Challenges on charging infrastructure support

ELECTRIC BUS PROJECT AT WATERLOO BUS GARAGE, LONDON

10th November 2016

UK eBus Summit

Leonard Chew – BYD
Adrian Llewellyn – SSE

Contents

About Us

Go-Ahead London

- Circa 25% London bus market
- 190 routes
- 2,300 buses
- 18 garages
- Introduced first hybrid buses in London
- Introduced first electric buses in London

About Us

BYD COMPANY LTD

- **Leading-edge** provider of **Green Energy** Technologies
- **World's largest** manufacturer of rechargeable batteries and **new-energy vehicles**
- More than **20 years** battery manufacturing experience
- Over **10,000** eBuses manufactured

BYD Pure Electric Bus and Coach Family

In the near future, BYD's roadmap to introduce a full spectrum of electrified **mini, midi, double-decker** and **articulated buses** and **BRT** solutions.

8.6-metre

10.8-metre

10.2-metre double-decker

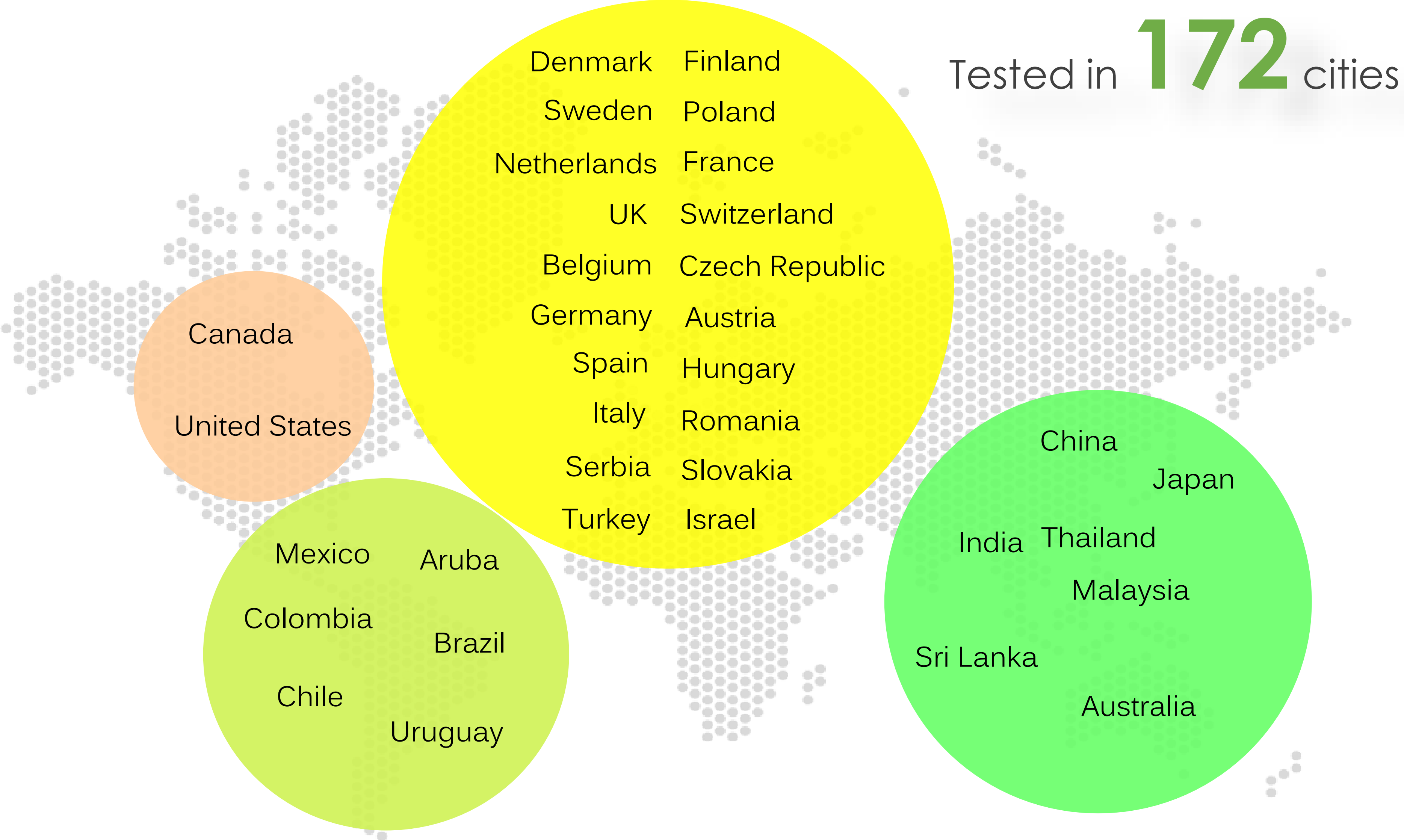
12-metre coach

12-metre

18-metre articulated

12-metre apron bus

BYD electric bus global footprint



BYD key projects in Europe

Schiermonnikoog, NL
6 units (Apr 2013)

Amsterdam Airport Schiphol, NL
35 units (Nov 2015)

Eskilstuna & Ängelholm, SE
2 & 5 units (Jan 2016)

London, UK
5 units (May 2016)

London, UK
51 units (Aug 2016)

Nottingham, UK
13 units (Oct 2016)

SSE

- 30th largest company in the FTSE 100*
- £14.95bn market capitalisation*
- Around 20,000 employees
- UK's broadest-based energy company
  - Electricity generation, transmission, distribution, supply and services
  - Gas production, storage, distribution, supply and services
- Ireland's fastest-growing energy company
  - Electricity generation
  - Electricity and gas supply
  - Street lighting maintenance
- Delivered a real dividend increase every year since 1999

*As at 22 July 2014

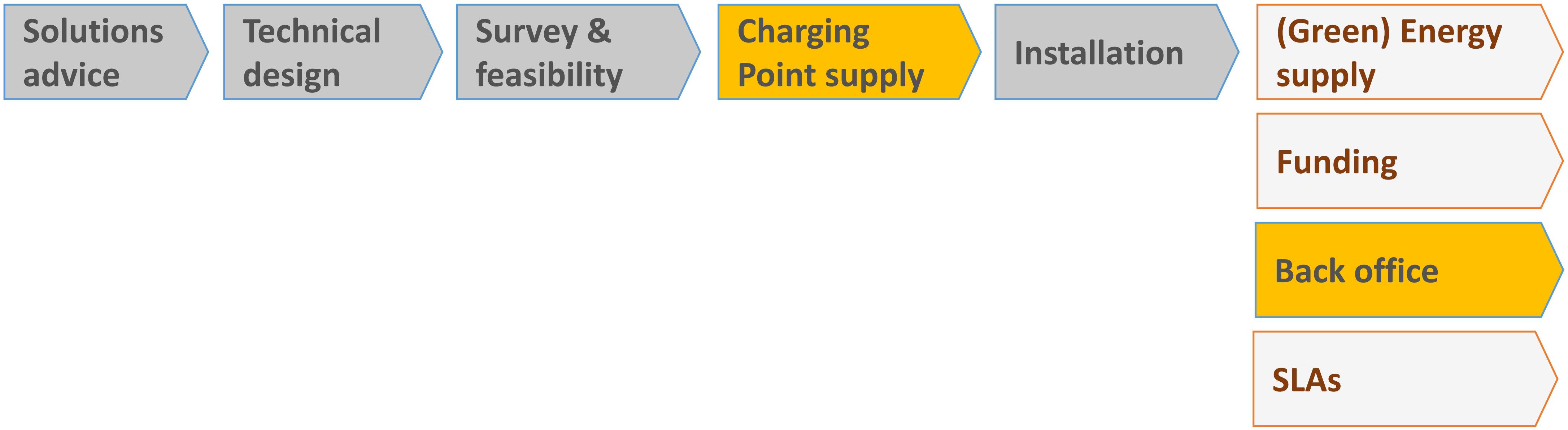
SSE Enterprise part of SSE PLC

Economically Regulated	Networks	Electricity Distribution	Electricity Transmission	Gas Distribution		
Market based	Retail	Energy Supply for the home	Energy related services for the home			
	Wholesale	Energy Portfolio Management and Electricity Generation	Gas Production	Gas Storage	Energy supply for business	
	Enterprise	Utilities	Contracting	Lighting	Energy Solutions	Telecoms

SSE Enterprise delivers essential services that improve

What's Next?

SSE's offer: end-to-end solutions



SSE is working towards the development of end-to-end solutions, adding value to their offer to customers (benefiting from spreading high upfront costs, equipment updates and business tax relief for leasing)

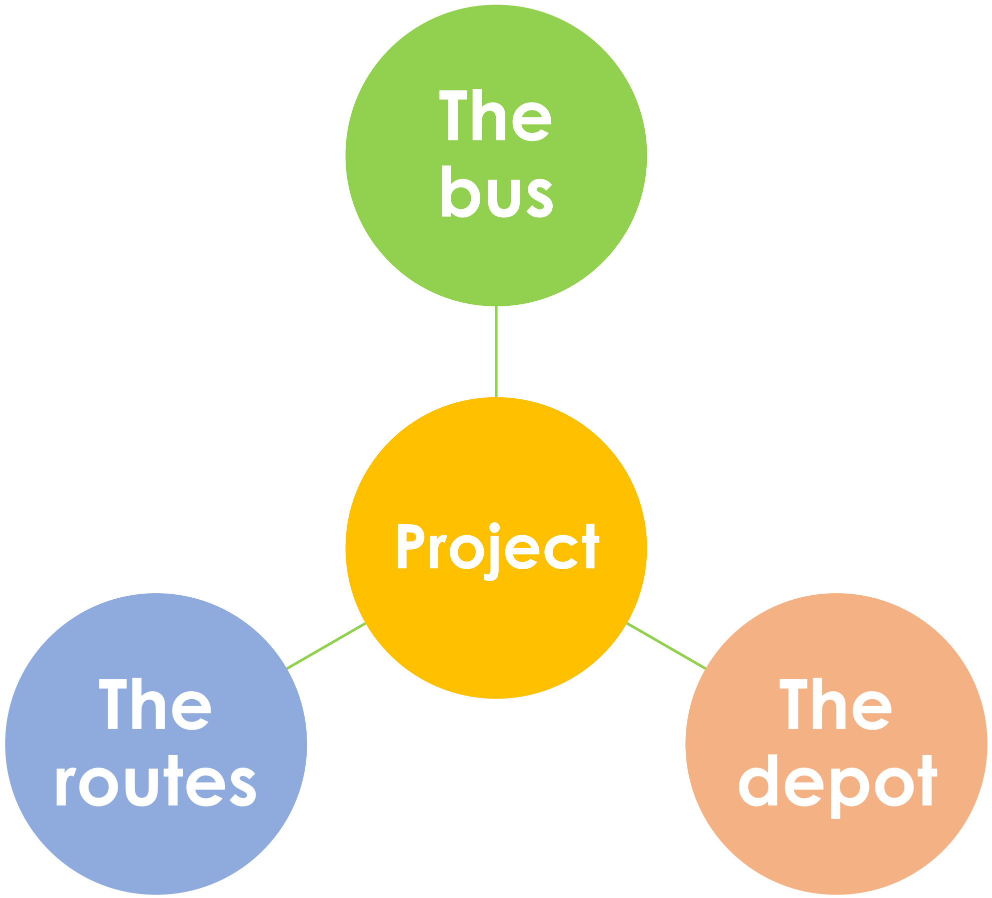
Legend:

The Project

Waterloo Bus Garage, London

Stakeholders

Project 'ingredients'



The bus

0 emissions

Reliable battery

LOW operating cost

Single-charge operation

The bus

- BYD battery, powertrain and chassis + ADL body
- >250 km range, 4h charging time
- 90 passengers (21 seats)

The routes

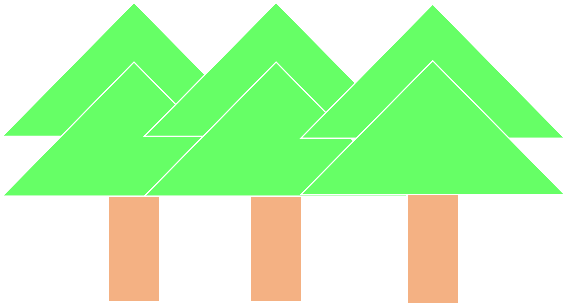
- Running through Ultra-Low Emissions Zone (ULEZ)
- 4.3 / 5.6 km per trip
- 0600 to 0030 overall operation
- High peak-time operation
- 7 million passengers per year
- 1 million km per year

The routes

CO_2 Reduction

912*

tonnes per year



Trees planted

5,069

yearly

*Well-to-wheel emission savings based on LowCVP and DEFRA grid electricity factors, mileage data from Transport for London, vehicle data based on LEB test cycle in the UK

The depot

The charger

Specifications	
Type	AC, Mennekes, Type 2, three-phase
Voltage	400 V
Max power	40 kW x 2
Max current	126 A
Cable length	3 m

Challenges & solutions

Running a large-scale electric bus depot

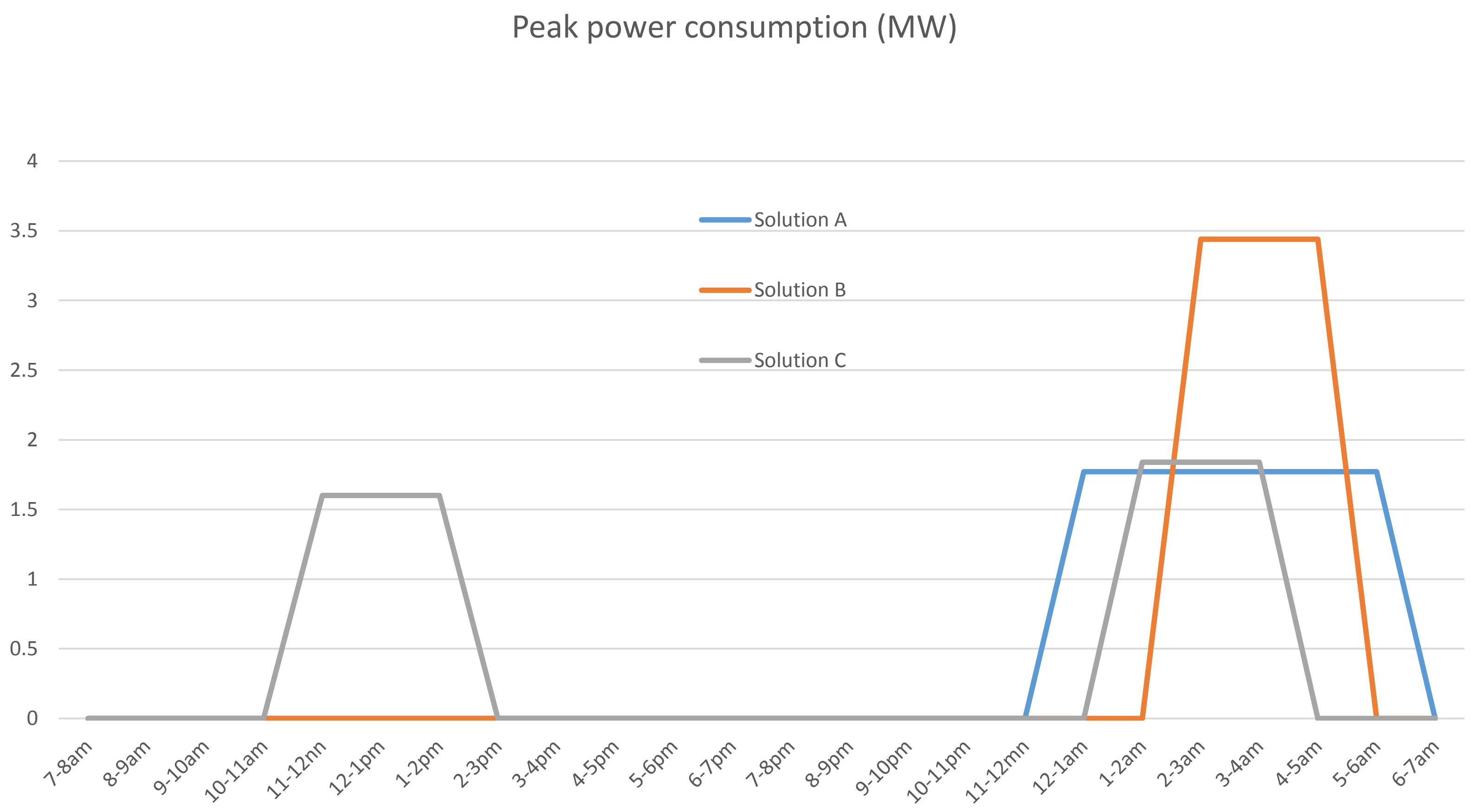
Challenges

- Overall: Large fleet of electric buses charging
- **Space** – no room for expansion, movement of buses not possible when full, compact chargers needed
- **Power** – available capacity, connection shared with residential buildings
- **Time** – project delivery, work needed on infrastructure

Space

(or the lack of)

Power – How much is enough?



40 kW

80 kW

Day + night

Power – When to charge?

Image source: Transport for London

Solution: Overnight charging

- Single overnight charge
- 40kW
- Off-peak hours

- No additional vehicles/ dwell time required

- 43 chargers for 46 buses
(5 buses run out from another garage)

Charging – a typical day's operation

~0030 Last bus returns

0000-0700 Charging window

~0600 First bus departs

At 40 kW, typically 2-5 hours required

The infrastructure

HV connection (grid) → LV connection (transformer) → BYD charger

- Survey of existing power supply
- Securing supply
- Upgrade (transformers installed)
- Connection
- Input on expected loads

Summary: The BYD-ADL/SSE solution for Go-Ahead

- Infrastructure may be the greatest barrier but there are solutions
- Operational flexibility is key, understanding vehicle capability
- AC charging – efficient, simple and cost-effective
- Established case for overnight charging as one of the viable solutions for electrified city transportation

Thank you!

Go-Ahead London

sse

BYD
Build Your Dreams

ALEXANDER DENNIS

10 NOVEMBER 2016

London Underground: Opportunities for bus electrification?

Mark Poulton
Vehicle Technology Manager

EVERY JOURNEY MATTERS

Contents

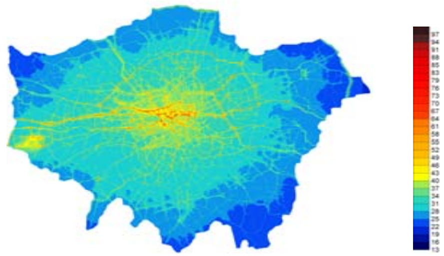
Transport in London

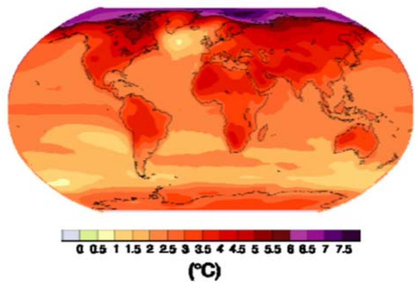
- Transport for London (TfL) manages London's integrated transport system
- Each weekday across Greater London, more than 30 million transport trips are made –
  - 6.5 million journeys on London's buses
  - 4.5 million on the Underground
  - 6 million on foot
  - 0.6 million by bicycle
  - 0.2 million by taxi
  - 12 million by car & motorcycle

TRAMS
UNDERGROUND AIR•LINE BUSES COACHES
ELIZABETH LINE CYCLES DIAL-A-RIDE DLR
OVERGROUND RIVER TAXI•PRIVATE HIRE TFL•RAIL

London’s challenges: environment

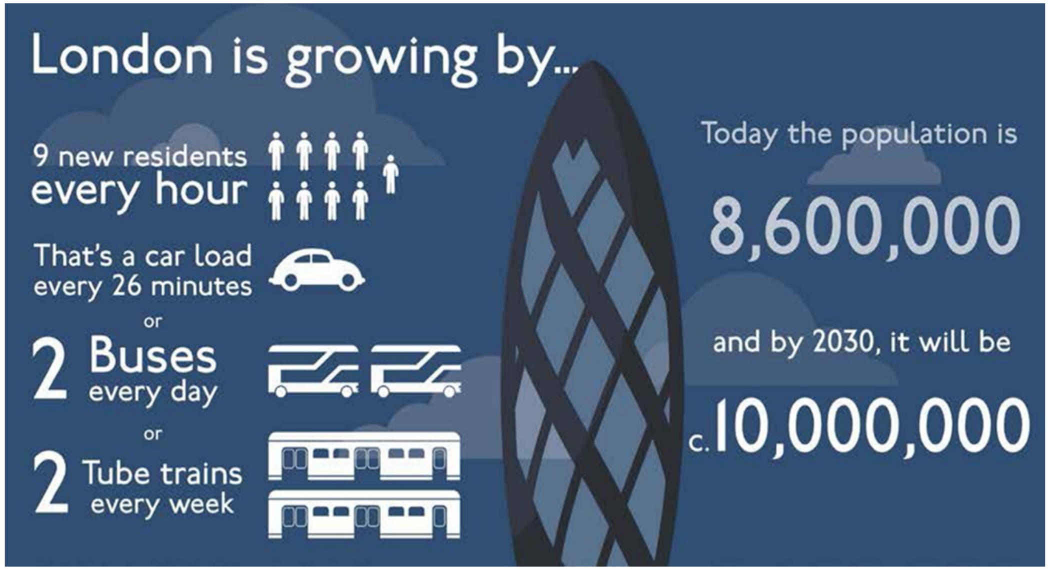
- Air quality – NO_2 (and PM_{10} & $PM_{2.5}$)
- Poor air quality is known to cause respiratory and cardiovascular conditions and is linked to around 9,400 premature deaths p.a. in London
- Road transport contributes 80% of PM and 63% of NOx emissions in London
- Target to reduce London’s CO_2 emissions by 60% by 2025
- Ambition for ‘Zero Carbon’ by 2050





London's challenges: growth

- Population growth – transport capacity
- Congestion (space for more active travel)
- Road safety



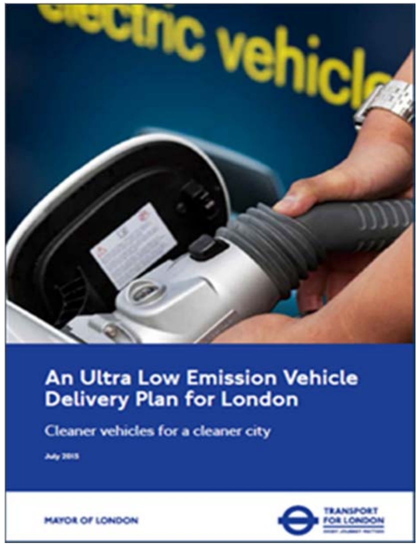
Mayor’s transport priorities

- Proposals for cleaning London’s air will achieve compliance with limits for NO_2 by 2025
- Further action will be required to allow London to become a zero-carbon city by 2050
- Encouraging the use of EVs where road vehicles are needed is key to reducing transport emissions

- All new vehicles should be zero emission by 2040 in order to achieve the 2050 goal

TfL is using its influence to increase all types of ULEVs on London's streets

New licencing requirements for zero emission capable taxis and Private Hire Vehicles

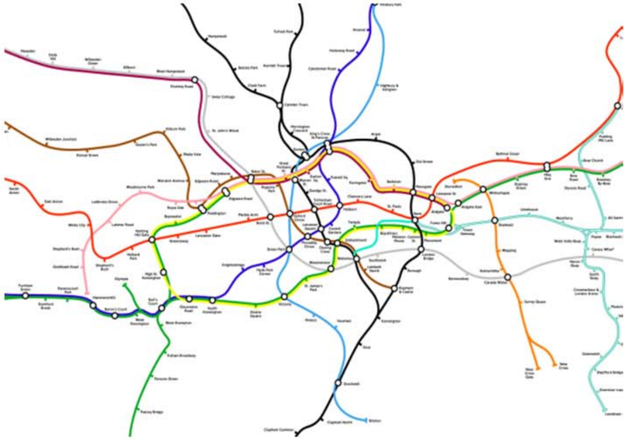


LoCITY programme to help the freight industry adopt ULEVs

Supporting innovation through Mayor's Air Quality Fund

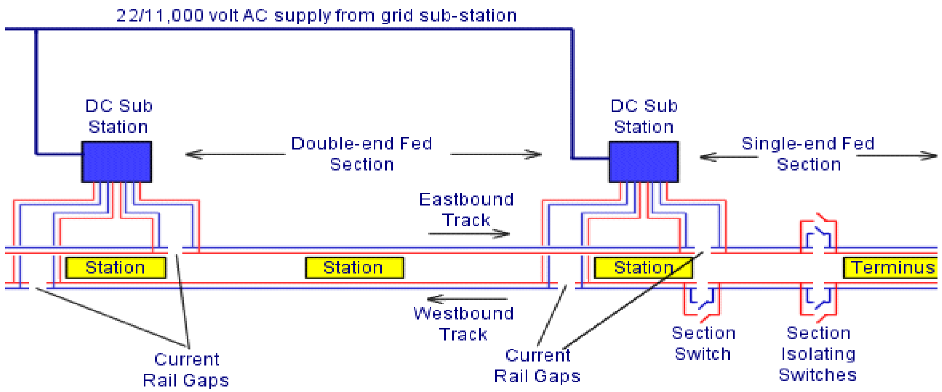
TfL and eLIPTIC: Use Cases

- Key aim: study of the London Underground energy system and London bus networks
- Identifying potential locations for access to the power network to charge electric buses (Pillar A)
- Other plug-in vehicles also of interest (Pillar C)

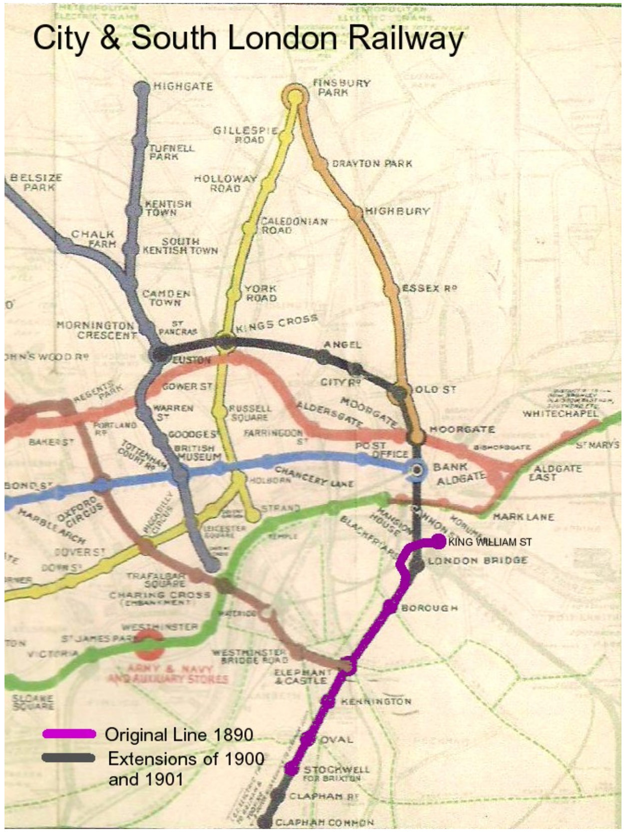


TfL and eLIPTIC: practical considerations

- Spatial (co-) location
- Cost effectiveness
- Legal, regulatory & commercial issues
- Analysis of demand patterns and available capacity
- Suitability of bus route conversion to plug-in vehicles
- Trial or pilot connection to quantify impacts on LU network



London Underground’s power network

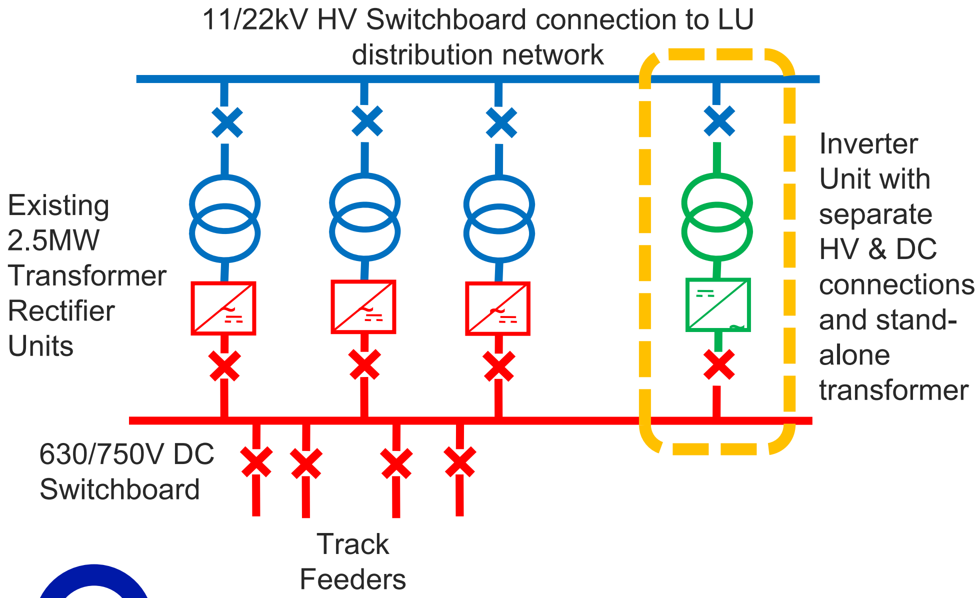


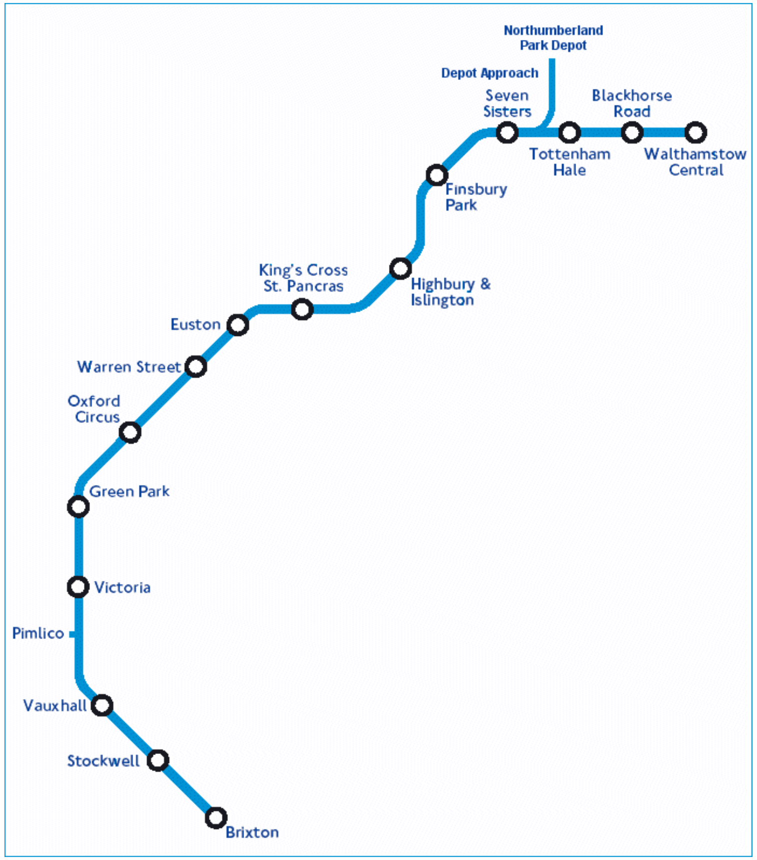
London Underground’s power network

- Over 1 TWh traction energy consumption p.a.
- Energy costs > £100m p.a.
- Transmission & distribution charges rising
- Energy efficiency projects include regenerative braking energy recovery
- Understand benefits of energy storage / load shifting
- Sourcing more low carbon, decentralised energy

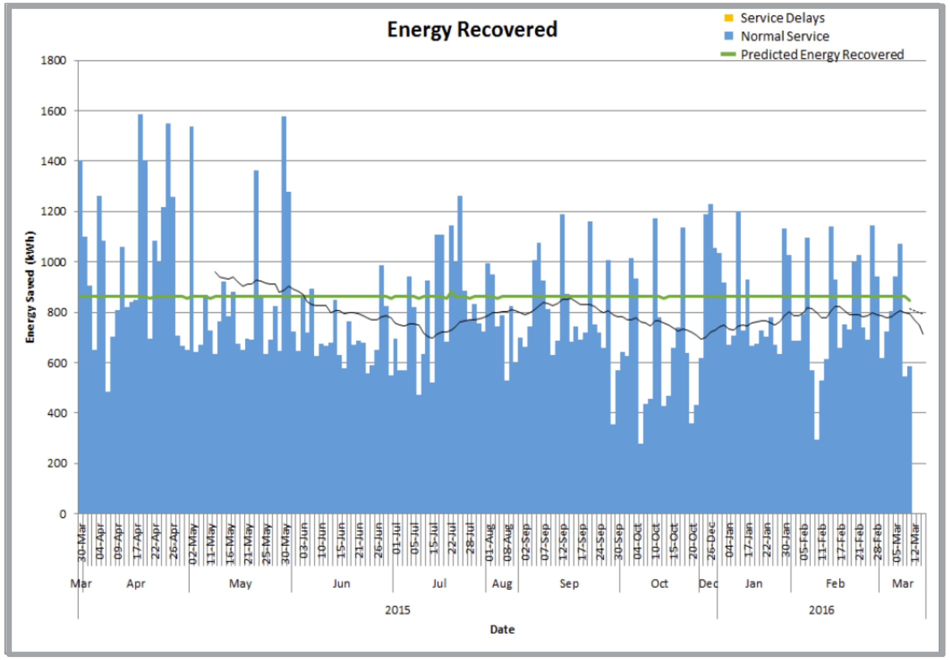
LU traction energy efficiency

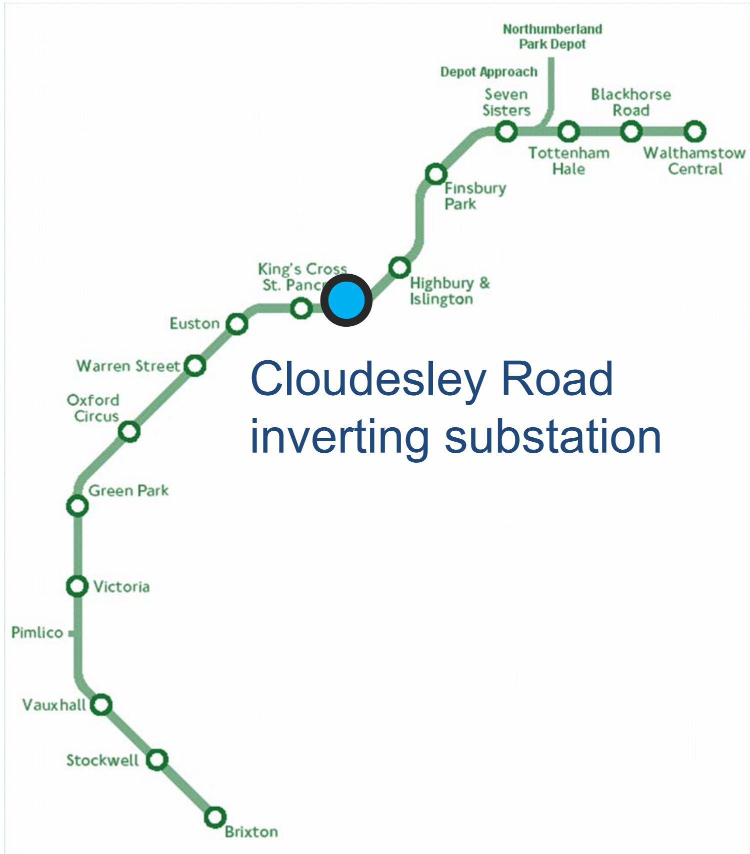
- Victoria Line: annual energy consumption ~ 80 GWh
- Trial of inverting substation to capture otherwise wasted energy





LU traction energy efficiency

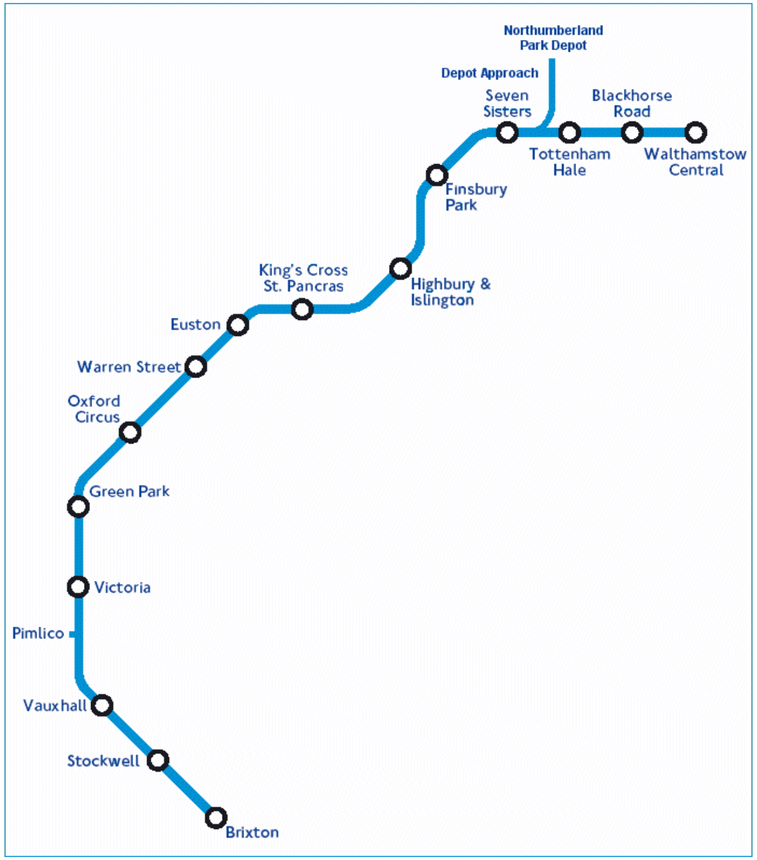




- Circa 5% traction energy recovered
- Results have validated simulation

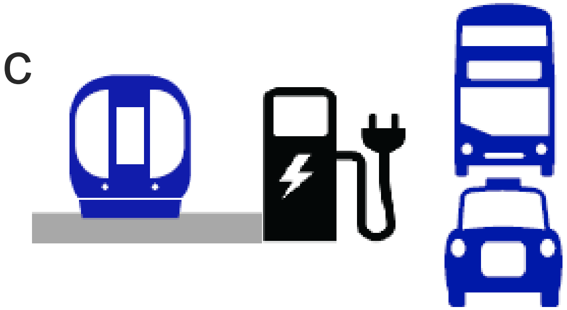
LU traction energy efficiency

- Almost 1 MWh per day saved on average on one DC section
- Role for energy storage?
- Possible link to surface transport electric vehicles?
- 1 MWh ≈ energy consumed by 4 or 5 electric buses



TfL and eLIPTIC: strategic relevance

- Future role of a smart HV network, supporting London's future energy needs
- Integration of energy storage & dynamic energy management (DSR, V2G)
- New value chains?
- Co-location of existing energy infrastructure with spatial demands for future EV charging networks



Electrification of London’s transport: future energy needs

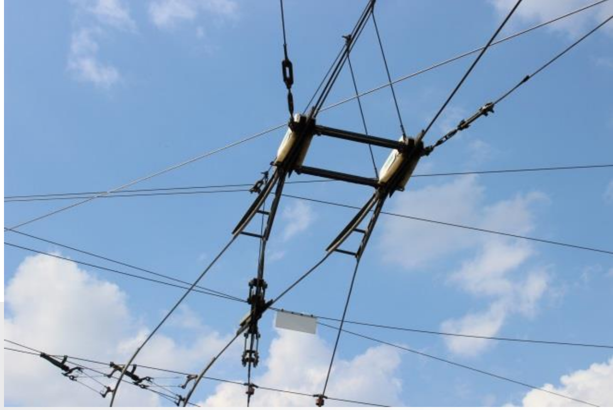
Mode or means of transport	Passenger journeys / vehicles	ENERGY consumption* p.a.	Maximum POWER consumption
London Underground	4.5 million / day	1.1 TWh (1,100,000,000 kWh)	~ 250 MW
London Buses	6.5 million / day 9,000 buses	~ 750 GWh	~ 250 MW (⅓ fleet charging @ 80kW)
Taxis & Private Hire	22,000 taxis > 80,000 PHVs	~ 750 GWh	Almost 10 times London
Commercial fleets	1,200 – TfL fleet > 220,000 LGVs reg’d in London	~ 10 GWh ~ 2.4 TWh	Underground’s annual traction energy
Private cars	~ 2.6 million	~ 5 TWh	consumption

* Energy consumption data for surface transport modes are estimated and provided to illustrate the broad scale of future needs. These are based on today’s fleet and mileage, and do not account for potential future changes in composition, usage etc.

For more information contact:

Mark Poulton
Vehicle Technology Manager

markpoulton@tfl.gov.uk



DYN@MO
AACHEN • GDYNIA • KOPRIVNICA • PALMA

Range Extended Trolley Buses in the city of Gdynia / PL

LowCVP UK E-bus Summit, 10th November 2016

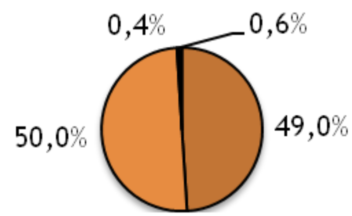
Marta Woronowicz, Mikolaj Bartlomiejczyk, PKT Gdynia

CIVITAS DYN@MO and ELIPTIC Project Coordinators

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION

GDYNIA PUBLIC TRANSPORT FACTS

- **250.000** inhabitants
- Length of public roads: ca. **400 km**
- Length of public transport routes: ca. **250 km**
- Motorization rate: **450 cars/1000 inhabitants**
- Transport modes market share: **50/50** individual transport and public transport:



- 77% of all Gdynia inhabitants live within a **5 min.** walk from a bus/trolleybus stop
- Trolleybus transport operated by PKT constitutes **26 %** of the whole public transport in Gdynia
- **93** trolleybuses run ca. **5 million** vehicle kilometres a year on **12 day** lines on **90 km** of traction supplied by **10** traction substations (**75** trolleys in daily operation)
- only **3** trolleybus cities in Poland (Gdynia, Lublin, Tychy)

Gdynia trolleybus depot

Roofed parking spaces and inside of the depot

CIVITAS DYN@MO in a nutshell

DYN@MO Project

- EU project realized within CIVITAS II PLUS initiative and co-financed from FP7
- Consortium of 28 partners from 2 leading cities: Aachen (Germany), Gdynia (Poland) and and 2 learning cities: Koprivnica (Croatia) and Palma de Mallorca (Spain)

Project objectives

- development of innovative transport systems and services
- introduction or reinforcement of ecological means of transport in the partner cities
- engaging citizens in sustainable mobility
- cooperation and experience exchange between the cities

CIVITAS DYN@MO TASK 1: Innovative hybrid trolleybuses with a new type of Li-ion battery running on a new line

2020 CIVITAS Cleaner and better transport in cities DYN@MO

- Purchase of **2 SOLARIS Trollino 12 M trolleybuses with an alternative power source – a Lithium-Ion battery** in March 2015; positive off grid tests
- Choice of a schedule trolleybus **line 21** which **since May 2015** has regularly been serviced by battery hybrid trolleybuses on an unwired extension – 2 trolleybuses gett off the traction and go for **2 km in Gdynia central Skwer Kościuszki street** solely on the battery
- Planned further expansion of trolleybus transport operation into new areas wiithout the traction network – CIVITAS DYN@MO set the ground for another EU Project – **CIVITAS ELIPTIC (*Electrification of public transport in cities basing on existing infrastructure*)**
- Enhancing the overall flexibility and reliability of the trolleybus transport / setting a showcase

400.000 EUR

eLIPTIC
electrification of public transport in cities

TECHNOLOGICAL INNOVATIONS IN NEW TROLLEYS

Modern equipment in purchased Li-Ion Solaris Trollino 12M

Automatic pantographs enabling automatic raising and lowering the current collector

Asynchronic drive with energy recuperation system

Alternative power supply – Lithium-Ion battery enabling regular off-traction operation up to 15 km

External and internal monitoring system

Air conditioning of the whole trolleybus space

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION

The battery location – at the back of the vehicle


3090
Trolejbus zasilany baterią
Li-Ion
Trolejbus
DANGER

Basic comparative data - traction batteries currently used in Gdynia

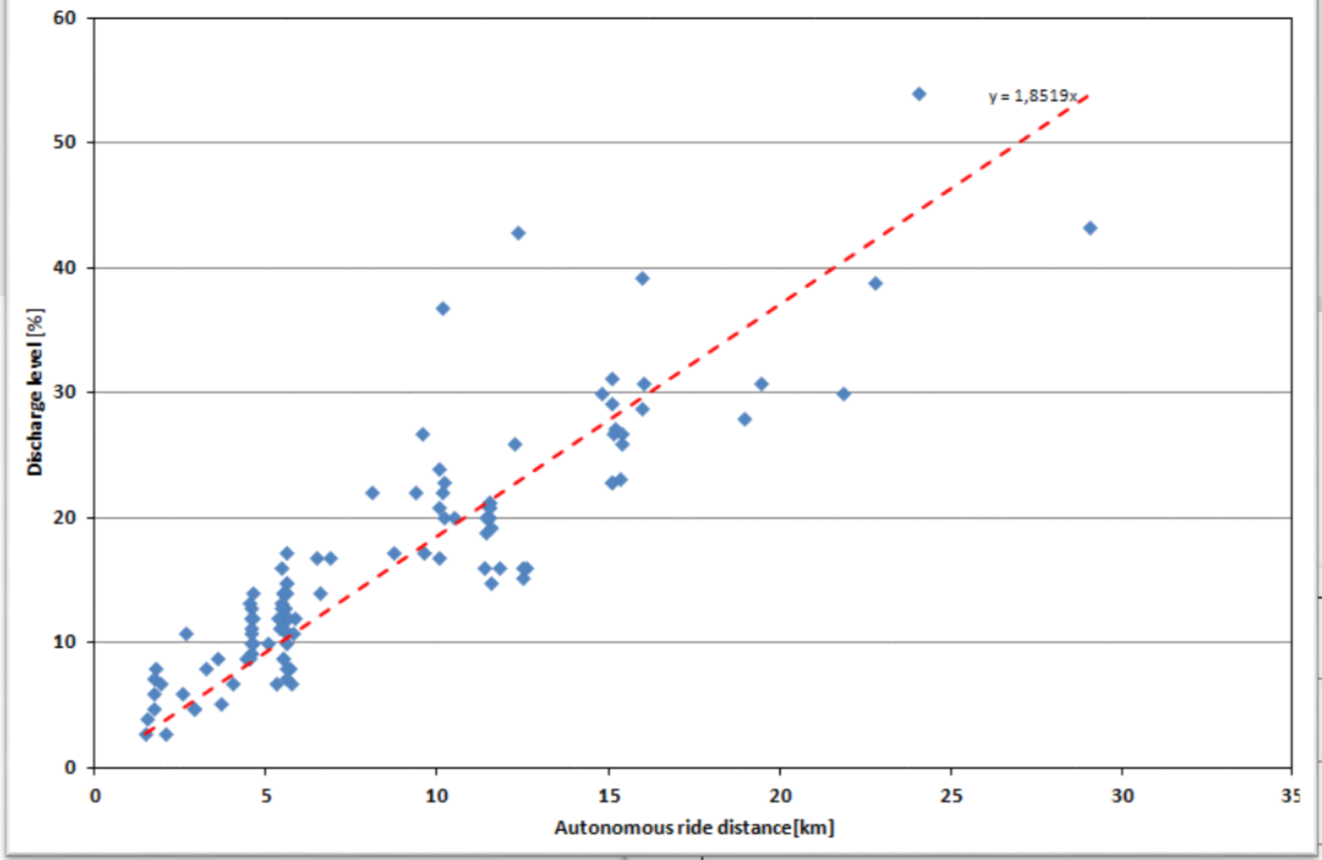
Traction batteries used in new Solaris Trollino 12M trolleybuses

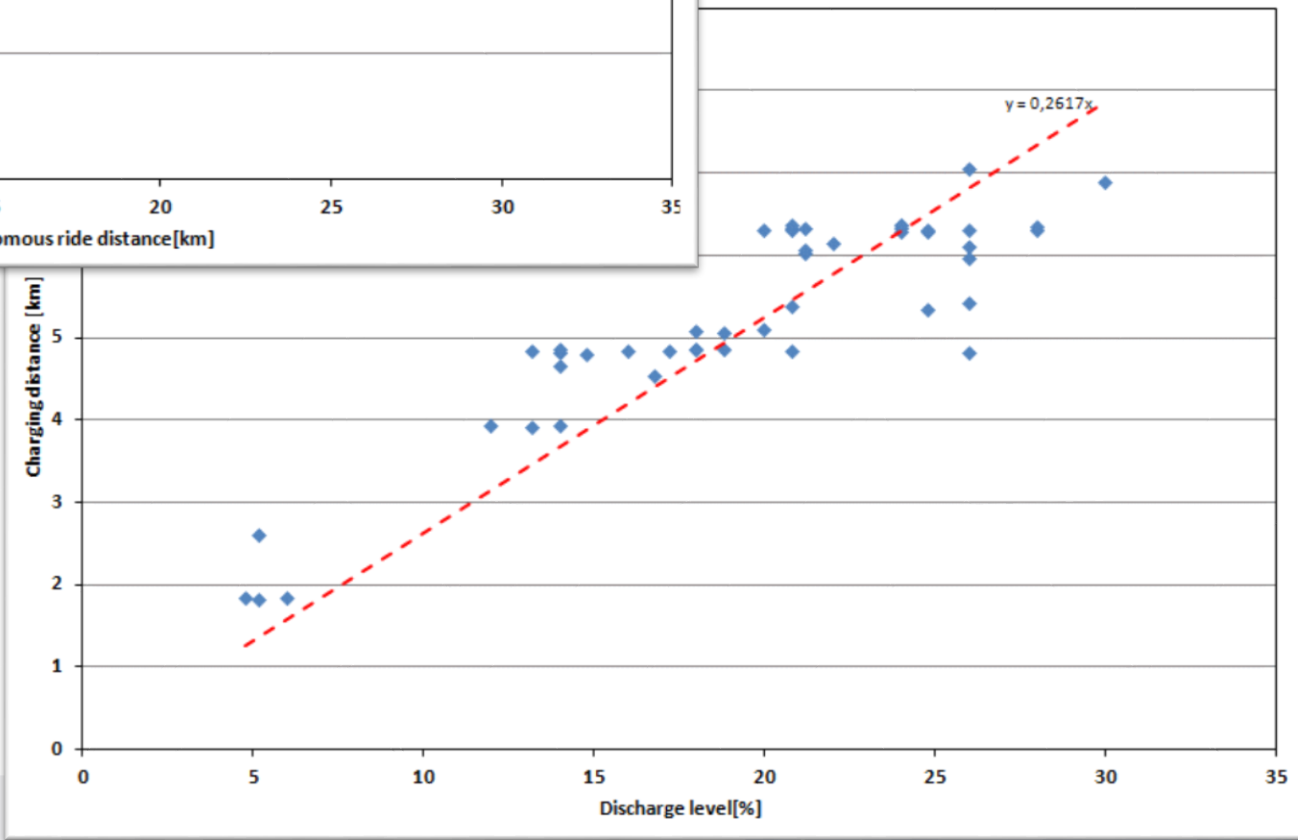
Type of the battery cell: Li-ion
Manufacturer: WAMTECHNIK
Two parallel modules 638 V
Energy capacity of 38 kWh / 27 kWh approximately available

Traction batteries used in older type of Solaris Trollino 12M trolleybuses

Type of the battery cell: Ni-Cd
Manufacturer: SAFT
2 paralel modules 100.6 V
Energy capacity of 16 kWh

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION





Only 30 % of total lenght of the line needs to be covered by overead infrastructure to be operated battery trolleybuses

An example of Landskrona (30.000 inhb.)/ Sweden


Skånetrafiken
Nobina
www.slidein.se
Life

CIVITAS DYN@MO TASK 2:
Supercapacitor for greater energy efficiency of trolleybus system in Gdynia

- July 2013 a contract for the supercapacitor was signed with the Polish company MEDCOM
- installation took place in April 2014; supercapacitor fully working now and successfully saving energy
- reduction of electric power demand on the network section where the supercap is installed by **12%**; supercapacitor cooperates with the traction network and trolleybuses equipped with recuperation braking system (over **50% of PKT's fleet** is equipped with it)
- enhancing energy efficiency of trolleybuses and existing infrastructure / setting a showcase

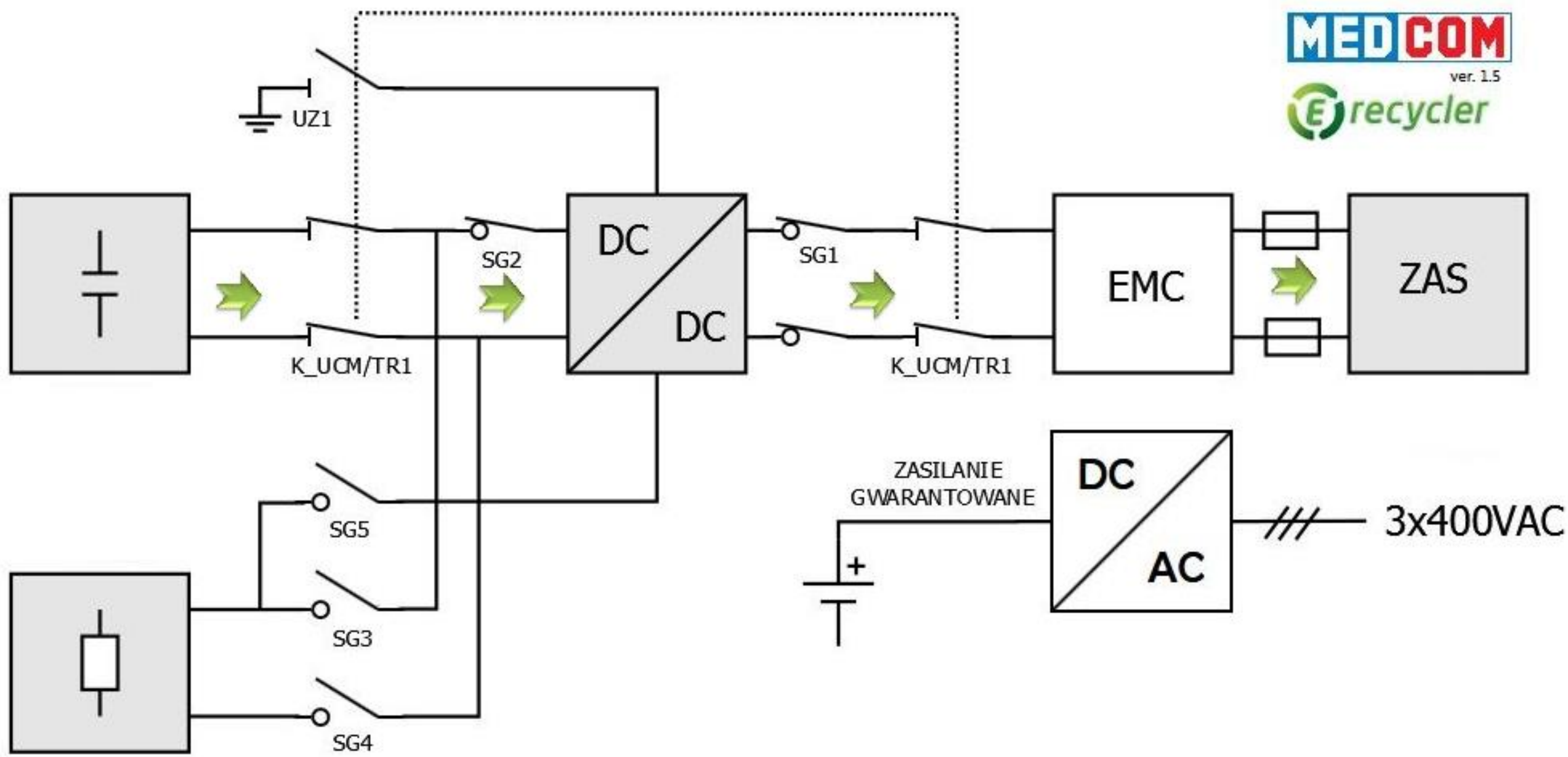
Supercap modules and resistor

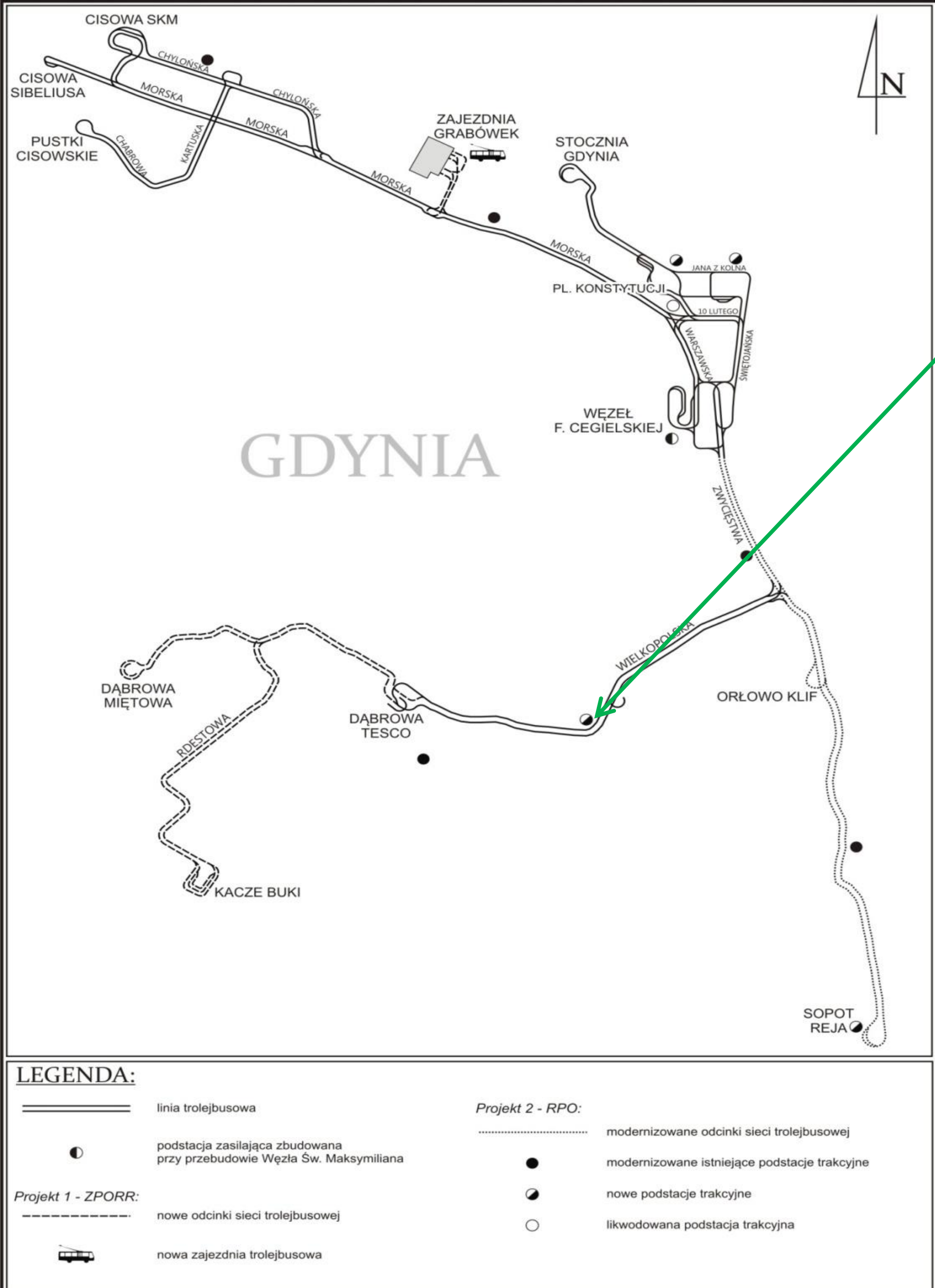
75.000 EUR

Technical data

General data	
Nominal input voltage	600 V DC
Max. input current	500 A
Max. input power	400 kW/20 s.
Data of SC bank	
The range of voltage during operation	187 - 375 V
Max. current	1000 A
Capacitance	104.15 F
Energy capacitance	1.56 kWh
Number of modules	15: 5 branches x 3 modules
The range of voltage during operation	187 - 375 V

Basic scheme



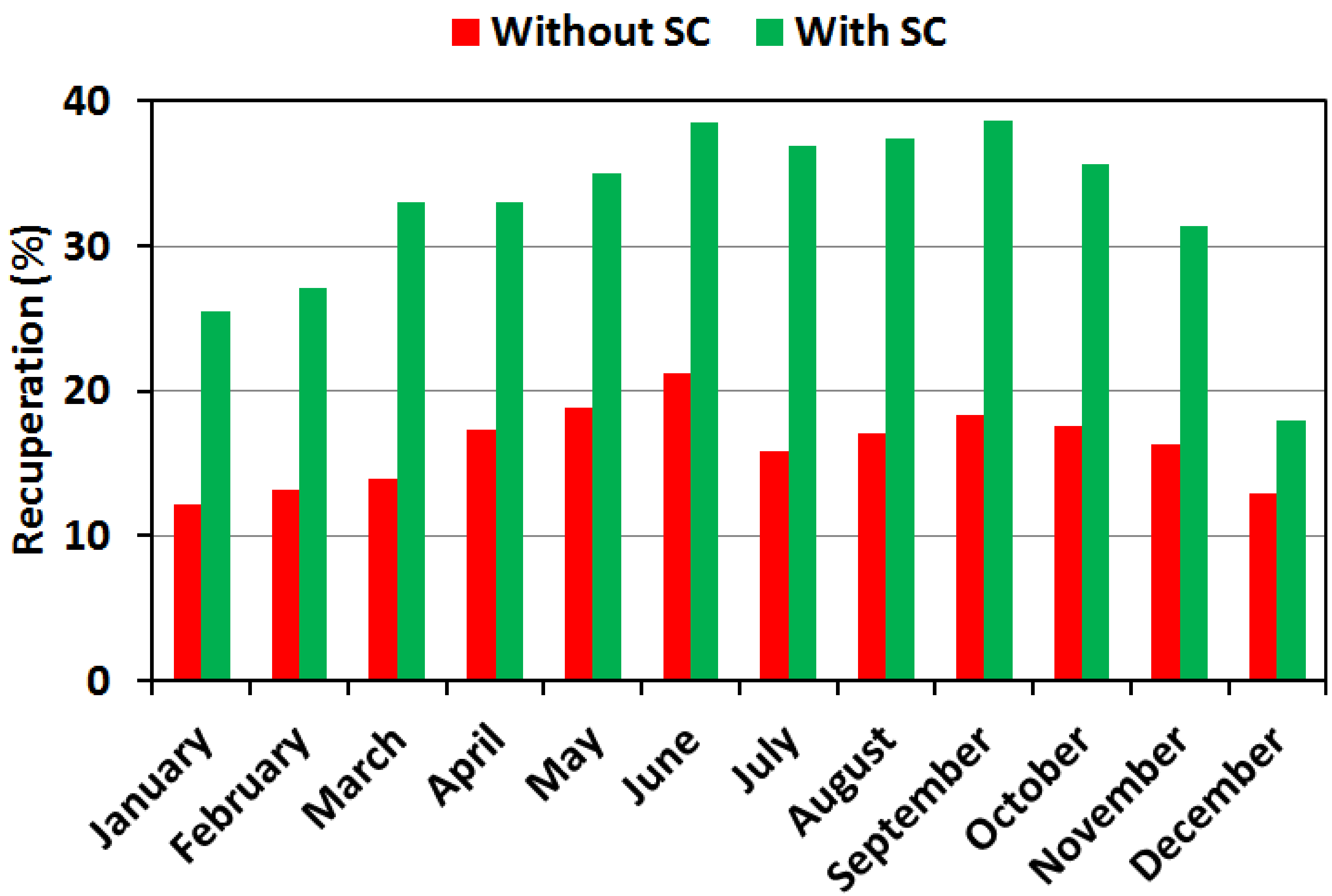


Wielkopolska Substation - Location of supercapacitor bank.

This substation was predisposed for supercapacitor installation due to the hilly terrain of the power supply area – there are more occurrences of trolleybuses braking and giving recuperative energy back to the traction network.

Supercapacitor 'catches' this energy and stores it for later use by other trolleybuses.

Results – recuperation of energy in 2015 in vehicles before and after SC installation



Direct presentation of the savings

Development plans for the near future

- after acquisition of 2 Solaris trolleybuses with Li-Ion batteries in CIVITAS DYN@MO project, PKT purchased in **1** more Solaris with the same battery capacity and **3** more with a double battery capacity
- from nationally governed EU funds PKT has now applied for **30** vehicles with Li-Ion batteries (incl. **16** articulated 18 M trolleys) and exchange of the Ni-Cd batteries to Li-Ion batteries in **21** trolleys
- plans for further unwired extension of several trolleybus lines to some **new districts of Gdynia** (incl. ELIPTIC studies),eg. to one of Gdynia districts Fikakowo / **winter 2017**
- building **several charging points** for e-vehicles is now considered (incl. ELIPTIC studies); the first one to be built this year also in Fikakowo, next one in Sopot / Ergo Arena Stadium
- Photovoltaic panels power plant on the roof of the depot – **5000 m2**

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION

Thank you very much for your attention!

Marta Woronowicz

Project Manager

m.woronowicz@pktgdynia.pl

Mikolaj Bartlomiejczyk

Energetics Manager

bartlomiejczyk@pktgdynia.pl

2020 CIVITAS
Cleaner and better transport in cities
DYN@MO

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION

UK Policy Framework and Market Development

UK eBus Summit 2016 – 10th November 2016

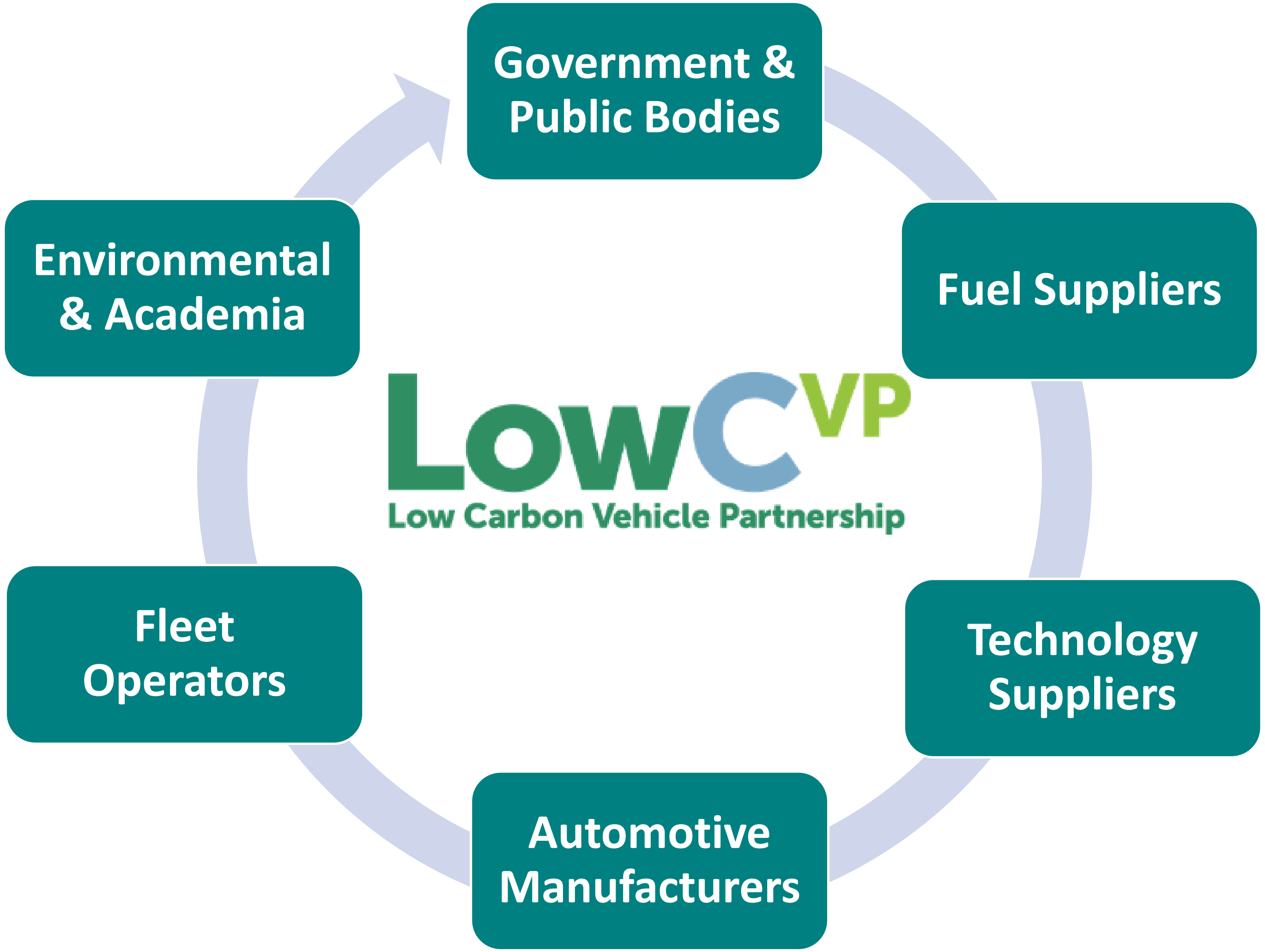
Holborn, London

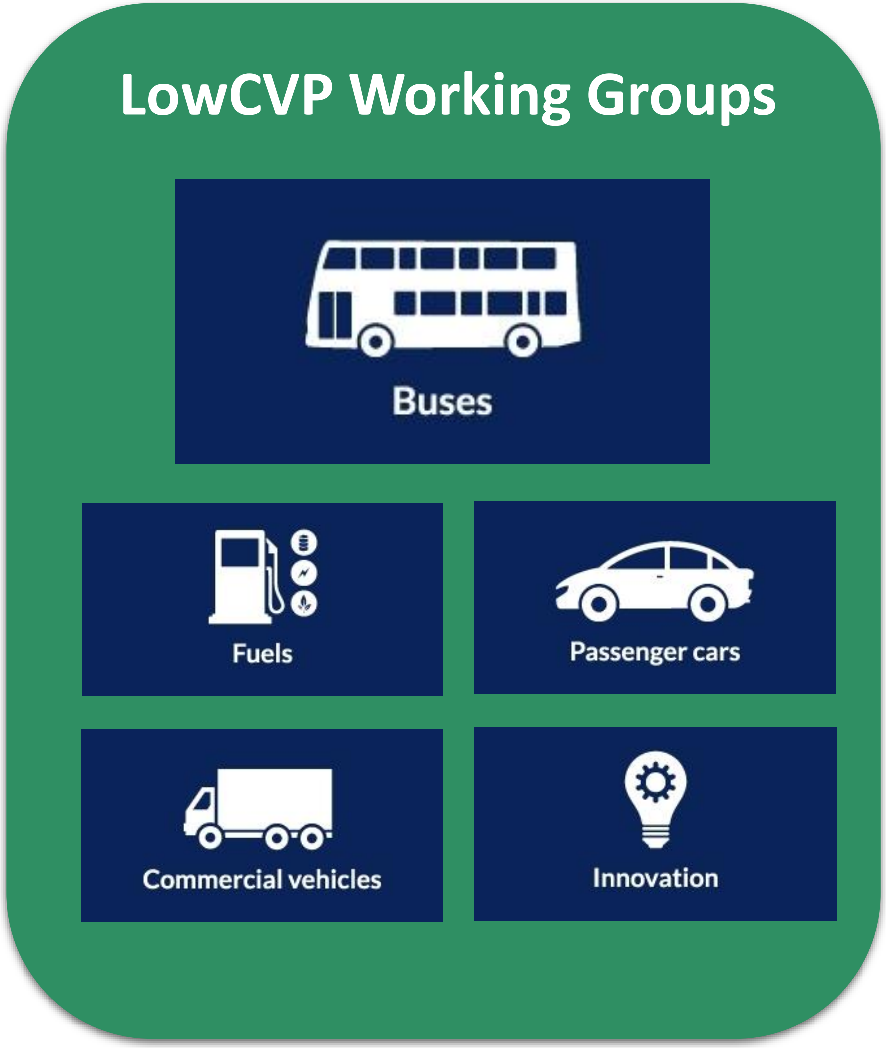



Andy Eastlake

Managing Director, LowCVP

LowCVP is a unique public-private membership organisation that *exists to accelerate shift to low carbon vehicles and fuels and stimulate UK business opportunities*





How the LowCVP operate

LowCVP activity/capability spectrum

Creating communities

Gathering the stakeholders around common challenges/ objectives

Building Understanding

Researching the common barriers or opportunities, creating common goals

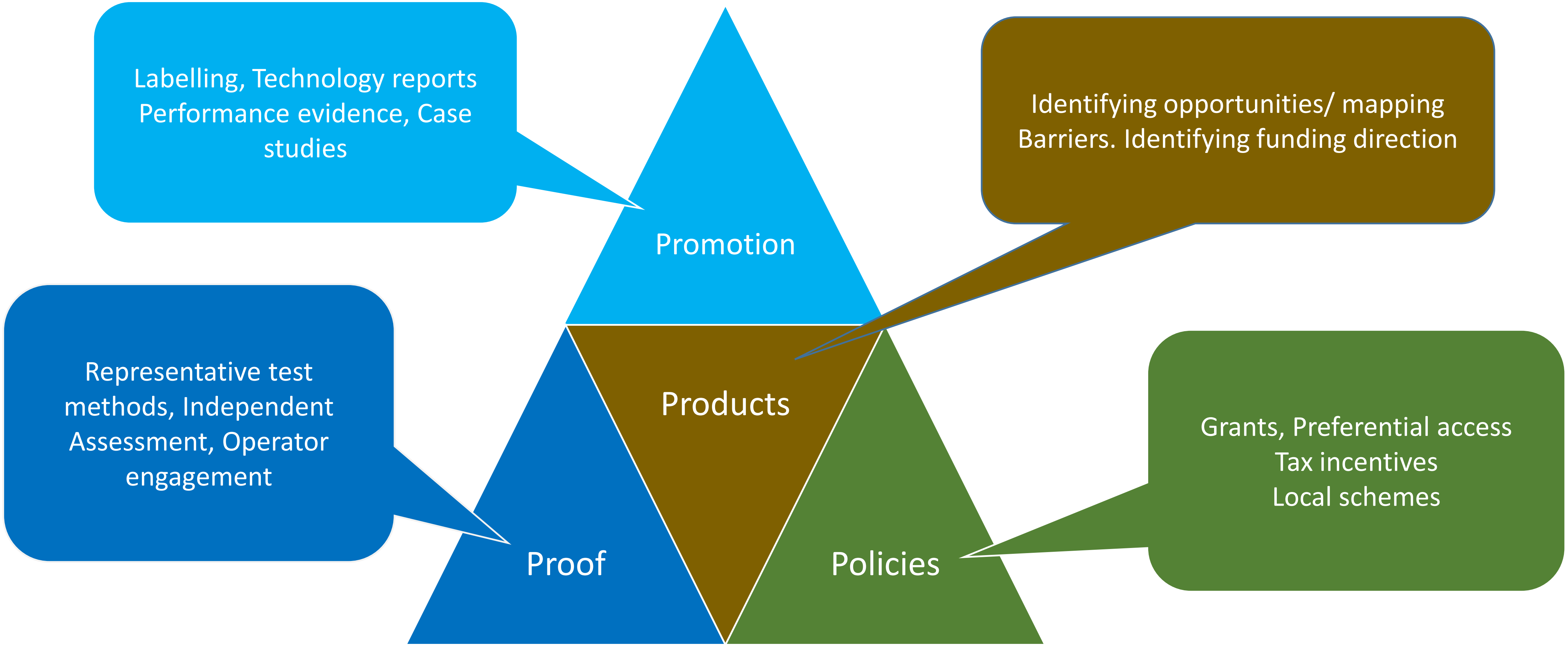
Influencing Policy

Defining measurement processes, schemes, labels, information, incentives at individual, local, regional, nation (international) level

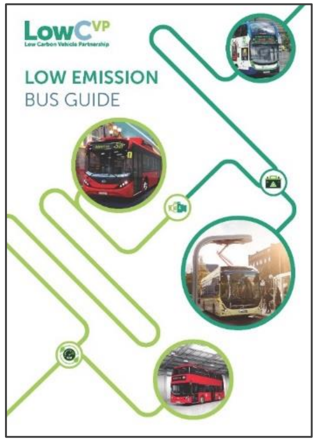
Accelerate the market

Promotion, of common policies, information, outreach to delivery partners

The 4 ‘P’s – LowCVP role, creating shared solutions



How did we get here?



Key milestones in the evolution of green bus policy in the UK

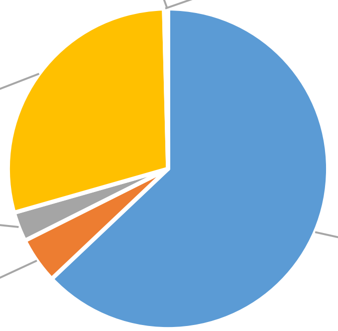
1996 **2007-08** **2009-10** **2014** **2015** **2016**

- Creation of the Millbrook London Transport Bus (MLTB) Cycle
- Definition of a 'Low Carbon Emission Bus' (LCEB)
- Creation of a LCEB Accreditation Scheme
- Green Bus Fund
  BSOG LCEB incentive
  Scottish Green Bus Fund
- Low Carbon Bus Technology Roadmap
  Research on overcoming barriers to LCEB take-up
- OLEV Low Emission Bus Grant Scheme
  Definition of a LEB and new accreditation scheme
- OLEV Low Emission Bus Scheme
  Winners Announced

20 years of collaborative development of products, performance and policy

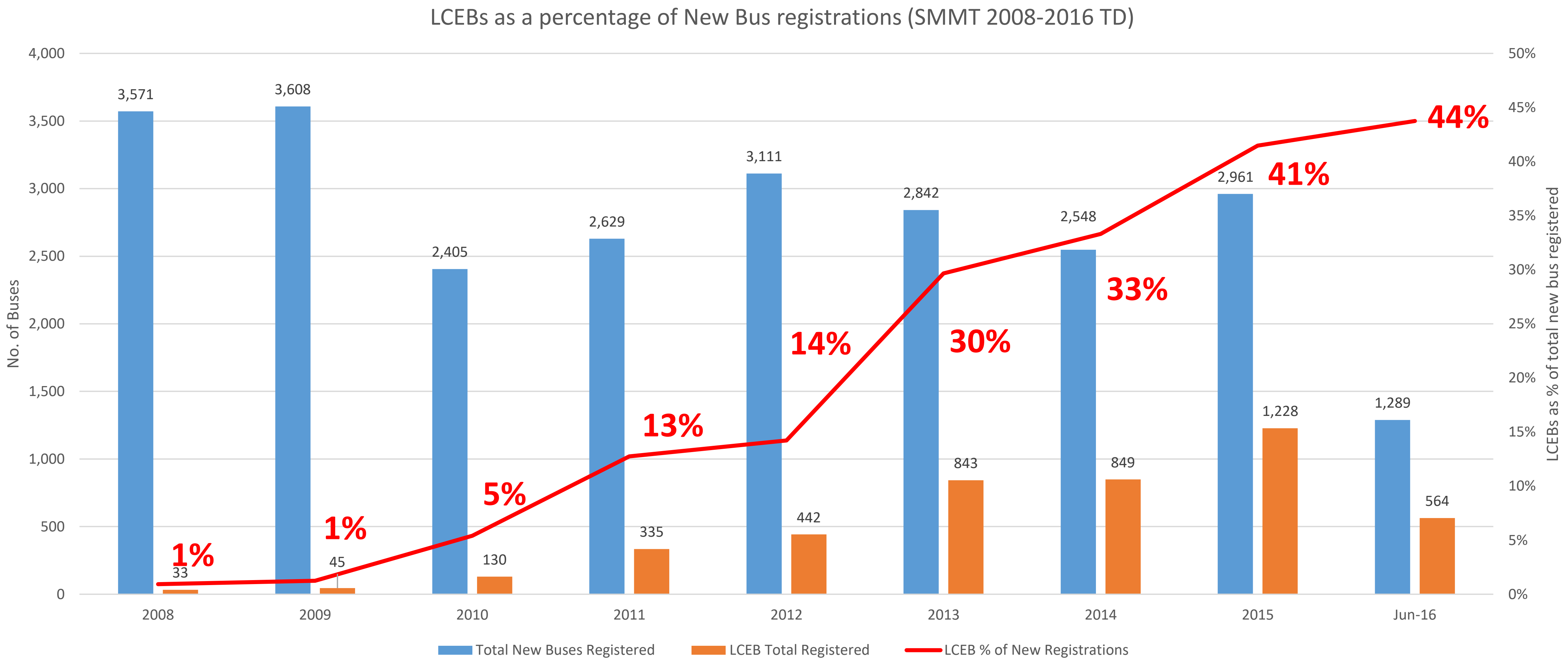
Market: Stimulation and Growth

- Low Carbon Emission Bus (LCEB) defined as producing a minimum of **30% GHG saving** on a **Well-to-Wheel basis vs Euro III diesel equivalent.**
- DfT's Green Bus Fund distributed **£88m** to local authorities and operators across England to purchase **1240** Low Carbon Emission Buses (LCEBs).
- Operation support through BSOG LCEB incentive: 6p/km.
- Scottish Green Bus Fund supported **269** buses with £12.9m (+£3m for round 6)
- Operational success of LCEBs has led to **over 4,000** LCEBs in operation today (Oct, 2016).
- **41% of new bus registrations** in 2015 in the UK were LCEBs (SMMT New Bus Registrations).
- 6 unique technologies and fuels represented by 27 different models from 7 manufacturers.



Visit the
[LowCVP Low Emission Bus Portal]
for more information.

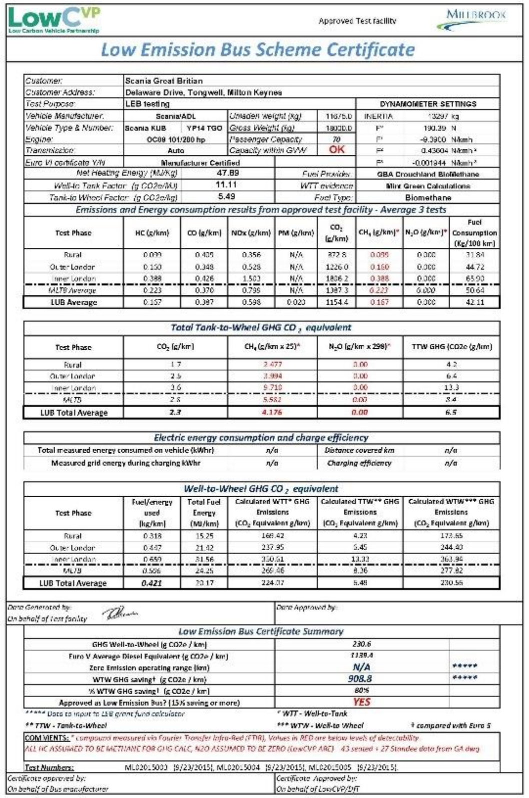
Growth of LCEBs in operation



Low Emission Bus Scheme

- **£30m** Low Emission Bus Scheme created to continue the push to decarbonise the bus market and target reduction in air quality emissions between 2016-2019.
- **LowCVP UK Bus** (LUB) test incorporates MLTB cycle with additional **rural** cycle.
- Creation of Low Emission Bus definition:
  - At least **15% GHG saving** on a Well-to-Wheel (WTW) basis vs. a Euro V diesel bus of equivalent passenger capacity.
  - **Euro VI** or equivalent engine.
- Focus on short-term challenges and long-term deployment:
  - **Proportional funding** for WTW GHG saving (greater savings = increased funding)
  - **'Zero Emissions Capable'** range: £1,000 / km up to 30km.
  - Funding available for **supporting infrastructure**.

- **OLEV Low Emission Bus Winners: Total of 326 buses funded**
- **£7.65m for Infrastructure to support future deployment of more LEBs.**



LowCVP Low Carbon Vehicle Partnership — Approved Test facility — Millbrook

Low Emission Bus Scheme Certificate

Customer:	Scania Great Britian				
Customer Address:	Delaware Drive, Tongwell, Milton Keynes				
Test Purpose:	LEB testing			DYNAMOMETER SETTINGS	
Vehicle Manufacturer:	Scania/ADL	Unladen weight (kg)	11675.0	INERTIA	13297 kg
Vehicle Type & Number:	Scania KUB YP14 TGO	Gross Weight (kg)	18000.0	F0	190.39 N
Engine:	OC09 101/200 hp	Passenger Capacity	70	F1	-9.3900 N/kmh
Transmission:	Auto	Capacity within GVW	OK	F2	0.43604 N/kmh²
Euro VI certificate Y/N	Manufacturer Certified			F3	-0.001844 N/kmh³
Net Heating Energy (MJ/Kg)	47.89	Fuel Provider:	GBA Crouchland BioMethane		
Well-to Tank Factor (g CO2e/MJ)	11.11	WTT evidence	Mint Green Calculations		
Tank-to Wheel Factor (g CO2e/kg)	5.49	Fuel Type:	Biomethane		

Emissions and Energy consumption results from approved test facility - Average 3 tests

Test Phase	HC (g/km)	CO (g/km)	NOx (g/km)	PM (g/km)	CO_2 (g/km)	CH_4 (g/km)*	N_2O (g/km)*	Fuel Consumption (Kg/100 km)
Rural	0.000	0.405	0.356	N/A	872.8	0.000	0.000	31.84
Outer London	0.150	0.348	0.528	N/A	1226.0	0.160	0.000	44.72
Inner London	0.388	0.426	1.503	N/A	1806.2	0.388	0.000	65.90
MLTB Average	0.223	0.370	0.799	N/A	1387.3	0.223	0.000	50.64
LUB Average	0.167	0.387	0.598	0.020	1154.4	0.167	0.000	42.11

Total Tank-to-Wheel GHG CO_2 equivalent

Test Phase	CO_2 (g/km)	CH_4 (g/km x 25)*	N_2O (g/km x 298)*	TTW GHG (CO2e (g/km)
Rural	1.7	2.477	0.00	4.2
Outer London	2.5	3.994	0.00	6.4
Inner London	3.6	9.710	0.00	13.3
MLTB	2.8	5.582	0.00	8.4
LUB Total Average	2.3	4.176	0.00	6.5

Electric energy consumption and charge efficiency

Total measured energy consumed on vehicle (kWhr)	n/a	Distance covered km	n/a
Measured grid energy during charging kWhr	n/a	Charging efficiency	n/a

Well-to-Wheel GHG CO_2 equivalent

Test Phase	Fuel/energy used (kg/km)	Total Fuel Energy (MJ/km)	Calculated WTT* GHG Emissions (CO_2 Equivalent g/km)	Calculated TTW** GHG Emissions (CO_2 Equivalent g/km)	Calculated WTW*** GHG Emissions (CO_2 Equivalent g/km)
Rural	0.318	15.25	169.42	4.23	173.65
Outer London	0.447	21.42	237.95	6.45	244.40
Inner London	0.659	31.56	350.61	13.33	363.94
MLTB	0.506	24.25	269.46	8.36	277.82
LUB Total Average	0.421	20.17	224.07	6.48	230.56

Data Generated by: On behalf of test facility — Data Approved by:

Low Emission Bus Certificate Summary

GHG Well-to-Wheel (g CO2e / km)	230.6	
Euro V Average Diesel Equivalent (g CO2e / km)	1139.4	
Zero Emission operating range (km)	N/A	*****
WTW GHG saving† (g CO2e / km)	908.8	*****
% WTW GHG saving† (g CO2e / km)	80%	
Approved as Low Emission Bus? (15% saving or more)	YES	

***** Data to input to LEB grant fund calculator — * WTT - Well-to-Tank

** TTW - Tank-to-Wheel — *** WTW - Well-to Wheel — † compared with Euro 5

COMMENTS: * compound measured via Fourier Transfer Infra-Red (FTIR), Values in RED are below levels of detectability
ALL HC ASSUMED TO BE METHANE FOR GHG CALC, N2O ASSUMED TO BE ZERO (LowCVP ARC) 43 seated + 27 Standee data from GA dwg

Test Numbers: ML02015003 (9/23/2015), ML02015004 (9/23/2015), ML02015005 (9/23/2015).

Certificate approved by: On behalf of Bus manufacturer — Certificate Approved by: On behalf of LowCVP/DfT

Visit the
LowCVP Low Emission Bus Portal
for more information on accredited LEBs.

Low Emission Bus Showcase at LCV 2016

- LowCVP members provided a selection of LEBs at largest Low Carbon Vehicle technology event in UK:
  - Pure electric, dedicated biomethane, diesel hybrids, biomethane range extender, flywheel hybrids.


ADL Enviro400H City


BYD Pure Electric 10.8m


Reading Buses Hybrid


Optare Solo EV


Scania ADL300

Torotrak Flybrid

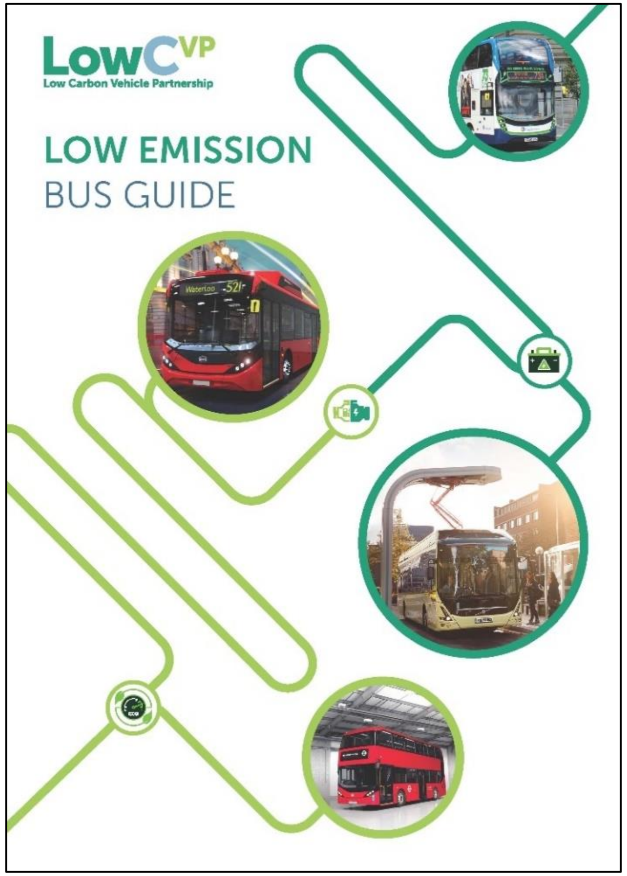

Volvo B5LH

LowCVP aspiration for 2020:

Every new bus sold to be a Low Emission Bus!

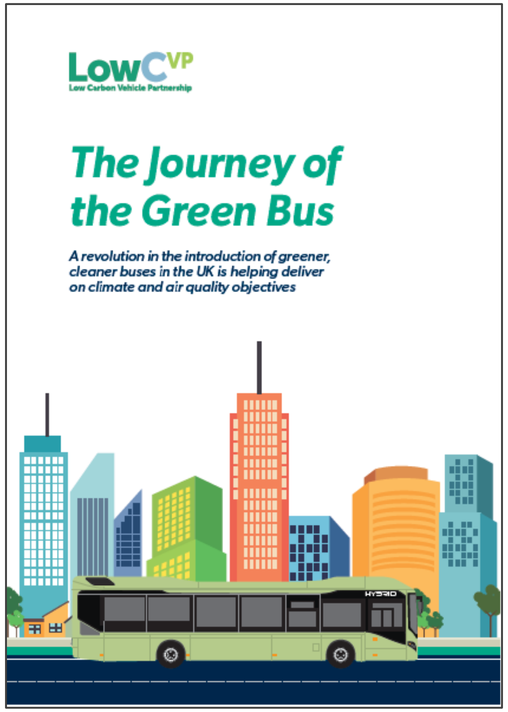
LowCVP Low Emission Bus Guide

- **Low Emission Bus Guide** created to assist bus fleet operators and local authorities procure clean and green buses.
- The LEB Guide:
  - Set out the **business, environmental and operational case** for using low emission buses including **OEM products** and **retrofit equipment.**
  - To provide greater depth of understanding about the **availability of low emission bus technologies and associated infrastructure**, and to identify the operational context to which they are best suited.
  - To provide case studies of real world experience of operators of LEBs.
- LEB Guide was launched at European Bus Expo 1-3rd November at NEC, Birmingham. Interactive pdf available for free download from LEB Portal.
- Dissemination workshops and webinars in 2017 for local authorities and operators.



Key LowCVP Events and Publications

- UK eLIPTIC e-Bus Summit: LowCVP ‘**A Green Bus for Every Journey’** Launch
  - 10th November / DoubleTree by Hilton West End, London
- Zero Emission Bus Conference: LowCVP chaired session
  - 30th November &1st December / City Hall, London
- Low Carbon Britain: Low carbon and low emission vehicle policy development
  - 1st December, Institution for Civil Engineers.
- LowCVP Bus Working Group meeting
  - 12th January, London
- UK Bus Summit 2017: LowCVP ‘**Any Journey by Green Bus’** Launch
  - 9th February 2017 / QEII Conference Centre, London
- LowCVP Low Emission Bus Workshops 2017: Operators and Local Authorities
  - Manchester in early 2017, others tbc later in 2017

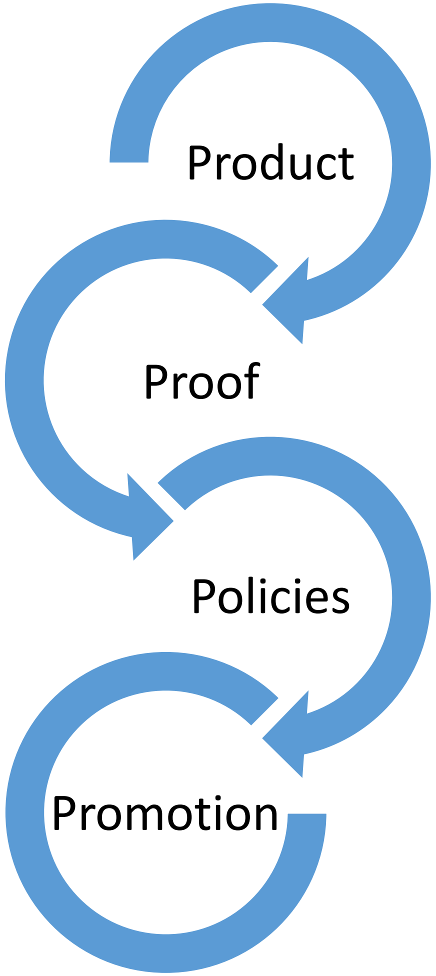


Visit the
[LowCVP Low Emission Bus Portal]
to download reports.

LowCVP Events: http://www.lowcvp.org.uk/events.htm

Summary of success through collaboration

- Two decades of development to truly make the shift to a lower carbon and lower emission bus market, illustrating **LowCVP membership benefits**:
  - **Long-term collaboration** to develop low carbon products
  - Developed world renowned **evidence-based testing** regimes.
  - **Influenced policies** which support growth of low carbon market in UK.
  - **Promoted range and benefits** of low carbon products to wider audiences.



Efficient mobility, lower carbon, cleaner air

Creating the platform for robust support of low emission and fuel efficient technologies

- **Connect**: With privileged access to information, you'll gain insight into low carbon vehicle policy development and into the policy process.

- **Collaborate**: You'll benefit from many opportunities to work – and network - with key UK and EU government, industry, NGO and other stakeholders

- **Influence**: You'll be able to initiate proposals and help to shape future low carbon vehicle policy, programmes and regulations

Andy Eastlake – andy.eastlake@lowcvp.org.uk
@aeastlake, @TheLowCVP

LowCVP is a partnership organisation with over 180 members with a stake in the low carbon road transport agenda.

greener journeys

LowCVP Low Carbon Vehicle Partnership

Connect
Collaborate
Influence

A Green Bus for Every Journey

UK eBus Summit 2016 – 10th November 2016

Holborn, London

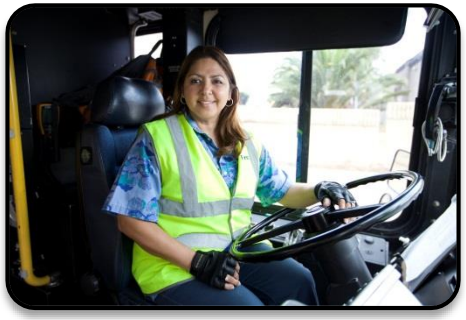



Mark Munday

Technical Director, FirstGroup

FirstGroup





First Bus

2.4 billion passengers per year

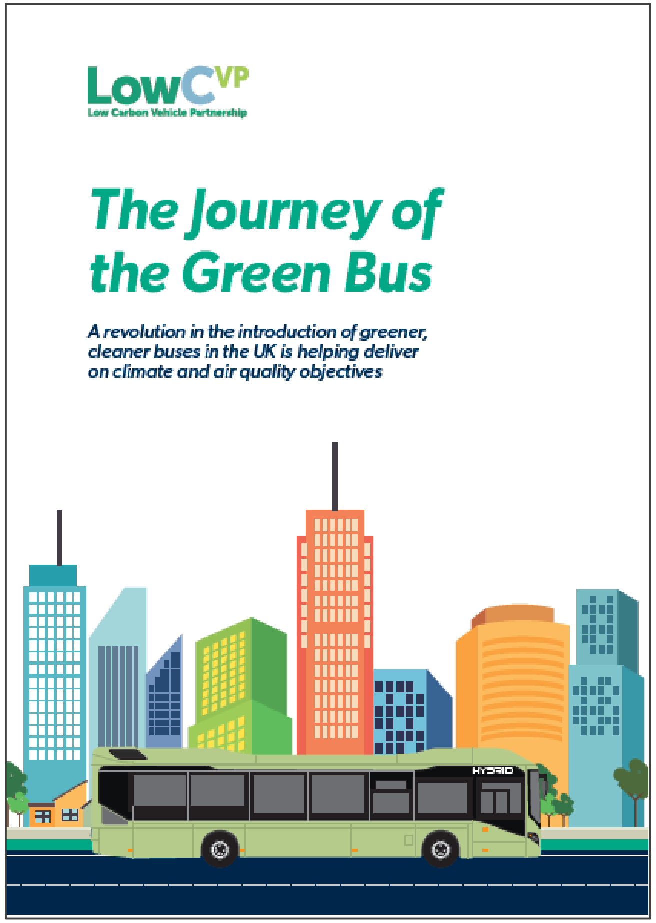
Greener Journeys

Low CVP
Low Carbon Vehicle Partnership
Connect
Collaborate
Influence

greener journeys

make the switch to bus and coach

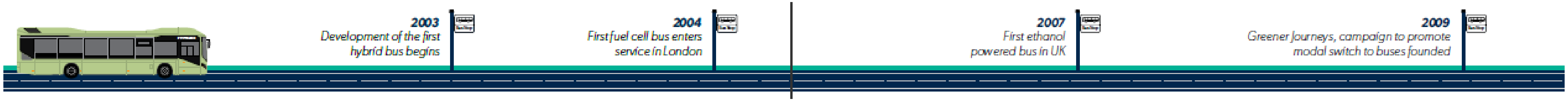
The Journey of the Green Bus



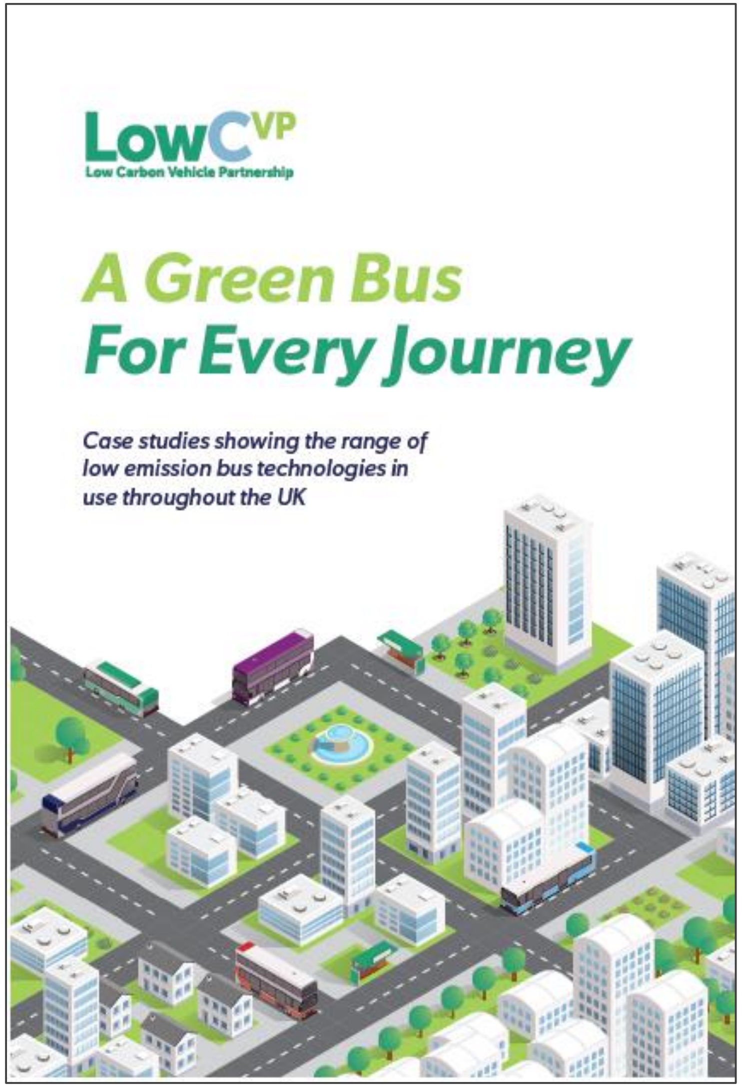
Published Feb 2016 at the UK Bus Summit 2016

Download LowCVP Low Emission Bus portal or LowCVP website

http://www.lowcvp.org.uk/initiatives/leb/Publications.htm



A Green Bus For Every Journey



Published today at the UK eBus Summit 2016

Download LowCVP Low Emission Bus portal
http://www.lowcvp.org.uk/initiatives/leb/Publications.htm

A Green Bus For Every Journey

LowCVP
Low Carbon Vehicle Partnership
Connect
Collaborate
Influence

Executive Summary

Buses reach into every corner of the UK, moving thousands of people through heavily congested cities and providing essential connections to our rural communities in remote areas of the country. Whilst we can't accurately forecast what the technological future holds for driverless, shared, advanced vehicles, our future green buses will remain the most space and energy efficient method of transport for many journeys.

Our first report, 'The Journey of the Green Bus', explained how manufacturers and policy makers have stimulated a revolution in bus technology by encouraging the development of cleaner buses over the last 20 years.

Here in 'A Green Bus for Every Journey', we show how the latest buses employing a range of fuels from biodiesel and biomethane, through a wide spectrum of hybrid options to full battery electric and hydrogen fuel cells, have been embraced by operators across the UK and are beginning to transform the sector. We aim to demonstrate how the combined and continuing efforts of industry, government and operators can deliver savings in fuel, emissions and money while dramatically reducing the environmental impact of this essential and efficient mode of transport. We are, however, only partway along the journey to fully decarbonising and cleaning the UK's vital bus sector. Successful steps have been taken, as this report shows, but there is a need for continuing financial support from Government to progress with technology advancements, including fiscal incentives such as the influential Bus Service Operators' Grant (BSOG) to continue to help the business case for operating low emission buses.

European engine legislation culminating in the latest Euro VI requirements has seen the air quality impact of new buses dramatically improve but, to date, carbon emissions have not been addressed in bus legislation. Here in Britain, low carbon emission buses have been under development for two decades or more, driven by strong Government policy. Manufacturers, bus operators and fuel suppliers are embracing the change, aware that to maintain their viability, buses must be amongst the cleanest and most carbon-efficient vehicles on the road. Almost 4,000 Low Carbon Emission Buses (LCEB) are now operating across the UK, with 40% of buses sold in 2015 meeting the low carbon requirements. These buses have saved over 55,000 tonnes of greenhouse gas emissions (GHG) per annum compared with the equivalent number of conventional diesel buses.

UK Government funding and policy has been critical in kick-starting this market for low carbon emission buses, to help manufacturers get out of the low production/high cost conundrum, and move through prototype vehicles to demonstrations, trials and, ultimately, full commercial operation. Most recently the Low Emission Bus Grant has provided funding to a number of bus operators for both low emission buses and refuelling/recharging infrastructure.

In supporting policies, Government has identified air quality damage costs to reflect the economic cost to society of different air pollutants related to impacts on human health and the environment. The key pollutants from diesel buses (and all combustion vehicles) are oxides of nitrogen (NOx) and particulate matter (PM). Around £8 million in damage cost savings have been achieved through the low carbon emission buses in operation to date.

Impressive progress is being made and the support of all parties must transform the market and achieve bus in 2020 will be a low emission "a Green Bus for Every Journey".

2

WWW.LOWCVP.ORG.UK

GREEN BUS TECHNOLOGY

Contents

4

WWW.LOWCVP.ORG.UK

Introduction

A wide range of technology solutions are revolutionising the operation of buses across the UK

With almost 4,000 'green', low emission buses currently in operation, no single technology will fit every route and nor will a specific route fit every technology, but with the unrivalled number of clean bus options now available to the UK operators this report shows that there truly is 'A Green Bus for Every Journey'.

This publication provides twenty case studies from across the UK showing how bus operators have introduced a variety of low emission bus technologies; how they are measuring up in terms of cost-effectiveness for operators as well as their contributions towards cutting carbon dioxide emissions and local pollution.

GREEN BUS TECHNOLOGY

INTRODUCTION

5

A Green Bus For Every Journey

LowCVP
Low Carbon Vehicle Partnership
Connect
Collaborate
Influence

A Green Bus For Every Journey

LowCVP
Low Carbon Vehicle Partnership
Connect
Collaborate
Influence

Plug-in Hybrid Buses

There are five plug-in hybrid buses operating in the UK, located in London and Bristol. These plug-in hybrid buses are in the early stages of commercialisation and are presently involved in demonstration trials.

Plug-in hybrid technology offers a stepping-stone to the full electrification of public bus fleets and zero emission operation in key areas while retaining wide route capabilities beyond those of a fully electric bus. Provided that sufficient battery charge is available, a plug-in hybrid can provide emissions-free operation over significant parts of a bus route. This can give the zero-emission benefits of an electric bus in the city centre combined with the range and flexibility of a diesel hybrid bus for sections of the route that are less emissions-sensitive or beyond the reach of electric vehicles.

The use of plug-in, inductive or conductive pantograph charging systems on the route further reduces overall dependence on the diesel engine. The ADL Enviro 400 Virtual Electric is the only plug-in hybrid bus model currently operating in the UK. It can travel up to 24 miles in fully electric operation.

Volvo has recently introduced the V900 PHEV in the UK. The vehicle has an electric range of five miles. The company has matched its plug-in hybrid buses with on-route 'opportunity charging' using pantograph conductive charging infrastructure.

Plug-in hybrid buses offer exciting opportunities in cities that experience poor air quality and which have designated low emission zones. Manufacturers can control and force the electric mode of a plug-in hybrid bus using GPS, known as 'geofencing', in defined geographical zones where the bus automatically switches to full EV mode on entry. In some cases geofencing can also take into account time of day, so a route connecting a residential area to a city centre could deploy EV mode in the city during the day, or during the night to reduce both noise and emissions.

While plug-in hybrid buses offer zero tailpipe air pollution and CO_2 emissions when operating in electric mode, like full EVs the carbon footprint of the electricity to charge the bus needs to be taken into consideration. When a plug-in hybrid bus operates as a conventional hybrid, CO_2 emission savings will be achieved. The latest plug-in hybrid buses meet Euro VI standards ensuring low emissions even when the engine is operating.

United Kingdom
Ireland

Location of plug-in hybrid buses in the UK

18

WWW.LOWCVP.ORG.UK

BRISTOL:

Virtual Electric buses in Bristol

First West of England operates two ADL Virtual Electric plug-in buses amongst a range of low carbon emission bus technologies.

The Virtual Electric plug-in buses are very expensive as they are prototype vehicles, designed to be charged using inductive charging infrastructure. The Virtual Electric buses, and accompanying infrastructure, were funded by the Department for Transport which wanted a location to trial plug-in hybrids outside of London.

The buses went into service in December 2015 and are used on the '72' route which runs through Bristol's air quality management area. The plug-in hybrid buses incorporate geofencing, switching the powertrain to pure electric mode automatically as soon as the bus enters an air quality management area. In total, the buses produce zero tailpipe emissions around 80% of the time.

The buses are charged at an inductive charging plate at the University of the West of England where the bus route terminates. The underground plate gives 20 miles of range from seven minutes of charging. The buses can also be fully charged in 45 minutes via a fast charging system.

First West of England also has three Nissan LEAF pure electric cars at its depot in Bristol to transport drivers at shift changes from the hospital back to the depot, one mile away. The electric cars have replaced travel by bus, resulting in savings in fuel and emissions.

Virtual Electric buses – the view from the driver

Drivers say that the Virtual Electric buses are excellent to drive; lots of torque means that they have good acceleration when needed, and they are very smooth and comfortable from the passengers' point of view. Drivers receive much positive reaction to the buses from the public.

PLUG-IN HYBRID

19

GREEN BUS TECHNOLOGY / PAVING THE WAY

A Green Bus For Every Journey

LowCVP
Low Carbon Vehicle Partnership

Connect
Collaborate
Influence

Hydrogen Fuel Cell Buses

There are currently 18 hydrogen fuel cell buses running in London and Aberdeen, supplied by WrightBus and Belgian coach and bus manufacturer Van Hool.

Hydrogen buses offer zero tailpipe emissions and longer range than electric models, though costs are higher. They use a hydrogen fuel cell to power an electric motor which provides propulsion. The fuel cell converts chemical energy from hydrogen into electrical energy, producing only water vapour. Like full electric vehicles, hydrogen buses offer benefits in terms of improving air quality in cities and the potential for cutting CO_2 emissions.

The latest hydrogen fuel cell buses are equipped with hybrid technology, which improves the fuel efficiency and electric range of the vehicle. Hydrogen is stored in cylinders in a compressed state, typically on the roof of the bus.

Hydrogen can be produced by several methods that vary significantly in carbon intensity. In the UK it is mainly produced industrially, through steam reforming of natural gas, compressed and transported by road to a fleet operator's refuelling station. Steam reforming of natural gas is associated with a high carbon footprint as the process is energy-intensive.

A lower carbon method of generating hydrogen is via the electrolysis of water using renewable electricity. This involves running an electrical current through water in an electrolyser to split the water into hydrogen and oxygen. By using electricity from renewable sources in this process, the hydrogen can be produced with very low carbon emissions.

The hydrogen transport sector is in the early stages of commercialisation with only a small number of vehicles currently on the roads in the UK. The opportunities for hydrogen fuel cell buses in cities have been given particular attention through several large demonstration projects - running for nearly a decade in Europe - to explore the practical, economic and environmental case for operating hydrogen buses.

United Kingdom

↑ Location of hydrogen fuel cell buses in the UK

HYDROGEN FUEL CELL

GREEN BUS TECHNOLOGY | PAVING THE WAY

21

LONDON:

London's hydrogen fuel cell buses

Tower Transit, on behalf of TfL, runs eight Wrightbus hydrogen fuel cell buses on the RV1 route in central London which links Tower Gateway Station and Covent Garden. Each bus is in operation between 16 and 18 hours per day, and covers a daily distance of 200km.

This is the first time a whole route has been fully operated by hydrogen-powered buses in the UK. The hydrogen buses play an important role in helping meet TfL's commitments to improving air quality in London.

The first three hydrogen fuel cell buses went into service in 2009 as part of the Cleaner Urban Transport for Europe (CUTE) European-funded project. A further five hydrogen hybrid fuel cell buses, which are more efficient and have a longer range, went into service in 2011 via the CHIC (Clean Hydrogen in European Cities) project.

The buses take approximately ten minutes to refuel; each bus has total storage capacity of 30kg on the bus and, typically, uses 15kg per day. The buses are refuelled at Tower Transit's Lea Interchange bus garage in East London at a facility supplied by Air Products, which also supplies hydrogen gas produced by steam methane reformation. The station has a total permanent storage capacity of 320kg of hydrogen.

Tower Transit has seen the performance and reliability of its hydrogen buses improve over time, evidenced by fewer breakdowns and longer range. This has been achieved by ongoing technological improvements made by hydrogen bus manufacturers and stronger familiarity with fuel cell buses by operators.

Two more hydrogen hybrid fuel cell buses, supplied by Van Hool, will come into service in central London early in 2017 as part of the CHIC project.

TfL and Birmingham City Council have recently been awarded £3.8 million through an OLEV LEB grant for 42 hydrogen fuel cell buses and hydrogen refuelling infrastructure.

22

WWW.LOWCVP.ORG.UK

ABERDEEN:

Europe's largest fleet of hydrogen fuel cell buses

The buses are used across the city's park and ride routes. They have the same range as diesel buses (up to 250 miles) and are refuelled just once per day. The local hydrogen refuelling station produces hydrogen through the electrolysis of water with renewable electricity, sourced via a green electricity tariff, being used to power the equipment. In future Aberdeen has plans to produce its own sustainable supply of hydrogen with the help of renewable energy from an offshore windfarm. There is also an intention to expand the number of other hydrogen vehicles in the city, including cars and vans.

The oil and gas industry is central to Aberdeen's history. This means that there is significant local experience in the high-tech handling of gases. Project leaders in Aberdeen have a clear vision for a future beyond oil and gas, which involves moving to sustainable energy. Aberdeen has a fleet of ten Van Hool vehicles, six operated by Stagecoach and four by First.

The hydrogen buses, owned by Aberdeen City Council and leased to the bus companies, started operation in March 2015 as part of a four-year EU demonstration project to make hydrogen buses more commercially viable. In total there has been a £21m investment, comprised of £19m funding (half from the EU and half from Innovate UK), and £2m from BOC for the hydrogen refuelling station.

Councillor Barney Crockett, Aberdeen's Lead Councillor for Hydrogen, says: "Aberdeen Council has a strategy and action plan to create a hydrogen economy. However, there is a need for an international approach – with the EU and beyond – to share best practice in the area of sustainable transport. This will also help to make technology such as hydrogen fuel cell buses more cost-effective."

THE BUS MANUFACTURER:

Van Hool

A Green Bus For Every Journey

Hybrid Buses

Hybrids are the most popular low emission bus technology in the UK. There are 2,367 hybrids operating across 32 regions throughout the country.

The first hybrid buses came into service in London in 2006, driven by the need to improve air quality whilst also saving fuel. Bus operators running the largest hybrid bus fleets include Transport for London, Stagecoach, Go-Ahead, First and Arriva. London, Scotland, Manchester and the West Midlands are the regions operating the ...est numbers of hybrid buses.

...brid-electric bus combines an internal combustion ...ne with an electric propulsion system. On a ...entional bus, when the driver brakes the kinetic ...gy of the moving bus is dissipated as heat in the ...es or retarder. The bus slows down but the energy is ... On a hybrid bus, when the driver brakes the hybrid ...m captures kinetic energy and stores it for use later, ...n it is required for propulsion. The next time the bus ...lerates, the stored energy is fed back to the driving ...els reducing the load on the engine, saving fuel and ...cing CO_2. Hybrid buses can save 30% or more in fuel ...umption compared to a conventional diesel vehicle.

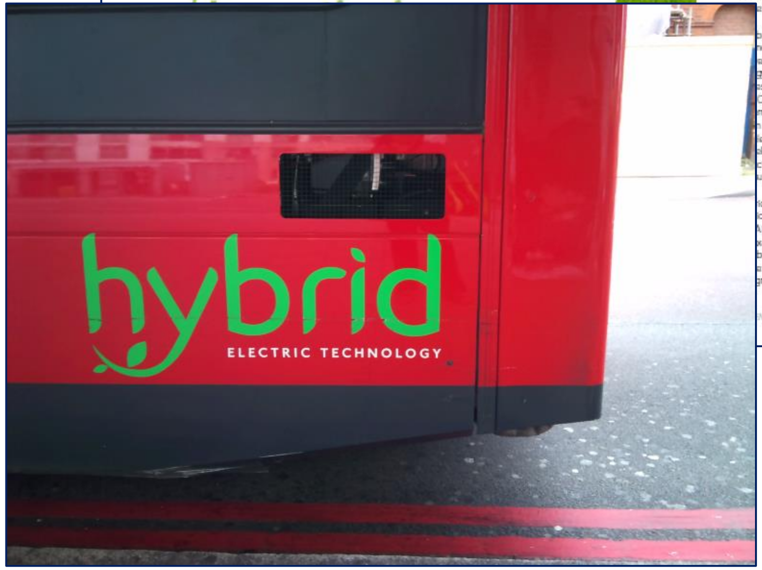
...rids are classified as either 'series' or 'parallel'. A series ...id bus is exclusively propelled by the electric motor. ...ADL Enviro 400 and the Wrightbus New Routemaster ...xamples of series hybrids. In a parallel hybrid bus, the ...bustion engine and the electric motor are connected ...e transmission independantly. The electric motor is ...gned to provide power during stop and start traffic, while at highway speeds the vehicle is powered solely by the internal combustion engine. The Volvo 7900H and B5HL are examples of parallel hybrids.

Some hybrids can travel up to 1 km in all-electric mode. The latest Euro VI hybrid buses can achieve very low levels of emissions, offering benefits in cities with poor air quality whilst also helping to cut CO_2 emissions significantly.

Location of hybrid buses in the UK

HYBRID 25

...N BUS TECHNOLOGY / INNOVATION



A Green Bus For Every Journey

LowCVP
Low Carbon Vehicle Partnership
Connect
Collaborate
Influence

Buses battle it out on the test track

The results of the competition play a major part in the First Bus vehicle procurement strategy. In 2016 First Bus is investing £70 million in 305 new vehicles, and since the event was implemented in 2012 the company has invested around £300 million in almost 1,600 new buses.

First Bus holds a competition at Millbrook Proving Ground every year to test new buses for fuel efficiency and a range of other criteria.

Vehicles are tested on a course that is designed to reflect a variety of rural, urban and inter-urban bus routes. The buses are fitted with sophisticated equipment to monitor many aspects of performance.

The latest innovations in bus manufacturing from vehicle manufacturers such as Wrightbus, ADL and Optare were most recently trialled in August 2016, leading to hopes that a further 10% fuel efficiency improvement could be achieved in 2017.

Smart Accessories

Buses with 'smart accessories' offer one of the more cost-effective ways to reduce emissions. Rather than have the diesel engine power all engine accessories (such as alternators and air conditioning) all the time, it just powers such ancillary items when the engine isn't being used for acceleration. These buses also often feature a stop-start system to reduce emissions further.

On top of the smart accessories, there are also low cost hybridisation options – for a much lower cost than full series hybrids, plug-in hybrids or full electric vehicles.

32 WWW.LOWCVP.ORG.UK

Electrified ancillary buses deliver payback within two years for the Go-Ahead Oxford Bus Company

The Oxford Bus Company is part of the Go-Ahead Group plc. It operates 120 buses in total, of which 18 hybrids are supplied by Volvo and ADL, plus 11 Wrightbus micro-hybrids.

The City of Oxford has an Air Quality Management Area (AQMA) and, in 2014, it declared a Low Emission Zone for buses, which currently has the strictest emissions standard in the UK, requiring compliance with Euro V.

The Oxford Bus Company has a close relationship with the local authority air quality team and says that it is focused on meeting local environmental objectives. It deploys the 'best buses in its fleet' in the AQMA. The company's Euro V hybrids have been judged to be a success in terms of environmental performance as they have contributed to an improvement in air quality in the AQMA since the vehicles were introduced.

The Oxford Bus Company purchased 11 Wrightbus StreetDecks (Euro VI) in 2015. Phil Southall, the company's Managing Director, says that this has been a good option for a double decker, offering very good performance and reliability. The Wrightbus StreetDeck achieves 9mpg, outperforming other diesel buses in the fleet and delivering a fuel saving of over 20% compared to conventional Euro VI buses at a price that produces a payback within two years. The company receives 6p/km BSOG LCEB incentive for operating the Wrightbus micro-hybrids – although Phil says that they would still purchase the vehicles without this.

Electrified ancillaries at First Bus

Across the UK, First Bus operates 869 electrified ancillary buses, split between Euro V and VI, across its fleet comprised of Wrightbus StreetLites and StreetDecks, and ADL E200 and E400 Smart Accessories. When assessing the whole-life costs of different technologies, First Bus was attracted to electrified ancillary buses as they provided reasonable fuel cost benefits at a relatively small increase in vehicle capital cost.

Both the Wrightbus and ADL electrified ancillary buses have proved very reliable and are tolerant of a wide range of route characteristics. The vehicles are performing well in terms of fuel economy, although the actual percentage improvement is highly dependent on the bus route and comparator vehicle. Compared to the older vehicles in the fleet, or the buses being replaced, the electrified ancillary buses have achieved fuel savings up to and in some cases beyond 30%. They are simple to maintain, with all maintenance carried out in-house. Given the success of First Bus's current fleet of electrified ancillary buses, the company has placed orders for another 131 buses this year.

GREEN BUS TECHNOLOGY / INNOVATION 33 MICRO-HYBRID

30 WWW.LOWCVP.ORG.UK

Electrified Ancillaries

Efficient diesel buses fitted with electrified ancillaries.

Several manufacturers have improved the fuel efficiency of conventional Euro V and Euro VI diesel buses through exploiting electrified ancillaries, thereby aiding CO_2 emissions reduction. Improvements can be achieved through the adoption of ancillaries such as the alternator, air compressors and electrical systems.

Different approaches have been adopted by manufacturers. For the ADL 'Smart Accessories' range, the electrical system and the compressed air system are controlled to enable charging when the vehicle is coasting/decelerating. In order to gain further reductions in fuel consumption, ADL has designed the E400 with lightweighting, e-cooling and stop-start technology.

'Micro-hybrid' is the terminology Wrightbus uses to describe the intelligent control of engine ancillaries to deliver energy and fuel savings. Wrightbus offers a range of micro-hybrid models, such as the StreetLite and StreetDeck, which have been designed with a variety of measures to improve fuel efficiency. The features include improved opportunity charging for electrical systems, optimising the electric radiator fan and electric power steering plus lightweighting of the vehicle bodywork.

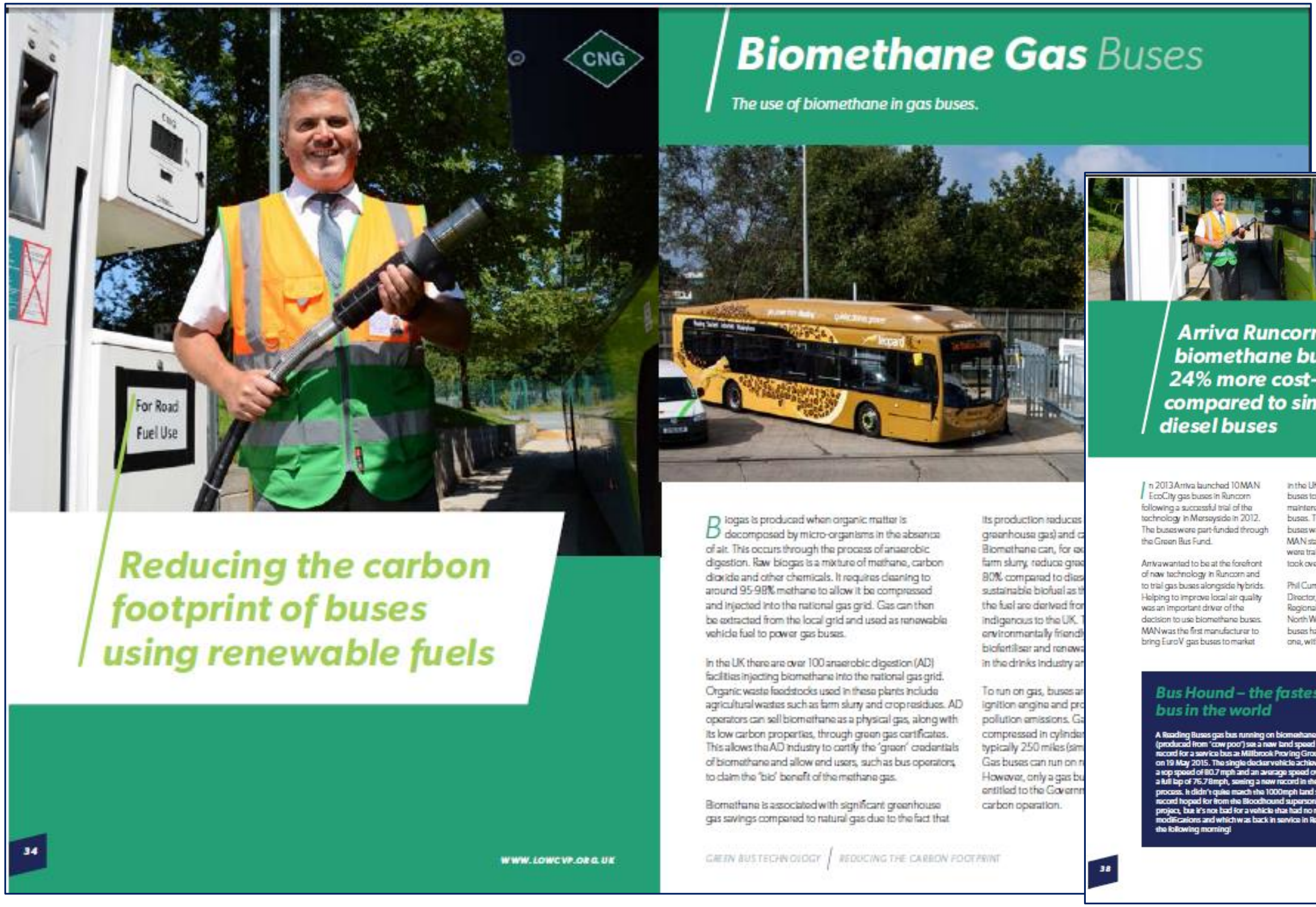
There are currently 1,091 diesel buses equipped with electrified ancillaries operating across twenty regions of the UK. First Bus has spearheaded the adoption of this technology and operates the largest fleet in the country. The regions operating the highest number of electrified ancillary buses are Glasgow, Bristol and Hampshire.

Location of electrified ancillaries in the UK

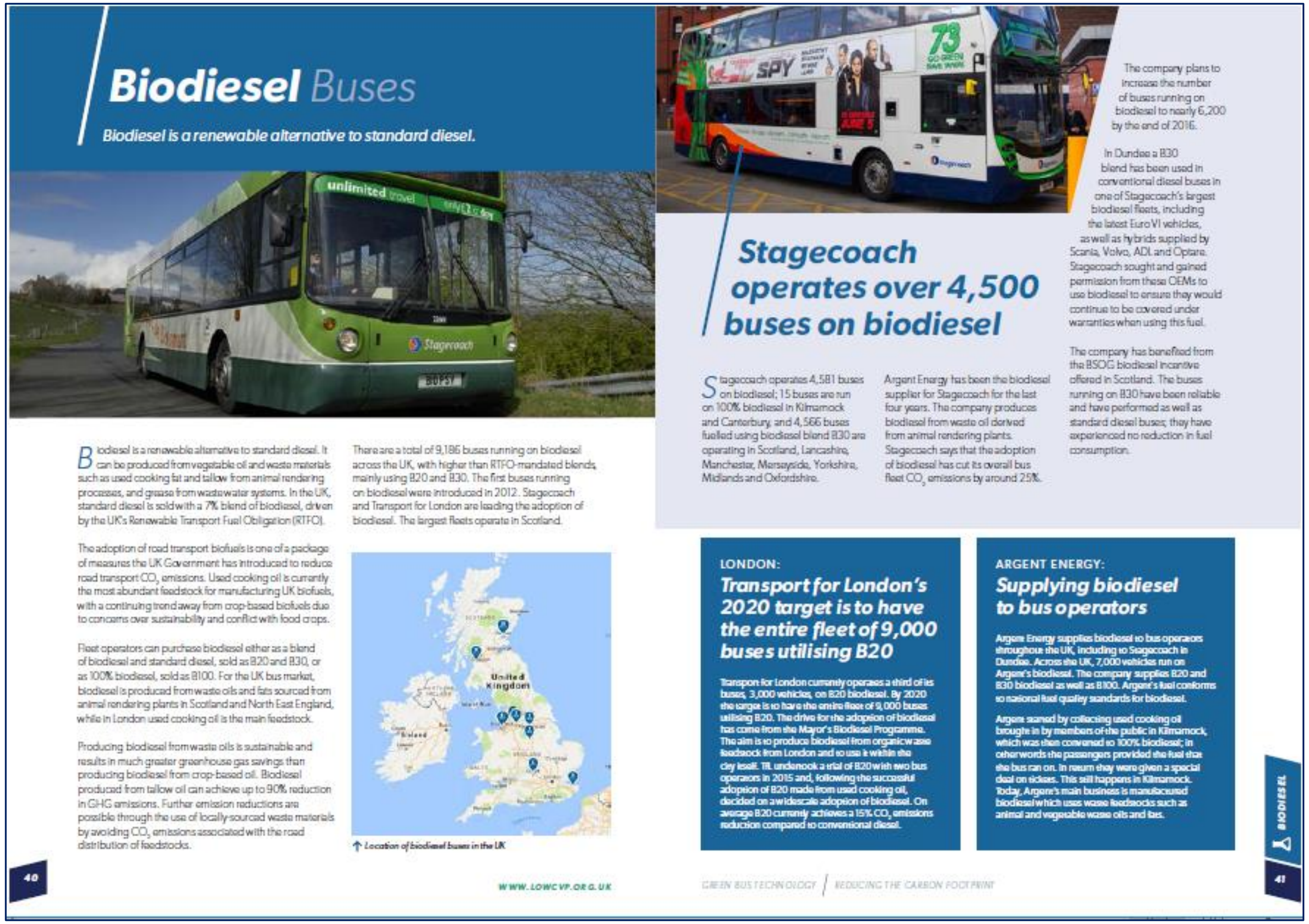
GREEN BUS TECHNOLOGY / INNOVATION 31 MICRO-HYBRID

A Green Bus For Every Journey

LowCVP Low Carbon Vehicle Partnership
Connect
Collaborate
Influence



A Green Bus For Every Journey



Biodiesel Buses

Biodiesel is a renewable alternative to standard diesel.

Biodiesel is a renewable alternative to standard diesel. It can be produced from vegetable oil and waste materials such as used cooking fat and tallow from animal rendering processes, and grease from wastewater systems. In the UK, standard diesel is sold with a 7% blend of biodiesel, driven by the UK's Renewable Transport Fuel Obligation (RTFO).

The adoption of road transport biofuels is one of a package of measures the UK Government has introduced to reduce road transport CO_2 emissions. Used cooking oil is currently the most abundant feedstock for manufacturing UK biofuels, with a continuing trend away from crop-based biofuels due to concerns over sustainability and conflict with food crops.

Fleet operators can purchase biodiesel either as a blend of biodiesel and standard diesel, sold as B20 and B30, or as 100% biodiesel, sold as B100. For the UK bus market, biodiesel is produced from waste oils and fats sourced from animal rendering plants in Scotland and North East England, while in London used cooking oil is the main feedstock.

Producing biodiesel from waste oils is sustainable and results in much greater greenhouse gas savings than producing biodiesel from crop-based oil. Biodiesel produced from tallow oil can achieve up to 90% reduction in GHG emissions. Further emission reductions are possible through the use of locally-sourced waste materials by avoiding CO_2 emissions associated with the road distribution of feedstocks.

There are a total of 9,186 buses running on biodiesel across the UK, with higher than RTFO-mandated blends, mainly using B20 and B30. The first buses running on biodiesel were introduced in 2012. Stagecoach and Transport for London are leading the adoption of biodiesel. The largest fleets operate in Scotland.

↑ *Location of biodiesel buses in the UK*

Stagecoach operates over 4,500 buses on biodiesel

Stagecoach operates 4,581 buses on biodiesel; 15 buses are run on 100% biodiesel in Kilmarnock and Canterbury, and 4,566 buses fuelled using biodiesel blend B30 are operating in Scotland, Lancashire, Manchester, Merseyside, Yorkshire, Midlands and Oxfordshire.

Argent Energy has been the biodiesel supplier for Stagecoach for the last four years. The company produces biodiesel from waste oil derived from animal rendering plants. Stagecoach says that the adoption of biodiesel has cut its overall bus fleet CO_2 emissions by around 25%.

The company plans to increase the number of buses running on biodiesel to nearly 6,200 by the end of 2016.

In Dundee a B30 blend has been used in conventional diesel buses in one of Stagecoach's largest biodiesel fleets, including the latest Euro VI vehicles, as well as hybrids supplied by Scania, Volvo, ADL and Optare. Stagecoach sought and gained permission from these OEMs to use biodiesel to ensure they would continue to be covered under warranties when using this fuel.

The company has benefited from the BSOG biodiesel incentive offered in Scotland. The buses running on B30 have been reliable and have performed as well as standard diesel buses; they have experienced no reduction in fuel consumption.

LONDON:

Transport for London's 2020 target is to have the entire fleet of 9,000 buses utilising B20

Transport for London currently operates a third of its buses, 3,000 vehicles, on B20 biodiesel. By 2020 the target is to have the entire fleet of 9,000 buses utilising B20. The drive for the adoption of biodiesel has come from the Mayor's Biodiesel Programme. The aim is to produce biodiesel from organic waste feedstock from London and to use it within the city itself. TfL undertook a trial of B20 with two bus operators in 2015 and, following the successful adoption of B20 made from used cooking oil, decided on a widescale adoption of biodiesel. On average B20 currently achieves a 15% CO_2 emissions reduction compared to conventional diesel.

ARGENT ENERGY:

Supplying biodiesel to bus operators

Argent Energy supplies biodiesel to bus operators throughout the UK, including to Stagecoach in Dundee. Across the UK, 7,000 vehicles run on Argent's biodiesel. The company supplies B20 and B30 biodiesel as well as B100. Argent's fuel conforms to national fuel quality standards for biodiesel.

Argent started by collecting used cooking oil brought in by members of the public in Kilmarnock, which was then converted to 100% biodiesel; in other words the passengers provided the fuel that the bus ran on. In return they were given a special deal on tickets. This still happens in Kilmarnock. Today, Argent's main business is manufactured biodiesel which uses waste feedstocks such as animal and vegetable waste oils and fats.

BIODIESEL

40 WWW.LOWCVP.ORG.UK

GREEN BUS TECHNOLOGY / REDUCING THE CARBON FOOTPRINT 41

A Green Bus For Every Journey

LowCVP Low Carbon Vehicle Partnership

Connect
Collaborate
Influence


Low emission buses – a vision for the future

There has been escalating action to reduce greenhouse gas emissions over the years and, more recently, greater attention to improving local air quality. As a consequence, there is greater political action at both local and national level. This is manifesting itself in the introduction of low and ultra-low emission zones in urban areas and progressively greater emphasis on the introduction of low emission vehicles.

Impressive progress is being made but much more will be needed and the support of all parties must be maintained if we are to transform the market and achieve our ambition that every new UK bus in 2020 will be a low emission bus, and show that there really is "a Green Bus for Every Journey".

A Green Bus For Every Journey

UK eBUS Summit
Low Carbon Vehicle Partnership

10 November 2016

Electric Buses In London

Colin Gerald
Bus Engineering Manager
Transport for London, London Buses

Electric Bus Trials

- Electric bus fleet: 17 single deck buses (BYD, Optare Metrocity, Irizar). Five BYD pure electric double decks and 51 ADL/BYD pure electric single deck buses from Autumn 2016.

- Primary focus on EV performance (battery management, drive train, duty cycles, charging strategies) other areas of interest, build quality, production methods and weight saving strategies (lighter seating, alloy wheels) driver and engineering feedback

- Operational in service experience to date: Batteries, charging technology and drive train continue to be reliable with good performance

- Four routes, and four different vehicle types employing different charging strategies, further adding to our operational experience, and knowledge.
- Charging infrastructure
- To date we have received no negative feedback from passengers.
- EV Battery Performance Data Loggers on five buses to further assist with real world conditions

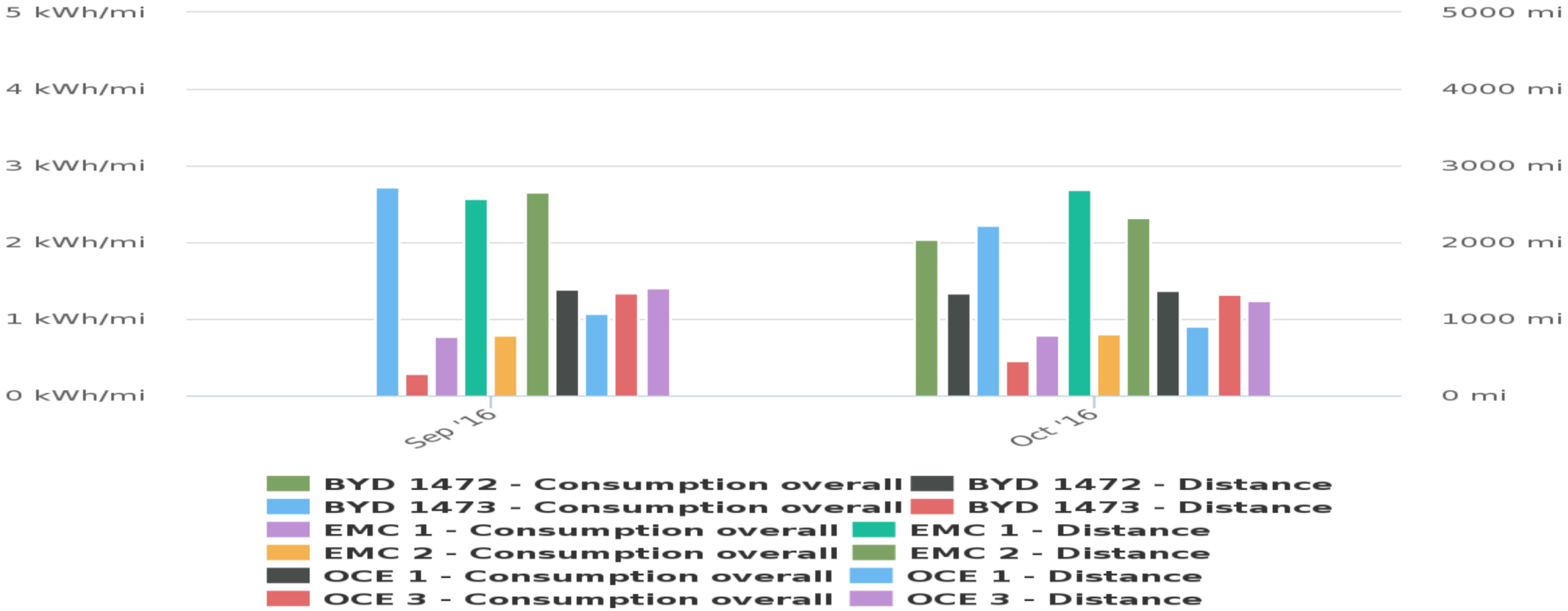
Electric Bus Trials

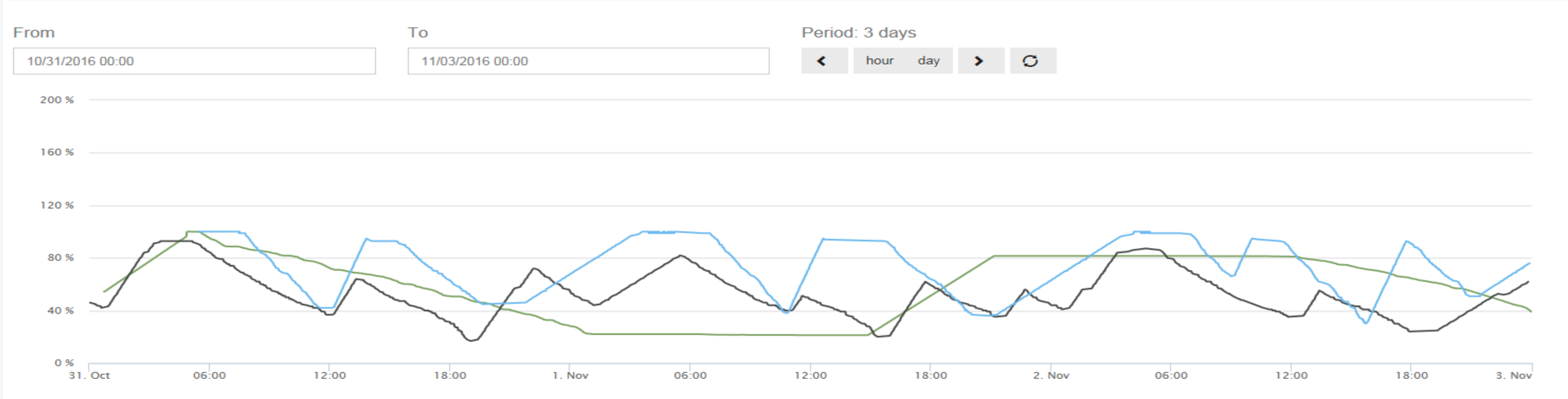
- Measure bus performance in real world conditions
- Understand scalability and wider use of electric buses on other routes, and full electrification of routes
- Understand scalability and wider use of wireless charging solutions on other routes
- The necessary tools to inform strategy going forward, procurement methodology, and framework agreements
- Sustainability

Electric Bus Trials

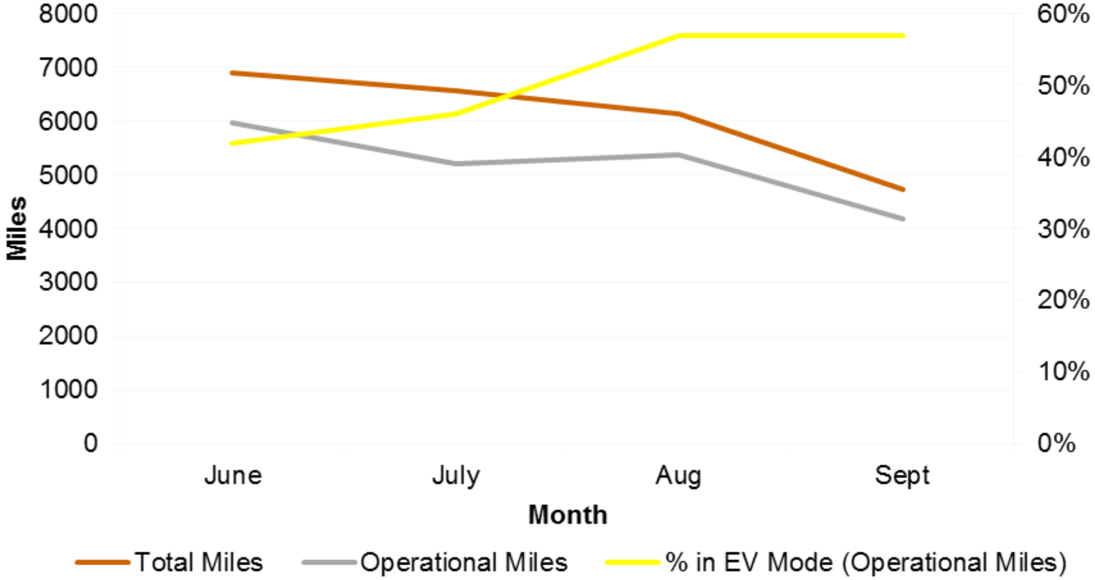
- The first two BYD buses went into service on route 507 and 521 - December 2013.
- Four Optare Metrocity buses entered service on route H98 - May 2014.
- Two Optare Metrocity vehicles entered service on route 312 with Arriva in December 2014. A further seven Optare Metrocity buses went into service Sept 2015.
- Two Irizar i2e buses entered service on route 507/521 with Go Ahead during August 2015.
- New E200 entered service on routes 507/521 – July 2016, a total of   51 buses will be in service by the end 2016.

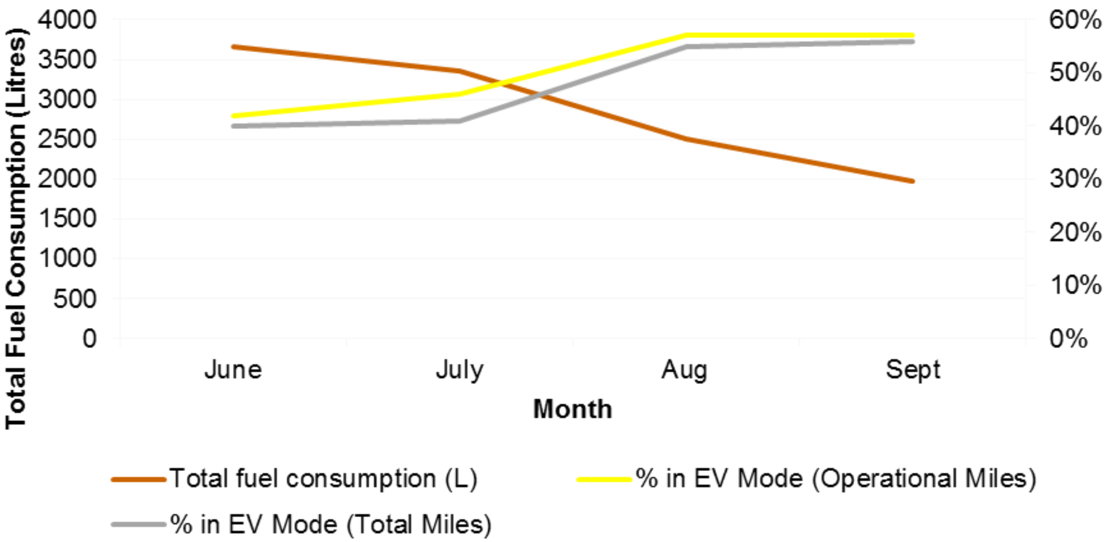
Performance Data





ZeEUS Project - Wireless Charging Bus Trials





TRL

2016
Sept

ZeEUS Monthly Report

Summarising the key results from TRL's analysis of London demonstrations of inductively charged electric buses.

OVERVIEW

TOTAL: 4741 miles — Hybrid 44% — EV 56%

OPERATIONAL: 4187 miles — Hybrid 43% — EV 57%

3714 kWh | 0 kWh | 1965 L

CONSUMPTION Per Mile

EV	2.40 kWh
HYBRID	8.10 kWh (0.81 L)
COMBINED	4.93 kWh
REF*	10.0 kWh (1.00 L)

*Ref bus (Euro IV with CRT)

BY VEHICLE

	SN65 ZGO	SN65 ZGP	SN65 ZGR
Total Distance (miles)	812	2395	1534
Average IPT Power (kW)	98	99	98

99.29% of time spent in Geo-Fenced areas*, the buses were running in EV mode.

*end of route bus stations

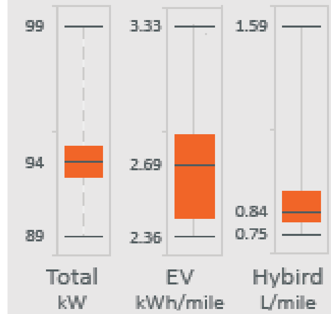
WIRELESS CHARGING

*Per Charge Event (Average)

OVERALL	3714 kWh
CHARGE TIME*	9.72 mins
ENERGY TRANSFER*	16.01 kWh
WALTHAMSTOW	2456 kWh
CHARGE TIME*	10.16 mins
ENERGY TRANSFER*	15.74 kWh
CANNING TOWN	994 kWh
CHARGE TIME*	11.45 mins
ENERGY TRANSFER*	16.30 kWh

Walthamstow IPT charger appears to be much more heavily used, with approximately 147% more energy delivered to buses during the month than Canning Town.

DRIVER EFFECT



BATTERY STATUS

Average state of charge

PRE CHARGE	26%
POST CHARGE	44%
DAY START	26%
DAY END	26%

NOTES

- Overall 25% of the total bus data had driver ID associated: No driver ID for bus 2.
- There were approximately 757 layover stops during the month for all three buses. Only 31% of the layover stops had a charge event (242 charge events across all three buses)
- There was no overnight plugin charging. Both wireless chargers were operational.

Transport for London

ZeEUS

Charging Infrastructure

- Operators bid for the entire cost of running a route – includes charging infrastructure
- Opportunity charging during the day – optimising range/cost/weight vs charging infrastructure – route dependant
- Power supply upgrades required
- Smart charging to manage overnight charging power demands, charge vehicles dependent on SOC and run out
- Space and safety requirements in some garages may mean over-head gantries, pantograph,
- Potential to connect to high voltage London Underground network at certain locations

Regulatory Framework

Enhanced TfL Bus Standards (facilitate new and emerging technologies)
Planning consent
Distribution Network Operator (DNO) Compliance, Installation standards (Harmonics)
DNO capacity/upgrades & timescales long lead times, confirmed orders, no speculative upgrades
EMC and EMF standards to meet rail standards , when adjacent to existing rail infrastructure

Standardisation

- Develop bus specification documents
- Common Standards
- Future proofing charging infrastructure
- Develop policy documents
- Interoperability to move buses around the network
- Energy supplier
- Develop standard framework agreements

Nottingham Electric Bus Project

Progress and Plans

Steve Cornes
Electric Bus Project Manager
Nottingham City Council

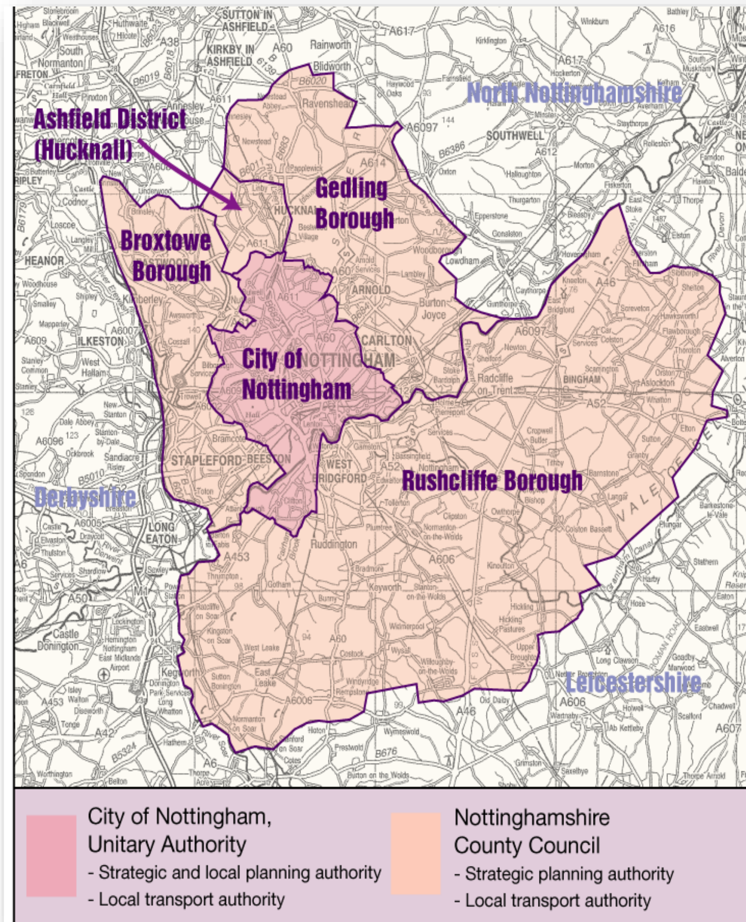
Nottingham City Council

Nottingham: Background

- 1M within travel to work area
- 0.5m conurbation residents
- 300k within city boundary
- Regional Centre
- Unitary authority

– Public Transport and Highways

- Pro-public transport



Nottingham City Council

Nottingham Public Transport

- Deregulated market
- Commercial Bus Services 90% of departures
- Contracted Bus Services (10 %)
- Socially necessary and strategic contracts
- Locallink network - a network of routes to workplaces, health and education sites and district centres, with seven million trips a year
- Tram - 3 lines, cross-city services

Nottingham City Council

The Council role

- Statutory Concessionary travel scheme (£9m)
- **Provision of contract bus services (£2.8m p.a.)**
- **City Centre SQPS Scheme since 2010**
- Robin Hood Multi-operator season ticket: Admin, auditing, publicity costs

Nottingham City Council

Electric buses

- Why electric?
- Cost savings
  - NCC Fleet ownership
  - DfT GBF Grant + WPL
  - Capital rich/revenue poor
  - BSOG removal
  - LCEB incentive
- CO_2 & NOx reductions
- Fuel security
- Wider policy
- Council strengths
  - energy supply
  - Property

Nottingham City Council

Business Case Per Electric Bus

- Capital cost difference £105k
- Grant (£85k)
- Apportioned spare £40k
- Additional 8 yr warranty £12k
- Maintenance diff £0k (-40%)
- Fuel savings (min) £18k
- Payback (grant) 4 years
- Payback (no grant) 8.7 years

Nottingham City Council

Electric Bus Network

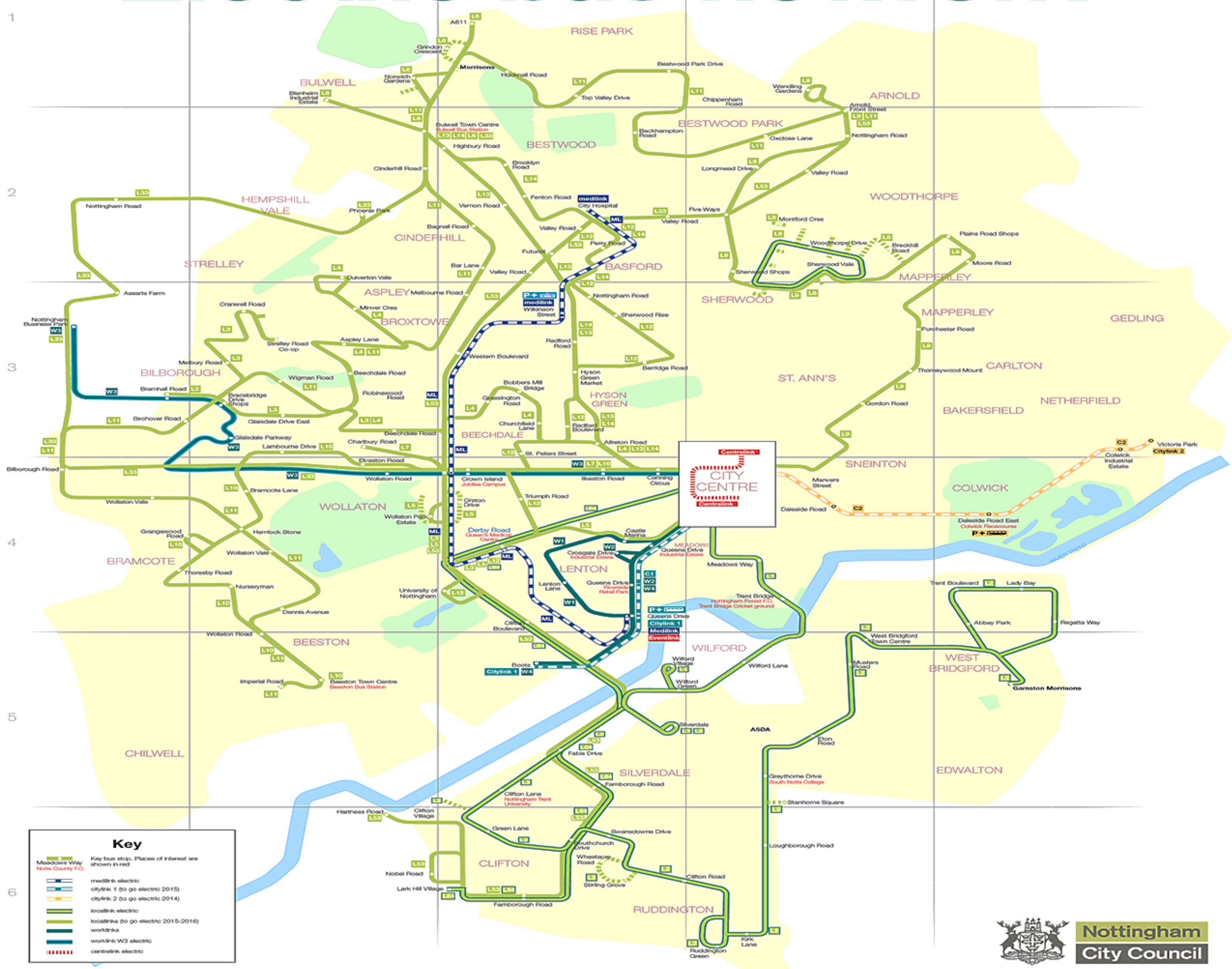
Implementation stages

- Charging network development
- Trickle charge/overnight base
- Fast chargers

Contracted Services

	Bus no.
• Centrelink – high ***f*** /small bus	4
• Localinks – low ***f*** /small	8
• Medilink – high ***f*** /small	16
• Localinks – high ***f*** /small	17
• Citylinks – high ***f*** /large	13

Electric bus network



Version 10.0 ©2005 Nottingham City Council

Electric Bus Network: Progress

- £15.1m project
- Phase 1 &2
  - 8 vehicles
- Phase 3 May 2014
  - 20 buses
- Phase 4 Feb 2015
  - 17 Buses delivered
- Phase 5 Sept 2016
  - Infrastructure in
  - 13 vehicles delivered
  - Fully operational Jan 2017
- Phase 6 2017-18
  - City-wide fast charger network planned

Nottingham City Council

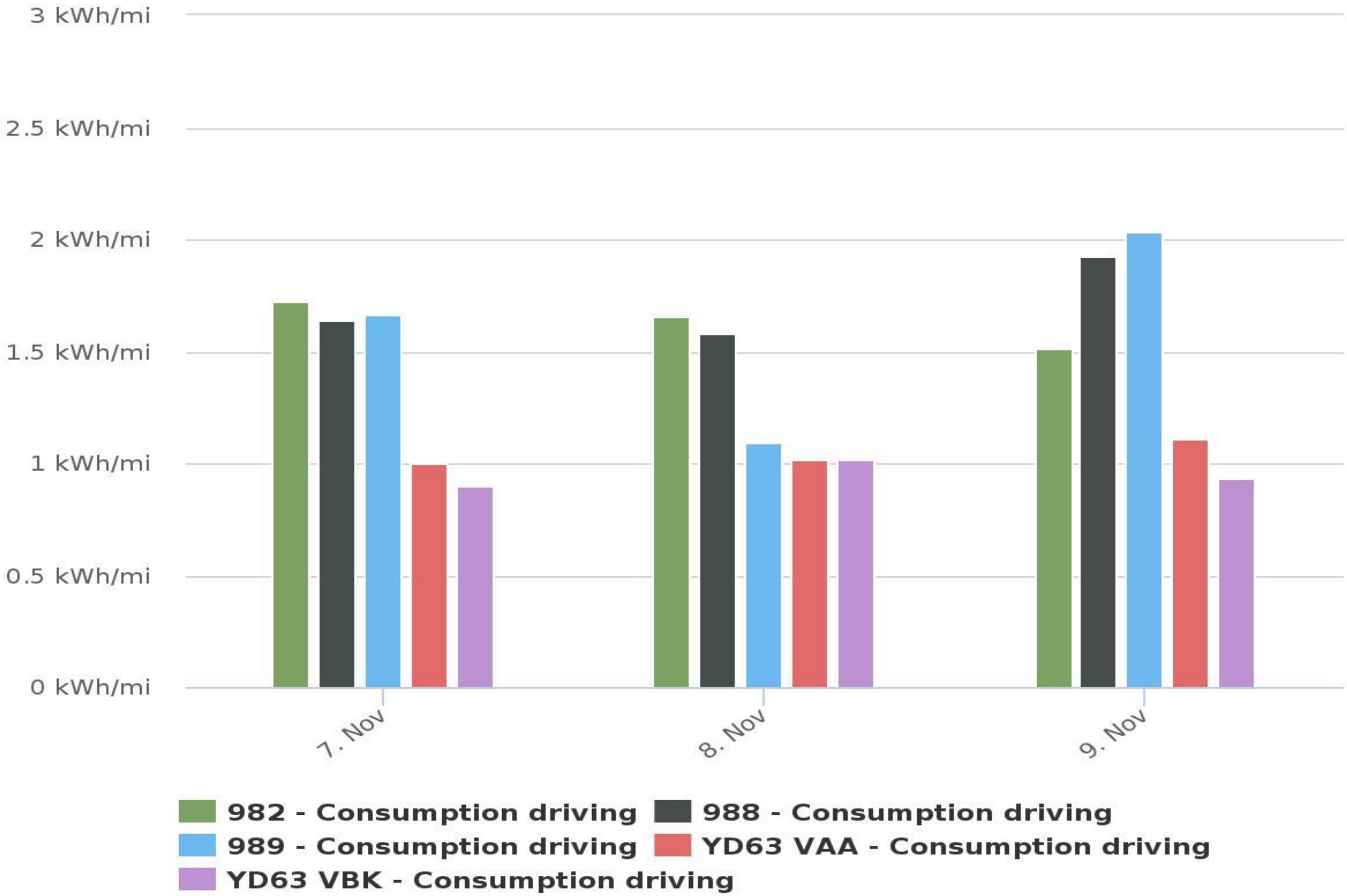
Feedback: Project

<u>Charging issues</u>
- Fast charging
- Ind. operational base
- Fast charger network
- Temperature!

<u>Vehicles</u>
- Timetables/driver rotas
- Driver variation
- Battery range
- Reliability
- Development

Feedback: Vehicles

Performance



Feedback: Vehicles
Energy consumption and cost

Vehicle	Fuel unit cost £	Distance Miles	L or kWh/Mile	£/mile	Grant/mile	Cost/mile	Saving/mile £
Diesel*	0.89	1	0.5	0.45	0.175	0.27	-
Solo EV	0.12	1	1	0.12	0.09	0.03	0.24
BYD	0.12	1	1.65	0.20	0.09	0.11	0.16
Off-peak electricity tariff							
Solo EV	0.07	1	1	0.07	0.09	-0.02	0.29
BYD	0.07	1	1.65	0.12	0.09	0.03	0.24

**Assuming 10mpg*
BSOG £.035/L
Electricity standing charges not inc.

Nottingham City Council

Feedback: Policy

- Perception
- Emissions
- Branding
- Engaging bus operators
- Partnerships
- Access areas
- Unlock funds
- Political

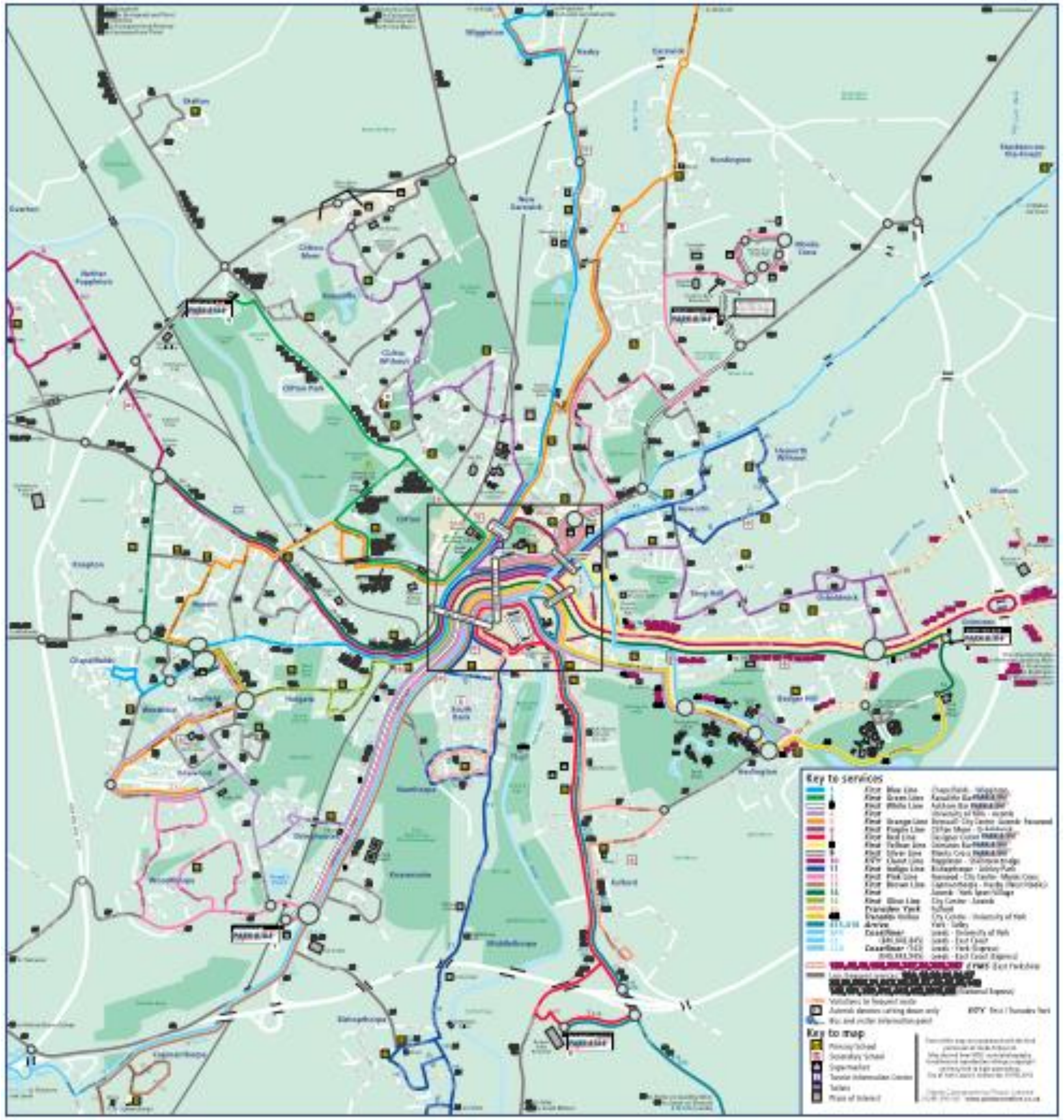
Future plans: ElectriCity…?

- Single electric solution
- So far: Tram & buses...
- GuL City
  - Cars, taxis
  - LEZ
- NCT 53 gas buses
- All buses entering city-centre Euro 6 by 2020

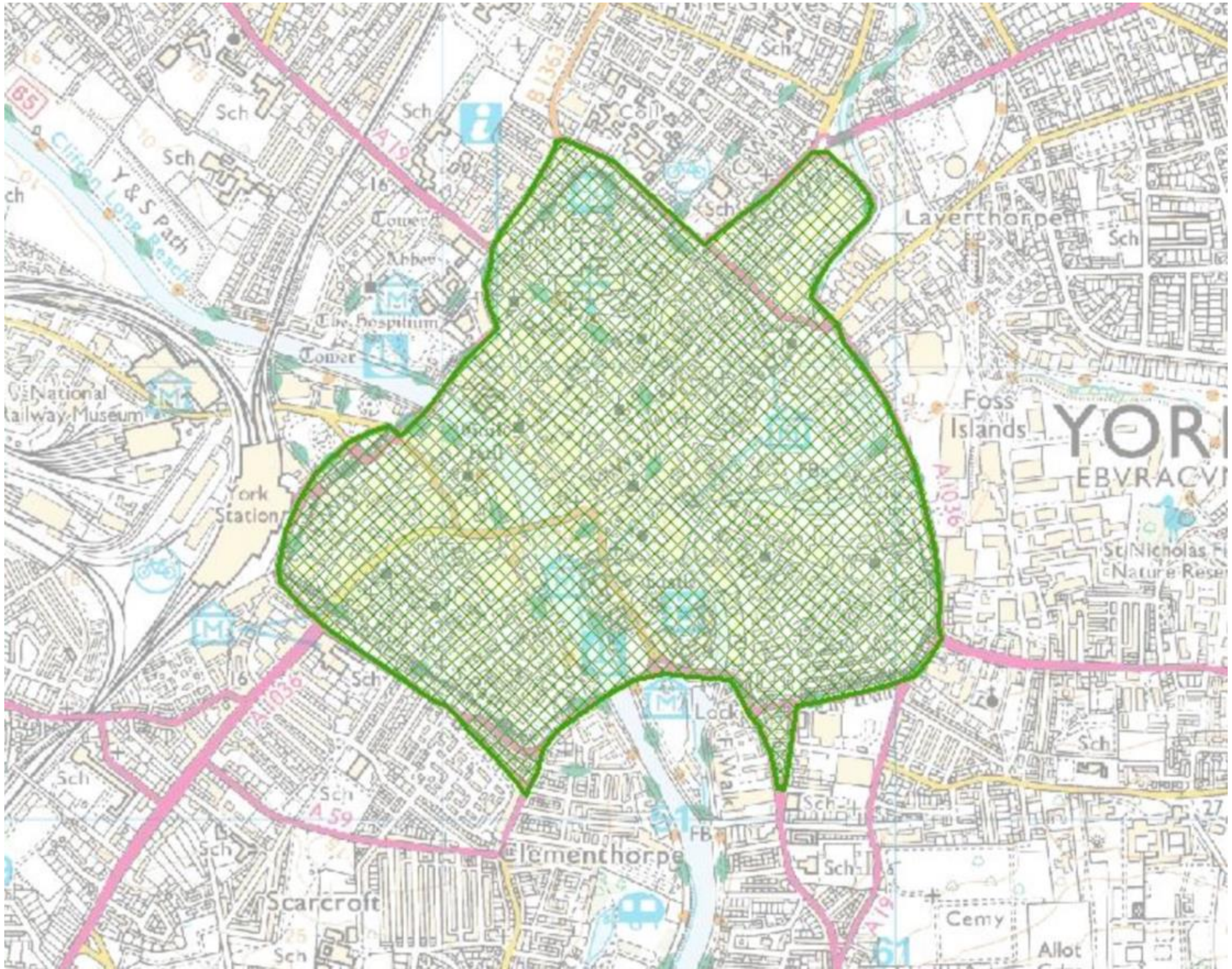
Nottingham City Council

York bus routes

80% of bus traffic can run zero emission



York - Clean Air Zone




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


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

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


York CitySightseeing

MAGTEC
HYBRID & ELECTRIC VEHICLE DRIVES

CITY OF
YORK
COUNCIL

transdev
MOBILITY INSPIRED BY YOU

York
CitySightseeing

Department
for Transport


York
CitySightseeing
Hop On
Hop Off
SOMERSTOTALKARE

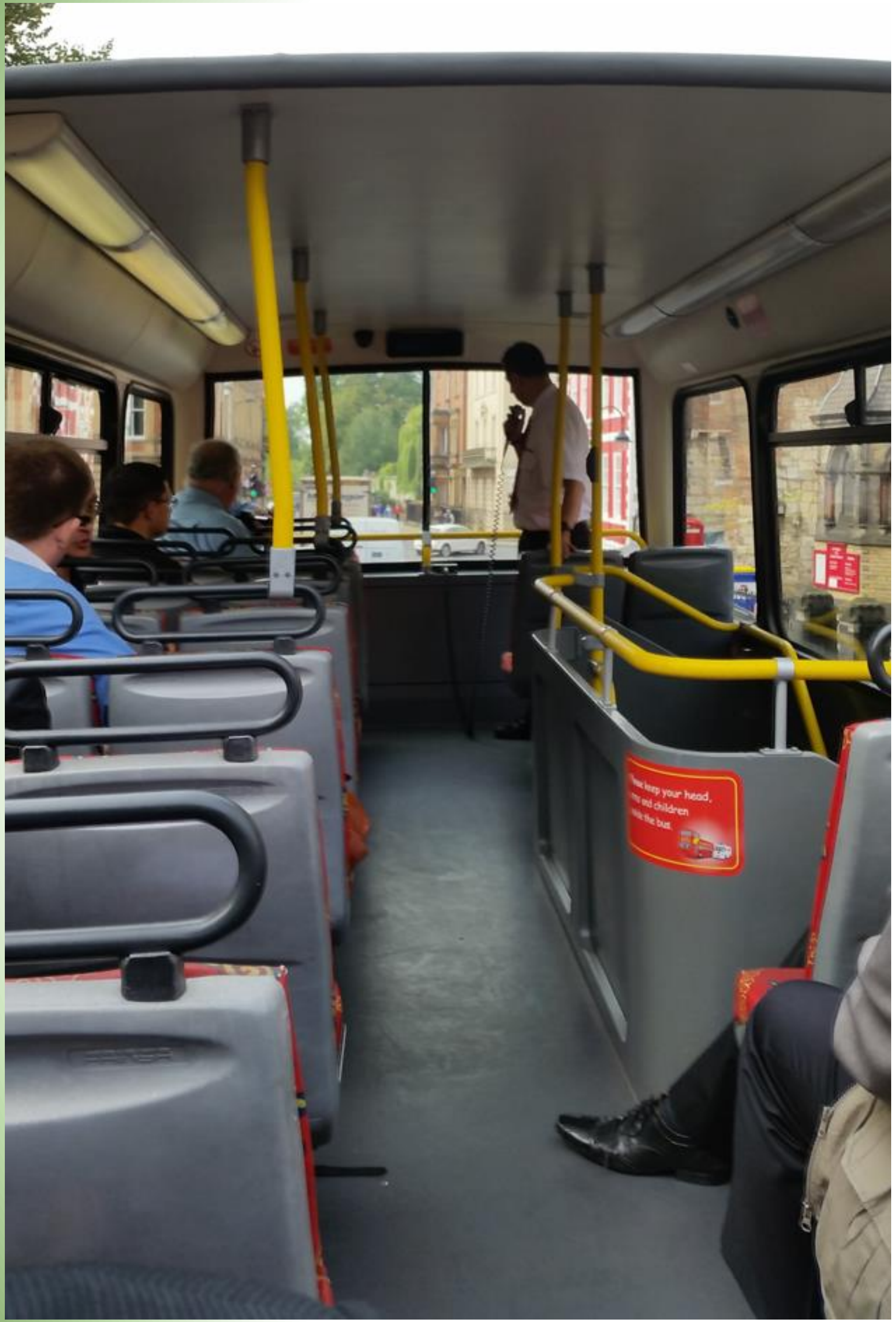

24hrs.
4009


MAGTEC
XB.851.069.00.004


York
City Sightseeing
T407 SNV


EMERGENCY ENGINE STOP
MAGTEC
MAGTEC
double deck bus
powered by MAGTEC
MAGTEC
MAGTEC
MAGTEC


York CitySightseeing
CITY SIGHTSEEING
OFFICIAL TOUR
UK's first 100% electric double deck bus
powered by MAGTEC
transdev
T407 SMV




CITY SIGHTSEEING
OFFICIAL
TOUR
York CitySi


York
CitySightseeing
UK's first 100% electric double deck bus
T407 SMV






1,000,000 km and counting…

Thank you for listening

Any questions...?

derek.mccreadie@york.gov.uk

CITY OF YORK COUNCIL

LowCVP
Low Carbon Vehicle Partnership

UK eBus Summit 2016

eLIPTIC
electrification of public transport in cities

The CIVITAS eLIPTIC project

Hendrik Koch
Project Coordination
Working Group Sustainable Mobility

Der Senator für Umwelt, Bau und Verkehr
Freie Hansestadt Bremen

10th November 2016, London

CIVITAS 2020
Horizon 2020 Programme

- Research and Demonstration project in EU Program „Horizon 2020“ (Mobility for Growth 5.1)
- Funding primarily for research and promotion (only small share for hardware)
- 33 partner in 8 Countries
- Duration: 01.06.2015 – 30.05.2018
- Coordinator: Freie Hansestadt Bremen
- Budget: 5,9 Million Euro

Horizon 2020 Programme

This project has received funding from the European Union‘s Horizon 2020 research an innovation programme under grant agreement No 636012

Project coordinator: Bremen
Project manager: Rupprecht Consult

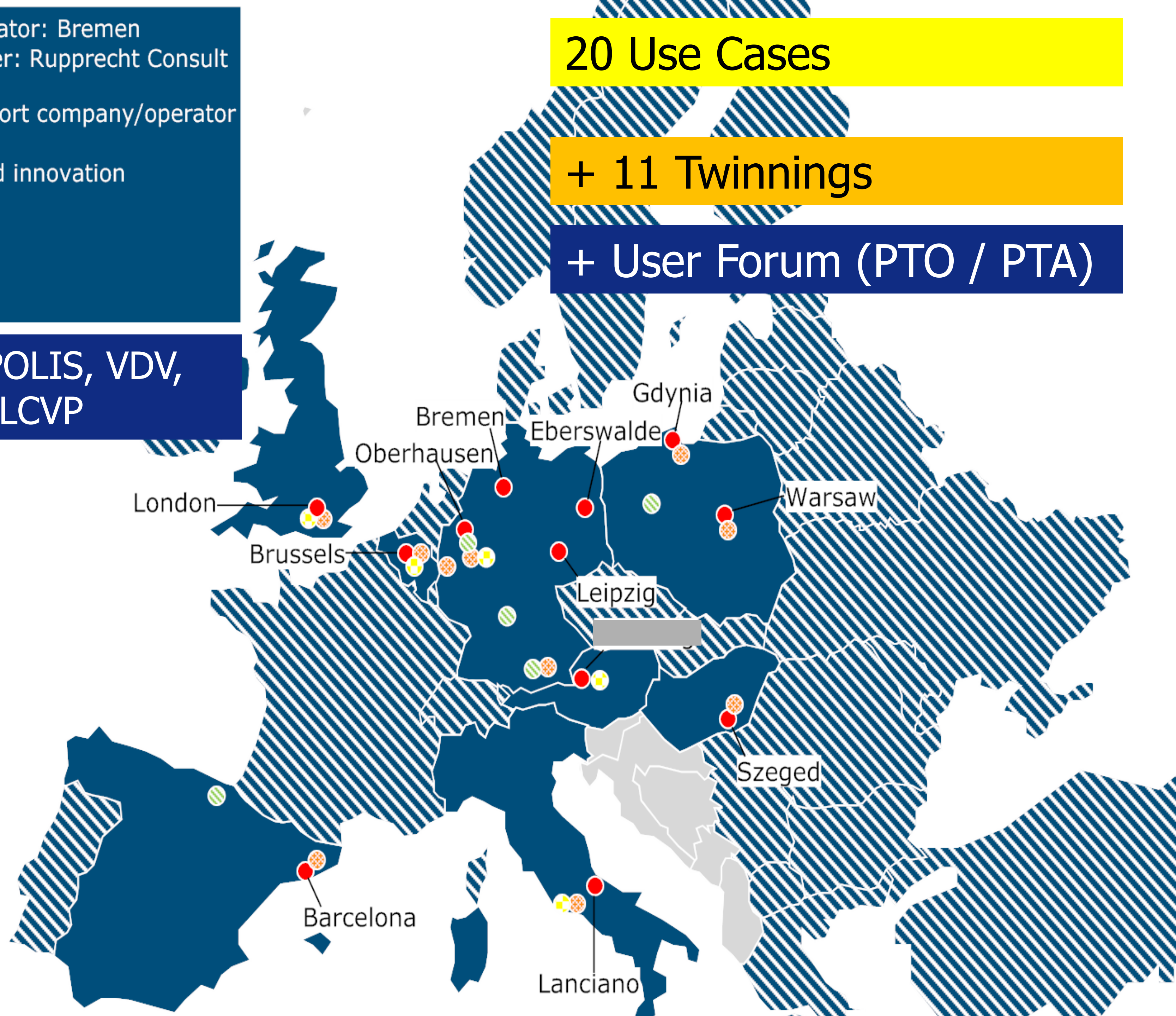
- Public transport company/operator
- Research and innovation
- Industry
- Associations

+ UITP, POLIS, VDV, ASSTRA, LCVP

20 Use Cases

+ 11 Twinnings

+ User Forum (PTO / PTA)



Three thematic technology pillars

eLIPTIC
electri ion of
public sport in cities

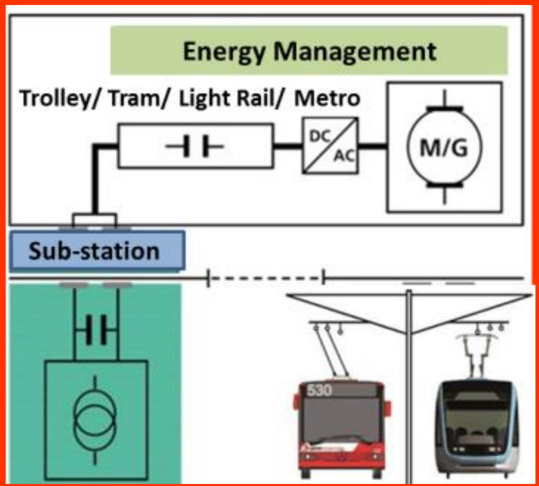
A

E-buses

Safe integration into existing electric PT infrastructure

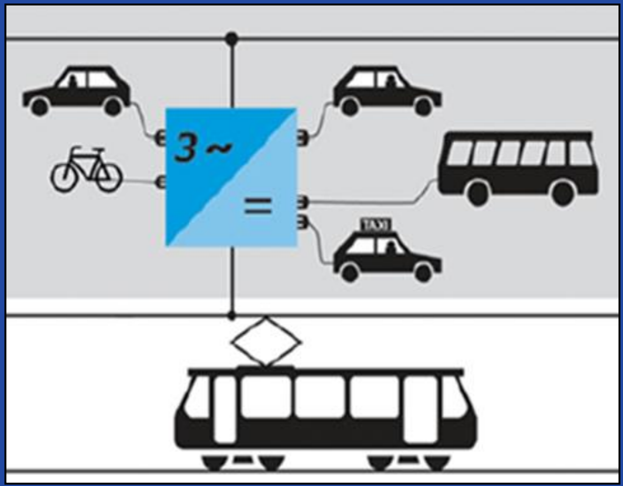
B

Energy efficient electric PT system



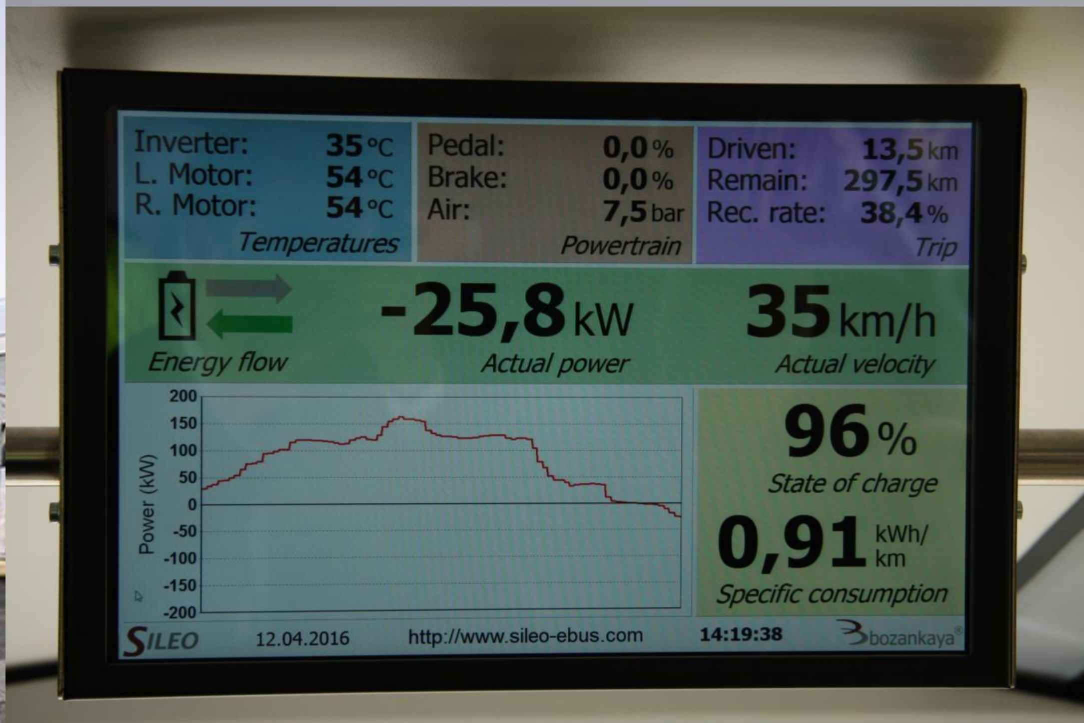
C

Multi-purpose use of electric PT infrastructure



Electric buses tested in real life at BSAG

18m battery bus long range



2016:

2 12m full electric battery buses (SILEO and EBUSCO)

1 18 m SILEO full electric battery bus

Charging at combined tram/ bus depot

Electric buses in regular service in Oberhausen

2015:

2 12m battery buses(SOLARIS Urbino 12), charging at tram stop and tram substation

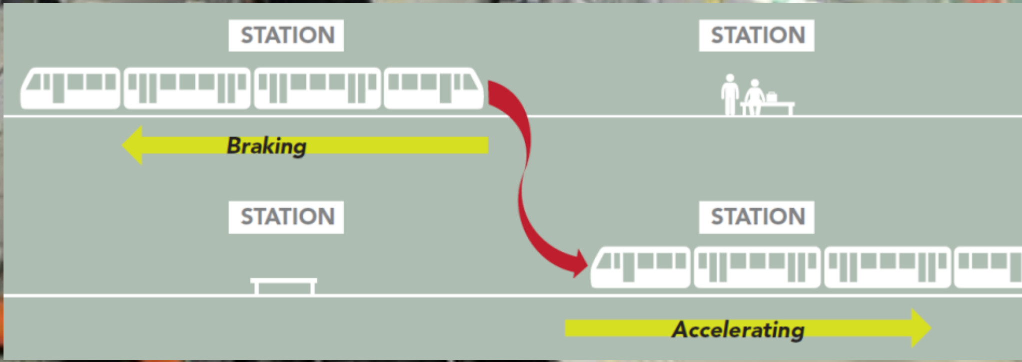
Battery-trolley-hybrid without overhead wire

Extended service on regional route without overhead wire
Tests of automated wiring and de-wiring for more flexibility in Eberswalde, Szeged and Gdynia

Innovative hybrid-trolleybuses in Gdynia (Poland)

2015: Hybrid-Trolleybus in regular service without catenary

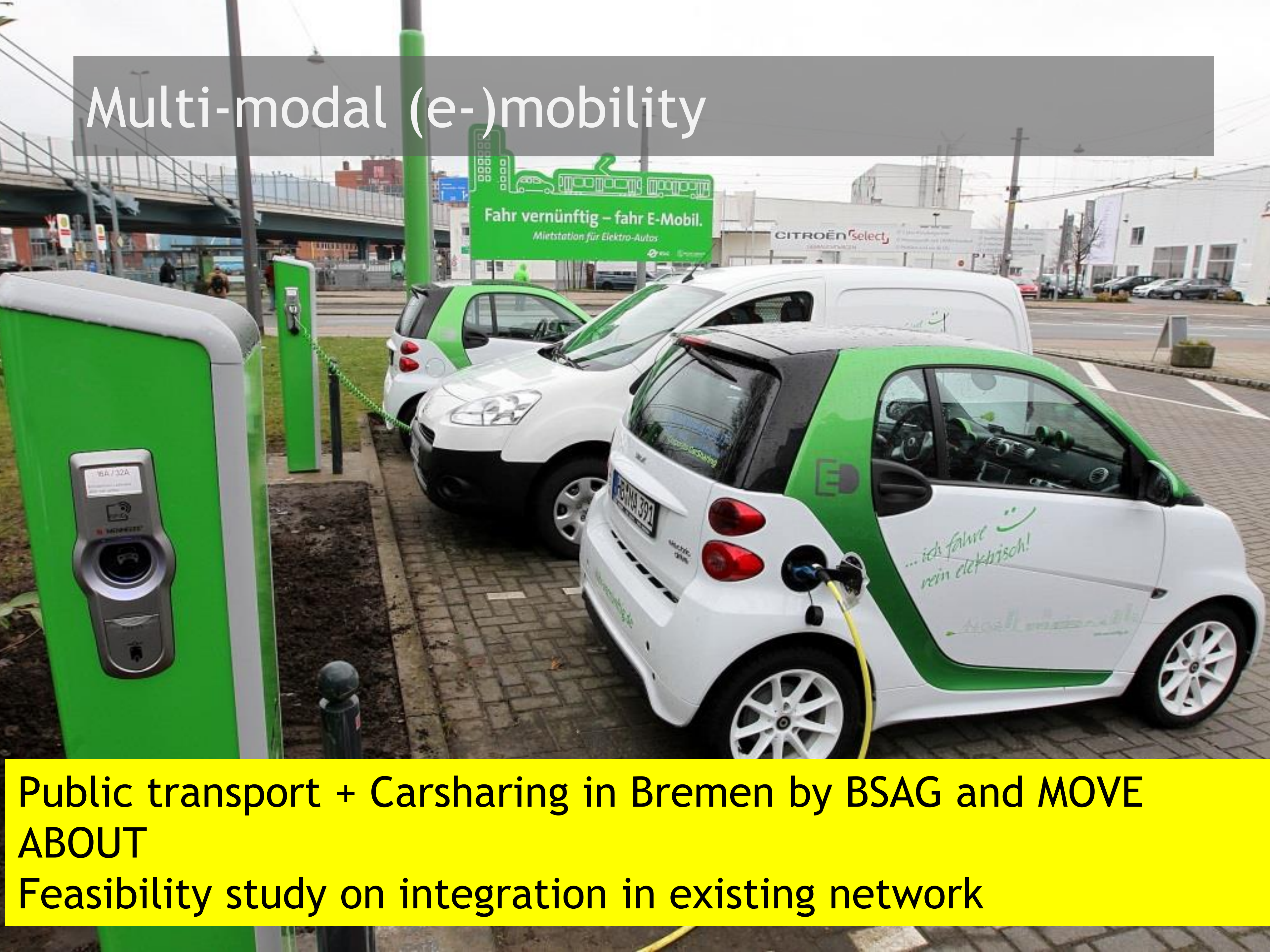
Energy efficient tram / metro



Source: www.tickettokyoto.eu/en

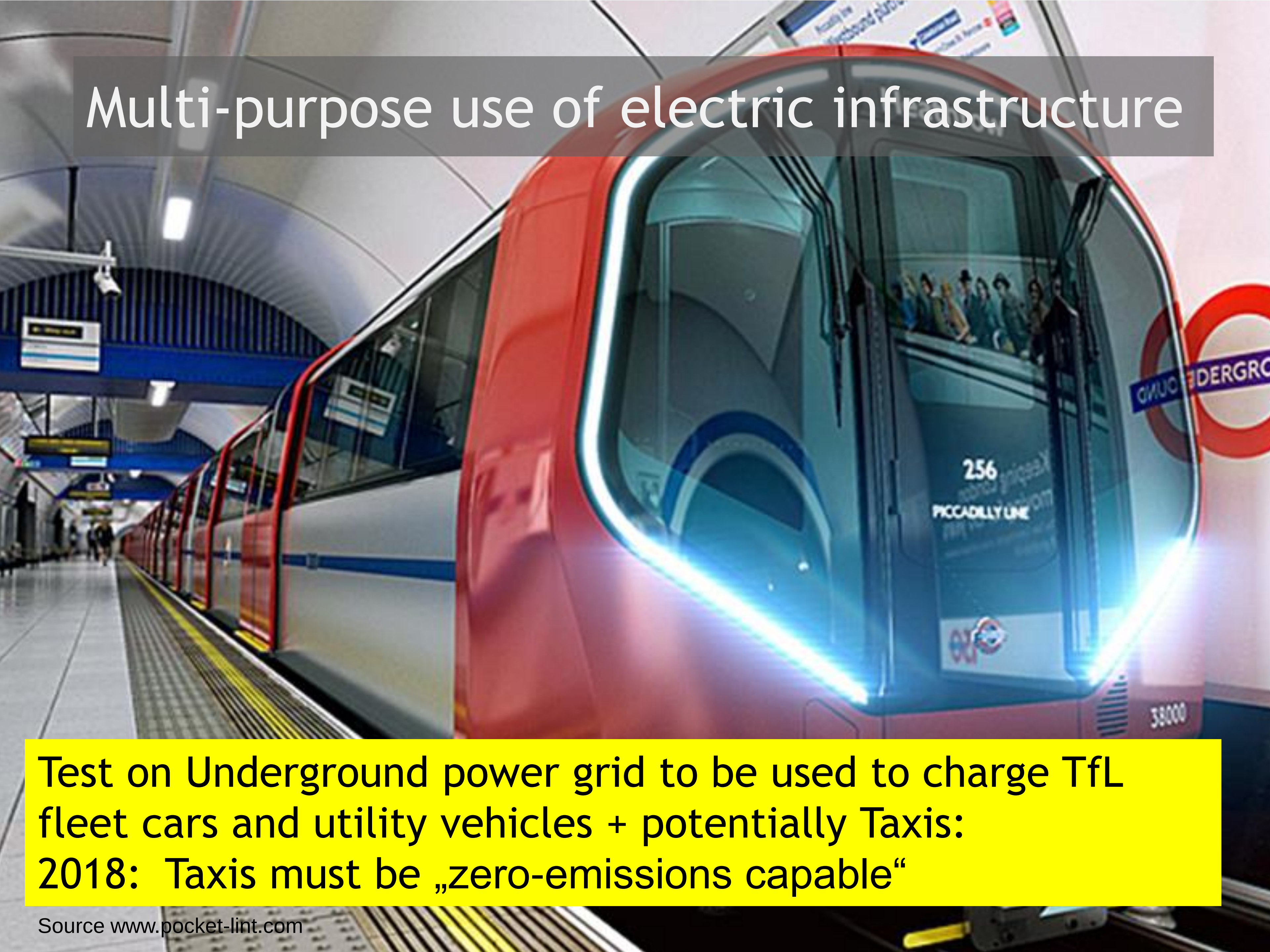
2014: Energy storage in tram substation in regular operation
2016: Feasibility study on potential to extend recuperation through braking in Brussels
2017: Feasibility study on potential to extend recuperation through braking in trolley network in Gdynia

Multi-modal (e-)mobility



Public transport + Carsharing in Bremen by BSAG and MOVE ABOUT
Feasibility study on integration in existing network

Multi-purpose use of electric infrastructure



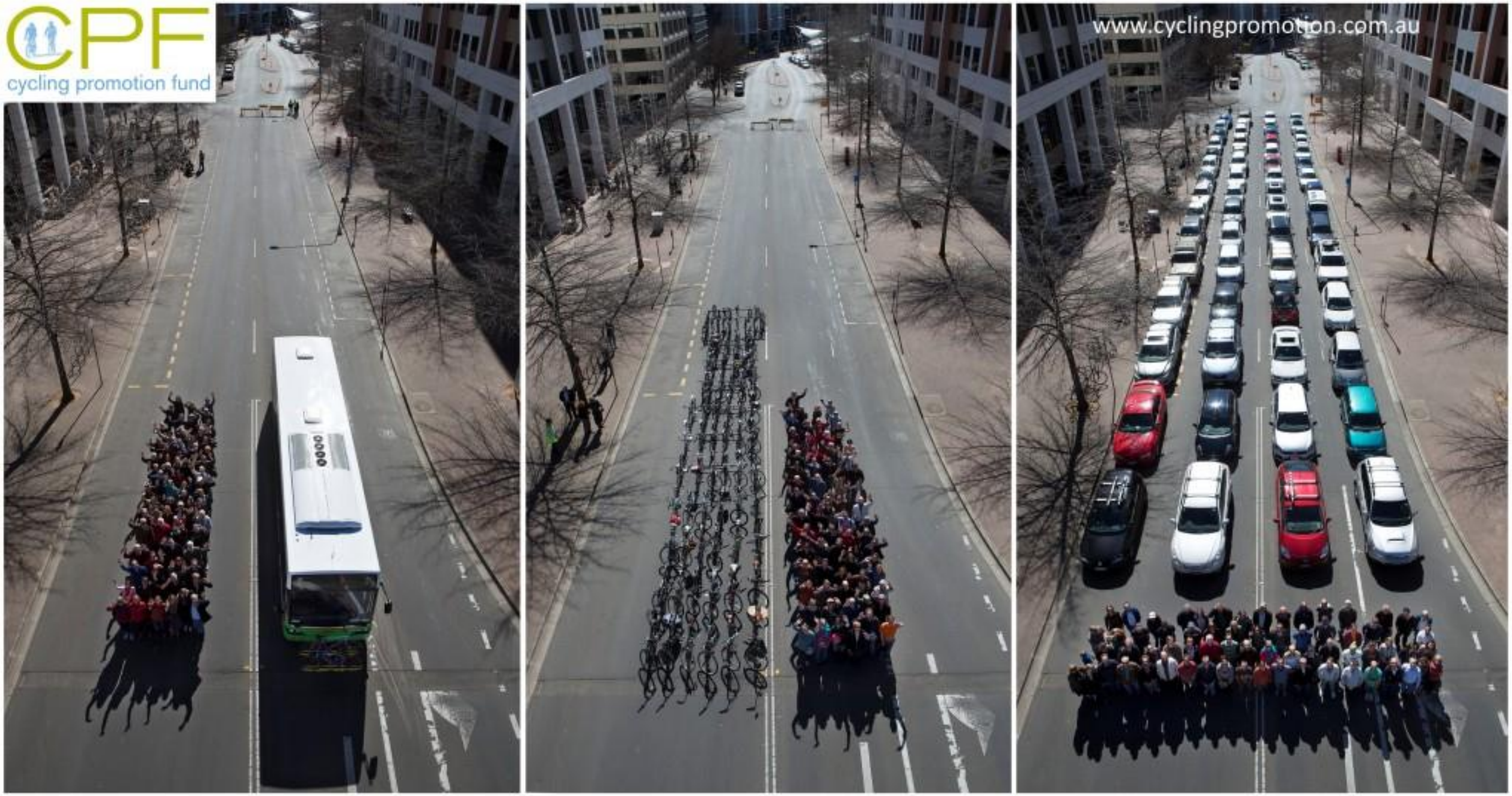
Test on Underground power grid to be used to charge TfL fleet cars and utility vehicles + potentially Taxis:
2018: Taxis must be „zero-emissions capable“

Source www.pocket-lint.com

Factor 100

Passenger car		Bus (18m)
< 1 hour	Daily usage	12 - 16 hours
Small (- medium)	Engine size	big
50 - 60% Diesel	Fuel	95 – 98 % Diesel
Diesel: PM_{10} + NO_2 Gasoline: low	local pollutants	Diesel: PM_{10} + NO_2
500 l gasoline/ Diesel	Annual fuel consumption	40,000 l Diesel
~ 1,2 to	CO_2 emission p.a.	~ 100 to
	Total impact	Equals to app. 100 electric passenger cars

Factor 100



x 100

... but not 100 fold financial support!

Halve the use of ‘conventionally-fuelled’ vehicles in urban transport by 2030, phase them out by 2050

achieve essentially CO2-free city logistics by 2030 – in major urban centres

No targets for urban public transport

Factor 100

eLIPTIC
electrification of
sport in cities

Besides indirect funding (no / less t
operational benefits)
fundi

For buses an equivalent support would mean
~ 500.000€ / bus

ermany = 4.000€

Data: 2015

CIVITAS
Horizon 2020
Programme

Thank you for your attention

eLIPTIC electrification of public transport in cities

www.eliptic-project.eu

2020 CIVITAS Cleaner and better transport in cities

Thank you for your attention!

Hendrik Koch

Free Hanseatic City of Bremen

Ministry for the Environment, Transportation and Urban Affairs
Project-coordination sustainable mobility

Der Senator für Umwelt, Bau und Verkehr

Freie Hansestadt Bremen

Hendrik.Koch@umwelt.bremen.de
eliptic@umwelt.bremen.de

www.eliptic-project.eu

Horizon 2020 Programme