NRW Carbon Positive Project

NRW Strategic Fleet Carbon Review

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Report No 278

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Published by:
Natural Resources Wales
Maes y Ffynnon
Ffordd Penrhos
Bangor

About this report

This report was commissioned by the NRW Carbon Positive Project to better understand the potential role low carbon technologies could play in reducing the carbon emissions associated with the operation of the NRW fleet and plant machinery.

The information within this report has been used to inform the evaluation of NRW's mitigation options and subsequently to outline the potential measures NRW may take forward to deliver decarbonisation in the future as part of the Carbon Positive Enabling Plan and its supporting Action Plan.

Report details

Report series:	NRW Evidence Report Series
Report number:	278
Publication date:	13th December 2017
Contractor:	Cenex
Contract Manager:	J. Kelly
Title:	**NRW Strategic Fleet Carbon Review**
Author(s):	**S. Carroll, N. McCarthy, L. Knott**
Technical Editor:	S. Carroll
Approved By:	J. Kelly
Restrictions:	None

1 Distribution List (core)

NRW Library, Bangor 2

2 Recommended citation for this volume:

Carroll, S., McCarthy, N., Knott, L. 2017. NRW Strategic Fleet Carbon Review. NRW Carbon Positive Project. Report No: 278, 123pp, Natural Resources Wales, Bangor

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Document Revisions

No.	Details	Date
1	Draft for customer comment	02/04/2017
2-4	Internal review	16/11/2017
5	Final release	13/12/2017

Contents

Table of abbreviations

AQ	Air quality
ATVs	All-terrain vehicle
AWD	All Wheel Drive
B25/B##	25%/##% blend of biodiesel in the fuel with remaining being conventional diesel
CapEx	Capital expenditure
CNG	Compressed natural gas
CO_2	Carbon dioxide. All CO_2 emissions stated include other greenhouse gas emissions on a CO_2 equivalence basis (CO_2e).
EV	Electric vehicle
GHG	Greenhouse gas
H_2	Hydrogen
HC	Hydro-carbon
HDi	High-pressure direct injection
hp	Horsepower
HGV	Heavy goods vehicle
HVO	Hydrotreated vegetable oil
ICE	Internal combustion engine
kg	Kilogram
KPI	Key performance indicator
kWh	Kilowatt-hours
LPG	Liquefied petroleum gas
MPA	Miles per annum
MPG	Miles per gallon
No.	Number
NO_X	Oxides of nitrogen
NRW	Natural Resource Wales
NVH	Noise vibration harshness
OEMs	Original engine manufacturers
PEM	Proton exchange membrane (hydrogen fuel cell)
PHEV	Plug-in electric vehicle
PiCG	Plug-in car grant
PiVG	Plug-in van grant
PM	Particulate matter
ppl	Pence per litre
PTO	Power take-off
REEV	Range-extended electric vehicle
RPM	Revolutions per minute
SUV	Sports utility vehicle
T	Tonnes
TCO	Total cost of ownership
TTW	Tank to wheel
WTW	Well to wheel

3 Executive Summary

Natural Resources Wales (NRW) commissioned Cenex to undertake a review of the carbon emissions resulting from its fleet use and to identify areas where carbon dioxide (CO_2) emissions could be reduced. Cenex undertook a detailed review of the NRW fleet vehicles and a higher-level review of operational plant.

The scenarios investigated by this review indicate that a significant proportion of the NRW fleet vehicles could become low emission. It is recommended that NRW pursue electric cars and small vans as a priority, alongside further investigation on wider decarbonisation of the fleet (including plant). An interim switch to petrol from diesel will not yield carbon savings but would, alongside increasing electrification, have a significant impact on the NOx emissions from the fleet contributing to addressing air quality issues.

A key message is that scoping of, and management commitment to, appropriate electric vehicle charging infrastructure is required ahead of any further expansion/investment in electric vehicles.

To support the business case for adopting low emission technologies, investment in telematics will generate a robust evidence base for future decisions and provide evidence for the scenarios outlined in this review.

Note: throughout the report "CO_2" is used to refer to "CO_2e" (carbon dioxide equivalent).

<u>Headline findings and recommendations:</u>

For fleet vehicles, it is recommended that NRW pursue the feasibility of implementing the Scenario 2 options described below. Utilising a mix of telematics, electrification and reduction in vehicle numbers a fleet **well to wheel (WTW) CO_2 reduction of 39% (59% tank to wheel (TTW) CO_2 reduction)** and **cost reduction of 22%** could be achieved. A 17% reduction in fleet vehicle numbers alone accounts for a 14% cost saving (CO_2 reduction is 0 as it is assumed fleet mileage and fuel consumption remains constant, but utilisation of vehicles is increased). Operating the fleet without a reduction in vehicle numbers or the installation of telemetry facilitates a WTW CO_2 reduction of 26% (TTW CO_2 reduction of 49%) and a cost reduction of 5%. For carbon emission reductions in vehicles where electrification options are uneconomic (e.g. 4x4s, large vans), the use of biodiesel blends would need to be considered. The additional benefit would be an 18% WTW (23% TTW) saving per vehicle, but at a 4% cost increase (which equates to around £20,000 per annum to convert all suitable vehicles) using biofuel derived from used cooking oil (i.e. not virgin oils).

Recommended next steps for fleet vehicles are:

- Reduce vehicle numbers in the fleet. Effective utilisation of vehicles is key to achieving the cost benefits available from low emission vehicles and so vehicle number reductions will increase the overall annual mileage of the fleet vehicles, which assists the case for technology change.
- It is recommended that a telematics technology trial is undertaken, especially in the 4x4 and large van categories where low carbon options are limited, with a view to installation of telematics on all vehicles. Telematics help to save fuel and also support identification of which vehicles are appropriate for electrification.
- Develop a strategy for implementation of low emission technologies outlined in this study. This must include appropriate charging infrastructure for the number of vehicles proposed for introduction into the fleet, which must be installed prior to commitment to EVs.

- Furthermore, it is recommended opportunities should be re-assessed every 12 months to consider the maturing supply of large panel van EVs, bioLPG availability, and a renewable diesel fuel, HVO (hydro-treated vegetable oil), which can drop-in to forecourt diesel with no effect on manufacturers' warranties or servicing regimes.

For plant vehicles, the high-level review highlighted that emission savings at similar or better total cost of ownership (TCO) could be available from interventions such as implementing fuel efficiency measures and driver training, diesel-hybrid excavators in the NRW operations, electric quads, electric mowers (for reservoirs) and biodiesel. For example, NRW could reduce their tractor based fuel consumption, and resultant emissions, by at least 20% by implementing fuel efficient staff training policies. This could also result in a 12% reduction in total operating costs of these vehicles. These options should be subject to a more detailed review and trialled where necessary to establish accurate emission and cost savings. Recommended next steps for plant vehicles are:

- An operational assessment of the suitability of fully electric quads and new, more efficient large excavators (for immediate replacement) should be undertaken.
- Fingerpost, Pont-y-Garth and Rhuddlan depots should be assessed for the implementation of biodiesel (engine compatibility and fuel demand is critical)[1].
- NRW should start to track, monitor and manage fuel use in plant operations to more robustly inform options appraisals moving forward.
- Training for fuel efficiency for all staff operating tractors should be delivered.
- Any diesel-powered equipment in the NRW fleet that is still powered with Stage-III diesel engines (or older) should either be replaced with modern Stage-IVB (or if possible Stage-V) at the earliest opportunity.
- NRW should continue to monitor low emission options to take into account new product offerings on an annual basis.

[1] Biodiesel facilities can be extended to include several other items of plant, but the business case for the creation of biodiesel infrastructure and policies will be highly reliant on tractor operations, with excavators also being a contributing factor. Fingerpost, Pont-y-Garth and Rhuddlan depots should be assessed for the implementation of biodiesel (engine compatibility is critical). The success of biodiesel projects will be dependent on a depot based 'champion' with the knowledge, skill, and authority to drive the changes to a successful conclusion.

3.1 Fleet Review

Cenex evaluated the NRW fleet, consisting of 584 vehicles undertaking 5.5 million miles per annum, emitting 1,645 tonnes of TTW CO_2 and 1,994 tonnes of WTW CO_2 per annum. The fleet comprises of Small Vans (40%), Cars (32%), 4x4 vehicles (22%), Large Vans (6%) and Trucks (1%). 61% of vehicles are less than 4 years old and 94% of vehicles comply with Euro 5 and 6 standards.

Technology Review:

Cenex undertook a high-level technology review to establish which technologies have the potential to deliver CO_2 savings at a similar or better total cost of ownership (TCO). Identified technologies were taken forward to the detailed review stage where TCO and CO_2 emissions models were used to estimate the likely performance of low emission vehicles in the NRW fleet. The conclusion of the review and recommended next steps are as follows.

Analysis Showed	Recommended Next Steps
Cars:	
Electric vehicles (EVs) are a good operational fit in the car fleet, saving 50% WTW (100% TTW) CO_2 whilst reducing the TCO by up to 25%, and providing a 100% nitrogen oxides (NO_X) and particulate matter (PM) air quality emissions saving. EVs should be implemented into NRW's fleet where practical. Petrol hybrids can offer improvements on CO_2 at a similar or lower TCO where an EV is not a practical solution. **Pool Fleet** – An analysis of pool fleet car usage showed that 43% of daily trips are less than 50 miles this indicates that a good proportion of office based pool vehicles are also suitable for transition to EVs.	Review individual vehicle mileages, preferably through the installation of telemetry systems, and develop an EV replacement strategy supported and informed by trialling of EVs. Investigate site power requirements for installation of recharging infrastructure. Analyse current Nissan Leaf performance data. Trial petrol hybrids to confirm desk-top study results. Following a successful trial, petrol hybrids should be implemented in the car fleet where EVs are not practical due to range and charging limitations.
Small Vans:	
EVs (e.g. Nissan e-NV200, Renault Kangoo ZE) are a good operational fit to the small van fleet, saving 50% WTW (100% TTW) CO_2 at a similar or better TCO. EVs should be implemented where practical.	Review individual vehicle mileages, preferably through the installation of telemetry systems, and develop EV replacement strategy supported and informed by trialling of EVs and investigation of site power requirements.
4x4:	
Reducing carbon from the 4x4s is challenging due to very poor availability of low emission alternatives in this segment. A less robust 4x4 drive system is offered through modern All Wheel Drive (AWD) vehicles which may be suitable for some applications currently carried out by 4x4s.AWD vehicles such as lower spec diesels (Dacia Duster), petrols (Seat Ateca), and	Review fleet to assess where options are available to downgrade 4x4s to AWD vehicles. Consider biodiesel use (see Scenario 3 notes below).

PHEVs (Mitsubishi Outlander PHEV) all offer emission and TCO benefit. Due to the limited options available to decarbonise the 4x4 fleet, biodiesel use around depots with sufficient demand and security to justify the installation of a bunkered tank should be considered. Vehicle warranties require discussion with manufacturers and not all vehicles will be compatible.	
Large Vans:	
Reducing carbon from the large vans is challenging: CNG and electric options are available but significantly increase TCO.	Consider biodiesel use (see Scenario 3 notes below). Reassess in 12-months as large EV van market matures and renewable diesel drop-in fuels may start to come to market.

Electric Vehicle (EV) Charging Infrastructure:

To realise the potential of EVs in the fleet, investment in charging infrastructure is essential. A feasibility study should be conducted on the charging infrastructure requirements taking factors into account such as:

- Infrastructure capacity and charge rate requirements (13amp charging from existing electrical sockets is not a long-term solution for charging due to safety concerns).
- Commitment to charging infrastructure before purchase of vehicles is required.
- Electrical capacity at sites should be investigated to ensure suitability for installing charging infrastructure and any future implementation of electric vehicles.
- Groundwork requirements.
- Payment platforms and back office system requirements (e.g. 3G requirements, data requirements etc.)

The assumption could be made that each unit will service two vehicles (taking into account vehicles that regularly visit the site).

Fleet Best Practice:

In addition to changes in technology, this review also highlighted the following:

Downsizing:

Downsizing diesel cars can lead to TCO savings of up to £2,000 (11%) and 87 kgs (8%) WTW CO_2 or 70 kgs (8%) TTW CO_2 per vehicle.

Recommended Next Steps: It is recommended that NRW review the size of vehicles used within their fleet and downsize vehicles where this is practical.

Ownership Model:

Analysis showed that changing to an ownership model for the diesel vehicles (compared to the current lease model) could result in 5-year TCO savings per vehicle of £4,912 for small cars (Ford Fiesta), £8,059 for medium cars (Ford Focus), £3,322 for small vans (Citroen Nemo), £8,651 for 4x4s (Mitsubishi

Outlander) and £8,160 for large vans (Ford Transit). Similar savings are also available for alternatively fuelled vehicles: for example a £2,780 saving for purchasing medium car EVs (Nissan Leaf) rather than leasing, £2,587 for medium car petrol hybrids (Toyota Prius) and £6,264 for small EV vans (Nissan e-NV200).

Due to capital constraints, NRW lease most fleet vehicles and future acquisitions of vehicles will largely be on a lease basis. It is recognised that significant TCO savings could be available if the organisation were able to pursue a vehicle ownership model.

Recommended Next Steps: Vehicle ownership and lease prices were taken from the Government Procurement Portal. It is recommended that NRW investigate the savings available through their procurement process and undertake a trial purchase of vehicles to confirm savings available through an ownership model.

Telematics:

Fleet telematics can reduce fleet CO_2 by around 15%. A simple payback calculation showed that telematics are only economically viable in higher mileage vehicles. For low mileage vehicles, the annual cost increase per vehicle (£40 - £50) is still a worthwhile investment to generate the robust evidence base (data and information) that telematics systems supply to inform future strategy. Furthermore, the cost analysis did not include costs associated with wider benefits of accident reduction and vehicle maintenance, which are difficult to quantify – case study evidence shows accident rates can drop by around 20 – 35%. Telematics help to save fuel and identify which vehicles are appropriate for electrification.

Recommended Next Steps: It is recommended that a telematics technology trial is undertaken, especially in the 4x4 and large van categories where low carbon options are limited.

Implementation Scenarios:

To demonstrate the effect of the recommended technologies on CO_2 emissions, three implementation scenarios were considered.

- **Scenario 1 – Alternative Vehicle Adoption** - A scenario focused on achieving the lowest CO_2 emissions (i.e. the highest carbon reduction) through the implementation of all recommended technologies in the current vehicle fleet (where practical) based on a business as usual scenario (same number of fleet vehicles and same total mileage of the fleet). This included a blend of EVs (324), petrol-hybrids (23), plug-in hybrids (6) and B25 biodiesel (88), which achieved a fleet **WTW CO_2 reduction of 26%, a TTW CO_2 reduction of 49% and resulted in a 5% overall TCO saving** (a saving of around £117,000 per annum). Without the biodiesel option a fleet **WTW CO_2 reduction of 22%, TTW CO_2 reduction of 44% and a similar 5% overall TCO saving are available** (a saving of around £136,000 per annum). This demonstrates that, in the short term, NRW should concentrate efforts on the electrification of its fleet, installation of telematics and reduction in vehicle numbers ahead of introducing biodiesel blends into the vehicle fleet to achieve maximum CO_2 impact.

- **Scenario 2 – Alternative Vehicle Adoption & Efficiency Improvement** - A scenario focused on a cost-effective transition to low emission vehicles was considered with a reduction in fleet size where a total of 100 vehicles were removed (based on NRW Fleet reduction targets, where most reduction is in the 4x4 category), leaving 477 vehicles in the reduced fleet in the scenario. The scenario also resulted in an increase in the average annual mileage of the other vehicles due to higher utilisation of a smaller number of vehicles. Furthermore, telemetry system uptake was included in this analysis to give a 15% fuel saving in each vehicle. This scenario included a blend of EVs (301), petrol-hybrids (23), plug-in hybrids (6) and B25 biodiesel (79). A total of 409 low emission vehicles were included in the scenario (forming 85% of the reduced fleet), which achieved a fleet **WTW CO_2 reduction of 39%, TTW CO_2 reduction of 59% and resulted in a 22% overall TCO saving** (a saving of around £500,000 per annum). Without the biodiesel option a fleet **WTW CO_2 reduction of 33%, TTW CO_2 reduction of 52% and a similar 22% overall TCO saving are available** (a saving of around £508,000 per annum). As in scenario 1, this demonstrates that, in the short term, NRW should concentrate efforts on electrification of its fleet, installation of telematics and reduction in vehicle numbers ahead of introducing biodiesel blends into the vehicle fleet to achieve maximum WTW CO_2 reduction.

- **Scenario 3 - Biodiesel-Based Assessment -** A scenario looking in more detail at B25 depot biodiesel implementation was considered. Here it was shown that two to six NRW sites potentially have sufficient demand to justify bunkered biodiesel storage. Vehicles that were suitable for electrification were not included in this analysis. NRW would need to consider varied manufacturer support and additional fuel management risks associated with biodiesel blends and increased fleet costs (e.g. associated with maintenance, additional costs of storage tanks, tank cleaning, fuel inspections). Large mixed fleets that operate biodiesel successfully employ and number of options, including i) use biodiesel in vehicles once they are out of the manufacturer warranty, ii) operate at risk invalidating the engine warranty, or iii) purchase only compliant and warranted vehicles (however this limits vehicle choice). Fleets that successfully operate with biodiesel require a dedicated champion of the technology to overcome challenges and manage fuel quality. In conclusion, the overall uptake of 88 B25 biodiesel vehicles would allow these vehicles to achieve a **WTW CO_2 reduction of 18%, (23% for TTW) at an additional 4% TCO increase** (at an additional cost of around £20,000 per annum) when compared to not converting these 88 vehicles. When compared to emissions of the **entire fleet**, implementing biodiesel across these sites resulted in an overall 4% emission saving.

The scenarios indicated that a significant proportion of the NRW fleet could become low emission. However, emission savings are limited by the fact that the high emitting vehicles (large vans and 4x4s are collectively responsible for 44% of fleet emissions) have limited decarbonisation options. The scenarios did not include any downsizing of vehicles in the fleet and this should also be considered where possible to yield further costs and carbon savings. There are technologies on the horizon which can assist in these hard to decarbonise areas and should be re-assessed in around 12 months' time. Upcoming technologies include the maturing supply of large panel van EVs and a renewable diesel fuel, HVO (Hydro-treated vegetable oil), which can drop-in to replace forecourt diesel with no effect on manufacturers warranties or servicing regimes.

Recommended Next Steps: It is recommended that NRW pursue the feasibility of implementing Scenarios 2 options. Even considering the limited options in the large van and 4x4 vehicle classes, significant cost and emission savings were available in Scenario 2 when combining alternative vehicle adoption and efficiency improvements (telemetry and reduction in vehicle numbers). NRW should continue to monitor low emission options to take into account new product offerings on an annual basis. For example, consideration should be made to the suitability of hydrogen vehicle options in the fleet once appropriate vehicles and fuelling infrastructure are available.

3.2 Plant Review

Cenex evaluated the NRW plant fleet consisting of 258 plant vehicles and attachments emitting 1,269 tonnes of WTW CO_2 and 1,036 tonnes of TTW CO_2 per annum. The fleet comprises of Tractors (27), Mowers (26), Digger/Dumper units (34), Chippers (11) and All-Terrain Vehicles (ATVs) (including quad bikes) (34), Forklifts (8), an assortment of specialised plant equipment (7) and a wide variety of miscellaneous plant attachments. 51% of plant vehicles are more than ten years old.

Many opportunities for fuel cost and engine emission reductions exist within the NRW plant fleet. Cenex have completed a high-level review of plant equipment operated by NRW, due to lower availability of detailed data on usage profiles and fuel use. A total potential saving from plant has not been provided due to the level of uncertainty around which options could be taken by NRW in its management of plant. Further detailed analysis of operations and business cases on individual options would provide more reliable cost and carbon savings, using the advice and figures contained within the plant section of this report. However, a scenario involving a mix of plant at a depot representative of NRW showed that a fuel consumption saving of 22% and a WTW CO_2 emissions savings of 39% could be achieved. This was in the main realised due to the adoption of B30 Biodiesel.

The 147 items considered were broken down into eight separate categories. Note that all fuel and emissions stated for plant are Cenex estimates. No fuel use data on plant were available and it is recommended NRW start to track, monitor and manage fuel use in plant operations. Several key opportunities for NRW plant fleet improvements were identified:

Analysis Showed	Recommended Next Steps
Tractors:	
Tractor units are estimated to consume 62% of the NRW plant fleet fuel per year. Tractor units can achieve up to 25% fuel and associated CO_2 savings through driver training. This could result in a 12% reduction in total operating costs of these vehicles.	NRW should investigate the implementation of fuel efficiency measures such as: • Fuel efficiency training with in-cab fuel monitors for drivers. • Optimised plant attachment fitting training. • Optimised tyre-pressures for operational-conditions training. • Regular staff training and assessment. Changes to heavy plant depot day-to-day practices may be required if these measures are adopted.
Quad bikes:	
NRW existing fleet of quad bikes emit 37 tonnes per year of CO_2. Fully electric quad-bikes are available that offer up to 45% reduction in CO_2. Up to 80% quad replacement with EV alternatives could be achieved. Higher priced electric quad bikes offer a payback period of 3.5 years resulting from reduced running costs.	An operational assessment of the suitability of fully electric quads should be undertaken.

Excavators:	
NRW's existing fleet of five 21 tonne excavators are generally more than 10 years old (with one exception). Electric-diesel hybrid excavators, in the 22 t and larger range, are available with up to 40% reduction in emission and fuel costs.	Manufacturers claim up to 40% reduction in emissions and operating costs (for high slew rate tasks). All 21t or larger excavators in the NRW plant fleet should undergo operational assessment of slew rates, to determine if there is a business case for immediate replacement.
Forklifts and Telehandlers:	
Forklifts and telehandlers with reduced emissions are available with up to 30% (electric-hybrid) and 50% (fully electric) WTW emission reduction.	Continue to monitor market offerings, as there are currently no cost-effective alternatives. The very low usage rates for NRW forklifts and telehandlers make the business case for new technology replacement difficult to make. These lower emission alternatives will be more expensive to operate on a total cost of ownership basis unless utilisation can be significantly increased. There is a CapEx premium for the purchase of all electric or hybrid vehicles. For maximised CO_2 reduction, any future purchases of forklifts and telehandlers should prioritise diesel-electric hybrid vehicles and (if ground conditions are suitable) fully electric forklifts (if the cost is justifiable).
Mowers:	
Electric mowers area available but the NRW fleet department report that mower operations, historically, have not been suited to alternative powertrain operations.	Maintain under review. NRW report that operational requirements for the existing NRW mower fleet may not be well suited to electrification. However, the grass mowing requirements at reservoirs have recently been changed, and electrification of mowers at reservoir sites may now be considered – a review of suitability is recommended.
Diesel Plant Replacements:	
Much (51%) of the NRW plant fleet is at least ten years old. All new non-road mobile machinery purchases will have to be Stage-V emissions compliant from 2019 or 2020 onwards depending on engine size (assuming the UK adheres to current EU legislative plans). Modern plant engines offer improved fuel efficiency and emission improvements of approximately 15% compared to 2006 and older engines.	Update fleet replacement schedules to accelerate compliance with Stage-V NRMM (Non-Road Mobile Machinery), emission standards for all plant engines to reduce overall emissions and running costs. Some plant units may be well suited to end-of-life retrofits of alternative fuels and powertrains. These should be considered as technology demonstration projects prior to wider fleet roll out.

Biodiesel:	
Biodiesel is a proven technology which can be implemented in the NRW fleet. However, it has several key limiting factors that need considering: • Increasing biodiesel content is only compatible with certain engines; fleet operators need to ensure the maximum percentage of allowable biodiesel is not exceeded in each vehicle. • Biodiesel is typically stored on site and this has additional security and environmental considerations. • Biodiesel based vehicles require additional maintenance and servicing compared to fossil diesel equivalents. • Biodiesel made from food crops has come under increasing criticism on ethical grounds. Cooking-oil derived biodiesels are available and have been recommended in this study. • Quality and quantity of supply has, historically, been an issue for some biodiesel suppliers causing reliability issues. • Biodiesel can only be used where bunkering facilities are available (normally large fleet depots sharing use with vehicles). • Biodiesel is an effective mechanism for reducing CO_2 but will normally increase fleet operational costs.	NRW should consider a more detailed assessment of biodiesel use and a trial of biodiesel within their operations which cannot be decarbonised through other means. Biodiesel facilities can be extended to include several items of plant, but the business case for the creation of biodiesel infrastructure and economic supply will be highly reliant on tractor operations to create sufficient fuel demand, with excavators being a contributing factor. Fingerpost, Pont-y-Garth and Rhuddlan depots should be assessed for the implementation of biodiesel (engine compatibility is critical). Success of biodiesel projects will be dependent on a depot based champion with the knowledge, skill, and authority to drive the changes through successfully.
Alternative hydrocarbon fuels	
Alternative hydrocarbon fuels: methane, propane, renewable diesels can be utilised for plant operations. Typically, those elements in the NRW fleet that are well suited to alternative fossil fuels (LPG, CNG) do not perform enough operational hours per year to justify the changeover.	Many of these fuels are growing in availability as bio-derived alternatives (e.g. bioLPG, biomethane, renewable diesel). The use of a biofuel is very effective at reducing WTW CO_2. NRW should continue to monitor the development of biogas fuels and technologies with a view to trialling the technology when an economic plant and infrastructure provision is available. There are new technical developments for tractors and excavators that may warrant demonstration trials for bioCNG technologies at NRW sites. These could be considered by NRW as non-economic technology demonstration projects in the shorter term.

Implementation Scenarios:

The scenarios explored showed:

- Electric quad bikes offer a 100% reduction in TTW CO_2 and a 58% saving in WTW CO_2 emissions. The annual cost of power consumption of an all-electric quad-bike fleet is £2,950 per year for the entire fleet, which represents a 77% saving in annual fuel costs (circa £550 per annum per bike).
- In a high uptake scenario of mature technology at a single, hypothetical depot representative of NRW, a fuel consumption saving of 22% can be achieved and a WTW CO_2 emissions could reduce by 39%, which is in large part to the adoption of B30 Biodiesel.
- A further scenario showed that 80% WTW CO_2 emissions savings through plant machinery by 2050 would be possible through a combination of implementing market-ready technology (from 2017), fuel efficiency programmes (from 2017), fleet replacement to comply with stage V NRMM emission standards (from 2019), and operating a strategy to implement fuel replacement options, e.g. biodiesel, biomethane, hydrogen, as they become mature technologies.

To maximise CO_2 savings from plant the following strategy is recommended:

Step 1 – Undertake detailed technology assessment:

- The high-level review highlighted that emission savings at similar or better TCO could be available from interventions such as implementing fuel efficiency measures and driver training, investigating the performance of diesel-hybrid excavators in the NRW operations, implementing electric quads, electric mowers (for reservoirs) and the implementation of biodiesel blends into compatible plant machines. All these options should be subject to a more detailed review/business case for implementation, and trialled where necessary. Part of this detailed review should assess if the utilisation of assets can be increased, which would assist in the payback of alternative technology options.

Step 2 – Implement fuel saving technologies:

- Following a more detailed review and successful trial of Step 1 technologies above, NRW should set a technology implementation plan. Where low emission plant alternatives are not available or uneconomic, NRW should include a plant fleet replacement programme to comply with Stage V NRMM emission standards from 2019 (if Stage V equipment is not available before this date).

Step 3 – Continue to monitor technology availability:

- NRW should continue to monitor low emission plant options taking into account new product offerings on an annual basis. For example:
    - Electric and hybrid plant products are expected to continue to mature and reduce in costs which will aid the business case.
    - Biofuels such as biomethane, bioLPG and renewable diesel (i.e. ‘drop-in diesel’ fuels fully compatible with manufacturers engines and warranties) are expected to be more widely available in the market place over the next 5 years.

4 Introduction

Natural Resources Wales (NRW) is the largest Welsh Government Sponsored Body, employing 1,900 staff across Wales. NRW was formed in April 2013, largely taking over the functions of the Countryside Council for Wales, Forestry Commission Wales and the Environment Agency in Wales, as well as certain Welsh Government functions. NRW provides a leadership role for the sustainable management of natural resources across Wales.

NRW's Carbon Positive Project is planning future implementation to reduce NRW's carbon impact as an organisation and to accelerate delivery of measures to help meet national and international carbon reduction targets. Analysis of the organisation's carbon footprint has shown diesel use to be the organisation's second highest source of emissions from its core activities and is therefore a key focus of carbon reduction work for the organisation.

NRW operate a fleet of nearly 600 pool and operational vehicles and around 150 plant vehicles. NRW commissioned Cenex to review carbon emissions from their existing fleet, evaluate carbon reduction options and advise future strategic planning for reducing carbon within the fleet. Recommendations were to be made considering the most suitable mix of vehicles in the fleet to achieve maximum carbon emissions reductions, whilst representing value for money against current fleet expenditure and without compromising the organisation's ability to deliver its role.

Cenex undertook the fleet review using the following methodology:

- **Fleet Baselining** - NRW fleet and plant items were segregated by type and function (e.g. Operational vehicles & Pool vehicles), and the performance and operational patterns of the vehicles were benchmarked.
- **Suitability Assessment -** The range of alternative technologies and fuels which had potential to reduce carbon emissions at similar or lower costs were researched and identified. The low carbon options were mapped to NRW fleet characteristics to ensure any recommended technologies could fulfil the required roles and duties without compromising operational performance.
- **Cost and Emissions Analysis** - Technologies which appeared to meet the financial and emission criteria were taken forward for a more thorough review.
- **Scenario Planning** - Implementation scenarios of recommended technologies were built to allow NRW to assess their impact on overall fleet costs and emissions.
- **Recommendations** - Cenex put forward recommendations for technology implementation which should be considered for inclusion in the wider carbon reduction strategy for NRW being developed by the Carbon Positive Project.

Note that, whilst a detailed review was undertaken on the operational pool and fleet vehicles, the plant items were subject to a high-level review, which differs from the bullets above. The methodology for the high-level plant review can be found at the start of section 15.

5 Fleet Baselining

The performance of the NRW fleet vehicles is summarised below. The baselining process allows the mileage, fuel consumption, emission, and operating patterns to be understood before the low emission vehicle technology assessment takes place.

5.1 Fleet Summary

Vehicle Type

Vehicle types were segregated into the groups shown in Table 1 below to allow presentation of fleet statistics and comparison of low-carbon technology by vehicle type. A total of 584 vehicles were assessed. The number of each vehicle is shown below together with the average annual mileage and fuel consumption of each vehicle type.

Vehicle Type	Number	% of Total Vehicles	Average Annual Mileage (Miles)	Average Fuel Consumption (MPG)
4x4	128	22%	10,864	29.7
Car	185	32%	7,103	49.6
Small van (<2.5t)	235	40%	9,626	45.1
Large van (>2.5t)	33	6%	10,032	31.6
Trucks (>18t)	3	1%	NA	NA
Total/Average	**584**	**100%**	**9,406**	**39.0**

Table 1 - Fleet Summary (composition, mileage, and fuel consumption – Vehicle operation from November 2015 to November 2016)

While the fuel efficiency of each vehicle group shown is typical, the average annual mileages are very low. Achieving financial savings from low emission vehicle operation relies on high mileages to allow the fuel savings to reimburse the additional capital costs of the vehicles.

Operational and Pool Fleet Usage

Operational Vehicles are vehicles employed by operational staff to carry out their duties and responsibilities (Forestry Works, Flood Defence, National Nature Reserve, Water Sampling, and Enforcement).

Pool Vehicles are vehicles utilised by office staff travelling to local sites and meetings (NRW meetings, site visits and visiting stakeholders).

Roughly two-thirds of the fleet are Operational vehicles, where the highest proportion of vehicles in this category are small vans (56%). Roughly one-third of the fleet are Pool vehicles and 93% of Pool vehicles are cars.

The percentage split for the vehicles in the Operational and Pool fleet are shown in Table 2.

Fleet Type	Vehicle Type	% of Vehicles	Fleet Split
Operational Vehicle	4x4	21.7%	**68.2%**
	Car	2.2%	
	Small van (<2.5t)	38.0%	
	Large van (>2.5t)	5.7%	
	Trucks (>18t)	0.5%	
Pool Vehicle	4x4	0.2%	**32.8%**
	Car	29.5%	
	Small van (<2.5t)	2.2%	

Table 2 - Operational & Pool Split (Vehicle operation from November 2015 to November 2016)

Allocated and General Pool Vehicles

For the Pool fleet, the vehicles are split into Allocated and General categories. The term 'Allocated' here means the vehicle is assigned to a team or purpose where 24-hour access is required, whereas the term 'General' means the vehicle is free to use by any staff in the organisation.

Since Allocated vehicles can only be driven for specific purposes and will have limited use, this results in lower mileages which can be seen in Table 3 below. For example, the average annual mileage for the General vehicles is 8,399 miles where the average for the Allocated vehicles is 5,552 miles.

Pool Vehicle Type	Vehicle Type	% of Vehicles	Fleet Split	Average Fuel Consumption (MPG)	Average Annual Mileage	Average Annual Mileage Split
Allocated	4x4	0.5%	45.2%	30.8	6,389	5,552
	Car	39.8%		49.0	5,316	
	Small van (<2.5t)	4.8%		44.4	7,401	
General	Car	52.7%	54.8%	49.7	8,441	8,399
	Small van (<2.5t)	2.2%		49.8	7,364	

Table 3 - Allocated & General Split (Vehicle operation from November 2015 to November 2016)

5.2 Fleet Emissions

Tank to Wheel CO_2 Emissions

TTW or Scope 1 emissions represent the amount of CO_2 (derived from fossil fuels) which is released from a vehicle's tailpipe. Under UK Greenhouse Gas (GHG) reporting protocol, these Scope 1 emissions are the direct responsibility of the transport operator (i.e. NRW in this case).

Vehicle Type	Number of Vehicles	Annual TTW CO_2 per vehicle (tonnes)	Total Annual Emissions of TTW CO_2 (tonnes)	% Emission Contribution to Total Fleet Emissions
4x4	128	4.6	595	36%
Car	185	1.7	310	19%
Small van (<2.5t)	235	2.6	609	37%
Large van (>2.5t)	33	4.0	131	8%
Trucks (>18t)	3	0.0	-	0%
Total	**584**	**2.8**	**1,645**	**100%**

Table 4 - Fleet TTW CO2 Emissions (Vehicle operation from November 2015 to November 2016)

Notes: Emission were calculated by applying DEFRA 2016 GHG Reporting CO_2 Emission Factors to fleet fuel consumption. Fuel consumption data missing from individual vehicles were estimated from vehicle segment average fuel consumption data.

Table 4 shows that the NRW fleet emits 1,645 tonnes of TTW CO_2 per annum. The largest emitter group is the small van (<2.5t) fleet, this is due to small vans being the largest fleet segment with over 200 vehicles (40% of fleet) and collectively is responsible for 37% of NRW fleet TTW emissions. The next largest vehicle type emitters are the 4x4s which represent 22% of the overall fleet but are responsible for 36% of the fleet TTW CO_2 emissions.

Wheel to Wheel CO_2 Emissions

WTW or All Scope emissions are a more holistic method of looking at CO_2 emissions and represent the amount of CO_2 emitted during the fuel's life cycle. This includes the upstream emissions associated with fuel extraction, processing, transportation, and dispensing, as well as the emissions from final fuel combustion. Although the upstream emissions from fuel manufacture is not the reporting responsibility of the transport operator (under UK emission reporting guidance), they are considered important by environmentally-conscious fleets when making decisions on fuel and transport options. Note, NRW's reporting of organisational carbon emissions encompasses WTW emissions.

Vehicle Type	Number of Vehicles	Annual WTW CO_2 per Vehicle (tonnes)	Total Annual Emissions of WTW CO_2 (tonnes)	% Emission Contribution to Total Fleet Emissions
4x4	128	5.6	721	36%
Car	185	2.0	376	19%
Small van (<2.5t)	235	3.1	738	37%
Large van (>2.5t)	33	4.8	159	8%
Trucks (>18t)	3	0.0	-	0%
Total	**584**		**1,994**	**100%**

Table 5 - Fleet WTW CO2 Emissions (Vehicle operation from November 2015 to November 2016)

Notes: Emission were calculated by applying DEFRA 2016 GHG Reporting CO_2 Emission Factors to fleet fuel consumption. Fuel consumption data missing from individual vehicles were estimated from vehicle segment average fuel consumption data.

Table 5 shows that when considered on a WTW basis the total emissions from the NRW fleet increase to 1,994 tonnes of WTW CO_2 per annum. The percentage contributions by each fleet segment remain the same as when TTW emissions were considered.

Annual NOx and PM

The UK National Atmospheric Emissions Inventory (NAEI) provides estimated real-world air quality emission look-up tables by vehicle weight, euro standard and drive cycle type. These tables were used to estimate the air quality emissions from the NRW vehicle fleet.

Table 6 below shows the NRW fleet emits 4,844 kgs NO_X and 30.2 kgs of PM emissions per annum.

Vehicle Type	Number of vehicles	Total Annual NO_X Emissions (kg)	% Contribution to NO_X Emissions	Total Annual PM Emissions (kg)	% Contribution to PM Emissions
4x4	128	875	18%	9.4	31%
Car	185	1,138	23%	12.4	41%
Small van (<2.5t)	235	2,469	51%	7.4	24%
Large van (>2.5t)	33	362	7%	1.1	4%
Trucks (>18t)	3	-	0%	0.0	0%
Total	**584**	**4,844**	**100%**	**30.2**	**100%**

Table 6 - Fleet NOx & PM Emissions (Vehicle operation from November 2015 to November 2016)

Notes: NAEI COPERT 4v10 (2013) air quality emission factors by vehicle and Euro standard are found here http://naei.defra.gov.uk/data/ef-transport. Euro standards of fleet vehicles were estimated from vehicle age where data was not provided in the NRW fleet list.

5.3 Fleet Age and Euro Profile

The NRW fleet has a young fleet profile compared to many public-sector fleets assessed by Cenex. 61% of the vehicles are less than 4 years old. This can be seen in Table 7.

Age (Years)	0-2	2-4	4-6	6-8	>8	Average Age
4x4	34%	34%	11%	12%	9%	3.7
Car	6%	57%	12%	21%	4%	4.5
Small van (<2.5t)	31%	26%	34%	7%	3%	3.3
Large van (>2.5t)	39%	15%	24%	15%	6%	3.7
Trucks (>18t)	33%	33%	0%	0%	33%	4.3
Fleet Total	**24%**	**37%**	**21%**	**13%**	**5%**	**3.8**

Table 7 - Fleet Age Profile (November 2015 to November 2016)

The young fleet profile also ensures relatively good air quality performance from the fleet where 94% of vehicles comply with Euro 5 and 6 standards. The Euro standards represent the legislatively allowable air quality emissions from vehicles. From Euro 1 (introduced in 1993) to Euro 6 (introduced from 2014) allowable exhaust emissions have been significantly reduced. Table 8 displays the fleet Euro Profile.

Euro Standard	3	4	5	6
4x4	0%	10%	33%	57%
Car	0%	10%	82%	8%
Small van (<2.5t)	0%	2%	54%	44%
Large van (>2.5t)	2%	2%	48%	48%
Trucks (>18t)	0%	25%	0%	75%
Fleet Total	**0%**	**6%**	**57%**	**37%**

Table 8 - Fleet Euro Profile (November 2015 to November 2016)

6 Technology Introduction

The table below introduces the technologies being assessed and provides a case study example, where available, of where the technologies have been successfully introduced into fleets.

Electric	
Description	**Case Study**
With zero tailpipe emissions, battery electric vehicles (BEVs) are significantly cleaner than conventional petrol or diesel offering zero tailpipe emissions and around 35% - 50% WTW CO_2 savings. Suitable for regular and low mileages – ideally for city and suburbs – due to their limited driving range between recharging. Electric vehicle models are available from a growing number of mainstream manufacturers and are strongly supported by government incentives. Electric vehicles are rapidly becoming a popular fleet choice.	**Case study: Leicester Council, 2015** Leicester Council had made the decision to replace a fleet of 15 diesel vehicles with all-electric zero-emission models. As part of a 6-month trial, the council trialled a small fleet of all-electric vehicles to reduce carbon emissions. A range of EVs were tested, including the Renault Kangoo ZE. With the trial success, the council are considering replacing a further 95 diesels with EVs over the next 3 years. City mayor Sir Peter Soulsby stated that, "Increasing the uptake of ultra-low emission vehicles is one of the key aims of our proposed action plan to further improve air quality in the city over the next 10 years. He goes on to say that, "As a local authority, we need to lead by example… [by having the] … majority of the council's diesel vehicles replaced with ultra-low emission alternatives over time".

Hybrid
Description
A Hybrid vehicle is a vehicle with a conventional engine (ICE) but includes a small battery. It uses this battery and an electric motor to capture and re-use braking energy. These vehicles are reasonably cleaner than conventional vehicles offering up to 20% TTW and WTW CO_2 savings. The battery cannot be plugged in; only regenerative braking supplemented by ICE maintains the charge. Availability is good in the car segment but limited in light commercial vehicles where battery electrics and plug-in vehicles are the most common low emission electrical alternative.

Plug-in Hybrids	
Description	**Case Study**
Plug-in hybrids (PHEV) models offer excellent flexibility – featuring the range of a petrol or diesel engine combined with the benefits of a small battery and electric vehicle's motor providing typically 10 – 30 miles or zero emission (EV only) operation. Once the battery has depleted, the petrol engine starts and the vehicle operates in a similar way to a normal hybrid vehicle. Plug-in hybrids recharge their main drive battery by connecting to the electricity network. Availability for PHEV is growing in the car segment as many mainstream manufacturers now have a plug-in hybrid vehicle out on the market, albeit at a premium price.	**Case study: Environment Agency, 2015** The Environment Agency operates over 1,400 commercial vehicles. The Agency's current CO_2 reduction initiatives include the use of 68 4x4 hybrids (Mitsubishi PHEV Outlander) which provided a great opportunity for them to expand their use of low carbon vehicles. The PHEV Outlanders leave the depots fully charged, and on average will travel around 60 miles a day. Dale Eynon, Head of Fleet Services explains *"We already use Mitsubishi Diesel Outlanders within the fleet, the PHEV is available at the same cost, and even with a low level of charging we expect to break even, the main focus for us is to maximise EV use to ensure we are maximising our CO_2 savings."*

Range-Extended Hybrids	
Description	**Case Study**
A range-extended electric vehicle (REEV) is a battery electric vehicle that runs and operates on electricity but includes an on-board ICE auxiliary power unit (APU) which provides additional miles of mobility through charging the battery 'on the go'. Note with a REEV, the propulsion technology is always electric, unlike a PHEV where the propulsion technology can be electric or hybrid. Availability for REEV is limited in the current market with only a few models released by mainstream manufacturers.	**Case study: Speedy Services & BMW i3 van, 2016** Tool hire company Speedy Services deployed 3 BMW i3s (2 in London, 1 in Manchester) which had been specially adapted for commercial use as part of a three-month trial. Head of transport and logistics at Speedy Services Mark Woodworth said: *"The i3, with range-extender, is the ideal powertrain set-up for us. It provides confidence for my drivers, who worry about being stranded on longer trips, and reduces vehicle downtime caused by charging."*

Natural Gas and Biomethane	
Description	**Case Study**
CNG vehicles run on compressed natural gas. CNG is stored on the vehicle in pressurised cylinders and used in a spark ignition engine, which is the type of engine used in petrol vehicles and offers similar TTW and WTW CO_2 emissions to diesel. CNG is a fossil fuel; however, a renewable and sustainable version of natural gas is also available called biomethane. Biomethane is produced from organic waste and can be directly used in CNG vehicles offering up to around 85% WTW CO_2 savings. CNG model availability is limited in the UK due to our lack of refuelling stations at the current time. Also, direct biomethane supply in the UK is very limited.	**Case study: London Borough of Camden, 2013** Following a successful implementation of their on-site natural gas refuelling facilities, London Borough of Camden incorporated 16 Volkswagen Caddy vans, 5 Iveco Daily vans, 2 Mercedes-Benz Sprinter NGT vans and 1 gas Volvo car into their fleet. *"The reliability of the gas vehicles has been fantastic"*, says fleet manager Callum Johnson, *"we haven't had a single breakdown from the Caddys in two years of operation."* He went on, *"The drivers like them too, they're very nice vehicles to drive. I think that they really come into their own on duties where they're heavily loaded, with a lot of stop-start."*

LPG and BioLPG	
Description	**Case Study**
Liquefied Petroleum Gas (LPG) is a fossil fuel extracted alongside natural gas and is also a by-product of the oil refining process. LPG is stored on vehicles under pressure as a liquid. LPG vehicles are quieter and emit less harmful air quality pollutants than diesel vehicles, although the CO_2 emissions are often similar. LPG vehicles are available from mainstream manufacturers in Europe, however in the petrol vehicle are only available as retrofit. Any installer should be approved by UKLPG – the LPG trade association.	**Case study: Clear Channel UK, 2012** Running LPG vans saved outdoor advertising firm Clear Channel UK £200,000 a year based on a 40% fuel cost savings. Glenn Ewen, Fleet Manager, Clear Channel UK, said: *"As part of our wider strategy to minimise our impact on the environment, Clear Channel UK has set a target of 84 per cent LPG usage against petrol. As part of our commitment to this target, we have installed seven bunkers at Clear Channel depots nationwide where our drivers refuel."*

Hydrogen	
Description	**Case Study**
Hydrogen as a road transport fuel is taking its first steps to becoming commercially available in the UK. Hydrogen is stored on a vehicle in compressed gas cylinders. On-vehicle hydrogen can be used to generate electricity through a fuel cell - 100% TTW savings are available and WTW CO_2 savings are depending on hydrogen manufacture. For vans, a fuel cell range extender is required to be fitted to a battery electric van. Here hydrogen is used to generate electricity onboard the vehicle to extend the van's daily range. Another option for vans (as described in the case study) is to combust hydrogen in a conventional internal combustion engine in combination with diesel. The hydrogen vehicle market is currently in its infancy with few fleets operating vehicles, however, several new models have been released as the supporting infrastructure is commissioned across the UK.	**Case study: Commercial Group, 2017** The Commercial Group are a business service supply company with a strong environmental focus. Taking advantage of grant funding mechanisms to subsidise vehicle deployment the company now operate nine retro-fit dual fuel diesel hydrogen Transit vans supplied by ULEMCo, which accounts for around half of their van fleet. The vans emit just 59g/km of CO_2 (over the regulated test cycle). Commercial Group's Andrew McKenzie explains the other benefits they are seeing operating the vehicles *'Much of our new sales interest and existing customer base look to our environmental commitments when awarding contracts, which is very much part of our USP. Operating with dual fuel technology, and retaining the ability to have pure diesel operation as a fall back, was important to us in what remains an emerging hydrogen market'.*

Biodiesel	
Description	**Case Study**
Biodiesel is a renewable fuel produced from vegetable crops and/or used cooking oil, and is a low carbon alternative to fossil diesel. If offers CO_2 savings of around 18% per 25% blend (B25) when the biodiesel is manufacturer from a waste product such as used cooking oil. Biodiesel use requires additional fuel management and quality control. Biodiesel is an organic product with a shelf life. Additional vehicle servicing is required when using biodiesel. Some availability from manufacturers such as Peugeot and Citroen who support the EN16709 standard up to a 30% blend (B30), but most vehicle manufacturers do not widely support or warrant high blends of biodiesel use in their vehicles.	**Case study: London borough of Hackney, 2014** The London borough of Hackney Council has been using biodiesel in many of its fleet vehicles since 2013. It operates 38 trucks on a 100% biodiesel blend (B100) and a further 100 on a B30 blend of biodiesel, and is seeking to roll out the biodiesel programme to additional vehicles where possible. Norman Harding, Corporate Fleet Manager at Hackney notes "…providing that operators source good quality biodiesel that meets the EN14214 standard for B100 or EN16709 for B20/B30 blends from a reputable supplier then vehicles should operate trouble-free." Harding ensures that his biodiesel is all derived from waste but is free from animal fats as the animal fats can cause the fuel to 'wax' at very cold temperatures.

Petrol	
Description	**Case Study**
Petrol, like diesel, is a fossil fuel. Petrol vehicles were dis-incentivised by government taxation policy due to their greater CO_2 emissions compared with diesel. However due to the current media focus on the poor real-world air quality emission performance of diesel vehicles, many fleets are now looking to petrol vehicles as a way of improving local air quality. Petrol is widely available in the UK with car models available from all mainstream manufacturers. Model availability for vans is very limited.	**Case study: Venson Automotive Solutions & BCF Wessex, 2015** BCF Wessex, vehicle finance and tax advisor, was commissioned by Venson Automotive Solutions to research benefits of petrol versus diesel. *"Fuel price volatility, reducing annual fleet mileage and improvements in the fuel economy of petrol-engine company cars mean diesel power may not always make the most cost-effective fleet choice,"* says Simon Staton, director of client management at Venson. *"However, all fleets are different and that means decision-makers should not always assume that the dominance of diesel as the company car of choice."*

7 Fleet Low Emission Technology Scanning

The low emission technology scanning exercise identifies alternative technologies which have the potential to deliver emission improvements at a similar cost to diesel technologies to be taken forward for a more detailed review.

7.1 Technology Scanning

Cenex undertook a high-level assessment of the main low emission alternative vehicle options using the colour key described below. Technologies that have the potential to reduce emissions at a lower or similar cost were identified in the technologies scanning phase.

Green	**Technology is available and has the potential to be commercially viable in certain applications.**
Amber	**Technology is available but not viable due to high costs, or is near market and unproven. The technology may be suitable for fleet trial/demonstration.**
Red	**Technology is not available or not viable.**

The technology scanning summary in Table 9 shows that for cars and small vans, electric vehicles have the potential to offer improved emission performance at a lower cost. As vehicles become heavier (large vans and trucks) the economics and availability of electric vehicles diminishes with the most likely sources of reduced emissions coming from gas vehicles and biofuels.

Vehicle Classification	Electric				Gas			Liquid	
	Battery Electric	Hybrid Electric	Plug-in Hybrid	Range Extended Electric	ICE (CNG/Bio)	ICE (LPG)	Fuel Cell (Hydrogen)	Biodiesel	Petrol
Car	Green	Green	Green	Green	Red	Green	Amber	Green	Green
Small Van (< 2.5t)	Green	Red	Amber	Red	Red	Amber	Amber	Green	Green
4x4	Amber	Green	Green	Red	Red	Red	Red	Green	Green
Large Van (> 2.5t)	Amber	Red	Red	Red	Green	Red	Red	Green	Red
Truck (7.5t)	Amber	Amber	Red	Amber	Red	Amber	Red	Green	Red

Table 9 - Technology Scanning Summary

Cars – Electric (battery, hybrid, plug-in & range extended), LPG, biodiesel and petrol have the potential to offer improved emission performance at a lower cost to the fleet, and so they have been taken forward to the technology review. Technologies not taken forward are CNG vehicles which are not available for cars.

Small Vans – For small vans the battery electric, biodiesel, and petrol technologies have the potential to offer improved emission performance at a lower cost to the fleet, for this reason, they have been taken forward to the technology review. The other types of electric technologies are not supported for small vans or are only available at a very high premium cost which would make them unviable. CNG small vans are not available to the UK market. A leasing price could not be obtained for small LPG vans;

therefore, these were not taken forward. However, LPG performance in the car category can be thought of as representative of the small van category.

4x4s – For 4x4s the most suited technologies are hybrid electric, plug-in hybrid, biodiesel, and petrol which have the potential to offer improved emission performance at a lower cost to the fleet, and so they have been taken forward to the technology review.

Large Vans – As vehicles become heavier the economics and availability of electric vehicles diminish with the most likely sources of improved emission performance at a lower cost coming from CNG and biodiesel technologies, thus they have been taken forward to the technology review. Note that all-electric technologies typically come at a cost premium of at least £20 - £30k for large vans.

Trucks – For all the alternative technologies, either the technology will not reach its payback point over the current NRW truck cycle or the technology is not supported for the vehicle. For example, an electric hybrid is available but the breakeven point requires a 10-year ownership period at 30,000 miles per annum (MPA) with an urban drive cycle to cover the high capital cost; therefore, these will not be taken forward further. Biodiesel is available for use in trucks, the considerations for biodiesel in trucks will be covered through the evaluation of biodiesel when looking at the other fleet segments.

Hydrogen Technology – Hydrogen has not been taken forward for a more detailed review. Hydrogen powered vehicles are still nascent and not currently economic, unless deployed as part of a grant funded activity. The vehicles, their maintenance and hydrogen fuel are all more expensive than incumbent technology. It is worth noting that the University of South Wales has a H_2 refuelling facility in Baglan, which would be a good platform to build a future demonstration activity. Therefore, it would be possible for NRW to trial hydrogen technology in the fleet in its Llandarcy office, subject to grant-funding.

8 Fleet Technology Performance Review

Technologies (identified in the technology scanning phase) which have the potential to offer emission savings at a similar cost to diesel vehicles have been assessed further in a detailed technology performance review below. Here a TCO and CO_2, NO_X and PM emissions model was built to allow more accurate vehicle cost and performance to be assessed.

8.1 Methodology

The TCO and emissions analysis presented in this section uses the following factors.

- **Costs** for the diesel and low emission vehicles were provided from the UK Government Public Sector Procurement portal, these can be considered as broadly representative of the prices paid by NRW. NRW undertake bespoke procurement exercises for vehicles which was not a practical method of obtaining vehicle prices for this assessment. Lease rates quoted are for a standard 5 year, 10,000 miles per annum ownership profile. Due to capital constraints, NRW lease most fleet vehicles and future acquisitions of vehicles will largely be on a lease basis. Therefore, the assessment of costs has been based on lease costs, rather than purchase (ownership model).
- **Fuel consumption** for diesel vehicles was taken from the NRW fleet data set. Independent test data, either from Cenex track testing or real-world MPG data from Emission Analytics testing under different driving cycles, were used to translate NRW diesel fuel consumption to energy consumption in the low emission vehicles. **Manufacturers' performance and emissions data were not used, i.e. the comparison is made based on real world data on vehicle types.**
- **Maintenance costs** were taken from the NRW fleet data set. With appropriate reduction/increase factors applied to represent the comparable maintenance cost of low emission vehicles.

Insurance costs were not accounted for in the model. NRW apply a flat rate insurance cost across all vehicle types and information from insurance brokers stated that alternatively fuelled vehicles were not subject to an insurance premium[2] and so alternative costings did not need to be modelled.

- **Vehicle make/models** of alternative vehicle technologies assessed were selected to offer similar performance to the standard NRW fleet.
- **Annual mileage** all analysis was undertaken at average fleet annual mileage.
- **Taxation** vehicle (road) tax rates were included in the model.
- **Infrastructure** was included for the EV cost analysis, this was applied at a rate of £1,500 (purchase and installation of the charging unit). Each unit was dual-head assumed to feed 2 vehicles) + £60 per annum data fees amortised over a 10-year period. No account of civil costs for cabling provision (i.e. groundworks) was included.
- **End of lease charges** of £1,000 per vehicle were applied.
- **Petrol** the rationale behind the inclusion of petrol vehicles was based around the additional consideration of NOx reductions and air quality improvements as an extra fleet factor.

[2] Correspondence with Towergate Insurers, 30 March 2017

- **Biodiesel** has been assessed using an emission factor for biodiesel from used cooking oil[3] at a blend of B25. B25 was used as this represents a lower risk blend of biodiesel which is supported by some manufacturers.
- **CO_2 emissions** were calculated based on applying UK Government Emission factors to fuel usage.[4]
- **Air Quality (AQ)** savings were estimated based on real-world testing undertaken by Emissions Analytics and published through the EQUA Index.[5]
- 93% NO_x 32% PM Call out boxes are used to denote approximate AQ savings. If only nitrogen oxides (NOx) saving is noted, then it should be assumed that particulate matter (PM) saving is minimal or unknown.

8.2 Cars Performance Review

A mix of cars (size, make/model) are used across the NRW fleet. The majority of the car fleet (97%) is made up of small to medium cars, where we have focused the following economic and environmental comparison of low emission vehicle technology – this is broken into two sections below: small car and medium car. Cars are typically replaced on a 5-year cycle. Maes y Ffynnon, Rivers House and Llandovery depots had the greatest number of cars operated from the site at the time of assessment. Table 10 below shows a breakdown of car type.

Subcategories	No. of vehicles	Average annual mileage	MPG	NRW Model examples
Hybrid	2	3,023	40.1	Toyota Prius
Small car (B-segment)	61	8,283	53.2	Ford Fiesta
Medium car (C-segment)	118	6,591	48.0	Ford Focus
SUV (J-segment)	1	3,060	30.3	Honda Crv
Small MPV (M-segment)	2	7,621	55.1	Renault Grand Scenic
Large MPV (M-segment)	1	6,787	42.2	Vauxhall Zafira
Total/Average	**185**	**7,103**	**49.6**	

Table 10 - Car Fleet Breakdown

8.2.1 Small Car Cost and Emission Comparison

Due to capital constraints, NRW lease most fleet vehicles and future acquisitions of vehicles will largely be on a lease basis. Therefore, the assessment of costs has been based on lease costs, rather than purchase (ownership model). For a comparison of lease vs. ownership costs please see *Section 8.8 Lease vs Purchase.*

Figure 1 below shows the % savings for the small car technologies when compared to a standard diesel vehicle.

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[3] Emission factor for used cooking oil from Olleco declared under the Renewable Transport Fuels Obligation scheme

[4] 2016 GHG Emission Factors for Company Reporting, DEFRA, accessed March 2017

[5] www.emissonsanalytics.com, accessed March 2017

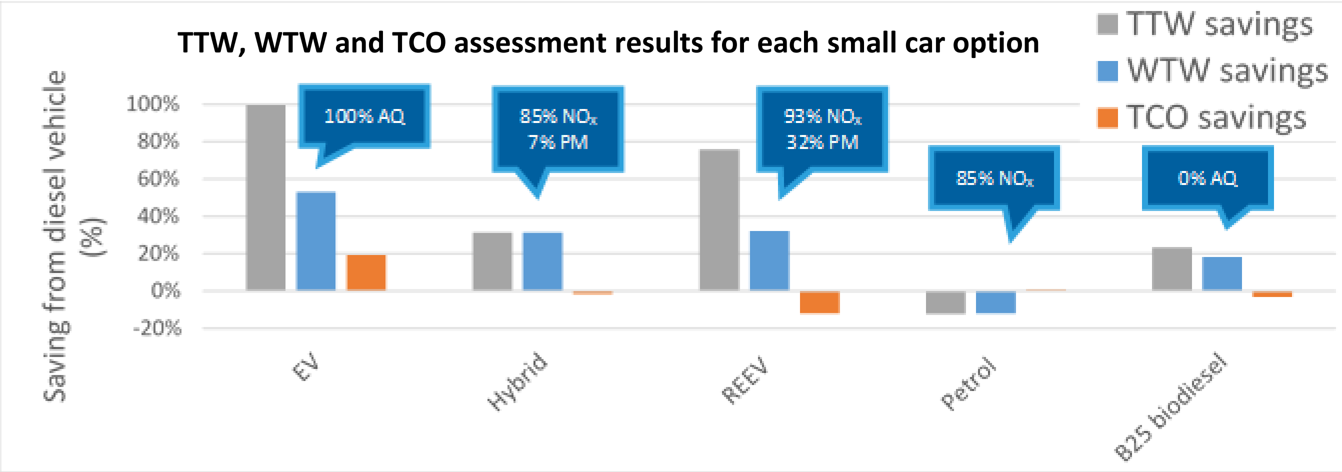

Figure 1 - Leased Small Cars. Note, lack of PM figure means that PM savings are minimal or unknown. The terms 0% and 100% AQ signifies zero or complete air quality emission savings respectively. Bars shown below 0% on this figure represent an increase in the emissions/costs associated with that measure when compared to a standard diesel vehicle.

- **Battery Electric Vehicles** – 100% TTW and ~50% WTW CO_2 emission savings. TCO decrease of around 20% when compared to a comparable leased diesel car (e.g. Ford Fiesta). Estimated average range of around 55 – 75 miles (dependent on driving style and conditions) for a typical 22 kWh battery. It should be noted however, that the make and model used for the Renault ZOE in this case is a 22 kWh battery version. For increased range a 41 kWh version is also available (ZOE 40). While the estimated average range would increase to around 100 – 120 miles for the current 41 kWh version, the TCO would increase to -5% unless the annual mileage increases to 12,000 where TCO parity with a diesel car is achieved. Therefore, effective utilisation of vehicles is key to achieving the cost benefits available from battery electric vehicles.
- **Petrol-hybrid Vehicles** – (such as the Toyota Yaris) offer good CO_2 emission savings at a similar TCO.
- **Range Extended Vehicles** – the only vehicle of its type currently on the market (BMW i3 REx), is an expensive vehicle resulting in a TCO increase of ~ 12%. However, this vehicle has a substantial all electric range before the engine starts resulting in CO_2 savings of 76% TTW and ~30% WTW.
- **Petrol Vehicles** – increase CO_2 emission but can offer ~ 85% reduction in real-world NOx emissions at a similar TCO when compared to an equivalent leased diesel.
- **Biodiesel Vehicles (B25)** – offer 23% TTW and 18% WTW emission savings and similar AQ performance but have a marginally greater TCO due to maintenance and fuel supply considerations.

8.2.2 Medium Car Cost and Emission Comparison

Figure 2 below shows the % savings for the medium car technologies:

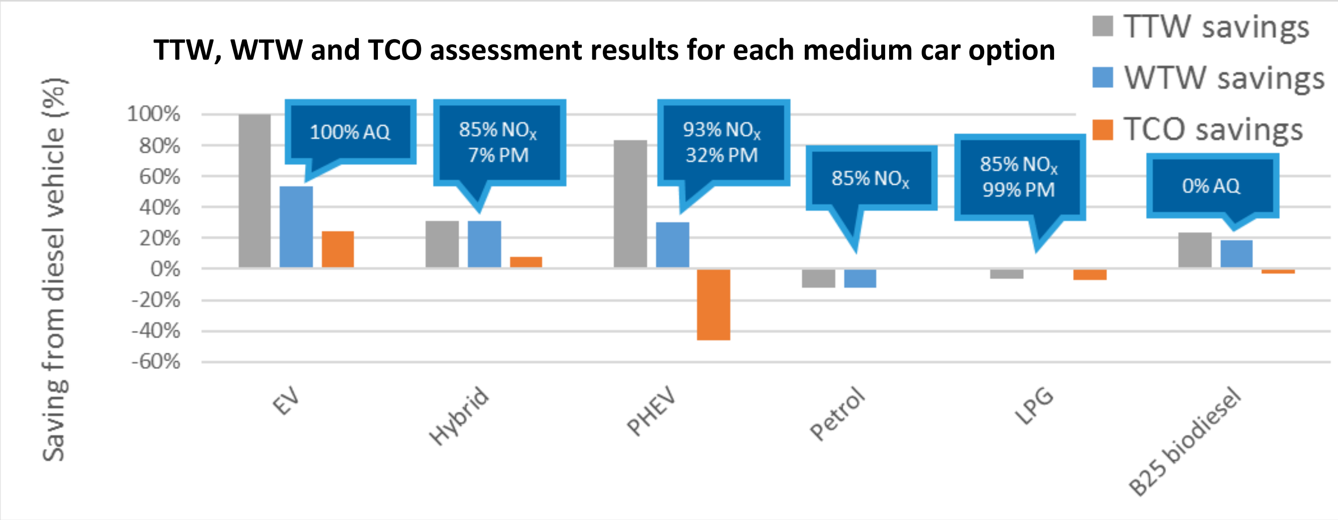

Figure 2 - Leased Medium Cars. Note, lack of PM figure means that PM savings are minimal or unknown. The terms 0% and 100% AQ signifies zero or complete air quality emission savings respectively. Bars shown below 0% on this figure represent an increase in the emissions/costs associated with that measure when compared to a standard diesel vehicle.

- **Battery Electric Vehicles** – 100% TTW and ~50% WTW CO_2 emission savings. TCO decrease of 25% when compared to a comparable leased medium-sized diesel car (e.g. Ford Focus). It should be noted however, that the make and model used for the Nissan Leaf in this case is the 24 kWh battery, 6.6 KW charger version giving an estimated real-world range of 60 – 80 miles. A larger battery 30kWh model is also available, which may give a real-world range of 80 – 100 miles, however to break-even with comparable diesel vehicle an annual average mileage of around 14,000 miles (~50 miles a day[6]) would need to be achieved.
- **Petrol-hybrid Vehicles** – (such as the Toyota Prius) offer good CO_2 emission savings at an 8% decrease in TCO.
- **Plug-in Hybrid Vehicles**[7] – (such as the petrol Toyota Prius Plug-in) present good driving range and emissions savings. However, the high capital cost results in a TCO increase of 46%
- **Petrol Vehicles** – increased CO_2 emission and marginal TCO rise of 1%, but it can offer ~ 85% reduction in real-world NOx emissions.
- **Liquefied Petroleum Gas Vehicles**[8] – increase TTW CO_2 emissions and costs, but offer up to 85% and up to 99% reduction in real-world NOx and PM emissions respectively.
- **Biodiesel Vehicles (B25)** – offers 23% TTW and 18% WTW emission savings and similar AQ performance to a leased diesel at a TCO rise of 3%.

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[6] Based on utilisation on 280 working days a year.
[7] Emission savings factored by EV only running duration.
[8] LPG emission savings are assumed to be the similar to petrol.

8.2.3 Car Suitability Assessment

Further decision-making information on the suitability of the cars has been summarised in the matrix below:

Suitability Key	Good	Variable	Poor

Electric Cars	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Growing selection of battery electric cars are available from mainstream manufacturers with no reliability issues. • The real-world range of EVs is between 60-80 miles (small 22 – 24 kWh battery) or 80 – 120 miles (larger 36 – 40 kWh batteries). Two examples for the medium car are given in Table 14. The distance travelled by small and medium cars are similar but will depend on battery capacity and weight. For example, smaller cars are generally lighter so would go further with the same size battery. • Given the low annual (and assumed low daily mileages) of the NRW fleet, the range restrictions of today's EVs should not pose an issue. Where daily mileage uncertainty exists, telemetry data should be used as an evidence base for conversion to EVs. • Charging infrastructure is required. Low-cost wall mounted units can be installed at depots/offices, employees' homes, and work destinations (pending EV supply). Where large penetrations of EVs exist around a single depot smart (distributed) charging or power upgrades may be required and could make adoption uneconomic. • EV offer zero tailpipe emissions and very good CO_2 emission savings.
Recommendation	**Recommended - EV cars should be implemented where operationally feasible due to significant emission savings for similar or lower total cost of ownership. Providing electrical services to chargers and the daily mileage trends of individual vehicles needs to be considered further.**
Petrol Hybrid Cars	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Growing selection of petrol hybrid cars are available from mainstream manufacturers with no reliability issues. NRW do not use bunkered diesel, therefore petrol hybrids offer no operational restrictions or increased mileage to refuelling facilities. • Petrol-hybrids offer a small CO_2 emission saving to diesel cars but with better air quality performance. • For the NRW fleet, vehicles appear suitable for economic conversion to basic low-cost petrol-hybrids. The performance will be most suited to more urban driving patterns.
Recommendation	**Recommended - Petrol-hybrids cars should be considered for higher mileage duties where the range of an electric vehicle is unsuitable. Petrol hybrids offer savings in CO_2 and improve the AQ performance of the fleet at a similar TCO.**
Range Extended / Plug-in Hybrid Cars	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Range extended and plug-in hybrid vehicles are available from a growing range of OEMs and they offer some zero-emission capability without the range restrictions of a pure battery electric vehicle. • Charging infrastructure is required. Low-cost wall mounted units can be installed at depots/offices, employees' homes, and work destinations (pending electricity supply). Where large penetrations of EVs exist around a single depot smart (distributed) charging or power upgrades may be required and could make adoption uneconomic. • For the NRW fleet, range extended cars are uneconomic due to their high capital cost compared to the standard low-cost diesel vehicles currently being used.
Recommendation	**Not recommended for high penetration - Plug-in hybrid and range-extended hybrid vehicles are operationally suitable for the day to day operations of the NRW fleet, offering both AQ and CO_2 improvements. However, these are premium vehicles and uneconomical against a standard fleet car and therefore not recommended for higher levels of fleet penetration.**
Petrol	

Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Petrol cars are readily available from all major OEMs, where there is a diesel there is usually a petrol variant. For cars, it is a mature technology that provides unrestricted range of over 300 miles on a full tank. In the case of engine downsizing, small cars will utilise a small direct-injection petrol engine alongside a turbocharger to provide the same output as diesel engines (e.g. such as the 0.9 Fiat Panda Twin Air model used in the small car assessment). • Compared to a diesel car, petrol gives an increase in CO_2 emissions, but an improvement in AQ. • Petrol vehicles, when compared to a similar diesel model, give similar whole life cost for the NRW fleet. Even though petrol vehicles will have a lower capital cost, it is the annual mileage and fuel consumption (which is somewhat worse than diesel) that determines whether a saving is gained.
Recommendation	**Not recommended - Petrol use can have the benefit of improving air quality emissions but would be operated at higher CO_2 emissions to diesel with the likelihood of no cost savings. It is not recommended that petrol vehicles are taken forward, as petrol-hybrids appear to offer CO_2 savings also at a similar TCO.**
LPG	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• LPG systems are generally available to any petrol vehicle. The quality of the system varies by retrofitter, but a list of approved companies is available on the LPGUK website. • There is good LPG station coverage across the UK at public forecourts, and the vehicle can revert to petrol if the onboard LPG supply runs out. Infrastructure can also be based at a depot. • Compared to a diesel car LPG gives an increase in CO_2 emissions, but an improvement in air quality. Against petrol, there is a considerable improvement in both CO_2 and air quality. • LPG vehicle usage causes an increase in whole life costs in the NRW fleet as the annual mileages are too low to allow the fuel savings to pay back the additional installation and servicing costs of the unit.
Recommendation	**Not recommended - LPG use can improve air quality emissions but would be operated at higher costs and CO_2 emission to diesel. Therefore, LPG is not recommended for introduction since cost and emission savings appear to be more easily achieved from petrol-hybrids. BioLPG is due to be released from CalorGas in 2017, which would allow a significant CO_2 reduction to be gained from LPG. LPG vehicles should be reassessed when bioLPG is available.**
Biodiesel (B20-B30)	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Product models available from OEMs with good reliability and support biodiesel at various blends. It is recommended to stay within the B20-B30 blend range for engine compatibility. Some vehicles require an upgrade kit from OEMs to make systems compatible. • Biodiesel has no operational restrictions, but does require increased maintenance (filter and oil changes) and tight fuel quality controls. It is common for fleets to reduce biodiesel blends in the winter, maintaining low biodiesel blends to reduce the risk of fuel waxing. • One major requirement is the implementation of a dedicated infrastructure around depots (bunkered biodiesel). • CO_2 emissions are reduced, also air quality has a variable benefit: it's commonly shown that there is a reduction in PM and similar NOx compared to diesel. • Cost wise, having bunkered biodiesel is slightly higher than conventional diesel. Furthermore, fuel consumption increases with biodiesel, since it has a lower energy content when compared to fossil diesel. Typically, these factors lead to marginal TCO increase.
Recommendation	**Not recommended subject to adoption of low emission options - Biodiesel operations will have limited AQ benefit and will be of slightly higher cost and additional fuel and fleet management is required. However, a CO_2 saving is available. Biodiesel is unlikely to be required in the car fleet since other low emission options are available.**

8.3 Small Vans

Small vans are typically replaced on a 5-year cycle. The greatest number of vans are currently operated from Resolven, Llandovery and Dolgellau depots at the time of this study. Table 11 below shows a breakdown of each main van type. We have focused the economic and environmental comparison of low emission vehicle technology on the diesel panel vans (78%), which is the largest collection of vehicles in the entire fleet. Additionally, NRW advised that the car derived van (CDV) variant will be phased out of the fleet and replaced with either passenger cars or small vans and so replacements for this type of vehicle were not sought.

Subcategories	No. of vehicles	Average annual mileage	MPG	Model examples
Car derived van	52	10,883	48.0	Ford Fiesta Van
Diesel panel van	183	9,267	44.3	Citroen Nemo Van
Total/Average	**235**	**9,626**	**45.1**	

Table 11 - Small Van Fleet Breakdown

8.3.1 Small Van Cost and Emission Comparison

Figure 3 below shows the % savings for the small van technologies:

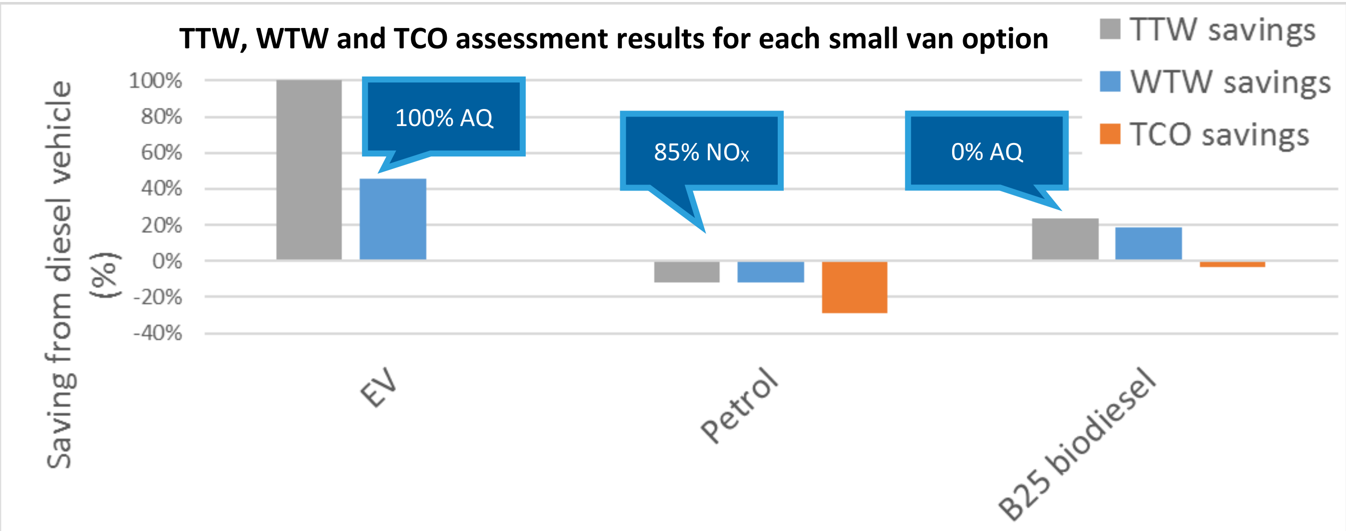

Figure 3 - Leased Small Vans. Note, lack of PM figure means that PM savings are minimal or unknown. The terms 0% and 100% AQ signifies zero or complete air quality emission savings respectively. Bars shown below 0% on this figure represent an increase in the emissions/costs associated with that measure when compared to a standard diesel vehicle. Additionally, you can't see the TCO on the EV due to it being close to cost neutral.

- **Battery Electric Vehicles** – 100% TTW and ~50% WTW CO_2 emission savings. TCO is comparable to an equivalent NRW leased diesel (Citroen Nemo) when using a Renault Kangoo ZE. For the new Nissan e-NV200 quoted lease prices resulted in an increased TCO.
- **Petrol Vehicles** – ~85% reduction in real-world NOx emissions, however a substantial TCO increase of 22% and a CO_2 emission increase and when compared to an equivalent leased diesel.
- **Biodiesel Vehicles (B25)** – offers 23% TTW and 18% WTW emission savings and similar AQ performance to a leased diesel at a TCO rise of 3%.

8.3.2 Small Van Suitability Assessment

Electric Small Vans	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• See small and medium car section for electric vehicle suitability comments. • The Nissan e-NV200 is a more expensive and larger capacity van and was not economic when compared to the small low-cost diesel vans used by NRW. Using the lower cost Renault Kangoo, the TCO was comparable. Estimated average range of around 50 – 70 miles (dependent on driving style and conditions) for a typical 22 kWh battery. It should be noted that Renault are due to release a large capacity battery (33 kWh) of the Kangoo during 2017, at a price of around £20,000, which will suit longer range requirements.
Recommendation	**Recommended - EV vans should be implemented where operationally feasible due to significant emission savings for similar or lower total cost of ownership. Providing electrical services to infrastructure and daily mileage trends of individual vehicles needs to be considered further.**
Petrol	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Petrol small vans are readily available from all major OEMs, where there is a diesel there is usually a petrol variant. For vans, it is a mature technology that provides unrestricted range of over 400 miles on a full tank. In the case of engine downsizing, small vans will utilise a small petrol engine alongside a turbocharger to provide the same output as diesel engines. • Petrol station coverage across the UK is easily assessable with all public forecourts readily providing petrol. Additionally, infrastructure can also be based at any depot. • Compared to a diesel van, petrol gives an increase in CO_2 emissions and improvement in air quality, with a significant increase in TCO.
Recommendation	**Not recommended - Petrol use can have the benefit of improving air quality emission but are likely to increase cost and CO_2 emission. Consequently, petrol uptake is not recommended.**
Biodiesel (B20-B30)	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• See small and medium car section on biodiesel suitability comments.
Recommendation	**Not recommended subject to adoption of low emission options - Biodiesel operations will have limited AQ benefit and will be of slightly higher cost and additional fuel and fleet management is required. However, a CO_2 saving is available. Biodiesel is unlikely to be required in the van fleet since other low emission options are available.**

8.4 4x4 Performance Review

4x4s are typically replaced on a 5-year cycle and highest numbers of vehicles are located in the Llandovery, Plas Gwendraeth and Maes y Ffynnon depots (at the time of this review). Table 12 below shows a breakdown of each main 4x4 type. The majority of 4x4s (77%) are double cab pickups, with only a small proportion being 4x4 SUV (10%).

Subcategories	No. of vehicles	Average annual mileage	MPG	Model examples
4x4 SUV	13	10,551	37.4	Mitsubishi Outlander Commercial
4x4 Double cab pickup	98	10,737	29.0	Ford Ranger Pickup
4x4 Land Rover	17	11,199	28.0	Land Rover Defender
Total/Average	**128**	**10,779**	**29.7**	

Table 12 - 4x4 Fleet Breakdown

8.4.1 4x4 Cost and Emission Comparison

Figure 4 below shows the % savings for the 4x4 technologies:

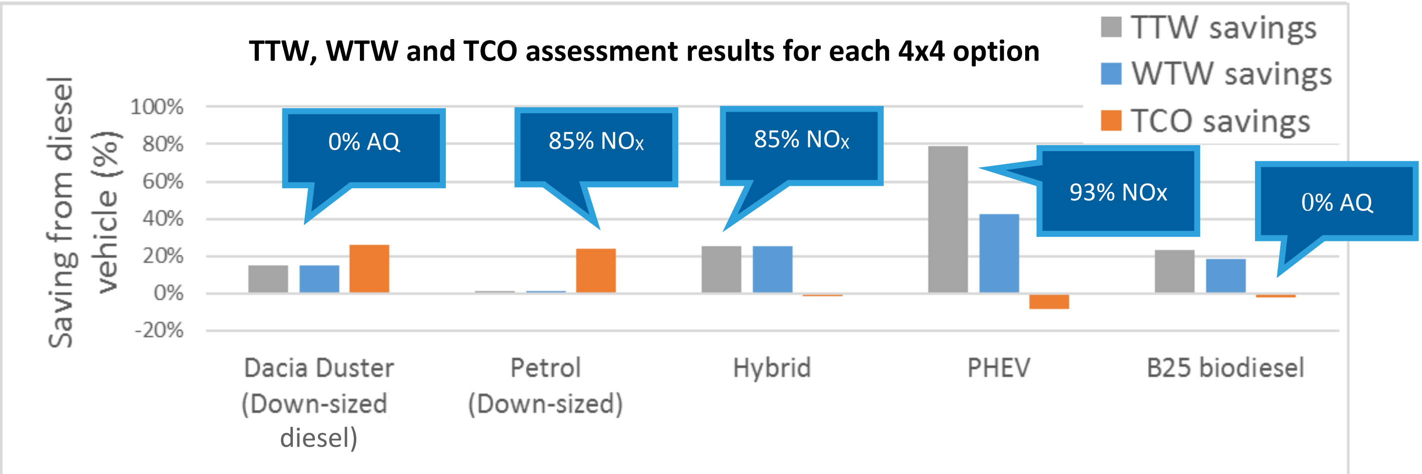

Figure 4 - Leased 4x4s. Note, lack of PM figure means that PM savings are minimal or unknown. The terms 0% and 100% AQ signifies zero or complete air quality emission savings respectively. Bars shown below 0% on this figure represent an increase in the emissions/costs associated with that measure when compared to a standard diesel vehicle.

There are limited alternative technology options to reduce CO_2 from 4x4 vehicles, except for a biodiesel blend which may be used in a standard vehicle. The alternative options evaluated above are not rugged 4x4 diesel vehicles, but a variety of lighter duty AWD vehicles which may be suitable for some NRW off road vehicles. As such the environmental savings offered by these vehicles are mainly due to improved fuel economy of a smaller engine rather than the alternative technology powertrain.

- **Downsized Options** – NRW currently use the Dacia Duster (diesel) as an alternative to a rugged 4x4 vehicle. As shown, this can provide around 18% CO_2 reduction and 25% TCO reduction from a Mitsubishi Outlander Diesel. A downsized petrol vehicle will also provide a good TCO savings but limited CO_2 savings.
- **Petrol-hybrid Vehicles –** Hybrid AWD vehicles offer similar good CO_2 savings (>20%), at a similar TCO.
- **Plug-in Hybrids Vehicles** – (such as the Mitsubishi Outlander PHEV 4work GX3h) offer 79% and 43% TTW & WTW CO_2 emission savings respectively, at an 8% increase in TCO. This option has the greatest CO_2 savings and is recommended in place of the Dacia Duster. The operational abilities of the PHEV should be considered.

- **Biodiesel Vehicles (B25)** – offers 23% TTW and 18% WTW emission savings and similar AQ performance to a leased diesel with marginally increased TCO.

8.4.2 4x4 Suitability Assessment

Further decision-making information on the suitability of the 4x4s has been summarised in the matrix below:

Hybrid 4x4s	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Currently, few 4x4 petrol hybrids are available from mainstream manufacturers. NRW do not use bunkered diesel, therefore petrol hybrids offer no operational restrictions or increased mileage. • AWD Petrol-hybrids offer slightly better CO_2 emissions to diesel 4x4s as well as better air quality performance. • AWD Petrol should be further assessed to ensure the vehicle is sufficient ruggedized to cope with NRW requirement. However, it should be noted that the transition to petrol hybrid will come at a minor TCO increase.
Recommendation	**Recommended in certain circumstances - Petrol-hybrid 4x4s, such as the AWD Toyota RAV4, should be considered to replace the Dacia Duster. The benefit would be that the petrol hybrids would offer both CO_2 savings and improved AQ. It is noted that not all 4x4/AWD vehicle have comparable off-road capability. Therefore, the NRW fleet team should consider where and if AWD hybrids have a place in the 4x4 category.**
Plug-in Hybrid 4x4s	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Plug-in hybrid 4x4s are currently limited in availability but future trends show that there are more to follow from a growing number of original equipment manufacturers (OEMs). • Like other plug-ins, charging infrastructure is required. Low-cost wall mounted units can be installed at depots/offices, employees' homes, and work destinations (pending EV supply). Where large penetrations of EVs exist around a single depot smart (distributed) charging or power upgrades may be required and could make adoption uneconomic. • Regarding emissions, a 4x4 plug-in can save a significant amount of CO_2 and provides better air quality performance. • These emission savings, however, come at a cost, with a moderate increase in the TCO.
Recommendation	**Recommended in certain circumstances - Plug-in hybrids offer the greatest AQ and CO_2 improvements for the NRW 4x4 fleet. Thus, an uptake of plug-ins is advised over the hybrids above, where the Dacia Duster fleet is exchanged for the AWD PHEV Mitsubishi Outlanders. It is noted that not all 4x4/AWD vehicle have comparable off-road capability. Therefore, the NRW fleet team should consider where and if hybrids have a place in the 4x4 category.**
Petrol	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• Petrol 4x4s are all but limited to major OEMs. The number of models available in a petrol version are low. Such models include the Land Rover Range Rover or, with a downsized petrol engine and turbocharger combo, the more SUV akin Seat Ateca. • Petrol station coverage across the UK is easily assessable with all public forecourts readily providing petrol. Additionally, infrastructure can also be based at any depot. • However, petrol 4x4s are not comparable to the fleet diesel vehicles. The emission saving is due to the smaller, less powerful petrol engine – on a like for like basis (petrol vs diesel engine), the result would be an increase in emissions. • Considering the Seat Ateca, compared to a diesel 4x4, the petrol 4x4 gives a marginal CO_2 saving with a considerable cost saving and an added improvement in air quality. It should be noted nonetheless, that the CO_2 and cost savings are only gained due to the decrease in engine size.
Recommendation	**Not recommended - Petrol 4x4 vehicles offer an economic savings however have no CO_2 advantage over the current Dacia Duster which is purchased as a lightweight 4x4 vehicle. Therefore, it is not recommended this technology is pursued.**

Biodiesel (B20-B30)	
Availability	• See small and medium car section on biodiesel.
Maturity	
Operational Restrictions	
Infrastructure	
Emissions	
Cost	
Recommendation	**Recommended in certain circumstances - Due to the limited options, to decarbonise the 4x4 fleet, biodiesel use around depots with sufficient demand and security to justify the installation of bunkered tank should be considered. Vehicle warranties required discussing with manufacturers and not all vehicles will be compatible.**

8.5 Large Vans

Large vans are typically replaced on a 5-year cycle and have a high number of operations in the Cilfynydd (4), Rhuddlan (4), River House (3) and Plas Gwendraeth (3) depots at the time of this study.

Table 13 below shows a breakdown of each main van variant. Most vehicles are in panel van configuration (82%), therefore, we have focused the economic and environmental comparison of low emission vehicle technology in this category.

Subcategories	No. of vehicles	Average annual mileage	MPG	Model examples
Diesel panel van	27	9,694	31.6	Ford Transit
Double cab	4	12,909	33.6	Volkswagen Transporter Pickup
Tipper	2	7,640	24.9	Citroen Relay Tipper
Total/Average	**33**	**10,032**	**31.6**	

Table 13 - Large Van Fleet Breakdown

8.5.1 Large Van Cost and Emission Comparison

Figure 5 below shows the % savings for the large van technologies:

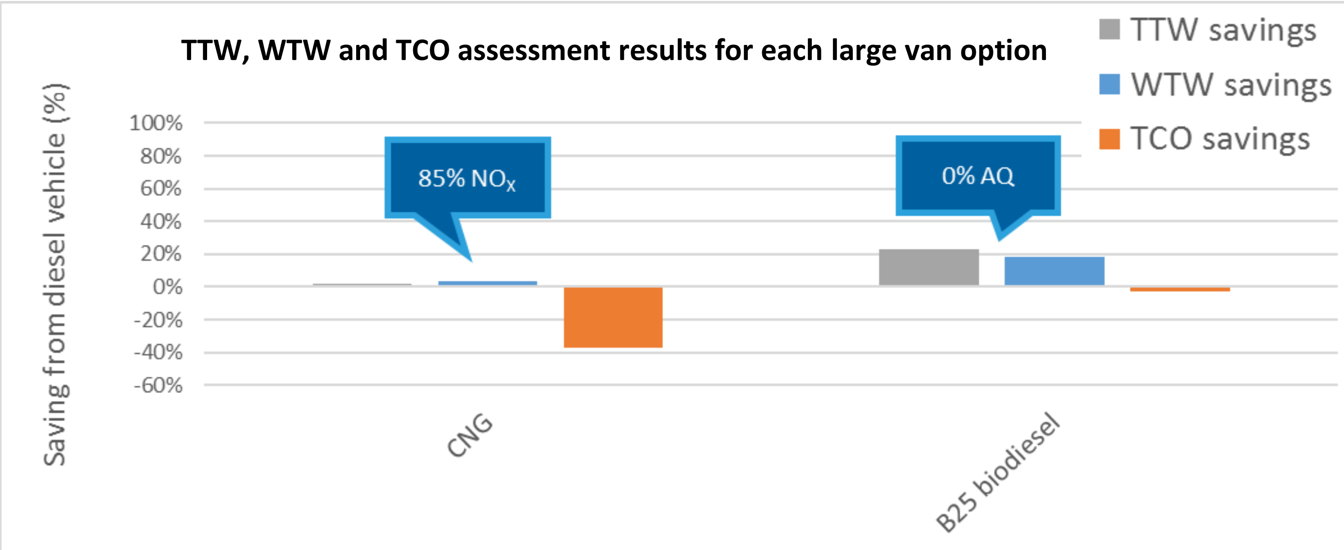

Figure 5 - Leased Large Vans. Note, lack of PM figure means that PM savings are minimal or unknown. The terms 0% and 100% AQ signifies zero or complete air quality emission savings respectively. Bars shown below 0% on this figure represent an increase in the emissions/costs associated with that measure when compared to a standard diesel vehicle

- **Compressed Natural Gas vehicles** – (such as Iveco Daily[9]) give marginal CO_2 emission savings and ~ 85% reduction in real-world NOx emissions, however a substantial TCO increase of 37% when compared to an equivalent leased diesel.
- **Biodiesel Vehicles** – offers 23% TTW and 18% WTW emission savings and similar AQ performance to a leased diesel at a similar or slightly increased TCO.

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[9] Fuel capacity 53 kg CNG + 14 litre petrol (emergency tank for use when CNG station is not available) giving a combined range of circa 300 miles. 3.5 tonne variant, 109 hp, www.gasvehiclehub.com

8.5.2 Large Van Suitability Assessment

CNG	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• CNG vehicle availability has changed over the last few years: with Mercedes ceasing the UK availability of the Sprinter Natural Gas van, the only UK OEM model available now is the Iveco Daily. • CNG technology has been around for a while and as such has had OEM product with good reliability. • There are few operational restrictions with CNG, with availability in most body configurations including double cab and tipper as well as the CNG fuel tanks taking no more space or weight than a conventional diesel vehicle. • There is limited public infrastructure and the costs if installing own site infrastructure for a relatively small fleet of vans would be prohibitive. However, considering if refuelling facilities were available Cenex estimates that vehicles could only be economically operated on CNG if a large capacity station was in place supplying gas at less than 70p/kg for high mileage vehicles (>12,000 MPA). • Compared to diesel, the emission savings for CNG are minimal, however, there is an improvement in AQ performance.
Recommendation	**Not recommended - CNG use can have the benefit of improving air quality emission and marginally decrease CO_2, however, the high demand and costs of setting up and making the operation of CNG large vans are uneconomic. Therefore, it is not recommended to implement CNG.**
Biodiesel (B20-B30)	
Availability Maturity Operational Restrictions Infrastructure Emissions Cost	• See small and medium car section for availability and operational comments on biodiesel.
Recommendation	**Recommended in certain circumstances - Due to the limited options to decarbonise the large van fleet, biodiesel use around depots with sufficient demand and security to justify the installation of bunkered tank should be considered. Vehicle warranties required discussing with manufacturers and not all vehicles will be compatible.**

8.6 Small vs Medium cars – Impact of Downsizing

The results of downsizing the medium car fleet to smaller vehicles can be seen in the table below which shows that downsizing from Medium to a Small diesel car can save £2,100 TCO and 87 kgs of WTW and 70 kgs (8%) of TTW CO_2 per vehicle. TCO savings from £260 to £8,000 are available from downsizing depending on the technology chosen. In this analysis, all respective technologies for the corresponding car fleet have been reviewed.

TCO over 5-Year (£)						
Technology:	**Diesel**	**EV**	**Hybrid**	**REEV/PHEV**	**Petrol**	**B25 biodiesel**
Small car	£ 17,842	£ 14,054	£ 17,992	£ 19,628	£ 17,958	£ 18,373
Medium car	£ 19,952	£ 14,355	£ 18,254	£ 27,876	£ 20,553	£ 19,494
Down-sizing TCO Saving per vehicle (£)	**£ 2,110**	**£ 302**	**£ 261**	**£ 8,248**	**£ 2,594**	**£ 1,120**
Annual CO_2 WTW Emissions (kgs)						
Technology:	**Diesel**	**EV**	**Hybrid**	**REEV/PHEV**	**Petrol**	**B25 biodiesel**
Small car	1,044	490	717	708	1,170	853
Medium car	1,131	530	781	791	1,269	924
Down-sizing CO2 Saving per vehicle (kg)	**87**	**39**	**64**	**83**	**99**	**71**

NRW currently operate 118 diesel medium cars, the effect of down-sizing 100% of these vehicles would result in a total TCO savings of £249,000 and 10,000kg WTW (8,129kg TTW) CO_2 per 5-year period using the current NRW vehicle leasing model.

8.7 Car & Van EVs – Typical Range from Drive Cycle

The **range** of an all-electric vehicle is defined as the driving distance a vehicle can travel on a single battery charge. In the case of a battery electric vehicle, it can only use power from its electric battery pack to traverse a given driving cycle. Additionally, a **driving cycle** is defined as the speed of a vehicle versus time. In this analysis we compare driving cycles representative of urban, rural and motorway driving patterns.

Cars – Cenex have a model of a 24 kWh Leaf which has been validated from testing over different driving cycles in a vehicle testing laboratory. This was used to calculate the respective range for the 30-kWh version – we deducted 20 miles range to the lower end to account for aggressive driving and high use of the heater, as to give a working range (i.e. on the table below the urban range on the 24kwh Nissan Leaf was 85 miles, from which we deducted 20 miles to give a range of 65-85 miles). Results are shown in Table 14:

Medium cars (C-segment)	**Drive Cycle**		
	Urban (Miles)	**Rural / B-Road (Miles)**	**Motorway / A-Road (Miles)**
Nissan Leaf (24 kWh Bat.)	65 – 85	90 – 110	50 – 70
Nissan Leaf (30 kWh Bat.)	85 – 105	120 – 140	70 – 90

Table 14 – Medium Car Driving Distances (different battery sizes over varying drive cycles)

Vans – Cenex have test data from range and performance testing at Millbrook, who are a UK based vehicle testing centre (and one of the largest in Europe), for the 24 kWh e-NV200. This was also used to calculate the typical range for the upcoming 33 kWh Renault Kangoo version – we deducted 25 miles range to the lower end to account for aggressive driving and high payloads, as to give a working range (i.e. on the table below the urban range on the 24kwh Nissan e-NV200 was 70 miles, from which we deducted 25 miles to give a range of 45-70 miles). Results are shown in Table 15:

Small vans (<2.5t)	Drive Cycle		
	Urban (Miles)	Rural / B-Road (Miles)	Motorway / A-Road (Miles)
Nissan e-NV200 (24 kWh Bat.)	45 – 70	60 – 85	35 – 60
Renault Kangoo (33 kWh Bat.)	85 – 110	110 – 135	70 – 95

Table 15 - Small Van Driving Distances (different battery sizes over varying drive cycles)

8.8 Lease vs Purchase

Due to capital constraints, NRW will lease all fleet vehicles in future. The TCO models built (as shown in previous sections) were modified to vehicle ownership models through i) using vehicle capital cost data from the Government Procurement Portal Service, ii) using residual values from the Fleet News Resources – reduced by £1,000 to match the end of lease fee which is applied to the NRW leasing cost models.

Table 16 below, highlights the difference in TCO cost for small cars between Leasing and Owning:

TCO Comparison			
Fuel Type	Leased (5 years 10,000 MPA)	Purchase (no internal cost of borrowing applied)	Savings from purchase
Small Cars			
Diesel	£17,152	£12,240	£4,912
EV	£13,849	£12,844	£1,005
Hybrid	£17,434	£13,407	£4,027
REEV	£19,200	£17,046	£2,154
Petrol	£17,046	£11,995	£5,051
Medium Cars			
Diesel	£18,469	£10,410	£8,059
EV	£13,917	£11,137	£2,780
Hybrid	£17,046	£14,459	£2,587
PHEV	£26,975	£17,338	£9,637
Petrol	£18,589	£12,071	£6,518
LPG	£19,815	£12,308	£7,507
Small Vans			
Diesel	£16,635	£13,313	£3,322
Nissan EV	£18,831	£12,567	£6,264
Renault EV	£16,492	£9,926	£6,566
Petrol	£21,403	£16,759	£4,644
4x4s			
Diesel	£25,362	£16,711	£8,651
Petrol	£19,323	£17,765	£1,558
Hybrid	£25,768	£22,084	£3,684
PHEV	£27,431	£19,239	£8,192
Large Vans			
Diesel	£32,428	£24,268	£8,160
CNG	£44,433	£39,261	£5,172

Table 16 - TCO Comparison between Leased and Owned Vehicles for Small Cars

The above high-level analysis table shows that the smallest difference for the TCO comparison is for the EV and hybrid cars, which is partially due to vehicle model selected and the lease rates on the government procurement portal. However, for the small and large vans and 4x4s the lowest TCO comparison comes from the diesel, petrol and CNG vehicles respectively. The general trend, however, indicates that significant TCO savings could be available if vehicles were switched to an ownership model. TCO savings of up to £4,912 per small car (**23%** - Ford Fiesta), £8,059 per medium car (**44%** - Ford Focus), £3,322 per small van (**20%** - Citroen Nemo), £8,651 per 4x4 (**34%** - Mitsubishi Outlander) and £8,160 per large van (**25%** - Ford Transit) could be available. This cost saving could assist in funding low emission vehicle implementation and infrastructure.

Figures quoted above include OLEV PiCG and PiVG grant on EV, PHEV and REEV vehicles.

8.9 Mileage and Ownership Sensitivity

The scenarios below demonstrate how savings increase with annual mileage, a target annual mileage scenario of 15,000 miles is also shown to demonstrate the effect of aggressive vehicle reduction and mileage increase activity across the fleet, which is an area currently under review by NRW. The analysis has been conducted on cars and small vans where electrification has been recommended.

Cars:

			Mileage Sensitivity			Ownership Increase	
Pool Cars	No. of vehicles		Ownership Period				
		5 years	5 years	5 years	5 years	7 years	7 years
		Average annual mileage	Allocated annual mileage	General annual mileage	Target annual mileage	Allocated annual mileage	General annual mileage
Small car (B-segment)	52	8,283	4,523	9,901	15,000	4,523	9,901
Electric TCO % Saving		**19%**	**14%**	**21%**	**26%**	**16%**	**24%**
Medium car (C-segment)	115	6,591	5,578	7,761	15,000	5,578	7,761
Electric TCO % Saving		**25%**	**24%**	**26%**	**32%**	**25%**	**28%**

Table 17 - Pool Cars Mileage & Ownership Evaluation

Small Vans:

			Mileage Sensitivity			Ownership Increase	
Pool Vans	No. of vehicles		Ownership Period				
		5 years	5 years	5 years	5 years	7 years	7 years
		Average annual mileage	Allocated annual mileage	General annual mileage	Target annual mileage	Allocated annual mileage	General annual mileage
Small van (<2.5t)	12	9,267	6,965	7,364	15,000	6,965	7,364
Electric TCO % Saving		**0%**	**-5%**	**-4%**	**11%**	**2%**	**3%**

Table 18 - Pool Van Mileage & Ownership Evaluation

9 Analysis of Fleet Pool Vehicle Usage

9.1.1 Vehicle Locations

For the Pool Fleet, most fleet vehicles are kept at Maes y Ffynnon (Bangor) (31), the Rivers House (Cardiff) (25), and at Llandovery (18). Note, a large amount of these vehicles are cars. Findings in Figure 6 below.

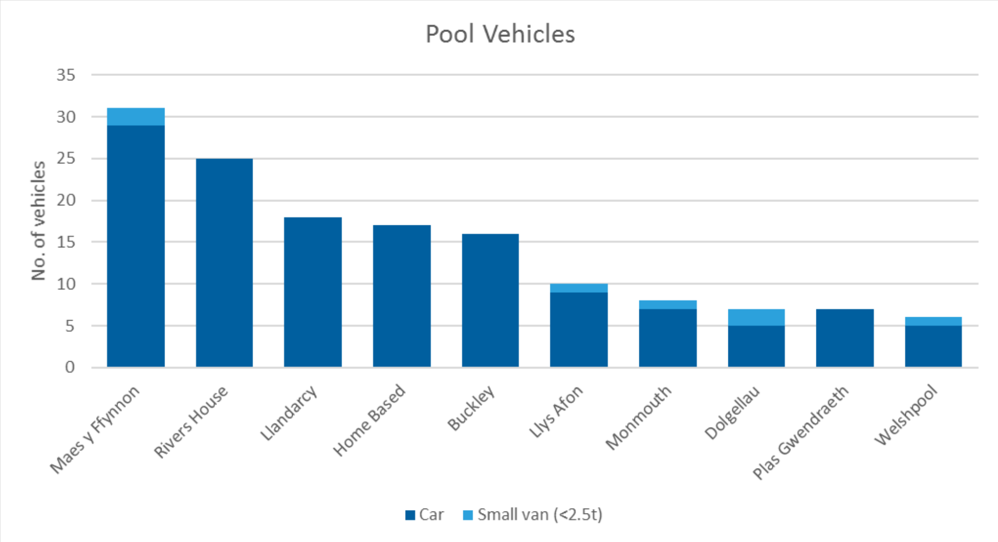


Figure 6 - Pool Fleet Breakdown by Location (May-July 2016 journeys)

Figure 10 shows the journey data for NRW's pool car fleet from a sample of the most active 8 offices, for those vehicles with daily mileage records. Note, that these records were for a 3-month period between May to July in 2016 and consisted of **mostly one journey per day**. From the analysis, it was found that 43% of daily trips are less than 50 miles and 65% are less than 100 miles.

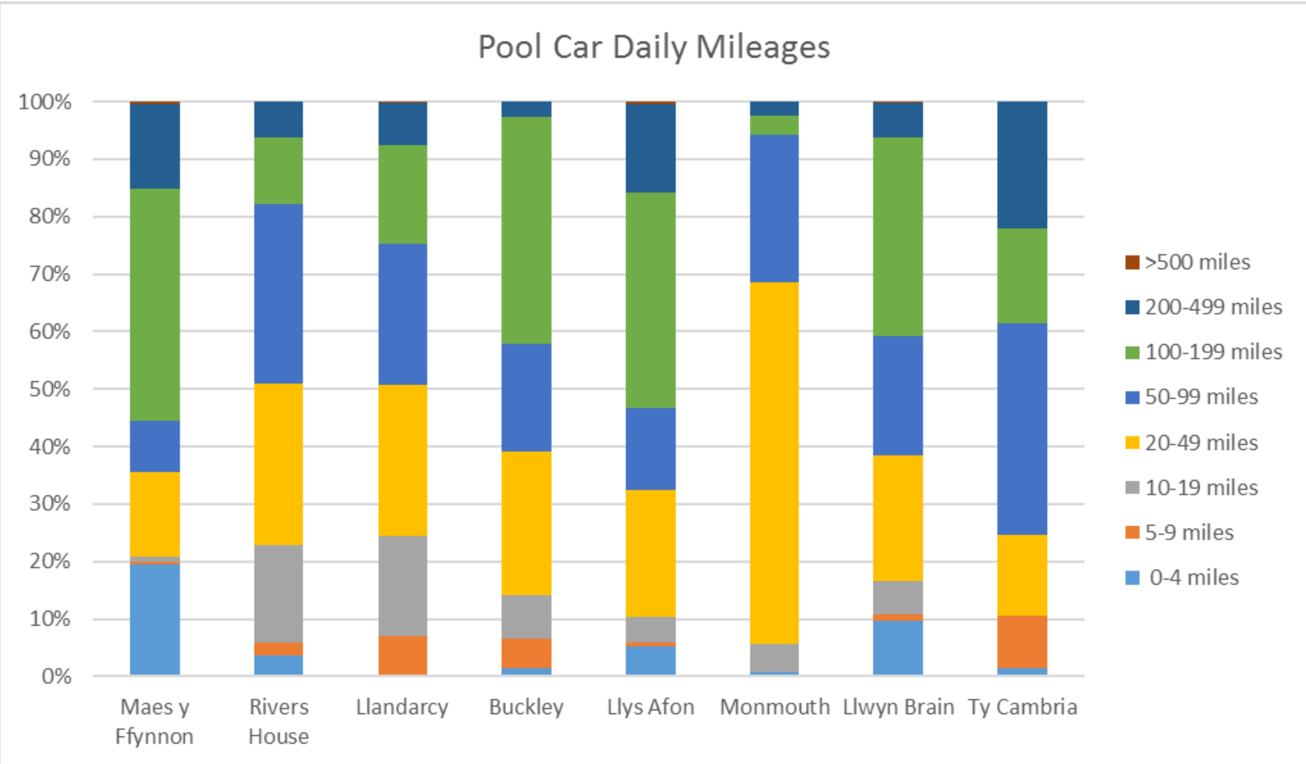


Figure 10 - Daily Mileage Analysis for Pool Cars (May-July 2016 journeys)

The analysis above highlights that due to the high proportion of low daily mileages (< 50 miles) undertaken by the Pool fleet, there is significant potential to introduce EV pool cars, providing CO_2 and costs savings. Figure 7 below shows the percentage of Pool vehicle journeys at each of the main sites that were less than 50 miles (in blue call out bubbles) and were less than 100 miles (in green ovals). These figures are for return journeys from each of the site locations. 50 miles for an EV represents an achievable mileage to undertake, which may be stretched to 100 miles as battery sizes increase and employees become comfortable with the range capabilities of EVs.

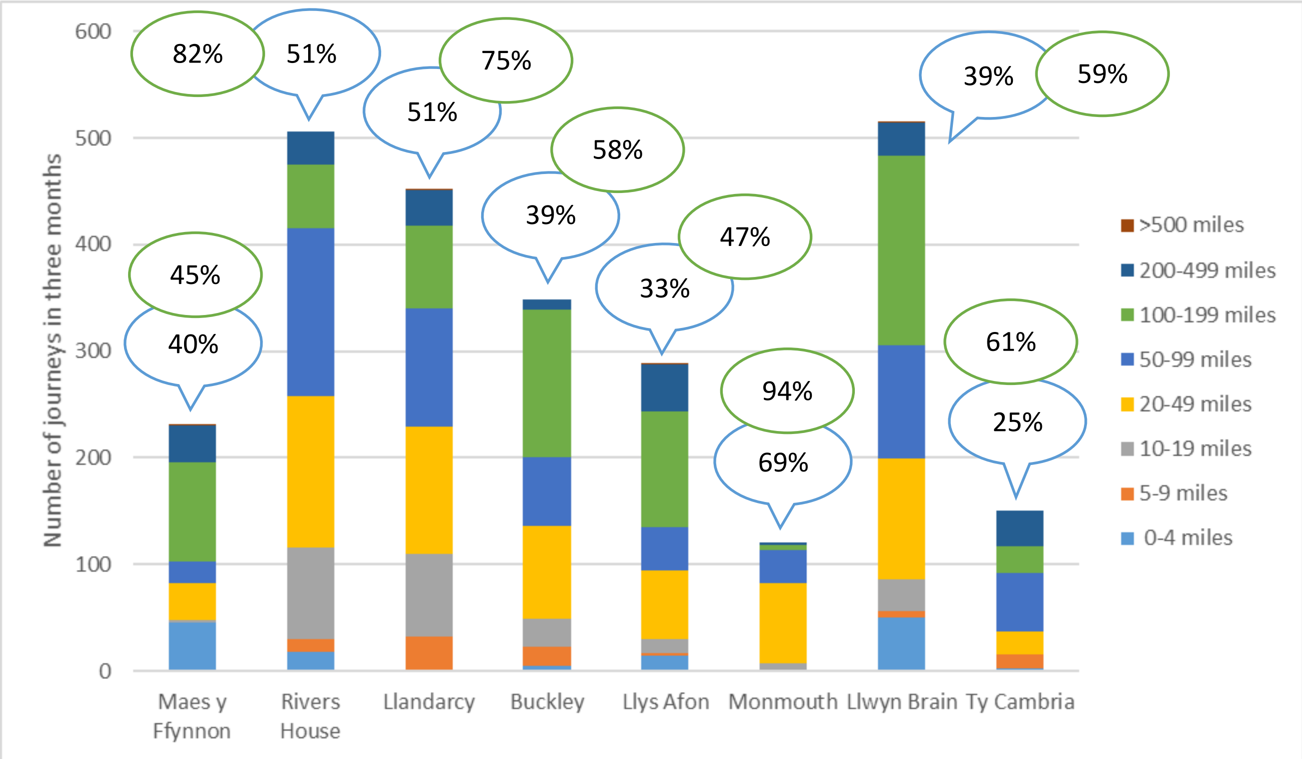


Figure 7 - Count of Pool Fleet Journeys Distances (May-July 2016 journeys)

10 Procurement of Electric Vehicle Charging Infrastructure

Successful procurement of electric vehicle charging infrastructure comes down to clear specifications and requirements that minimise uncertainty, and future proofing any purchases. Electric vehicle charging infrastructure technology is continually progressing, but there are certain parameters that can, and should, be included in procurement specification before tenders are released.

As a minimum, tenders or requests for EV charge point quotes should include:

- Locational data of where the charge points are to be installed including postcode, address, land owner details and, where possible, a photo of the installation area.
- An assessment of the existing power capacity, or any associated upgrade costs for the chosen sites (this information would need to be gathered from your Distribution Network Operator).
- A minimum technical specification that defines the types of charge point and charge point management system requirements.
- Details of your expected service, maintenance, and repair requirements (or have agreed maintenance with your existing maintenance contractor to ensure capabilities).
- Depending on your contract type, a Land Lease or Land Licence may be required if you are installing on any private land. As a minimum, a letter will be required from the Purchaser to the Supplier that gives them permission to investigate power and install infrastructure on their land.

Where possible financial tenders should include a shopping list, or basket of goods, that suppliers are asked to quote against, including the cost of groundworks and installation, project management and the hardware/software aspects to allow a fully rounded, and accurate, financial analysis. Where possible limit the suppliers to only being able to charge the fees stated in the proposal (e.g. they provide their maximum price). Quality should also be assessed, and recommendations are to put a higher weighting on the quality aspects, particularly around Service, Maintenance, and Repair packages. The majority of charge points come with 3 years' warranty (some manufacturers offer up to 10 years), but additional warranty can be purchased for years 4 and 5 if desired.

There are some existing frameworks that Public Bodies can access on the Crown Commercial Service framework under Traffic Management Technology 2 (Contract ID: RM1089).

- **Lot 10 Sustainable Transport Infrastructure** is a useful framework, but this has a more limited range of suppliers and requires a quote activity, so is suited for larger scale projects.
- **Lot 15 Catalogue providing items within the scope** is a much more varied framework with a greater number of suppliers, and acts similarly to an Argos catalogue. Suppliers have pre-submitted prices for a range of services including hardware, software, installation, groundworks, project management, commissioning etc. and a Public Body can simply go online and add the items to their basket that they want and make an order. It is a direct award framework, and the advantage is that organisations who have submitted prices are not allowed to charge you more than they have stated for the items on the framework (e.g. if they have quoted £100 per metre square of trenching to install a point, they cannot charge you any more than that regardless of what they find whilst completing the work).

Private Bodies do not have access to frameworks, however the Office for Low Emission Vehicles (OLEV) has released the Electric Vehicle Homecharge Scheme approved changepoint model list[10], and this

[10] Available at https://www.gov.uk/government/publications/electric-vehicle-homecharge-scheme-approved-chargepoint-model-list

would be a good starting point for any procurement exercise. Where possible Cenex always recommends gaining three quotes from local suppliers (or companies who have service depots close to you), and comparing the different quotes to ensure maximum value for money and quality. Concession contracts as opposed to service contracts are preferential (provided it is a 'pay-for-use' network) and these are becoming industry norm as they allow for better future proofing and service schedules, as well as higher KPI/SLA potential.

Industry documents that should be consulted during a procurement exercise include:

- The Office for low Emission Vehicle **Minimal Technical Standards**[11] – a specification that define key technical specifications and requirements for installations using public money.
- The **UK Electric Vehicle Supply & Equipment Association Procurement Guidance[12]**, which is a general procurement guide for private and public sector organisations wishing to purchase equipment and services to support the conductive charging of EVs.

Cenex have successfully supported the installation and procurement of over 1,000 charge points across the public and Private Sector, and have authored the OLEV Minimum Technical Standards Documentation used in all Government Grant Schemes. We have also written the technical standards for the UKs first Concession Framework for four Local Authorities.

[11] Available at https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/564605/workplace-charging-scheme-technical-spec.pdf

[12] Available at http://ukevse.org.uk/resources/procurement-guidance/

11 Fleet Telematics Review

11.1 Capabilities and Benefits

Introducing a vehicle tracking and telematics system is a widely-accepted method of reducing mileage, costs, and accidents. Vehicle telemetry has developed to such a stage that the data acts as a real aid to identifying high-risk drivers. It can provide meaningful information about the driver's performance by collecting data from the vehicle, leading to better fuel efficiency through driver feedback. Some of the other advantages of telemetry systems are:

- Providing accurate mileage data, avoiding over mileage and phantom mileage claims (from Grey Fleet).
- Analysing routes, both in real time and retrospectively, enabling better routing, scheduling, and minimising unnecessary detours.
- Helping to increase driver safety, particularly in reducing the reliance on mobile phones for lone working procedures.
- Encouraging drivers to be responsible for their driving and to be more aware of bad habits, resulting in;
    - Cost savings from reduction in insurance premiums and fuel use associated with certain driving habits
    - Reduction in vehicle wear and tear
    - Possible improved reputation with the public
- Reducing any unauthorised private use of fleet vehicles.

At present, there are 3 main types and/or functions of telematic systems:

1. **Fleet Review Telemetry** – Monitors fuel and/or energy consumption and tracks journey patterns, some systems can also be used to identify suitable EVs for their duty cycles – e.g. available from FleetCarma
2. **Driving Style Telemetry** – Rate driver's performance by collecting data from the vehicle, leading to driver feedback and in-cab coaching – e.g. available from Microlise
3. **Driving Aid Telemetry** – Add-on warning dashboard in vehicles to provide real-time indicators of bad driving habit such as over revving and harsh braking – e.g. available from Lightfoot

In addition, telematics systems extend beyond vehicle tracking and into enterprise management. Today's telematics technology provides a way of controlling and organising vehicles and mobile workforces. Companies like FleetCarma provide a system which is good for optimising and tracking alternatively fuelled vehicles.

Some of the mainstream telemetry system providers are:

11.2 Purchase and Running Costs - Fuel and Mileage Savings

In the tables below, the potential savings from the uptake of telematic systems can be seen. The capital and annual subscription costs have been derived from the 'Royal Mail' and 'Vale of Glamorgan Council' case studies in section 11.3. Furthermore, the fuel cost was taken as **£0.94 per litre (excl. VAT)** from the average UK price in the AA Fuel price report (average from February 2016 – 2017), and fuel savings were assumed as **15%** (from average telematic company quoted figures and case study data[13]).

Cars

Below, in Table 19, the car fleet (both pool fleet and allocated vehicles) telemetry savings are shown. At the current annual mileage, the telemetry system, regardless of the benefits, will not pay back. In the blue rows, it is displayed that for the systems to break even, an average annual mileage of **12,000 MPA** for small cars, and **11,000 MPA** for medium cars is required. For low mileage vehicles, the annual cost increase per vehicle (£40 - £50) is a worthwhile investment to generate the robust evidence base (data and information) that telematics systems supply to inform future strategy. **The costs below do not include additional benefits of cost reductions associated with accident reduction and maintenance, which are difficult to quantify – case study evidence below states accident rates drop by around 20 – 35%.**

Vehicle Type		No. of vehicles	Average MPA	MPG	Capital cost (unit)	Annual subscription cost (unit)	Annual fuel cost (vehicle)	5-year WTW (TTW) CO_2 Savings (fleet)	Annual fuel saving (vehicle)	Annual saving (vehicle)	Total 5-year savings (fleet)
Car	Small car	61	8,283	53.2	£ 220	£ 96	£665	102t (83t)	£100	-£40	-£12,295
	Small car	42	12,000	53.2	£ 220	£ 96	£963	148t (120t)	£144	£4	£929
	Medium car	118	6,591	48	£ 220	£ 96	£586	170t (138t)	£88	-£52	-£30,728
	Medium car	70	11,000	48	£ 220	£ 96	£978	285t (232t)	£147	£7	£2,356

Table 19 - Car Fleet Telemetry Savings

Vans and 4x4s

This also applies for the small van fleet where an average annual mileage of **10,000 MPA** is required to gain a return on telematics. For the rest of the fleet (4x4s and large vans), there is no need for a sensitivity analysis by annual mileage as the current averages provide a considerable annual and lifetime fuel saving. In some cases, for example the 4x4 double cab pickup, telemetry can achieve over £47,000 in fuel saving alone over a 5-year period. Results in Table 20:

[13] Royal Mail reduced its fuel use by over 10% and the Vale of Glamorgan Council achieved a fuel saving of between 10%-20%.

Vehicle Type		No. of vehicles	Average MPA	MPG	Capital cost (unit)	Annual subscription cost (unit)	Annual fuel cost (vehicle)	5-year WTW (TTW) CO2 Savings (fleet)	Annual fuel saving (vehicle)	Annual saving (vehicle)	Total 5-year savings (fleet)
Small van	Panel van	183	9,267	44.3	£ 220	£ 96	£893	469t (381t)	£134	-£6	-£5,546
	Panel van	170	10,000	44.3	£ 220	£ 96	£964	506t (411t)	£145	£5	£3,853
4x4	4x4 van	13	10,551	37.4	£ 220	£ 96	£1,204	39t (31.6t)	£181	£41	£2,641
	Double cab pickup	98	10,737	29	£ 220	£ 96	£1,580	399t (324t)	£237	£97	£47,559
Large Van	Panel van	27	9,694	31.6	£ 220	£ 96	£1,309	118t (96t)	£196	£56	£7,617
	Double cab	4	12,909	33.6	£ 220	£ 96	£1,640	23t (19t)	£246	£106	£2,120

Table 20 - 4x4, Small & Large Van Telemetry Savings

Summary

- Increased utilisation of vehicles would make telematics viable and yield cost savings.
- It is a worthwhile investment to generate the robust evidence base (data and information) that telematics systems supply to inform future strategy for vehicle replacement and electrification.
- Introduction of telematics on 4x4s and large vans is recommended.
- If telemetry were applied to all vehicles, **without** alteration to the MPA and fleet size, the total 5-year CO_2 saving could be 1,320 t WTW (1,072 TTW) CO_2 with a total cost saving of £11,367.
- If utilisation were increased on low mileage vehicle groups in line with the sensitivity analyse in the tables above (small cars to 12,000 MPA, medium cars to 11,000 MPA and small vans to 10,000 MPA), this would result in 1,518 (1,233 TTW) tonnes of CO_2 saving with a cost saving of £67,074 over the 5-year period.
- Because of the simple, low power and wireless nature of the telemetry systems, a lifetime of at least ten or more years is expected. As long as the telemetry provider is made aware of the change of vehicle, the expected life makes it possible to re-use the unit at the end of the 5-year period.

This analysis has shown the case for installing telemetry. NRW should undertake a trial and procurement exercise for telemetry systems.

11.3 Case Studies

Technology delivers savings for Royal Mail (2009) – Royal Mail reduced its fuel usage by more than 10% - a saving of £4.4 million - whilst improving the efficiency and accident record of its collections and delivery fleet by using driving style telemetry. More than 8,000 Royal Mail vehicles were fitted with a tracking system as part of a drive to improve road safety, reduce fleet size and drive down fuel consumption. To date, driver productivity has increased by 3%, accident rates have been reduced by 20% and instances of speeding are down by more than 60%. Meanwhile, harsh braking has been reduced by 70% contributing to greater fleet efficiency.

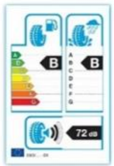
The Vale of Glamorgan Council Vehicle Tracking (2013) – Officers at the Welsh Vale of Glamorgan Council undertook a completive tender exercise, involving 6 of the most advanced telematics companies operating in the UK. The tender was for 240 driving style telemetry units and a three-year ongoing subscription trial in the sum of £133,867. This equated to a total annual cost of £44,622 over the 3-year period and a cost of £186 per vehicle per annum per vehicle. Additional vehicles could be added at a cost of £260 for the first year and £210 per year thereafter for the bare model. From fuel savings alone, telematics' companies suggest that fuel savings from such systems can achieve between 10%-20%, hence an annual cost saving of £75,377 could be realised by the fitting of the devices.

Morelli Group & ALD Automotive (2016) – The UK's leading independent refinish supplier, Morelli Group, recently saw impressive results from its programme to further improve safety amongst its **63 van delivery drivers**. At the end of **2013** with an increase in driver accidents, the decision was made to implement the full driving style/aid telemetry system, ProFleet2, from ALD in addition to the standard basic mileage capture system. Following its introduction:

- **1st year** - own fault accidents dropped by **26%**
- **2nd & 3rd year** - own fault accidents dropped to an overall of **35%**

12 Fleet Best Practice

Irrespective of the vehicle type and the fuels used in the organisation, focusing on understanding the day-to-day vehicle performance and making it more efficient will help to reduce fuel costs and emissions. The vehicle fleet size and telematic best practices elements in the table below have been built into scenario 2 of this study. Below are some examples of fleet best practice, further information and examples of best practise are available on the Fleet News website[14].

Fuel Management	Understanding fuel usage in the fleet is the first step in reducing it. You could appoint a 'Fuel Champion' who will monitor and track fuel use and costs and drive fuel efficiency improvements. 
Environmental Benchmarking	Get involved with and learn best practice from other fleet operators. You can join a benchmarking scheme, such as 'Eco Stars', or join one of the fleet operator associations.
Driver Behaviour	The first easy win when reducing fuel costs is through encouraging employees to drive more economically. This not only reduces your fuel bills, but has the additional effects of reduced accidents and maintenance costs.
Vehicle Maintenance[15]	Maintaining your vehicles properly helps to keep them running efficiently. For example, a 20% drop in tyre pressure can result in a 2% increase in fuel consumption. Tyre labels provide an easy to understand indicator of tyre performance when it comes to fuel economy and wet grip. 
Vehicle size	The best ways to reduce emissions and cost is to either decrease the fleet size or use smaller and lighter vehicles. Downsizing from a larger vehicle will also open doors to more low emission car and van options, for example most plug-in vans are only available in the smaller van range.
Telematics	Installing telematics onto vehicles gives you an insight into your working patterns, allowing more efficient routing of vehicles, elimination of non-business mileage, highlighting areas for improvements, and vehicle or driver based performance reporting.
Eco Technology[15]	A growing number of fuel reduction retrofit technologies are available for fleet vehicles. The systems should save money and emissions and a reputable system provider should be able to prove this to you before you part with your money. **Driver aids** - such as the Lightfoot system, provide real time visual and audible feedback to the driver, improving driving behaviour which commonly results in CO_2 and fuel savings of between 10% and 20%. The system sends regular performance reports to drivers and managers.  **Speed limiters** - reduce fuel consumption by reducing the maximum driving speed. Driving at 70mph uses 9% more fuel than at 60mph and driving at 80mph uses 25% more fuel than driving at 70mph. 
Positive Reinforcement	Companies engaged with employees in a positive way help the uptake and support of alternatives to convenient diesel as well as encourage safe and efficient driving. This can be through the start of monitoring and driving style performance scheme to exercise healthy competition for the employees through fleet driver league tables and the driver of the year awards. Also, this can take form via regular communication feeds to drivers which can be used to condition perception and driver behaviour. For example, e-learning courses for driving training and education courses, winter warnings to top up de-icer etc. and reminders about efficient and safe driving.

[14] Best practice guidance, https://www.fleetnews.co.uk/fleet-management/best-practice/

[15] Source: Low Emission Van Guide, November 2016 edition, http://www.lowcvp.org.uk/Hubs/lev.htm

13 Fleet Scenarios Review

To demonstrate the effect of implementing the recommended low emission vehicles, the following three scenarios have been developed.

- **Scenario 1 - Alternative Vehicle Adoption** A scenario focussed on achieving the greatest reductions in CO_2 emissions through the implementation of recommended technologies (where practical), using the current fleet profile (i.e. the same number/spread of vehicles).
- **Scenario 2 - Alternative Vehicle Adoption & Efficiency Improvement** As well as alternative vehicle adoption, this scenario focuses on maximum cost savings through additional efficiency improvements, including a large reduction in the number of vehicles that have limited low emission options and the installation of fleet telemetry.
- **Scenario 3 – Biodiesel Based Assessment** This scenario looks more closely at a detailed assessment of the potential for biodiesel introduction at major depots.

The scenarios were evaluated through a Cenex model which compared TCO and WTW emissions for alternative vehicle uptake in the NRW fleet.

Assumptions across all scenarios

- The baseline scenario represents the current fleet within NRW. The results of each scenario are compared against these baseline annual emissions and annual TCO.
- The vehicle cost and emission model is based on the outputs of the vehicle modelling in *Section 8 Fleet Technology Performance Review* and therefore includes lease costs, applicable purchase grants, maintenance, management fee, fuel, and indicative EV infrastructure costs within the analysis. The lease period is fixed at 5 years (part of the current NRW fleet management strategy).
- The cost and emission models developed in *Section 8 Fleet Technology Performance Review* covered the main vehicle types only, which were small and medium cars, small and large panel vans, and 4x4s. For vehicles outside these categories, the scenario model assumes the same performance as the nearest equivalent vehicle. This means the small van emissions model was used for the car derived vans, and the large panel van model was used for other body configurations of large panel vans. Just seven vehicles were not included in the scenario model at all. These consisted of four cars (MPV/SUV) and three HGVs. Therefore, the scenario model includes 577 vehicles (98% of the total fleet vehicles).
- Once the vehicles were loaded into the scenario model the overall model was then then calibrated to the actual fleet emissions by changing the average emissions per vehicle group. On average a 2% adjustment was required, which shows that the approach was appropriate, as we got very close to the actual results by modelling just the key vehicle types the fleet would take forward. The emissions of the scenario model were adjusted to match the actual NRW fleet emissions. This allowed the actual NRW emissions reported in *Fleet Emissions Section 5.2* (e.g. 1,994 t WTW CO_2 per annum) to be used as the scenario fleet baseline emissions.
- The exact daily mileage patterns of all NRW vehicles were not available for this study. The NRW fleet team advised that daily mileages for vehicles should be reasonably consistent with most vehicles being used 4 to 5 days per week. Therefore, when estimating suitability of low emission technologies based on range, Cenex estimated the daily mileage of each vehicle from the annual mileage by assuming 200 days usage per annum (representing use on 4 out of 5 days per week, 52 weeks per annum) – details for each vehicle type are shown in the scenario tables.

When the assumption used (consistent daily mileages) is compared to the small sample of pool car data analysed and presented in *Section 9*, the actual car data showed higher daily mileages across fewer days (e.g. 35% of journeys were over 100 miles, making them unsuitable for undertaking in current EV technologies). Therefore, the assumption above of consistent daily mileages has limitations and additional work should be undertaken to better understand the fleet usage profile at individual sites to inform the delivery of electrification in the fleet. This reiterates the value of installing telemetry on to vehicles so that journey patterns can be understood to aid the appropriate deployment of electric vehicles.

- The level of implementation of electric vehicles was based on the assumption of a low emission vehicle achieving daily mileages of 60 miles or less. This uses the assumption above of consistent daily mileages across NRW to provide the proportion of the fleet which could be low emission. It is worth noting that the range of EVs are constantly increasing with many higher range vehicles being released, and so this 60 mile range could be extended by investing in premium models of current technologies. For example, a new Nissan Leaf with up to 235 mile range is due out in early 2018, and the Renault Zoe with > 250 miles (over the regulated drive cycle) is available now. These vehicles would need to be deployed over the highest mileage drive cycles to allow a favourable TCO, due to the higher vehicle cost.
- For the usage profiles, it was assumed that the utilisation rates (i.e. 200 days per year, approximately usage in 4 out of 5 days per week, 52 weeks per year) and daily mileage (calculated from the annual mileage per vehicle) for the baseline would remain the same for Scenario 1 and 3, however these were altered for Scenario 2 due to a reduction in fleet size where overall fleet mileage remained constant, but shared across less vehicles which increased the annual mileage of each of the remaining vehicles.
- Vehicles that have been converted to biodiesel in all the scenarios are those which operate from major depots where the annual fuel use is sufficient to justify the installation of biodiesel tanks. No other vehicles have been assumed to be using biodiesel at any other sites, and where no alternative was available those vehicles have remained as diesel-fuelled in the model. Switching vehicles to electric and hybrid technologies was prioritised, therefore only vehicles unsuitable for other low emission options, and which were based at a depot with sufficient fuel demand, were switched to biodiesel use. The detail of this assumption is further outlined in Scenario 3.
- The model and scenarios below include indicative installation costs for infrastructure (dual type-2 wall socket for EVs and biodiesel tanks and cleaning). This has not included any groundworks, which may be required for cable laying. There may be higher costs associated with this that have not been considered, for example, a high implementation of electric vehicles at a location may require sequenced charging, power upgrades or major civil/electrical works to get sufficient power to the charging head and therefore require further investment. These additional practicalities of installing infrastructure (charging points or biodiesel tanks) at locations have not been explored as part of the Scenario analysis, and any expansion of electric vehicles should consider charging infrastructure ahead of any commitment to purchasing vehicles.

13.1 Scenario 1 – Alternative Vehicle Adoption

This scenario is focused on achieving the greatest reductions in CO_2 emissions through the implementation of technologies recommended in this report. The fleet profile (number of vehicles and annual mileages) remains unchanged. All vehicles are switched to low emission variants where available and practical (i.e. considering range limitations of the electric vehicles and sites appropriate for biodiesel use), with limited cost consideration. Where electrification options were not possible, biodiesel was used as the substitute where suitable (please see scenario 3).

For this analysis, a total of 577 vehicles were included in Scenario 1 which comprises 56% (324) EVs, 1% (6) PHEVs, 4% (23) petrol hybrids, 15% (88) biodiesel and 24% (136) diesel vehicles. The breakdown per vehicle type is given in the table below.

Small cars	Medium cars	Small vans	4x4's	Large vans
79% (48) electric (small cars assumed to be undertaking less 60 miles/day on average, which have been substituted with EVs) 21% (13) petrol-hybrids (remaining vehicles) 61 vehicles in scenario 505,263 total annual mileage covered 8,282 average annual mileage per vehicle 41 miles daily average mileage	92% (110) electric (medium cars assumed to be undertaking less than 60 miles/day on average, which have been substituted with EVs) 8% (10) petrol-hybrids (remaining vehicles) 120 vehicles in scenario 834,120 total annual mileage covered 6,951 average mileage per vehicle 35 miles daily average mileage	71% (166) electric (small vans assumed to be undertaking less than 60 miles/day on average, which have been substituted with EVs) 9% (22) biodiesel B25 (based on suitable locations – see scenario 3) 20% (47) diesel (remaining vehicles) 235 vehicles in scenario 2,177,745 total annual mileage covered 9,267 average mileage per vehicle 46 miles daily average mileage	5% (6) plug-in hybrids (based on assumption that six 4x4s can be replaced with lower off-road capability 4x4 PHEVs) 43% (55) biodiesel B25 (based on suitable locations) 52% (89) diesel (remaining vehicles) 128 vehicles in scenario 1,378,772 total annual mileage covered 10,780 average mileage per vehicle 54 miles daily average mileage	33% (11) switched to using biodiesel B25 (based on suitable locations – see scenario 3) 67% (22) diesel (remaining vehicles) 33 vehicles in scenario 331,056 total annual mileage covered 10,032 average mileage per vehicle 50 miles daily average mileage

For the electric vehicles, it should be noted that higher driving ranges (beyond the 60 miles referenced above) could be achieved through purchasing models with higher ranges, or through utilising charging infrastructure on journeys to recharge to achieve a greater overall journey distance. This could further reduce the requirement for vehicles (with larger batteries) suitable for longer journeys. The results for Scenario 1 are presented below as stack graphs in Figure 9 and Figure 8 (CO_2 savings) and Figure 10 (cost savings). The 'Baseline' columns represent the current fleet emissions and TCO respectively and the 'Scenario' columns represent the Scenario 1 resultant emissions and TCO respectively.

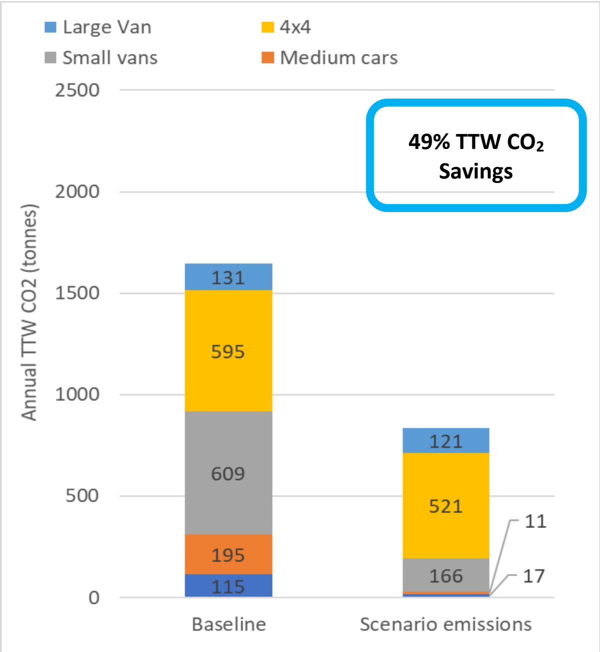


Figure 9 – Scenario 1 TTW CO_2 Savings. Example: '595' on the yellow bar represents 595 tonnes of TTW CO2 from 4x4s in the Baseline condition.

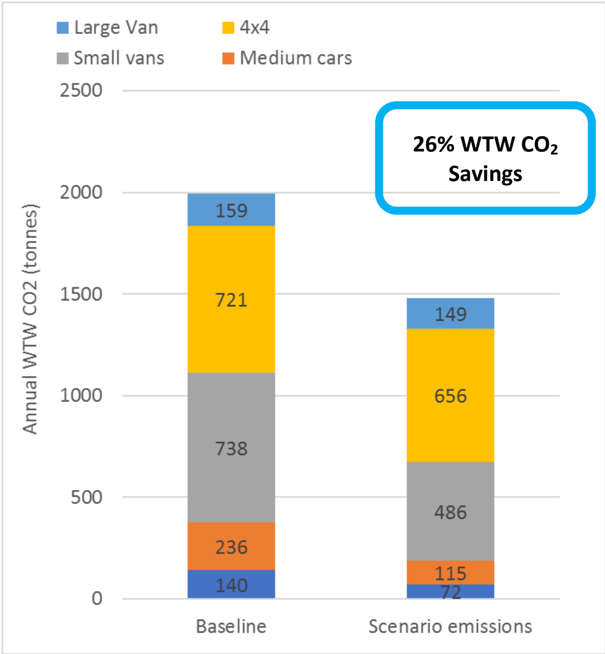


Figure 8 – Scenario 1 WTW CO_2 Savings. Example: '721' on the yellow bar represents 721 tonnes of WTW CO2 from 4x4s in the Baseline condition.

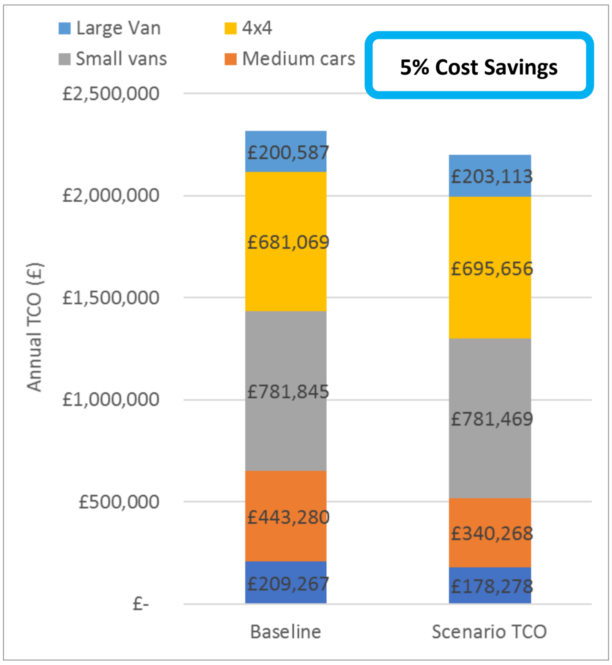


Figure 10 – Scenario 1 TCO Savings. Example: '£681,069' on the yellow bar represents an annual TCO of £681,069 from 4x4s in the Baseline condition.

The tables below show the annual savings available from implementing Scenario 1. Table 21 shows the annual savings per vehicle type and Table 22 showes the annual savings by technology type. Note that a negative cost value represents a cost/emissions increase.

Each row of these tables compares the emission and cost savings of each type of vehicle or technology against the fleet baseline and their respective contribution to the fleet emission and cost savings as part of this scenario.

For example, the small cars row in table 21 considers changing 61 fleet vehicles to lower emission alternatives (as outlined in the table on p.53). The changes to the small cars result in emission savings of 68t WTW CO_2 (48%) and 99 t TTW CO_2 (85%) and costs savings of £31,000 (15%) against the baseline for small cars in the fleet (i.e. compared to the emissions and costs of the current NRW fleet of small cars).

There are two further columns on the tables (light blue), which show the changes as a proportion of the Scenario 1 emission and cost savings. Using the small car example again, the proportion of Scenario 1 savings from changing the 61 small vehicles contributes 13% of the WTW CO_2, 12% of the TTW CO_2 saving and 26% of the TCO saving seen in Scenario 1 respectively.

Vehicle Type	Emission savings /annum of CO_2 possible within specific vehicle type against the baseline fleet emissions		Percentage contribution to scenario 1 fleet CO_2 savings from vehicle type	TCO savings /annum possible within specific vehicle type against the baseline fleet costs		Percentage contribution to scenario 1 fleet TCO savings from vehicle type
	WTW CO_2 (TTW CO_2 in brackets)					
	tonnes	%	%	£	%	%
Small cars	68 (99)	48% (85%)	13% (12%)	£31,000	15%	26%
Medium cars	121 (183)	51% (94%)	24% (23%)	£103,000	23%	88%
Small vans	252 (443)	34% (73%)	49% (55%)	£500	0%	0%
4x4s	65 (74)	9% (12%)	13% (9%)	£-15,000	-2%	-12%
Large vans	10 (10)	6% (8%)	2% (1%)	£-2,500	-1%	-2%
Total Savings	**516 (809) CO_2 emissions saving on baseline**	**26% (49%) emissions saving on baseline**	**100% (of the 26% (49%) emissions saving under Scenario 1)**	**£117,000 cost saving on baseline**	**5% cost saving on baseline**	**100% (of the 5% cost saving under Scenario 1)**

Table 21 – Scenario 1 savings per vehicle type

Technology Type	Emission savings /annum of CO_2 possible within specific technology type against the baseline fleet emissions		Percentage contribution to Scenario 1 fleet CO_2 savings from technology type	TCO savings /annum possible within specific technology type against the baseline fleet costs		Percentage contribution to Scenario 1 fleet TCO savings from technology type
	WTW CO_2 (TTW CO_2 in brackets)					
	tonnes	%	%	£	%	
Electric	413 (700)	49% (100%)	80% (86%)	£136,000	12%	116%
Plug-in hybrid	10 (15)	42% (79%)	2% (2%)	£-2,000	-8%	-2%
Petrol hybrid	15 (13)	31% (31%)	3% (2%)	£2,000	3%	2%
Biodiesel (B25)	78 (81)	18% (23%)	15% (10%)	£-19,000	-4%	-16%
Total Savings	**516 (809) CO_2 emissions saving on baseline**	**26% (49%) emissions saving on baseline**	**100% (of the 26% (49%) emissions saving under Scenario 1)**	**£117,000 cost saving on baseline**	**5% cost saving on baseline**	**100% (of the 5% cost saving under Scenario 1)**

Table 22 – Scenario 1 savings by technology type

It should be noted that with a significant annual WTW CO_2 reduction, a small cost saving is also achievable. As shown, the significant savings available from the implementation of pure electric cars could subsidise the higher costs associated with biodiesel and PHEV use.

If biodiesel is not included in the scenario the annual WTW CO_2 savings reduce to 438 tonnes CO_2e (22%), the annual TTW CO_2 savings reduce to 728 tonnes CO_2e (44%) and the annual cost saving increases by 16% to £136,000 (6%).

13.2 Scenario 2 – Alternative Vehicle & Efficiency Improvement

For this scenario, a more cost effective focused transition to low emission vehicles is considered. A total of 100 vehicles are removed from fleet, the majority of which represent large vehicle reductions from areas where low emission vehicle options are limited (large vans and 4x4s). This approach was taken to show a best-case emission reduction from vehicle removal as the large vans and 4x4s are also the most emitting vehicles (in terms of gCO_2/km) as well as having limited low emission options available. Furthermore, telemetry was also applied across the vehicle types.

For this analysis, a total of 477 vehicles were included in Scenario 2 which comprises 63% (301) EVs, 1% (6) PHEVs, 5% (23) petrol hybrids, 17% (79) biodiesel and 14% (68) diesel vehicles. The breakdown per vehicle type is given in the table below.

Small cars	Medium cars	Small vans	4x4's	Large vans
8% (5) of small cars removed 77% (43) electric (small cars assumed to be undertaking less 60 miles/day on average, which have been substituted with EVs) 23% (13) petrol-hybrids (remaining vehicles) 56 vehicles in scenario 505,263 total annual mileage covered Vehicle annual mileage has increased (8%) from 8,283 to 9,023 in this scenario due to the reduction in vehicle numbers 45 miles daily average mileage	4% (5) of medium cars removed 91% (105) electric (medium cars assumed to be undertaking less than 60 miles/day on average, which have been substituted with EVs) 9% (10) petrol-hybrids (remaining vehicles) 115 vehicles in scenario 834,120 total annual mileage covered Vehicle annual mileage has increased (4%) from 6,951 to 7,253 in this scenario due to the reduction in vehicle numbers 36 miles daily average mileage	9% (20) of small vans removed 71% (153) electric (small vans assumed to be undertaking less than 60 miles/day on average, which have been substituted with EVs) 10% (22) biodiesel B25 (based on suitable locations) 19% (40) diesel (remaining vehicles) 215 vehicles in scenario 2,177,745 total annual mileage covered Vehicle annual mileage has increased (9%) from 9,267 to 10,129 in this scenario. 51 miles daily average mileage	39% (50) of 4x4's removed 9% (7) plug-in hybrids (based on assumption that seven 4x4s can be replaced with lower off-road capability PHEVs) 63% (49) biodiesel B25 (based on suitable locations) 28% (22) diesel (remaining vehicles) 78 vehicles in scenario 1,378,772 total annual mileage covered Vehicle annual mileage has increased 39% from 10,779 to 17,690 in this scenario 88 miles daily average mileage	60% (20) of large vans removed 54% (7) biodiesel B25 (based on suitable locations) 46% (6) diesel (remaining vehicles) 11 vehicles in scenario 331,056 total annual mileage covered Vehicle annual mileage has increased 61% from 10,032 to 25,466 in this scenario 127 miles daily average mileage
For this scenario, the annual mileage of those vehicles removed were applied across the remaining vehicles in the vehicle type, thus increasing utilisation of remaining vehicles. 15% savings from telemetry introduction were then applied to the CO_2 and fuel costs, to represent more efficient driving. In reality the 15% emission savings associated with telemetry will be a blend of fuel-efficient driving and some mileage reduction. The cost model also includes an increase in maintenance and lease costs associated with greater annual mileages on remaining vehicles.				

This analysis should be thought of as a high-level indication of a large vehicle reduction strategy. It assumes that vehicle reductions will not result in a change of vehicle type use, whereas in reality, tasks undertaken by 4x4 and large vans are may be transferred to other vehicle types. This could increase the utilisation of other vehicle types, in some cases with a positive outcome. For example, a small van may be used instead of a 4x4 due to reduced 4x4s in the fleet, resulting in further reductions of emissions and costs.

The scenario results are presented below as stack graphs in Figure 13 and Figure 12 (CO_2 savings) and Figure 11 (cost savings). The 'Baseline' columns represent the current fleet emissions and TCO respectively and the 'Scenario' columns represent the Scenario 2 resultant emissions and TCO respectively.

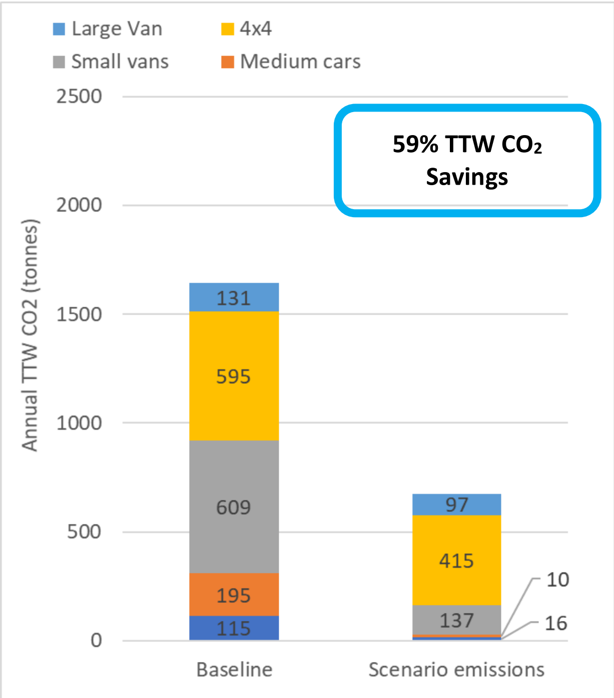


Figure 13 – Scenario 2 TTW CO_2 Savings. Example: '595' on the yellow bar represents 595 tonnes of TTW CO2 from 4x4s in the Baseline condition.

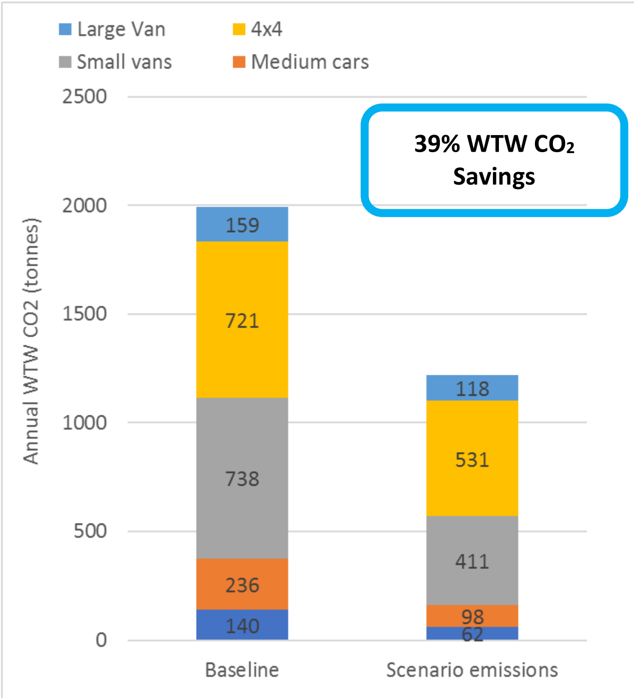


Figure 12 – Scenario 2 WTW CO_2 Savings. Example: '721' on the yellow bar represents 721 tonnes of WTW CO2 from 4x4s in the Baseline condition.

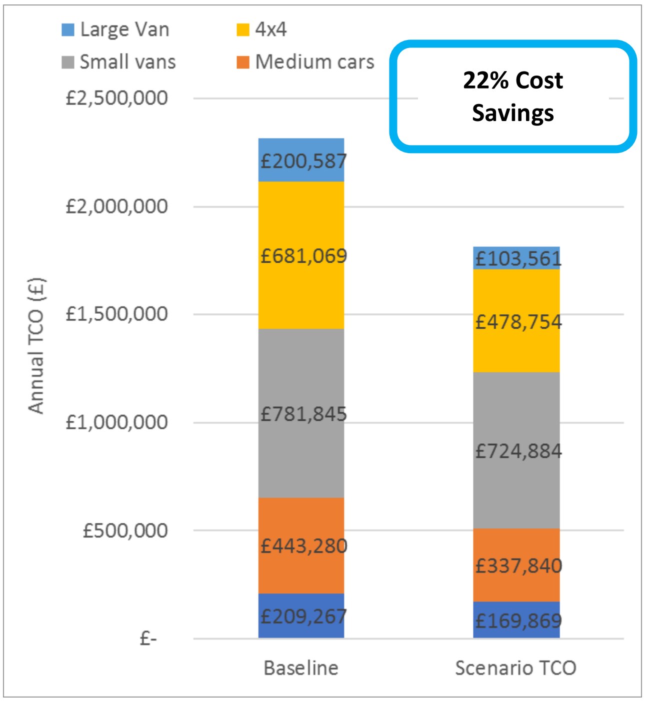


Figure 11 - Scenario 2 TCO Savings. Example: '£681,069' on the yellow bar represents '£681,069' annual cost of from the 4x4s in the Baseline condition.

The tables below show the annual savings available from implementing Scenario 2. Table 23 shows the savings per vehicle type and Table 24 shows the annual savings by technology type.

Each row of these tables compares the emission and cost savings of each type of vehicle or technology against the fleet baseline and their respective contribution to the fleet emission and cost savings as part of this scenario.

For example, the small cars row in Table 23 considers where the original fleet of 61 small cars is replaced with low emission alternatives as well as removing 5 small cars from the fleet (leaving 56 small cars, as outlined in the table on p. 57). The changes to the small cars result in emission savings of 78t WTW CO_2 (56%) and 100 t TTW CO_2 (86%) and cost savings of £39,000 (19%) against the baseline for small cars in the fleet (i.e. compared to the emissions and costs of the current NRW fleet of small cars).

There are two further columns on the tables (light blue), which show the changes as a proportion of the Scenario 2 emission and cost savings. Using the small car example again, the proportion of Scenario 2 savings from changing the 61 small cars contributes 10% of the WTW CO_2, 10% of the TTW CO_2 savings and 8% of the TCO saving seen in Scenario 2 respectively.

Vehicle Type (including vehicle reduction, low emission vehicle uptake and telemetry)	Emission savings /annum of CO_2 possible within specific vehicle type against the fleet baseline emissions		Percentage contribution to Scenario 2 fleet CO_2 savings from vehicle type	TCO savings /annum possible within specific vehicle type against the fleet baseline costs		Percentage contribution to Scenario 2 fleet TCO savings from vehicle type
	WTW CO_2 (TTW CO_2 in brackets)					
	tonnes	%	%	£	%	%
Small cars	78 (100)	56% (86%)	10% (10%)	£39,000	19%	8%
Medium cars	138 (184)	59% (95%)	18% (19%)	£106,000	24%	22%
Small vans	327 (472)	44% (78%)	42% (49%)	£57,000	7%	11%
4x4s	190 (180)	26% (30%)	25% (19%)	£202,000	30%	40%
Large vans	37 (34)	23% (26%)	5% (3%)	£96,000	48%	19%
Total Savings	**771 (920) CO_2 emissions saving on baseline**	**39% (59%) emissions saving on baseline**	**100% (of the 39% (59%) emissions saving under Scenario 2)**	**£500,000 cost saving on baseline**	**22% cost saving on baseline**	**100% (of the 22% cost saving under Scenario 2)**

Table 23 - Scenario 2 savings per vehicle type. Savings include vehicle reduction, low emission vehicle uptake and telemetry

Intervention element	Emission savings /annum of CO_2 possible from intervention element against the baseline fleet emissions		Percentage contribution to Scenario 2 fleet CO_2 savings from vehicle type	TCO savings /annum possible from intervention element against the baseline fleet costs		Percentage contribution to Scenario 2 fleet TCO savings from vehicle type
	WTW CO_2 (TTW CO_2 in brackets)					
	tonnes	%	%	tonnes	%	%
Vehicle reduction only	0[16] (0)	0% (0%)	0% (0%)	£324,000	14%	65%
Low emission vehicles[17]	555 (851)	28% (52%)	72% (88%)	£121,000	5%	24%
Telemetry	216 (119)	11% (7%)	29% (12%)	£55,000	3%	11%
Total Savings	**771 (920) CO_2 emissions saving on baseline**	**39% (59%) emissions saving on baseline**	**100% (of the 39% (59%) emissions saving under Scenario 2)**	**£500,000 cost saving on baseline**	**22% cost saving on baseline**	**100% (of the 22% cost saving under Scenario 2)**

Table 24 – Breakdown of savings associated with each Scenario 2 intervention

The reduction in cost in this scenario is mainly associated with vehicle reduction which makes up 65% the total cost savings. With the shift to low emission vehicles resulting in a 24%, and the telemetry 3% of the overall cost savings. No emission savings are attributed to the vehicle reduction programme as the annual mileage has remained constant. This scenario results in a 39% WTW (59% TTW) CO_2 saving on baseline. Although the low emission vehicles only account for 24% of the total cost savings, they account for 88% of the total emission saving.

If biodiesel is not included in the scenario the annual WTW CO_2 savings reduce to 674 tonnes WTW CO_2 (33% on baseline). The TTW CO_2 savings reduce to 867 tonnes CO_2e (52% on baseline). The annual fleet cost savings increase to £508,000 (22%) on the baseline scenario.

13.3 Scenario 3 – Biodiesel Based Assessment

For this scenario, a more detailed assessment of biodiesel introduction was carried out. In the assessment, all vehicles that were not part of the major depots and were also suitable for EV or hybrid conversion were removed and the remaining vehicles were switched to a B25 biodiesel variant where

[16] There is no carbon saving as annual mileage is assumed to remain constant and the mileage from the vehicles disposed of are assumed to have been transferred on to remaining vehicles.

[17] As detailed in table 23.

available. When creating this scenario, two biodiesels suppliers, Olleco and Regenesis, were consulted. Both could supply biodiesel from 'Used Cooking Oil' (for maximum WTW emission savings) and biodiesel from virgin oils if required[18]. There were 2 key findings from these discussions:

1. High volumes of fuel use are required for economic delivery – this poses a challenge for biodiesel use as the current NRW fleet is split across a large geographical area, i.e. using lower amounts of fuel across several locations.
2. The minimum on-site delivery would be 10,000 litres. Biodiesel is organic and has a shelf life, and would, therefore, require using within 3 – 4 months. This means only sites with the capacity of 30,000 – 40,000 litres per annum are appropriate.

The cost analysis includes the one-off purchase of a biodiesel tank (£5000 with a life of ten years), annual tank cleaning (£750 per annum) and the additional cost of biodiesel servicing (doubling of the oil change frequency costing £80 per annum).

This scenario was used as the basis for the biodiesel use seen in scenarios 1 and 2.

The scenario results are presented below as stack graphs in Figure 15 and Figure 14 (CO_2 savings) and Figure 16 (cost savings) below.

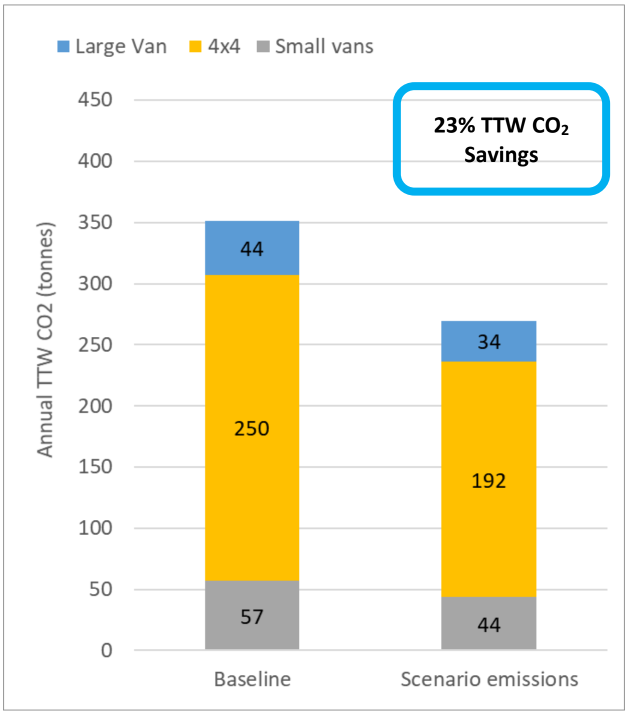


Figure 15 - Bio Depots TTW CO2 Savings – bio depots is the scenario 3 results. Example: '250' on the yellow bar represents 250 tonnes of TTW CO2 from 4x4s in the scenario.

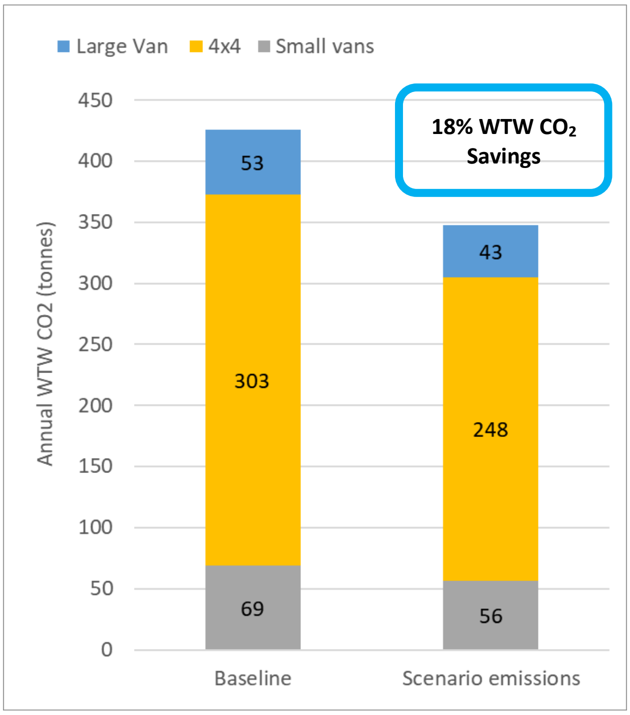


Figure 14 - Bio Depots WTW CO2 Savings – bio depots is the scenario 3 results. Example: '310' on the yellow bar represents 310 tonnes of WTW CO2 from 4x4s in the scenario.

[18] Note, NRW has previously successfully operationally used biofuels derived from used cooking oil.

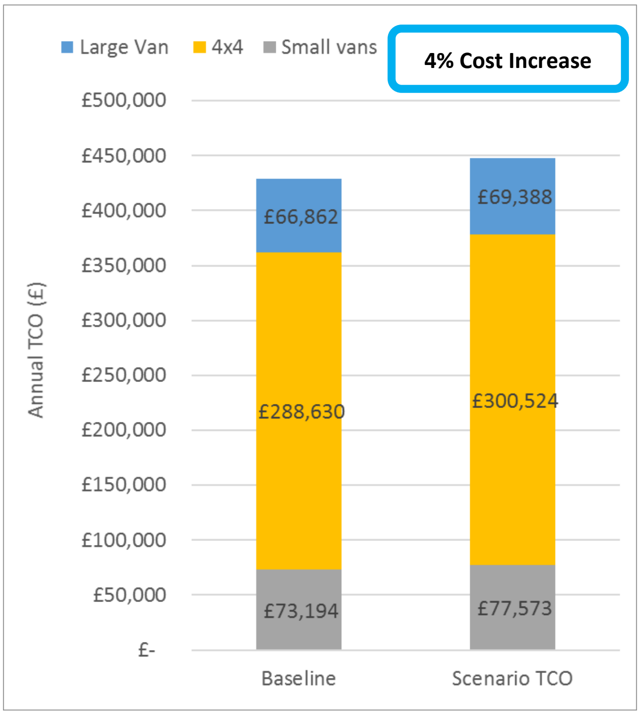


Figure 16 - Bio Depots TCO Savings – bio depots is the scenario 3 results. Example: '£288,630' on the yellow bar represents an annual TCO of £288,630 for 4x4s in the scenario.

In this scenario, we calculated the fuel use from each site where fleet vehicles were based. If the site had a fuel demand of over 20,000 litres per annum, we transferred to biodiesel on the assumptions that some NRW vehicles based in the area / passing the depot could also use the facility or external fleets may use the facility (bringing the demand up to a minimum of 30,000 litres per annum). It should be noted however that use of biodiesel from vehicles located at other depots has not been factored into this analysis and would require further feasibility work. We identified 6 sites with a refuelling demand of over 20,000 litres per annum – some already exceed the 30,000 litres fuel consumption required to be suitable for biodiesel. This excluded any vehicle based at the depots which are suitable for EV or hybrid conversion and the fuel demand remains above the required threshold. Results are shown in Table 25 and Table 26.

Note that the figures in these two tables exclude the vehicles which will be switched to low emission vehicles. Empty cells in the table below indicates that no suitable vehicles exist at the stated location.

Sites	Amount of fuel used by different vehicle types (litres)							Annual fuel consumption (litres)
	4x4			Small van (<2.5t)	Large van (>2.5)			
	4x4 van (litres)	Double cab pickup (litres)	Land Rover (litres)	Diesel panel van (litres)	Diesel panel van (litres)	Double cab (litres)	Tipper (litres)	
Plas Gwendraeth	678	23,905	4,744	5,236	3,264			**37,827**
Resolven		15,946	4,336	11,271		1,268		**32,821**
Monmouth	2,112	17,760		7,133				**27,005**
Llandovery		11,270	3,569	9,549	1,705			**26,093**
Cilfynydd Depot	2,070	11,295	2,372	1,631	3,817	2,276	1,397	**24,858**
Llandarcy	4,003	10,775		1,496	4,295			**20,569**
Total	8,863	90,951	15,021	36,316	13,081	3,544	1,397	**169,173**

Table 25 - Breakdown of Site Annual Fuel Consumption

Sites	4x4			Small van (<2.5t)	Large van (>2.5)			Number of Vehicles
	4x4 van	Double cab pickup	Land Rover	Diesel panel van	Diesel panel van	Double cab	Tipper	
Plas Gwendraeth	1	10	2	3	3			**19**
Resolven		6	2	7		1		**16**
Monmouth	2	6		4				**12**
Llandovery		5	1	6	1			**13**
Cilfynydd Depot	1	5	1	1	2	1	1	**12**
Llandarcy	3	10		1	2			**16**
Total	7	42	6	22	8	2	1	**88**

Table 26 - Breakdown of Site Fleet Using Biodiesel

The site with the largest demand is Plas Gwendraeth with around 38,000 litres per annum. This depot currently services 19 vehicles which are not suitable for EVs/hybrids and can also cross fill with further vehicles from other sites. For just the 88 vehicles considered, biodiesel uptake at this scale could save NRW 18% WTW CO_2 per annum (23% TTW), at an additional 4% TCO increase (an additional cost of around £20,000 per annum) when compared to not converting these 88 vehicles. When considered for its contribution to emissions savings across the entire fleet, implementing biodiesel across these sites (and 88 vehicles) resulted in an overall **4% emission saving** (against the baseline). It should be noted that at some sites, additional benefit could be derived from supporting NRW contractors to use biodiesel supplied via this infrastructure to reduce emissions associated with procurement (i.e. the embedded carbon associated with fuel use when buying in contractors' services).

Furthermore, there are 3 other main considerations to take forward when implementing biodiesel:

1. Not all vehicles are supported under warranty for the use of biodiesel. Cenex were also advised by a biodiesel supplier that blends above B20 – B30 (20 - 30% biodiesel) may cause issues with modern diesel with a diesel particulate filter (DPF). Consequently, this can invalidate manufacturer warranty – some biodiesel users only run biodiesel through vehicles once they are out of the manufacturer warranty, some operate at risk and others purchase only compliant vehicles[19].

2. Biodiesel refuelling is expected to remain similar in price to diesel. For low volume supply, though, there could be a delivery charge of up to 3 pence per litre. However, if the purchase of conventional diesel originally was from forecourts (which is more costly than bulk diesel), the price including delivery for biodiesel may be similar.

3. Maintaining fuel quality is the key to successful operation on biodiesel. Suppliers should be using biodiesel to **BS14214** with appropriate winterisation agents to ensure the fuel does not wax in low temperatures. Low blends, with the right additives and feedstocks, such as B20 – B30 are quite robust against winterisation and biodiesel manufactured from virgin oil is most robust against cold plug flow. **Biodiesels manufactured from used cooking oil offer the greatest CO_2 savings**.

[19] CCW, and subsequently NRW, successfully implemented biodiesel blends of up to 100% in its operational vehicles. Case study available on request.

14 Fleet Summary and Recommendations

The tables below summarise the WTW CO_2 and air quality emissions as well as the costs and practicability of implementing alternative technologies within the fleet. Note, green text in cost boxes represents a cost saving as outlined in the key below. Additionally, some boxes are left blank to display that for a technology type there are no available vehicles.

Key	> 10% CO2/AQ saving > 5% Total Cost of Ownership (TCO) saving	Similar emissions and cost saving	<-10% CO2/AQ saving <-5% TCO saving	Overall increase (+)/decrease (-) in TCO	Not available

Vehicle Classification	Electric															
	Battery Electric				Petrol Hybrid				Plug-in Hybrid (PHEV)				Range extended electric vehicle (REEV)			
	WTW CO2	AQ	TCO	Cost	WTW CO2	AQ	TCO	Cost	WTW CO2	AQ	TCO	Cost	WTW CO2	AQ	TCO	Cost
Small Car	53%	100%	19%	-£3.3k	31%	85%	-2%	+£0.3k					32%	93%	-12%	+£2.0k
Medium Car	53%	100%	25%	-£4.6k	31%	85%	8%	-£1.4k	30%	83%	-46%	+£8.5k				
Small Van (<2.5t)	46%	100%	0%	-£0.1k												
4x4					26%	85%	-2%	+£0.4k	43%	83%	-8%	-£2.1k				
Large Van (>2.5t)																

Table 27 - Electric Vehicle Alternatives for Fleet

Vehicle Classification	Gas								Liquid							
	LPG				CNG				Petrol				Biodiesel (B25)			
	WTW CO2	AQ	TCO	Cost	WTW CO2	AQ	TCO	Cost	WTW CO2	AQ	TCO	Cost	WTW CO2	AQ	TCO	Cost
Small Car									-12%	85%	1%	-£0.1k	18%	0%	-3%	+£0.5k
Medium Car	1%	85%	-7%	+£1.3k					-12%	85%	-1%	+£0.1k	18%	0%	-3%	+£0.5k
Small Van (<2.5t)									12%	85%	-22%	+£3.7k	18%	0%	-3%	+£0.6k
4x4									1%	85%	24%	-£6.0k	18%	0%	-2%	+£0.6k
Large Van (>2.5t)					3%	50%	-37%	+£12k					18%	0%	-2%	+£0.8k

Table 28 - Gas & Liquid Alternatives for Fleet

14.1 Fleet Fit Overview

The tables below summarise the overall viability of implementing alternative technologies. This considers both emission savings and probability of economic operation. Note, green represents a savings as outlined in the key below. Additionally, some boxes are left blank to display that for a technology type there are no available vehicles.

Key	Good fleet fit, emissions, and economic operation likely	Fits some fleet segments, economic operation under certain conditions	High risk or uneconomical or no emission savings	Not available

Operational Factor	Small Car	Medium Car	Small Van	4x4	Large Van
Electric	Good fleet fit for low mileage and high use over repeatable drive cycles at a TCO saving (due to range restrictions)		Ideal fleet fit with adequate payload sizes over low mileage and high use at a breakeven TCO.		
Petrol-Hybrid	No operational restrictions with good vehicle maturity. Economic operation available at a similar TCO.	No operational restrictions with good vehicle maturity. Economic operation available with significant TCO saving.		Very limited model compatibility. Operational restrictions (not rugged 4x4) with good vehicle maturity. Economic operation available when compared to Diesel 4x4.	
PHEV/REEV	No operational restrictions with good vehicle maturity and emission savings. However, unsuitable compared to conventional diesel fleet vehicle due to greater operational cost.			Very limited model compatibility. Operational restrictions (not rugged 4x4) with good vehicle maturity. Economic operation available when compared to Diesel 4x4.	
Gas	Marginal CO_2 performance at greater costs.				No infrastructure available. Marginal Environmental savings available at much greater costs.
Petrol	No operational restrictions with great vehicle maturity. Similar TCO to diesel but worse CO_2 performance savings.		No operational restrictions with good vehicle maturity. However, comes at a greater operational cost.	Engine downsized with petrol. Operational restrictions (not rugged 4x4), with good vehicle maturity. Economic operation available at better TCO to diesel with marginal environmental savings.	
Biodiesel	CO_2 benefits available at slightly increased cost and additional fuel and fleet management required. No AQ benefit. Biodiesel compatibility is make/model specific, and the economic installation of infrastructure and fuel delivery requires reasonable (30,000 – 40,000 litres) site biodiesel demand annually. Vehicle compatibility and a disparate fleet will limit economic and practical uptake of biodiesel blends in fleet vehicles.				

Table 29 - Operational Attributes for Alternative Technology Fit within Fleet

14.2 Discussion of Results and Recommendations

A high-level results summary and recommended actions are presented below.

Cars

EVs are a good operational fit in the car fleet, saving around 50% WTW (100% TTW) CO_2 at a lower TCO (cost saving). EVs should be implemented where practical and with the appropriate charging infrastructure. Petrol hybrids can offer improvements in CO_2 at a similar or lower TCO where an EV is not a practical solution (i.e. where longer journeys are required or charging infrastructure cannot be accommodated). With regards to the pool fleet, an analysis of pool fleet car usage showed that 43% of daily trips are less than 50 miles, and 65% are less than 100 miles - this indicates that a significant proportion of office based pool vehicles are suitable for transition to EVs.

Charging Infrastructure:

- Charging at 13amps not a long-term solution
- Appropriate infrastructure for charging needs to be in place prior to purchasing/integrating EVs
- Electrical capacity at sites should be investigated to ensure suitability for installing charging infrastructure and any future implementation of electric vehicles.
- Groundwork requirements must be considered
- Consideration on payment platforms and back office system requirements (e.g. 3G requirements, data requirements etc.) are essential and may require buy in from senior management.

Recommended Next Steps:

- Review individual vehicle mileages, preferably through the installation of telemetry systems
- Develop an EV replacement strategy supported and informed by trialling of EVs
- Investigate site power capacity/requirements to develop a strategy to install required charging infrastructure ahead of expansion of EVs
- Analyse current performance data of 3 Nissan Leafs introduced into the fleet in May 2017
- Trial petrol hybrids to confirm desk-top study results. Following a successful trial, petrol hybrids should be implemented in the car fleet where EVs are not practical due to range and charging limitations.

Small Vans

EVs are a good operational fit to the small van fleet, saving 50% WTW (100% TTW) CO_2 at a similar or better TCO. EVs should be implemented where practical.

Recommended Next Steps:

- Review individual vehicle mileages, preferably through the installation of telemetry systems, and develop an EV replacement strategy supported and informed by trialling of EVs, investigate site power requirements.

4x4

Reducing carbon from the 4x4s is challenging due to very poor availability of low emission alternatives in this segment. A less robust 4x4 drive system is offered through modern AWD vehicles, this may be suitable for some 4x4 applications, where this is the case lower spec diesels, petrols, and PHEVs all offer emission and TCO benefit.

Recommended Next Steps:

- Review fleet to assess where down-grading options are available. Consider biodiesel use (see biodiesel Scenario 3 summary note below).

Large Vans

Reducing carbon from the Large Vans is challenging, CNG and Electric options are available but significantly increase TCO.

Recommended Next Steps:

- Consider biodiesel use (see biodiesel Scenario 3 summary note below). Reassess this advice in 12-months as large EV van market matures.

Fleet Best Practice

In additional to changes in technology, this review also highlighted that down-sizing diesel cars can lead to TCO savings of £2000, and 87 kg WTW (70 kg TTW) CO_2 per vehicle per annum. Due to capital constraints, NRW lease most fleet vehicles. **Significant TCO savings could be available if vehicles are switch to an ownership model - TCO savings of up to £4000 per vehicle could be available**. This could assist in funding low emission vehicle implementation and infrastructure. Fleet telematics have ability to reduce fleet CO_2 by around 15%, whilst a simple payback calculation showed that telematics were only economically viable in higher mileage vehicles. For low mileage vehicles, the annual cost per vehicles (£40 - £50) is still a worthwhile investment to generate the robust evidence base (data and information) that telematics systems supply to inform future strategy. Furthermore, the cost analysis did not include costs associated with accident reduction and maintenance, which are difficult to quantify – case study evidence showed accident rates can drop by around 20 – 35%. If NRW progress to a high EV implementation scenario, telematics will be required to assess potential vehicles more accurately.

Implementation Scenarios:

To demonstrate the effect of the recommended technologies on WTW CO_2 emissions, three implementation scenarios were considered.

- **Scenario 1 – Alternative Vehicle Adoption -** A scenario focused on achieving the lowest CO_2 emissions through the implementation of all recommended technologies in the current vehicle fleet (where practical) based on a business as usual scenario (same number of fleet vehicles and annual mileage). A total of 577 vehicles were included in Scenario 1 which comprised of 56% (324) EVs, 1% (6) PHEVs, 4% (23) petrol hybrids, 15% (88) biodiesel and 24% (136) diesel vehicles. This scenario achieved a fleet **WTW CO_2 reduction of 26%, a TTW CO_2 reduction of 49% and resulted in a 5% overall TCO saving** (a saving of around £117,000).
- **Scenario 2 – Alternative Vehicle & Efficiency Improvement -** A scenario focused on a cost-effective transition to low emission vehicles was considered with a reduction in fleet size where a total of 100 vehicles were removed (based on NRW targets – where most reduction is in the 4x4 category), leaving 484 vehicles in the reduced fleet in the scenario. To clarify, this scenario did not include any downsizing for medium to small cars for the remaining vehicles in the fleet. The scenario assumed the same annual mileage and so resulted in an increase of the annual mileage of the other vehicles. This is due to higher utilisation of a smaller number of vehicles. Telemetry system uptake was also used in this analysis to give a 15% fuel saving in each vehicle. This scenario included a blend of EVs (301), petrol-hybrids (23), plug-in hybrids (6) and B25 biodiesel (79). Totalling 409 (85% of reduced fleet) low emission vehicles which achieved a fleet **WTW CO_2 reduction of 39%, a TTW CO_2 reduction of 59% and resulted in a 22% overall TCO saving** (a saving of around £500,000 per annum). Without the biodiesel option, where the

select vehicles remain diesel, a fleet **WTW CO2 reduction of 33%, a TTW CO_2 reduction of 52% and a similar overall TCO saving are available** (a saving of around £508,000 per annum).

- **Scenario 3 - Biodiesel Based Assessment -** A scenario looking in more detail at B25 depot biodiesel implementation was considered. Here, it was shown that two to six NRW sites potentially have sufficient demand to justify bunkered biodiesel storage. Across these sites a 4% increase in costs would be incurred when additional costs of storage tanks, tank cleaning, fuel inspections and vehicle maintenance were considered. Furthermore, NRW would need to consider varied manufacturer support and additional fuel management risks associated with biodiesel blends and increased fleet costs (e.g. associated with maintenance). Large mixed fleets that operate biodiesel successfully either i) use biodiesel through vehicles once they are out of the manufacturer warranty, ii) some operate at risk invalidating the engine warranty, and iii) others purchase only compliant and warranted vehicles (however this limits vehicle choice). Fleets which successfully operate with biodiesel require a dedicated proponent of the technology to overcome challenges and manage fuel quality. In conclusion, the overall uptake of 88 B25 biodiesel vehicles would allow these vehicles to achieve a WTW CO2 reduction of 18%, (23% for TTW) at an additional 4% TCO increase (at an additional cost of around £20,000 per annum) when compared to not converting these 88 vehicles. When compared to emissions of the entire fleet, implementing biodiesel across these sites resulted in **an overall 4% emission saving** (at an additional annual cost of around £20,000 across all 88 vehicles) when compared to not converting these vehicles.

14.3 Final Conclusions

The scenarios indicated that a significant proportion of the NRW fleet could become low emission. However, emission savings are currently limited by the high emitting vehicles (large vans and 4x4s), which have limited decarbonisation options.

Recommended Next Steps:

In order to pursue the carbon savings modelled/estimated within this report NRW should consider the following next steps:

- Reduce vehicle numbers in the fleet and install telematics on all vehicles.
- Vehicle number reductions increase the overall annual mileage of the fleet vehicles which assists the case for technology change.
- Develop a strategy for implementation of low emission technologies outlined in this study. This must include appropriate charging infrastructure for the number of vehicles proposed for introduction into the fleet, which must be installed prior to commitment to EVs.
- Telematics help to save fuel and also identify which vehicles are appropriate for electrification. It is recommended that a telematics technology trial is undertaken, especially in the 4x4 and large van categories where low carbon options are limited.
- Furthermore, there are technologies on the horizon which can assist in these areas and it is recommended opportunities should be re-assessed in around 12 months to consider the maturing supply of large panel van EVs, bioLPG availability, and a renewable diesel fuel, HVO (Hydro-treated vegetable oil), which can drop-in to forecourt diesel with no effect on manufacturers warranties or servicing regimes.

15 Plant Assessment

Cenex undertook the high-level plant review using the following methodology:

- **Fleet Baselining** - NRW plant items were segregated by type and their performance and operational patterns were benchmarked. Fuel use from plant vehicles were not available from NRW, therefore Cenex estimated plant fuel consumption and CO_2 emissions based on engine size and operating patterns.
- **Suitability Assessment -** The range of alternative technologies and fuels that have the potential to reduce carbon emissions were researched and identified. The low carbon options were considered in line with NRW operational characteristics to ensure any recommended technologies could fulfil the required roles and duties without compromising operational performance.
- **Cost and Emissions Analysis** – The suitability assessment included a high-level assessment of plant costs and emission reduction performance using information readily available from suppliers. Unlike the detailed fleet review, full TCO and performance models were not developed for plant options.
- **Scenario Planning** - Implementation scenarios of recommended technologies were built to allow NRW to assess their impact on overall fleet emissions.
- **Recommendations** - Cenex identified the most likely technologies which could offer NRW improved CO_2 performance at similar or better TCO which should be subject to a more detailed plant review before being considered for inclusion in the wider carbon reduction strategy for NRW being developed by the Carbon Positive Project.

16 Plant Baselining

The baselining process allows the usage, fuel consumption, emissions, and operating patterns to be understood before the low emission vehicle technology assessment takes place.

16.1 Types and Categorisation of Equipment

258 plant vehicles and attachments are reported on from across the NRW fleet. The items are shown in the chart below. The plant items are located across numerous locations, primarily at depots.

Depot/Location	Number of Plant Items
Rhuddlan Depot	27
Fingerpost Depot	22
Plas Gwendraeth	21
Tan Lan Depot	20
Pye Corner	18
Bryn Mwcog	16
Monmouth Office	16
Cilfynydd Depot	14
Pont Y Garth	14
Porthmadog	11
Bala	7
Welshpool Depot	7
Newport Wetlands	6
Coychurch	5
Mill Street	5
Penmaen	5
Dolgellau	4
Tregaron	4
Clawdd Newydd	3
Corwen	3
Llandovery	3
Marian Mawr	3
Resolven	3
Tal Y Bont on Usk	3
Hafod	2
Llys Afon	2
Non-Fixed	2
Stackpole	2
Abergavenny	1
Bodffordd	1
Coed Y Brenin	1
Crychan Workshop	1
Disposed Vehicles	1
Fenns Whixall	1

Itton	1
Maerdy Hatchery	1
Mawddach Hatchery	1
Radnor Deer Larder	1
Three Cocks Ind Est	1

Table 30 - Plant and Attachments by Location

Plant equipment were grouped into nine broad categories:

- All-terrain vehicles (ATV), quad, bike.
- Chipper.
- Digger/Dumper.
- Forklift.
- Mower.
- Other.
- Pump.
- Tractor.
- Plant Attachment.

Other than the generic advice given later in section 18.11, plant attachments have been excluded from this study, as their energy is provided by the vehicles (usually tractors) they are attached to. This means there are 147 self-powered vehicles, or towed devices with built-in engines, identified in the NRW plant fleet. Figure 17 shows a breakdown of plant equipment by type (excluding plant attachments).

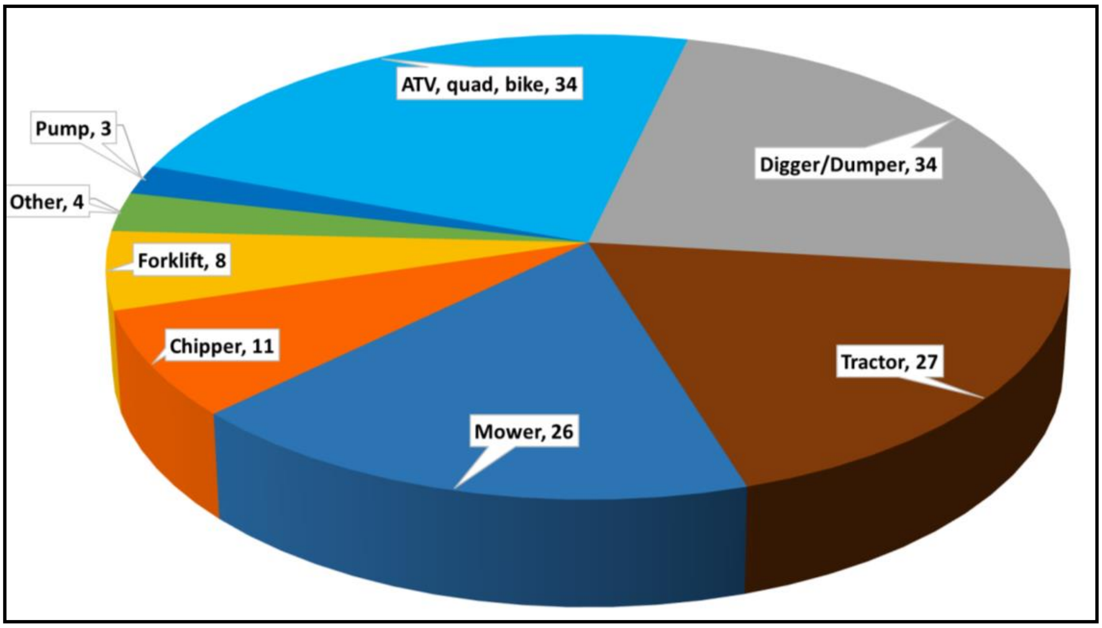


Figure 17 - Count of Powered Plant by Type

16.2 Operational Hours

Figure 18 shows the operational hours by engine size per year. The axis in Figure 18 labelled 'Annual hours of operation' indicates the sum of yearly hour of operation in that category of vehicle and engine size, based on the usage data provided by NRW.

Operational time of these devices varies by type and location. Some are in-storage and reserved for emergency response only, resulting in low operational times for those vehicles, whilst others are in daily operation all year round. A third category is seasonal work, where the plant will be in daily operation for several months of the year. The total annual hours have been calculated appropriately for each vehicle, using the values provided to Cenex by NRW. It is clear to see in Figure 18 that five major categories dominate the total hours of operational use per year.

1) 0.2 to 1.2 litres ATV, Quad, and Bike.
2) 1.2 to 2.2 litres Chipper.
3) 2.2 l to 3.2 litres Dumper and Digger (there are a small number of 4.2 Litre. to 6.2 Litre dumpers/diggers that are likely to have a disproportionate impact on total plant fleet emissions).
4) 0.2 to 3.2 litres Mowers (highly seasonal).
5) 4.5 to 8.2 litres Tractors (highly seasonal).

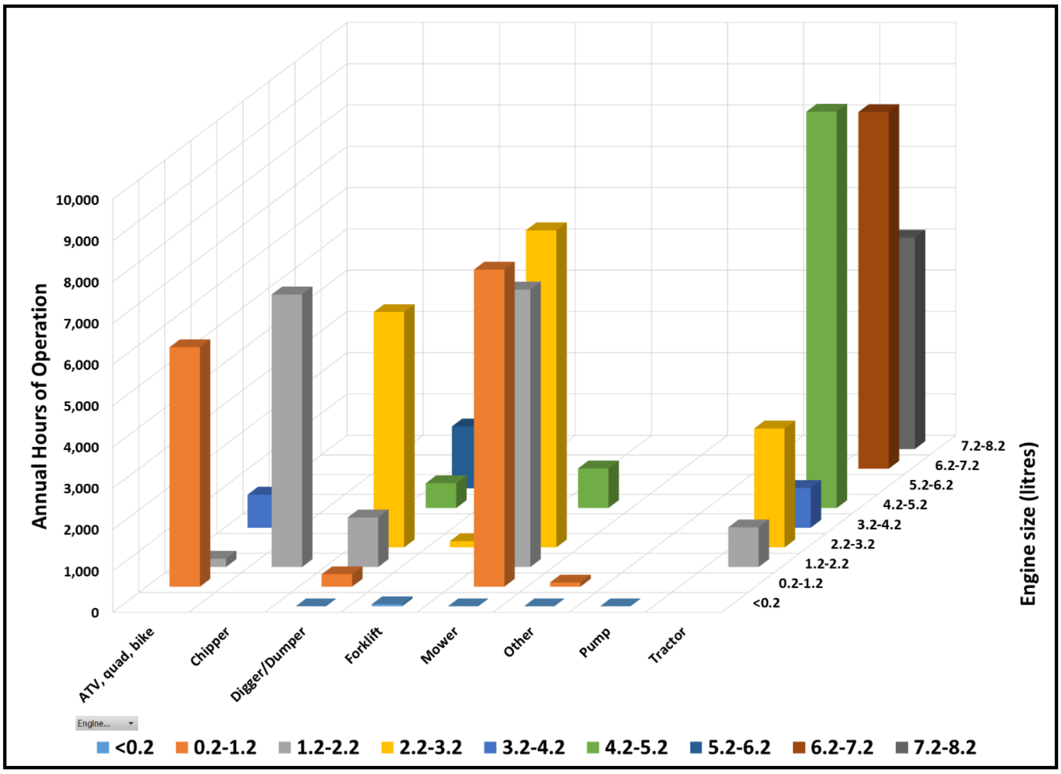


Figure 18 - Annual Hours of Operation by Type and Engine Size

The graph above shows that tractors have high utilisation and use large engines which are likely to have a large fuel consumption and relatively high emissions. The ATV, quad and bike, Mower and Digger / Dumper categories show high utilisation of smaller engine sized units. The Tractor category shows high usage of large engine sized plant, this in turn means the Tractor category will be the most significant emitter of pollutants. The remaining categories have minimal usage and emission (in comparison to the rest of the NRW plant fleet).

16.3 Estimated Fuel Consumption and Emissions

For plant where fuel type was provided, the vast majority run on diesel, as can be seen in Figure 19, there is also one LPG forklift operating at Resolven. Plant fuel consumption data was not available. Therefore, fuel consumption was estimated based on the reported operational hours and engine size of the equipment. **Please note, this provides indicative figures only.** Estimated fuel consumption and emissions are shown in Table 31 below.

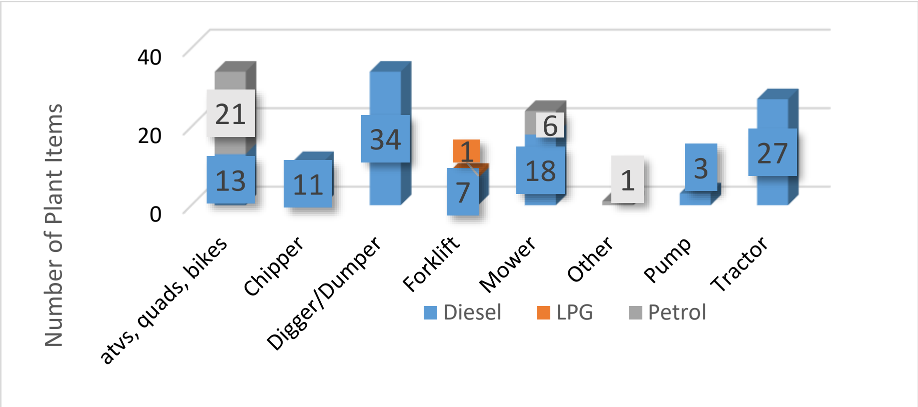


Figure 19 - Count of Plant Type by Fuel

Equipment	Number of units	Model Engine Size (frequency)	Sum of Hours of Use per Annum[20]	Estimated Annual Fuel Consumption (litres)	Tank to Wheel (TTW) CO_2 emissions (tonnes)	Well to Wheel (WTW) CO_2 emissions (tonnes)	% of Total Fuel and Emissions
Tractor	**27**	**4.5 Litre (9/27)**	**27,200**	**246,741**	**638**	**781**	**62%**
Mower	26	1.8 Litre (7/26)	24,000	71,878	186	227	18%
Digger/ Dumper	34	3.0 Litre (14/34)	9,300	49,324	127	156	12%
Chipper	11	1.8 Litre (11/11)	6,600	20,269	52	64	5%
ATV, quad, bike	34	450 cc (16/34)	6,800	10,787	28	34	3%
Forklift	8	2.5 Litre (2/8)	350	1,972	5	6	1%
Plant Attachments	111	NA[21]	NA[5]	NA[5]			
Other	7	400 cc (1/4)	NA	NA			
Total	**258**			**400,971**	**1,036**	**1,269**	**100%**

Table 31 - Estimated Annual Fuel Usage and Emissions

Based on estimated fuel use, the NRW plant consumes around 400,000 litres of fuel per annum, emitting 1,000 tonnes of TTW CO_2 and 1,300 tonnes of WTW CO_2. Tractors are the largest emitters, accounting for 62% of plant fuel consumption and emissions. Mowers and diggers/dumpers are also significant emitters.

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[20] Based on NRW estimates of plant usage (hours per day multiplied by days per year for each vehicle)

[21] Plant attachment fuel consumption/emissions are dominated by the plant it is attached to: see 'Tractor' entry for fuel consumption/emissions data.

17 UK and EU Non-Road Mobile Machinery Emission Requirements

This section provides an introduction to plant emission standards.

Plant emission standards for off road and agricultural plant equipment have traditionally lagged behind road transport in terms of emission reductions. However, that is changing. In part, this is due to legislative pressures to clean up all aspects of the modern society to reach key regional, national, and global emission targets.

NRMM regulations are an internationally standardised set of emission guidelines. The date when a piece of plant machinery was manufactured determines which stage of the standards a given item of machinery must comply with. At the time of writing Stage-IV (also called Tier-III or Tier-IV in reference to American legislation) is in effect [1][22]. The next set of emission standards (Stage-V) comes in to force in 2019/2020.

The majority of the NRW fleet is 10 years old or more, and as such it complies with Stage-III regulations on emission standards. The growing awareness of the impact of pollution in urban environments is driving companies, and organisation that commission work in urban environments, to specify Stage-IV, Stage-V and, in some cases, better than Stage-V emission standards for plant machinery used in the completion of the contracted work.

Figure 20 below shows the air quality emission reduction occurring between Stage I and Stage V emission regulations [2].

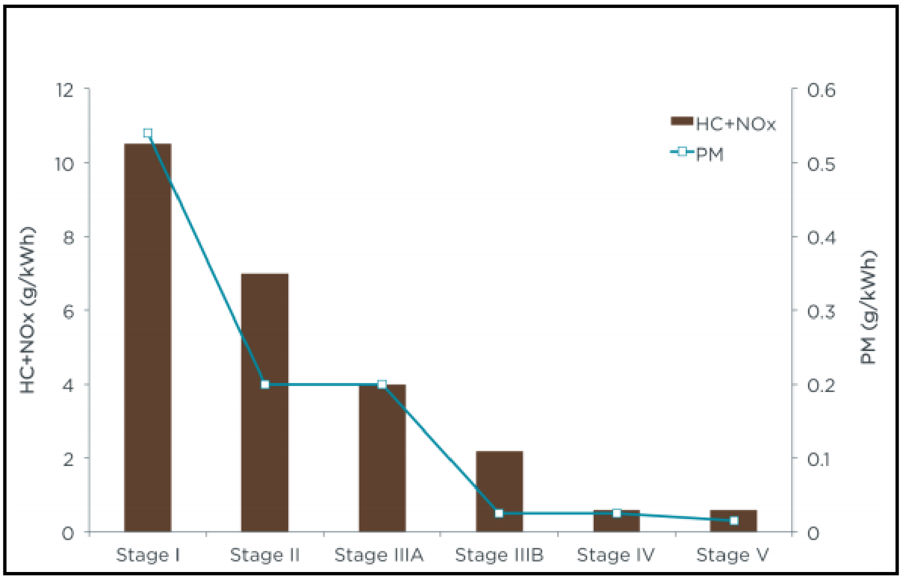

Figure 20 - NRMM HC, NOx and PM limits

The various stages are summarised as follows in Table 32, for clarification of the details of this table the interested reader is directed to the NRMM standards, which are available from both the European and UK government. [1]

[22] See reference list at the end of the document for references.

Stage III

Cat.	Net Power kW	Date†	CO g/kWh	HC	HC+NOx	NOx	PM
Stage III A							
H	130 ≤ P ≤ 560	2006.01	3.5	-	4	-	0.2
I	75 ≤ P < 130	2007.01	5	-	4	-	0.3
J	37 ≤ P < 75	2008.01	5	-	4.7	-	0.4
K	19 ≤ P < 37	2007.01	5.5	-	7.5	-	0.6
Stage III B							
L	130 ≤ P ≤ 560	2011.01	3.5	0.19	-	2	0.025
M	75 ≤ P < 130	2012.01	5	0.19	-	3.3	0.025
N	56 ≤ P < 75	2012.01	5	0.19	-	3.3	0.025
P	37 ≤ P < 56	2013.01	5	-	4.7	-	0.025

† Dates for constant speed engines are: 2011.01 for categories H, I and K; 2012.01 for category J.

Stage IV

at.	Net Power kW	Date	CO g/kWh	HC	NOx	PM
Q	130 ≤ P ≤ 560	2014.01	3.5	0.19	0.4	0.025
R	56 ≤ P < 130	2014.1	5	0.19	0.4	0.025

Stage V

Category	Ign.	Net Power kW	Date	CO g/kWh	HC	NOx	PM	PN 1/kWh
NRE-v/c-1	CI	P < 8	2019	8	7.50a,c		0.40b	-
NRE-v/c-2	CI	8 ≤ P < 19	2019	6.6	7.50a,c		0.4	-
NRE-v/c-3	CI	19 ≤ P < 37	2019	5	4.70a,c		0.015	1×1012
NRE-v/c-4	CI	37 ≤ P < 56	2019	5	4.70a,c		0.015	1×1012
NRE-v/c-5	All	56 ≤ P < 130	2020	5	0.19c	0.4	0.015	1×1012
NRE-v/c-6	All	130 ≤ P ≤ 560	2019	3.5	0.19c	0.4	0.015	1×1012
NRE-v/c-7	All	P > 560	2019	3.5	0.19d	3.5	0.045	-

a HC+NOx
b 0.60 for hand-startable, air-cooled direct injection engines
c A = 1.10 for gas engines
d A = 6.00 for gas engines

Stage v static generator sets

Category	Ign.	Net Power kW	Date	CO g/kWh	HC	NOx	PM	PN 1/kWh
NRG-v/c-1	All	P > 560	2019	3.5	0.19a	0.67	0.035	-

a A = 6.00 for gas engines

Table 32 - NRMM standards

The latest Stage-IV and Stage-V engines offer increased fuel efficiency compared to Stage-III engines currently operated in the majority of the NRW plant fleet. The "eco blue eSCR" engines offered by New Holland, for example, report a 10% reduction in fuel costs compared to Stage-III compliant engines, while meeting Stage IV-B requirements for emissions. The latest Stage-V requirements are projected to reduce emission still further, and companies such as John Deere anticipate still further fuel savings. Deutze claims to have perfected Stage-V compliant powertrains and offer them for sale as of 2016. **All new NRMM purchases will have to be Stage-V compliant from 2019 or 2020 onwards depending on engine size (assuming the UK adheres to pre-existing EU legislative plans)**.

There is a growing concern in the construction and agricultural plant sector around emission requirements. It must be acknowledged that public awareness, and the ever-increasing stringency of environmental compliance when bidding for procurement and construction projects, is having an impact on the resale value of the older plant. Any anticipated residual value estimates for older plants should be re-visited if Stage-IV or Stage-V compliance becomes mandatory in the construction and agricultural sectors in the near future. NRW may decide to sell off Stage III and Stage IV plant earlier than planned as their resale value may decrease rapidly once Stage V legislation comes into effect.

This has three implications for NRW:

- Older machinery should be available on the second-hand market in the next few years at a reduced purchase price as Stage-V compliance in the construction and demolitions sector becomes increasingly compliant.
- The residual value of NRW's existing plant fleet should be re-assessed, as there is a possibility that the residual market value of non-Stage-V compliant equipment will fall rapidly over the next five years – though it is difficult to predict the extent of this.
- From 2019 onwards there should be a large array of equipment suppliers who can provide new Stage-V emission compliant plant for most, if not all of NRWs requirements. Such equipment will have significantly reduced emissions, and frequently offers significantly reduced fuel consumption rates.

Recommendation: Any diesel-powered equipment in the NRW fleet that is still powered with Stage-III diesel engines (or older) should either be replaced with modern Stage-IVB (or if possible Stage-V) at the earliest opportunity. There is an argument to be made that the entire NRW plant fleet should undergo a programme of modernisation and all vehicles replaced with Stage-V compliant equivalents as they become available in the 2019/2020 financial year.

18 Plant Type Assessment and Alternative Technologies

This section assesses the alternative technologies available for each of the plant categories.

Each category of plant was assessed regarding their suitability against the following fuels/powertrains[23]:

- **Biodiesel**
- **Diesel - Electric hybrid**
- **Electric**
- **Alternative fuel (HC)** – This is a range of hydro-carbon based fuels such as LPG and CNG.
- **Hydrogen**

The maturity of each fuel/powertrain technology is also assessed as shown in Table 33:

Maturity level	Meaning
1	Basic principles and concepts.
2	Experimental, laboratory-based, validation of concept.
3	Pre-production / Proof of concept prototype, field tested.
4	Production ready – demonstration project underway or completed, CE approval in hand.
5	Production ready, CE approved, operational experience, real world use data available.

Table 33 - Technology Maturity Level

The alternative technology sections for each class of vehicle will focus on **Maturity level five solutions**. Maturity level five represents market ready solutions that NRW can adopt today. A summary of lower maturity level technologies will be detailed where possible. Maturity level four should also be of interest to NRW. Typically, these are units that have yet to break into the UK market, but are close to doing so. Such vehicles may well be eligible to a degree of grant funding for demonstration trials that could help to mitigate costs. NRW are advised to monitor emerging technologies, and relevant funding opportunities on a yearly basis.

Lower maturity technologies should be considered as R&D projects. They are at least five years away from being an operational solution with unfavourable economics. NRW are ideally situated to operate as a demonstrator partner in R&D consortia, but it must be recognised that NRW will not recover all costs accrued when participating in R&D projects. However, participation as a demonstrator in such projects is a way to encourage and foster low emission plant technologies, and to help to steer research agenda in a direction that benefits NRW operational requirements in the long term.

Where prices are considered, as far as possible supplier list prices have been quoted. NRW staff have stated that cheaper quad bikes (for example) are available. However, this does not reflect the publicly available list price for such equipment. For the ease of comparison, no purchasing discounts have been included in publicly listed prices, as NRW would have to negotiate this with individual suppliers. In some cases suppliers would not provide a list price directly, and historic Capex purchasing information, provided by NRW, has been used instead. In the sections below, two tables are presented per plant category, the first provides a summary of current NRW plant equipment in each group followed by a

[23] Powertrain, the mechanism that transmits the drive from the engine of a vehicle to its axle

table summarising the alternatively fuelled plant options. Information on the current plant items were supplied by NRW.

18.1 Tractor

NRW's Operational Plant	
	
Resource Type: Tractors **Average cost:** £42,000 (NRW historic Capex)	
Annual Usage	27,200 hours a year, 1,000 hours per vehicle
Small, Medium, and Large engine categories and count of vehicles **Small:** 0.1-2.9 Litre (2), **Medium:** 3.0 to 5.9 Litre (13), **Large:** 6.0 to 9.0 Litre (12)	
No of vehicles	27
Typical operating pattern	8 hours a day, 120 days a year. Some vehicles are more heavily utilised than others and so will exceed the typical operating pattern.
Vehicle locations	Between one and three units at 16 separate locations (see Figure 21)
Additional notes	With a diverse selection of plant attachments available, these vehicles perform an extensive number of tasks and can be quickly adapted to perform in many scenarios. Fuel cost and emission savings can be made for both tractors, and their associated plant attachments, using efficient tractors and improved operational practices (i.e. operator fuel efficiency training as detailed in Chapter 0.)

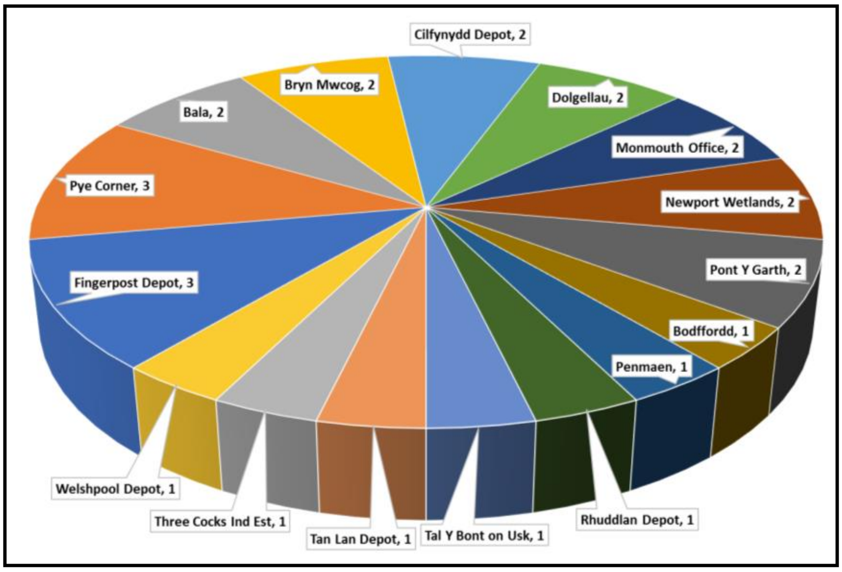

Figure 21: Tractor locations, NRW plant fleet

Alternative Technologies for Plant
Resource Type: Tractors
Maturity and practicality
Biodiesel: Maturity= 5 for Stage V emission engines
Operational restrictions and benefits
Biodiesel: None
Range
Biodiesel: Like for like replacement
Refuelling / recharging time
Biodiesel: Like for like replacement
Emission reduction
Biodiesel: Variable depending on blend (circa 18% WTW CO_2 reduction available from B25 blend). Engine design, fuel quality and operational cycles essential in assessing total emission with biodiesel – with some authors reporting increases in emitted NOx, particulates and CO [3].
Additional notes
• The newest ICE engines, operating to the latest emissions reduction standards, offer improvements in fuel consumption (and emissions) reduction. Changing to the latest generation of powertrains (by accelerating the scrappage rate of legacy vehicles) would have a positive impact on emission reduction. • Deutze offer Stage-V complaint powertrains which run on standard (EN590) diesel such as that available on UK forecourts. John Deere Stage-IV power trains can include particulate certification and monitoring (partial compliance to Stage-V emission regulations). • Tyre inflation – it has been demonstrated that operating conditions change year round, and that optimal tyre pressure for the type of soil being worked on, can result in significant fuel savings – up to 10% has been reported [4]. Correct tyre inflation can be performed at depot at the start of each day, or in the field using additional equipment. • It should also be kept in mind that a tractor's primary purpose is to provide power to implements where work is done. It has been shown, for ground engaging equipment, that correct positioning on the implement frame can reduce load requirements on the engine by up to 45%. Ensuring all staff are well trained on the correct fitting and use of tools can result in significant fuel savings [4].
Recommendations
Recommended: driver training programme and feasibility / pilot trial of biodiesel at Fingerpost, Pont-y-Garth and Rhuddlan depots. Replace older fleet with Stage-V compliant plant • Tractors are the largest emitters in the NRW plant fleet and it is recommended that fuel consumption of tractors is monitored and a fuel efficiency programme implemented. Section 19.6 has further details of the savings available and suggests fuel efficiency program items.

Future purchasing strategy:

Focus on the latest generation engines and built in tyre pressure optimisation.

NRW should consider their biodiesel policy and decide if they are willing to undertake the additional work required to achieve still further CO_2 reduction using biodiesel vehicles and infrastructure at suitable deports.

Biodiesel facilities can be extended to include several other items of plant, but the business case for the creation of biodiesel infrastructure and policies will be highly reliant on tractor operations, with excavators also being a contributing factor. Fingerpost, Pont-y-Garth and Rhuddlan depots should be assessed for the implementation of biodiesel (engine compatibility is critical). Success of biodiesel projects will be dependent on a depot based champion with the knowledge, skill, and authority to drive the changes.

Other alternative technologies – Tractors

Diesel - Electric Hybrid: Maturity level = 4: Diesel-electric Powertrain retrofit commercially available in the US, with a 25% reduction in fuel consumption and resultant emissions (manufacturers' claim). No such service is offered in the UK, with no indication of such a service ever being offered by the US company.

Alternative Fuel (HC): Maturity = 4: Valtra dual fuel CNG-Diesel, New Holland T6.180 methane fuelled Tractor. Both technologies appear to be based on existing HGV equivalent power trains. No independent data was found to verify cost or emission savings. New Holland are actively seeking demonstration partners for their Methane tractors. New Holland claim between 25-40% savings on fuel costs and Stage-IV emission compliance – it is not clear from the new Holland reported figures if this applies for any use of compressed natural gas, or if it only applies if locally generated biomethane is used.

Hydrogen: Maturity = 3: New Holland H_2 PEMFC. High power, long duration workloads are ideally suited to ICE diesel technology. There is little evidence of research into hydrogen-fuelled tractors, andthis project has been abandoned in favour of pursuing bio-methane based tractor units, largely over concerns of the hydrogen on board fuel storage and its compatibility with plant attachments.

18.2 Mower

NRW's Operational Plant	
 	
Resource Type: Mowers **Average cost:** £32,905 (NRW CapEx history: very wide variation between £8,800 to £75,000)	
Annual Usage	24,000 hours of operation, 960 hours of operation per vehicle
Small, Medium, and Large engine categories and count of vehicles **Small:** 0.1 – 1.9 litres (15), **Medium:** 2.0 – 3.9 litres (8), **Large:** 4.0 – 6.0 litres (1)	
No of vehicles	26 units in total (includes one for disposal, one not detailed)
Typical operating pattern	8 hours a day, 120 days a year
Vehicle locations	Between one and five units at 15 separate locations
Additional notes	Approximately 15 plant attachments identified that can also act as mowing devices.

Alternative Technologies for Plant

Resource Type: Mowers

Average cost: MeanGreenMowers list price = £8,500 to 19,995

Maturity and practicality

Diesel: Stage IV emissions regulations engines Maturity = 5 (John Deere claim compliance with end of Stage IV & Stage V emission regulations)

Biodiesel: Maturity = 5 (B30 Biodiesel compatible vehicle from Etesia)

Electric: Maturity = 5 (site work and recharging times could be problematic, quiet running, reduced maintenance costs: Mean-Green-Mowers claim to have large 100% EV mowers with up to 7-hour operational time)

Alternative fuel (HC): LPG Maturity = 5 (limited models, Etesia only)

Operational restrictions and benefits

Biodiesel: See previous comments in assessment tables.

Electric: may require additional infrastructure for rapid charging if required. Operational cutting time for large electric mowers is typically 2 hours for the majority of manufacturers' claims (though MeanGreenMowers claim up to 7-hour operational time), reduced maintenance regime. Reduced operator risk from NVH[24], allows operators to use them for longer periods of time with reduced H&S risks associated with NVH. "Short grass cutting only, regularly maintained grass" according to manufacturer, length of grass not defined in absolute terms.

Alternative fuel (HC): LPG = Additional site infrastructure (gas store).

Range

Biodiesel: Like for like replacement

Electric: Electrified = 2 to 7 hours operation (depends on charging rate and battery capacity)

Alternative fuel (HC): Like for like replacement

Refuelling / recharging time

Biodiesel: Like for like replacement

Electric: 7 hours at 13 amps (for MeanGreenMowers long duration charge, manufacturers claim)

Alternative fuel (HC): Like for like replacement

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[24] Noise Vibration and Harshness – a measure of the sound and vibration of a vehicle

Emission reduction
Biodiesel: See previous comments in assessment tables. **Electric:** 100% tailpipe reduction, WTW typically 40 – 50% CO_2 reduction (based on DEFRA UK 2016 national grid emission profile.) **Alternative fuel (HC):** LPG - No data available
Additional notes
• Mean-Green-Mowers UK distributor is Overton UK Ltd • Mean-Green-Mowers are limited to regular maintenance of grass. Noise, vibration, and harshness of electric mowers is significantly reduced (in comparison to Stage-III diesel), which allows operators to use them for longer periods of time with reduced H&S risks associated with NVH
Recommendations
Maintain under review • NRW report that operational requirements for existing NRW mower fleet may not be well suited to electrification – NRW's typical grass mowing activities involve steep embankments not suited to ride on mowers, longer grass and mowing near river banks and on soft ground (again not suited to ride on mowers) .However, the grass mowing standards at reservoirs for which NRW are responsible have recently been changed, and electrification of mowers at reservoir sites should be considered, as operational experience of the new reservoir grass cutting standard is gained.

18.3 Digger/Dumper

NRW's Operational Plant	
	
Resource Type: Diggers & Dumpers	
Annual Usage	9,300 hours per year, 300 hours per vehicle
Small, Medium, and Large engine categories and count of vehicles **Small:** <2.1 Litre (1), **Medium:** 2.1 to 4.1 (27), **Large:** 4.2 to 6.1 Litre (7)	
No of vehicles	34 (including 3 not in service)
Typical operating pattern	6 hours a day, 50 days a year
Vehicle locations	Up to 5 units located at a given location. Detail of digger fleet distribution is provided in Figure 22.
Additional notes	There are at least three plant attachments that operate as grabbers/diggers.

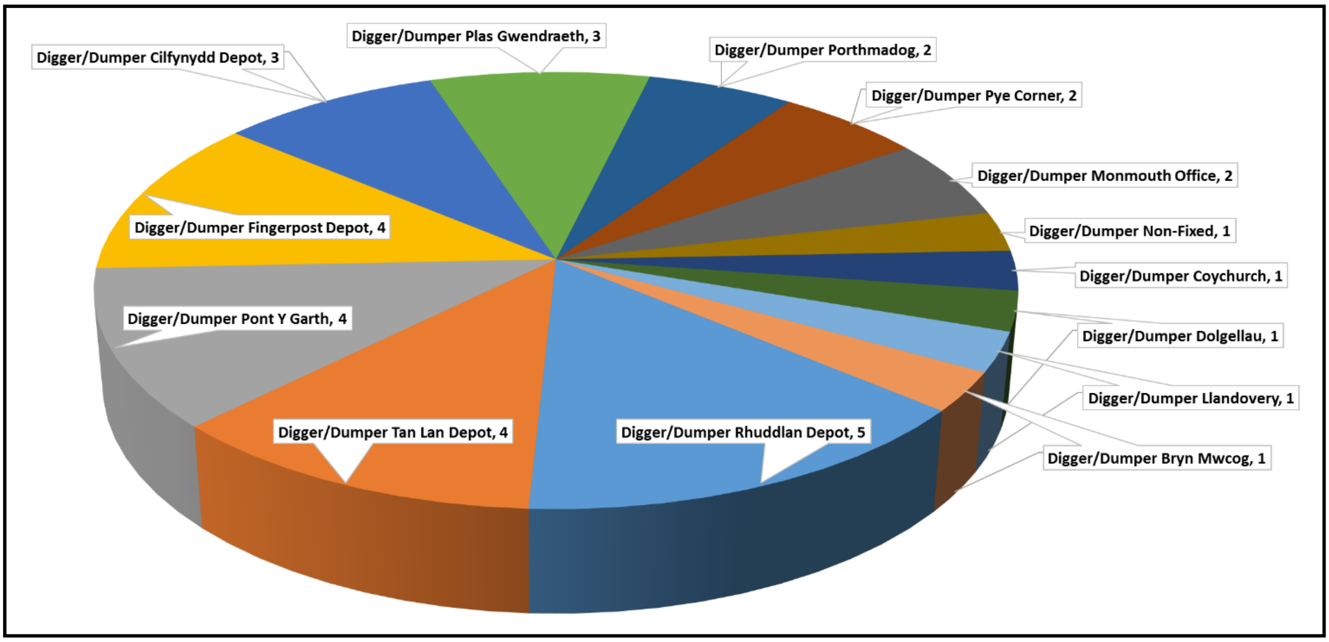


Figure 22: Digger / Dumper NRW fleet Locations

Alternative Technologies for Plant

Resource Type: Diggers & Dumpers

Average Cost: £130,000 22t Komatsu Diesel-electric hybrid power (vs £95,000 standard)

Maturity and practicality

Biodiesel: Maturity = 5

Diesel - Electric Hybrid: Maturity = 5 (22 ton and upwards)

Operational restrictions and benefits

Biodiesel: Increased maintenance regime, mineral diesel fuel and engine flush required before storage, fuel quality requires monitoring and managing.

Diesel - Electric Hybrid: Reduced maintenance regime, regenerative power comes slewing action – savings maximised by slew-heavy operation.

Range

Biodiesel: Like for like replacement.

Diesel - Electric hybrid: Up to 25% increased operational time (manufacturer's claim) due to reduced fuelling time and increased slew speed. Note – this figure is likely to apply in cases where the housing slews continuously, with little or no track movement.

Refuelling / recharging time

Biodiesel: Like for like replacement.

Diesel - Electric Hybrid: Like for like replacement.

Emission reduction

Biodiesel: Variable depending on blend (circa 18% WTW CO_2 reduction available from B25 blend). Engine design, fuel quality and operational cycles essential in assessing total emission with biodiesel – with some authors reporting increases in emitted NOx, particulates and CO[3].

Diesel - Electric Hybrid: The manufacturer claims up to 40% reduction in fuel consumption and associated emissions (based on 'real world customer experience' since 2009). If the manufacturer claims are correct; anticipated savings are in the order of 50 to 60 litres of fuel per day. This equates to reduced CO_2 of 148kg per day or 7.4t of CO_2 per replaced vehicle per year (based on NRW 21t excavator operational profile).

Note – this manufacturer claim is likely to apply in cases where the housing slews continuously, with little or no track movement.

Additional notes

- 22t Komatsu Diesel-electric hybrid powertrain excavators have been on sale since 2008, and are now available in the UK. A diesel-electric hybrid system takes advantage of energy recovery systems to recharge the battery. Additional improvements are gained by ensuring the main diesel generator is operating in the most fuel-efficient way. **This 22t Komatsu Diesel-electric hybrid appears to be a close match to the 21t vehicle used by NRW.**

- 13t to 14t hybrid excavators are under development in Japan (Maturity level = 4), and that market sector should be monitored closely once they become available in the UK. There is no official announcement as to the availability of this product at this time.
- An acceptable biodiesel fuel blend of up to 20 percent volume concentrate (B20) biodiesel with 80 percent mineral diesel can be used for all Komatsu engines. Customers must adhere to strict requirements of Komatsu when using biodiesel blends above B20.
- John Deere, Hitachi and others all offer diesel-electric hybrid Loaders & Excavators.
- For existing fleet of excavators, Biodiesel policy is mixed – CASE announced in 2008 that all CASE equipment will be B20 (20% biodiesel) compatible. However, the latest policy from Isuzu (suppliers of the engines used in the CASE 130D for example) is that only diesel EN590 is permitted (UK forecourts must comply to this standard at the time of writing, and it is assumed this requirement will stay in place after the exit from the EU). Direct contact with the equipment supplier and written confirmation of biodiesel policy should be made before converting to biodiesels.
- Site Dumpers: - No hybrid systems currently available. This situation should be monitored closely as JCB, Hitachi, Toyota, Wacker-Neuson and many others are all in the process of hybridising their power trains for construction equipment. There are no official announcements on timelines.

Future purchasing strategy:

Clarify biodiesel usage for existing CASE plant. Manufacturers need to be contacted directly to inform any biodiesel adoption plans (i.e. manufacture confirmation of maximum permissible biodiesel content and changes to operational procedures).

Hybrid diesel-electric power train alternatives are now available. Diesel-electric powertrains can also be used in conjunction with biodiesel for further emission reductions. Manufacturers should be contacted directly to inform any biodiesel adoption plans (i.e. manufacturer confirmation of maximum permissible biodiesel content and changes to operational procedures).

Recommendations

Recommended subject to further feasibility study

- Conduct a 'slewing' assessment on all existing 21-tonne (and larger) excavator units in the NRW fleet. The rotational movement of the house/cab (known as slewing), is the operation that gains the most benefit from hybridisation.
- With manufacturer claims of up to 40% fuel reduction (in high slew rate vehicles); a business case assessment should be made on the rapid replacement of all 21t (or larger) excavators.

Other alternative technologies – Digger and Dumpers
Fully Electric: Maturity = 1: electrification of heavy plant has been an ongoing research topic for many years, and has been a stated long term goal for several companies. **Alternative Fuel (HC):** Maturity = 4: Several companies have trialled CNG heavy plant of several types and classes. There are no CNG refuelling facilities near NRW locations. **Hydrogen:** Maturity = 3: From 2000 to 2008 Caterpillar developed a prototype hydrogen fuel cell heavy loader, targeted at underground mining operations, that completed operational trials. This project was shelved as the power density of the technology was not then high enough, and hydrogen safety concerns in enclosed spaces were not addressed well at the time. Fuel cell developments in the last ten years are beginning to overcome these limitations. At this time, no heavy plant equipment suppliers are publicising their hydrogen based R&D programmes.

18.4 Chipper

NRW's Operational Plant	
Resource Type: Chipper **Average Cost:** £11,990 (NRW CapEx history)	
Annual Usage	6,600, 600 hours per vehicle
Small, Medium, and Large engine categories and count of vehicles **One size only:** 1.8 Litre	
No of vehicles	11
Typical operating pattern	6 hours a day, 100 days a year
Vehicle locations	One each at Cilfynydd, Clawdd, Coychurch, Hafod, Monmouth, Penmaen, Plas, Rhuddlan, Tan Lan, Tregaron, Welshpool.
Additional notes	There are at least three more wood chippers in the plant attachment category (i.e. chipper attachments without an in-built power source).

Alternative Technologies for Plant
Resource Type: Chipper
Maturity and practicality
Biodiesel: Maturity = 5 **Electric:** Maturity = 5
Operational restrictions and benefits
Biodiesel: Increased maintenance regime, mineral diesel fuel and engine flush required before storage, fuel quality requires monitoring and managing. **Electric:** Operation from cable supply to power source required. Maximum power and size of branches are less than that available for diesel powered chippers.
Range
N/A
Refuelling / recharging time
Biodiesel: Like-for-like replacement. **Electric:** Cable power supply required.
Emission reduction
Biodiesel: Variable depending on blend (circa 18% WTW CO_2 reduction available from B25 blend). Engine design, fuel quality and operational cycles essential in assessing total emissions with biodiesel – with some authors reporting increases in emitted NOx, particulates and CO [3]. **Electric:** Zero at tailpipe, normally around 40 - 50% WTW CO_2 savings.

Additional notes
• 37.5hp Kubota provides diesel engine in a standard Chipper, but does not warrant high blends (i.e. higher than 5% of biofuels). • There are all-electric chippers available – but it is not clear that these will be suitable for NRW use due to requirement of a power supply to plug into due to the use of a cable and smaller engine size of electric chippers. • Typical list prices are in the order of £10,000 (depending on operational requirements). Depending on availability it may be preferable to operate PTO[25] chippers (assuming Stage-V[26] compliant tractor units are available). Tracked independent chippers tend to operate on Stage-III or early Stage-IV compliant engines. • From 2019 onwards reduced emission chippers should be available as the Stage-V emission regulations come into force
Recommendation
Maintain under review (2019/2020) • Limited low emission alternatives available. • Conduct a survey of current chipper users to identify if any scale of electrification is feasible. • A PTO driven chipper could be used from a tractor or other vehicle, however emissions will only be reduced if a lower carbon fuel powers the powered vehicle. In the PTO driven chipper scenario, fuel consumption rates, and therefore operational costs per hour of activity, will be higher than that used by a 1.8 litre chipper unit. • Stage V compliant engines should become available from 2019/2020 – a Chipper replacement purchasing policy should be implemented to replace the aging NRW Chipper fleet if/when stage V complaint chippers become available.
Other alternative technologies – Chippers
Diesel - Electric Hybrid: Maturity = 1: Similar types of engines have been used in diesel electric mode, but no evidence was found to indicate their application in Chippers like those used in the NRW fleet **Alternative Fuel (HC):** Maturity = 3: There is a thriving hobby community of agricultural engineers who have adapted Chippers to run on a wide range of alternative fuels, from LPG to home-made biomethane. None of these technologies are seriously being developed as saleable products. **Hydrogen:** Maturity = 1: Similar types of engines have been used in hydrogen combustion mode, but no evidence was found to indicate their application in Chippers like those used in the NRW fleet.

[25] PTO, a power-take-off shaft that creates a mechanical linkage between the plant engine and the plant attachment.

[26] Stage-V (also known as Stage-V) are the emission standards for non-road mobile machinery and generator powered devices that come into force from 2019 onwards.

18.5 ATV, Quad & Bike

NRW's Operational Plant



Resource Type: All-Terrain Vehicle, Quad, and Motorbike

Average Cost: £34,906 (NRW CapEx history: mean CapEx price for inflated specialist ATVS). Average Quad CapEx was not recorded. 450cc road legal Honda or Quadzilla Ltd typical list price = £5,000 - £7,000, higher for 4WD variants.

Annual Usage	6,800 hours per year, 200 annual hours per vehicle on average

Small, Medium, and Large engine categories and count of vehicles

Small: 0.1 to 1.1 Litre (29), **Medium:** 1.1 to 2.1 Litre (1), **Large:** 3.1 to 4.1 Litre (4)

No. of vehicles	34
Typical operating pattern	4 hours per day, 50 days per year
Vehicle locations	One to four vehicles at 22 separate locations
Additional notes	The majority of these vehicles (21) are Petrol engines.

Alternative Technologies for Plant

Resource Type: All-Terrain Vehicles, Quads, and Motorbikes

Maturity and practicality

Biodiesel: Maturity = 5

Electric: Maturity = 5: EcoCharger Ltd supply electric quads and small-scale sales of dedicated conversions. List prices start from £8,995.

Other suppliers: Polaris.

Operational restrictions and benefits

Biodiesel: Increased maintenance regime, mineral diesel fuel and engine flush required before storage, fuel quality requires monitoring and managing.

Electric: Reduced maintenance regime – (Manufacturer claims improved performance over diesel/petrol equivalent). Six batteries, with a total replacement cost of up to £1,500. Battery replacement unknown, may be required once every three to five years (assumes daily operation and charging). It should be noted that it is unlikely that all 6 batteries would require replacing at the same time.

Range
Biodiesel: Like-for-like replacement (~75 miles on a 15 litre tank). **Electric:** Around 30 miles dependent on usage pattern (72 volt, 100 AH, 7.2 KWH).
Refuelling / recharging time
Biodiesel: Same as diesel. **Electric:** 3.5 hours at 13 amps. Rapid charge (battery capacity taken from 20% charge to 80% charge, in a 30-minute charge cycle) possible if additional infrastructure fitted. 25 amp rapid charger fittings supplied as standard from 2018 onwards by EcoCharger Ltd.
Emission reduction
Biodiesel: Variable depending on blend (circa 18% WTW CO_2 reduction available from B25 blend, and circa 23% TTW saving for the same blend). Engine design, fuel quality and operational cycles essential in assessing total emission with biodiesel – with some authors reporting increases in emitted NOx, particulates and CO [3]. **Electric:** Zero at tailpipe, zero TTW emissions and normally around 40 - 50% WTW CO_2 savings (based on DEFRA UK 2016 national grid emission profile.)
Additional notes
• Eco Charger Ltd offers Two and four-wheel drive vehicles all electric Quads. Sites that operate quad-bikes may well benefit from significant emission reductions if re-charge time does not limit operations. Eco Charger Ltd is a small company – unclear on the number of vehicles they can supply in a short period. • Reduced service and maintenance cost (fewer moving parts in electric drive trains). No direct evidence to support this for EcoCharger Ltd, but is generally true for EV systems. • HAULER® 1200X provides a fully electric ATV. John Deere Gator TE provides a fully electric ATV **Future purchasing strategy:** All John Deere engines are warranted to use biodiesel blends up to B20 (20%), EN 14214 specification. John Deere engines without exhaust filters can operate with higher blends of biodiesel.
Recommendation
Recommended additional trials required • Operational assessment of the suitability of fully electric quads should be undertaken with a vehicle purchased for trial. • Desk based feasibility study of other electric ATVs should be undertaken.
Other Alternative Technologies – ATVs
Diesel - Electric Hybrid: Maturity = 1: Similar types of engines have been used in diesel electric mode, but no evidence was found to indicate their application in ATVs like those used in the NRW fleet. **Alternative Fuel (HC):** Maturity = 3: There is a thriving hobby community of agricultural engineers who have adapted ATVS and quads to runs a wide range of alternative fuels, from LPG to home-made biomethane. None of these technologies are seriously being developed as saleable products. **Hydrogen:** Maturity = 1: Similar types of engines have been used in hydrogen combustion mode, but no evidence was found to indicate their application in ATVs like those used in the NRW fleet.

18.6 Forklift

NRW's Operational Plant	
 	
Resource Type: Forklifts **Average cost:** £36,425 (NRW CapEx history)	
Annual Usage	350 hours, 50 hours per vehicle
Small, Medium, and Large engine categories and count of vehicles **Small:** 2.5 Litre (3), **Large:** 4.5 Litre (4)	
No of vehicles	8 (including 1 not in service)
Typical operating pattern	1 hour per day, 50 days a year
Vehicle locations	One each at Coychurch, Llandovery, Marian Mawr, Monmouth Office, Plas Gwendraeth, Pye Corner and Resolven. Crychan workshop forklift not in service
Additional notes	Telehandlers and forklifts are grouped together under this category.

Alternative Technologies for Plant
  
Resource Type: Forklifts
Maturity and practicality
Merlo Diesel - electric hybrid telehandlers: Maturity = 5 **Fully electric forklifts:** Maturity = 5 **LPG:** Maturity = 5 **Plug Power & Toyota Hydrogen fuel cell Forklifts:** Maturity = 5

Operational restrictions and benefits
Biodiesel: See previous comments in assessment tables. **Diesel - Electric Hybrid:** Basic training for staff in safe charging procedures. Offers reduced maintenance compared to internal combustion engine (ICE). Recharging times can limit operation unless additional batteries are purchased. **Electric:** Electric forklifts require good quality floors to operate on – not suitable for soft ground. Basic training for staff in safe charging procedures. Offers reduced maintenance compared to internal combustion engine (ICE). Recharging times can limit operation unless additional batteries are purchased. **Alternative fuel (HC):** Same as diesel. Fuel infrastructure must be available. **Hydrogen:** H_2 Fuel cell requires specialised infrastructure (gas store) and training (hydrogen refuelling). Fuel infrastructure must be available. Site specific operational consideration would determine the acceptable distance between depot and refuelling infrastructure (e.g. can the depot spare the time for an employee to transport a forklift to a refuelling point several miles away, several times a week?).
Range
Biodiesel: Same as diesel **Diesel - Electric Hybrid:** Same as diesel **Electric:** 8 hours charging time in each 24-hour period recommended per battery **Alternative fuel (HC):** Same as diesel **Hydrogen:** Similar to diesel
Refuelling / recharging time
Biodiesel: Like-for-like replacement **Diesel – Electric Hybrid:** Like-for-like **Electric: standard charging:** 8 hours at 13 amp for single battery **Electric: rapid charging:** 20% charge to 80% charge in 30 minutes for a 3-phase, 32 amp or higher, system – battery change stations increase Capex but reduce 'refuelling' time. **Alternative fuel (HC):** < 5 minutes **Hydrogen:** < 5 minutes
Emission reduction[27]
Biodiesel: See previous comments in assessment tables. **Diesel - Electric Hybrid:** Around 30% WTW CO_2 emissions reduction (in comparison to Stage-III diesel). Manufacturers claim 25% reduction in fuel consumption and emissions (tailpipe). The ability of NRW to realise a 25% emission saving will be depending on its operations. **Electric:** Around 40% WTW CO_2 emission reductions (in comparison to Stage-III diesel) based on DEFRA UK 2016 national grid emission profile. Tailpipe emissions are zero.

[27] Emission reductions from Forklift Technology Modelling report, Cenex. Private report to Coca-Cola Enterprises.

Alternative fuel (HC): Wide variety of powertrains and fuel combinations are available WTW emission reduction in the order of 25% (LPG with hydrostatic drive) to 15% CO_2 WTW reduction (CNG with hydrostatic drive).

Hydrogen: Highly dependent on origin of Hydrogen. For fuel cell forklifts operating on steam reformed hydrogen around 40% WTW emission reduction is available, with zero tailpipe emissions. Hydrogen generated through renewable electrolysis has a 100% WTW emission reductions, with zero tailpipe emissions.

Additional notes

- Diesel electric can achieve further emission improvements using Biodiesel - Merlo Deutz engines are warranted up to 7% biodiesel blends according to EN 590. DEUTZ also offer a Natural Fuel Engine® which can be operated with 100% rapeseed oil. It is not known if this technology is compatible with the Merlo hybrid, however. Merlo Hybrid Telehandler on sale worldwide, currently going through EU-Type Approval (approval anticipated in 2017/2018 financial year).
- Electric forklifts typically require smooth and firm ground surfaces to operate on. If these are available in any of the sites that utilise forklifts, significant cost and emissions saving can be made by converting to electric forklifts. The typical one hour per day operational cycle reported makes NRW forklifts ideally suited to all electric operation.
- LPG forklifts operate in the same environments as diesel equivalents, with slightly reduced overall CO_2 emissions. Particulate emissions are reduced 98% compared to traditional diesel vehicles. NOx emissions can be significantly reduced as well (operation cycle dependent).
- Hydrogen fuel cell forklifts are typically recommended for large numbers of forklift operating in a single location to mitigate the cost of hydrogen infrastructure. However, the Baglan hydrogen refuelling site may well impact the economics of any nearby NRW sites. Real world cost models for H2PEM forklifts are not yet publicly available, and projections from suppliers should be treated with caution. Hydrogen fuel cell materials handling equipment is often eligible for UK or EU grant funding, and this can have a significant impact on the adoption of this technology.

Recommendations

Recommended: Business case dependant

- The very low usage rates for NRW forklifts and telehandlers make the business case for new technology replacement difficult to make. These lower emission alternatives will be more expensive to operate on a total cost of ownership basis; unless utilisation can be significantly increased. There is a CapEx premium for the purchase of all electric or hybrid vehicles. Higher utilisation recovers this cost in fuel savings over the life of the vehicle. NRW's low usage rates (typically one or two hours per day) indicates that the CapEx premium may not be recovered from fuel cost savings over the life of the vehicle.
- For maximised CO_2 reduction, any future purchases of forklifts and telehandlers should prioritise diesel-electric hybrid vehicles and (if ground conditions are suitable) fully electric forklifts (if the cost is justifiable).

18.7 Other

NRW's Operational Plant	
Resource Type: Other – miniature tracked vehicles, vibratory rollers, etc.	
Usage	1 tracked miniature dumper (all others for disposal or auction)
Small, Medium, and Large engine categories and count of vehicles **Small:** 400cc	
No of vehicles	1 (3 not in use)
Typical operating pattern	2 hours 50 days a year
Vehicle locations	Dolgellau
Additional notes	
Lumag Distribution Ltd offers three types EV Tracked Mini Dumper – three hours of operation per day should be fully compatible with NRW requirements. Provides zero tailpipe emission and WTW emission savings. 450kg tracked EV list price = £2,245 (in comparison to £2,000 for diesel equivalent). Short term operational costs can be much reduced (reduced maintenance: fewer oil and belt changes etc.) however battery life is only three years, and cost of replacement batteries should be considered. £450 for battery replacement (verbal quote from supplier).	

18.8 Pump

NRW's Operational Plant	
Resource Type: Pumps	
Usage	Not reported
No of vehicles	3
Vehicle locations	Pye Corner(2), Rhuddlan Depot(1)
Additional notes	
All pumps operate on diesel – without operational details, no recommendations can be made as to reduced emission technology. All pumps specified can, however, be run from electric motors if they are operating in a suitable environment. Biodiesel may also be an option, but engine specifications must be investigated first.	
Recommendations	
Recommended subject to further feasibility study • Gather data on pump usage in NRW • Analyse use against operational capacity of electric motors. • Switch to electric motors if operationally suitable and there is a sufficient power source.	

18.9 Plant Technology Summary

The operational, emission and costs (CapEx/OpEx) identified in the plant alternative vehicle technology study are summarised in a traffic light matrix in Table 34 below. The 'Amber' classification may still offer emission savings, but is unlikely to result in cost savings and there may be parts of NRW's operational requirements that cannot be completed by amber technologies. NRW may choose to pursue amber technologies in order to achieve emission savings and conduct further investigations to assess economic performance.

Factor	Red	Amber	Green
Operational	Fails to meet operational requirements	Meets some operational requirements	Meets all operational requirements
Emissions	Higher CO_2 emission (in comparison to Stage-III)	Reduced CO_2 emission (in comparison to Stage-III)	Zero emissions at tailpipe
CapEx[28]	Significantly higher plant + infrastructure CapEx	Broadly similar plant + infrastructure Capex	Potential CapEx saving (in comparison to Stage-III)
OpEx	Significantly higher operating costs	Broadly similar operating costs	Lower operating costs (in comparison to Stage-III)

In some cases there is no information available for a suitable technology, for a given NRW plant operation (for example electrified excavators suitable for NRW operations). Where there is insufficient data to make an informed decision, that block has been left grey in Table 34 - NRW Plant Assessment Summary.

If more detail is required to understand Table 34, please refer to the appropriate section of chapter 18 (e.g. refer to section 18.6 if more detail is required on forklifts).

[28] CapEx estimate compares reported NRW historic purchase price (where available) to manufacturers list price for proposed technology

Fuel	Factor	ATVs, Quads, Bikes	Chipper	Digger / Dumper	Forklift	Mower	Other	Tractor
Biodiesel	Operational							
	Emissions							
	CapEx							
	OpeEx							
Diesel – Electric Hybrid	Operational							
	Emissions							
	CapEx							
	OpeEx							
Electric	Operational	Quads only						
	Emissions							
	CapEx	For 3-hr charge option						
	OpeEx							
Alternative hydro-carbon based fuels	Operational	CNG		CNG	LPG	LPG		CNG
	Emissions							Bio-methane
	CapEx							
	OpeEx							
Hydrogen	Operational							
	Emissions							
	CapEx							
	OpeEx							

Table 34 - NRW Plant Assessment Summary

18.10 Fuel Replacement

The definition of alternative or replacement fuels will vary depending on the exact application, but in the context of the NRW plant review, any fuel other than diesel or petrol is considered a replacement fuel.

The basic concept of replacement fuels is quite straight forward. If an equivalent amount of energy can be released, with a reduction in either local or total emissions (preferably both), then it should be considered preferable to do so. Arguments around which replacement fuel to use centre around the six following points[3]:

1. **Cost of the fuel.**
2. **Ease of use** (e.g. plant or infrastructure changes).
3. **Operational requirements** (e.g. more frequent maintenance or refuelling).
4. **True emissions measurement** (e.g. OEM stated emissions compared to real world usage including slips, leaks and spills).
5. **Security and purity of supply** (e.g. small-scale productions lack redundancy, the UK does not have sufficient capability to produce all its own biofuels).
6. **Other, wider, social, and environmental impacts** (e.g. rapeseed and soybean-based biodiesel crops utilise land traditionally used for food crops, and so increase the price of food globally). Note that biodiesel can be sourced from re-used cooking oil, which does not present a risk to land traditionally used for crops. NRW's use of biodiesel to date has been from re-used cooking oils and not virgin crops.

Biodiesel is the most widely used replacement fuel that can achieve significant WTW reductions in CO_2 emissions. However, these reductions will be limited to the compatibility of different plant items and their usage patterns (i.e. minimum blend requirements and duration between plant usage). CO_2 reductions are also available from less mature technologies for plant, such as duel fuel green hydrogen combustion engines and biomethane. All options have an associated cost and will require the purchase of new plant equipment and, in some cases, modification after purchase. In addition, all are likely to require the bunkering of fuel at depot sites (and associated additional costs) and additional training for staff and operators at those sites.

18.11 Plant Attachments

NRW use several plant attachments. These are tools which are powered from the item of plant. This means that any technology or fuel change in the plant item will improve emissions in the plant attachment. This section sets out a high-level review of low emission alternatives for plant attachments.

The clear majority of plant attachments are driven either through direct mechanical linkages known as power take off (PTO) shafts or hydraulically driven. Whist PTO drives are very efficient, Hoy et al. (2014) [4] suggest that the efficiency at the point of use can be far lower (between 9% and 60%, depending on the equipment being operated, and the operational speed of the engine versus the required speed of the attachment).

Hydraulic systems draw their power from the main tractor unit as well, and their overall efficiency is typically in the region of 89% [5]. However, this value is measured at full power and with the hydraulic system operating under ideal conditions. Approximately 50% of plant attachment operations, which require hydraulic systems, can double the estimated power losses (depending on leak rates). High-temperature operation reduces the viscosity of the hydraulic fluid, which in turn reduces its effectiveness at power transference even further.

Electrically operated plant equipment is also available, often as a like for like replacement for the equivalent PTO or hydraulically powered unit. ZF Technology GmbH has claimed a 10% reduction in energy use for like-for-like replacement of hydraulic attachments [4]. The agricultural industry electronics foundation is actively engaged in researching and approving electrically powered equivalents of PTO or hydraulically operated plant attachments. Whist electronically driven drives have efficiency improvements, hydraulic systems have a far greater power density than their electric equivalent. It is unlikely that electric systems will replace larger, heavy duty plant attachments anytime soon.

Recommendation: Currently, the largest gains/opportunities in plant attachment efficiency are through improvements to the main plant equipment. It is recommended that NRW concentrate initial efforts on reducing the emissions from the plant vehicles. After completing a fleet wide plant replacement programme to update Stage III equipment with Stage V (2019 standard) equipment, the plant attachment potential for energy savings could be re-considered.

19 Plant Best Practice

One of the key polluting elements in the operational plant for NRW are the tractor units: as can be seen in Figure 18, tractor units have some of the largest capacity engines, with the some of the largest hours of operation per year. This means they have a significant impact on the total emissions of the NRW plant fleet (with an estimated 780 tonnes of WTW CO_2 being emitted from the NRW tractor fleet representing 62% of the total NRW CO_2 emissions).

The versatility of tractors is one of their key virtues. However, the same versatility means that operators can become complacent about optimising the tractor for a given task. Fuel efficient use of the tractor for a given task can make a significant difference to its fuel consumption, without significantly increasing the time taken to complete the task. In fact, for some operations, optimised setting of tools and tyres can improve overall output of work. For example, it has been shown for the use of heavy equipment in heavy soils, that wheel slip is largely eliminated, and output is increased (+3.5% per hectare/hour improvement) when tyre pressure and machinery settings are optimised for reduced fuel use.

One of the key, cost effective, ways to limit the emission from this section of the fleet is through good practice and driver training[6,7]. Modern tractor operators are highly skilled workers, who are required to make complex decisions when balancing the performance of the vehicle and attached machinery they operate. It is hardly surprising if perceived efficiency and operational pressures divert tractors operators away from fuel efficiency best practice.

As a high-level summary of fuel saving operation for tractors, there are five broad factors to consider which are discussed further in the sections below.

1. **Direct fuel consumption feedback**
2. **Tyre pressure**
3. **Machine settings**
4. **Ballast**
5. **Engine speed**

19.1 Direct Fuel Consumption Monitoring

Fuel consumption can be reduced through having a flow meter based display in the cab although retrofitting such devices to existing vehicles can be problematic as it requires interference with fuel lines which can impact warranties and insurance premiums. The mobile FCM - 100 fuel consumption meter is one such solution, supplied by KL Maschinenbau GmbH. Several tractor manufacturers offer a wide variety of in-cab displays for optimum equipment operation, but not all makes and models offer fuel consumption data. The table below shows a range of vehicles which offer in-cab fuel consumption displays.

Brand	Model	Current consumption (L/h and/or L/ha)	Total consumption (L)	Average consumption (L/h or L/ha)
Case	Maxxum	•	•	••
	Puma	•	•	•
	Puma CVX	•	•	•
	Magnum	•	•	•
	Steiger	•	•	•
Fendt	Vario 200-300	•	•	•
	Vario 400-800	•	•	•
	Vario 800-900	•	•	•
John Deere	6030 Premium	•		
	7030 Premium	•		
	8R range	•		
Claas	ARION 400-600 CIS	•		
	ARION 500-600 CEBIS	•	•	
	Axion 800 CIS	•		
	Axion 800 CEBIS	•	•	
	Xerion	•	•	
Lindner	Geotrac 84-104		•	•
	Geotrac 114-124		•	•
DeutzFahr	Agrotron TTV	•	•	•
	Agrotron M Profiline	•	•	•
	Agrotron X	•	•	•
Massey Ferguson	MF6400	•	•	•
	MF7400	•	•	•
	MF8600	•	•	•

Table 35 - In cab fuel consumption display vehicles (2012)

Typically, tractor operators do not utilise the fuel consumption data well, even when it is available, often because of a lack of training in how to display and interpret the data correctly while using the equipment [8]. In-depth training on cab computers, displays and user interfaces should be carried out wherever they are available. Dealers usually have specially trained staff who are more than happy to provide after sales support in this regard. NRW would have to negotiate the costs of such fuel efficiency training on a case by case basis with equipment suppliers. New equipment purchases could include such training as part of the price negotiations. For tractor units and their associated plant, fuel efficiency units are typically provided in litres per hour or litres per hectare. Depending on the work being carried out, more usual estimates based on distance travelled are not a useful comparator.

Some of the factors that are known to impact fuel efficiency in tractor operations are:

- Type of soil (e.g. clay or sandy).
- Soil conditions (e.g. meadow or deep ploughed).
- Moisture content and humidity levels (e.g. water content of timbers, or grass surface beading).
- Working speed (e.g. correct gear selection).
- Woking intensity (e.g. correct RPM selection).
- Harvest amount (e.g. desired throughput per hour for the task).
- Setting of machines (e.g. optimised tine depth for rakes).
- Machine and Tractor maintenance (e.g. hydraulic system connectors and hoses).
- Plot size (e.g. number of turns, and space to disengage attachments while turning).
- The distance between field site and depot (e.g. tyre pressure optimisation for road or field).

- Driver skill in setting attached machinery.
- Driver skill in economic operation.

19.2 Tyre Pressure and Tractor Operations

It has been shown that correct tyre pressure, tailored to the soil type and operating conditions on the day, can result in significant reductions in the amount of fuel used for a given task [8,9].

The EU-funded Efficiency-20 group has published a number of reports and guidelines on fuel efficient use of agricultural and forestry equipment.

The practicalities of changing tyre pressure daily must of course also be considered. However, with such extensive fuel savings available, the business case for improved tyre inflation policies should be given serious consideration. t is understood that a simple hardware fix is not enough to gain these benefits: every operator also needs to be trained to recognise the changes in the surface they are driving on and to make appropriate changes to the vehicle (and any towed equipment) they are operating [8/9].

Figure 23: Effect of tyre inflation on fuel efficiency

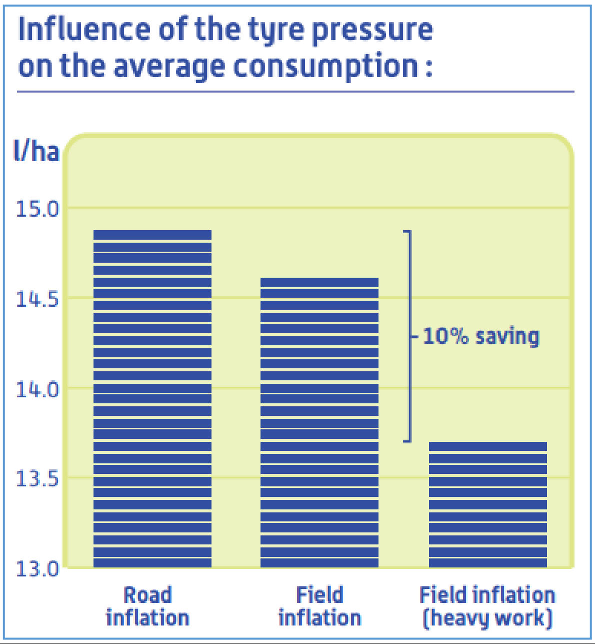
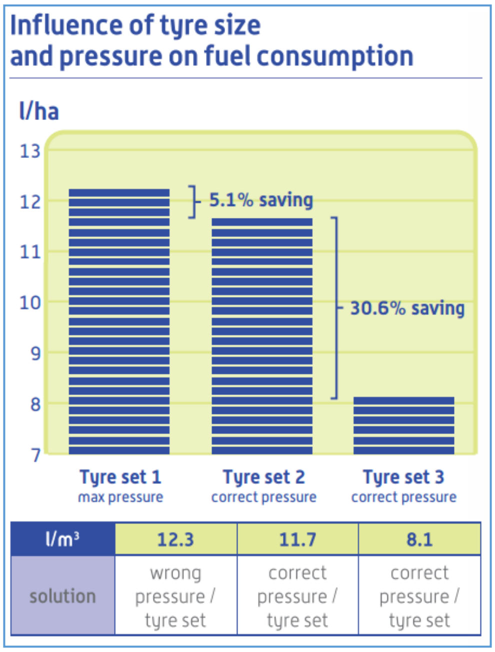


Figure 24: Effect of tyre size and inflation on fuel efficiency



Tractor suppliers, plant attachment machinery providers and tyre companies can all advise on the correct tyre pressure for their equipment in a wide variety of operating conditions and provide onsite training. Other resources for daily use are also available to support operators in implementing good tyre pressure practice: As an example, Michelin offers a tyre inflation recommendation service online[29].

Tyre pressure could be checked daily at the depot. Alternatively, there are vehicle-mounted solutions, enabling the driver to make multiple tyre pressure changes throughout the day. The ability to change tyre pressure out in the field is preferable in most circumstances.

[29] http://agricultural.michelin.co.uk/uk/pressure_calculator/default#pc-tabs-tractor

At its simplest, a tractor mounted, PTO driven, compressor system with pressure lines can be used. There are also models of the tractor that include central tyre inflating system. For example, VarioGrip adapts the tyre pressure from 0.6 to 2.5 bar even while driving. Fent Ltd /Trelleborg GmbH/Mitas Ltd, Challenger Ltd, and Unimog Ltd, all have central inflation designs and compatible equipment for plant attachments, though it is not clear how cross-compatible these systems may be. The central inflation system fitted to a new tractor will determine which plant attachment manufacturers will be considered, and this must be factored into the original purchasing decision.

Recommendation: Specify in-cab fuel consumption equipment when purchasing plant. Train drivers in efficient driving and correct tyre pressure setting. NRW will have to negotiate training costs with tyre/equipment suppliers on a case by case basis. If NRW are not already using such a system, consider trialling an automatic tyre inflation devise and assess its effects on fuel consumption.

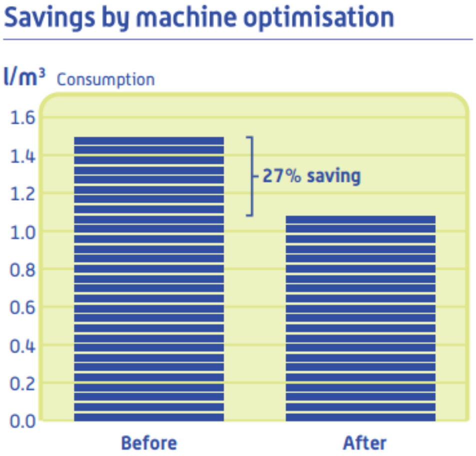
19.3 Machine Settings

Operating plant and attachments at the correct (or incorrect) settings can have a significant effect on fuel consumption. The Efficiency-20 case study of a tractor based harvester unit is detailed, to provide a representative case study of the impacts of optimum machine settings.

Harvesters are heavy plant that is used in tree felling operations. Harvester optimised settings for operational throughput and fuel use can be summarised in the table below:

Operational Factor	Operational issue
Engine speed	1,200-1,400 rpm
Saw feed pressure	Timber type and cross section dependant
Knife feed pressure	Timber type and cross section dependant
Knife feed limit value	Timber type and moisture content dependent
Knife angle	Timber type and moisture content dependent
Saw position	Ensure sensors and controls positioned correctly
Hydraulic system	Ensure pressure set to optimum levels
Method	Keep cutting head low to the ground and close to the cab where reasonable to do so

Table 36 - Forestry Harvester operational factors that impact fuel use per m^3 of timber processed



l/m³	1.5	1.1
solution	without optimised settings	with optimised settings

Consider the representative operational controls shown for a forestry harvester unit in Table 36; there are seven broad factors to consider. If we assume that there are only two possible settings for each factor (low, high) this results in 49 different setting combinations to optimise to achieve the most fuel-efficient operation of the equipment. Fortunately, expert tuition tailored to match the day-to-day operational requirements of the NRW fleet should be available from the dealership. The expert tuition provided by the equipment supplier will help operators to quickly define a combination of operational settings that are best suited to NRW duty cycles, and the skill to quickly identify and apply those settings as conditions change over the year.

Figure 25 - Harvester Optimised Settings [8/9]

In a case study carried out by the Efficiency-20 group, based on the volume of timber processed a, 27% fuel saving was possible after several[30] days of training of the harvester operation teams [9].

Recommendation: Review key plant operations and scope to train operators in correct machine settings. Case study example shows that a 27% saving in fuel was possible following machine setting training on a Harvester.

19.4 Ballast

Ballast is added to tractor units to improve grip and reduce wheel slip during operation. This results in several operational factors that can negatively impact fuel consumption rates:

- Some drivers will put in place the maximum amount of ballast needed for a single task, and not change it.
- Some drivers will minimise ballast to increase road speed, and not change it.

Both approaches are sub-optimal, both regarding fuel consumption, and also tend to reduce the effectiveness of the equipment and reduce operational output. Excessive ballast in most operations will cause the tractor wheels to engage more fully than required with the soil. This, in turn, increases the rolling resistance of the tyres, and so requires more power from the engine to overcome it. Conversely, overly-reduced ballast can result in tyre slip during normal operations, which increases the amount of time to complete tasks. This requires longer periods of operation, and so increased fuel use. Tractor and machinery suppliers can provide training on the optimum ballast for a given operation under different weather and soil conditions. In addition to providing the training, it is critical that NRW and depot managers be supportive in allowing the time required to adjust the ballast loading required for each day's operation.

Recommendation: Consider training operators in the correct use of ballast for plant operations.

[30] Report did not specify exact number of days training required, or the number of individuals that were trained in the reported case study

19.5 Engine Speeds

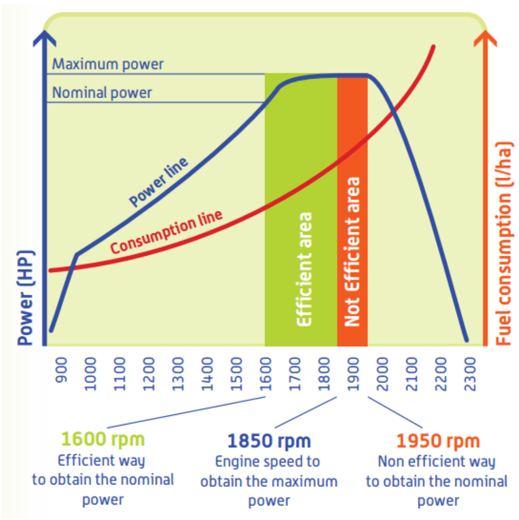


Figure 26 - Engine Power, Speed, and Fuel Consumption

Many drivers will operate tractors based on the engine noise rather than visual observation of the RPM counter.
When seeking to operate in a fuel-efficient fashion, the operator should endeavour to operate the engine in such a way that they are using the least amount of power possible to complete the task in hand. Diesel engines typically have a relatively narrow band of engine speeds at which peak power can be achieved (see Figure 26). Understanding the power requirement of the vehicle, and machinery being operated, and utilising the in-cab display to select a minimum engine speed to achieve that operational power can result in significant fuel savings.

Figure 26 shows that operating the engine in the left side of the power chart offers significant fuel saving per hectare. The Efficiency-20 group found that drivers operating by-ear are usually operating on the right-hand side of the power chart, typically by around 400RPM higher than they need to be [9].

Recommendation: By retraining the drivers to listen for the lower engine noise, and with visual confirmation through in-cab displays, significant fuel savings can be made utilising correct RPM monitoring alone; the Efficiency-20 group reported the fuel saving results detailed in Table 37 below. For the avoidance of doubt, the first two columns in Table 37 (litres per hour and litres per hectare) indicate a fuel saving when a negative value is show, and an increase in fuel consumption when a positive value is shown. The third column (hectares per hour) indicates a reduction in productivity when a negative number is displayed.

	l/h	l/ha	ha/h
Chisel	-5.5%	-6.4%	1%
Cultivator	-14.6%	-7%	-8.2%
Disc Harrow	-12.5%	-12.5%	0%
Fertilizer	-33.3%	-25.9%	-10%
Front loader	-19.9%	N/A	N/A
Moldboard plow	-6.5%	-6.4%	-0.1%
Roller	-16.9%	-16.9%	0%
Seed drill	-15.8%	-15.8%	0%
Sugar harvester	-12.7%	-12.7%	0%
Transport	-32.5%	-17.6%	-18.2%

Table 37: Reduced engine RPM fuel savings and productivity [8/9]

Depending on the operational requirements of the user, it has been shown that anywhere between 5% and 25% fuel savings per activity are possible.

19.6 Summary Recommendations

The five listed targets (Fuel consumption monitoring, Tyre pressure, Machine settings, Ballast, Engine speed) can each reliably save between 5 and 10% of total fuel use for most vehicles. NRW can reduce their tractor based fuel consumption, and resultant emissions, by 20%, and possibly more, by adopting fuel efficient training policies. Assuming fuel costs constitute 60% of operational costs for these vehicles, this would also result in a 12% reduction in total operating costs of these vehicles. The anticipated savings could be used to implement a dedicated tractor fuels reduction policy. Such a policy would need to include several key factors:

- A fuel saving champion is appointed with the enthusiasm and authority to drive the programme forward from within NRW.
- Implementing schemes focused on fuel reduction through monitoring fuel consumption and optimising tyre pressures, machine setting, ballast, and engine speed.
- Clear explanation of the productivity, fuel cost, maintenance cost, environmental impacts, and driver health benefits of reduced fuel use to tractor operators, depot managers, and all other plant equipment stakeholders.
- Baseline measurements of current fuel consumption rates to be carried out by the operators.
- Professional fuel efficiency training by machinery and vehicle experts.
- An NRW implementation programme that supports fuel efficient operations (e.g. additional time at depot to optimise tyre pressures and ballast loads at the start of each day).
- S.M.A.R.T. Fuel consumption targets as part of NRW employees KPI and review processes.
- Procurement strategy to be linked to fuel saving policies (e.g. tractors within in-cab fuel meter displays, central tyre inflation systems and compatible towed equipment).
- Recognition and rewards for significant fuel saving activities by operators and depot managers.
- Ongoing depot based training and ‘tool-box talks’ to share experiences and best practices, led by tractor operators with proven fuel saving skills.
- Ongoing external expert training sessions on a regular basis (e.g. every four years) once the programme is established.

20 Plant Scenarios

Low emission plant options are presented in scenarios to demonstrate the effect of implementing recommended technologies in the NRW fleet.

Low emission plant options have been implemented in the following three scenarios.

- **Scenario A - All Electric Quad Bikes** This scenario assumes that 80% of the quad bikes in the NRW fleet are replaced with 100% electric equivalents between 2017 and 2021.
- **Scenario B – Mature Technology Adoption Scenario** This considers a single, hypothetical depot in three emission reduction strategies. These three strategies involve the low, medium, and high uptake of emission reducing work practices and technologies between now and 2021 (with 2016 plant information as a baseline comparison).
- **Scenario C – Technology Adoption to 2050** This scenario assumes that NRW implements a progressive CO_2 reduction scheme possible with the aim of assisting the Welsh and UK governments in achieving their 2050 CO_2 reduction targets. A key element of the 2050 scenario is the complete elimination of fossil fuel use by 2040.

In all the scenarios about to be presented, **it must be stressed that we have made 'high level' estimates fuel use and emissions**. Calculations have been made based on the information provided to Cenex by NRW on its plant fleet. Operational information was limited to the total number of hours worked per year. No fuel consumption data for plant were available therefore we have based fuel consumption estimates on engine size and typical engine loading rates. To refine the scenarios for greater certainty of return, real world fuel consumption data should be gathered from the plant fleet to refine the presented scenarios.

20.1 Scenario A - All Electric Quad Bikes

It was identified that electrification of quad bikes across NRW was a technology opportunity well suited to early and cost-effective implementation. Therefore, this scenario considers the likely costs and time frames for implementation of this technology.

20.1.1 Petrol Quad Performance

18 quad-bike vehicles have been identified in the information provided. There are other vehicles in the fleet that may also be suited to increased electrification; however, they are excluded from this scenario as they are highly specialised items of equipment that will need to undergo individual feasibility studies to ensure electrification can be achieved. NRW data provided to Cenex indicates that all quads in the fleet are petrol based. The industry trend moving forward is for quad bikes to only use petrol (for example Quadzilla Ltd, the UKs largest quad bike supplier, have, or soon will be discontinuing all diesel quad variants). Therefore, this emission simulation scenario assumes that all quads in use from this point forward should be compared to petrol engine quads. Our estimates of petrol fuel consumption and quad emissions are summarised in the Table 38 below.

Annual Fuel Consumption per Quad	Total Annual Fuel Consumption (18 Quads)	Total Annual WTW CO_2 Emissions[31]	Annual Fuel Costs
775 litres	13,959 litres	37,104 kgs	£13,010

Table 38: Petrol Quad Fuel and Emissions

Table 38 shows that the 18 quads consume nearly 14,000 litres of petrol each year emitting nearly 40 tonnes of CO_2 emissions.

20.1.2 Electric Quad Performance

Electric quad bikes, such as those provided by EcoCharger, have been selected as suitable replacement quads. The recommended 'Eliminator' all electric quad has a 7.2kWh battery, and a nominal 40 km range. This gives and effective 0.18kWhs/km. Assuming an average speed of 14.5kph (9mph). Based on and estimated 12,586 operational hours (no idle time required for electric motors). Table 39 below shows the fuel and emission factors for the electric quad bikes.

Annual Fuel Consumption per Quad	Total Annual Fuel Consumption (18 Quads)	Total Annual WTW CO_2 Emissions[31]	Annual Fuel Costs
1825 kWh	32,850 kWh	15,752 kgs	£2,950

Table 39: Electric Quad and Emissions

This analysis indicated that electric quad bikes offer a 100% reduction in TTW CO_2 and a 58% saving on WTW CO_2 emissions. Furthermore, the annual cost of power consumption of an all-electric quad-bike fleet is £2,950 per year for the entire fleet, which represents a 77% saving in annual fuel costs (circa £550 per annum per bike).

20.1.3 Electric Quad Replacement Scenario

The following assumptions are made for the Quad-Bike replacement scenario:

- A full suitability assessment and operator acceptance plan has been successfully implemented.
- 80% of Quad bikes are identified as being well suited to EV replacement.
    - The remaining 20% (4 vehicles) are occasionally required for long range operations, or refuelling in remote locations.
- Vehicles are replaced at the rate of three per year from April 2017 onwards, except for 2021, when only two vehicles are replaced.
- No additional charging infrastructure is required for 14 electric quad bikes.
    - This assumes charging overnight in a standard plug socket.
        - 7 hours to charge from zero to fully charged using a standard 13 amp, 3 pin, single phase socket.

[31] Based on DEFRA 2015 GHG Emission Factors for Company Reporting

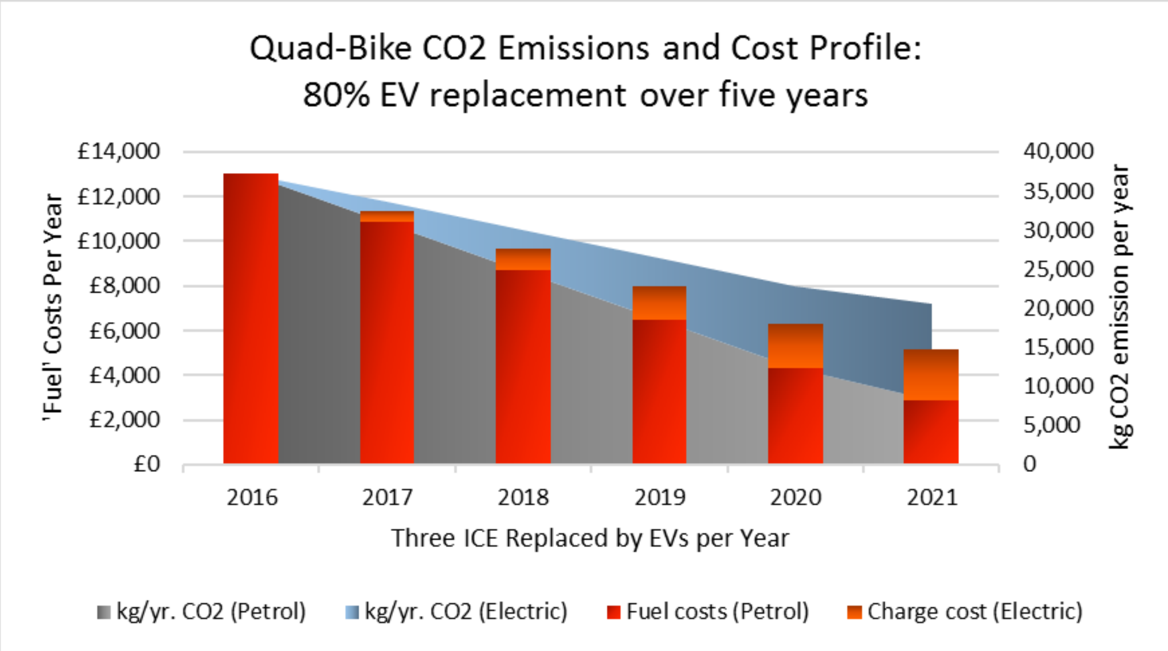


Figure 27 - Quad-Bike ICE-EV Replacement Scenario

NRW have relativity low quad usage, however electric quads still result in annual fuel cost savings of circa £550 per quad. Typically, an electric quad cost £2000 more than a petrol equivalent (Eco-Charger EV Eliminator 4x4 model[32]). Therefore, payback is achieved in around 3.5 years (excluding any maintenance cost savings) as shown in the table below.

Item	Additional Purchase Cost of Low Emission Option	Annual Fuel Savings	Simple Payback Period (years)
Electric Quad (EV Eliminator 4x4)	£2000	£550	3.6

Table 40: Quad replacement scenario simple payback estimate

Cenex were advised that a battery pack replacement is £1,500 and when used daily[33] and battery packs can last up to 5 years. Typically, the battery packs for these quads consist of multiple battery units (up to 6 depending on variant). It is unlikely that all battery packs would need replacing at the same time. Replacing one battery a year after the first three years of operation is more likely. Therefore, we can assume that as a minimum **an electric quad can be operated at around £550 lower TCO to a petrol quad**, but it is likely that the light battery use of the NRW operational cycle will allow longer battery life allowing further savings to accumulate. If this proves to be true, the actual payback period will be less than that indicated (i.e. savings to NRW fleet operations will be even greater than indicated).

[32] http://www.ddc-wales.co.uk/creo_files/upload/documents/alternative_fuel_vehicles_cropped.3.pdf

[33] EcoCharger indicate this based on a six hour day with a 30 minute rapid charge in the middle of each day, five days a week.

20.2 Scenario B – Mature Technology Demonstration Scenario

Scenario B shows potential savings of adopting mature technologies around a single, hypothetical, depot. Analysis of the distribution of equipment in detail reveals that selecting a single 'representative' depot to reflect the entire NRW fleet was not possible; due to the large variation in numbers and types of plant kept at the various depots. Therefore, we have based the numbers of plant on the median average numbers across the NRW depots. The number and type of plant in the hypothetical depot scenario is shown below.

Typical plant sizes and operational hours have been selected, as shown below.

Plant	Number of Units	Purchase Date	Engine Size (Litres)	Annual Operational Hours
Quad Bike	1	2003	0.45	200
Chipper	1	2006	1.8	600
21t excavator	1	2007	5.9	300
13t excavator	1	2007	2.9	300
Telehandler	1	2007	4.2	50
Mower	1	2014	1.8	960
Massey Ferguson tractor	1	2006	6.6	960
John Deere tractor	1	2009	4.5	2080

Table 41: Depot scenario plant

20.2.1 Low, Medium and High Uptake Scenarios

Three scenarios are used in the depot assessment and are summarised in the table below:

Low Uptake	Medium Uptake	High Uptake
• Electric quad implemented • Excavator and tractor fuel reduction programme implemented in line with recommendations in *Section 0 Best Practice Recommendations* (incl. driver training) allows a year-on-year 2.5%[34] fuel reduction PA	• Electric quad implemented • Hybrid 21t excavator implemented • Electric chipper purchased, completes 10% of light wood chipping located close to depot/power supply • Excavator and tractor fuel reduction programme implemented in line with recommendations in *Section 0 Best Practice Recommendations* (incl. driver training) allows a year-on-year 5% fuel reduction PA	• Electric quad implemented • Hybrid 21t excavator implemented • Electric chipper purchased, completes 10% of light wood chipping located close to depot/power supply • Excavator and tractor fuel reduction programme implemented in line with recommendations in *Section 0 Best Practice Recommendations* (incl. driver training) allows a year-on-year 5% fuel reduction PA. Includes tractor mounted tyre pressure units. • Tractor, Excavator and telehandler run on B30 (assumed tank installed at depot[35]) • Two tractors mounted plant chippers (PTO was driven) replace the existing plant chipper

The scenarios include a plant fuel reduction programme are outlined in *Section 0 Best Practise Recommendations.* As discussed in section *0* training and installation costs for additional fuel saving best practice will have to be negotiated by NRW on a case by case basis with their existing suppliers. As such it Is not possible for Cenex to estimate the cost of these devices and training session and they are omitted from this high-level scenario. Fuel saving best practice includes items such as:

- Purchase, fitting and training in the correct use of fuel consumption in-cab displays wherever possible.
- Toolbox talks and end of day debriefs regularly highlight fuel saving policies.
- Environmental, employee and public health, and economic arguments for fuel saving are highlighted.
- Professional plant and attachment training for fuel efficient operation is undertaken.
- Employee and management KPIs incorporate fuel-saving and emissions reduction targets.
- Successful fuel saving initiatives are publicly rewarded.
- Vehicles operators that demonstrate a high degree of skill in fuel saving practices are promoted to fuel-saving champion, with the best operators providing fuel efficiency training to other NRW depots.

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[34] Reduced fuel saving for low uptake scenario anticipated as a result of less aggressive implementation by NRW (e.g. no cash payments to vehicle operators linked to annual fuel savings).

[35] 40,000 litre per year site requires £5,000 of installed tank and dispenser, this hypothetical depot uses 25,000 litres per year, but cost savings on the £5,000 estimate will be site specific and non-linear: Assume £4,000 for tank and dispenser in this scenario.

If alternative fuels (biodiesel for example) are to be adopted, this can be done as part of the fuel champion programme. Such emissions reduction drives will only be successful if an enthusiastic member of the depot management team, who has the authority and budget to implement biodiesel programmes, is involved.

20.2.2 Technology Trial Methodology

Managing the implementation of a new technology is generally done in the following phases.

1) Desktop study: This report falls into the category of a 'Desktop study'. The potential fleet fit, associated costs and expected performance of different fuels and powertrains are investigated through consultations with suppliers and undertaking general research. Talking to other operators of the proposed technology is one of the best methods to assess if the technology is right for your fleet. Once a preferred technology or fuel is selected, the technology is trialled in a real-world scenario. The desktop study informs the trial planning stage, helping to define vehicles most likely to be replaced with lower emission and cost saving fuel and technology alternatives. The identified vehicles are then included in the performance data gathering carried out in the trial planning phase.
2) Trial planning: Adequate systems must be put into place to gather performance data from the trial vehicle and conventional comparator vehicle/s (cost, reliability, fuel, driver/operator perception, fleet manager perception). To understand the cost and emission performance, accurately measuring fuel consumption is critical. This can either be done through recording at refuelling events or by installing telemetry. It is also critical that the trial vehicle and comparator vehicle/s operate over similar duty cycles for a valid comparison. Depending on the complexity of the equipment a trial duration between 3 – 12 months is normal. For items where requirement or performance vary by season (such as biodiesel), 12 months' trial is preferred.
3) Trial monitoring: Whilst a technology is being trialled, performance data should be analysed on a regular basis to identify any errors in the reporting systems and to understand and take remedial action of the trial vehicle is not performing as expected. Personnel should be interviewed and surveys conducted of perceptions, integration and other issues relating to the trial system.
4) Trial reporting: The results of the trial should be formally recorded and written up for future reference and circulation.
5) Implementation: Following the successful trial of an individual or small set of vehicles a pilot purchase is made, either for a low number of individual vehicles or sufficient to support a depot for a larger scale role out trial.

20.2.3 Scenario Results

The impact of the scenarios on fuel purchased and WTW CO_2 emissions are shown in Figure 28 and Figure 29 below.

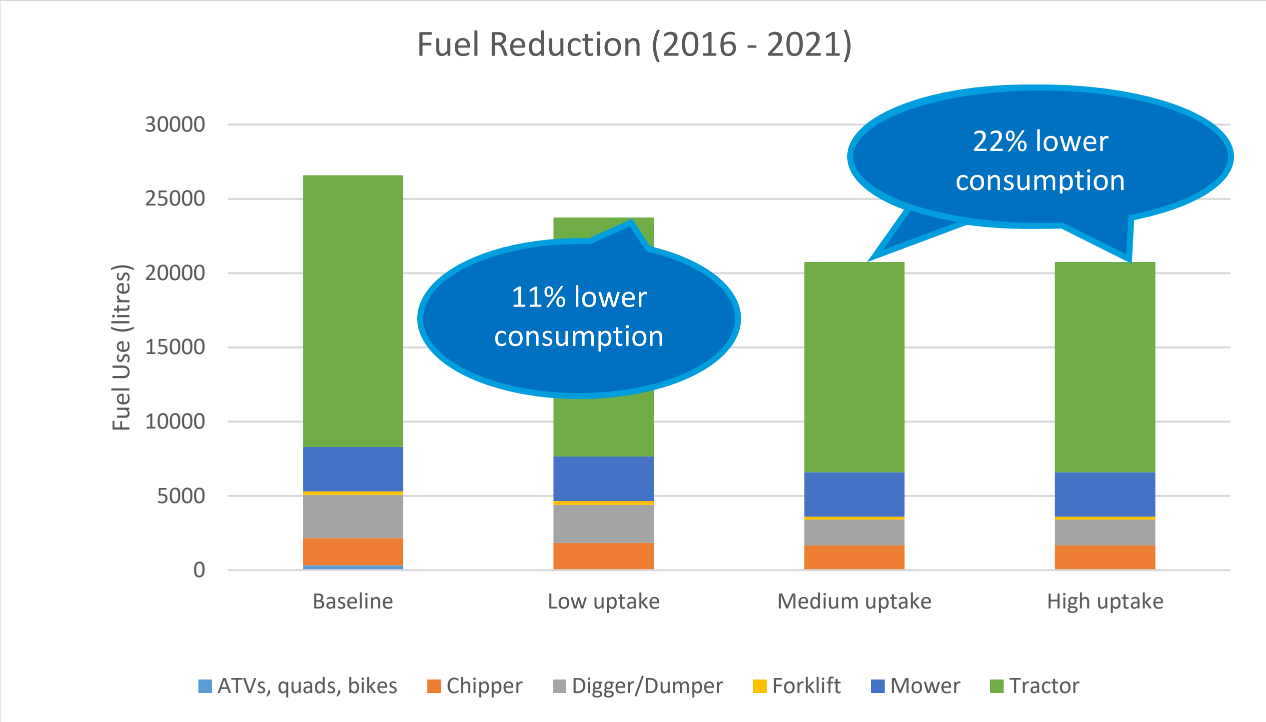

Figure 28: Depot scenario fuel reduction potential

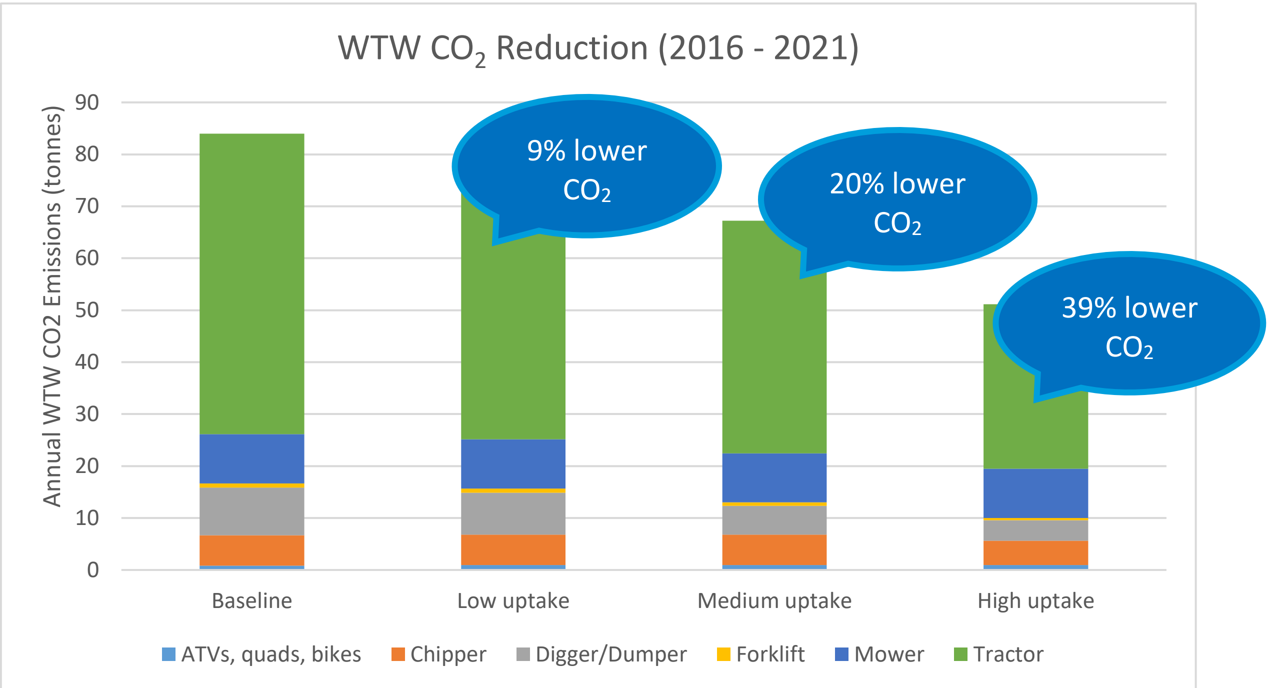

Figure 29: Deport scenario WTW CO_2 reduction potential

The depot scenarios show that for low uptake, an 11% fuel reduction and 9% WTW CO_2 saving can be achieved. The majority of the savings made are due to the fuel reduction programme, which has the best potential for cost effective savings from large plant.

In the high uptake scenario fuel consumption falls from 26,580 liters to 20,744 litres per year across the depot resulting in a 22% saving and WTWT CO_2 emissions reduce from 84t to 51 tonnes, a 39% saving which is in large part to the adoption of B30 Biodiesel. Hence why the CO_2 reduces in the high uptake scenario but there is little effect on fuel usage.

20.3 Scenario C – Technology Adoption to 2050

To eliminate emissions by 2050, NRW has asked for a 'maximum emission reductions possible' scenario to show the level of uptake required to achieve 80% emission target by 2050 [10].

- Figure 30 shows the estimated total WTW CO_2 emissions for all NRW plant fleet between 2016 and 2050. The following points provide clarity on the structure of the scenario:
    - The assumption is made that an intensive tractor and heavy plant training system is implemented in 2017/18 financial year to minimise emissions.
    - Note that at 2020, the time scale changes and the assumption is made that between 2020 and 2025; B50 compatible diesel-electric hybrids become the norm for the clear majority of plant equipment.
    - The projection assumes that NRW aggressively pursues a major fleet restructuring exercise, to replace existing plant with the new biofueled-hybrid equivalents.
    - The next major reduction in emissions is achieved between 2035 and 2040. Drop-in biofuels (such as HVO) are widely available and can be combined with sustainably generated hydrogen gas; for combustion in a dedicated or duel fuel B100-H2-hybrid powertrains.
    - It is assumed in this scenario that decarbonisation of the electricity and primary fuel supply (renewable diesel, green H2 etc.) occurs in-line with government projections and targets.

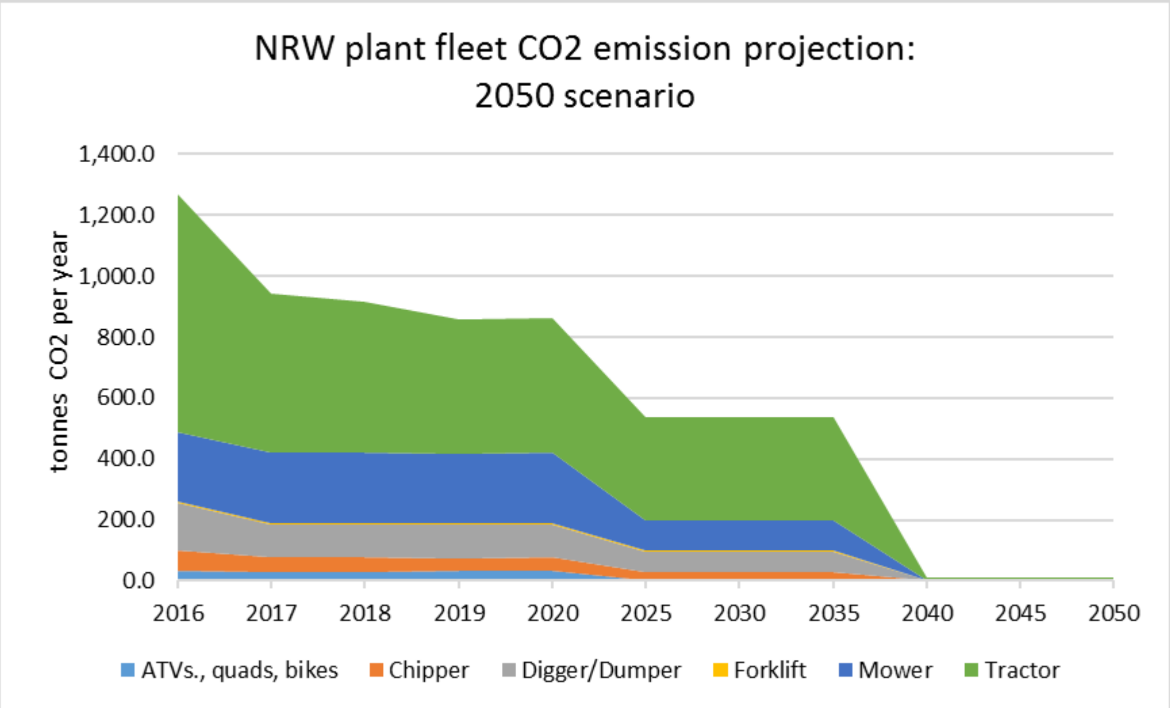

Figure 30 - NRW plant fleet - 2050 scenario

Figure 30 shows one, theoretically possible, pathway to eliminate fossil fuel use and WTW CO_2 by 2050. This requires the aggressive adoption of B50 biofuels, and the purchase of new plant that can run on such fuels, between 2020 and 2025. Then another round of aggressive technology and fuel adoption from 2040 onwards to meet the zero CO_2 emissions target. It should be noted that any strategy to eliminate fuel use by 2040 should be reassessed regularly as plant fuel and technology trends move away from direct fossil fuel use.

To achieve 80% emissions reductions targets under UK legislation, several steps are required:

- Implement low emission technologies where operationally suitable (e.g. quad bikes) starting this year (2017).
- Implement fuel efficiency programmes for drivers and operators, starting this year (2017).
- Implement a plant fleet replacement programme to comply with Stage V NRMM emission standards from 2019 (if stage V equipment is not available before this date).
- Monitor and review the development of lower carbon plant, trialling technologies which show potential to reduce emissions at similar operating costs. Implement fuel replacement with a WTW fuel that is operationally suitable after appropriate feasibility studies, fleet replacement and fuel storage strategies have been implemented. At the time of writing the most likely replacement fuels (in order of technology maturity and proven track record in sustainable WTW emissions reductions) are:
    a) Biodiesel or Renewable Diesel (i.e. HVO).
    b) Biomethane[11].
    c) green Hydrogen ICE vehicles[12].

21 Plant Summary and Recommendations

Significant opportunities for fuel cost and engine emission reductions exist within the NRW plant fleet which can be implemented now. Cenex have completed a high-level review of plant equipment operated by NRW. The 147 items considered were broken down into eight separate categories. Several key opportunities/recommendations for NRW plant fleet improvements are identified below to meet emissions reduction ambitions:

Analysis Showed	Recommended Next Steps
Tractors:	
Tractor units are estimated to consume 62% of the NRW plant fleet fuel per year. Tractor units can achieve up to 25% fuel and associated CO_2 savings through driver training. This could result in a 12% reduction in total operating costs of these vehicles.	NRW should investigate the implementation of fuel efficiency measures such as: • Fuel efficiency training with in-cab fuel monitors for drivers. • Optimised plant attachment fitting training. • Optimised tyre-pressures for operational-conditions training. • Regular staff training and assessment. • Changes to heavy plant depot day-to-day practices may be required to implement fully.
Quad bikes:	
NRW existing fleet of quad bikes emit 37 tonnes per year of CO_2. Fully electric quad-bikes are available that offer up to 45% WTW reduction in CO_2. Up to 80% quad replacement with EV alternatives could be achieved. Higher priced electric quad bikes offer a payback period of 3.5 years resulting from reduced running costs.	An operational assessment of the suitability of fully electric quads should be undertaken.
Excavators:	
NRW's existing fleet of five, 21 tonne, excavators are generally more than 10 years old (with one exception). Electric-Diesel hybrid excavators, in the 22 tonne and larger range, are available with up to 40% reduction in emissions and fuel costs.	Manufacturers claim up to 40% reduction in emissions and operating costs (for high slew rate tasks). All 21t or larger excavators in the NRW plant fleet should undergo operational assessment of slew rates, to determine if there is a business case for immediate replacement.
Forklifts and Telehandlers:	
Forklifts and telehandlers with reduced emissions are available with up to around 30% (electric-hybrid) and 50% (fully electric) WTW emission reduction.	Continue to monitor market offerings. There are no cost-effective alternatives. The very low usage rates for NRW forklifts and telehandlers make the business case for new technology replacement difficult to make. These lower emission alternatives will be more expensive to operate on a total cost of ownership basis; unless utilisation can be significantly increased. There is a CapEx premium for the purchase of all electric or hybrid vehicles. For maximised CO_2 reduction, any future purchases of forklifts and telehandlers should prioritise diesel-electric hybrid vehicles and (if ground conditions are suitable) fully electric forklifts (if the cost is justifiable).

Mowers:	
Electric mowers area available but the NRW fleet department report that mower operations, historically, have not been suited to alternative powertrain operations.	Maintain under review. NRW report that operational requirements for the existing NRW mower fleet may not be well suited to electrification. However, the grass mowing requirements at reservoirs have recently been changed, and electrification of mowers at reservoir sites may now be considered.
Bio-diesel:	
Biodiesel is a proven technology which can be implemented in the NRW fleet, but it has several key limiting factors that need considering: • Increasing biodiesel content is only compatible with certain engines; fleet operators need to ensure the maximum percentage of allowable biodiesel is not exceeded in each vehicle. • Biodiesel is typically stored on site and this has additional security and environmental considerations. • Biodiesels based vehicles require additional maintenance and servicing compared to fossil diesel equivalents. • Biodiesel made from food crops have come under increasing criticism on ethical grounds. • Quality and quantity of supply has, historically, been an issue for some biodiesel suppliers causing reliability issues. • Biodiesel can only be used where bunkering facilities are available (normally large fleet depots with sharing use with vehicles). • Biodiesel is an effective mechanism for reducing CO_2 but will normally increase fleet operational costs.	NRW should consider a more detailed assessment of biodiesel use and a trial of biodiesel within their operations which cannot be decarbonised through other means. Biodiesel facilities can be extended to include several items of plant, but the business case for the creation of biodiesel infrastructure and economic supply will be highly reliant on tractor operations to create sufficient fuel demand, with excavators being a contributing factor. Fingerpost, Pont-y-Garth and Rhuddlan depots should be assessed for the implementation of biodiesel (engine compatibility is critical). **Success of biodiesel projects will be dependent on a depot based champion with the knowledge, skill, and authority to drive the changes through and successfully.**
Diesel Plant Replacements	
Much (51%) of the NRW plant fleet is at least 10 years old. All new NRMM purchases will have to be Stage-V emissions compliant from 2019 or 2020 onwards depending on engine size (assuming the UK adheres to pre-existing EU legislative plans). Modern plant engines offer improved fuel efficiency and emission improvements of approximately 15% compared to 2006 and older engines.	Update fleet replacement schedules to accelerate compliance with Stage-V NRMM, emission standards for all plant engines to reduce overall emissions and running costs. Some plant units may be well suited to end-of-life retrofits of alternative fuels and powertrains. These should be considered as technology demonstration projects prior to wider fleet roll out.

Alternative hydrocarbon fuels	
Alternative hydrocarbon fuels: methane, propane and wide variety of other carbon-hydrogen based fuels can be utilised for plant operations. Typically, those elements in the NRW fleet that are well suited to alternative fossil fuels (LPG, CNG) do not perform enough operational hours per year to justify the changeover.	Many of these are growing in availability as bio-derived alternatives (e.g. bioLPG, biomethane). The use of a bio-fuel is very effective at reducing WTW CO_2. NRW should continue to monitor the development of bio-gas fuels and technologies with a view to trialling the technology when an economic plant and infrastructure provision is available. There are new technical developments for tractors and excavators that may warrant demonstration trials for bio-CNG technologies at NRW sites. These could be considered by NRW as non-economic technology demonstration projects in the shorter term.

The actions in the table above can be summarised into an action plan as below.

Step 1 – Undertake detailed technology assessment

- The high-level review highlighted that emission savings at similar or better TCO could be available from interventions such as implementing fuel efficiency measures and driver training, investigating the performance of diesel-hybrid excavators in the NRW operations, implementing electric quads, electric mowers (for reservoirs) and the implementation of biodiesel blend into compatible plant machines. All these options should be subject to a more detailed review and trialled where necessary. Part of this detailed review should assess if the utilisation of assets can be increased, which would assist in the pay back of alternative technology options.

Step 2 – Implement fuel saving technologies

- Following a more detailed review and successful trial of Step 1 technologies above, NRW should set a technology implementation plan. Where low emission plant alternatives are not available or uneconomic NRW should include a plant fleet replacement programme to comply with Stage V NRMM emission standards from 2019 (if Stage V equipment is not available before this date).

Step 3 – Continue to monitor technology availability

- NRW should continue to monitor low emission plant options to take into account new product offerings on an annual basis. For example
    - Electric and hybrid plant products are expected to continue to mature and reduce in costs which will aid the business case.
    - Biofuels such as biomethane, bioLPG and renewable diesel (i.e. 'drop-in diesel' fuels fully compatible with manufacturers engines and warranties) are expected to be more widely available in the market place over the next 1 – 5 years.

22 References

These references are for the plant section only. The fleet section references are in footnotes.

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