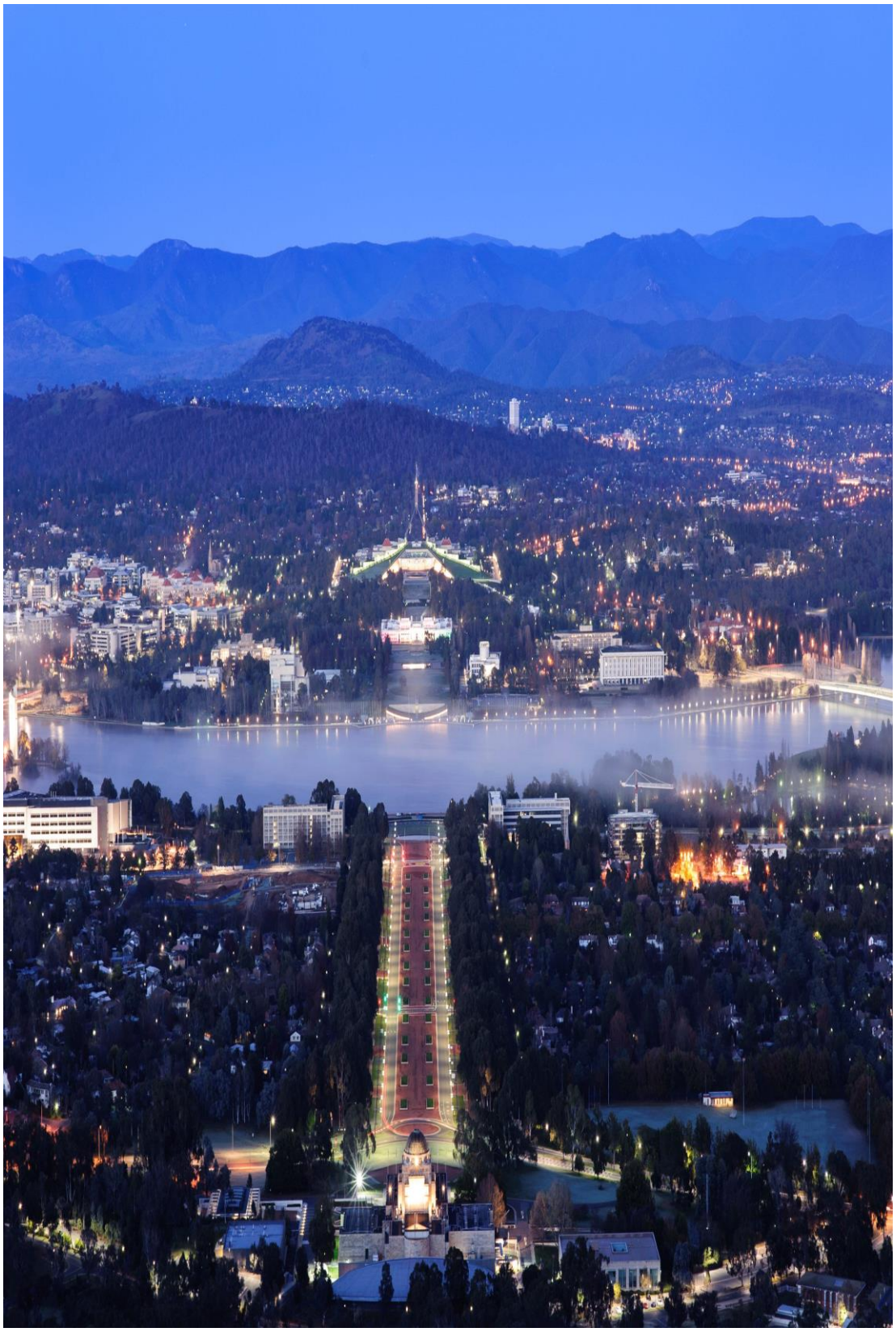
Alternative Fuel Bus Trial Assessment

Summary based on findings of the 2019 AECOM report on the trial of Alternative Fuel Buses in the Transport Canberrra Bus fleet.



The ACT's transition to zero emissions vehicles action plan 2018-21 outlines the actions to be implemented to support the rapid uptake of zero emissions vehicles in the ACT as part of the broader plan to ensure Canberra grows into a highly sustainable and liveable city. To help understand the feasibility of transitioning to a zero-emissions bus fleet, based on the current market and technology ability. Transport Canberra has conducted a 12-month trial of buses with alternative fuel use on the ACTION bus network. The results of this trial will provide information on issues to consider in making the transition to a zero-emissions bus fleet.

The trial was primarily focussed on available zero emission technology which at this time in Australia is battery electric buses. A Hybrid diesel /electric bus was also included in the trial to test this technology with battery electric buses and diesel control buses chosen for the trial. While electric buses operate in large numbers in other countries Australia has different, and often stricter, heavy vehicle regulations meaning that at the time of this study there was no suitable mass "off the shelf" product.

The trial commenced in October 2017 with three Scania Euro VI diesel buses, a Volvo Hybrid diesel/ electric (Euro V) bus and one Carbridge Toro battery electric bus. An additional electric bus was added to the trial in March 2018.

This report documents an assessment of the operational, environmental and economic benefits of a future move to electric or hybrid bus technology for additional or replacement fleet purchases. This assessment used information from a range of sources, including:

1. Independent performance testing of buses used for the trial
2. On-board operational data from data loggers installed in the trial buses
3. Driver and passenger surveys.

Operational Performance:

Passenger Capacity

The additional weight of an electric bus due to the size battery required to provide a reasonable operating range, creates an issue with their ability to carry the same number of passengers as a comparable diesel bus. This is a potential obstacle for their future use and integration with existing bus operations, but may be overcome by future technological improvements.

Reliability

In terms of operational reliability, the diesel buses performed much better than the electric or hybrid buses, with fewer unscheduled breakdowns or technical issues for all months of the trial. The diesel buses only missed 1.7% of scheduled peak route services during the trial period.

The electric buses proved to be the most unreliable of the three trial bus types during the trial. These buses missed 35% if scheduled peak services during the trial due to unscheduled technical issues, breakdowns and increased servicing requirements. It should be noted that for the most part the reliability issues with the electric buses were not due to battery faults, but other components of the supplied buses.

Range

The range is the maximum distance that a vehicle can travel when fully refuelled. This was calculated for each vehicle type using fuel tank or battery capacity and fuel efficiency during the trial. The outcome of this analysis is summarised in **Table 1**. The diesel and hybrid buses have a longer range than the electric bus, but all buses exceed the current maximum trip length undertaken by buses in the Transport Canberra fleet (about 350 km). That is, the trial buses were able to perform a day's work without the need to refuel or recharge and therefore the range of each of the trial buses was not a performance factor. However in the case of the electric buses the weight penalty of the carried battery banks to enable that range greatly affected the passenger carrying capacity.

Table 1:

Diesel	Electric	Hybrid
810 km	450 km	760 km

The refuelling time for electric buses is much longer than that for electric and hybrid buses. It takes six hours to charge electric buses from zero charge, whilst six minutes for refuelling diesel and hybrid buses from empty. The recharge/refuel time will vary depending on the battery state of charge or the amount of fuel left in the tank. During the trial battery charging times were not considered a factor as the two buses were easily scheduled to accommodate recharging. It is when there are significant numbers of electric buses at a depot and having to schedule enough time for recharging or managing buses that need to do double shifts with minimum turnaround time that recharging time will become an issue.

Environmental Performance:

The Euro VI diesel bus travelled the most total kilometres each month and therefore emitted the most greenhouse gases, PM10 (soot) and NOx emissions each month throughout the trial period. Of note, due to the performance of the Euro VI engine, PM10 and NOx emissions per/km travelled were less than the Hybrid bus.

As expected the electric buses had the best environmental performance producing zero GHG and NOx emissions and much less PM10 than diesel or hybrid buses.

The hybrid bus produced the most PM10 and NOx emissions due to the hybrid bus having a Euro V engine whereas the diesel bus has a Euro VI engine that meets a more stringent standard. As a result, the hybrid bus produces more PM10 and NOx emissions, despite the fuel efficiency of the hybrid.

Overall, based on the total monthly greenhouse gas emissions for each bus type, switching from a diesel bus to a hybrid or electric bus would emit less total greenhouse gas emissions (GHG) into the atmosphere and would contribute towards the targets in the *Climate Change and Greenhouse Gas Reduction Act 2010* and the ACT's Climate Action Plan.

Economic and Financial Assessment

The financial and economic performance of electric, hybrid and diesel bus in the trial have been appraised based on the recorded trial data.

The financial and economic Whole of Life Costs of each bus type are subject to change as technology improves, costs reduce and energy prices fluctuate.
Overall the diesel bus performs best financially, due primarily to a lower capital cost.
The electric bus performs best economically followed by the diesel and hybrid buses.

The economic whole of life cost of each bus type is:

- Diesel: $1,002,361
- Electric: $727,055
- Hybrid: $1,089,463.

Sensitivity testing reaffirmed that the electric bus is an economically preferred option over the diesel bus under all scenarios.

A summary comparison of key criteria analysed in this this assessment is shown in **Table 2**.

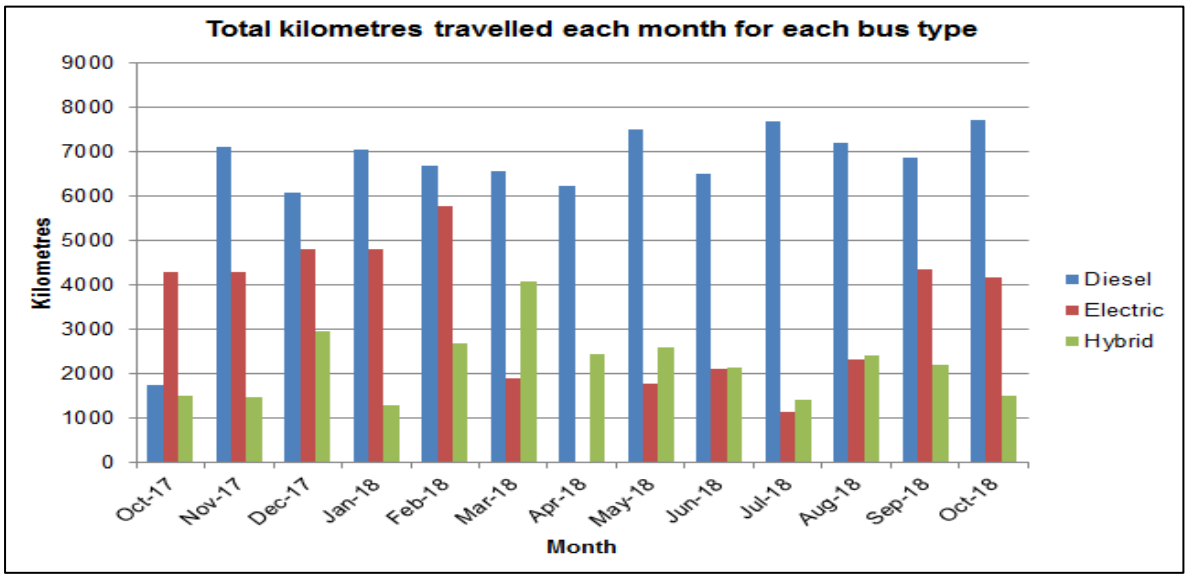
Diesel buses generally perform best in relation to daily operation and financial cost, while electric buses perform best in relation to environmental emissions and energy efficiency.
The performance of Hybrid buses generally falls between the diesel and electric bus for all criteria

Table 2: Key Criteria Summary Comparison

Criterion		Diesel Euro VI	Electric	Hybrid Euro V
Operational	Passenger capacity	68 (48 seated)	49 – 55 (35 seated)	68 (44 seated)
	Fuel energy efficiency	938.4 GJ/year	179.6 GJ/year	686.6 GJ/year
	Unscheduled missed peaks	0.8% peaks/bus	35.7% peaks/bus	14.2% peaks/bus
	Range	810 km	450 km	760 km
Environment	GHG (CO_2) emissions	62.7 t/year	1.6 t/year	51.1 t/year
	PM10 emissions	4.9 kg/year	4.6 kg/year	7.1 kg/year
	NO_x emissions	28.6 kg/year	0 kg/year	41.5 kg/year
Economic	Capital cost	Figures have been removed as public reporting of capital cost predictors is not in the public interest as it could prejudice the Territory's competitive commercial activities.		
	Whole of life cost (financial)	$418,280	$545,665	$597,190
	Whole of life cost (economic)	$1,002,361	$727,055	$1,089,463

Table 3 shows the average kilometres travelled per bus each month for each bus type during the trial. In all but one month the diesel buses travelled considerably more kilometres than the other bus types.

Table 3: Kilometres Travelled



Driver surveys showed a preference for diesel buses rather than electric or hybrid buses. This is because the diesel buses are considered by drivers as more reliable, quieter and easier to drive, having better acceleration and braking. Acceleration was highlighted as a weakness of hybrid buses during performance tests, but braking of all buses was similar and considered satisfactory.

Feedback about the electric bus was varied where some drivers felt that the buses were smooth and quiet to drive while others said there was a constant “whining” noise and the drive was rough. Other commentary from drivers about the electric bus was uncertainty regarding their reliability, they were slow to accelerate and braking could be improved especially when coming into a bus stop. However, of note, acceleration and braking were not highlighted as a weakness during performance tests.

The consensus of drivers about the hybrid bus was that it was not a pleasant bus to drive. Commentary about the bus was that it was slow through gear changes and was rough to drive. Slow acceleration was also concern and was considered dangerous especially when accelerating from standing.

Passenger surveys on electric and hybrid buses indicated that the performance of these buses in relation to noise, smell and smoothness of travel was satisfactory. The responses were more positive for the electric buses than the hybrid buses, aligning with driver preferences.

Summary:

Key strengths of each of the buses are:

- **Diesel** – passenger capacity, reliability (unscheduled missed peaks), capital cost and whole of life financial cost
- **Electric** – fuel energy efficiency, all emissions (GHG, NO_x and PM10) and whole of life economic cost
- **Hybrid** - passenger capacity and whole of life economic cost.

Key weaknesses are:

- **Diesel** - fuel energy efficiency, all emissions (GHG, PM10 and NO_x) and whole of life economic cost.
- **Electric** – passenger capacity, reliability (unscheduled missed peaks), capital cost and whole of life financial cost.
- **Hybrid** – fuel energy efficiency, reliability (unscheduled missed peaks), GHG and NO_x emissions, capital cost and whole of life financial cost.

The main issues with the electric bus are passenger capacity, cost and reliability. These are likely to be addressed in future. The rate of uptake of electric buses will depend on new or alternative technology which results in vehicles with:

- Lower axle weight with lighter batteries
- Increased seating and overall passenger carrying capacity
- Lower capital costs

During the trial a major factor limiting the operation of electric buses was their exceedance of legal weight restrictions under the Road Transport (Mass, Dimensions and Loading)

Regulation 2010 at the time of their introduction. This resulted in the electric buses being unable to operate for seven weeks or more whilst Transport Canberra obtained a temporary permit for them to operate at 18t in the ACT. Since that time the Mass Dimension and Loading Regulation has been amended to allow operation of two-axle rigid buses to 18t fully laden. The additional weight of an electric bus due to the size battery required to provide a reasonable operating range, creates an issue with their ability to carry the same number of passengers as a comparable diesel bus. This is a potential obstacle for their future use and integration with existing bus operations, but may be overcome by future technological improvements.

Capital costs for electric buses will come down in future. This will occur as demand for these buses increase and more are manufactured.

In terms of operational reliability, the diesel buses performed much better than the electric or hybrid buses, with fewer unscheduled breakdowns for all months of the trial. The electric buses proved to be the most unreliable of the three trial bus types during the trial. They were off the road more than the other buses, not just because of the weight issue but also missed peak services due to unscheduled breakdowns and servicing requirements. The key issues were related to brake and suspension issues; not due to battery system performance (other than weight), but was due to other build quality issues. Better build quality and more local supplier familiarity with the electric vehicle and spare parts could reduce downtime and improve reliability in future.

In 2016-17, transport was the second largest contributor to ACT greenhouse gas emissions accounting for 29 per cent of emissions after electricity (52 per cent) (ACT Government, 2017). As the electricity supply will be 100 per cent renewable (zero emissions) by 2020, the ACT is now focused on targeting emissions reductions in transport, domestic natural gas and waste.

Transport is expected to create over 60 per cent of the ACT's emissions by 2020, with the majority created by the use of private cars.

The ACT's transition to zero emissions vehicles action plan 2018-21 (the plan) outlines the actions to be implemented to support the rapid uptake of zero emissions vehicles in the ACT as part of the broader plan to ensure Canberra grows into a highly sustainable and liveable city.

In this context zero emission buses will undoubtedly become part of the future transport landscape. Transport Canberra should regularly review the technology, specifications and capability of electric buses, with a view to potentially introducing these buses into the Canberra fleet in future. This could occur within two to three years, depending on technological advances and funding and demand for manufacturing larger quantities of electric buses.

Conclusion:

This analysis is based on a small trial sample, however ability to meet the operational expectations of Transport Canberra and City Services' bus fleet (capacity/passenger potential and reliability) should be considered in tandem with these results.

Based on the more favourable economic results of the electric bus type, a sensible approach to its uptake in Canberra is recommended. This could be likened to the advised uptake of renewable energy in general: a stable and reliable base is required to ensure service expectations are met during the transition toward the more environmentally friendly but currently less reliable alternative.

The 'advisable' rate of uptake would require further investigation into operational issues during the trial, deeper analysis of the operational expectations of TCCS's bus fleet and reassessing of the advised rate over time.