

London Buses' Emissions Strategy

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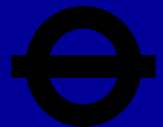


Another red
bus going
green for
LONDON

Route 360
A new generation of electric hybrid buses are now operating on this route. This means less greenhouse gas emissions, fewer harmful pollutants and lower noise levels. Better for the environment, better for London.

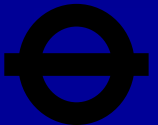
Pick up a leaflet on the bus for more information or visit: tfl.gov.uk/hybrid

MAYOR OF LONDON Transport for London 



Presentation Content

- **Review of London's bus fleet**
- **Environmental Priorities and Achievements**
- **Emission Trends and Impacts of the Bus fleet**
- **Fuels and Technologies trialled to date**
- **Clean Urban Transport for Europe (CUTE)**
- **Future Environmental Programme**
- **Hybrid Buses**
- **Hydrogen Buses**
- **Hydrogen Bus Alliance**



Review of London's Bus Fleet

- **March 2007, 8181 vehicles in fleet**
 - PVR Weekday 7024
 - PVR Saturday 6229
 - PVR Sunday 3881
- **Single decks 33%, double decks 62%, articulated 5%**
 - 6 Large operators (87% of Fleet)
 - 12 Small operators
 - 87 Depots
- **Engine Euro rating**
 - Euro II + DPF 36%
 - Euro III + DPF 61%
 - Euro IV by SCR/EGR 3%
- **Average 56750 km (35469miles) per vehicle per year**
- **Average speed 8mph, thus average operating day 13hrs but many vehicles in service for up to 18hrs a day**



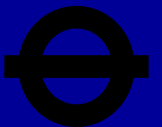
Review of London's Bus Fleet

- 8181 vehicles in fleet
- Single decks 33%, double decks 62%, articulated 5%
- 500 vehicles replaced each year and a similar number refurbished
- Average age 5.1 years
- Forecast network growth of 4% in bus km between 2006/07 and 2014/15
- 40% aggregate growth in number of trips since 1999/00
- 460 million operated km and 1.9 billion passenger trips in 2006/7



Environmental Priorities

- **Climate Change**
 - Carbon dioxide (CO₂) and other greenhouse gases such as nitrous oxide
- **Air Quality**
 - Fine particles (PM10)
 - Oxides of nitrogen (NO_x) and nitrogen dioxide (NO₂)
- **Noise and vibration**
 - Idling buses
 - Engine/fan noise

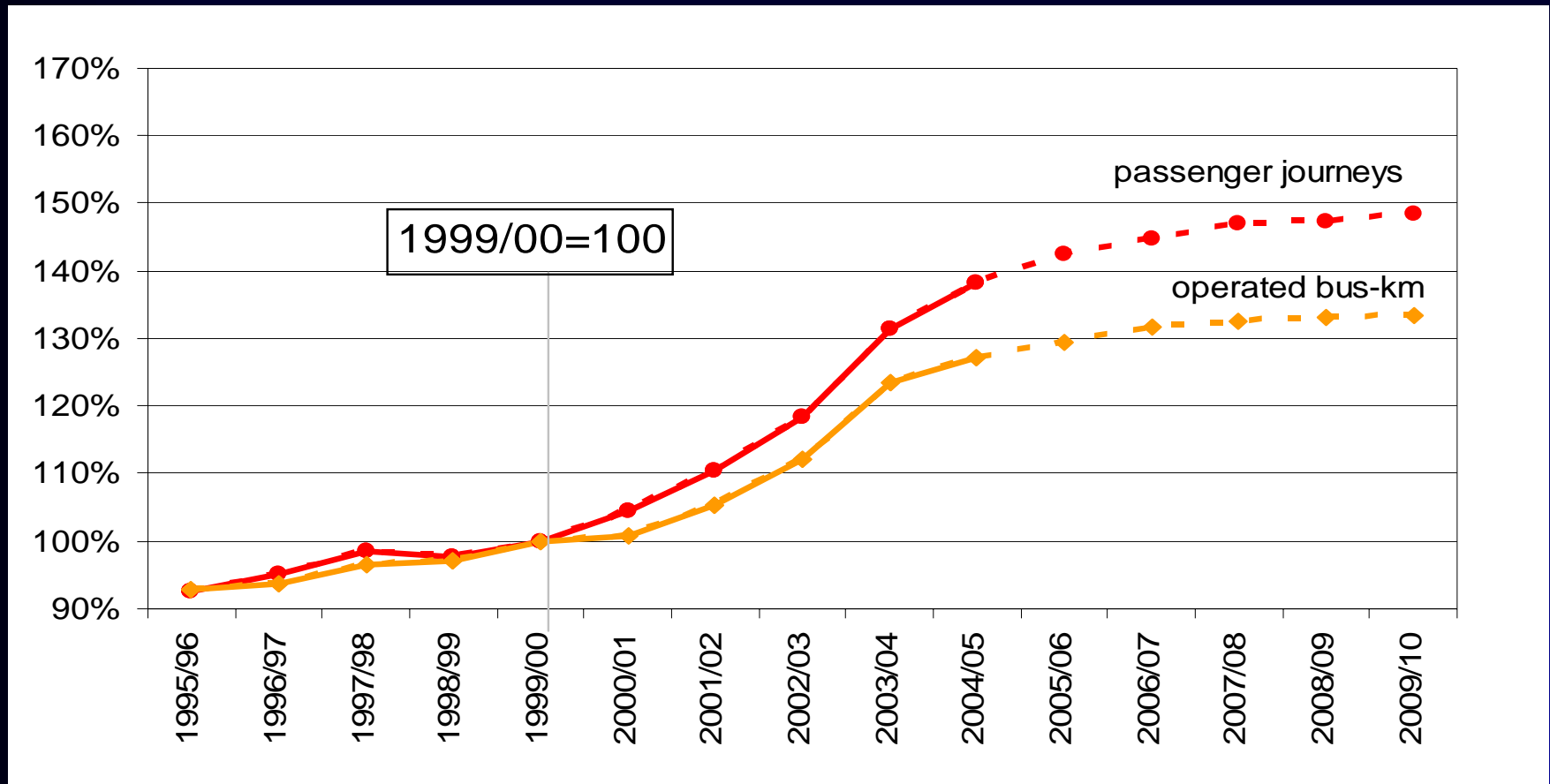


Environmental Achievements to date

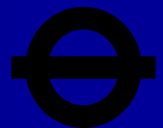
- Focus has been on delivering reduction in local pollutants, driven by Mayor's Air Quality Strategy e.g. NO_x, PM₁₀
- Developed a London bus specific emission tests protocol to evaluate new fuels and technologies before they enter the fleet
- All buses met minimum of Euro II emission standards by December 2005, over 60% now meet Euro III
- All buses were fitted with a particulate filter by December 2005 – fleet emissions reduced by approx 90% compared with 2000 for PM₁₀, hydrocarbons and carbon monoxide
- Drive by Noise test level reduced by 2dB(A) also extended to include acceleration tests and interior noise standards



Demand & Service Level 2006/07 Business Plan



The Business Plan projects a levelling-off of demand growth in the period to 2009/10.



London Bus Emissions Test Cycle

Requirements of a Dedicated Test Cycle

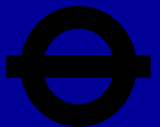
- A real life test cycle required to evaluate all forms of bus emissions based on a typical route and load condition for London
- Evaluation of none EU regulated emissions
- Evaluation of emissions on a g/km travelled not g/kw-hr
- Ability to test effects of any additional equipment or fuel supply against standard test procedure
- Utilisation of data collected to determine emissions strategy and specifications for new buses



London Bus Emissions Test Cycle

London Bus emissions test cycle and other testing conducted at Millbrook proving ground

- Provides constant test conditions over many years of testing with direct comparisons as Euro ratings are introduced
- Delivers independent results from bus manufacturer, operator or engine system provider
- Ability to vary load condition based on size and capacity of the bus



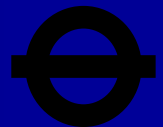
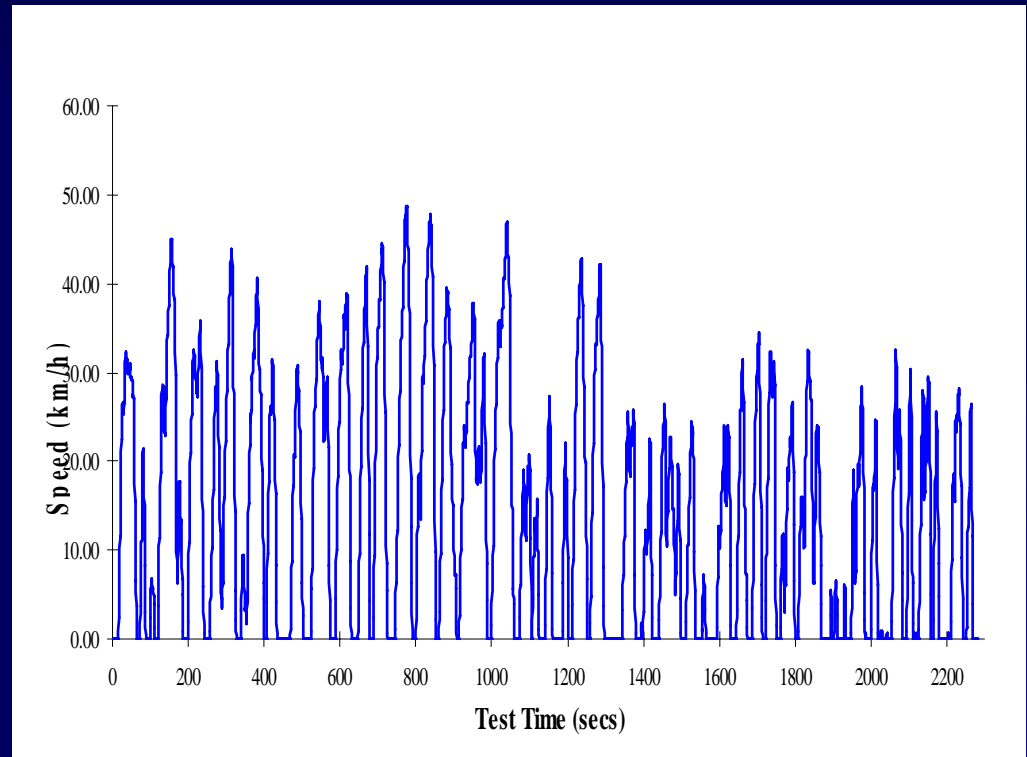
London Bus Emissions Test Cycle

Route 159 as typical mapped for operational profile

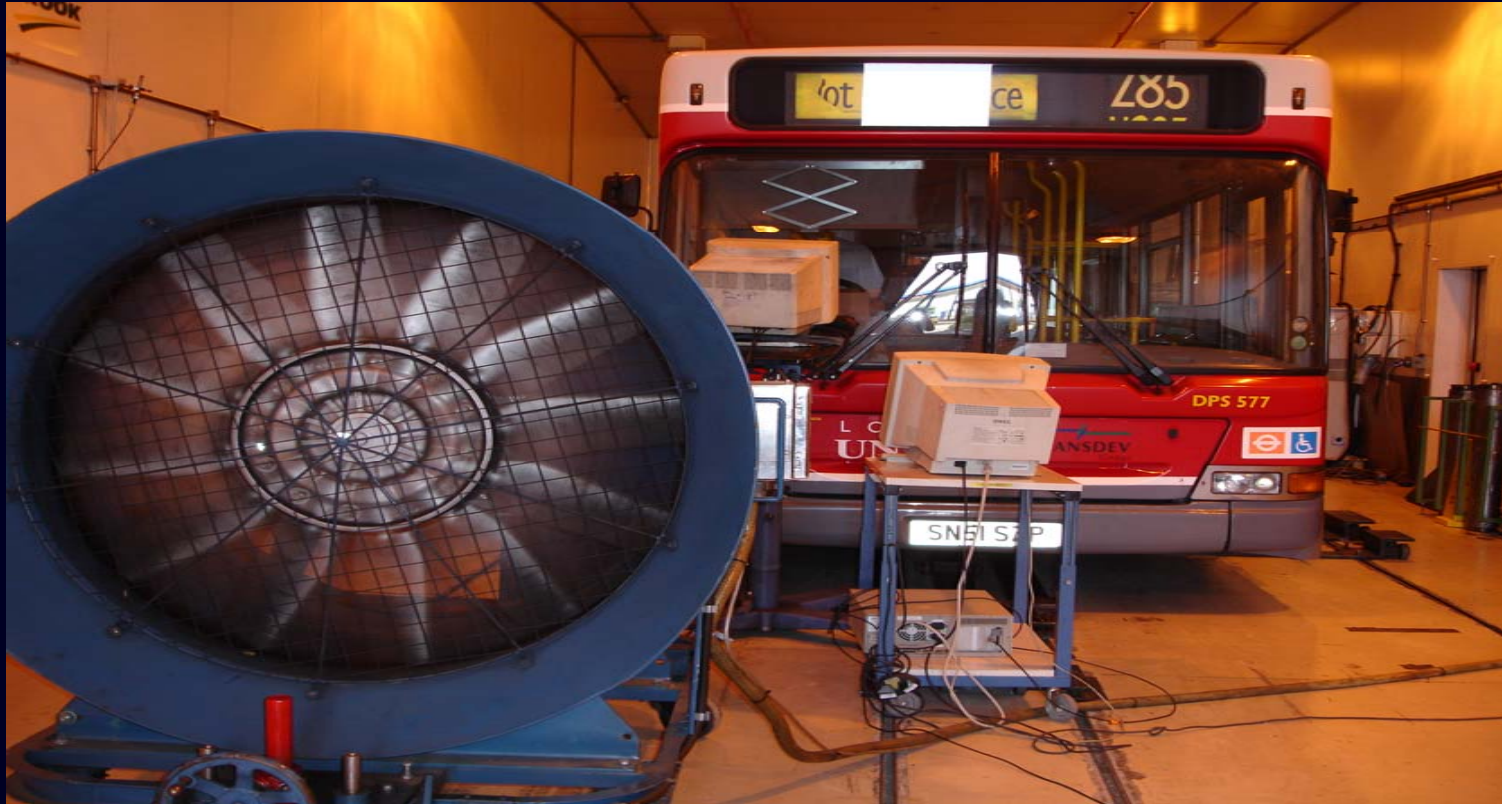
Route operated Brixton to Baker Street

Overall 8.8 mph
Outer city 10.5 mph
Inner city 6.2 mph

High frequency stop
start operation



London Bus Emissions Test Cycle



- Route profile simulated on dynamometer
- Loaded to simulated passenger weight
- Road speed movement simulated by air fans
- Test chamber kept at constant temperature for all tests
- Hybrid test, calibration & integration

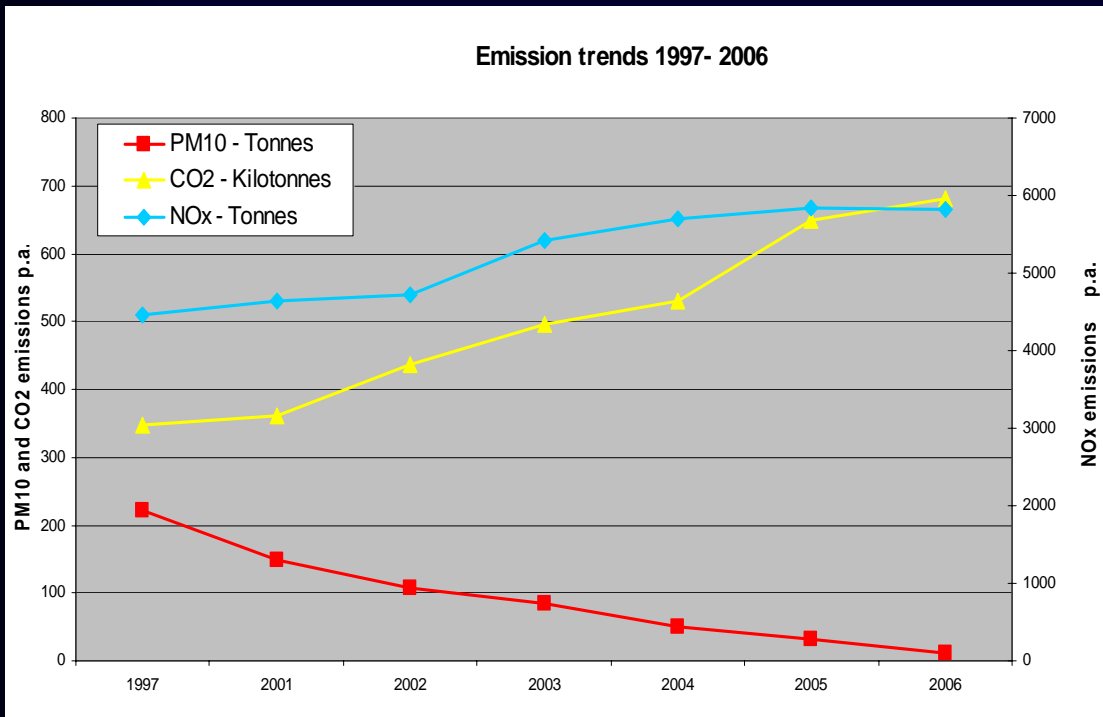


London Buses Test Protocol

- **Millbrook emissions test cycle established prior to Euro 1 introduction. Thus, test history by bus type analysis and comparisons over all Euro ratings**
- **Full Emissions test cycle with detailed reporting and comparisons**
- **Noise Testing**
 - Drive by (London Bus requires 2dB(A) below legal limit)
 - Drive by with all auxiliary equipment in operation
 - Drive by at start 10kph then full acceleration
 - Interior saloon at 3 road speeds
 - Noise frequency at full range of engine speeds
- **Stability**
 - Acceleration and retardation rates and g forces on passengers
 - Manoeuvring g forces at various speeds and acceleration rates

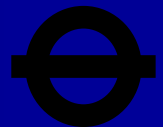


Fleet Emission Trends



- NOx emissions have increased since 2001
 - increased fleet size
 - worse g/km emissions under London conditions with Euro III engines
- Introduction of Euro IV buses will reverse this trend

- PM reduction due to:
 - better engine technology
 - particulate trap programme
 - trap reduces PM by over 90% including ultrafines
- Similar trend in HC & CO due to better engine technology and catalysed trap usage
- CO2 emissions have risen over the last 6 years
 - increased fleet size/km travelled
 - no improvement in fuel consumption with new Euro III technology



CO₂ impact of London's bus fleet

- Buses are largest contributor to TfL's CO₂ footprint at 40%
- Network consumes 260 million litres of diesel per year
- 682,000 tonnes of CO₂ emissions produced per annum
- 103 grammes per passenger km (based on average occupancy of 15 passengers/vehicle)



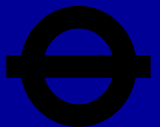
Fuels & Technologies trialled to date

- **Water Diesel Emulsion (WDE)** – Initial trials were promising but technical problems occurred on Euro III vehicles. Tax arrangements results in WDE costing 3 pence per litre more than diesel
- **Gas to Liquids** – short trial with Shell using articulated Citraro. Trial showed promise and Shell now attempting to develop production capability and engine manufacturer acceptability
- **LPG** – emissions tests showed 30% reduction in NO_x but virtually no change in CO₂
- **NO_x Abatement** – 24 Euro II vehicles currently in retrofit trial. NO_x emissions potentially reduced by up to 65% with no significant increase in greenhouse gas emissions. Trial results under review but costs of retrofit restrictive



Clean Urban Transport for Europe (CUTE)

- Trial 27 fuel cell buses over 2 years in 9 European Cities
- Daimler Chrysler Citaro buses with Ballard fuel cells delivered to each city between June and December 2003
- London having 3 Buses in service by January 2004
- Gain experience in design, construction and operation of necessary infrastructure
- Experience of differing conditions among companies/ environments
- Comparison of air quality and carbon emissions with conventional alternatives
- London trial ended January 2007, having been extended by 1 year

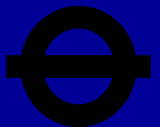


Fuel Cell Bus trial in London

- Very good operational availability achieved for the buses – 90% on average



- Main limitation is the high fuel consumption and range of the vehicles
 - Next generation vehicle will address this through hybridisation

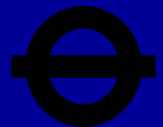


Hydrogen Filling Station

- BP constructed hydrogen filling station as part of trial
- Based on storage of liquid hydrogen underground – dispensed as gaseous

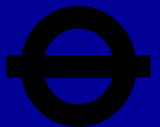


- Reliability good but refuelling times too long
- WTW CO2 emissions high due to use of liquid hydrogen trucked into station



Future Environmental Programmes

- **Strategy will focus on reducing carbon dioxide**
- **Programmes will focus on delivering reductions in line with Mayor's Climate Change Action Plan**
- **Extensive research and development programme to test new fuels and technologies that may offer environmental benefits**
- **Short to medium term focus will be to introduce diesel electric-hybrid technology**
- **Long term strategy is to move towards hydrogen and fuel cell technology**

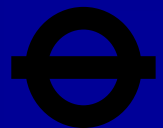


Hybrid Single Deck Bus

- Six single deck diesel-electric hybrids introduced in March 2006
- Vehicles are Wright Bus 'series' hybrid, powered by 336 volt battery pack and 1.9 litre diesel Euro IV engine



- 38% reduction in CO₂, 89% reduction in NO_x, 4dBA noise reduction
- Smooth acceleration
- Compared to equivalent Euro III bus on London test cycle

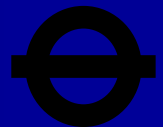


Hybrid Double Deck Bus

- One double deck diesel-electric hybrid introduced in March 2007
- Vehicles are Wright Bus 'series' hybrid, powered by 660 volt lithium Iron battery pack and 1.9 litre diesel Euro IV engine

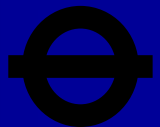


- 30% reduction in CO₂, 12% reduction in NO_x, 2dBA noise reduction
- Smooth acceleration
- Compared to equivalent Euro IV bus on London test cycle



Hybrid Bus – Introduction plan

- **Intention is to introduce 50 - 60 hybrids by end 2008 from various manufacturers**
 - **to evaluate technology, reliability, performance, fuel economy, emissions profiles and long term operational costs**
 - **to establish range of supply for future roll – out**
- **A number of manufacturers currently in process of developing demonstration vehicles to achieve the 50 – 60 buses by December 2008**
- **Roll - out beyond initial phase**
 - **100 hybrids introduced during financial year 2009/2010**
 - **200 hybrids introduced during financial year 2010/2011**
 - **500 hybrids introduced during financial year 2011/2012**
- **All new buses entering service from April 2012 to be hybrid**



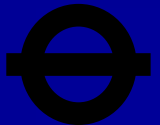
Hybrid – Specification Requirements

- **Compared to an equivalent Euro IV on the London Bus Emissions Test Cycle**
 - **Low Emissions**
 - 80% reduction in hydrocarbons
 - 95% less carbon monoxide
 - 30% drop in carbon dioxide
 - 15% reduction in oxides of nitrogen
 - Equivalent to TfL's particulate matter standard for Euro IV
 - Zero emission running not currently envisaged for predetermined locations
 - **Fuel Saving**
 - 30% to 40% less fuel consumption
 - Potential to run on bio-diesel blends, greater than 5%
 - **Reduced Noise levels**
 - Potential 4dB(A) reduction on legal drive by test (currently 2dB(A) for diesel)
 - Aim for interior noise levels similar to passenger car levels
 - **Smooth acceleration to improve ride and passenger environment**



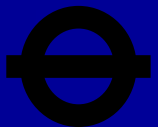
Hydrogen Transport Programme - Buses

- London Buses is now taking steps towards a hydrogen bus programme to build on the success of the CUTE project
- The bus programme forms part of the London Hydrogen Transport Programme which aims to deliver 70 hydrogen vehicles into London by 2010
- A fleet of 10 hydrogen buses will be operated on one London route, starting in 2008/9. Technology will be either hydrogen ICE or fuel cell
- A dedicated hydrogen refuelling facility will be built at the bus depot – main objective will be reliability, but consideration will be given to reducing CO2 emissions where possible
- Aim to achieve operation as close as possible to diesel buses
 - **18 hour days (370km range specified)**
 - **364 days per year**
 - **five year contract**
 - **fast refuelling of buses in quick succession**



Hydrogen Transport Programme – Cars & Vans

- 60 vehicles to be comprised of motorcycles, small cars, larger passenger cars and vans
- Phase 1 will involve delivery of 20 hydrogen vehicles and construction of two hydrogen refuelling facilities by 2008-2010
- Vehicles operated by GLA family
- Remaining 40 vehicles in Phase 2 may be combination of hydrogen and other low carbon technologies
- Operation may extend to London local authorities



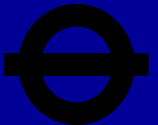
Looking forward - CO₂ reduction

- **Diesel- Electric Hybrid**
 - Short to medium term focus will be to introduce diesel electric-hybrid technology
 - Hybrids are potentially the most viable options for reducing CO₂, local pollutants and noise in the short to medium term – 30 to 40% reduction in CO₂ achieved in current Millbrook testing
- **Other Options**
 - Acceleration rate control on standard bus engine systems and driver training
 - Extensive research and development programme involving testing of alternative fuels and technologies that may offer CO₂ benefits such as ethanol and other bio-diesel products (could be combined with hybrid technology)
- **Hydrogen Technology**
 - Long term strategy is to move towards hydrogen and fuel cell technology, to build on the success of the CUTE project
 - The London Hydrogen Transport Programme aims to deliver 10 hydrogen buses into London by 2008



Hybrid Bus Evaluation Group

- **London Buses has formed a Hybrid Bus Evaluation Group with all London operators utilising the first 60 Hybrid Buses**
- **Objectives of the group being proposed but generally to openly share knowledge , operational experience and establish provisional life cycle costings for each type and technology utilised over the variety of Hybrid buses in service**
- **A carbon footprint of each bus type is a desirable objective**
- **All buses introduced will undertake Millbrook emissions evaluation as a starting point for direct comparison to similar buses at Euro 3 and Euro 4 engine status**



Hydrogen Bus Alliance

- London Buses has formed a Hydrogen Bus Alliance with other cities
- Currently seven cities have signed a MoU
- New members welcomed, who are actively seeking to procure hydrogen buses in near future

- ✓ London
- ✓ Barcelona
- ✓ Berlin
- ✓ Hamburg



- ✓ British Columbia
- ✓ Amsterdam
- ✓ Perth
- ✓ ????????

- Aim of Alliance is to:
 - Share information especially with regards procurement process
 - Give clear signal to the market that there is demand for hydrogen buses
 - Work with hydrogen bus industry to develop a pathway towards commercialisation
 - Achieve economies of scale where possible through co-ordinating procurement programmes

