LowCVP Low Carbon Vehicle Partnership | Connect Collaborate Influence

National Policy Outlook

Low Emission Bus Workshop – Manchester

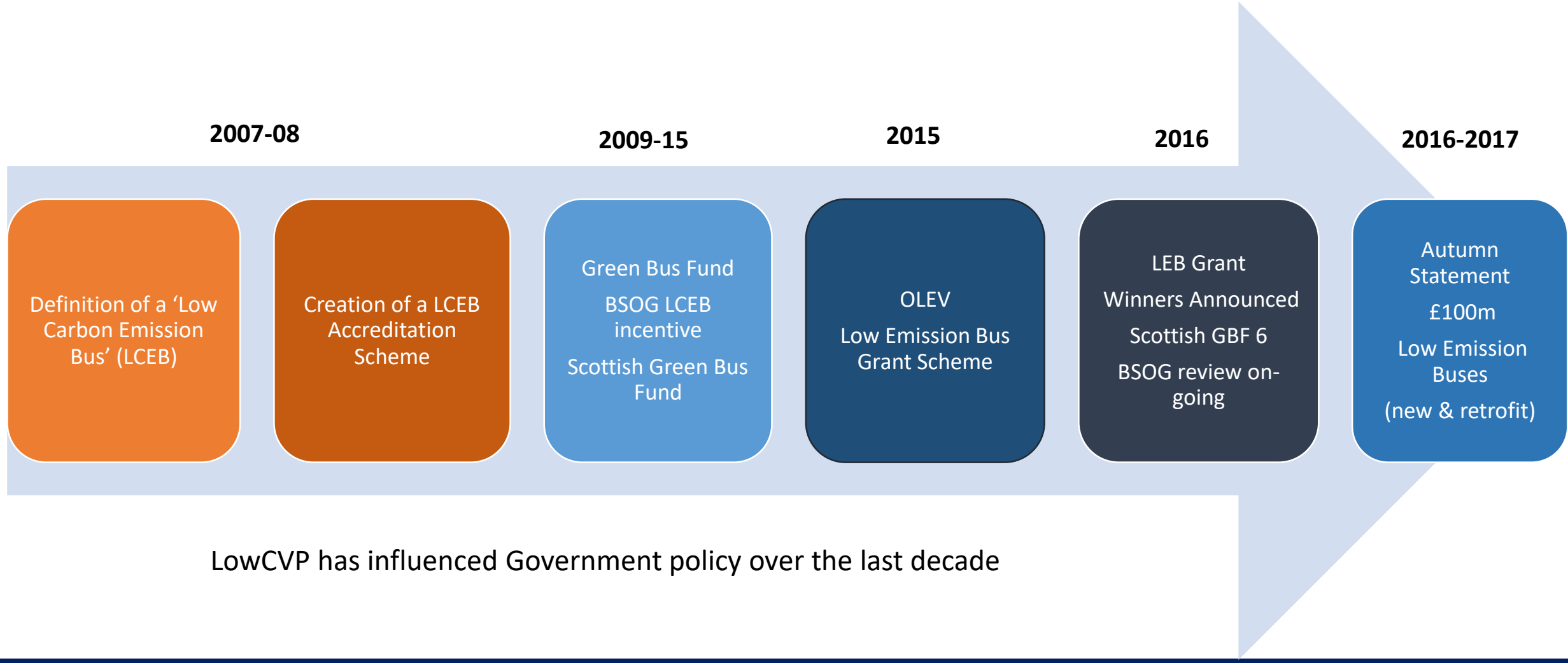
Thursday 30th March 2017


Gloria Esposito, Head of Projects

Low Carbon Vehicle Partnership

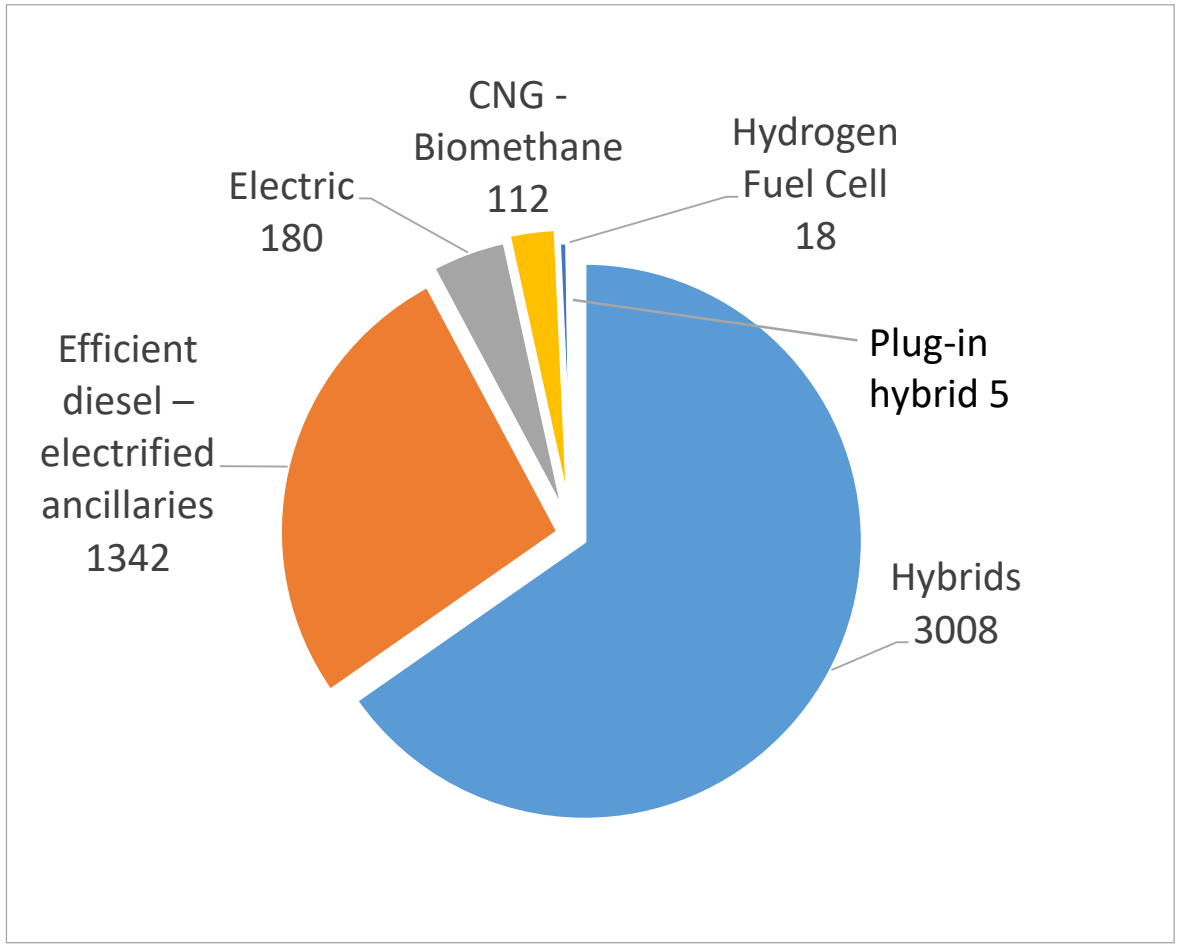
National Policy Evolution - Low Carbon to Low Emission Buses

Low Carbon Vehicle Partnership | Connect Collaborate Influence



LowCVP has influenced Government policy over the last decade

Low Carbon Emission Buses What's Been Achievements to Date?



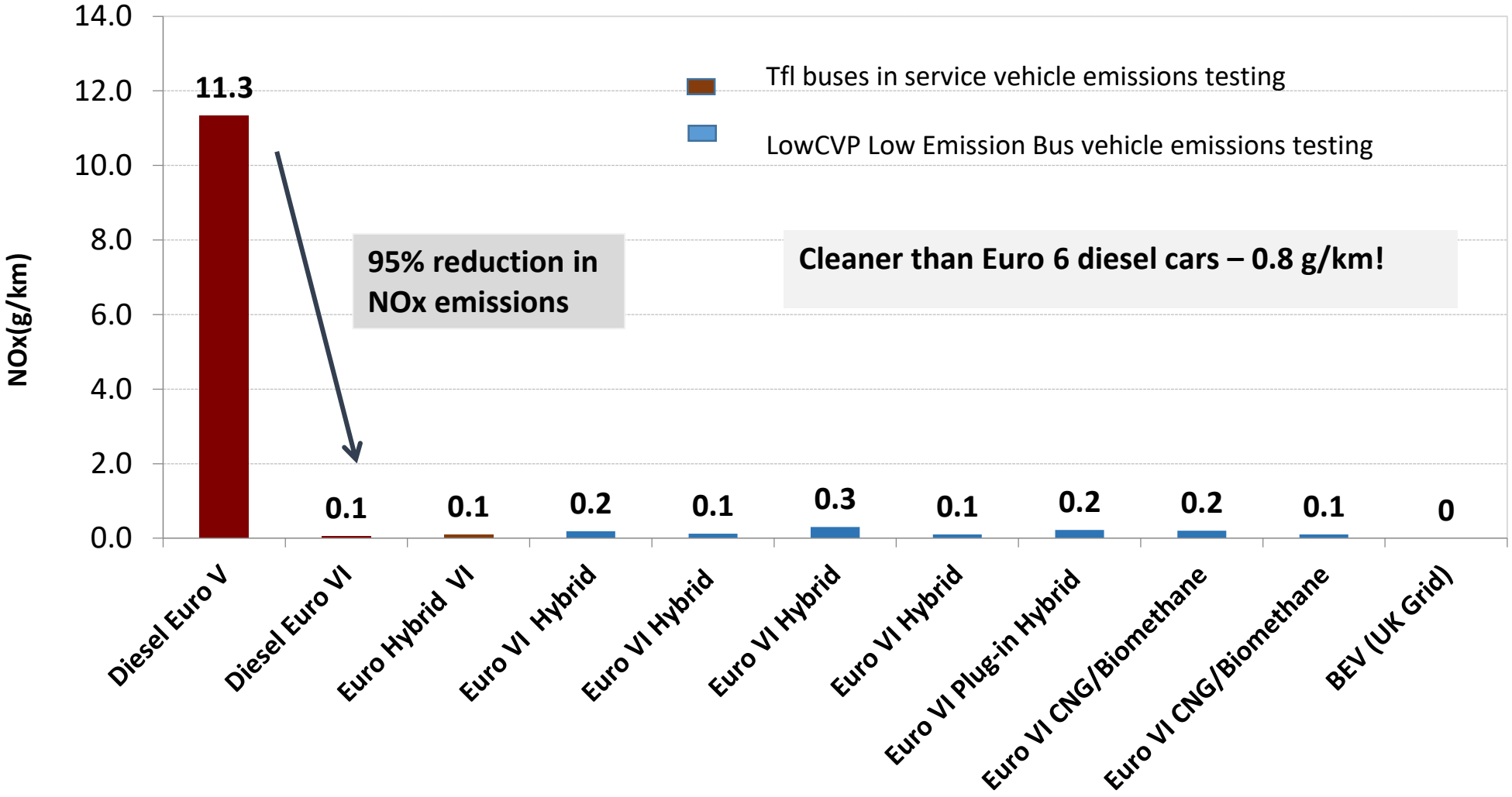
- 4,743 LCEBs in service across 38 UK cities
- LCEB achieve 30% WTW GHG savings vs Euro III diesel equivalent bus
- 44% of new bus registrations in 2016 were LCEB
- >9000 diesel buses running on B20 biodiesel
- Progressed more than any other vehicle sector – 4% new car sales alternative fuel/ULEV

OLEV Low Emission Bus Scheme

- A Low Emission Bus (LEB): achieves >15% **WTW GHG emission savings** compared to a Euro V diesel bus & achieves the **Euro VI engine standard or equivalent**
- **Low Emission Bus Accreditation Scheme** – Uses representative real world bus cycle (UK LowCVP LUB cycle) to measure emission and operational performance of an LEB
- **Low Emission Bus Grant Scheme**
  - Funding based on WTW GHG emission savings of an LEB
  - Additional funding for zero emission capable miles
  - Funding for infrastructure
- 2016 scheme funded 326 LEBs
- Awaiting launch of OLEV £100m funding for LEBs (new and retrofit)


Low Emission Bus Scheme Certificate

Euro VI buses are achieving very low NOx emissions – don't try to pick winners!



WTW CO2e performance varies for different LEBs important to consider vehicle technology and low carbon fuels

Low Carbon Vehicle Partnership

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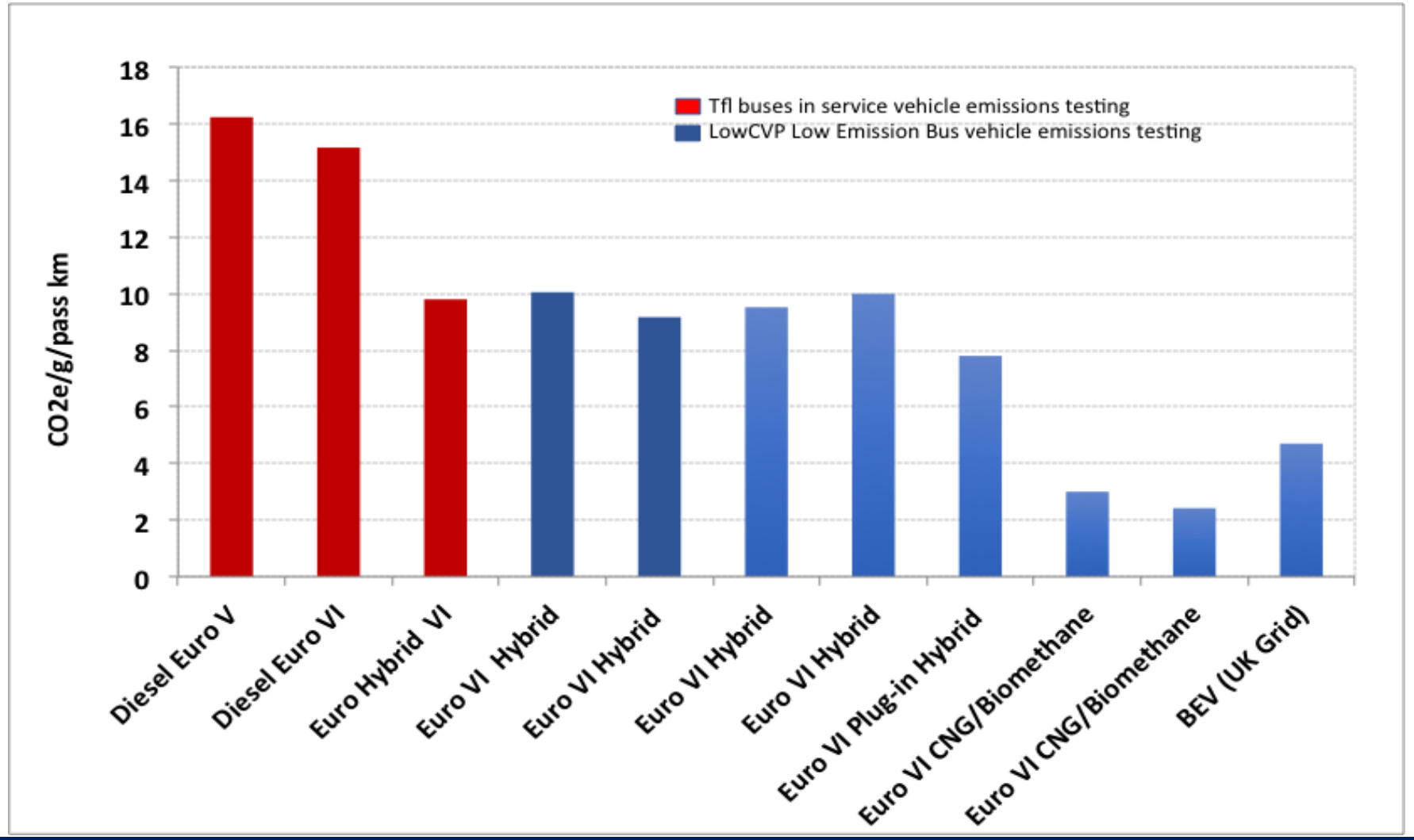


National Air Quality Action Plan
Joint Air Quality Unit

- Focus on reducing NOx emissions from road transport to meet compliance with NO_2 Limit Value by 2020
- Creation of **Clean Air Zones** to improve air quality
- Strong emphasis on the shift to cleaner vehicles – new or retrofit of diesel vehicles required to meet Euro VI or equivalent for HDV (Euro 6 diesel, Euro 4 petrol LDVs).
- Two types of Clean Air Zones
  - ❖ Mandatory: 'charging' zone entry based on vehicle emission standards
    Five regions identified + London ULEZ – **All include buses**
  - ❖ Non-mandatory: local authorities adopt range of local measures
- Draft National Air Quality Action Plan due to be released for consultation mid April, final report July. Many more CAZ likely to be announced.

Opportunities for Retrofitting Older Diesel Buses

- Various options for retrofitting older diesel buses to achieve high NOx emission reductions in CAZ – examples exhaust after treatment(SCR), engine conversion to hybrid or electric powertrain.

- OLEV £100m for Low Emission Buses will include retrofit technologies, first vehicle class to be offered funding.

- Accompanied by a Clean Vehicle Retrofit Technology Accreditation Scheme – being developed by LowCVP to certify the NOx emission reduction performance of different retrofit technologies

  - Emission limit values – air pollutant and GHG emissions

  - Vehicle emission testing procedures (representative bus drive cycle)

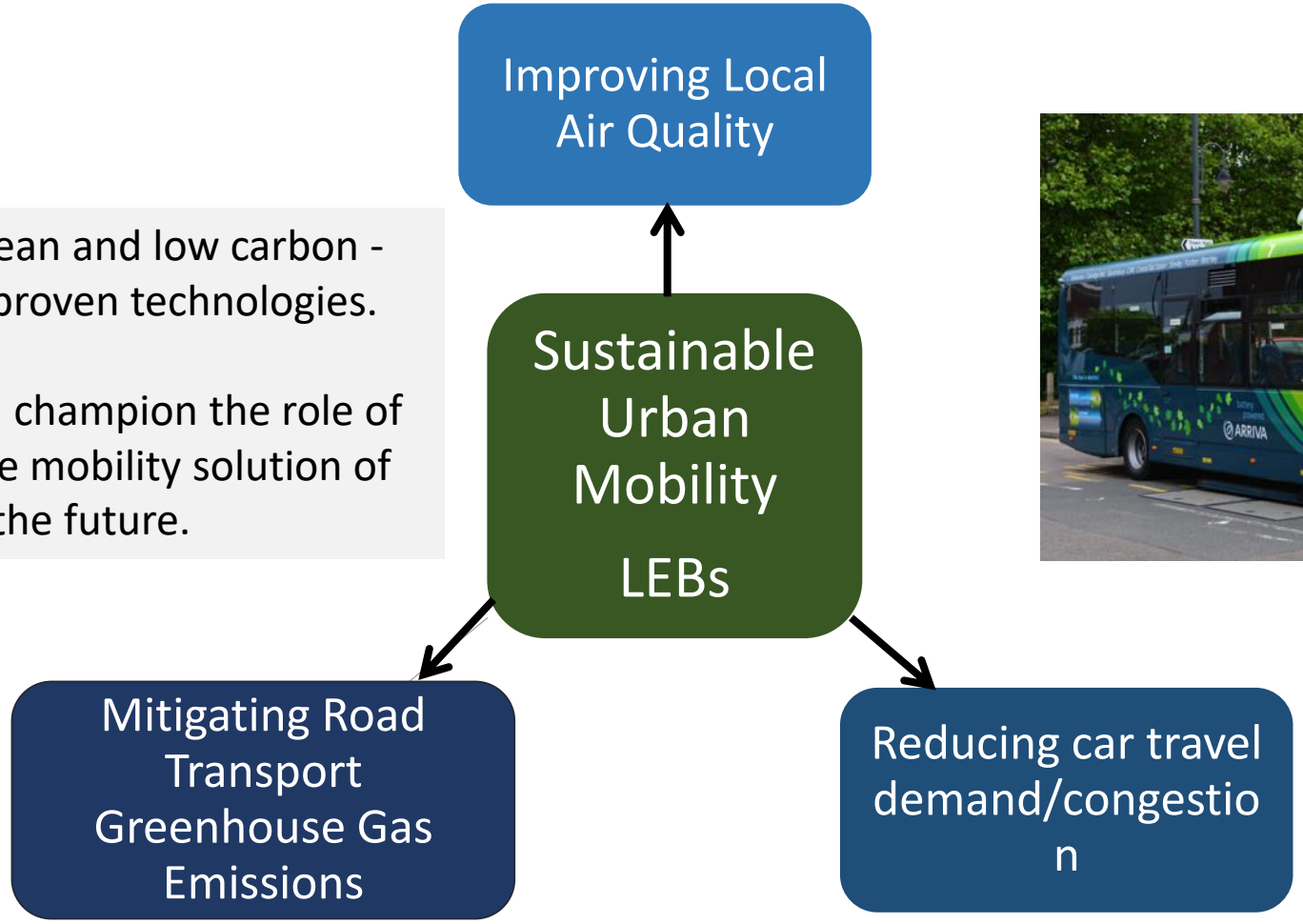
  - Assessing methods for in service durability of retrofit equipment

Huge opportunity for the bus industry to set itself up for the future as THE urban mobility solution

LowCVP Low Carbon Vehicle Partnership | Connect Collaborate Influence

LEBs are clean and low carbon - variety of proven technologies.

LowCVP will champion the role of buses as the mobility solution of the future.



Transport for Greater Manchester

GMCA GREATER MANCHESTER COMBINED AUTHORITY

Greater Manchester Local Enterprise Partnership

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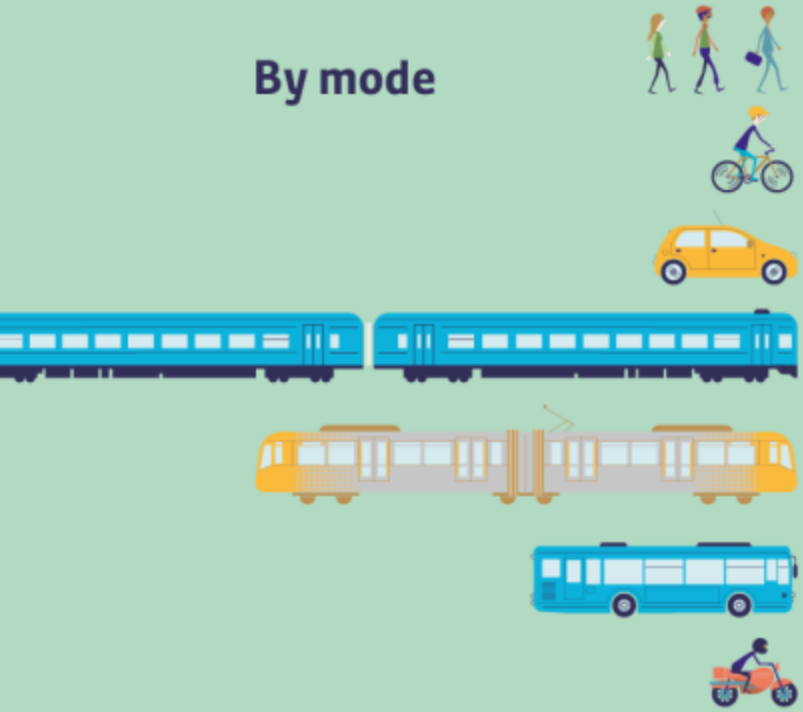
Greater Manchester Local Enterprise Partnership

Integration at the heart of our 2040 Strategy

Old way

By mode

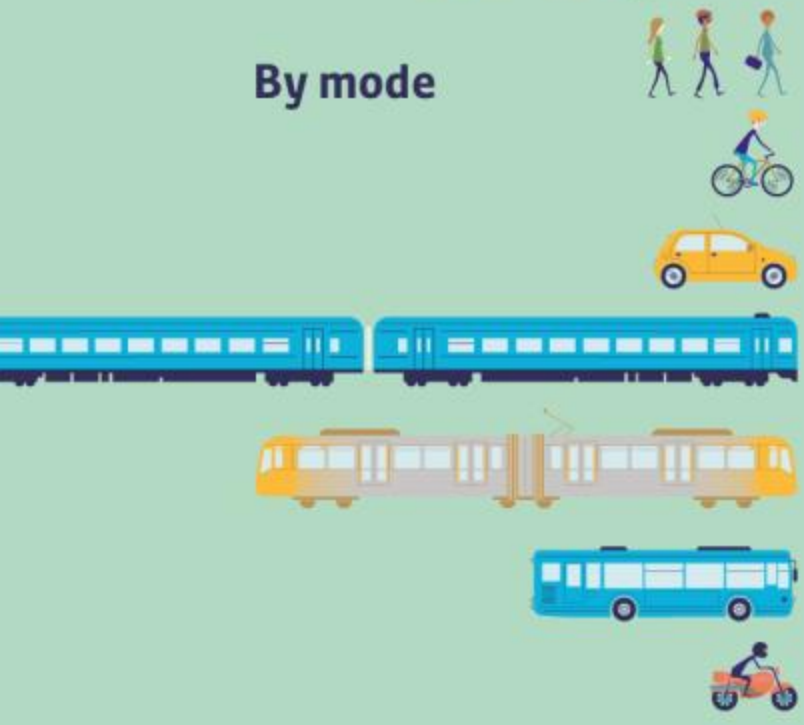


By district

Integration at the heart of our 2040 Strategy

Old way

By mode



By district

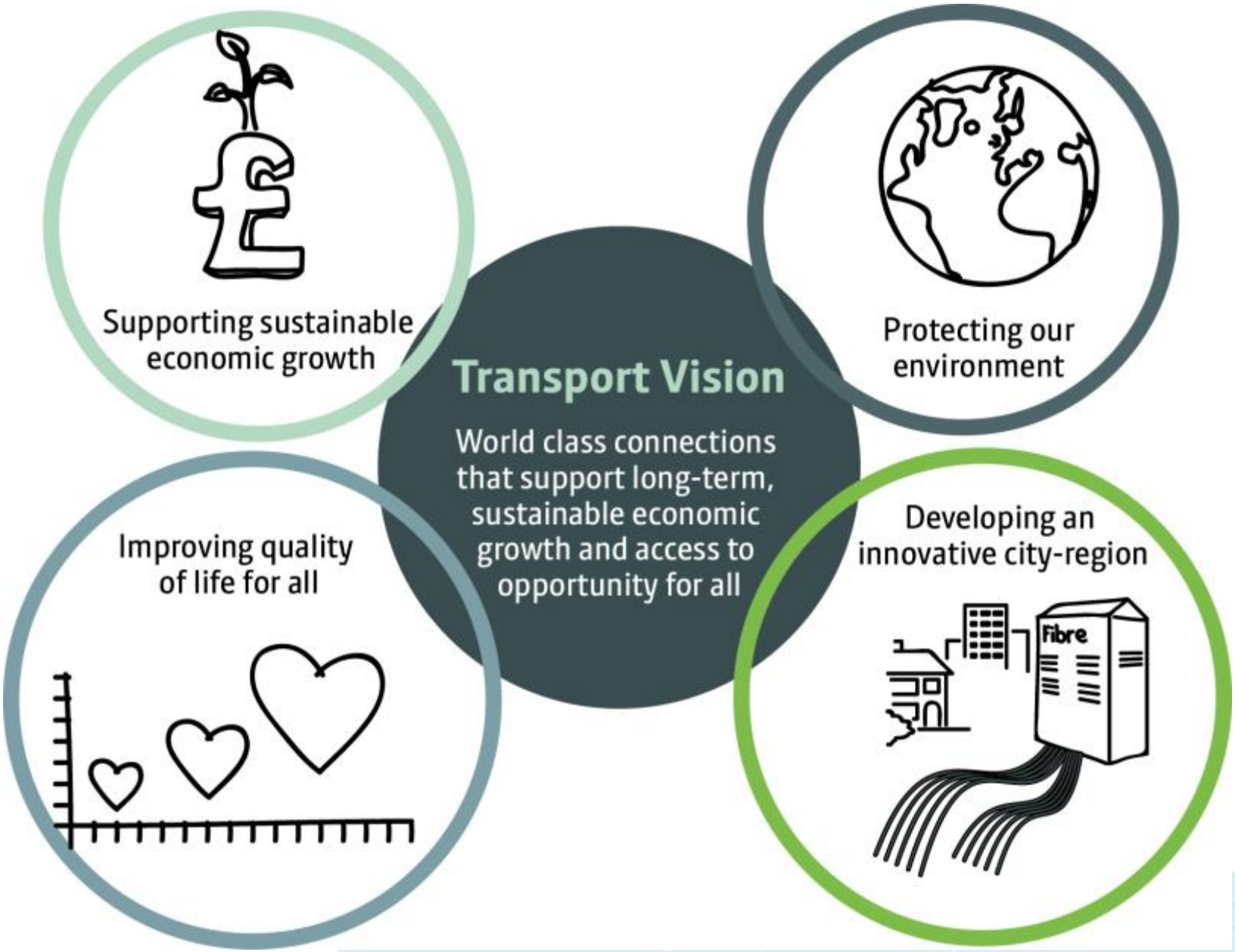
New way

People

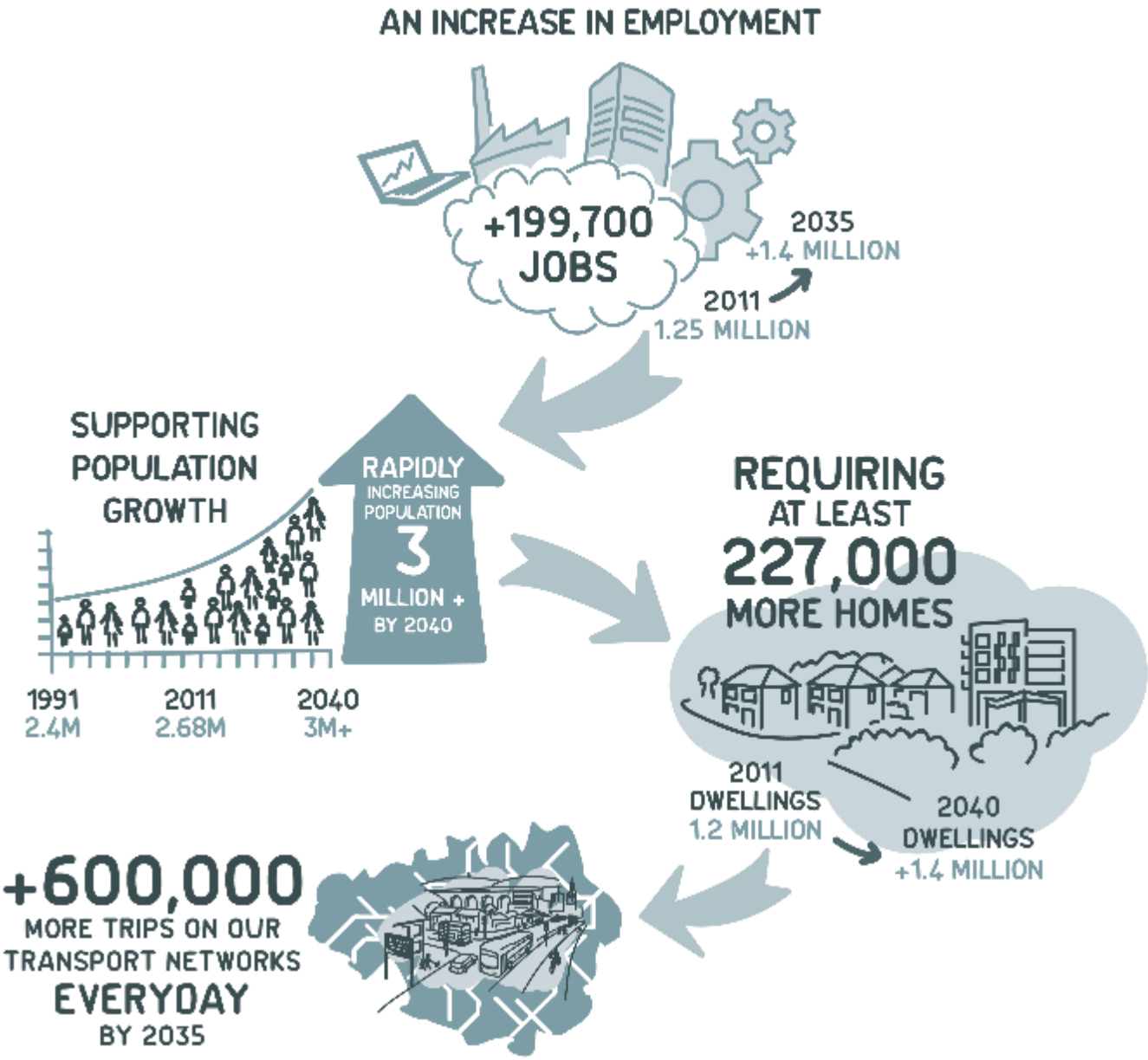
Places

Seamless journeys

Our Vision


Supporting sustainable economic growth
Protecting our environment
Transport Vision
World class connections that support long-term, sustainable economic growth and access to opportunity for all
Improving quality of life for all
Developing an innovative city-region
Fibre

SUPPORTING SUSTAINABLE ECONOMIC GROWTH



IMPROVING THE QUALITY OF LIFE

1/5 OF THE GM POPULATION LIVES IN ONE OF THE 10% MOST DEPRIVED AREAS OF THE UK

31% OF HOUSEHOLDS HAVE NO CAR

1/2 OF ALL ADULTS DO NOT GET THE RECOMMENDED LEVEL OF PHYSICAL ACTIVITY

£35M THE COST TO THE NHS IN GREATER MANCHESTER OF PHYSICAL INACTIVITY

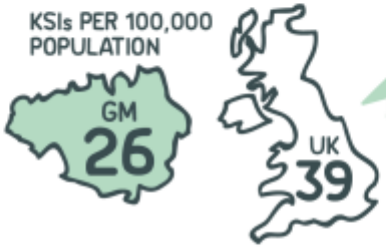
BY 2040
1-IN-4
ADULTS WILL BE OVER 60

1-IN-6
ADULTS WILL BE OVER 70

HALF OF ALL TRIPS ARE LESS THAN 2KM

AND 38% OF THESE SHORT TRIPS ARE BY CAR

Greater Manchester has reduced accident rates to below the national average



but we still have a high number of pedestrian and cycle injuries

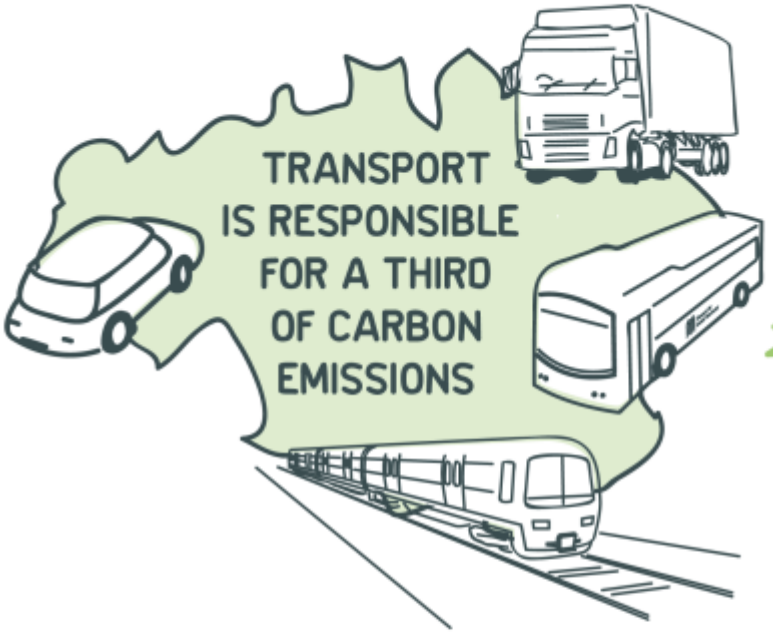
1000 PEDESTRIANS INJURED ON GM ROADS (2014)

569 CYCLIST INJURED ON GM ROADS (2013)

and many of these involve children

OVER 1/3 WERE CHILDREN (AGED 0-15yrs)

PROTECTING OUR ENVIRONMENT



TRANSPORT IS RESPONSIBLE FOR A THIRD OF CARBON EMISSIONS

48% CARBON REDUCTION BY 2020

CO_2

£20bn ECONOMIC COST IF WE DO NOT TACKLE CLIMATE CHANGE

13% INCREASE IN WINTER RAINFALL

1000 DEATHS PER YEAR FROM AIR POLLUTION

AND ANNUAL MEAN TEMP RISE OF UP TO

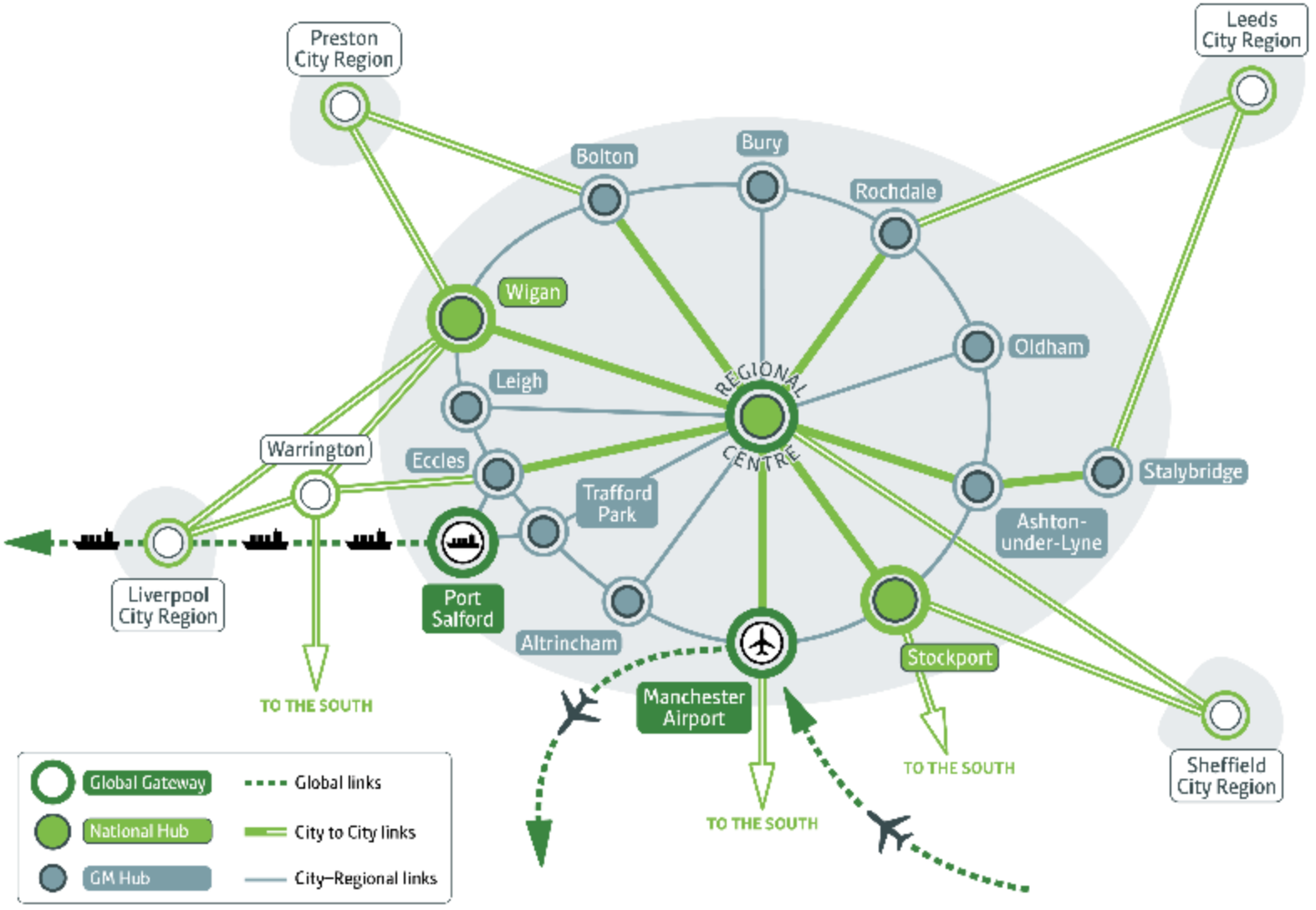
+2.3°C BY 2050

Our network principles

Our modal principles

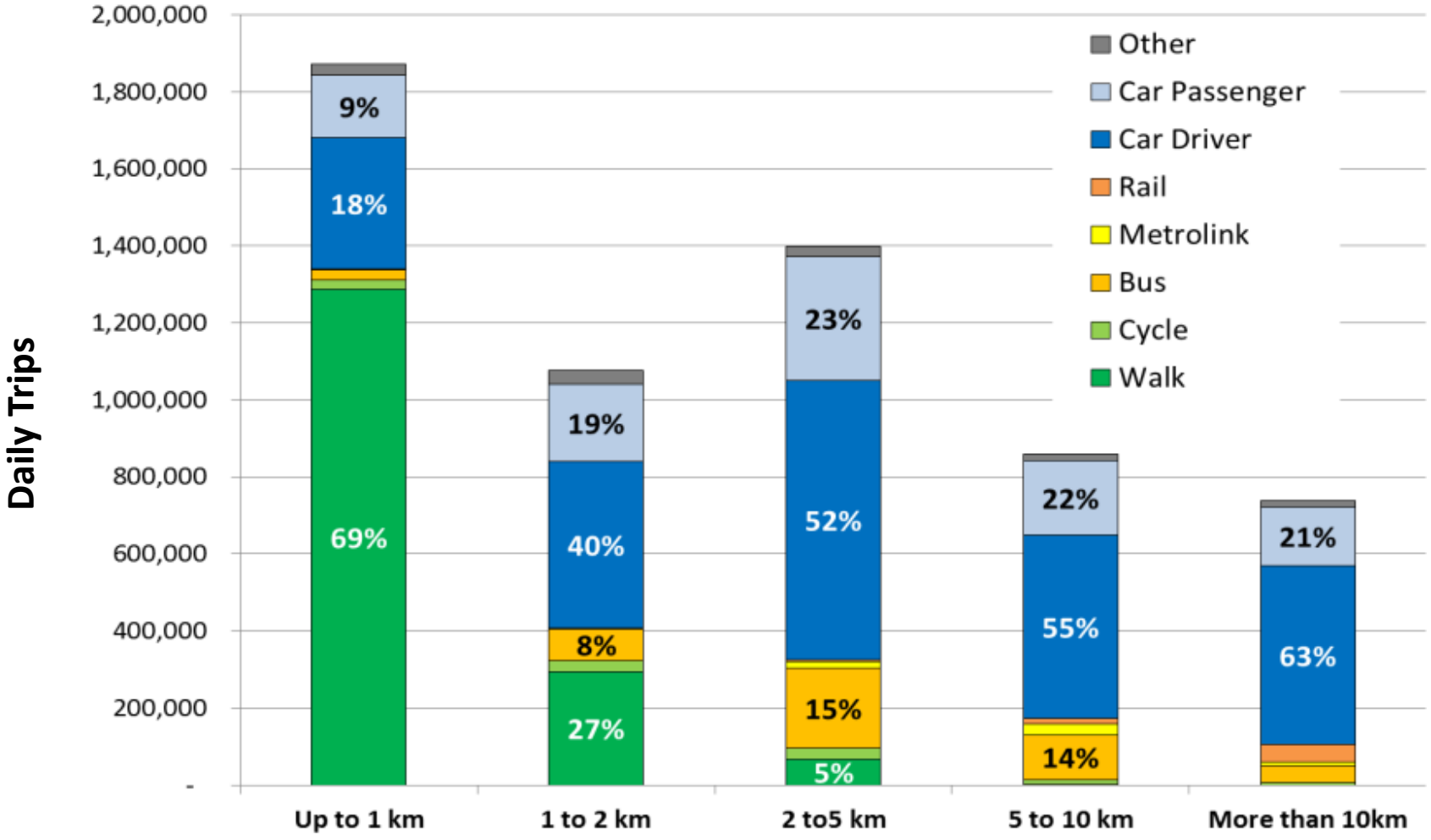
Our 2040 spatial themes

A full integrated public transport network



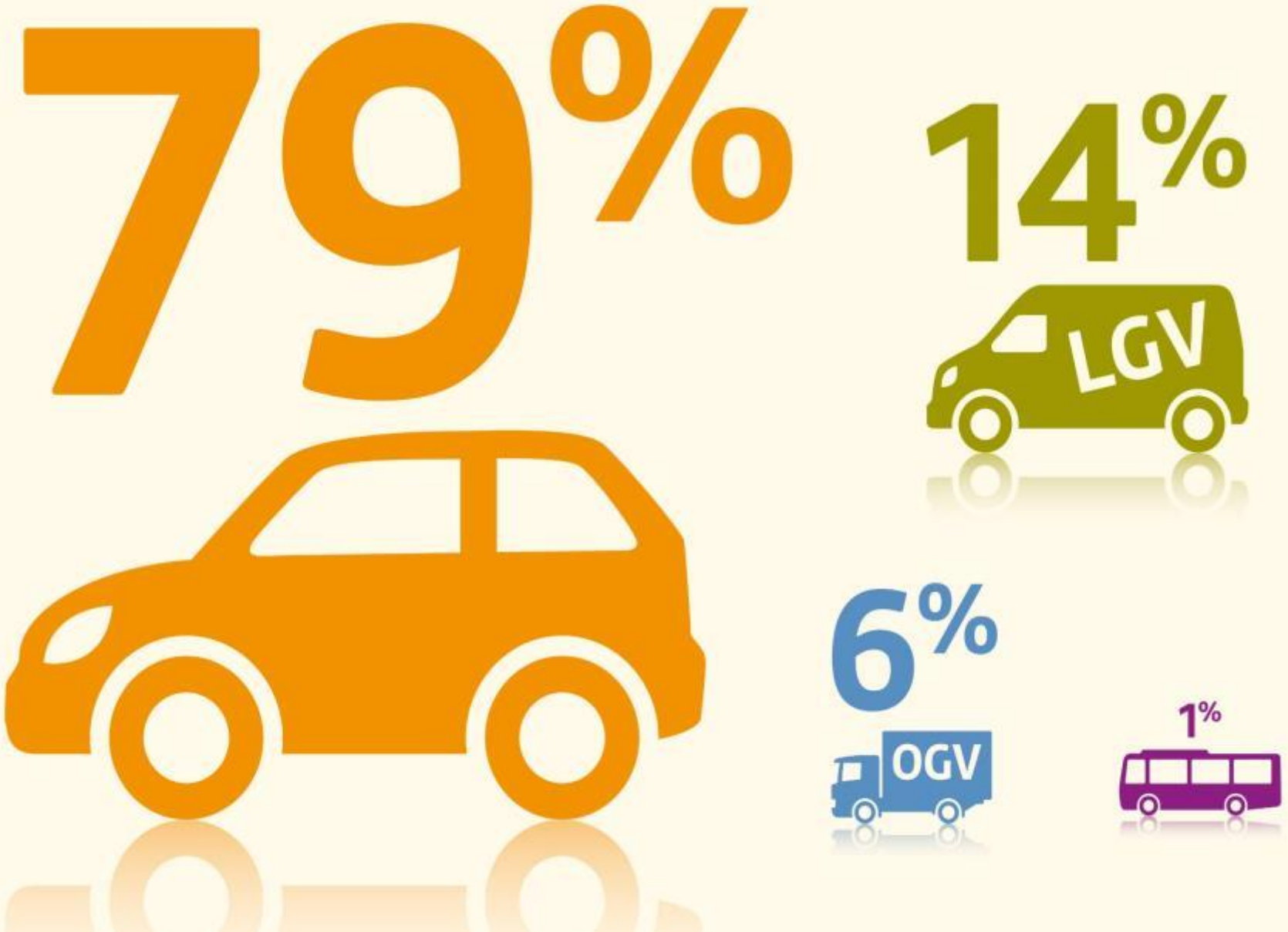
The role of buses in delivering our air quality ambitions

The role of bus for different length trips

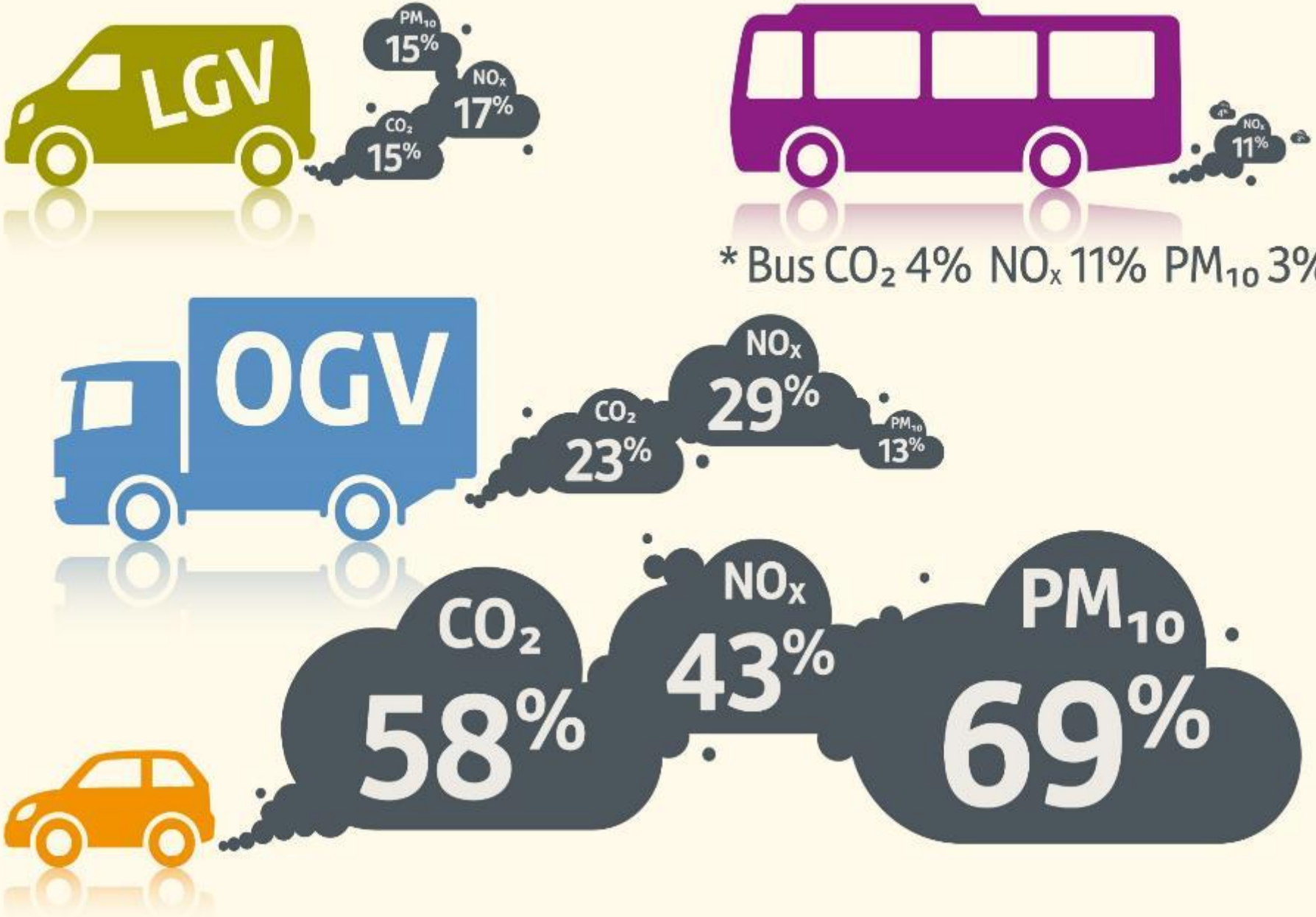


** All trips by GM residents - including those that end outside GM*

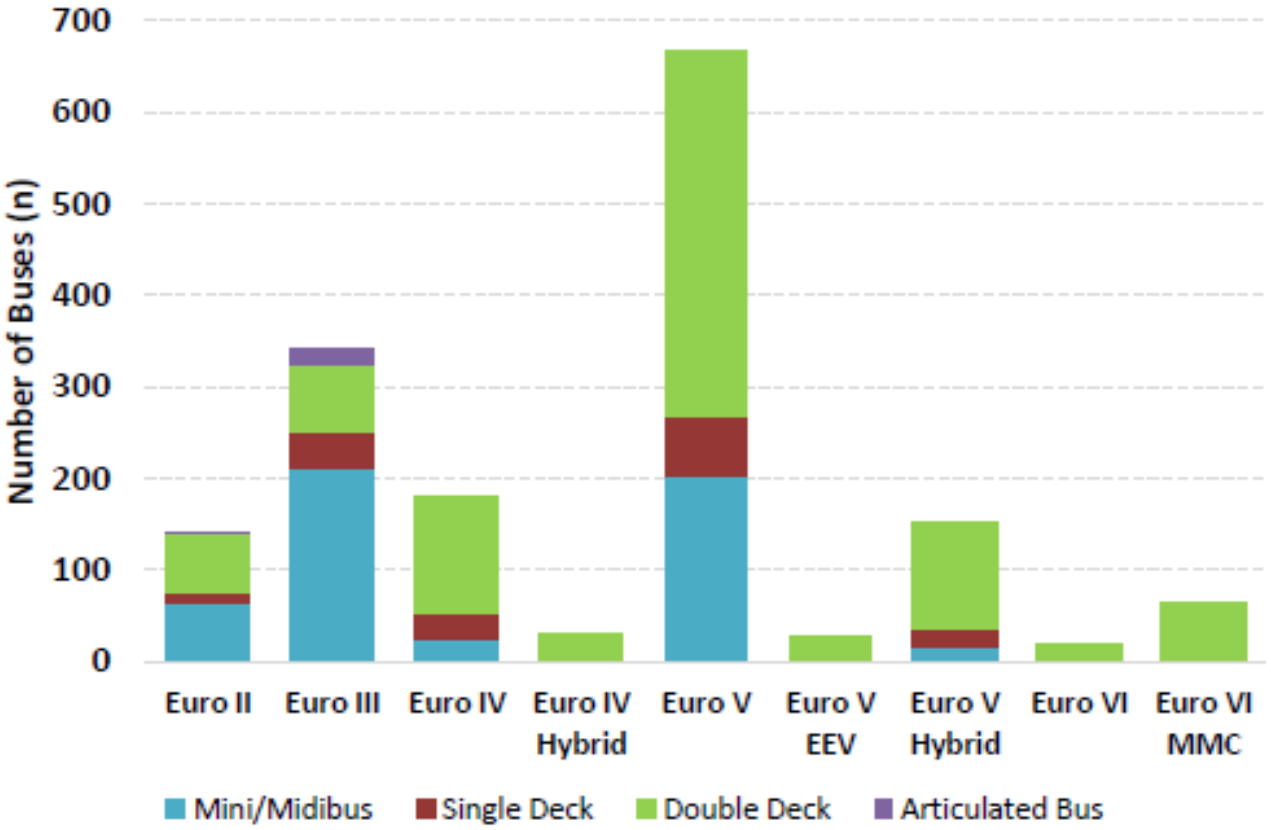
Breakdown of vehicle types on Greater Manchester roads.



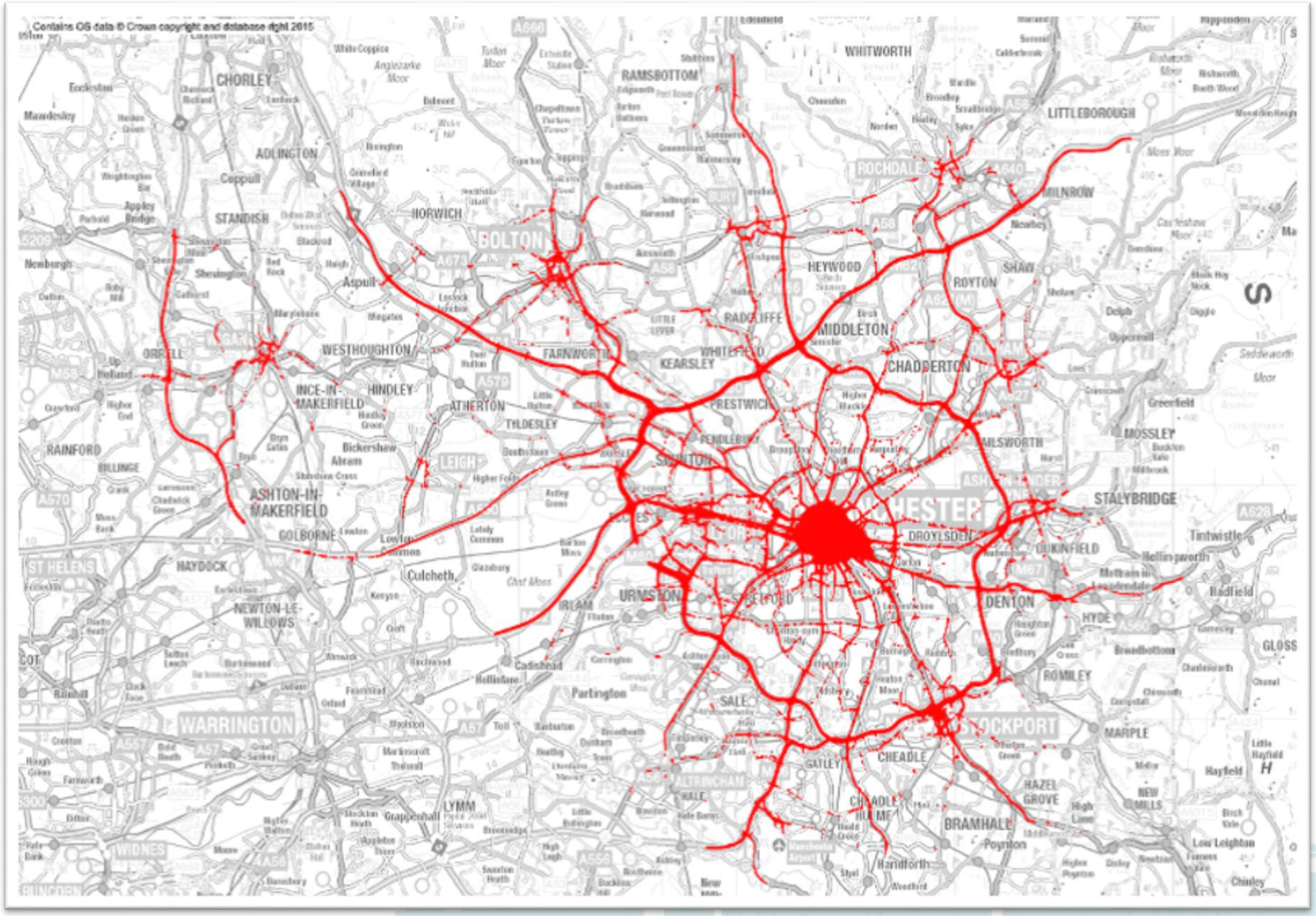
Levels of key pollutants, and which vehicle types are responsible.

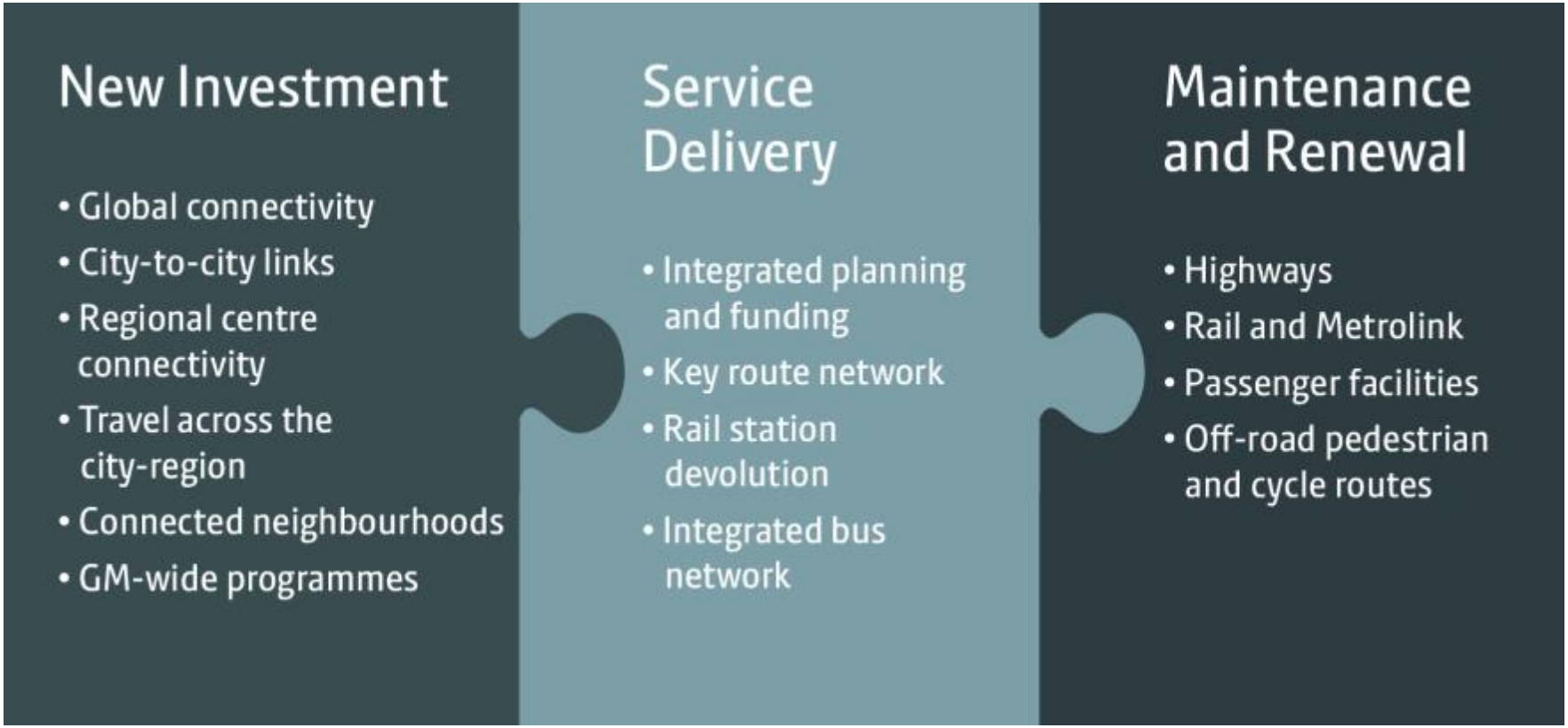


Bus Fleet Type & Euro Emission (April 2016)



Air Quality Management Area




New Investment
• Global connectivity
• City-to-city links
• Regional centre connectivity
• Travel across the city-region
• Connected neighbourhoods
• GM-wide programmes
Service Delivery
• Integrated planning and funding
• Key route network
• Rail station devolution
• Integrated bus network
Maintenance and Renewal
• Highways
• Rail and Metrolink
• Passenger facilities
• Off-road pedestrian and cycle routes

Final thoughts…

Transport for Greater Manchester

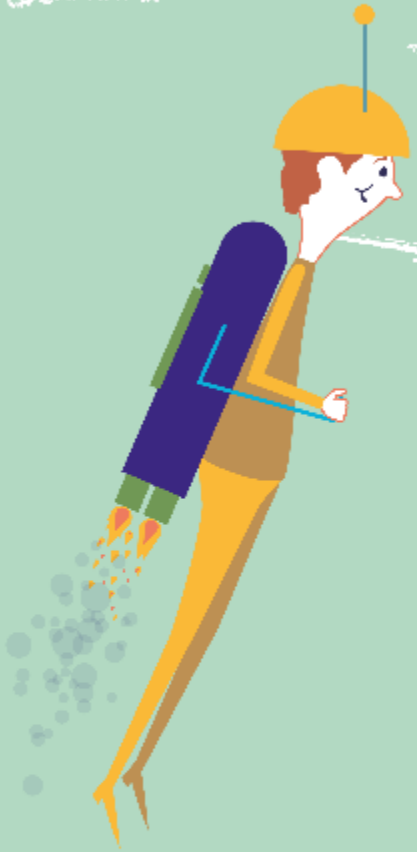
GMCA GREATER MANCHESTER COMBINED AUTHORITY

Greater Manchester Local Enterprise Partnership

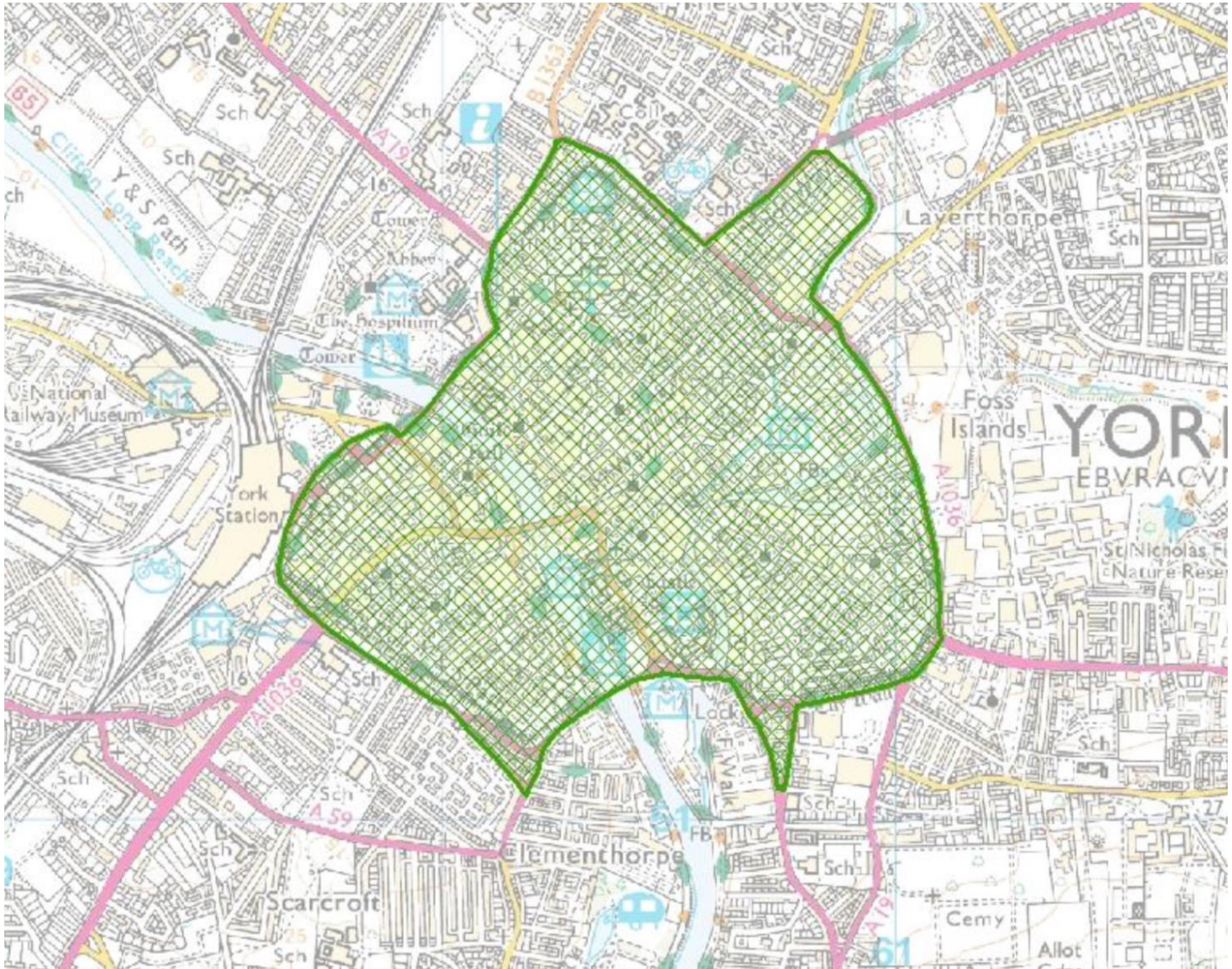
Thank you!

tfgm.com/2040

Nicola.Kane@tfgm.com

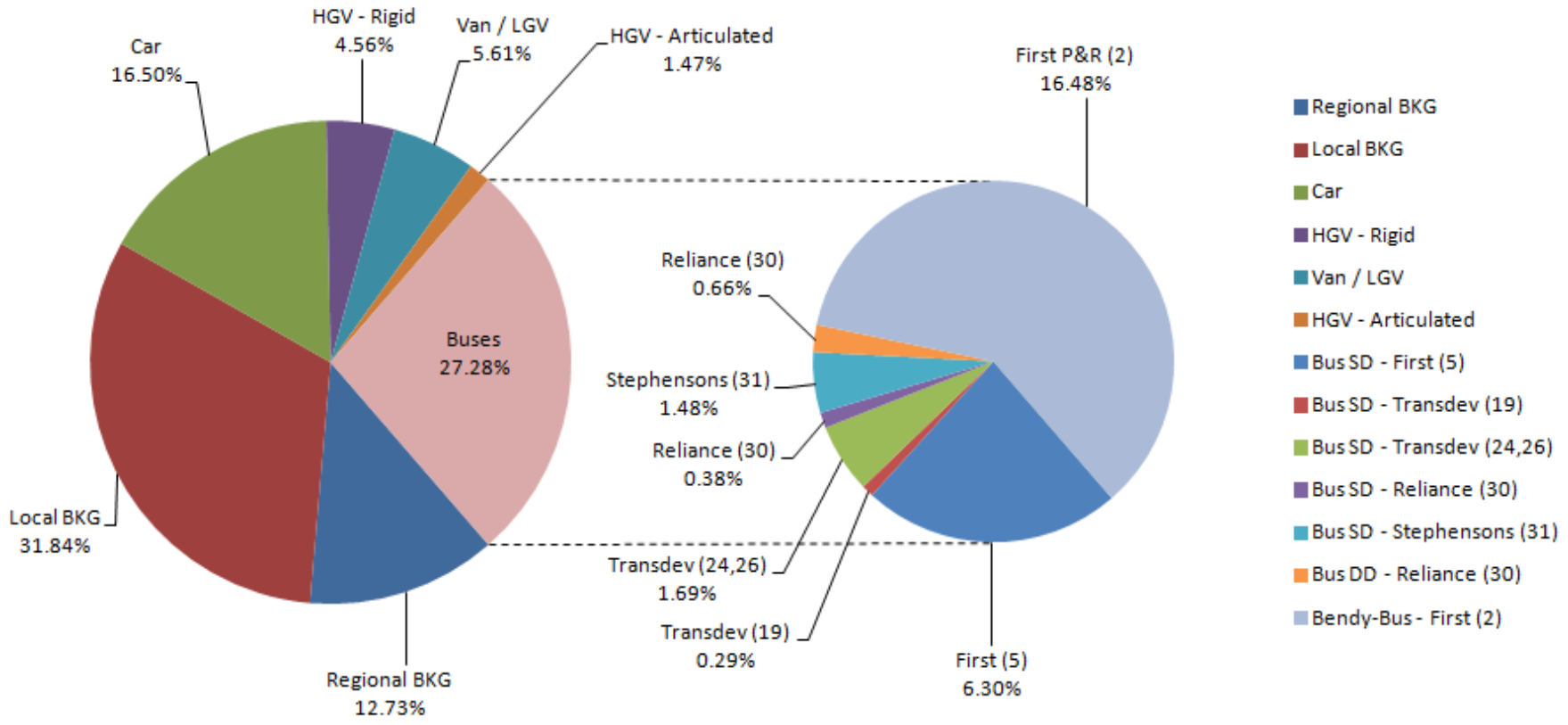


York - Clean Air Zone



CITY OF YORK COUNCIL

Air pollution source apportionment



Air pollution factors – March 2012

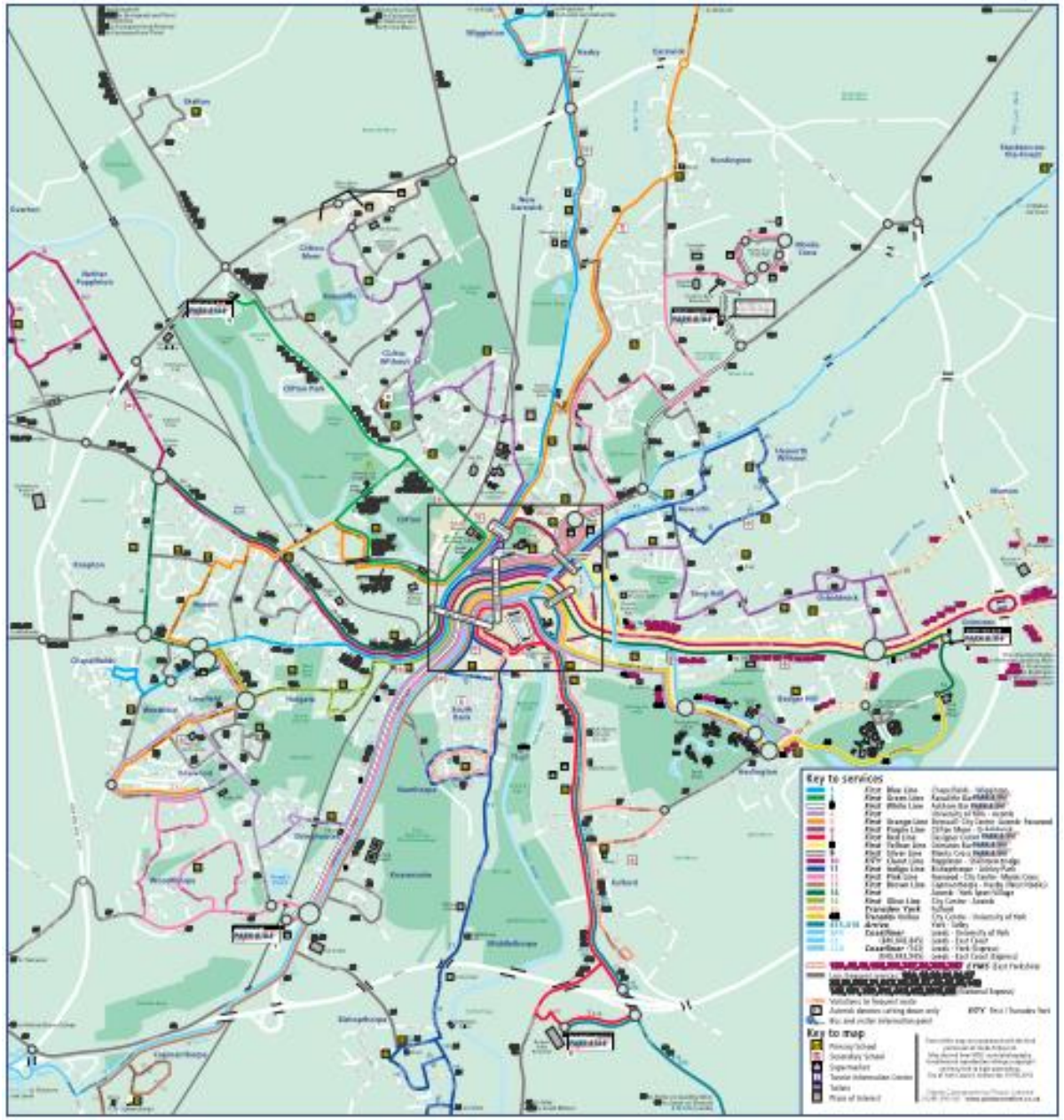
- Type of Fuel – Diesel worst
- Weight of vehicle
- Route through city
- Frequency of journeys

0.3% of vehicles create 20%-30% NOx

Electric bus feasibility November 2012

York bus routes

80% of bus traffic can run zero emission



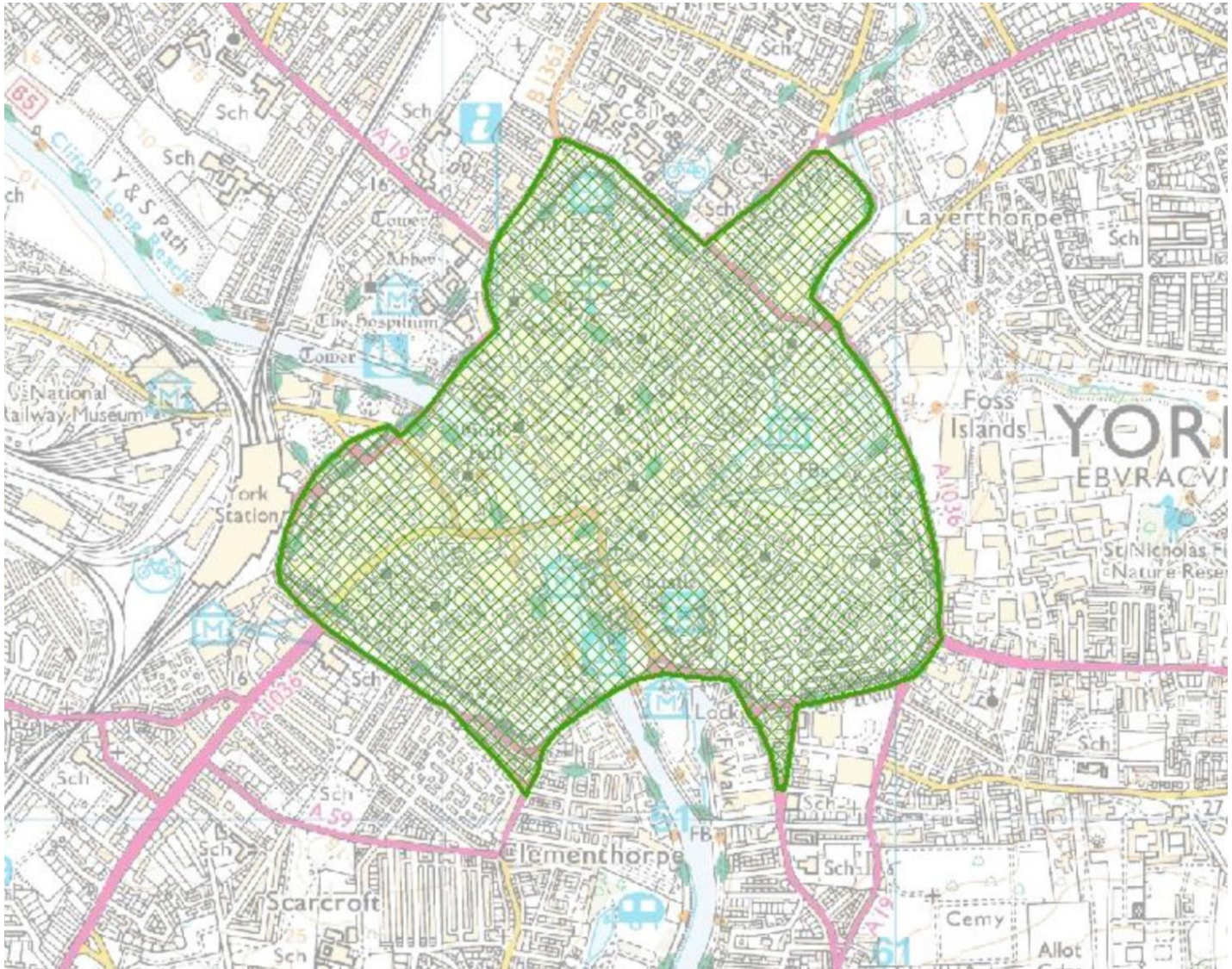

First York
First York
First York
First York
First York
First York

March 2013

March 2013

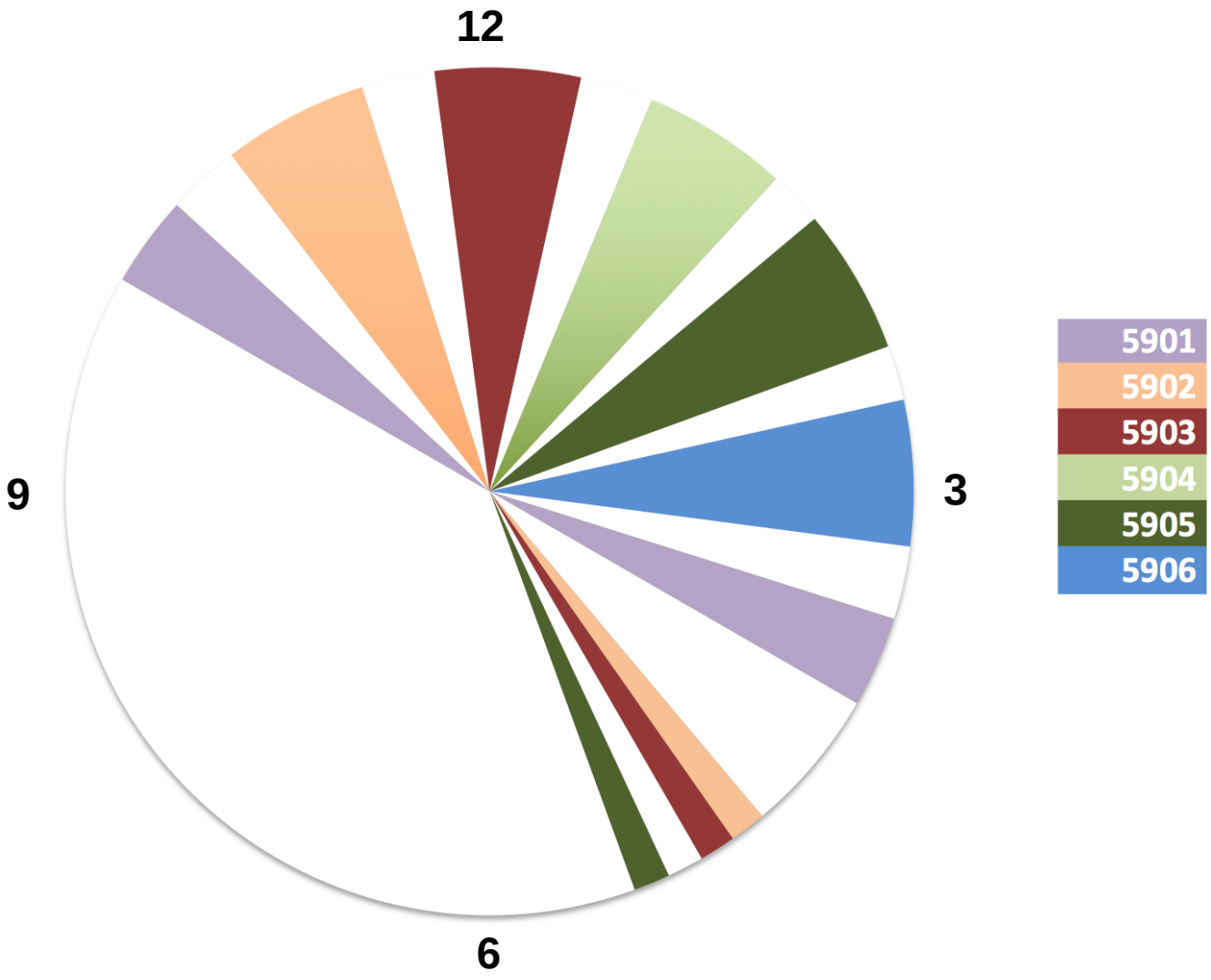
May 2013

York - Clean Air Zone proposal July 2013



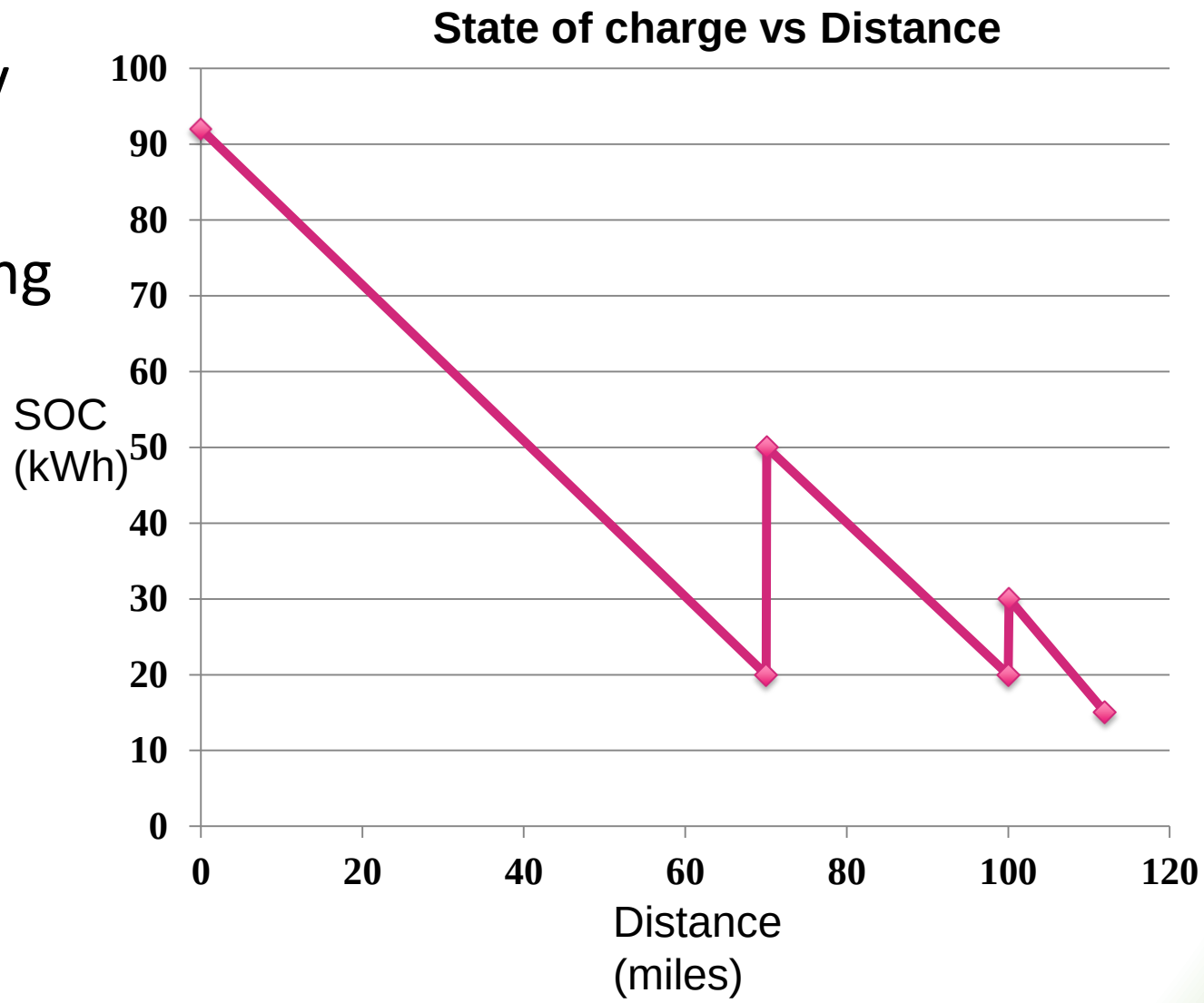
June 2014 – first fully electric P&R

Charging schedule



Range – how far will an electric bus go ?

- Driver variability
- Speed of route
- Passenger loading
- Stop/start
- Topography
- Ancillary load
- Temperature
- Weather

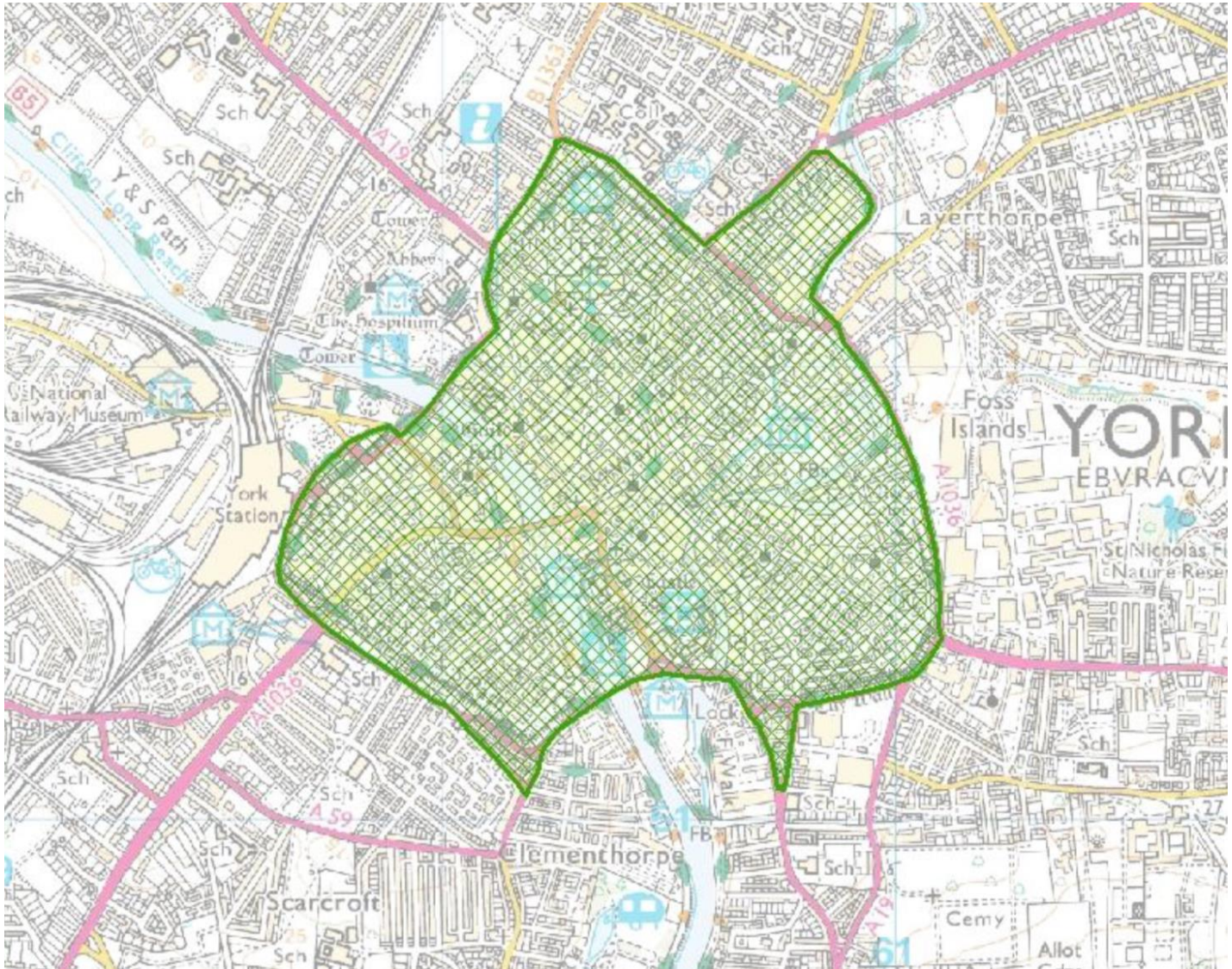



York
City Sightseeing
UK's first 100% electric double decker bus
T407 SMV

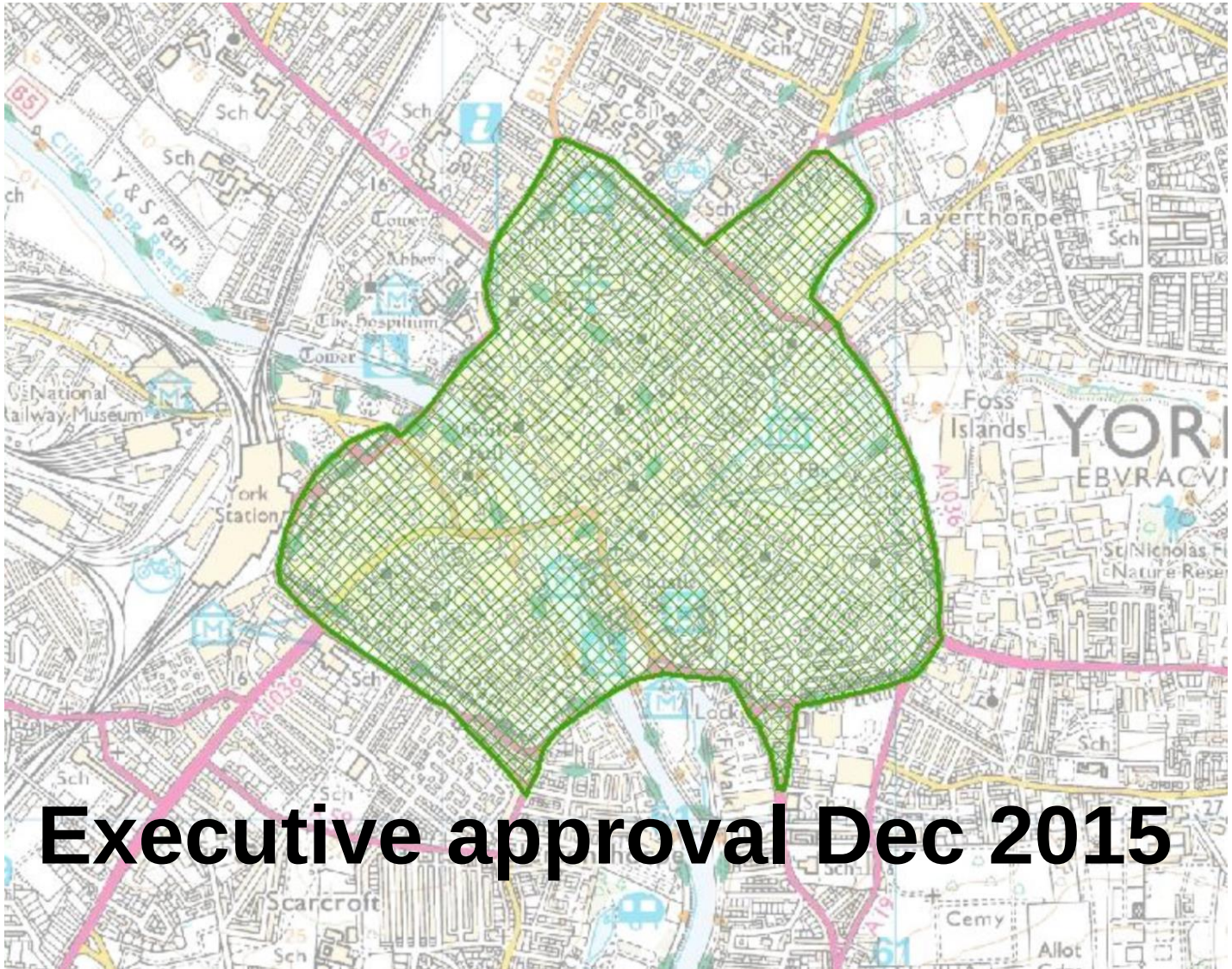





York - Clean Air Zone consultation Dec 2014

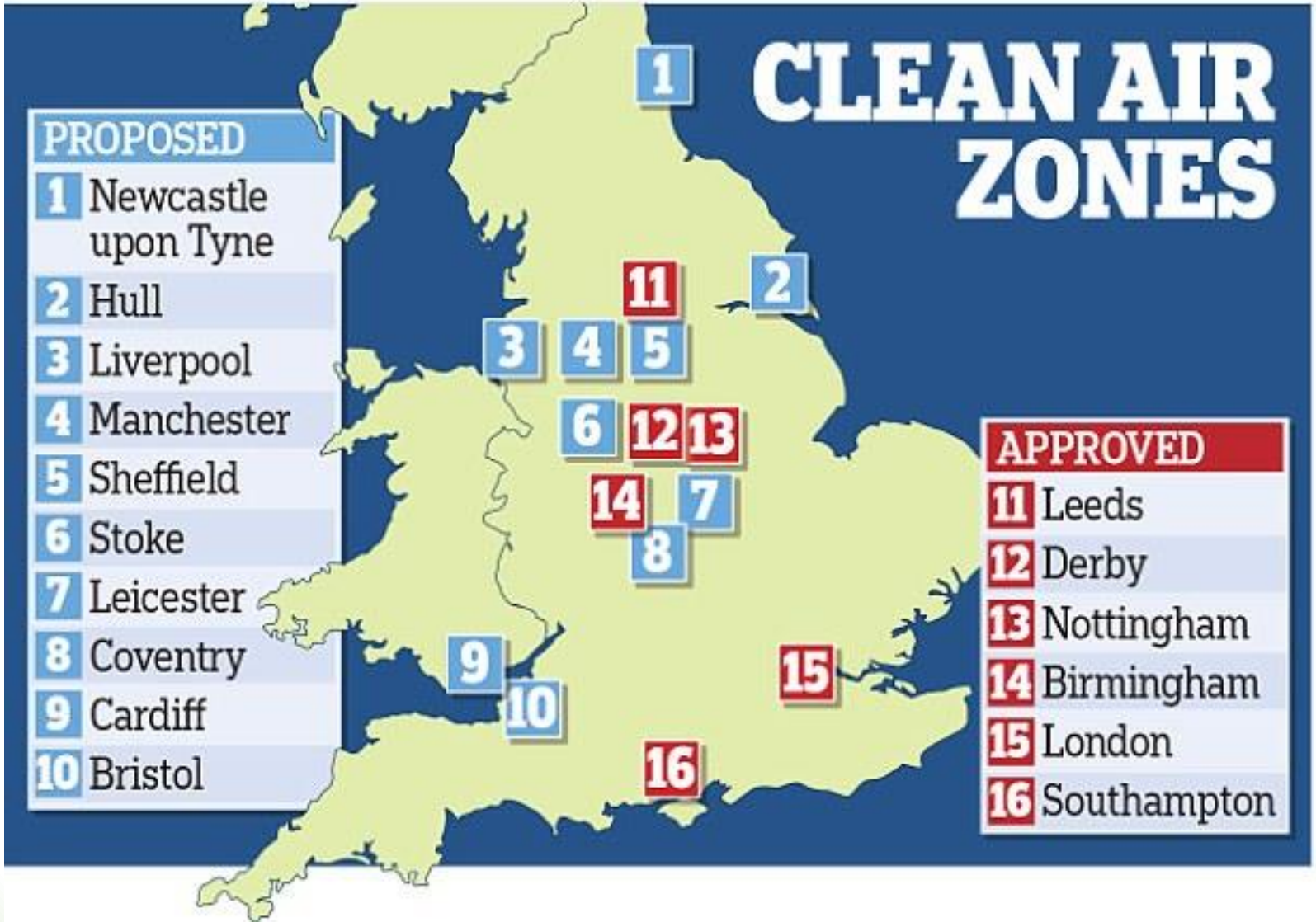


York - Clean Air Zone consultation Dec 2014



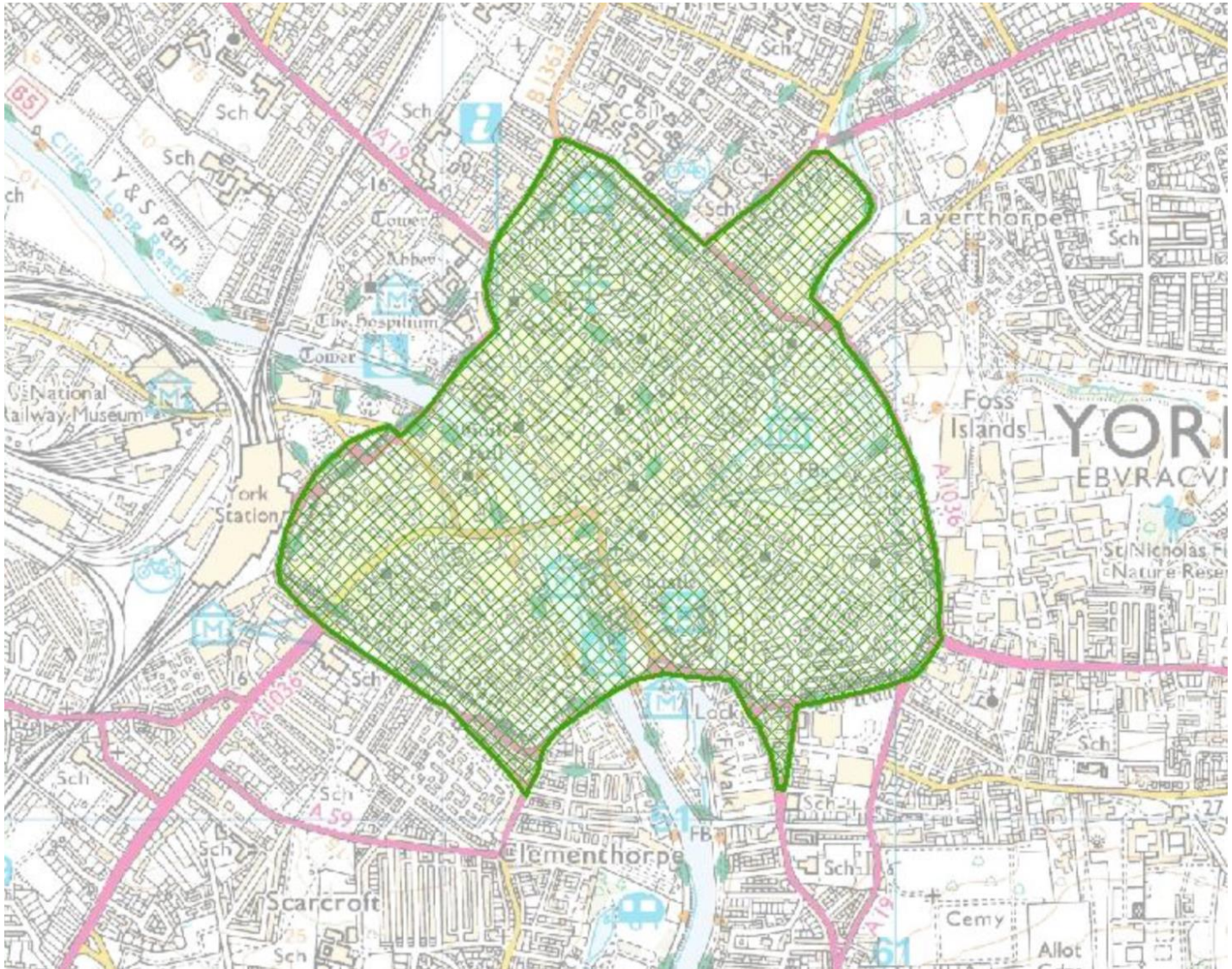
Executive approval Dec 2015

...other Clean Air Zones



Technology advances

York - Clean Air Zone - future



1,300,000 km and counting…

1,300,000 km and counting…

Thank you for listening

Any questions…?

derek.mccreadie@york.gov.uk

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The Low Emission Bus Guide
Greener Journey's Trilogy

Low Emission Bus Workshop - Manchester

Thursday 30th March 2017

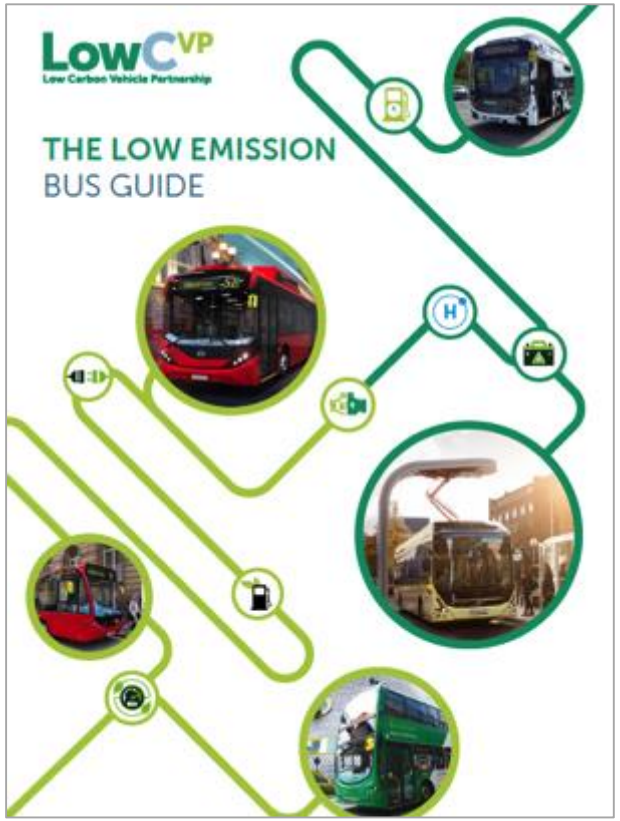

Daniel Hayes, Project Officer

Low Carbon Vehicle Partnership

Low Emission Bus Guide

Low Carbon Vehicle Partnership | Connect Collaborate Influence

- LowCVP identified the **provision of information** has key role to play in encouraging the growth of low emission bus market
- Focus on small operators and local authorities.
- Low Emission Bus Guide created to aid procurement decisions and increase knowledge of available options, including:
  - National policy framework including grants and incentives
  - Technical – *how different bus technologies & supporting infrastructure work*
  - Environmental – *Well-to-Wheel greenhouse gas & AQ emissions*
  - Operational – *variation compared to conventional diesels.*
  - Financial – what to consider when assessing total cost of ownership
- Aims to answer how can LEB technologies and fuels best suit different routes and ambitions.
- Supported by case studies of in-service bus fleets in the UK & Europe.

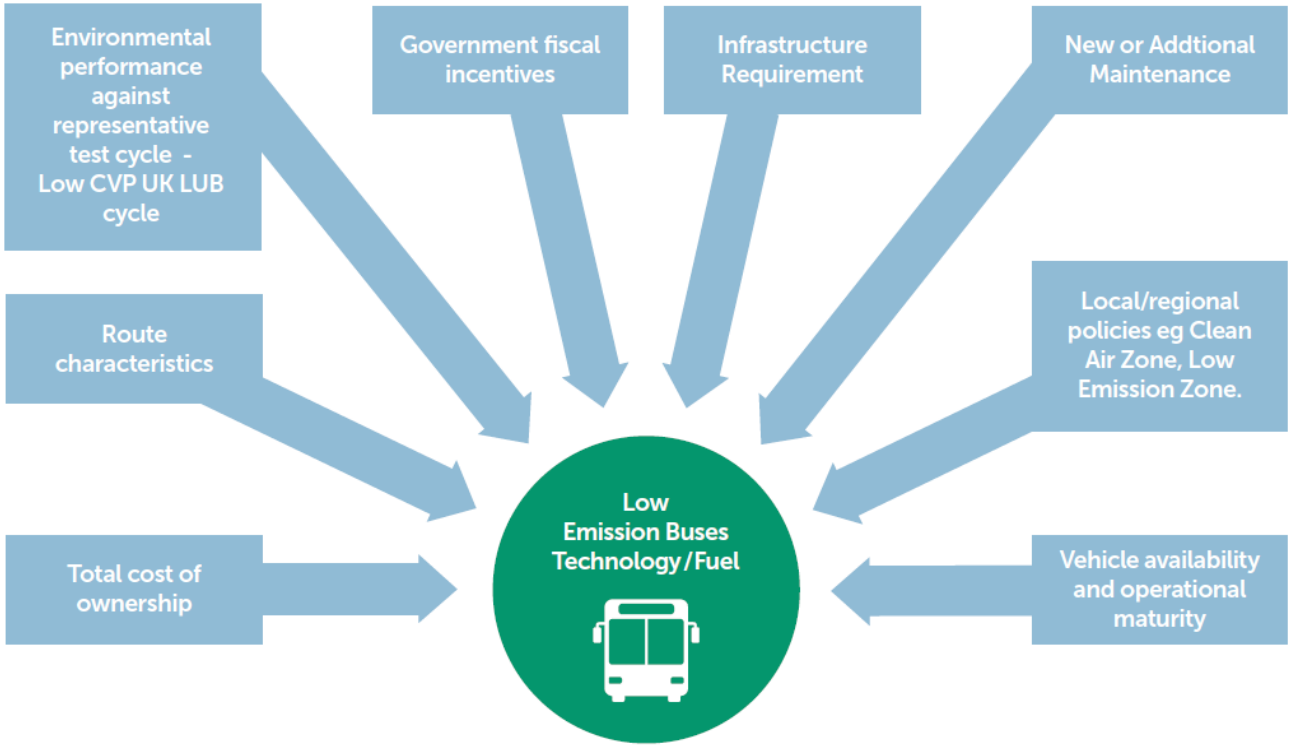


What to consider?

Low Carbon Vehicle Partnership | Connect Collaborate Influence

Guide highlights key elements to consider when assessing different LEB options:

- Local policies
- Route characteristics
- Infrastructure requirements
- Vehicle availability
- Environmental performance
- Fiscal incentives
- Total cost of ownership

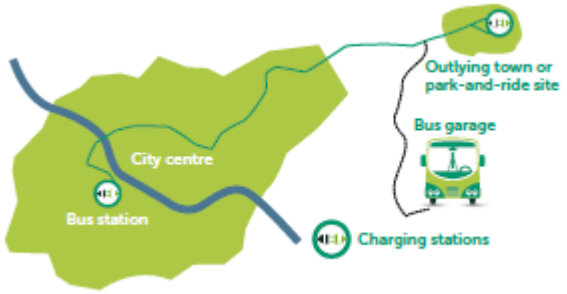


Overview of Technologies, Fuels and Infrastructure

LowCVP Low Carbon Vehicle Partnership | Connect Collaborate Influence

8 different technologies and fuel options covered:

- Battery Electric
- Hybrid
- Plug-in Hybrids
- Biomethane
- Hydrogen Fuel Cell
- Biodiesel & HVO
- Efficient Diesels (Electrified Ancillaries)
- Retrofit SCR for NOx emissions reduction



Emissions performance data from Low Emission Bus accreditation scheme for new buses.

View all models on [LowCVP Low Emission Bus Portal]

	Hybrid Bus Models	Fuel Consumption	WTW GHG and Air Pollution Emissions
	**Volvo 7900 Electric** Single Decker Length: 12m Passenger capacity: 80 GVW: 18,000 kg	24.1 l/100km	WTW GHG emissions: 824.1 gCO2e /km 10.05 gCO2e/passenger km WTW GHG Savings: 34% Achieves Euro VI
	**Volvo B5HL** Double Decker Length: 10.5m Passenger capacity: 90 GVW: 19,000kg	25.7 l/100km	WTW GHG emissions: 870 gCO2e /km 9.2 gCO2e/passenger km WTW GHG Savings: 37% Achieves Euro VI
	**Streetlite H.E.V.** Single Decker Length: 7.1- 10.6m Passenger capacity: 69 GVW: 13,408 kg	22.2 l/100km	WTW GHG emissions: 731.4 gCO2e /km 10.6 gCO2e/passenger km WTW GHG Savings: 35% Achieves Euro VI
	**Wrightbus Street - Deck H.E.V** Double Decker Length: 7.1- 10.6m Passenger capacity: 95 GVW: 18,000 kg	27.4 l/100km	WTW GHG emissions: 904.2 g CO2e/km 9.52 g CO2e/passenger km WTW GHG Savings: 35% Achieves Euro VI
	**ADL E400 48V Hybrid** Double Decker Length: 10.3-11.5m Passenger capacity: 99 GVW: 18,000 kg	31.8 l/100km	WTW GHG emissions: 1072.1 gCO2e /km 10.8 gCO2e/passenger km WTW GHG Savings: 24% Achieves Euro VI
	**ADL E200 48V Hybrid** Single Decker Length: 11.5m Passenger capacity: 72 GVW: 13200 kg	23.0 l/100km	WTW GHG emissions: 767.9 gCO2e/km 10.6 gCO2eq/passenger km WTW GHG savings: 34% Achieves Euro VI

A Green Bus for Every Journey

Low Carbon Vehicle Partnership | Connect Collaborate Influence

- Produced trilogy of reports in collaboration with GJ

"A Green Bus for Every Journey:

- Provides the bus operators perspective of low carbon buses and fuels:
  - Hybrid, Battery Electric, Biomethane, Hydrogen, Biodiesel, Efficient Diesels
  - 20 case studies including: TfL, Nottingham CC, Stagecoach, National Express, Lothian Buses, First Bus, Arriva, Reading Buses and more..
  - Includes environmental and financial benefits

Conclusions

- Low Emission Bus Guide provides comprehensive details regarding how bus operators can choose different low emission fuels and technologies for their fleet upgrades.
  - Regularly update vehicle data and new models on website.
- A Green Bus for every journey gives wide variety of cases studies of LCEBs and LEBs in operation across UK.
- LowCVP hosting 3 more regional workshops this year to reach out to more operators and local authorities.

Download reports from the LowCVP website.

- For more info on joining LowCVP speak to Gloria, Alec or myself.
- Please visit Scania and Vantage Power stands during break for bus tours after lunch.

www.lowcvp.org.uk

Experience Operating Hybrid Vehicles

LEB Workshop

30/3/17

Tom Large – Head of Engineering – Arriva Yorkshire

Vehicles

- Volvo B5LH
  - Wrightbus Eclipse Gemini body
  - 13 plate
  - Parallel hybrid transmission
  - Volvo I-Sam motor
  - Volvo I-Shift transmission

- ADL Enviro 350H
  - 12 plate
  - Series hybrid transmission
  - BAE Hybrid-Drive system

ARRIVA
a DB company

Operation

- No major operational issues. Expectation in terms of reliability is in line with that of a standard diesel
- Personal experience shows better reliability is achieved on lower speed, urban routes. Particularly true for series hybrid vehicles
- No personal experience operating hybrid vehicles older than 5 years old

MPG

- Volvo B5LH – 8.75 MPG
  20% better than equivalent standard diesel

- E350H – 8.75 MPG
  2/3% better than equivalent standard diesel

- Very route dependent

Maintenance Costs

- B5LH on an all inclusive maintenance contract with Volvo. Very good service, fixes costs but is expensive
- E350H under extended driveline warranty
- Need to consider whole life cost of vehicle. Particularly with regards to battery packs

Arriva North West & Wales

Experience of operating MAN EcoCity CNG buses

Dave Smith, Fleet Engineer Arriva NW

Arriva – a DB company

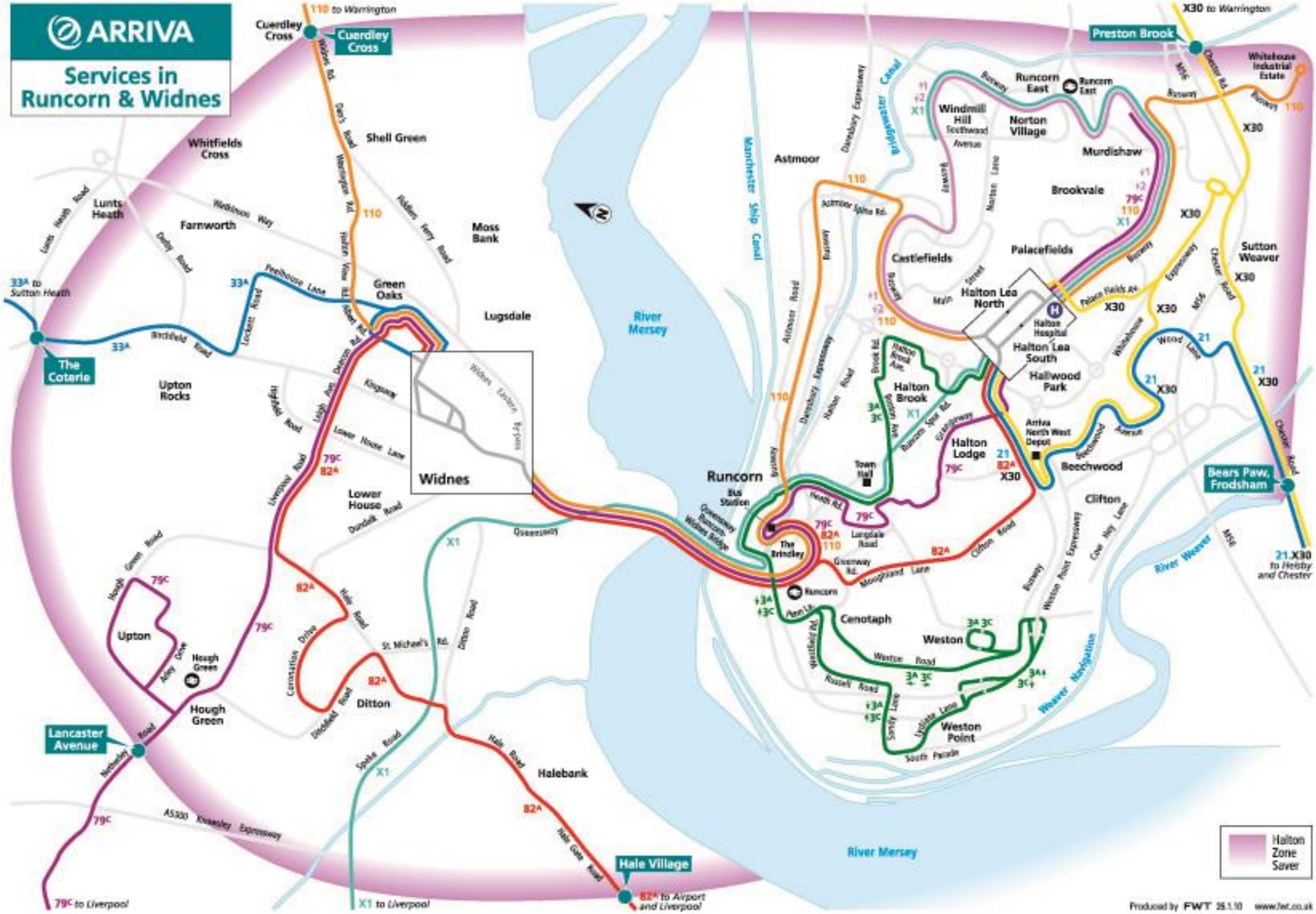
Why Gas buses ?

A simple cost effective environmental solution

- Arriva Europe: 300 + Gas Buses
- Known Technology - No surprises
- Simple maintenance regime
- MAN expertise in Gas technology - 4000+ Gas Buses
- Gas Bus Alliance Solution

Why Runcorn depot ?

- Fleet 47
- PVR 42
- 10 gas buses 5 SB200's 32 SB120's
- Annual mileage 2,971,326 of which gas bus miles = 698,366

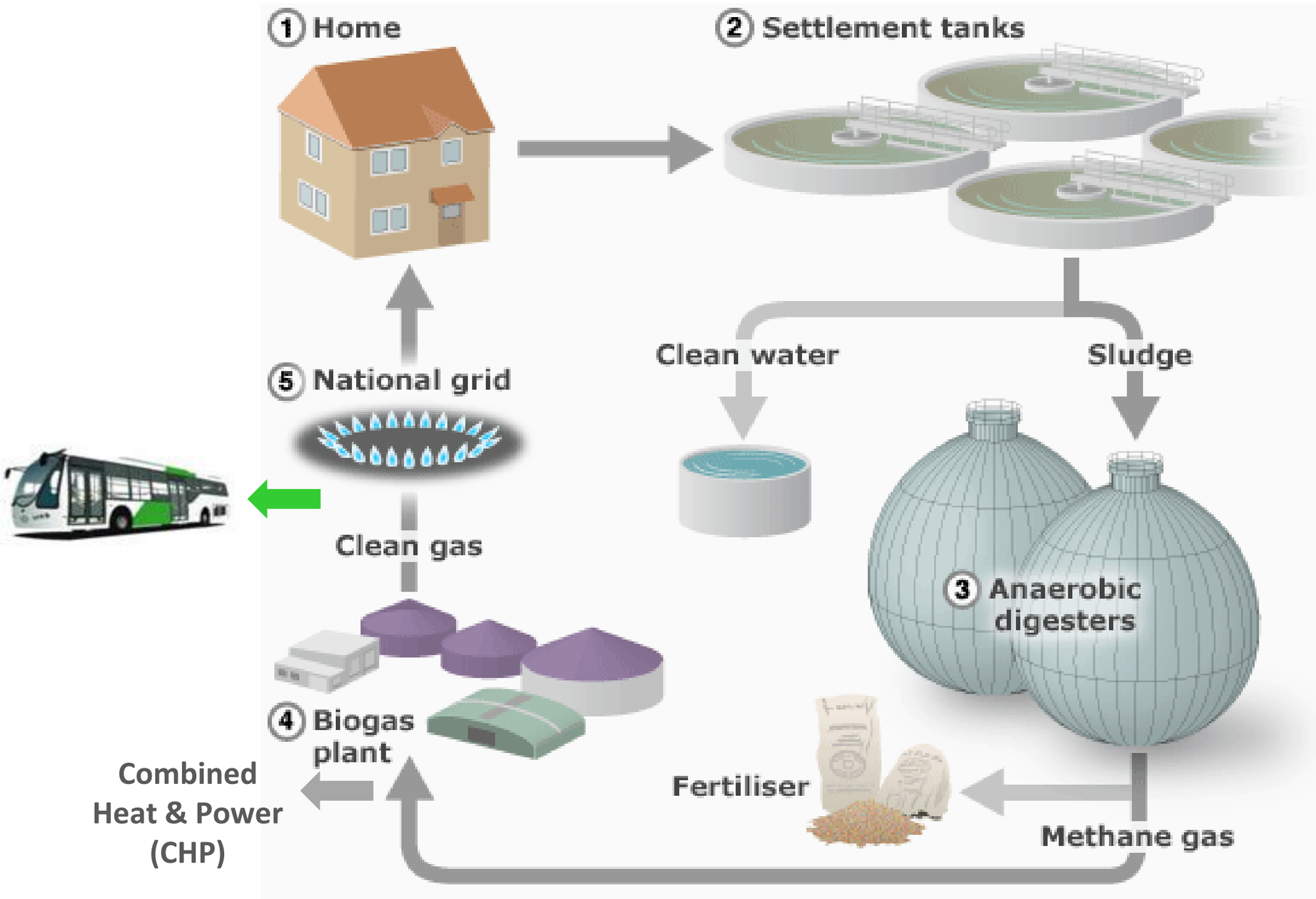

ARRIVA
Services in Runcorn & Widnes
110 to Warrington
X30 to Warrington
Cuerdley Cross
Preston Brook
Whitehouse Industrial Estate
Runcorn East
Windmill Hill
Norton Village
Murdishaw
Shell Green
Whitfields Cross
Astmoor
Brookvale
Lunts Heath
Farnworth
Moss Bank
Castlefields
Palacefields
Sutton Weaver
33A to Sutton Heath
Green Oaks
Lugsdale
River Mersey
Halton Lea North
Halton Hospital
Halton Lea South
The Coterie
Upton Rocks
Halton Brook
Hallwood Park
Halton Lodge
Arriva North West Depot
Beechwood
Widnes
Runcorn
Bus Station
Town Hall
Bears Paw, Frodsham
Lower House
Clifton
The Brindley
21, X30 to Helsby and Chester
Cenotaph
Upton
Hough Green
Weston
Ditton
Weston Point
Lancaster Avenue
Halebank
Hale Village
River Mersey
Halton Zone Saver
79C to Liverpool
X1 to Liverpool
82A to Airport and Liverpool
Produced by FWT 28.1.10 www.fwt.co.uk

Runcorn - Gas Station

- Designed & Built by Gas Bus Alliance
- Installed 2014
- To date: 100% Operation
- Capacity: 20 Buses

100% Biomethane

GBA - Biomethane Production



MAN Ecocity

- E2876 – Dedicated Gas Engine
- 6 Cylinder 12.8 ltr - Spark Ignition
- 270 bhp
- 4 Gas Tanks: 1136 ltr, approx 300 miles
- EEV/Euro V1 (On order)
- Capacity 70 passengers

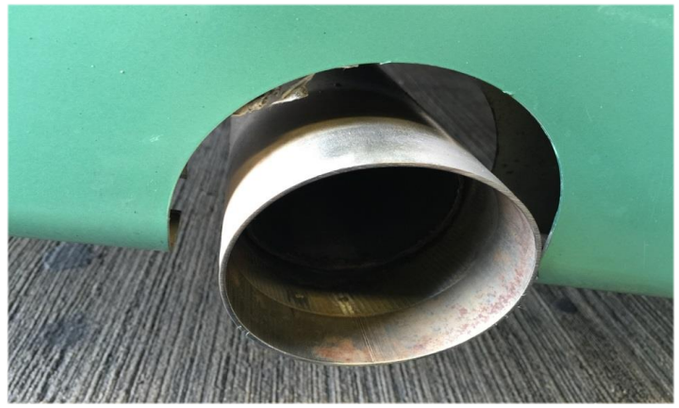
Current Fleet Size: 10 (Further 9 on Order)

Results to Date

- 3.6 million Kgs CO2 saved
- Operational Savings: 21% v Fleet average
  - Fuel
  - Maintenance
  - Reliability
- Replaced Euro 3 & 4 Buses
  - NOx & PM reduction +95%

- Annual spark plug change
- No EGR system to maintain.
- No Particulate traps to service.
- Longer intervals between engine oil changes.
- No messy fuel filters to replace.
- All of this saves on cost of running these vehicles.

Euro V1 Gas
(100,000+ Kms)



Euro V1
Diesel Hybrid

Euro V1 Gas

Advantages of CNG/Biomethane technology

The cleanest, CO2 neutral, reliable, non-fossil and affordable solution for public transport:

- Buses readily available
- Proven reliable technology
- Lowest PM emission
- Lowest NOx emission
- Low noise production (-2 dB)
- No link with food chain discussion (Bio-fuels)

Advantages of CNG/Biomethane technology

The cleanest, CO2 neutral, reliable, non-fossil and affordable solution for public transport:

- Exceeds Euro 6
- No Adblue
- No Battery Packs, disposal or replacement
- Biogas compatibility
- No Spillage risks
- Future Proof - Biogas
- Manure, Municipal Waste, Food waste – Not crop reliant
- Biogas can be fed directly into the UK Gas Main

Initial running cost comparator

- Gas: £0.38/mile

- Diesel: £0.48/mile

- Initial expected saving: 22%.

- However, to date the savings have exceeded 24%

Vehicle cost

- MAN EcoCity (to Arriva specification) circa £220,000
- Standard Arriva specification single deck bus circa £165,000
- Variance = circa £55,000 per vehicle

What the passengers think

- Quiet
- No vibration
- No diesel smell
- Good heating and ventilation
- Good interior lighting

What the drivers think

- Good cab ergonomics
- Good seat
- Driveability
- Blown air – demisting
- Effortless drive

In Summary

- Sustainable renewable fuel
- Carbon Neutral
- Farming community opportunities
- UK produced fuel
- Solution for now
- No Guinea Pigs

CBN065g MAN A69CNG

ARRIVA

Large fleet rollout of Electric Buses

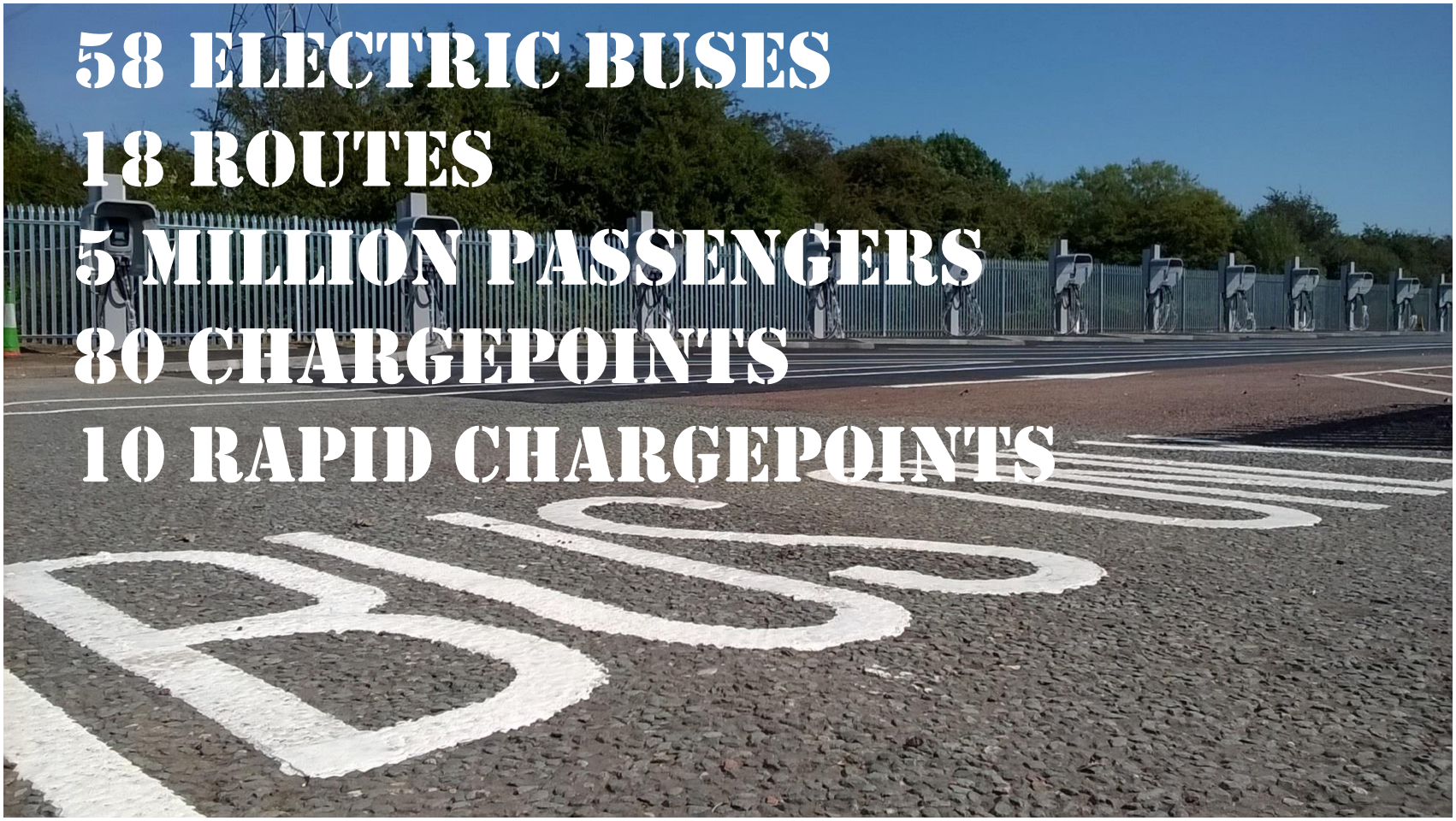
Steve Cornes

Electric Bus Project Manager

Nottingham City Council Public Transport Team

Nottingham City Council

Nottingham City Council Electric Bus Project



GREAT CITY
GREAT WORKFORCE
CITIZENS AT THE HEART
GREAT SERVICES
GREAT COUNCIL

Nottingham City Council

The 5 Ws

- What?
- Who?
- Where?
- When?
- Why?
- How?
- How much?

- Air Quality
- *Your name here*
- *Your local AQMA/LEZ*
- *Your timescale here*
- Environment, Health, Cost
- Using zero emission buses
- *How much do you have available/ can you get hold of? Business case*

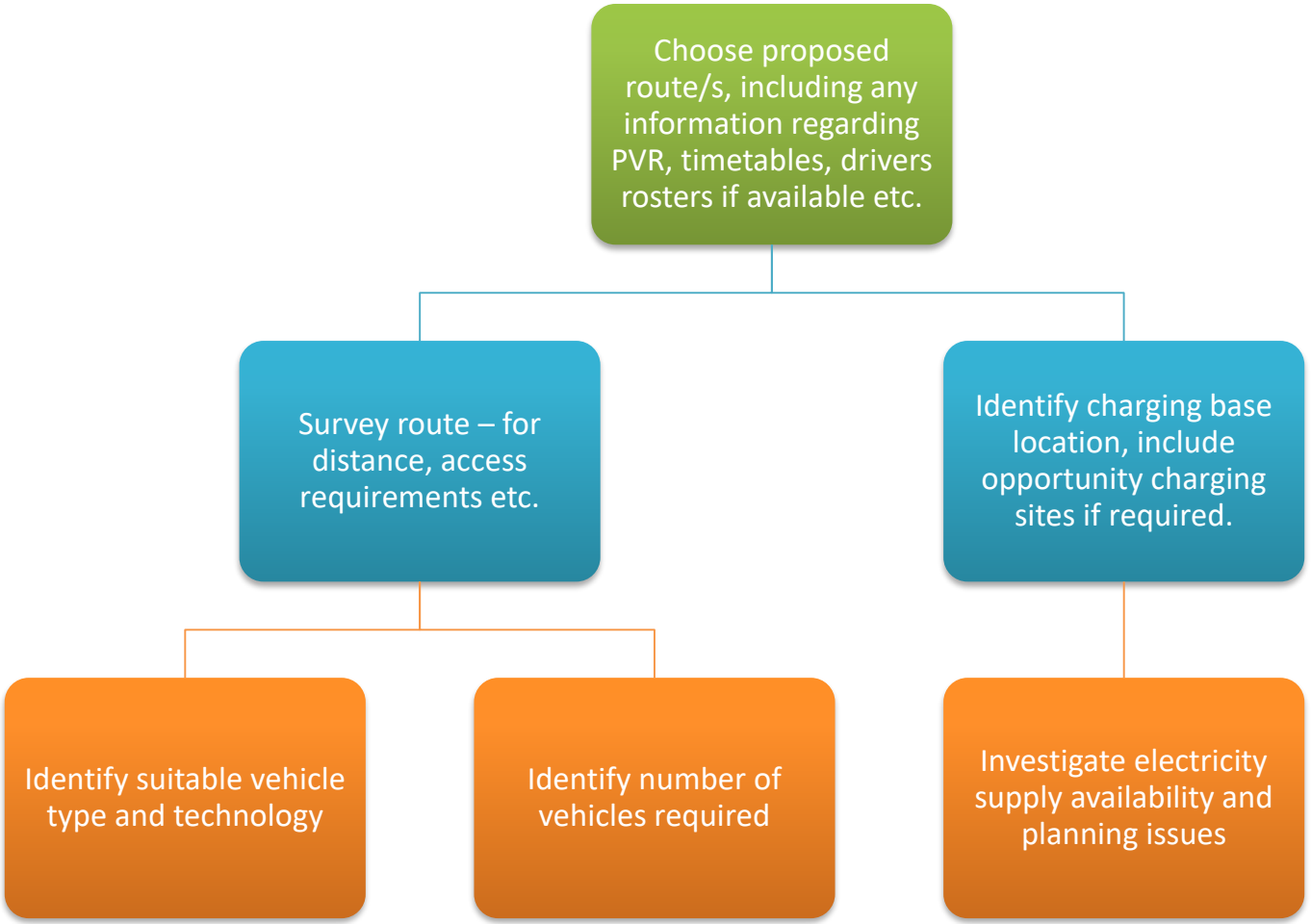
Nottingham City Council

How? Planning

- Initial scoping exercise – scale, route/s
- Different scenarios concerning vehicle ownership
- Contract lengths
- Who is responsible for the provision of vehicles and charging base?
- Think about the expertise and personnel you will require
- Investigate and visit working projects
- Talk to operators and manufacturers
- Think about ancillaries - ticketing, real time and telemetry requirements

Nottingham City Council

How? Planning: Infrastructure and Vehicles



How? Planning: Finance and procurement

- Write/respond to tenders for vehicles and/or services – importance of SLAs and guarantees. Ensure contracts are signed with warranty service providers before delivery.
- Consider extended warranty options
- Consider charging base design and other charging equipment factors
- Consider complete operating costs e.g. standing charges on electricity supplies, the impact of regenerative braking, can you use low tariff electricity?

Nottingham City Council

How? Planning: Vehicles

- Identify suitable vehicles: technology, range, seating, costs, vehicle dimensions
- Heating and a/c types and impacts
- Take into account vehicle build and delivery times
- Keep in touch without the manufacturer throughout
- Testing

Nottingham City Council

How? Infrastructure construction

- Plan ahead – long lead-in times with DNOs etc. so apply early for POCs, permits to work etc. if required
- Take account of extra civils costs for enclosures, highways works, storage requirements – grant implications
- Program with vehicle delivery – does any charging equipment from the manufacturer need delivering before the vehicles arrive for installation?
- Allow time for trialling with vehicles

How? Operations and monitoring

- Importance of good telemetry
- Charging times – peak/off-peak
- ASC standing charges – can the asc be lowered/offset?
- Grid impacts

When?

- Delivery - Project management
- Launch event

- time to coincide with significant local/national event

Future..

- Keep looking for funding opportunities
- Electricity Supply Grid Developments
- V2G developments
- Energy trading/brokerage
- Marketing – keep your profile high

Nottingham City Council

Thank you for your attention.

Any questions?

steve.cornes@nottinghamcity.gov.uk

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GREAT SERVICES
GREAT COUNCIL

Nottingham City Council

Integration of Efficient EuroVI Diesels

James Blackshaw BEng, MSc, MSc, CEng MIMechE
Technical Projects Manager
First Bus

First Bus

- First is one of the UK's largest Bus operators, with around 6200 buses across the UK and carries 1.6million people per day.
- First operates around 1000 low carbon certified buses with in the UK.
- Fleet includes: Hybrids, MicroHybrids, Electric, Hydrogen, Virtual Electric, and we have recently trialled Bio-methane.

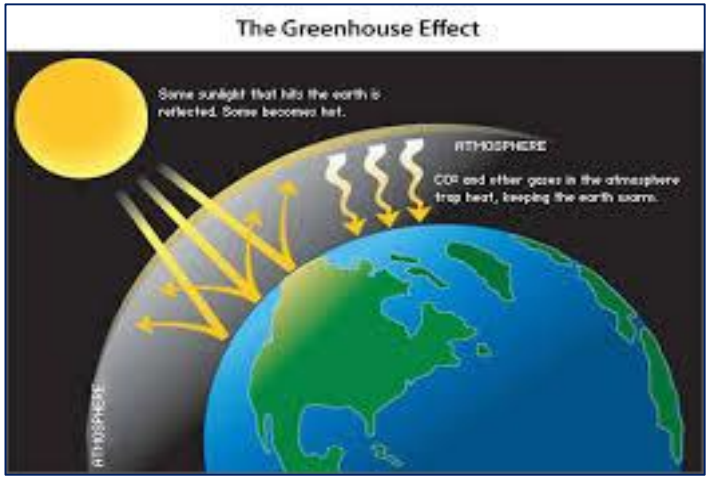
Low Carbon Vehicle Operator of the Year 2016

Low Carbon Champions Awards

THE LOWCVP LOW CARBON CHAMPIONS AWARDS

Emissions Agenda

Double Challenge for Passenger Transport

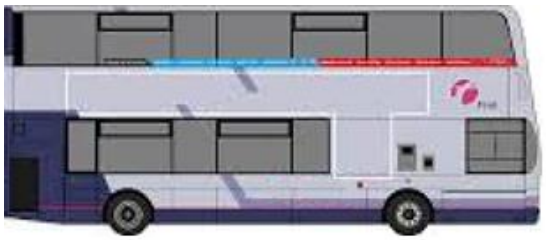


Climate Change – Impacted by Green House Gases / Carbon emissions **(CO2)** which directly relate to fuel consumption. Increasingly on Global and UK Government agenda.

Air quality – Many cities in breach of EU's Oxides of Nitrogen (**NOx)** emission limits – Reported as hazardous to human health and driving factor behind the push for Clean Air Zone introduction. Emissions rate of Particulate Matter (**PM**) is also of concern.

Emissions Agenda

Emissions in Context



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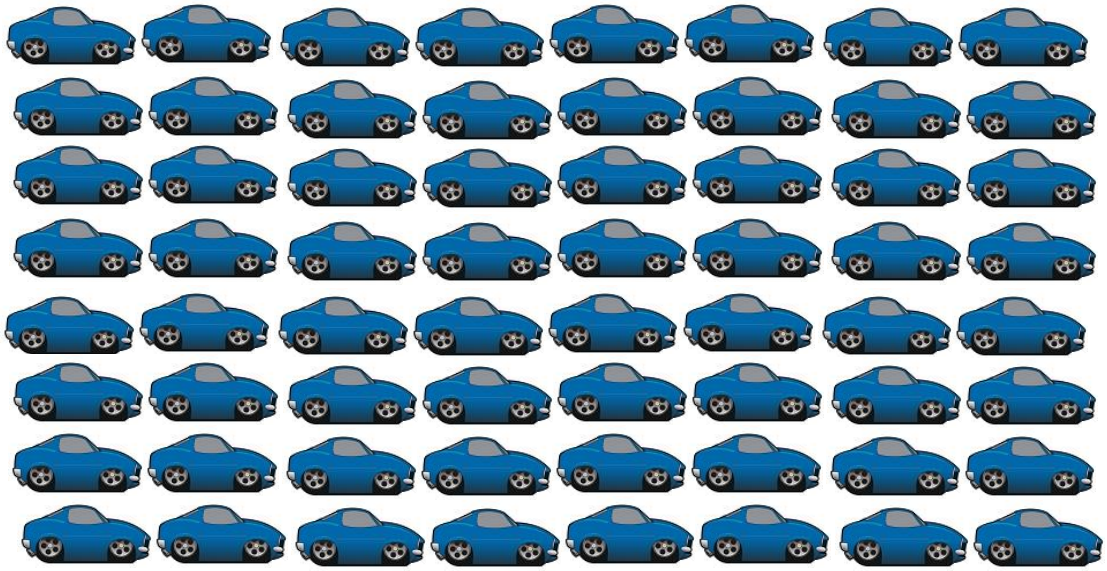


Regardless of the technology used

- Buses offer a significantly more efficient way of travel – therefore helping to reduce impact on climate change.
- Buses can and should be a vital part of effort to improve air quality.
- **However** - Buses are becoming stuck in the very congestion they can help to solve therefore more help and work is needed to improve journey times for bus users.

Timeline of Efficiency Development

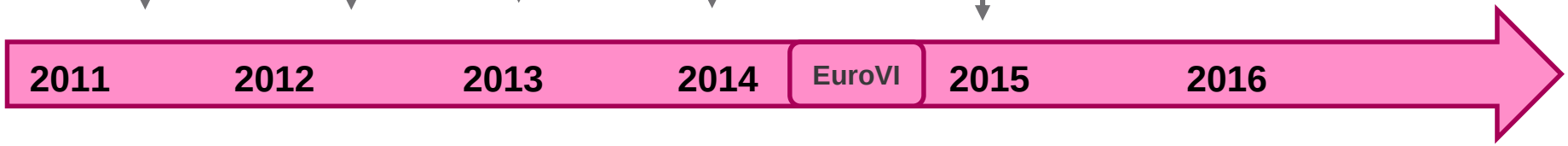
2011- Historical and continuing declining trend in diesel efficiency identified

2012 - Commenced supplier testing at Millbrook Proving Ground.

2012/13 – GPS Data capture to develop FMFET test cycle.

2014 – Continued refinement of test cycle and procedures.

2015 - Annual testing continues

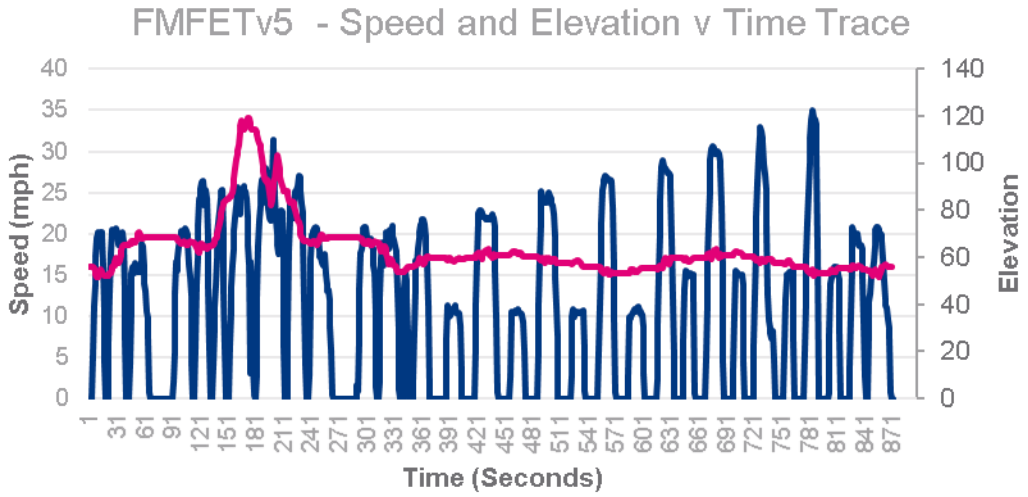


FirstGroup Millbrook Fuel Economy Test (FMFET)

FirstGroup Millbrook Fuel Economy Test (FMFET)

Millbrook Testing: Based on real word operational data to replicate what buses actually do. Test incorporates:

- Junctions
- Roundabouts
- Bus stops with door openings
- Varied idling periods
- Flat and hilly sections
- Straight and windy roads
- Varying speed profile



- Buses fitted with fuel flow meters and advanced GPS tracking
- Driven by independent Millbrook's drivers
- Process also involves Gradient and Acceleration testing

Timeline of Efficiency Development

2011- Historical and continuing declining trend in diesel efficiency identified

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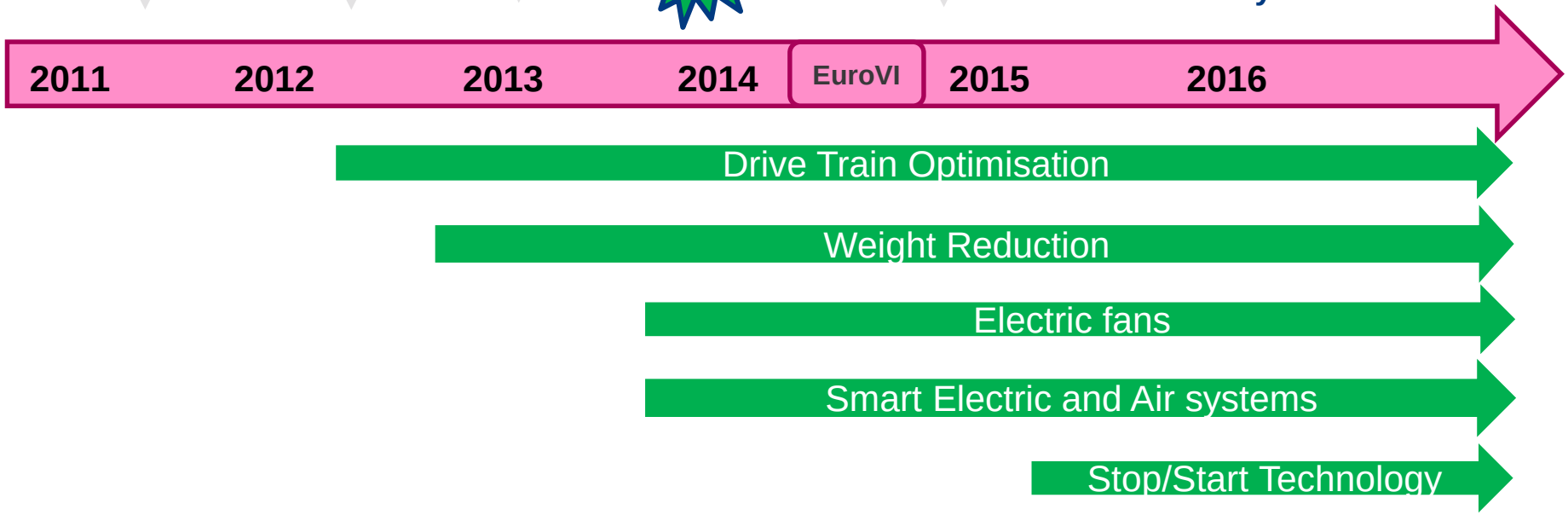
2014 – continued refinement of test cycle and procedures.

2015 - Annual testing continues

Low Carbon Emission Bus Certification achieved without need of conventional hybridisation



Air Quality – EuroVI Diesel

First moved to EuroVI engine vehicles in April 2015 and now has over 600 within its fleet.

EuroVI HD Diesel Engines –

- Widely acknowledged as delivering a huge improvement on previous standards
- verified by independent testing and further improvement is already being made.

EuroVI Diesel Double Deck Example - LEB Test Results

Test Phase	HC (g/km)	CO (g/km)	NOx (g/km)	PM (g/km)
Rural	0.000	0.011	0.005	N/A
Outer London	0.000	0.037	0.004	N/A
Inner London	0.000	0.045	0.006	N/A
MLTB Average	0.000	0.039	0.005	N/A
LUB Average	**0.000**	**0.027**	**0.005**	**0.0116**

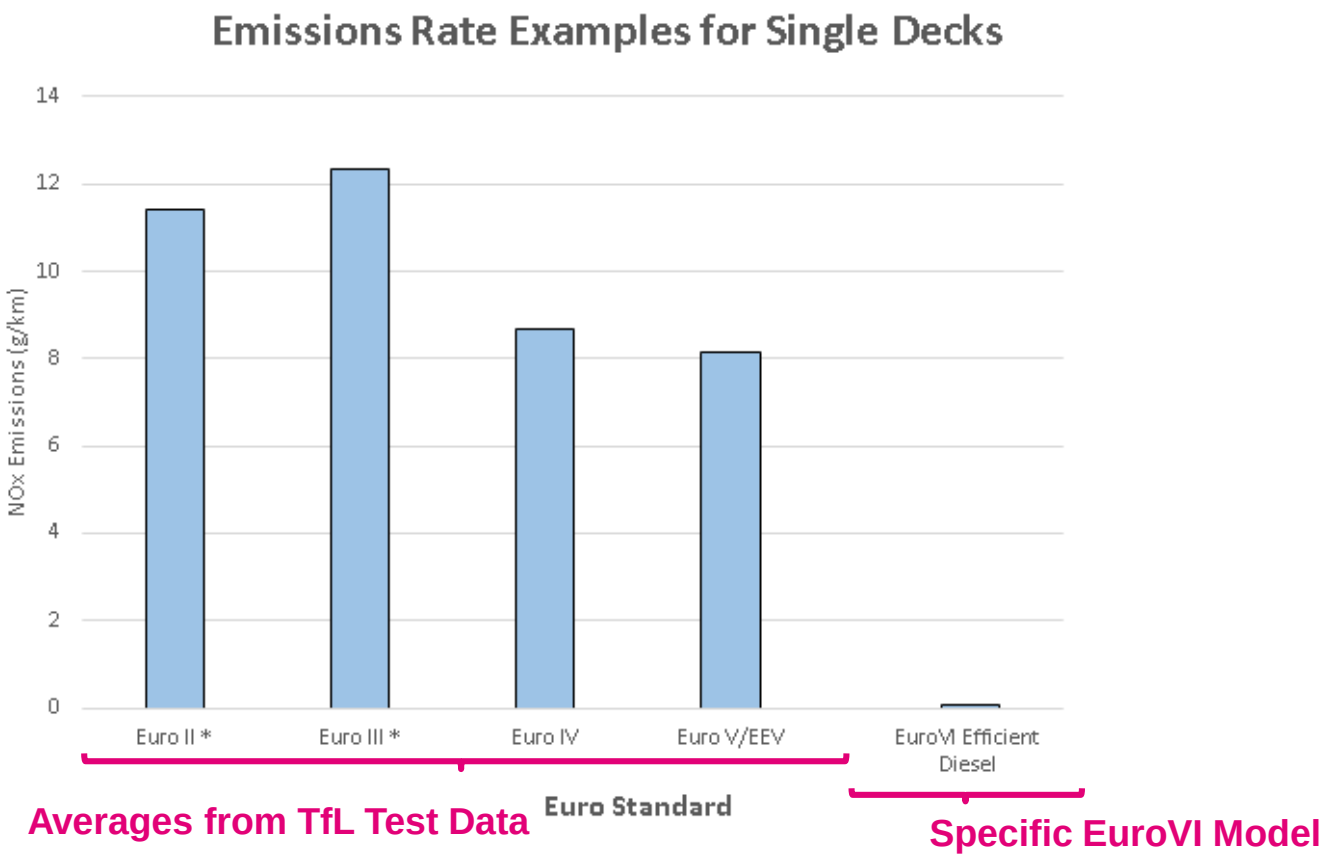
Euro6 Passenger Car Avg – DfT Test Data*

NOx (g/km)
0.5

*DfT Data based on real world testing, average of 19 diesel models.

Emissions Agenda – Vehicle Options

- **Modern efficient Euro VI diesel** most cost effective emissions reduction solution in short term. New vehicles can deliver up to 99% reduction in NOx emissions and over 30% Carbon emissions relative to end of life EuroII / III buses..



Data based on publically available and credible sources recognised by DfT, DEFRA and OLEV.

Summary

Efficient EuroVI diesel models are the most cost effective new bus solution to improving air quality.

- Offer significant improvements in both NOx and Carbon emissions
- No requirement for new infrastructure
- Technology fairly well understood
- Carries a cost premium but is commercially viable particularly with LCEB BSOG incentive.
- Emergence of new generation of Hybrids that offer even further carbon benefits.

Other technologies - Longer term outlook

- Drive towards zero emissions and further reducing carbon emissions means Electric will increasingly have a place in the long term.
- Whilst bio-methane is not zero emission it does have strong carbon credentials

- ❑ **Increasing number of technologies are becoming available**
- ❑ **The specific local objectives need to be determined and understood before the most appropriate technology solution can be chosen.**

Transport for Greater Manchester

Clean Air for Schools Programme

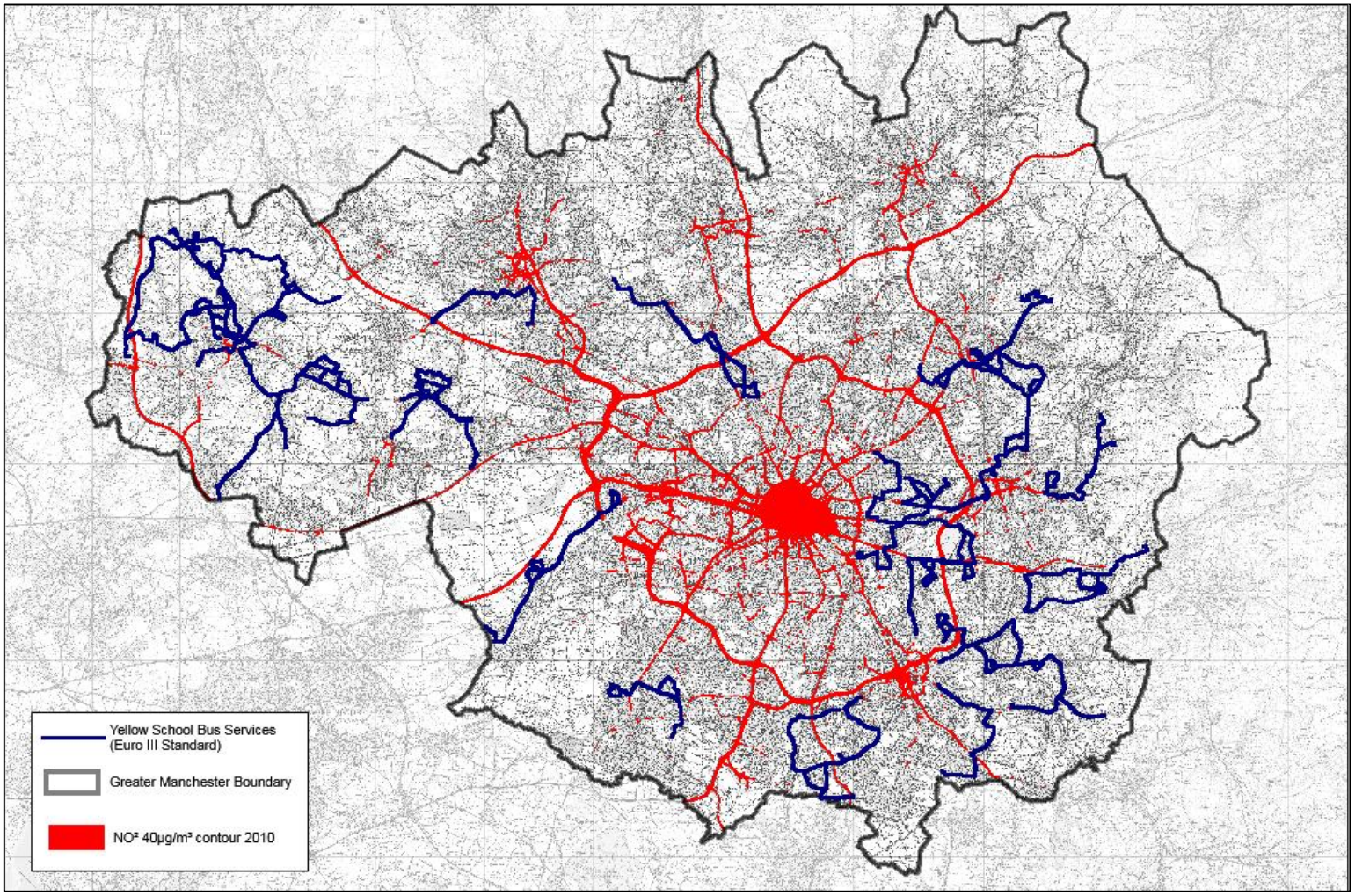
Transport for Greater Manchester

TfGM Yellow School Bus Fleet

- TfGM has a fleet of 93 Yellow School Buses.
- 52 Optare Versa hybrid buses.
- 41 conventional diesel Iveco Scolabuses, purchased between 2003 and 2009, which were Euro III/IV emission standards and the subject of this project.
- These vehicles operate on dedicated school services across Greater Manchester.

Transport for Greater Manchester

School Bus Operating Area



Transport for Greater Manchester

Project Objectives

- To improve local air quality in the vicinity of the school services and the communities that the buses serve.
- To reduce tailpipe emissions of nitrogen oxides (NOx) and other harmful by-products with air pollution control equipment to upgrade them to Euro V emissions standards or better for all legislated pollutants (CO/HC/PM/NOx).
- TfGM continue to set example to local operators, with regard to air quality responsibilities.

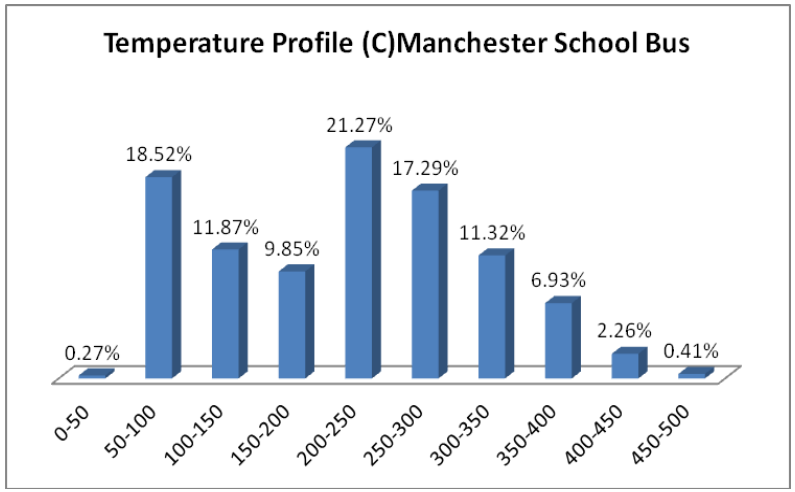
Transport for Greater Manchester

Project Scope

- Consider and evaluate alternative retro fitment technologies comprising Diesel Oxidation Catalysts (DOC), Diesel Particulate Filters (DPF), Selective Catalytic Reduction filters (SCR) and Ammonia Generators.
- Focus on significant levels of reduction in PM/HC/NOx/PM without adverse effects on CO2.
- In-service monitoring of emissions performance data and system reliability.
- The installation of idle limiters, to help reduce engine idling time, conserve fuel and reduce harmful emissions.
- The installation of fast acting windscreen de-misting equipment to reduce the need to operate engines prior to commencing the journey.

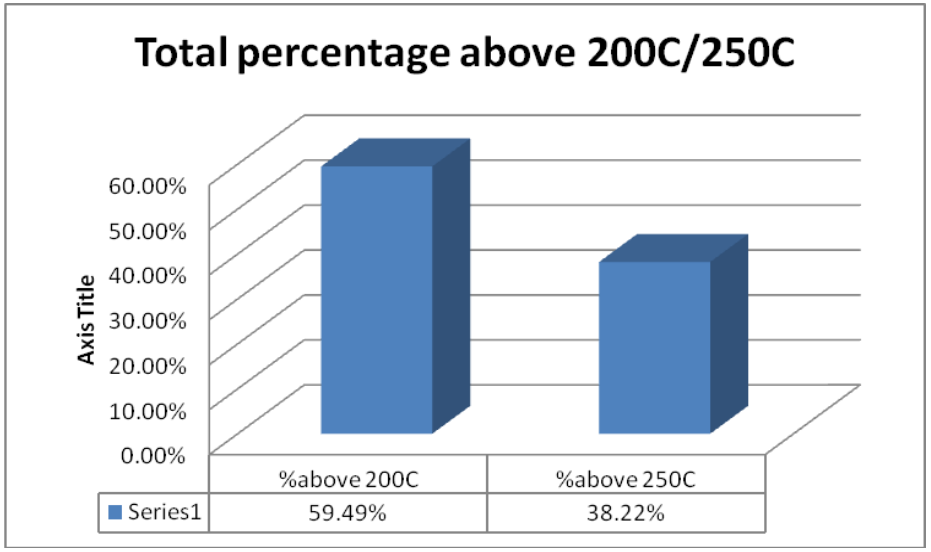
Transport for Greater Manchester

Temperature Profile



To assist with the project, exhaust gas temperature measuring equipment was installed on a representative Yellow School Bus.

Data was provided to allow the selected suppliers to develop a bespoke solution.



Transport for Greater Manchester

Supplier Selection and Award

- TfGM conducted an open OJEU procurement process. The scoring was evaluated against 60% Technical and 40% Financial.
- Clean Bus Technology Fund 2013 - Baumot UK Ltd and HJS Emission Technology awarded.
- Clean Bus Technology Fund 2015 - Baumot UK Ltd.
- The average retro-fitment package costs across the projects equates to 10% of the purchase cost of a new Euro 6 equivalent Yellow School Bus.

Transport for Greater Manchester

SCRT® - System (= SCR + CRT®)

CRT-System Stage 1

SMF® - Sintered Metal Filter

Oxi-Cat

Urea (AdBlue®)-Doser

SCR - Catalyst

Ammonia Slip-Catalyst

SCR-System Stage 2

Stage 1

Hydrocarbon (HC)
Carbon monoxide (CO)

↓

Diesel-**O**xidation-**C**atalyst
(DOC)

Particulate Matter
(PM)

↓

Diesel particulate filter

Stage 2

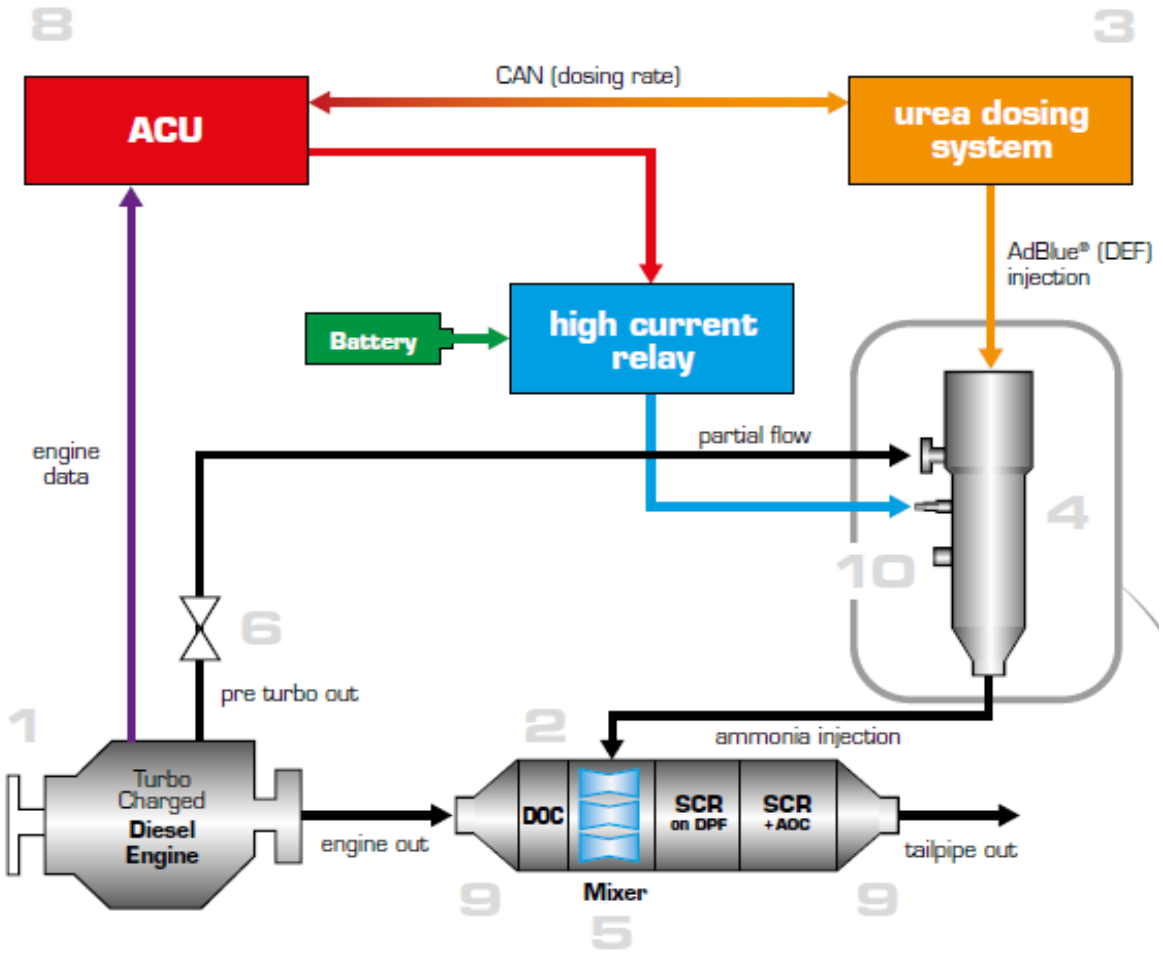
Nitrogen Oxides
(NO_x)

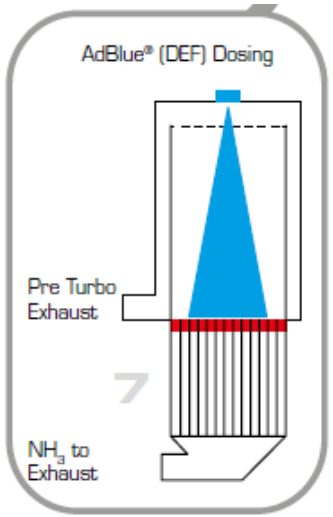
↓

Selective **C**atalytic **R**eduction
(SCR)

Transport for Greater Manchester

TwintecBaumot B-NOx SYSTEM OVERVIEW





Turbo Diesel engine 1, Exhaust System with PM- and NOx reduction 2, Ammonia (NH_3) Generator 4 and Mixing Unit 5.

DEF (Urea Solution) is injected via Urea Dosing System 3 into Ammonia Generator 4. NH_3 is generated inside and injected into Exhaust Mixing Unit 5.

The generator uses the heat sources from pre turbo exhaust gas 6 and electrically heated catalyst 7

Partial flow is defined by tube diameter 6.

Injection control by ACU 8, Urea Dosing System 3, Temperature- 10 and NOx Sensors 9.

Transport for Greater Manchester

Emission Testing at Millbrook Proving Ground

- Baseline emission data for a sample Euro III and IV bus was obtained using the Millbrook London Transport Bus test cycle, in conjunction with the Low Carbon Emission Bus test weight.
- The prototype Euro III retro fitments were specified to be tested on the Millbrook London Transport Bus test cycle.
- Follow up testing of the Euro III retro fitment was conducted after 2 years in operation.
- The prototype Euro IV retro fitment was specified to be tested on the Millbrook London Transport Bus test cycle, with the Low Carbon Emission Bus test weight.

Transport for Greater Manchester

Millbrook Emission Test Results

Twintec Baumot B-NOx SCR System result a on Euro III bus

Millbrook London Transport Bus Test Cycle – Low Carbon Emission Bus Test Weight

	Units	HC	CO	NOx	CO2	PM	Fuel Consumption Litres/100km
Baseline	g/km	1.375	3.677	12.742	1252.1	0.399	47.67
After	g/km	0.008	0.083	0.097	1288.7	0.026	48.67
Level of Reduction %		-99.42%	-97.74%	-99.24%	2.92%	-93.48%	2.10%

HJS SCRT System result on a Euro III bus

Millbrook London Transport Bus Test Cycle

	Units	HC	CO	NOx	CO2	PM	Fuel Consumption Litres/100km
Baseline	g/km	1.375	3.677	12.742	1252.1	0.399	47.67
After	g/km	0.000	0.063	0.14	1390.9	0.005	52.53
Level of Reduction %		-100.00%	-98.29%	-98.90%	11.09%	-98.75%	10.20%

Transport for Greater Manchester

Millbrook Emission Test Results

Twintec Baumot B-NOx System results on Euro III after 2 years

Millbrook London Transport Bus Test Cycle - Low Carbon Emission Bus Test Weight

	Units	HC	CO	NOx	CO2	PM	Fuel Consumption Litres/100km
Baseline	g/km	1.375	3.677	12.742	1252.1	0.399	47.67
After	g/km	0.000	0.037	0.041	1309.1	0.0226	49.44
Level of Reduction %		-100.00%	-98.99%	-99.68%	4.55%	-94.34%	3.71%

Twintec Baumot B-NOx System results on Euro IV

Millbrook London Transport Bus Test Cycle – Low Carbon Emission Test Weight

	Units	HC	CO	NOx	CO2	PM	Fuel Consumption Litres/100km
Baseline	g/km	0.034	1.769	8.716	1155.9	0.0435	43.76
After	g/km	0.007	0.038	0.081	1239.2	0.012	46.8
Level of Reduction %		-79.41%	-97.85%	-99.07%	7.21%	-72.41%	6.95%

Transport for Greater Manchester

Project challenges

- New technology challenges.
- Component mounting challenges due to variations in the chassis layout.
- Component ECU failures experienced.

Transport for Greater Manchester

Next Steps

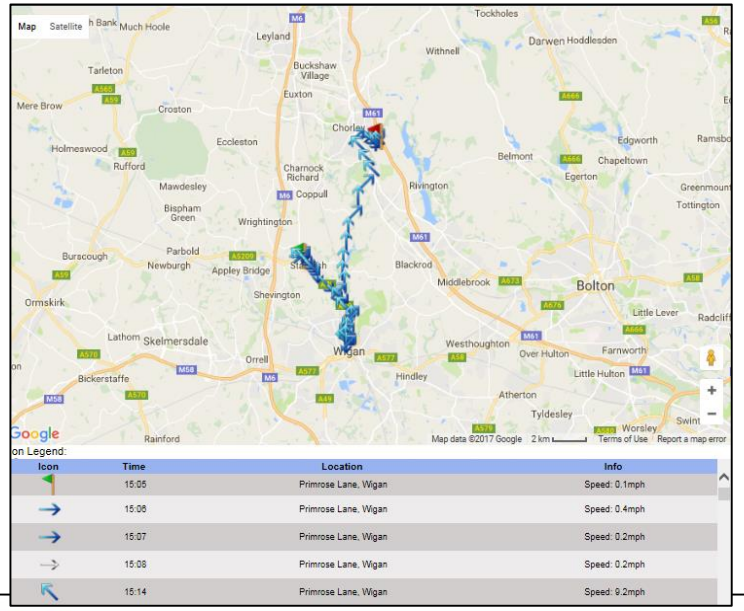
- Installation of telematics onto the 41 Iveco Yellow School Buses.
- To enable real-time monitoring of:

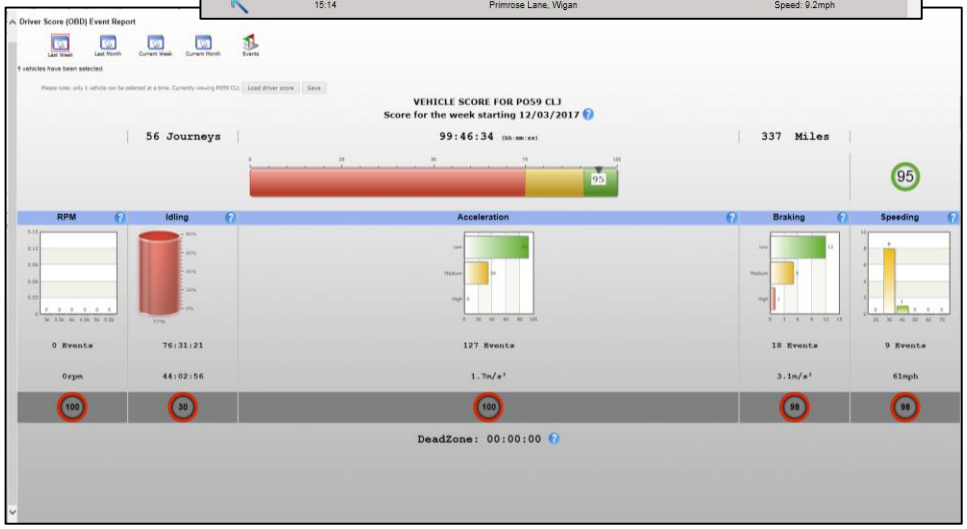
➢ Driver performance including idling, harsh acceleration and braking events.

➢ CAN Bus data for driveline systems.

➢ Exhaust system data and performance.

➢ Real time alerts for active faults.





Transport for Greater Manchester

Thank you.

David Ives

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