INTRODUCING ELECTRIC BUSES TO THE CITY OF TSHWANE

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1 Introduction

This report provides the City of Tshwane (CoT) with an overview of developments within the electric bus market, a high-level assessment of the environmental benefits and an operational assessment of the suitability of converting the Tshwane Bus Services (TBS) fleet to zero-emission electric operation. The report also recommends several actions for the CoT to allow them to move closer to electric bus deployment.

The CoT is committed to addressing climate change and has undertaken a GPC-compliant Greenhouse Gas Emissions Inventory that has demonstrated that greenhouse gas emissions associated with transport amount to the third highest source of emissions in the City. In response to this inventory, the City has drafted a Climate Response Strategy comprising ten high level interventions. Intervention 5 is intended to address clean mobility and it summarised as follows:

"Intervention 5: Promote cleaner mobility - motorised transport will always have a place in a City such as Tshwane that covers a vast area – over 6,000km2. However, an uptake of mass transit and cleaner modes of transport such as electric vehicles are priorities as the City intends to reduce transport-related emissions"

The CoT have recently introduced a Compressed Natural Gas (CNG) bus fleet onto its new Bus Rapid Transit system, however they are also keen to understand the implications of introducing zero-emission electric buses into non-BRT operation provided by TBS.

CoT representatives have already started to explore the potential for electric buses having participated in C40 Financing Clean Buses Workshops and the C40 European electric bus study tour.

In addition to reducing CO_2 greenhouse gas emissions, improving local air quality is becoming an increasing priority in most urban areas and fleet replacement policy over the forthcoming years needs to reflect this.

The last ten years have seen significant developments in electric bus technology, led by China but closely followed by Europe and North America. Worldwide trends show that many cities are now moving from small-scale trials and demonstrations to larger-scale deployment. Whilst China has the highest number of electric buses, which is heavily influenced by Government subsidy, the number of pure electric buses being deployed in Europe is also significantly increasing.

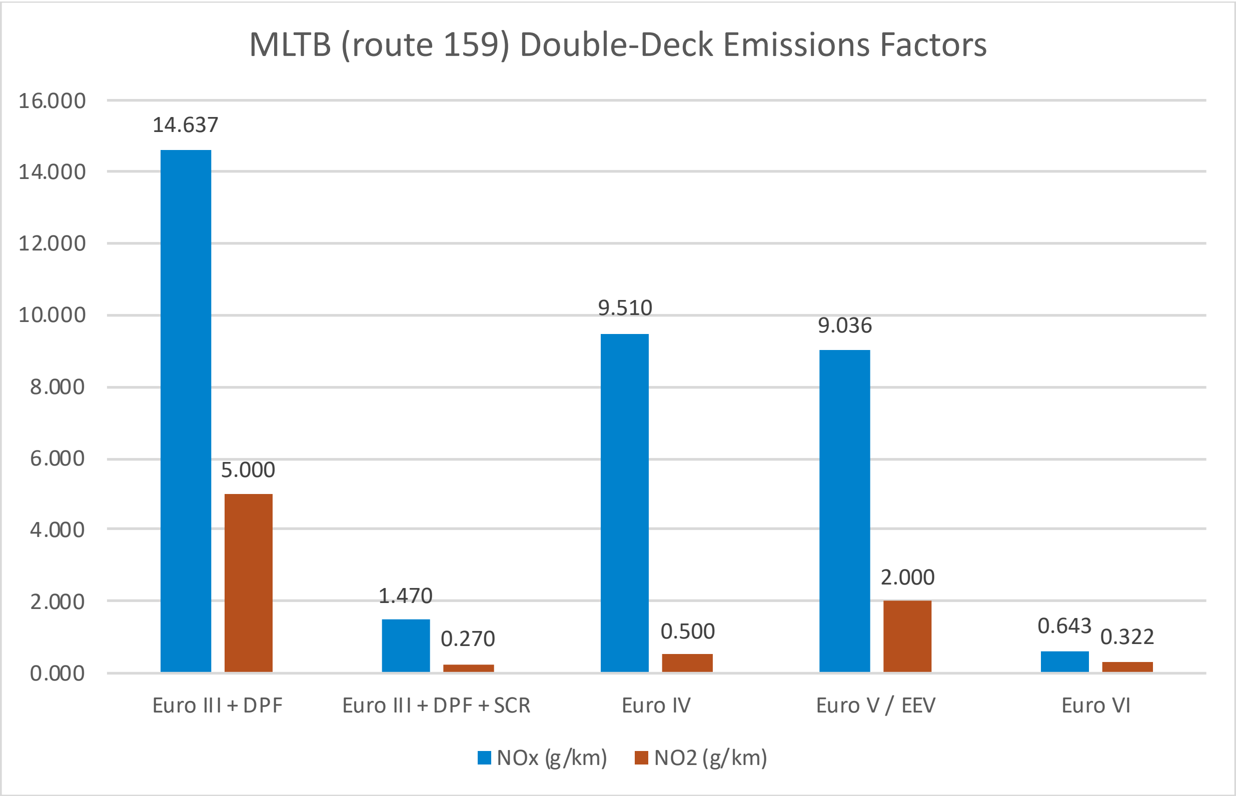
UITP forecast estimate that by 2025 32% of new buses purchased in Europe will be electric and by 2030 this figure will have increased to 50%. Similar trends, although to different timescales, are expected around the world.

There is an industry expectation that the electric bus technology will mature over the next few years, especially with regards to batteries where energy density, weight and cost are all expected to improve.

C40 has commissioned Bloomberg New Energy Finance to review the impact future battery development in weight, energy density, cost and life expectancy will have on the future business case for electric buses. This study reported in April 2018 and is reviewed in section 6.

2 TBS Operation – Environmental Benefits

The current Tshwane bus fleet is dominated by diesel buses up to Euro III standards although CNG buses have recently been introduced onto the new BRT system. As shown in the chart below, the local air quality benefits of introducing Euro VI buses or retro-fitting the existing diesel fleet with enhanced exhaust systems (Selective Catalytic Reduction (SCR) etc.) would be significant. However, it is understood that the lack of Ultra Low Sulphur Diesel within the South African supply chain currently makes these options unachievable.



Source: Transport for London/Millbrook Emissions Data - 2016

The graph shows the emissions of NO_x and NO_2 in g/km for different engine types based on London's standard Millbrook London Transport Buses (MLTB) test cycle. The figure demonstrates the clear benefits of retro-fitting Euro III buses with SCR exhaust systems, bringing these vehicles (column 2) to levels far better than Euro IV and Euro V buses fitted as standard with factory SCR systems.

Whilst the introduction of a modern diesel fleet would significantly improve local air quality, it would not contribute to the CoT's Climate Change commitments. However, whilst the opportunity to upgrade the existing diesel fleet for the remainder of its economic life is worth exploring, this should not form part of the longer-term strategy.

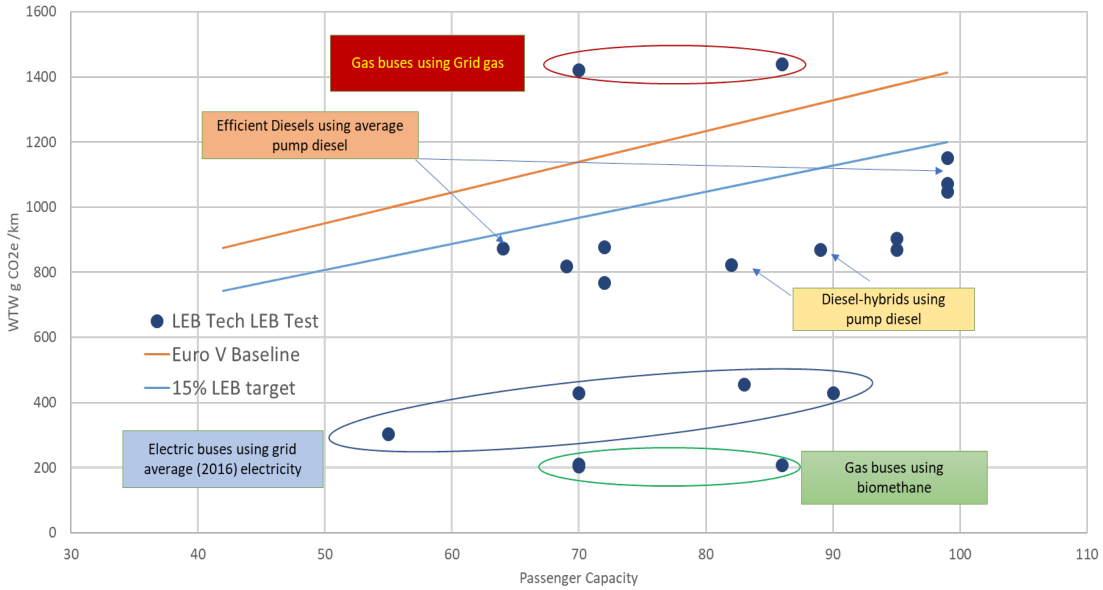
The current electricity grid mix for South Africa is dominated by coal which will reduce the overall CO_2 benefits of introducing an electric bus fleet compared with countries with greener grids. However, as indicated in the attached report, it is forecast that dependency on coal will decline over the next 15 years hence the CO_2 benefits of an electric fleet will increase overtime. The report indicates that coal is used to generate over 92% of South Africa's electricity, although this is expected to decline to 29.7% by 2030[1].

> **"the dependency on coal will decline over the next 15 years and increase the CO_2 benefits of an electric bus fleet"**

The recent introduction of CNG buses is significant, although the environmental benefits are highly dependent upon the source of fuel, as illustrated in the following analysis by the UK's Low Carbon Vehicle Partnership.

[1] Presentation Daniel Modise / Vania Mahotas, South African Department of Energy

Performance of Certified Low Emission Buses



Source: UK Low Carbon Vehicle Partnership (LowCVP) 2018

The performance of the electric buses in the chart assumes UK average grid mix based on 2016 UK Department for Business, Energy and Industrial Strategy (DBEIS) figures for gas and electricity mix (The figures were published in 2016) - Electricity: 516.8 g CO_2e/kWh or 143.6 gCO_2e/MJ

Even with the current SA grid mix, the performance of electric buses in terms of CO_2 is still expected to be better than the Euro V baseline although further work should be undertaken to quantify these benefits. These benefits will be further improved if clean electricity from sources such as solar were available.

> “Even with the current SA grid mix, the CO_2 performance of electric buses is still expected to be better than the Euro V baseline”

Although biogas derived from waste can offer significant reduction in CO_2 emissions, it offers little or no benefits in terms of local air quality when compared with Euro VI diesel buses. Whilst buses with Euro VI engines, using either diesel or biogas, are significantly cleaner than their predecessors they still contribute to poor air quality and associated health problems.

CNG also offers a practical solution on routes with high mileage requirements, for example inter-urban services; however global trends suggest that electric buses will dominate the urban landscape over the next two decades. Both Barcelona and Paris are adopting a strategy of both electric and CNG buses with the latter being used on the more demanding routes. RATP, the Paris public transport operator, expects its fleet to be low emission by 2025 with approximately 70% electric and 30% CNG. Tshwane should consider the appropriateness of this strategy, however as highlighted above such an approach would require a source of clean bio-gas to achieve the desired CO_2 benefits.

In summary, pursuing the introduction of electric buses offers the opportunity to improve both local air quality and contribute towards the CoT's CO_2 objectives.

3 Electric Buses – Global Trends

Globally an increasing number of cities are declaring their intention to convert to zero-emission bus fleets for their urban bus network. Two common approaches are being adopted, to firstly set a date from which only zero-emission buses will be purchased, and secondly a date by which the whole network should be zero-emission. Examples are as follows:

London – as part of the Mayor's Draft Transport Strategy, London is proposing that the whole bus fleet (approx. 9,200 buses) be zero-emission by 2037 with existing diesel buses being replaced with zero emission as part of the normal fleet replacement programme.2 The strategy sets clear milestones; for example, 50% of the single-deck fleet to be zero-emission, and 85% of the double-deck fleet to be either hybrid or zero-emission by 2025.

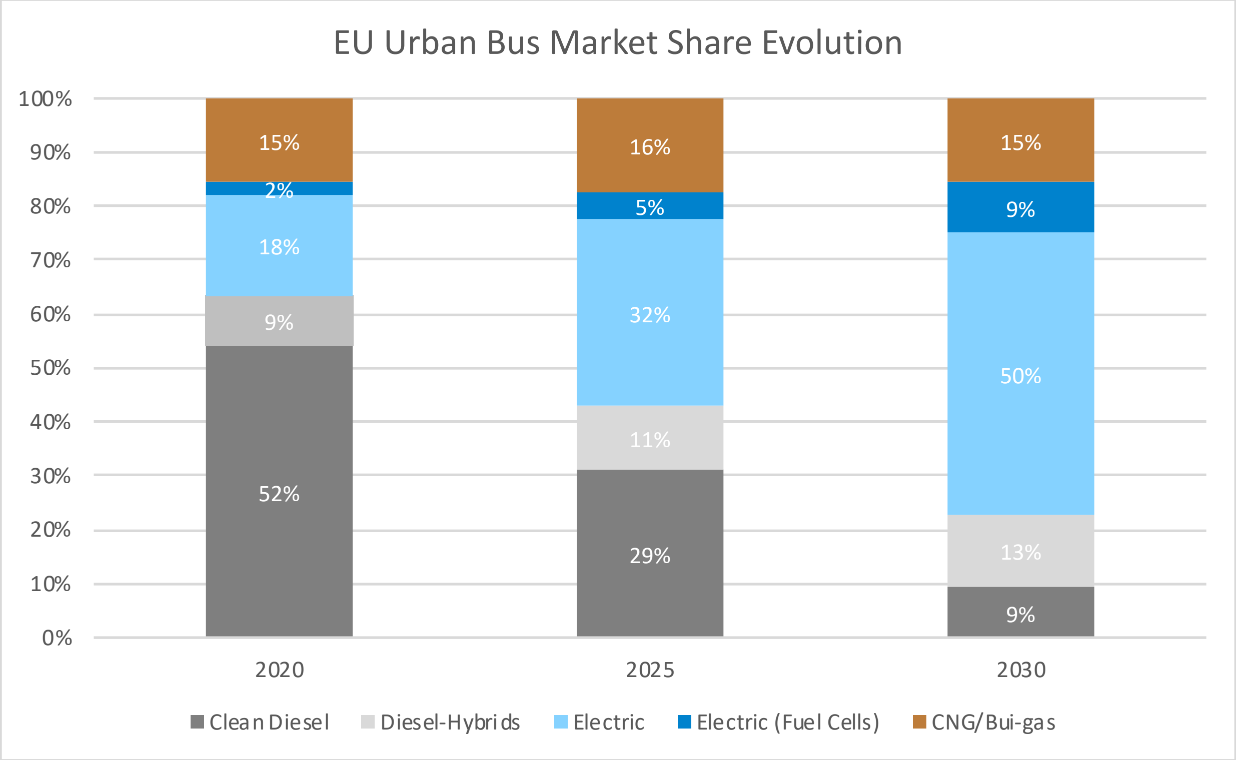
Brussels – 100% zero-emission by 2030.

Paris – RATP, the Paris transport operator of buses, trains, trams and metro, has declared its Bus2025 Strategy which will see two thirds of the bus fleet zero-emission by 2025, with the remaining third operating with CNG buses (mainly deployed on the more challenging routes in terms of operating range required).

Netherlands – 100% electric fleet by 2025.

These declarations, more often backed with political support, are helping cities and their stakeholders put plans, including securing funding and stakeholder support, in place to deliver their ambitions.

Within Europe, this approach is rapidly increasing demand for zero-emission buses. The following chart produced by Union Internationale des Transports Public (UITP) shows their forecast for bus demand by type of technology up until 2030.



Source: UITP 2017

Many regions of the world are starting to see the rapid electrification of urban city buses, with most UK and European manufacturers now selling pure electric buses. The UITP research also found that across Europe over 1,000 electric buses had been ordered during 2017.[2]

Local and national policy will be the main driver for further uptake of electric buses. In order to achieve a zero emission fleet by 2037, the Mayor of London has already stated his intention that all new single deck buses purchased from 2020 should be zero-emission electric or hydrogen. Several other European cities have made similar declarations including Oslo, Paris and Hamburg, and again whilst the timescales might change this is the clear direction of travel.

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[2] Research undertaken by UITP as part of ZeEUS project. Presented by UITP to C40 European Bus Study Tour on 29th November 2017

4 Operational Challenges

There remain several challenges to overcome before pure electric buses can be incorporated successfully into city bus fleets:

4.1 Operational

An operator or transport authority needs to be satisfied that zero emission buses have adequate range to cover the existing operation. If charging/vehicle swaps are required during the day then this can lead to the operator incurring additional costs for extra drivers and vehicles. It is important these costs are identified and built into the business case.

It is expected, however, that battery development (energy density and weight) and the construction of lighter buses will reduce this range-related cost risk over time. These developments, especially battery development, will happen over the next 2-3 years as the product rapidly matures. As detailed in section 5, most of the current TBS operation appears particularly well-suited to depot-based charging.

There are two main methods of charging currently being developed and deployed: depot-based overnight charging or on-route opportunity charging where buses are given short charges during the operational day at the route terminus. In general, the latter approach is most commonly adopted when the operational demands of a network make depot-based approach unviable.

Although opportunity charging avoids the need for buses to return to depot during the daytime, adequate time at the route terminals must be guaranteed to ensure sufficient charge can be maintained during the day. This can also result in timetables requiring extra vehicles and drivers. Whilst individual opportunity charging installations are more expensive than depot-based charging units they will be used by several buses thus less units are required. A number of opportunity charging units spread across a city may also reduce the potentially high grid connection costs associated with a large bus depot.

4.2 Technical

In addition to battery development and operating range, gross vehicle weight presents an issue. It would be useful, through early market engagement, to assess the products currently available and compare with local weight restrictions to ensure the required passenger capacity can still be maintained.

The provision of passenger heating and ventilation while avoiding unnecessary drain of bus batteries remains a challenge. Currently, many electric buses have small auxiliary diesel heaters, although many European cities have stated that this is not sustainable environmentally and that all auxiliary equipment must be electrically-operated. This will clearly have an impact on operating range. In hotter climates air conditioning presents similar challenges.

4.3 Maintenance

Preliminary data from operators of electric buses reveal that electric buses require less maintenance than diesel buses due to the presence of fewer moving parts. However, in the short term, many operators have relied upon vehicle manufacturers to provide maintenance, but with the goal of training their own staff with the necessary skills to reintegrate this function back into in-house operations. The primary training requirement is around the maintenance of high-voltage systems.

4.4 Infrastructure

The provision of charging infrastructure represents a significant upfront investment. Information gathered as part of technical visits during both the C40 Clean Bus Finance Academy in London and the C40 Electric Bus Operator Study tour during 2017 indicated that the cost of installation of charging infrastructure and the associated grid connection averages around €25,000 per vehicle (~400,000 South African Rand), although the cost of the national grid connection can be a large variable factor depending upon the proximity to a suitable grid connection.

4.5 Smart Charging

The adoption of smart charging may offer a cost-saving solution, as it allows the operator to charge different buses at various times during the night to reduce to overall peak demand. Since this approach reduces the peak demand it can have a significant impact on the grid connection cost especially if the amount of spare power in the local area is already limited. Smart charging will be achieved by using software provided by the supplier of the charging units and is thus relatively low cost.

4.6 Opportunity Charging

On-street opportunity charging allows buses to charge, either via a pantograph or via an inductive plate built into the road, at the terminus at the end of each journey. This form of charging potentially allows buses to have smaller and therefore cheaper battery packs that are charged regularly throughout the day. The cost of this additional infrastructure, plus the space to accommodate it at on-street terminal points is a potential barrier to the rapid uptake of this solution. However, the approach does help spread the energy demand across a city thus helping mitigate the impact on the local grid.

The impact on the local energy grid of converting to an electric bus fleet is critical and the CoT should undertake further work to understand this issue.

Whilst it is too early to say how widespread on-street opportunity charging will become, anecdotal evidence, including during the C40 Electric Bus Operator Study tour, indicated that many bus operators would prefer overnight depot-based charging that allows buses to complete an entire operating day without any additional charging during the day. However, on-street opportunity charging can be an effective way to spread electricity demand both by time of day and across the city.

"The impact on the local energy grid of converting to an electric bus fleet is critical and the CoT should undertake further work to understand this issue."

All methods of charging – depot and opportunity (conductive or inductive) – are being adopted and cities will need to examine and understand the local issues within their city before deciding which approach to adopt. Recent trials including those being undertaken as part of the European ZeEUS project will provide valuable experience of these options. www.zeeus.eu.

4.7 Redundancy

Operators should also consider redundancy and resilience issues as part of the depot infrastructure planning process. During the C40 Electric Bus Operator Study tour one operator spoke about their plans to have two separate grid connections to a garage to ensure continuity of service should one supply fail. The reliability of the local grid network should also be considered as regular interruptions to supply could impact on the ability to deliver a reliable bus service.

4.8 Summary

Electric bus deployment in global urban bus networks will increase significantly over the next few years. At the same time, the battery technology used in these vehicles is forecast to develop rapidly, reducing costs and weight, and improving operating range. The progress made in other regions make it an ideal time for CoT to develop and seek approval for an electric bus deployment plan.

5 Operational Capability of Electric Buses

5.1 Current Operation – Tshwane Bus Services

TBS currently operate 250 12m single-deck buses from three depots at:

Depot Location	No of Buses am peak	No of Buses pm peak
C.de Wet bus depot – W.F.Nkomo street - Pretoria West	101	93
Pretoria North depot – Ben Viljoen street – Pretoria North	37	30
East Lynne depot – Jan Coetzee street – East Lynne	23	19

Other operational data is summarised as follows:

Total fleet	250
Am peak bus requirement	161
Pm peak bus requirement	142
Average operating hours	8 hours
Max operating hours	n/a
Average km per bus	180
Max km per bus per day	n/a
Total km per day	n/a

n/a – data not currently available

As part of this technical assessment the largest depot at C.de Wet bus depot was reviewed. The layout and parking arrangements at C.de Wet bus depot would appear to support depot-based charging, as buses are reversed-parked in a herring-bone pattern thus potentially allowing charging units to be installed at the rear of each electric vehicle. Further detailed work would be required but it is possible that this could be achieved with minimal impact on overall garage capacity. Understanding the peak power supply for overnight charging will be critical and early engagement with the energy supplier is essential.

The current generic 12m electric specification for Europe has a battery capacity of around 350kWh, so assuming an operator/manufacturer would want to maintain a minimum state of charge (SOC) of 10% and a vehicle had a consumption of 1.7kWh/km[3] (including air conditioning), this would allow an operating range of around 185km.

Based on the vehicle operating data provided for C.de Wet bus depot this suggests that most buses used daily would not require additional charging during the day whilst some may need to be charged during the day. At present all buses return to the garage after the morning peak period, so with careful management the right buses could be charged during the day prior to the evening peak period. Rescheduling of vehicle workings may allow the amount of daytime charging that is required to be reduced by averaging out the operating hours between some buses.

Most electric bus manufacturers are now offering detailed analysis of local operations to understand the charging strategy which would be best suited for each individual city, examining topography, routes characteristics and depot locations. Early market engagement with the supply industry is highly recommended to allow some of this analysis to take place.

> **“Early engagement with suppliers is recommended to develop a suitable charging strategy based on local specification and requirements.”**

[3] Figure not attributable to any particular manufacturer but based on information gathered during C40 Europe Bus Study Tour. 12m single deck traction only of 1.0 - 1.1kWh/km uplifted for air conditioning demand.

6 Financial Overview & Funding Requirements

In March 2018, Bloomberg New Energy Finance published a report[4] commissioned by the C40 Cities Climate Leadership Group examining the development of electric buses in cities including the Total Cost of Ownership (TCO).

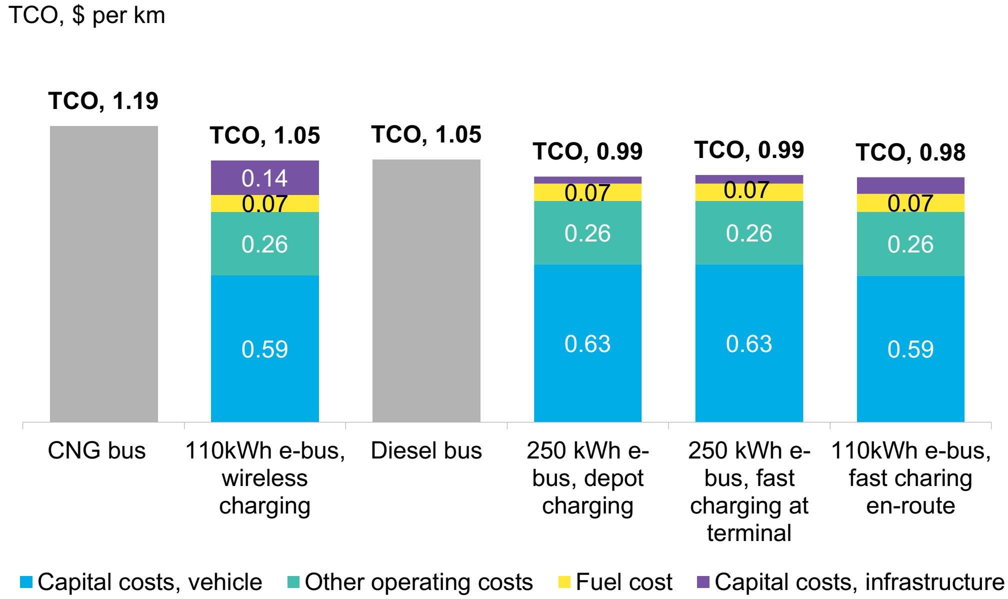
The report concluded that whilst the biggest challenge is still the high upfront cost of electric buses, focusing on these costs may not be the best approach since the operating costs of electric buses can be significantly lower than diesel buses. Hence it is necessary to examine the TCO to understand the overall impacts on City Authority or Bus Operator. This new model is forcing cities to consider innovative ownership and financing mechanisms to compensate for the higher upfront costs of electric buses by leveraging their lower operating costs.

The analysis of future battery cost in the report indicates that electric buses will reach unsubsidised capital cost parity with diesel by 2030 with the cost of the battery pack representing 8% of the total electric bus price compared with the current estimate of 26%.

> **"The lower operating costs of electric buses make it necessary to examine the Total Cost of Ownership to understand the long-term financial impact for cities and local authorities"**

[4] Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO_2

TCO comparison for the most likely e-bus configurations in a medium city



Source: Bloomberg New Energy Finance, AFLEET, Advanced Clean Transit – Cost Assumptions and Data Sources (California Air Resources Board) Note: Diesel price at $0.66/liter ($2.5/gallon), CNG price at $15 per MMBtu, electricity price at $0.10/kWh, annual distance traveled – 60,000km.

The conclusions of the report are very helpful to cities in understanding future cost trends and the impact on the TCO, however this analysis is based on data collected globally. Therefore it is necessary for cities to undertake their own TCO calculations using local factors.

Financial analysis undertaken by the City of Durban comparing the operation of diesel buses and battery electric buses indicated very similar total cost of ownership (TCO) over a vehicle's life. This high-level analysis has used SA data for energy costs. It is recommended that the CoT work with C40 using their TCO model to verify and compare their CNG and diesel operations with future electric operation.

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7 Recommended Next Steps

It is recommended that the City of Tshwane take the following actions:

Recommendation	Approach/Benefits	Timescale
1 Understand the grid capacity issues at the three TBS depots	Will help focus which depot might offer the quick win in terms of electrification and reduced capital costs for grid connection etc. Recommend use same methodology adopted by the Auckland Transport depot study.	October 2018
2 Establish a South African Clean Bus Working Group	Other cities in South Africa have already announced their intention to trial electric buses and the sharing of information with these cities will significantly increase knowledge. Recommend quarterly meetings using a mix of conference calls and face to face meetings (perhaps annually)	October 2018
3 Conduct early market engagement with electric bus suppliers.	It is critical to create competition within the supply base as this will help drive down vehicle capital costs. This engagement, which could take place through the Clean Bus Working Group, will also help determine which suppliers are interested in participating in the trials and supplying the South African market in the longer term.	October 2018
4 Understand the Total Cost of Ownership (TCO) for electric buses	Work with C40 to develop a regionalized estimate of the total cost of ownership (TCO) of electric buses based on local factors.	November 2018
5 Develop a zero-emission bus roadmap for the CoT bus fleet	Use international best practice and seek appropriate City endorsement. This will help drive future policy, support funding applications and demonstrate to suppliers the opportunities available.	January 2019
6 Develop options for the trial of depot based charged electric buses	Work with TBS to seek funding and develop a project to trial a small fleet of electric buses.	January 2019

7	Commission design study to determine infrastructure layout at the C.de Wet bus depot	Will allow TBS to understand the impact on depot capacity and layout the installation of charging units will have.	January 2019
8.	Understand future direction of SA energy grid in terms of renewables	Engage with the SA electricity generating industry to understand the plans and timescales to reduce the CO_2 impact of the SA grid.	April 2019
9	Understand the CO_2 benefits of electric buses in South Africa	Commission further analysis to understand the future CO_2 benefits of electric buses in comparison to existing technology including the output of action 8. This analysis should also understand benefits of current and future CNG supplies.	April 2019
10	Evaluate the health benefits of electric buses	Commission analysis to investigate the potential reduction in NOx and NO_2 resulting from transition to electric buses, and the subsequent health benefits for the local population	April 2019
11	Deliver electric bus trial	These trials will allow CoT and TBS to gain first hand operational experience. Will also allow operational capability, range and other practical issues to be assessed in more detail.	January 2019