezes the 2032 RTFO target out to 2035, the average blend gets to a little under 25%. While the modelling does not distinguish between FAME biodiesel and HVO, these high average blends in the early 2030s could materialise as widespread uptake in HVO or B20 or combination of biodiesel and HVO blends. In all the modelled alternative scenarios, average blend percentages in the 2020s increase quite modestly, to around 20-25%.

If the additional renewable diesel volumes are used over a wider market, embracing all heavy duty vehicles and NRMM sectors, the average blend percentages would, naturally, be slightly lower than for the HGV sector alone (**Figure 16**). For this situation, Scenario 2A would achieve an overall average blend of only around 18% in the 2032-35 period. In the other scenarios modelled, the blend percentages increase to around 15-20% by 2030 and 35-45% by 2035.

7. Costs and GHG savings benefits

7.1 GHG savings benefits

The preceding section describes our modelling of various scenarios supplying more renewable diesel fuel into the UK HDV and NRMM fleets than would be the case simply under the existing RTFO conditions. In greenhouse gas savings terms, each litre of additional renewable fuel (that displaces what would otherwise have been a litre of pump average, mostly fossil-derived diesel) saves 2.5 kg of carbon dioxide equivalent emissions[12]. This means by simply deducting the scenario-modelled annual volumes of renewable diesel from the baseline (current RTFO) scenario, the annual and cumulative GHG emissions savings can be calculated (**Table 4**).

		Scenario 1A		Scenario 1B		Scenario 2A		Scenario 2B	
Year	Current RTFO (Baseline) supply (Ml)	Fuel displaced (Ml)	GHG savings (MT CO_2e)	Fuel displaced (Ml)	GHG savings (MT CO_2e)	Fuel displaced (Ml)	GHG savings (MT CO_2e)	Fuel displaced (Ml)	GHG savings (MT CO_2e)
2021	1924	0	0.00	0	0.00	0	0.00	0	0.00
2022	2206	0	0.00	0	0.00	0	0.00	0	0.00
2023	2155	50	0.13	150	0.38	133	0.33	133	0.33
2024	2012	193	0.48	393	0.98	279	0.70	279	0.70
2025	1858	348	0.87	648	1.62	414	1.03	414	1.03
2026	1700	505	1.26	905	2.26	539	1.35	539	1.35
2027	1623	582	1.46	1082	2.71	654	1.63	654	1.63
2028	1537	668	1.67	1168	2.92	755	1.89	755	1.89
2029	1434	772	1.93	1272	3.18	837	2.09	837	2.09
2030	1306	900	2.25	1400	3.50	893	2.23	893	2.23
2031	1160	1046	2.61	1546	3.86	923	2.31	923	2.31
2032	1013	1193	2.98	1693	4.23	930	2.32	930	2.32
2033	843	1362	3.41	1862	4.66	830	2.08	1349	3.37
2034	706	1500	3.75	2000	5.00	730	1.82	1756	4.39
2035	593	1613	4.03	2113	5.28	630	1.58	2009	5.02
Totals	**22069**	**10732**	**26.8**	**16232**	**40.6**	**8545**	**21.4**	**11469**	**28.7**

Table 4. Additional renewable diesel volumes and GHG savings under modelled scenarios

To put these cumulative savings into context, the UK HGV fleet is currently responsible for emitting about 20 MT CO_2e per annum, so the four scenarios modelled would all save at least one year's worth of HGV emissions between now and 2035 and at most (Scenario 1B) over two years' worth. This is particularly important given that HGVs are responsible for 18% of road transport GHG emissions and one of the hardest sectors to decarbonise.

[12] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2021

In a scenario where higher blends of renewable diesel (biodiesel and HVO) were directed only towards the HGV sector (via a fiscal incentive), the analysis has shown that an average 30% renewable diesel adoption across the HGV fleet could be feasible by 2035. The CCC's Carbon Budget 6 has estimated the cumulative GHG emission abatement required to meet net zero in 2050. By 2035 the HGV sector will need to mitigate GHG emissions by a significant magnitude - 100 million tonnes. Higher blends of renewable diesel have a key role to play in contributing this level of decarbonisation, given that zero emission vehicles are unlikely to be deployed at scale by that time. Zemo has quantified the cumulative GHG emission abatement in 2035 for HGVs using our forecasted transition zero tailpipe emission vehicle technologies (central scenario), assuming no changes to the RTFO. We have then determined the 'additional' cumulative GHG emission savings for an average 30% blend of renewable diesel adoption across the HGV fleet by 2035, combined with a growth in biomethane artic HGVs. As can be seen in **Figure 17** an additional saving of 50 million tonnes could be achieved through the adoption of sustainable low carbon fuels in HGVs; with higher blends of renewable diesel abating in the order of 25 million tonnes of GHG emissions by 2035. (As the analysis has shown previously, the RTFO target would need to increase to enable this to materialise.)

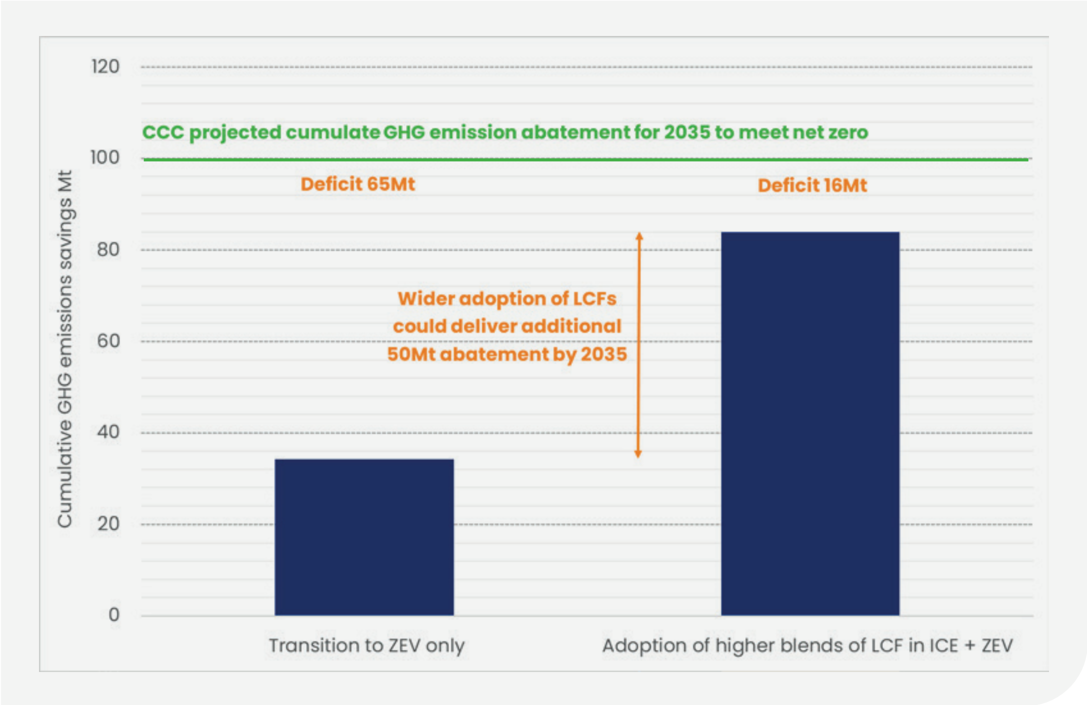


Figure 17. Modelled GHG emission savings with and without the adoption of higher blends of low carbon fuels in HGVs

7.2 Cost analysis

7.2.1 Carbon price analysis

As well as quantifying the environmental savings via calculations of displaced greenhouse gas emissions, it is possible to assign financial values through official carbon price projections. These are published by the UK Government as part of its supplementary guidance to the Treasury's Green Book methodology for policy appraisal[13]. Over the period modelled, carbon values increase annually from £245 per tonne of CO_2e in 2021 to £302 in 2035 (forecast based on 2020 equivalent prices).

Applying Net Present Value techniques and using the official 3.5% social discounting rate, yields combined values (at 2020 prices) of the cumulative GHG savings from each of the scenarios of:

- Scenario 1A: £5.7 billion
- Scenario 1B: £8.8 billion
- Scenario 2A: £4.7 billion
- Scenario 2B: £6.1 billion

[13] https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal (Table 3, Central values used)

To inform our analysis of various fuel duty discount rates described elsewhere in this report, these GHG savings valuations have been divided into the overall supply volumes of renewable diesel in each scenario (for all volumes supplied after 2022), providing at least a broad indication of the pence per litre value if spread across all renewable diesel supplied (including that needed for light duty vehicles and current RTFO compliance). The pence per litre supplied values of GHG savings, cumulatively and at 2020 prices, for each modelled scenario are:

- Scenario 1A: 20 pence
- Scenario 1B: 26 pence
- Scenario 2A: 16 pence
- Scenario 2B: 19 pence

These figures suggest that support mechanisms to encourage and incentivise the wider uptake of renewable diesel fuel to displace fossil-derived diesel can cost the equivalent of 15-25p per additional litre incentivised, depending on the exact scenario, and still be cost effective in overall terms out to 2035. This has been confirmed by more detailed net present value (NPV) modelling for each scenario – at an assumed equivalent expenditure of 15 ppl supplied, all the scenarios produce cumulative benefit: cost ratios of more than one (range 1.3-2.1). At a higher assumed cost of 20 ppl equivalent, Scenario 2A generates a ratio of 0.95 (i.e. the costs just outweigh the benefits) but the other scenarios remain beneficial overall, with ratios in range 1.2-1.6.

7.2.2 Indicative cost to Treasury

The HDV average % blend predictions for Scenario 2A have been used to determine an indication of the cost to Treasury from the fuel duty incentive for renewable diesel. As shown in **Table 5**, the reduction in income to Treasury is predicted to be about 1% in 2022, rising to 6% in 2032. This indicative cost is based upon the following assumptions and simplifications:

- The HVO supply in 2022 is 40 million litres and grows by 10% per annum (the Renewable Fuel Statistics 2020 Final Tables list HVO as 37.8 million litres). This is supplied as 100% HVO.
- The remaining renewable diesel volume for the RTFO is FAME, supplied as B7 and B30.
- The total diesel demand volume is made up with mineral diesel (blended with FAME in B7 or B30).

	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Standard income to Treasury from fuel duty (£m)	6649	6639	6633	6602	6518	6375	6189	5962	5669	5300	4855
Income to Treasury with renewable diesel fuel duty incentive (£m)	6603	6606	6563	6499	6389	6204	5982	5725	5412	5029	4579
Cost difference (£m)	46	34	70	102	129	170	207	236	257	271	276
% Cost difference	1%	1%	1%	2%	2%	3%	3%	4%	5%	5%	6%

Table 5. Illustrative projection of cost to Treasury of introducing a fuel duty incentive for renewable diesel across HDV and NRMM fleet

8. Conclusions

The increase in whole life costs associated with running HDVs and NRMM equipment on higher blends of biodiesel and HVO is a key barrier to the wider scale adoption of renewable diesel. A financial incentive for increasing the adoption of renewable diesel has been proposed to help improve the business case for fleet and NRMM equipment operators. The incentive entails a reduction in fuel duty, based on the blend and GHG saving potential of the renewable fuel. It is proposed the incentive should apply to low carbon liquid distillate fuels with renewable fuel blends of 20% or more, and only for renewable fuels which comply with the RTFO GHG emissions savings threshold and sustainability standards. The analysis explored a maximum fuel duty discount of 15 ppl for 100% FAME and HVO, which would be scaled down to 3 ppl discount for a 20% blend of FAME and HVO. This revealed -

- In general, although reduced, there are still additional WLC for using higher renewable diesel blends. Engagement with various stakeholders indicated this would be acceptable and sufficient to encourage a switch to higher blends of renewable diesel.
- B20 becomes more affordable for operators and might even reach price parity (or close to) for some HDV and NRMM applications and use cases.

It is important for operators considering a switch to renewable diesel (particularly where upfront investments vehicle/equipment and fueling infrastructure are required) to understand the impact that fluctuations in fuel prices might have on the WLC. A sensitivity analysis (performed for the 18t HGV truck with regional duty cycle) shows that:

- A 20% increase in the renewable fuel price would erode most of the financial benefit from a fuel duty discount with a maximum of 15 ppl.
- A 20% increase in the fossil diesel price would make the renewable fuels more affordable for operators, with B20 and the HVO blends even offering WLC savings, compared to diesel.

Zemo received positive feedback on the proposed approach for a fuel duty discount from industry stakeholders in the HDV and NRMM sectors. Higher blends of renewable diesel are considered essential, as an immediate and necessary bridging technology with regards to meeting net zero. This is especially the case for operators who purchase second-hand vehicles and for those with customers less willing to accept increased costs for low carbon fuels; as well as the long-haul HGV, coach and NRMM sectors, where there are significant challenges with alternative powertrain technologies. Feedback suggests that preference for HVO may be higher than FAME due to its 'drop-in' nature.

Zemo's analysis on the future demand for diesel fuel in transport shows:

- With the transition of vehicles to non-diesel alternatives, the annual diesel fuel demand for transport is projected to fall from its current level of 34 billion litres, to between 20 and 24 billion litres in 2030, and 1-3 billion litres by 2045.
- Between 2022 and 2032 some parts of the HGV and NRMM sectors will be in the very early stages of transitioning to electric propulsion technology. As a result of this, a significant volume of diesel will continue to be used in ICE powered vehicles and off-highway equipment. Renewable liquid fuels therefore offer an immediate near-term opportunity for reducing GHG emissions in these sectors. Indeed, they offer the only real opportunity, as the market for electric propulsion systems is in its infancy. Given the Government's ambition to reduce economy-wide GHG emissions by 68% by 2030, mitigating GHG emissions from heavy duty sectors that continue to rely on diesel over the next decade will be paramount.
- As the demand for diesel reduces over time for the light duty vehicle sector, due to electrification, this will liberate both biodiesel and HVO which could be supplied to the HDV and NRMM sectors as high blends of renewable diesel. Additional supplies of drop-in renewable diesel fuel will also become available over the next decade.
- As the demand for diesel falls over time, the existing RTFO targets are likely to be met through E10 petrol and B7 forecourt diesel. Hence there is little or no incentive for supply of higher blends of renewable diesel in the HDV and NRMM fleets, and an immediate and gradual decline in overall volumes of renewable diesel supply is expected.
- The RTFO targets should be increased to support a growth in the overall supply of renewable diesel (HVO and biodiesel) into the UK HDV and NRMM sectors.

Zemo's analysis on the uptake of renewable diesel and GHG savings shows:

- Average blend percentages of renewable diesel could increase to around 15-45% by 2035 across the HDV and NRMM sectors, or to around 20-65% within the HGV sector alone.
- The cumulative GHG savings could reach 20-40 million tonnes of CO_2e by 2035 (for comparison, the UK HGV fleet is currently responsible for emitting about 20 million tonnes of CO_2e per annum).
- With an increase in the RTFO target and the adoption of higher blends of renewable fuels to achieve an average of 30% across the HGV fleet by 2035, it is estimated that around 25 million tonnes of CO_2e could be abated by 2035. This contribution is absolutely essential for meeting net zero by 2050.

Zemo's analysis on the carbon pricing and the indicative cost to Treasury from a fuel duty discount shows:

- Renewable diesel fuel incentives of 15-25 pence per additional litre incentivised can be cost effective in terms of carbon pricing, out to 2035.
- It is estimated that by incentivising higher blends of renewable diesel with a maximum fuel duty discount of 15 ppl, the income to Treasury from HDV diesel sales will reduce by about 1% in 2022, rising to 6% in 2032.

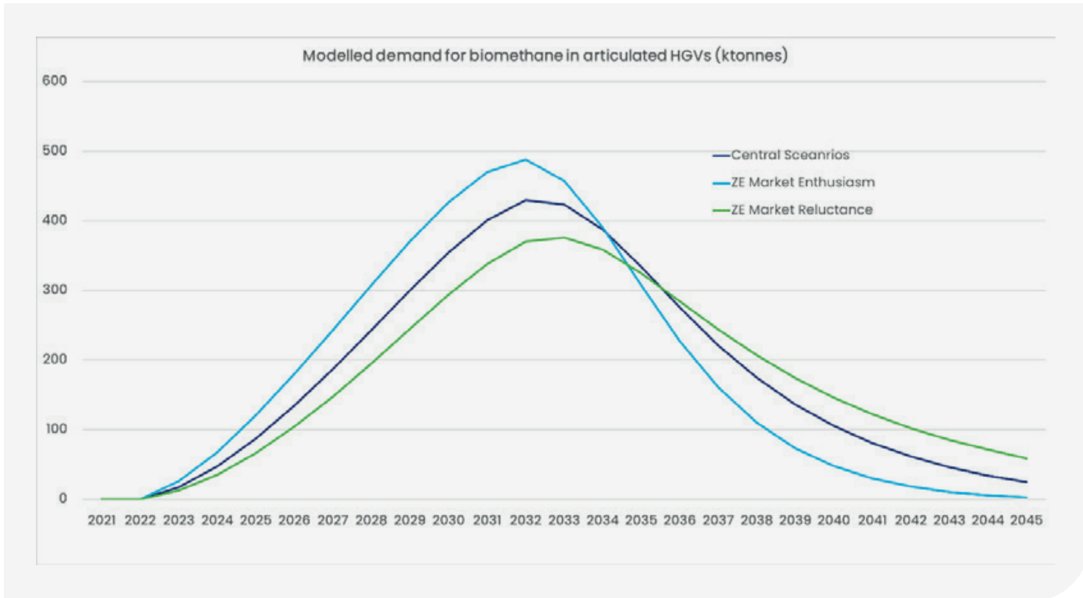
9. Appendix

Whole life costs analysis input data and assumptions:

Application and use case	Lifetime	Annual milage / operation	Vehicle diesel consumption	Annual diesel* consumption	Fleet size
Rigid HGV truck (18t), regional duty cycle	8 years	60,000 km	28.0 L/100km	16,800 litres	50
Mini excavator (<5t)	10 years	1,100 hours	3.7 litres/h	4,100 litres	10
Wheel Loader (>5t)	10 years	1,200 hours	18.1 litres/h	21,700 litres	10

* It is assumed that the energy required is the same for all fuels, hence fuel consumption for the renewable diesel blends is calculated using the energy density of the renewable and fossil fractions.

Modelled projections of biomethane demand (for articulated HGVs):



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