The Case for **Repowering Refuse Collection Vehicles** from Diesel to Electric

MAGTEC
ELECTRIC VEHICLE DRIVES

ROYAL borough of GREENWICH

dg:Cities

Introduction to the ERCV Project

In 2017, a consortium of partners comprising Magtec, the Royal Borough of Greenwich, and DG Cities Limited, secured funding from Innovate UK (the UK Government's innovation agency) to repurpose and trial a 26-tonne end-of-operational-life diesel Refuse Collection Vehicle in Greenwich.

Diesel Refuse Collection Vehicle (RCVs) emissions contribute to poor air quality, increased noise pollution, and other problems within the city. The **Repowered Electric Refuse Collection Vehicle Project** (ERCV Project) seeks to address these problems. It involved repowering a diesel RCV to an electric drive train and electric actuators for its hydraulic systems and demonstrating that this is technically feasible. The vehicle was also fitted with a new body to maintain overall usability and increase durability of the end-of-life vehicle. This is the first example of a repowered zero-emission RCV in the world.

By electrifying an end-of-life diesel RCV, a number of benefits are anticipated. These include: a reduction in air pollution from diesel emissions; reduced noise pollution; and reduced resource consumption by the repowering of an end-of-life asset. By repowering end-of-life diesel RCVs, waste service providers and local authorities have the option of introducing zero-emission vehicles to reduce greenhouse gas (GHG) emissions over diesel fleets on current grid-electricity generation mix.

Operational trials of the vehicle will commence in the Royal Borough of Greenwich in July 2018. The repowered ERCV will operate on routes around Greenwich on double-shifts to test how it performs and how the available payload is maintained, compared with current diesel models.

What has been carried out?

- This project has completed the first conversion of a full-size 26-tonne Refuse Collection Vehicle from diesel to electric power, a world first.
- The repower has extended the life of the used vehicle.

What will be shown in the trials?

- The capability of the ERCV to work a two-shift daily duty cycle without recharging and without a loss of available payload.
- The reduction of operating costs as a result of the electric repower.
- The reduction in harmful air pollution and noise levels as a result of replacing a diesel RCV with an electric RCV.

This paper provides an overview of the anticipated benefits from a conversion of a diesel engine to an electric repower and the reuse of an end-of-life asset. These are discussed in the following structure:

1. **RCV Cost Comparison**
2. **Fuel and Technology Savings**
3. **Impact on Emissions**
4. **Impact on Noise Reduction**
5. **Reduced Resource Consumption**

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The project consortium includes Magnetic Systems Technology Ltd (Magtec), the Royal Borough of Greenwich, and DG Cities Limited.

Magnetic Systems Technology is the UK's largest and longest established manufacturer of drive systems for electric commercial vehicles. It has supplied complete electric vehicle drive systems to Original Equipment Manufacturers in the UK, Europe, USA and China. Magtec has developed highly efficient high-power density motor technology that has been applied to Electric Vehicle (EV) drivetrain in various heavy-duty vehicles. These include: single-decker (re-power and new build) and double decker buses and trucks.

The Royal Borough of Greenwich (RBG) is one of 33 local authorities in London and is internationally renowned for its work in city innovation and its strong commitment to environmental sustainability. RBG directly manages and operates a mixed fleet of 600 vehicles, which it supports through a 20-bay vehicle engineering facility. RBG currently owns and operates 40 full size (26T) RCVs and 3 smaller (12T) vehicles. The Royal Borough of Greenwich's commitment to innovation, improving air quality, and the environment, combined with the areas' complex and varied urban location makes Greenwich ideally suited to run the first operational trails of a repowered ERCV.

DG Cities Ltd (DGC) is an Urban Innovation Company that specialises in the development and implementation of smart city approaches. It utilises advances in technology and data analytics to reduce pressures on city infrastructure, services, and the environment. A subsidiary of the Royal Borough of Greenwich, it has played a prominent role in establishing Greenwich as one of the UK's leading smart cities. In this project, DGC is undertaking research and development by supporting the trial and analysing the vehicle's performance, efficiency and environmental impact.

Background

In November 2017, the Mayor of London, Sadiq Khan, introduced plans to create an Ultra-Low Emissions Zone (ULEZ) in Central London. Effective from April 2019, the ULEZ is projected to affect up to 60,000 vehicles a day and dramatically reduce harmful air emissions. The ULEZ will replace the Toxicity Charge (T-Charge) currently in place in Central London. The T-Charge deters the use of older, more polluting vehicles and encourages walking, cycling, and using public transport. The ULEZ builds on this, being in place 24/7, all year round whilst the T-Charge is only active during weekdays.

In adapting to new regulations and charges, Local Authorities and service providers will need to adjust their existing fleets to become ULEZ-compliant and absorb higher costs. In the case of RCVs, many Local Authorities in Central London will have to replace existing RCV fleets with newer, more compliant fleets of Euro VI standard RCVs before the ULEZ becomes effective. The measures introduced in London are likely to be replicated in other cities in the UK and beyond. In addition, many local authorities are already committing to measures that address poor air quality.

Across the UK, additional pressures are being felt in the UK Waste Management sector. Local Authorities (acting as Waste Collection Authorities, Waste Disposal Authorities, or Unitary Authorities) are responsible for the collection and/or disposal of all domestic and a substantial portion of commercial waste. In accordance with the Proximity Principle, waste is disposed close to the point of generation, requiring mass transportation using heavy-duty vehicles to collect all waste and transport it to local sites. As part of wider EU policy, there is increasing movement to incentivise usage of recyclable and compostable material. This must also be collected and transported using large Refuse Collection Vehicles' that have been specifically adapted to carry large loads and run two daily cycles.

RCVs are primarily diesel-powered [1], resulting in considerable emissions of CO2, NOx and particulate matter into the local environment that negatively impact human health. Levels of pollution attributable to RCVs are also increasing as demand for Refuse Collection Vehicles has continued to rise over recent years. In the UK, in 2017, demand for refuse trucks increased by more than 20%.[2] This is in contrast with many other heavy-duty vehicles, where usage declined over the same time period.

The pollution problems are exacerbated by the nature of a diesel RCV. A 26-tonne diesel RCV operating in an urban environment has a fuel consumption of between 2.5 and 4.5 mpg.[3] RCVs typically operate a duty cycle on residential streets, driving at low speeds, idling and revving to operate the equipment to empty the bins or compact the waste. This exposes local residents to elevated levels of pollution at their front door. Furthermore, the layout of many city streets creates a canyon effect where the pollutants remain at street level instead of being dispersed by natural ventilation.[4]

With the latest EU, national, and local regulations continuing to limit diesel-powered vehicles within urban areas, such as London, alternatives such as electric and hydrogen vehicles are being developed at an increasingly rapid rate. However, new electric and hydrogen vehicles are still not widely available, especially for bespoke vehicle types such as RCVS. They are also expensive in comparison to a standard diesel vehicle. For many waste management authorities this is an additional expense that, in the current economic climate, is very difficult to absorb. This makes the ERCV Project particularly relevant.

This project offers a solution, providing an affordable, zero-emission RCV option for operators and local authorities. With every Local Authority utilising Refuse Collection Vehicles, it is of interest to Local Authorities and service providers who wish to explore alternative Refuse Collection Vehicle options in order to save costs and create a healthier environment.

[1] Other low and zero-emission fuel options being: diesel hybrid, natural gas, fuel cell, and battery. This project is repowering a diesel RCV to zero-emissions using battery technology.

[2] SMMT News, 'UK HGV Market Declines in 2017 but Demand for Artics and Refuse Trucks Bucks Trend'; 12 February 2018. SMMT News. https://www.smmt.co.uk/2018/02/uk-hgv-market-declines-2017-demand-artics-refuse-trucks-bucks-trend/

[3] Based on the Royal Borough of Greenwich's fleet.

[4] WSP, 'City Air Quality at Height – Lessons for Developers and Planners'; 2017; http://www.wsp-pb.com/PageFilesn/80156/WSPPB%20City%20Air%20Quality%20at%20Height.pdf

Refuse Collection Vehicle Cost Comparison

Stakeholders who operate RCVs (Local Authorities or service provider companies) have five options when purchasing or operating a vehicle:

1. **Option 0:** a current, non-regulatory compliant diesel RCV incurring Toxicity Charge (specific to London)
2. **Option 1:** a diesel RCV retrofitted with Selective Catalytic Reduction (SCR) to become regulatory compliant;
3. **Option 2:** a new diesel RCV that is designed to be regulatory compliant;
4. **Option 3:** a repowered an end-of-life diesel RCV to an electric RCV;
5. **Option 4:** a buy a new electric RCV

The following figures (Table 1) show that there is a potential cost-saving for a prototype repowered ERCV, when compared with the diesel options (Options 0, 1, and 2). The figures are for the total lifetime of each vehicle – an average of seven-years – and cover both upfront fixed costs and variable costs over the vehicles lifespan. They are estimates and may vary depending on vehicle, fleet, and duty cycle. Option 4 (buying a new electric 26-tonne RCV) is commercially sensitive and no accurate projected costs are available at this time.

Option	Description	Total Cost of Ownership Over 7-years*
Option 0	Diesel RCV with London Congestion Charge	£601,000
Option 1	Refurbished diesel RCV with SCR	£332,000
Option 2	Emission compliant new diesel RCV	£366,000
Option 3	Refurbished and repowered to electric RCV	£299,000
Option 4	New electric RCV	To be determined

Table 1: Prototype Pricing Estimates for RCV Lifetime Costs - *Number rounded to the nearest 1000 to showcase the approximate pricing of each vehicle option.

Combined with the environmental and social benefits of a zero-emission heavy duty RCV (section 4), there is a strong case for the use of repower technology in end-of-life Local Authority and service supplier fleets. Phase 2 of this project will provide the data for a more detailed analysis that will take account of information including the discounted costs and benefits of repowered solutions, and the market value of carbon offsets.

Environmental and Social Benefits

Environmental and socio-economic benefits of the ERCV repower are reasoned to be multiple and wide-ranging. The following section explores the potential benefits to the environment, society, and the economy, from electrifying and repowering an RCV.

Fuel and Technology Savings

Running an electric RCV will offer significant financial savings in fuel. This differential is likely to increase given the expectation that diesel will become increasingly expensive over time.[5] The complexity of diesel engines means that additional ancillary systems are required to keep NOx emissions low. These systems are expensive to purchase and maintain and reduce the fuel economy of the vehicle. The UK Department for Energy and Climate Change predicts average fuel prices to increase by more than 22% from 2012-2030[6] , whilst other projections see prices continuing to rise in the near-term.[7] The UK and the majority of major powers are committed to reducing GHGs in line with the Paris Agreement of 2015. Taxes on fossil fuels are likely to further increase the price of diesel and petrol for vehicles over time, in line with these targets. Therefore, there is a significant financial benefit to adopting electric vehicles to avoid additional operating costs in the future.

Although exact savings are difficult to quantify, investment in new, electric technology for powering vehicles (such as ERCVs) is likely to be a long-term, cost-saving venture.[8] The initial electric infrastructure costs may also become lower as battery power, charging, and renewable energy plants become more advanced.[9]

Furthermore, the stop-start nature of refuse collection is ideally suited to an electric vehicle, with the braking motion enabling recharging of the battery. A case study of one company estimated that they could produce savings of up to 100,000 litres of fuel a day for their 800-vehicle fleet.[10] These fuel savings would result in significant financial savings for waste management authorities, particularly if prices continue to rise.

Zero Emission Benefits

Reducing carbon emissions from vehicles is essential in aiding the UK in mitigating one of the causes of climate change. Vehicle carbon emissions are a major contributor to global warming and anthropogenic climate change, with emissions acting as a potent greenhouse gas. This causes the earth to retain imbalanced proportions of radiation from the sun, leading to a global rise in temperatures. Climate change will have a substantial impact on the economy, environment, and society due to extreme weather events and mass migrations. This is predicted to result in global losses in productivity and biodiversity. Avoiding temperature rises upwards of 1.5°C is therefore a priority of the majority of the world nations, demonstrated by their commitment to the 2015 Paris Agreement.

It is estimated that repowering an end-of-life diesel RCV to be electric will prevent 287-tonnes of carbon emissions from entering the atmosphere per year of operation. This can be translated into a financial savings of around £5,100, per ERCV, per year.[11] When spread across an entire fleet of RCVs the savings can have a considerable impact on the associated carbon emissions.

Diesel RCVs emit unburned hydrocarbons, carbon monoxide, nitrogen oxides, sulphur oxides, particulate matter, and other toxic compounds. RCVs have been found to emit these toxicities at a significantly higher concentrations than smaller vehicles. The higher concentration, combined with the nature of an RCVs operation (frequent stops and low speed in residential areas) results in a greater exposure of these toxins by pedestrians and local residents in comparison to other road vehicles. Such emissions have a negative impact on human health, increasing risk of asthma, lung problems, and premature death. A study by King's College London estimated that there were over 9,400 premature deaths due to long-term exposure to NO2 and Pm2.5.[12] Reducing emissions in the local urban area is therefore a priority to ensure all urban citizens can lead a healthy and long life.

Noise Reduction Benefits

As well as reducing air pollution, electrification of refuse vehicles will also reduce noise pollution, as electric motors are significantly quieter. As well as improving quality of life for the everyday citizen, this also will enable an extension of working hours for refuse collection, with the vehicle able to operate during off-peak hours without causing duress to citizens. Efficiency savings could be made by operating the vehicle during the early morning hours, when there are less cars on the road and the majority of the population are in bed. As well as reducing collection times, this would also reduce delays to other drivers, freeing up roads and preventing blockages for commuters and other transportation vehicles during peak morning and evening rush hours.

The Benefits of Reduced Resource Consumption

Using an end-of-life diesel RCV and repowering it for an electric drivetrain and hydraulic system optimizes an expensive asset and has wider environmental benefits. It reduces waste by extending the life of the vehicle as well as having multiple environmental benefits of reuse, rather than scrappage. A circular economy is an alternative to a traditional linear economy (make, use, dispose) where resources are in use for as long as possible, the maximum value is extracted whilst in use, and then products and materials are recovered and regenerated at the end of each service life.

Concepts such as the circular economy are becoming increasingly important, and there is growing awareness of the need to reduce waste, maximize re-use and increase recycling. Repowering a diesel RCV builds on this concept, helping to reduce waste and drive greater resource productivity.

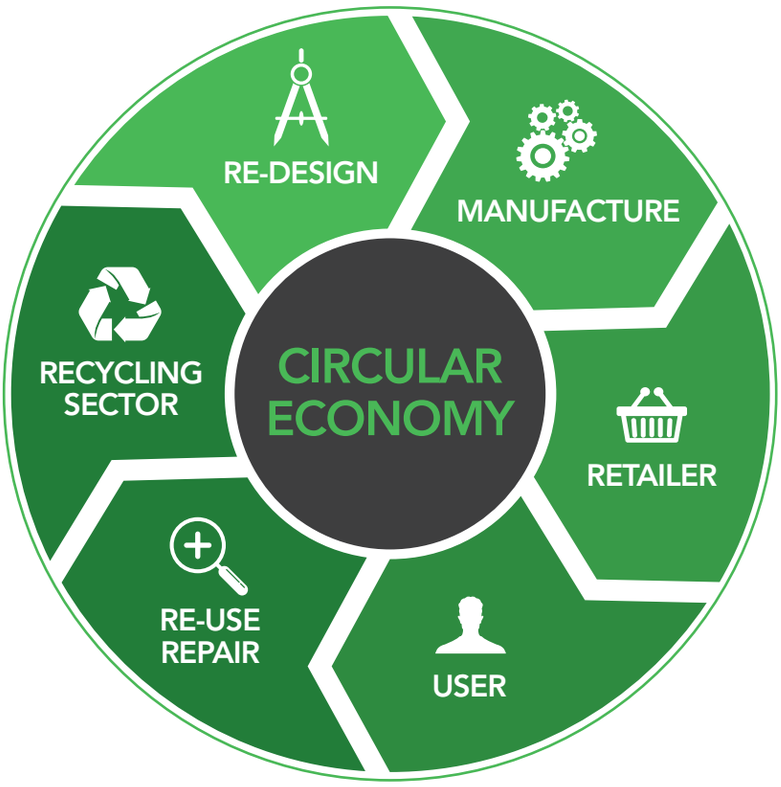

Figure 2: Diagram of how the Circular Economy Works

[5] https://www.independent.co.uk/news/business/news/uk-petrol-prices-high-three-years-unleaded-per-litre-motorists-car-costs-a8140066.html

[6] Department of Energy and Climate Change, 'DECC Fossil Fuel Price Projections'; July 2013; DECC; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/212521/130718_decc-fossil-fuel-price-projections.pdf

[7] Walter, Stephen, 'RAC Warns Good Times of Lower Cost Fuel Appear to be over as Prices Reach Three Year High'; 4 January 2018; The Telegraph; https://www.telegraph.co.uk/news/2018/01/04/rac-warns-good-times-lower-cost-fuel-appear-prices-reach-three/

[8] Perchard, Edward, 'Electric Wheels: A Future Without Petrol for Waste Collection Fleets?'; 20 February 2018; Resource Magazine; https://resource.co/article/electric-wheels-future-without-petrol-waste-collection-fleets-12418

[9] Perchard, Edward, 'Electric Wheels: A Future Without Petrol for Waste Collection Fleets?'

[10] Nickels, Tom, 'Bringing Electric Trucks to New Zealand'; Pure Advantage News; http://pureadvantage.org/news/2017/02/02/bringing-electric-trucks-new-zealand/

[11] Hirst, David, 'Carbon Floor Pricing and the Price Support Mechanism'; 8 January 2018; House of Commons Briefing Paper No. 05927. P.8

[12] Mayor of London, 'Health and Exposure to Air Pollution'; 2018; https://www.london.gov.uk/what-we-do/environment/pollution-and-air-quality/health-and-exposure-pollution

Conclusion

The ERCV project has successfully repowered an end-of-life diesel RCV into a zero-emission electric RCV. From July 2018, the project will trial the repowered ERCV on residential streets in Greenwich, to assess the economic, social, and environmental benefits gained from conversion. By repowering RCVs, Local Authorities and waste management services are offered a viable, financially secure option to significantly reduce air pollutants such as NOx, CO2, PMx, in their diesel fleets on the current grid-electricity generation mix.

The expected benefits from converting current diesel RCV fleets into repowered electric RCVs are financial, social, and environmental. The cost of converting of an existing RCV is less than alternative diesel RCV purchase options. Using an electric repower to collect waste reduces the noise pollution in residential neighbourhoods. It also has the potential to extend the operational hours of the vehicle enabling it to be operated during off-peak hours. An ERCV would replace the toxic emissions from its diesel counterparts with zero-emissions, reducing residents' exposure to emissions, helping to improve the local air quality. It would also significantly contribute to reductions in carbon emissions from the transportation sector. This sector is a contributor to dangerous levels of anthropogenic global warming which is resulting in our changing climate.

The consortium is proud to have successfully repowered a diesel RCV to an electric RCV. The trials will offer an exciting opportunity to test out this new technology in a real-world context. A follow-up project will build on this projects' innovation and explore the scalability of the technology and the plausibility of fleet integration.

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