Policy Context

The Public Service Obligation (PSO) bus fleet forms the backbone of Irish public transport provision with over 164 million passenger journeys provided for in 2018 on urban bus services alone. A successful measure which has mitigated against Irish transport emissions has been continued investment in public and sustainable transport networks, leading to an increase of over 56 million journeys on subsidised public transport since 2013.

Under the National Development Plan 2018-20271 (NDP), Ireland has committed to replacing existing diesel buses for the urban public bus fleet with low-emission alternatives. As of July 2019, Ireland will no longer purchase diesel-only buses for PSO services; this commitment will help reduce transport carbon (CO₂) emissions as well as potentially contributing towards renewable energy ambitions and improving air quality. Furthermore, removing fossil fuels from our public fleets plays an important role in normalising and promoting the uptake of low- and zero-emission fuels and technologies across the transport sector.

In order to prepare for this transition the Department of Transport, Tourism and Sport (DTTAS) convened a Working Group in June 2018 to undertake a comprehensive series of bus trials assessing real-world carbon and air quality emissions from a range of alternative fuel and technology options to help identify the most suitable alternative for bus fleet transition. The Working Group consisted of DTTAS, the National Transport Authority (NTA), Dublin Bus and Bus Éireann. Following a comprehensive tender process undertaken by DTTAS, Byrne Ó’Cléirigh Ltd. was appointed in November 2018 to project manage the operational phase of the trials and to analyse the findings.

This document summarises the key findings arising from the Low-Emission Bus Trial and is prepared in response to our commitment under the Climate Action Plan2 to publish the outcomes by end-September 2019. A more detailed report will be published before the end of 2019.


Summary of Trial Methodology

In total, fifteen buses, from four different technology categories (full electric, electric-hybrid, compressed natural gas (CNG) and diesel) underwent assessment as part of the trial. The trial was carried out in Dublin and Cork over a period of 5 months (December 2018 to April 2019) and had two primary objectives:

1. To prepare and implement a method of testing the buses that would be repeatable and provide a fair means of comparing different technologies; and
2. To gather emission and fuel economy data that reflects real-world operating conditions.

The trial simulated regular bus operating conditions as much as possible. Testing was carried out over the typical operating cycle of a bus, i.e. during rush hour and off-peak; it also included cold start test runs to capture fuel consumption and emissions data prior to the engines reaching their optimum operating temperature. Cold start tests were carried out along a 1.4 km loop in the vicinity of Broadstone depot (Dublin) and a 1.9 km loop in the vicinity of Capwell depot (Cork). Buses were loaded to simulate 30 passengers (2,000 kg) and stopped for 20 seconds at each designated bus stop along the route. Independent test drivers were appointed to undertake the testing in each city. In so far as possible, drivers attempted to complete test runs in a consistent manner to reduce the influence of driver style and behaviour on the results. Test routes were selected by the Working Group as representative of the ‘typical’ routes serviced in both cities. The routes were nominated by Dublin Bus and Bus Éireann and are set out in Table 1.

<table>
<thead>
<tr>
<th>Location</th>
<th>Bus route</th>
<th>Start and end location</th>
<th>Test cycle distance (km)</th>
<th>No. of stops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dublin</td>
<td>Dublin Bus No. 9 (Southern half)</td>
<td>Broadstone Depot, Phibsborough Road, Dublin 7</td>
<td>19.8</td>
<td>58</td>
</tr>
<tr>
<td>Cork</td>
<td>Bus Éireann No. 207a (modified)</td>
<td>Merchant's Quay, Cork</td>
<td>21.4&lt;sup&gt;Note&lt;/sup&gt;</td>
<td>44</td>
</tr>
</tbody>
</table>

Note: The Cork test route was approximately half the distance of the Dublin test route (10.7 km) and, therefore, the test cycle distance represents two complete journeys along the route.

Each bus completed six test loops over two days at each location (12 loops in total). At least one rush hour test was completed each day.

In total, fifteen buses were assessed:

- 3 x diesel, from the Dublin Bus fleet (a Euro IV, Euro V and Euro VI);
- 2 x single-deck micro-hybrid (diesel);
- 2 x double-deck electric-hybrid buses;
- 1 x single-deck compressed natural gas (CNG)/bio-CNG bus;
Eleven buses were tested using Portable Emissions Measurements Systems (PEMS) equipment to measure carbon and other air pollutant emissions. PEMS facilitates direct measurement of tailpipe emissions and fuel consumption for vehicles operating under real world driving conditions. The PEMS is fitted to the vehicle exhaust and the exhaust gas is analysed using a range of analysers. The emissions measured were:

- Carbon dioxide (CO₂)
- Carbon monoxide (CO)
- Nitric oxide (NO)
- Nitrogen dioxide (NO₂)
- Nitrogen oxides (NOx)
- Particulate number (PN) (not measured on CNG buses)
- Methane (CH₄) approximated by Total Hydrocarbons (THC) (measured on CNG buses only)

While PEMS testing was not carried out on the four battery-electric buses as there are no tailpipe emissions, identical test conditions were employed.

**Summary of Trial Results**

Results from different models of the same fuel/technology have been aggregated to derive the average performance for each fuel or technology. The findings of the Low-Emission Bus Trial show that electric buses performed strongly across a range of metrics. In addition, hybrid-electric technology, where deployed in conjunction with hydrotreated vegetable oil also emerged as a potentially viable alternative, as did gas buses when run on biomethane (bio-CNG).

The trials demonstrate that there is a strong correlation between the energy efficiency of a bus and its emissions. On a final energy basis (the actual energy consumed by the vehicle to perform its operation) battery-electric was found to be the most efficient of the technologies examined, followed by electric-hybrid, diesel and finally by compressed natural gas/bio-CNG.

Electric-hybrid and gas buses can be run on alternative fuels (e.g. biodiesel and bio-CNG) and at various fuel blends as such several technology and alternative fuel penetration scenarios were examined during this study. Under all the scenarios examined, NOₓ emissions from the urban bus 

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³ Selective Catalytic Reduction (SCR) is an advanced active emissions control technology system that injects a liquid-reductant agent through a special catalyst into the exhaust stream of a diesel engine. This reduces levels of air pollutants such as NOₓ using ammonia as a reductant within a catalyst system.
fleet were reduced by more than 80% by 2030 largely due to removing older Euro IV and Euro V diesel models from the existing fleet.

Of the range of technologies assessed, hybrid-electric buses run on biodiesel and gas buses run on bio-CNG offer the greatest potential contribution towards Ireland’s renewable energy transport targets in 2030. Battery-electric buses do not contribute significantly towards the renewable energy targets because this technology is more energy efficient and thus the amount of renewable energy consumed is lower than that of the other technologies.

A cost benefit analysis was also carried out on the four different technology categories (battery-electric, CNG/bio-CNG, diesel/biodiesel and electric-hybrid). The analysis found that, in general, electric buses may be preferable to other technologies, followed by: HVO diesel electric-hybrid, Bio-CNG, Diesel electric-hybrid and CNG.

The overall results suggest that electrification represents a feasible option for fleet transition, reducing carbon and air quality emissions while increasing renewable energy use in transport.