Development of a strategy to accelerate the adoption of Soot-free buses in Johannesburg, South Africa

South Africa Flagship on Green Mobility: Johannesburg Metrobus

Dr. Francisco Posada
Senior Researcher, ICCT
Department of Transport identifies the transport sector as the source of 10% of national GHG emissions, while road transport produces 91% of transport sector emissions.

Their Green Transport Strategy aims for the government to set an example by instituting guidelines for publicly owned fleets that set appropriate targets for the procurement of alternative fuels and efficient vehicle technologies and fuels.

Johannesburg Growth and Development Strategy – 2040, which aims for all city fleets to use green and renewable energy and fuel sources. Additionally, the city’s 2017/2018 Integrated Development Plan (IDP) emphasizes the growth of low-carbon transport and modal shift in favor of public transport.

Metrobus is an operator of public transit services in the greater metropolitan area of Johannesburg.

This study aims to identify technology pathways to improving air quality and reducing GHG emissions from the Metrobus fleet.
Baseline fleet performance evaluation

146 Euro V DDF buses

DDF buses - Diesel Dual Fuel
Fueled by diesel and CNG
Manufactured by Mercedes Benz
Emissions from Metrobus Euro V DDF buses

DDF buses are a niche technology

PEMS testing was contracted with West Virginia University to gather emission factors from DDF buses

2 Buses x 3 different routes

Representative of Johannesburg driving
DDF Emissions performance results

**NOx emissions**
- 60-70% lower NOx than legacy fleet.
- 33% lower NOx than Euro V diesel.
- ~2x higher NOx than Euro V CNG.

**CH₄ emissions**
- DDF emits 12 times higher CH₄ than Euro V CNG technology.

**GHG emissions**
- DDF is marginally better than legacy metrobus technology due to excessive CH₄ emissions.
Alternative technologies to achieve GHG and local pollution reduction goals

Minimum **Euro VI** Technologies, or **BEBs**

- Diesel
- Hybrid
- Biogas
- Natural Gas
Except for diesel and hybrid buses fueled with CTL diesel, all technology and fuel options provide WTW GHG emission savings.

Low-carbon technology options—biomethane and battery electric buses powered by decarbonized grid electricity—provide the greatest GHG emission benefits, with reductions of 60%–70% relative to the baseline.

Electric grid: We consider two scenarios from the DOE’s Integrated Resource Plan (IRP). The IRP3 scenario results in a 52% reduction in grid carbon intensity, and the IRP1 scenario reflects a situation in which there are no build limits on renewable generation sources results in a 63% reduction in grid carbon intensity relative to the 2017 baseline.
Air quality benefits of soot-free Euro VI and zero emission technologies: much better particulate matter and NOx control in real world driving

Figure 8. PM and NOx emission factors for standard-sized diesel urban buses by emissions control level and engine technology. Data sourced from HBEFA (2017).

Figure 9. Particle number emission factors for standard-sized diesel urban buses by emissions control level and engine technology. Data sourced from HBEFA (2017).
# Fleet renewal roadmap: Model development - TCO

## Total cost of ownership

### Vehicle acquisition
- Vehicle purchase cost
- Infrastructure cost
- Financing cost
- (Incentives)

### Operations
- Fuel/energy cost
- Arla 32

### Maintenance
- Vehicle maintenance
- Infrastructure maintenance
- Engine overhaul/battery replacement

### Other fees
- Insurance
- Licensing/registration

## Bus technology

<table>
<thead>
<tr>
<th>Bus technology</th>
<th>Assumption</th>
<th>Value used for TCO modeling (Rand)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro V DDF (baseline)</td>
<td>Reported by Metrobus</td>
<td>R 3,174,539</td>
<td>Metrobus</td>
</tr>
<tr>
<td>Euro VI diesel</td>
<td>+2% relative to baseline technology</td>
<td>R 3,238,000</td>
<td>CARB, 2017</td>
</tr>
<tr>
<td>Euro VI hybrid</td>
<td>+50% relative to baseline technology</td>
<td>R 4,761,800</td>
<td></td>
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<tr>
<td>Euro VI CNG</td>
<td>+12% relative to baseline technology</td>
<td>R 3,555,500</td>
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<tr>
<td>Battery electric bus</td>
<td>+75% relative to baseline technology</td>
<td>R 5,555,400</td>
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</tbody>
</table>

## Bus technology (continued)

<table>
<thead>
<tr>
<th>Bus technology</th>
<th>Assumption</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro V DDF</td>
<td>R 100,000/bus Calculated assuming daughter station servicing 60 buses costs R 6 million</td>
<td>Metrobus</td>
</tr>
</tbody>
</table>
| Euro VI CNG          | R 230,000/bus                                       | Rob Short, personal communication

| Battery electric bus | R 715,000/bus Calculated assuming depot charger servicing 1 bus costs $50,000 | CARB, 2017 |

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a The currency conversion rate is $1 = R 14.3.

b Owner, Sustainable Transactions, Johannesburg, South Africa
The CNG bus with commercial CNG is estimated to have the lowest TCO of any of the alternative technologies considered in the baseline assessment.

Both the Euro VI hybrid and the battery electric bus are estimated to have a higher TCO than the baseline Euro V DDF bus.

This is driven by higher capital expenses (vehicles and infrastructure).

Operational cost savings are not enough due to low km/year (36,000)
Long-term procurement schedule for Metrobus fleet
The size of the fleet is kept constant - 460 buses
Fleet composition

Emissions

Modeling scenario: All new buses entering fleet are Euro V DDFs and fueled with fossil CNG
Technology and emissions trajectory for CNG to biomethane scenario

Fleet composition

Modeling scenario: All new buses entering fleet are Euro VI CNG; fraction of biomethane in fuel mix increase 10% annually starting in 2021, 100% biomethane from 2030 onwards

Emissions
Technology and emissions trajectory for zero emissions scenario (with grid decarbonization)

**Fleet composition**

Modeling scenario: BEB account for 10% of new buses from 2020-2022, 25% from 2023-2025, 50% from 2026-2028, 100% from 2029 onwards; all other new buses are Euro VI diesels
We propose the following fleetwide emissions reduction targets and accompanying actions to achieve them:

- **Target 1**: Reduce fleetwide PM and NOx emissions to 80% below projected levels by 2030.
  - Action 1.1: Require minimum Euro VI emissions certification in all future vehicle procurements.
  - Action 1.2: Require maximum 10 parts per million sulfur content in new diesel fuel supply contracts.
  - Action 1.3: Prioritize the replacement of the oldest buses in the fleet to maximize fleetwide emission reductions.

- **Target 2**: Reduce fleetwide life-cycle GHG emissions by 25% within 12 months.
  - Action 2.1: Ban coal-based feedstock from existing and future diesel fuel supply contracts.

- **Target 3**: Reduce fleetwide GHG emissions to 50% below projected levels by 2040.
  - Action 3.1.a: Establish a long-term purchasing agreement to expand biomethane share of gas supply by at least 5% annually and in combination with immediate procurement of Euro VI CNG buses, or
  - Action 3.1.b: Procure Euro VI diesel buses immediately and transition to 100% zero emission bus purchases by 2029.
Fleetwide strategy to implement the desired fleet-renewal pathway

1. A goal of a full transition to soot-free buses and low-carbon fuels including target year for both.
2. Identification of the types of soot-free bus technologies and low-carbon fuels the transit agency plans to deploy.
3. A schedule for the construction of facilities and infrastructure modifications or upgrades, including for charging, fueling, and maintenance facilities, needed to deploy and maintain soot-free buses. The schedule should specify the general location of each facility, type of infrastructure, service capacity of infrastructure, and timeline of construction.
4. A schedule for bus purchases and lease options. The schedule for bus purchases must identify bus types, fuel types, emissions standard, and number of buses.
5. A schedule for retirement and end-of-life management of buses, including the number of buses, bus types, emissions standard, and plans for disposal of vehicles and batteries.
6. A schedule for deployment of soot-free buses by route and depot, as well as retirement of buses by route and depot.
7. A training plan and schedule for bus operators and maintenance staff.
8. Identification of potential funding sources and their application.
Thank you!
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Background slides
Electric buses are a great GHG reduction option where the carbon intensity of the network is low

One key challenge for BEB in Metrobus is ensuring that the electricity is based on renewable source generation.

Current SA national grid carbon intensity places SA electricity as one of the most carbon emitting options globally.