Urban Foresight

Shuttle Buses

Zero Emission Bus Market Transition Scheme

STREAM 1 REPORT

Contents

Introduction

This project has been completed as part of stream 1 of the Zero Emission Bus Market Transition Scheme (ZEBMTS) which is funded by Transport Scotland and administered by Energy Saving Trust. The scheme aims to assist SME bus and coach operators understand the steps required in transitioning to zero-emission vehicles. This would provide a basis for the application of potential ScotZEB Phase 2 application in Spring 2023.

Stream 1 of the scheme is aimed at supporting individual bus and coach operators in assessing the zero-emission technology that would best suit their business and how this may be implemented.

This report presents the options available to Shuttle Buses in the transition to a zero-emission fleet. The recommendations have been established through the completion of a high-level total cost of ownership (TCO) analysis of the existing fleet and the most suitable transition options. The results of this will provide a baseline of potential operational savings of transitioning.

Due to the availability of indicative costings for vehicles and infrastructure, all cost recommendations are high-level. Shuttle Buses has been provided with the full analysis of its fleet which can be altered following the acquisition of fixed costs.

Current context

Decarbonisation

Buses and coaches have a vital role to play in a variety of sectors across Scotland. By increasing the number of journeys carried out on zero-emission buses and coaches, congestion on roads and air quality issues could be improved. In 2021, the Scottish Government published a report which looks at the decarbonisation of road transport. Two main targets within this report focus on the decarbonisation of buses in Scotland:

- End the sale of fossil fuel buses by **2025** and begin a retrofitting program for the installation of zero-emission technology in older buses.
- All buses manufactured from 2015 must be scrapped or repowered by **2030**.

Operational activities

Shuttle Buses is one the largest SME bus operators in the west of Scotland. With a workforce of over 60 employees, they provide reliable, high-quality bus and coach services throughout Ayrshire.

Shuttle Buses provides a range of services from traditional service contracts to private hire coach tours. With a fleet of roughly 50 buses, operations include a demand-responsive transport (DRT) service transport for elderly and disabled people and those without a local bus service.

Service routes include:

- Kilwinning to Stewarton
- Largs
- Kilmarnock
- Whitehirst Park to Irvine
- Cumnock
- Galston

Having already received funding from ScotZEB Phase 1 to purchase its first electric buses, they are keen to take this a step further through the introduction of additional zero-emission buses.

Existing fleet requirements

Shuttle Buses currently has 49 vehicles within its fleet. These range from smaller 16-seater minibuses up to 70+ seater coaches. Vehicles are used for a mix of work, depending on the passenger and route requirements. For example, the smaller buses are predominantly used for DRT services in areas that have smaller roads.

Table 1 shows a breakdown of Shuttle Buses' current operational activities.

Table 1 Shuttle Buses' operational activities

Average annual mileage per vehicle	32,985 miles
Average annual fuel cost per vehicle	£20,000.00
Average lifetime cost per vehicle	£350,000.00

The UK Government has recently published new guidance for electric and alternatively fuelled heavy goods vehicles. This states a two-tonne increase for electric vehicles and a one-tonne increase for other alternatively fuelled vehicles[1]. If this guidance is further employed for buses and coaches, this could equate to a boost in the manufacture of better-suited passenger vehicles with luggage capacity.

Technology requirements & availability

Available technology options

Technologies considered

Electric (EV)

Plug-in electric vehicles make use of batteries to power a motor. They, therefore, produce zero tailpipe emissions. Electric vehicles are 'refuelled' similar to other battery-powered devices through a charging cable. Charging capability ranges from 3.6kW up to 350+kW.

Electric vehicles have become increasingly prevalent in the zero-emission market in recent years. There are three types of electric vehicles for purchase at present – battery electric, hybrid, and plug-in hybrid. Hybrid vehicles utilise petrol to power the electric motor rather than electricity.

Consistent advancements in technology mean batteries are becoming smaller. Therefore, weight has decreased over time while the range has increased. This has increased the number of electric options entering the larger vehicle market. As it is possible to install private electric vehicle infrastructure, this has meant decreased time visiting fuel stations as vehicles can be recharged at home.

Pros	Cons
• Widespread public charging is available • Zero emissions at the tailpipe • An increasing number of models available • Lower maintenance costs than ICE	• Increased refuelling time • More expensive than ICE vehicles • Reduced mileage range compared to ICE • Expensive grid upgrades may be needed

Hydrogen

Hydrogen is an alternative fuel option for vehicles and produces zero tailpipe emissions. Hydrogen vehicles make use of a fuel cell in which chemical energy is converted to mechanical

[1] GreenFleet 2023. Weight-limit increase for alternatively-fueled and electric HGVs

energy by burning hydrogen. This then powers an electric motor. Although zero emissions are produced at the tailpipe of a hydrogen vehicle, the environmental impact of hydrogen varies depending on the generation method.

- Grey hydrogen – Created through natural gas extraction which produces and emits carbon dioxide. Grey hydrogen is the most common form of generation in the UK.
- Green hydrogen –Generated through electrolysis. This process electricity (renewably generated) to split the hydrogen and oxygen from water. Green hydrogen is the cleanest production method.

Hydrogen vehicles can travel around 300 miles on a single tank, however, refuelling stations are not readily available in the UK and the technology is expensive.

Hydrogen fuel cell electric (HFCEV)

As the name states, hydrogen-electric combines both hydrogen and electric technologies to reduce vehicle weight and increase mileage. Theoretical analysis shows that hydrogen-electric technology would be best suited to heavy goods vehicles and could extend ranges to 500+ miles.

HFCEVs can be refuelled using hydrogen facilities. This type of fuel is in its infancy at present and only a small number of trials are being carried out, primarily by energy companies. The technology is similar to a hybrid electric vehicle where petrol or diesel is used to produce electricity.

There are currently three hydrogen refuelling stations in Scotland – in Orkney, Aberdeen, and Edinburgh – and over 2,400 public charge points[2]. Due to the limited infrastructure, vehicle manufacturers still hesitate to produce vehicles at scale as they do not see the demand.

Pros	Cons
• Mileage range comparative with ICE • Only water vapour emitted • Weight load is lighter than electric and 14 times lighter than traditional petrol	• Refuelling infrastructure availability • More expensive than ICE and electric • Fewer vehicle options are available • Expensive and not as easily installed as electric • A variance in hydrogen production methods

Technologies not considered

Biodiesel

Biodiesel is a variety of diesel fuel which is derived from plants or animals. It is typically manufactured from domestic vegetable oils, animal fat, or recycled oil from restaurant cooking. The most common type of biofuel is hydrotreated vegetable oil (HVO). This type utilises hydrogen at high temperatures and pressures to treat vegetable oil and create a fuel similar to diesel. This type of fuel is only a suitable replacement for diesel vehicles.

This fuel has not been considered due to its higher cost than traditional diesel and because it is not a zero-emission fuel. Emissions are still produced by burning biofuel. It is, a preferable alternative to conventional diesel but can still contribute to emitting CO2 emissions.

[2] ChargePlace Scotland (2022) Accessing the network

CNG and LNG

Compressed natural gas (CNG) is currently the cleanest fossil fuel on the market and, like biodiesel, is an eco-friendly alternative to diesel. CNG is typically generated by compressing methane to less than 1% of its original volume.

Liquified natural gas (LNG) is the liquid form of CNG. LNG also takes up less storage space than CNG. For example, after processing, 1m³ of fuel equates to 100m³ of CNG and 600m³ of LNG. However, at present, the process to create CNG and LNG is timely and complicated.

CNG and LNG have not been considered part of this project as they are not fully zero-emission at the tailpipe. Moreover, refuelling options for both CNG and LNG are low. This may partially be due to the temperatures they need to be stored at, -162°c.

Engagement with stakeholders

Vehicle availability

Project engagement commenced with a desk-based review of the zero-emission bus and coach market and the vehicles that are available to purchase at present. Vehicle manufacturers and dealerships were then contacted to gain a wider understanding of the vehicles that may be entering the market and their suitability for Shuttle Buses' operations.

Over 20 vehicle manufacturers and dealerships were engaged in this process and seven attended individual engagement sessions to detail their current and future plans for zero-emission buses and coaches. Engagement sessions were carried out with the following:

- ADL (Alexander Dennis)
- Daimler (Mercedes)
- EVM UK
- Pelican (Yutong)
- Stanford Coachworks
- Switch Mobility
- Wrightbus

Of the engagement sessions held, manufacturers were positive about the growth of the zero-emission bus market. However, it was also noted that this sector is still in its relative infancy and not all available vehicles will suit all operator needs. For example, while there is a growing market for electric buses which can be used for service routes in cities there is a lack of availability in the zero-emission coach market.

Currently, battery electric technology appears to be favoured by vehicle manufacturers. This may be due to the unavailability of widespread hydrogen refuelling infrastructure compared to electric. There are currently three hydrogen refuelling stations in Scotland – located in Orkney, Aberdeen, and Edinburgh – and over 2,400 public charge points[3]. Due to this, vehicle manufacturers are still hesitant to produce vehicles as they do not see the demand at this time.

However, the longer ranges and lighter vehicle weights associated with hydrogen could be ideal for application within the bus and coach market. Vehicle weight can be especially challenging for bus operators who travel on smaller, more rural roads. Hydrogen could be beneficial for these operators and, with the appropriate provisions for refuelling infrastructure, could increase opportunities for all operators.

[3] ChargePlace Scotland (2022) Accessing the network

Infrastructure

While engagement activities were underway with vehicle manufacturers and dealerships, a review of Shuttle Buses' local distribution network operator (DNO), SPEN, was carried out. SPEN agreed to undertake a desk review of the power availability at Shuttle Buses' depot.

SPENs desk-based review noted that the transformer serving Shuttle Buses' depot does not appear to be heavily loaded and neighbouring cables also have capacity. However, to install charging infrastructure that supports the entirety of Shuttle Buses' fleet, substation upgrades will almost definitely be needed.

> "Local transformer does not appear heavily loaded and there is capacity within the neighbouring cables, however due to size of connection it is almost certain a substation upgrade will be required."

Engagement outcomes for Shuttle Buses

As noted by a number of bus operators and the Green Finance Institute and Confederation of Passenger Transport, there are four main challenges associated with transitioning a bus or coach fleet:

1. High up-front costs associated with vehicle and infrastructure
2. Residual value risks for both financiers and vehicle operators
3. Insufficient real-world operational data on the costs
4. Lack of policies associated with coaches

This project has investigated the above challenges to give operators such as Shuttle Buses a real-world perspective on what transitioning means to them and their operations. As Shuttle Buses offer a number of DRT services, they require a fleet of varied vehicle types. These vehicles also travel within community areas that are not suited to larger coaches and buses. This should therefore be considered in the transition plan.

As Shuttle Buses' operations are varied and often in local community areas, a variety of vehicle sizes are required, particularly smaller, slimline buses. The unavailability of suitable vehicles will likely mean that Shuttle Buses and similar operators will be unable to offer the same levels of service as they do at present. Additionally, the current capital cost of these vehicles could be a limiting factor.

Although Shuttle Buses is one of the largest bus operators in the west of Scotland, they are still classed as an SME. Therefore, a fleet transition must meet the needs of their operations to avoid loss of revenue or reduction in services offered.

The short-term solution may be to transition a small percentage of the existing fleet vehicles, those which are on shorter routes in locations suited to the vehicles on the market. The operational savings from these vehicles could then be used to subsidise the transition of the rest of the fleet at a later time, or over a predetermined timeframe. This will depend on the total financial savings from the initial transitions and the vehicle replacement periods.

The Road to an Electric Fleet

Vehicle and infrastructure analysis

The following vehicles have been identified and were used to carry out a total cost of ownership (TCO) analysis (see financial analysis section below) of Shuttle Buses' fleet:

Diesel	Zero-emission
• Optare Solo • Volvo (B9R, B12, B12B, B12M, B12R) • Irizar PB Scania • Volkswagen T5 • Fiat Ducato • MAN A91 • Kinglong (XMQ6120C, XMQ6130C) • Ford Transit • Mercedes (Sprinter, 921L, O.818)	• Switch Mobility e3 • Pelican Yuton Tce12 • EVM Novus • Pelican e10 • ADL Enviro 100

Of these vehicles, only four are currently Zemo certified – the ADL Enviro 100, and the Pelican Yutong Tce12, e10 and EVM Novus[4].

Infrastructure

To fully transition Shuttle Buses' fleet of vehicles, it has been established that this would require at least one charge point per vehicle plus an optional ultra-rapid charger for every ten vehicles to be used if emergency top-ups are required.

Therefore, it is recommended that up to 15 double-connection 40kW chargers, twelve 120kW, two 150kW chargers, and one 350kW charger are installed to support a full fleet transition. Alternatively, this configuration could be made up of 22 double-connection 120kW chargers, six 150kW chargers, and two 350kW chargers.

This would provide Shuttle Buses with the appropriate charging infrastructure to ensure each vehicle is fully charged prior to being used. It is also to note that public charging infrastructure may be required for longer routes that do not return to the depot or when hired out for specific purposes. Local authorities and private organisations must consider larger vehicle needs when installing public infrastructure. This will increase the likelihood of bus, coach, and HGV operators being able to transition.

Sequential charging opportunity

It is also recommended that sequential charging be utilised for the 150kW+ chargers. This allows several chargers to be connected through a single smart unit that fully charges vehicles in a sequence with no intervention. When multiple vehicles are plugged in, the unit automatically switches power to each charger when the previous vehicle battery is full. This allows multiple vehicles to be charged overnight at a higher power without needing large grid connection upgrades[5].

Although the initial investment would be higher than for fast or rapid charging units, reductions could be made on operational costs and the additional investment required for upgrades.

[4] Zemo (updated 23.01.2023) Zero Emission Bus Certificates

[5] ABB (Unknown) Electric Vehicle Infrastructure Overnight charging for electric buses and trucks

Financial analysis

A TCO analysis was carried out for each of the existing vehicles in Shuttle Buses' fleet. This was followed by two subsequent analyses of the potential transition options.

The TCO analysis takes the following information into account:

- **Vehicle costs**: the total purchase price, potential disposal price, and high-level funding. This is used to assess the potential annual cost of the fleet and compare the cost between diesel and zero-emission vehicles.
- **Operation and maintenance**: annual cost of maintenance, servicing, MOT, and tax.
- **Fuel cost**: utilises information on vehicle efficiency and tour mileage to determine the typical fuel cost of each tour.
- **Funding**: assumes the availability of funding for vehicles is up to £80,000 to reach diesel price parity and 75% of the cost of charging infrastructure, including installation and connection costs.

For a full description of the methodology used, please see appendix 1.

The findings from this analysis were used to assess the financial savings of transitioning to a zero-emission fleet – with and without potential funding. The savings made over the life of the fleet could then be used to replace vehicles when required.

Feasible Transition

The TCO analysis carried out on the zero-emission fleet transition options utilises the vehicles that are currently on the market (or are soon to enter). For example, several vehicles are in the production stages at present and will not be available to purchase right away. Table 2 shows the maximum potential savings from transitioning the 10% of Shuttle Buses' fleet.

Table 2 initial transition analysis

No. of vehicles	Years of ownership	TCO	Cost to Shuttle Buses without price parity of vehicles	Max potential savings with price parity of vehicles
5	10	Up to £2.8 million	Up to £1.2 million	Up to £860,000

Transitioning these vehicles would require the installation of four charge points at the depot. Table 3 shows the split of required infrastructure and the indicative costs for this.

Table 3 Charge points required for feasible transition

Option	No. of chargers	Total charge points	Indicitive install cost (without funding)	Indicitive install cost (with funding)
1	5	8	£105,000	£26,000
2	5	8	£165,000	£42,000

Full transition

Transitioning the remaining vehicles could be carried out at a later date by Shuttle Buses when additional vehicle models are released and savings are made from the initial transitions. Table 4 shows the potential savings a full fleet transition could offer Shuttle Buses.

Table 4 Full fleet transition analysis

No. of vehicles	Years of ownership	TCO	Cost to Shuttle Buses without price parity of vehicles	Max potential savings with price parity of vehicles
46	10	£17 million	£3.9 million	£3.4 million

Without funding to support the purchase of vehicles, it is likely Shuttle Buses will be unable to transition its fleet in time to meet net-zero targets. A full transition will also depend on the total financial savings from the initial transition and the vehicle replacement periods.

Transitioning all 49 of Shuttle Buses' vehicles would require up to 30 charge points at the depot. Due to the size of the connection required for this configuration, both scenarios also take into account the installation of a substation at £100,000. Table 5 shows the split of required infrastructure and the indicative costs for this.

Table 5 Charge points required for full transition

Option	No. of chargers	Total charge points	Indicitive install cost (without funding)	Indicitive install cost (with funding)
1	30	45	£745,000	£186,000
2	30	60	£1,120,000	£280,000

Due to commercial sensitivity, full TCO analysis can be provided to Transport Scotland upon request.

Feasibility of a step-by-step transition

Conditions

Vehicles

The TCO analysis carried out on the potential zero-emission fleet transition options utilises the vehicles that are currently on the market (or are soon to enter). For example, several vehicles are in the production stages at present and will not be available to purchase right away.

Urban Foresight recommends that Shuttle Buses transition 10% of its existing diesel vehicle fleet to continue the move to a zero-emission fleet. As stated prior, the operational savings from these transitions could then be used to subsidise the transition of the remaining vehicles.

Infrastructure

To support the transition of 10% of Shuttle Buses' fleet, private chargers would likely need to be installed at the existing depot. High-level figures from charge point providers suggest this may cost in the region of up to £165,000 for Shuttle Buses without funding.

Collaboration Opportunities

Taking a collaborative approach with other operators allows for the sharing of costs, risks, and learnings associated with the purchase of vehicles and associated infrastructure. Shuttle Buses, therefore, chose to undertake a research project through stream 2 of the ZEBMTS funding.

This stream 2 work looks to investigate the potential of creating a centre for excellence to support SME in their transition by playing a central role between manufacturers, financiers and bus operators, notably undertaking maintenance ofZEBs, offering advice on transitioning and picture of the regional demand to stakeholders. As Shuttle Buses has already transitioned a number of vehicles within its fleet, they have experience and knowledge of operating a zero-emission fleet.

Next steps required

To successfully to a zero-emission fleet, there are several steps to take and considerations to be made. These can be broken down into a three-step process focusing on vehicles, infrastructure, and people.

Vehicles

It will become increasingly important that manufacturers release additional vehicle models to ensure more operators can transition their vehicles to zero-emission. This will be particularly significant for operators that have a range of vehicle types and sizes.

To grow its zero-emission fleet, Urban Foresight recommends that Shuttle Buses looks to transition a further 10% of its fleet. To achieve this, it is important to carry out the following steps:

1. Further engagement with vehicle manufacturers of feasible replacements as outlined in the TCO tool to fully assess feasibility.
2. Obtain direct quotes from manufacturers for vehicle purchases

Recommended next steps:
Urban Foresight recommend that five vehicles are transitioned within Shuttle Buses' existing fleet. High-level costs suggest that the purchase of vehicles would require between £1.0 million and £1.7 million in capital finance. This is between £270k and £720k more than the cost of existing diesel vehicles.

Infrastructure

To support the purchase of additional zero-emission vehicles within Shuttle Buses' fleet, private charging infrastructure should be installed at the vehicle depot. We recommend investigating sequential charging opportunities to maximise site operations. Additionally, considerations should be made for public charging infrastructure in the areas of operation.

It is recommended that the following steps are carried out to assist in the installation of additional electric vehicle charging infrastructure:

1. Engage with charge point providers to obtain a full site assessment and quotation to have charging infrastructure installed at the depot as well as solar PV and battery storage to decrease costs.
2. Work with local authorities such as SPT and local councils and private businesses to have suitable public charging infrastructure installed along main tour routes.

Recommended next steps:
Urban Foresight recommends that Shuttle Buses install one of the following charge point configurations at its depot:

Scenario 1
- Three double connector 40kW chargers
- One 120kW and one 150kW charger

£105k required in capital finance

Scenario 2
- Four double connector 120kW chargers
- One 150kW charger

£165k required in capital finance

People

As zero-emission vehicles have fewer moving parts than their internal combustion engine (ICE) equivalent. Therefore, the maintenance and servicing costs of zero-emission vehicles are often lower. However, the unique components associated with zero-emission vehicles must also be considered. For example, during maintenance and servicing of electric vehicles, work on oil, spark plugs and drive belts is not necessary, but battery packs, electric motors, and regenerative braking systems will require work.

Training will likely be required for those who are maintaining and servicing vehicles as well as for drivers[6]. The following training is required for electric buses and coaches and aimed to be provided through the centre of excellence in partnership with Bus manufacturers:

- **Drivers**
  - Ensuring drivers are aware of how to efficiently use the vehicle, making use of regenerative braking to conserve energy.
- **Maintenance**
  - Upskilling staff by providing training on the maintenance of electric-specific components. This can be carried out by vehicle OEMs.
- **Depot management**
  - Providing training on safely and efficiently recharging vehicles.
  - Training is required for staff to work with high-voltage systems.
- **Operation**
  - Ensuring staff are aware of locations for opportunity charging where necessary.
  - Telematics can support this in the long term by assessing routes and mileage.

[6] Zemo (10.2022) Zero Emission Bus Guide

Appendix 1 TCO Methodology

TCO Methodology

Urban Foresight's Electric Mobility team has designed its own in-house total cost of ownership tool. This is used to assess and compare the cost of a fleet of vehicles across a variety of fuel types.

The tool allows an analysis to first be carried out on the existing vehicles within a fleet to determine the total cost of ownership before a potential transition to zero emissions. Fleet replacement options can then be established and a TCO analysis can be carried out on these vehicles using operational data from the existing fleet.

Information required

Existing fleet

To carry out the initial fleet analysis, the following information was requested from the operator:

1. Vehicle details
    a. Vehicle type, number of seats, purchase cost, residual value (where known), average age of vehicles
2. Operation and maintenance data
    a. Servicing and maintenance schedules and costs, MOT and road tax rates
3. Fuel usage data
    a. Annual vehicle mileage (or mileage per trip), vehicle efficiency (MPG), and/or litres of fuel consumed annually or per trip
4. Trip information (optional)
    a. Number of trips carried out annually (for those who provided fuel data per trip)

Zero-emission fleet

For zero-emission vehicles, the following data was gathered to compare to the existing fleet:

1. Purchase price of vehicle
    a. Including available grants and residual value
2. Maintenance and servicing costs
    a. Price per kilometre or mile of travel based on real-world data where available
3. Fuel costs
    a. Miles/kWh or kWh/km
    b. Electricity cost – split between required use of private and public infrastructure

Results of analysis

Analysis of the information provided by operators and gathered on zero-emission options allows the following conclusions to be drawn:

1. Total annual ownership cost of each vehicle (and overall fleet)
    a. Vehicle cost
    b. Operational and maintenance costs
    c. Fuel costs
2. Total lifetime ownership of each vehicle (and overall fleet)
    a. Vehicle cost
    b. Operational and maintenance costs
    c. Fuel costs

Assumptions:

The following assumptions have been made in the TCO analysis for this project:

1. Fuel costs
    a. Diesel cost determined by the average cost at the time of analysis (£1.60 per litre at time of writing)[7].
    b. Electricity cost determined to be 35p per kWh for private infrastructure and 55p per kWh for public infrastructure.
2. Private vs public infrastructure use
    a. Established through the range of the alternative vehicle option and required range per trip (e.g a vehicle travelling 300 miles with 200 miles of range will require 34% public charging).
3. Servicing and maintenance
    a. Determined to be between £0.03 and £0.10 per km from real-world data[8].

[7] Fleet News (03.2023) Regional fuel prices

[8] Ember Buses Dundee

The Catalyst, 3 Science Square, Newcastle Helix,
Newcastle upon Tyne, NE4 5TG

Flour Mill, 34 Commercial Street,
Dundee, DD1 3EJ

Registered in England & Wales No. 07705420
VAT No. 179 2207 93

E: info@urbanforesight.org

T: +44 191 814 2210

W: http://urbanforesight.org