Safety, Sustainability and Human Resources Panel

Date: **21 March 2017**

Item: **Low Emission Technology Buses**

This paper will be considered in public

1 Summary

1.1 The purpose of this paper is to inform the Panel on the strategy to reduce emissions across the bus fleet.

2 Recommendation

2.1 **The Panel is asked to note the paper.**

3 Background

3.1 One of the Mayor's key manifesto commitments is to improve London's air quality. Over half of London's toxic air pollution is produced by road transport, of which 20 per cent is caused by buses. Low-emission bus technology has a significant role to play in delivering the Mayor's commitment.

3.2 The capital now has higher recorded levels of nitrogen dioxide (NO_2) than any other European capital city. London also has significant levels of particulate matter (PM).

3.3 London is at the forefront of using cleaner bus technology as a lever to quickly improve air quality. TfL already has the largest electric bus fleet in Europe, with 71 pure-electric buses currently in operation. We also have eight hydrogen fuel-cell buses, with secured international and UK funding for at least 20 more which should start entering the fleet from the end of 2018. Appendix 1 shows the current bus fleet data at 13 January 2017.

3.4 The Mayor has set out ambitious plans to make existing vehicles much cleaner for NOx and PM, and introduce the most promising zero-tailpipe emission vehicles as early as possible. Combining this with hybrid technology will also bring down carbon dioxide (CO_2) emissions and help combat the threat this poses to global warming and climate change.

3.5 Our plans include:

(a) making sure all double-decker buses operating in the Ultra Low Emission Zone (ULEZ) comply a year earlier by 2019, meaning each of the 3,100 double-decker buses operating in the zone will be Euro VI hybrid;

(b) expanding the ULEZ retrofit programme to up to 3,000 buses outside the central zone by 2020 and to 4,200 by 2021;

(c) all new buses entering the fleet from 2018 will be hybrid diesel-electric or zero-emission;

(d) creating 12 Low Emission Bus Zones to be operational by 2020, that will see NO_2 tailpipe emissions along particular routes fall by more than 80 per cent; and

(e) more than 3,100 double-decker buses operating in London to be hybrids by 2019.

3.6 The Mayor announced these commitments and unveiled the world's first double-decker hydrogen bus at the International Zero-Emission Bus Conference and Summit that was held at City Hall in November 2016. At this conference manufacturers were challenged to deliver advances in new emission technology.

4 Immediate Strategy

4.1 In the near term, the fastest and most affordable method of reducing bus emissions is to retrofit the existing bus fleet with much cleaner exhaust systems. This is to bring them up to the Euro VI engine emission standard and replace age-expired buses with new vehicles that are already at this standard or better.

4.2 The most cost-efficient method to introduce new buses into the fleet is through contract renewal, allowing between 600 and 1,000 new buses to be introduced each year.

4.3 Through these two methods of upgrade and replacement, the entire fleet will be at the Euro VI emission standard or better by 2020, and make a significant difference before zero-emission technologies can catch up in performance and price.

4.4 This approach does not require investment in new infrastructure for the capital's 9,500 vehicle fleet as it involves continued use of diesel as its principal fuel. Because of restricted space at many garages, this is often the only viable choice in the short term. While vehicles could be refuelled off-site with an alternative energy, this would not be operationally viable. It would entail significant cost in dead mileage, additional fuel consumption and more tailpipe emissions.

4.5 TfL has undertaken third-party assurance to ensure tailpipe performance delivers significant emission reductions. This takes place over a simulated London route cycle at Millbrook Proving Ground and enables identical benchmarking to take place. Results of this testing can be found in Figure 1 below and are described further in section 5.

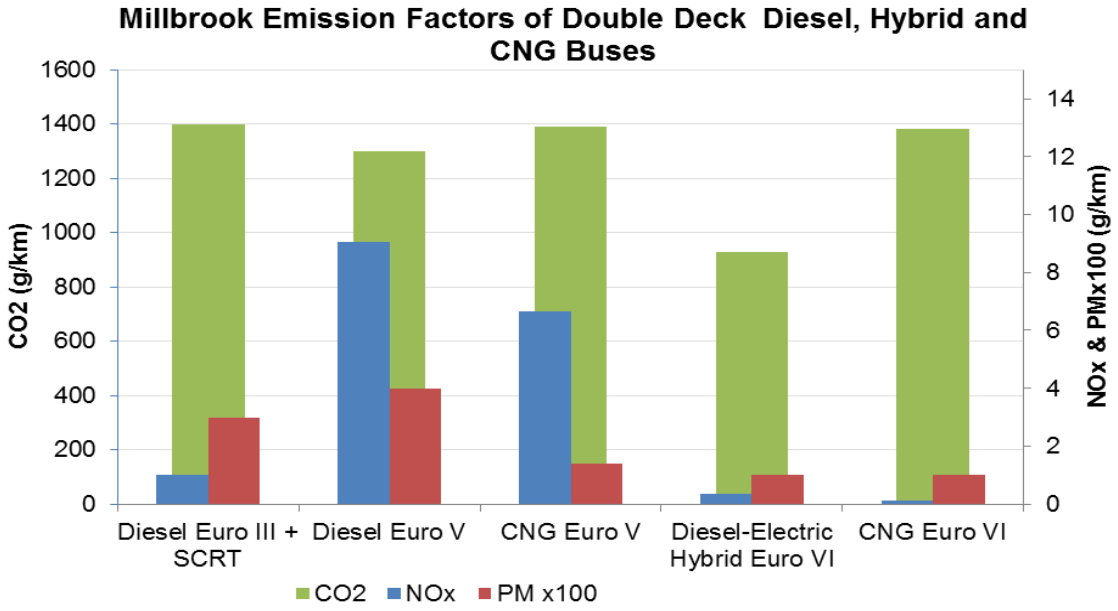

Figure 1. SCRT Selective Catalytic Reduction Technology.

4.6 The performance and cost of zero-emission buses, such as pure-electric and hydrogen fuel-cell, are currently a barrier to application on all routes, but improvements in battery power and larger scale production look set to make them viable alternatives in the medium term.

5 Types of Technology

5.1 **Compressed Natural Gas (CNG)** is a mature technology but is not being pursued for wider emission and infrastructure cost reasons. Gas refuelling infrastructure has high installation costs and many bus depots do not have the space available, making parallel refuelling impractical or prohibitively expensive. Emissions standards at Euro VI set the same stringent limits for diesel and gas-powered vehicles. Given the effectiveness of Euro VI emissions standards, gas powered buses no longer offer any significant air quality benefit.

5.2 **Range-extended hybrid buses** are currently being trialled as a proof of concept on route 69 to potentially offer significant reduced well-to-wheel (the end to end process of emissions) CO_2 reduced emissions. The trial is currently under consultation until April 2017 with the possibility of this being extended to April 2018.They can offer reduced emissions due to their ability to operate up to 80 per cent of the time in battery power. However this does not translate into an 80 per cent reduction in NOx due to the inefficiency of its selective catalytic reduction system on start-up and the switching on and off its diesel engine. Further analysis needs to be conducted to identify how far its higher emissions in diesel mode are offset by the time spent in electric mode. There are also higher costs associated with the rapid wireless inductive charging infrastructure. A similar proof of concept trial for conductive over-head charging using pantograph technology is currently

under consideration. This is to allow us to assess the benefits of an alternative charging infrastructure. Like inductive charging, it would not entail over-head wires along the route, due to cost, security and safety.

5.3 This type of range-extended hybrid technology may provide a transition path to full zero-emission buses. Geo-gating (the use of GPS to define boundaries) may allow for the guaranteed use of electric propulsion at points in a route of particularly poor air quality.

Figure 2. Example of our route 69 range-extended hybrid bus.

5.4 **Pure-electric buses** are becoming increasingly available from the market but remain of a limited range on a single battery charge. To operate a comparable distance to a conventional diesel or hybrid-diesel-electric bus, they need to recharge on street, at a bus stand or at their garage while out of service. These options carry with them significant capital cost premiums until battery range more closely matches diesel.

5.5 There are currently 71 pure-electric buses in the fleet, which have already demonstrated a 50 per cent CO_2 saving compared to an equivalent diesel bus. A further 14 pure-electric buses will be added to route 360 at the end of this year, plus 36 in Spring 2018 on routes C1 and 70. This will take the total number to over 100 on the network. These buses rely on the decarbonisation of the National Grid to reduce the overall levels of CO_2, however they are helping to reduce the direct effects in the areas of poorest air quality in central London. There are also associated issues with providing suitable charging facilities with considerable additional capital expense associated with these.

Figure 3. One of our pure-electric buses on route 507.

5.6 **Trolley buses** are not considered to be a financially viable proposition because of the cost of on street fixed infrastructure compared to their plug-electric counterparts. There would also be significant safety and security concerns to overcome along with local objections to unsightly power lines. Even in their London heyday, trolley buses did not operate in central London. Trolley buses and overhead lines are far more impacted by changes to roads, such as borough urban realm schemes. They offer the bus network less flexibility around public events when vehicles need to operate around curtailments and event cordons due to their fixed infrastructure. On congestion, financial and emissions grounds, trolley buses are not expected to play a role in the fleet currently.

Figure 4. An example of a Trolley bus.

5.7 **Hydrogen fuel-cell buses** offer the benefits of zero-tailpipe emissions and comparable range to conventional diesel and diesel-electric-hybrid buses, but entail a significant capital cost premium for vehicle and infrastructure. TfL is working with the DfT and European agencies to trial new hydrogen vehicles where fuelling stations can be provided and funds can be obtained to offset the vehicle premium in the short to medium terms. The buses are propelled by a fuel-cell that consumes hydrogen to release electricity to power the vehicle. The production of hydrogen through electrolysis is carbon intensive, therefore well-to-wheel hydrogen buses do not offer a CO2 benefit over diesel at present. The decarbonisation of the UK grid will make production of hydrogen using electrolysis less carbon intensive in the future, as will the potential to generate hydrogen from renewables or through grid balancing. Hydrogen can also be produced from the reforming of natural gas either offsite or onsite. This technology does offer a significant CO_2 reduction over diesel buses and it is very mature as it is widely used in the industrial gas sector. However, the well-to-wheel emissions cannot be further decarbonised, unlike production through electrolysis.

5.8 No commercial double-decker hydrogen bus is available at present. However trials are set to commence in London from summer 2017.

Figure 5. An example of one of our hydrogen fuel-cell buses on Route RV1.

6 Conclusion

6.1 TfL is committed to lifting its bus fleet up to Euro VI standard through retrofitting and fleet replacement, and adoption of hybrid technology over the life of its Business Plan (2016). This will achieve radical and affordable emissions reduction ahead of the anticipated move to zero-emission vehicles at the earliest opportunity.

List of appendices to this report:

Appendix 1: Breakdown of current bus fleet

Appendix 2: Euro VI Emissions Standard

List of Background Papers:

None

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Appendix 1 – Table showing the current bus fleet data at 13 January 2017

Vehicle Type	Vehicle Total 13/01/17
Total (Excluding Heritage Routemasters)	9578
Total Diesel	7192
Total NRM	873
Total Electric	71
Total Hydrogen Fuel Cell	8
Total Hybrid	2307

Appendix 2 – Euro VI Emissions Standard

Euro VI is the sixth incarnation of the European Union directive to reduce harmful pollutants from vehicle exhausts. The Euro 6 standard was introduced in September 2015 with the aim to reduce levels of harmful exhaust emissions, both in petrol and diesel vehicles. This includes nitrogen oxide (NOx), carbon monoxide (CO) and particulate matter (PM).

For diesel vehicles, the permitted level of NOx emitted has been dramatically dropped down to a maximum of 80mg/km, compared to the 180mg/km level that was required for the previous Euro V standard. The NOx limit for petrol vehicles has remained at 60mg/km.