Wellington trolley bus network supply arrangements and future options beyond 2017

Prepared by	Approved by	Revision	Date
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1. Introduction

Wellington Electricity ("WELL") is the electricity lines business which distributes electricity to over 165,000 homes and businesses within the areas covered by the Wellington, Hutt, Upper Hutt and Porirua City Councils.

In addition to supplying electricity to homes and businesses, Wellington Electricity also provides supply to the trolley bus overhead network (the "poles and wires") owned by Wellington Cable Car Limited ("WCCL") from 15 DC substations, which in turn supply the trolley buses owned and operated by New Zealand Bus Limited ("NZ Bus").

Greater Wellington Regional Council ("GWRC") has requested input into the report being compiled for them by PricewaterhouseCoopers evaluating different fleet configurations for the public transport system in Wellington City.

This report covers the assets owned by WELL only, and is to be read in conjunction with contributions from NZ Bus and WCCL to gain a full view of the costs associated with the trolley bus network.

2. Background

2.1 History of the Trolley Bus supply network

The trolley bus system has been in Wellington for over 50 years, with trolley bus routes introduced from 1949 to 1964. It was during this initial introduction of trolley buses that the supply network was predominantly installed, with few changes made subsequently.

The trolley bus electrical supply system was at that stage, largely an upgrade from the earlier single wire tram system, by the addition of a second overhead contact wire installed to replace the negative return path via tram rails.

The network was operated by the Wellington City Council ("WCC") under the Wellington MED, and later Capital Power, until the early 1990s. It was at this time (1992) that the WCC also sold the bus operator, Wellington City Transport Limited, to Stagecoach.

The system had been installed and operated in such a way to reflect the joint ownership and management of both the supply entity and the bus operator by WCC. As such the DC supply equipment is located within shared substations owned by WELL and used for supply to other consumers. In the field WCCL poles carry WELL-owned wires supplying consumers – the Wellington Electricity system and the WCCL trolley bus overhead network are intrinsically linked.

2.2 Overview of the system

WELL supplies the trolley bus overhead network from 15 distribution substations. Each of these substations takes alternating current supply at 11,000V from WELL's primary network and through the use of special transformers (3, 6 and 12 phase traction transformers) converts this to around 550V. This is then converted from alternating current (AC) to direct current (DC) through the use of a rectifier.

In Wellington two types of rectifier are used, early sites have mercury arc valve rectifiers, whereas more modern sites have solid state diode-type rectifiers.

This DC supply is then distributed through circuit breakers (one or more per substation) and underground DC cables to supply pillars owned by WCCL.

From these pillars, WCCL takes the supply to their overhead network where the buses operate along the contact wires.

Both WELL and WCCL have requirements under the Electricity (Safety) Regulations 2010 for safety of their systems. Work has been done by both parties to identify and assess areas where non-compliance could occur due to the age and configuration of assets installed to meet past standards or regulations which have now been superseded.

2.3 Contractual arrangements regarding trolley bus supply

At present, WELL has a supply contract with NZ Bus for supply of "line function services" to the trolley buses, for which it is paid through a line charge. This arrangement does not cover the energy used, and this is a separate contract between NZ Bus and their energy retailer. WELL collects a portion of its revenue from these sites through the variable energy component.

The supply contract was executed by Vector Limited, WELL's predecessor and runs for a period from 2007 to 2017. As this contract currently stands, there is neither clarity nor certainty around network operation post-2017.

WELL have no contractual arrangements in place with WCCL, to whom it connects with at the supply pillars, and requires operational liaison with on a regular basis. This discrepancy has been contentious, although a workable relationship exists informally between WCCL and WELL.

One of the key points of the supply contract is the decision to not fund the replacement of Tie cables in the DC network. These cables connect directly between different substations and provide some supply in the event of a transformer or rectifier failure. At the time the contract was executed, many of these cables had faulted and were out of service. To overcome the supply security issue, the onus was put on WCCL to close open points in the overhead network to restore supply, despite not being a party to this contract. This ability has been rejected by WCCL on the basis of electrical safety.

3. Age and Condition of the existing network

3.1 Overview

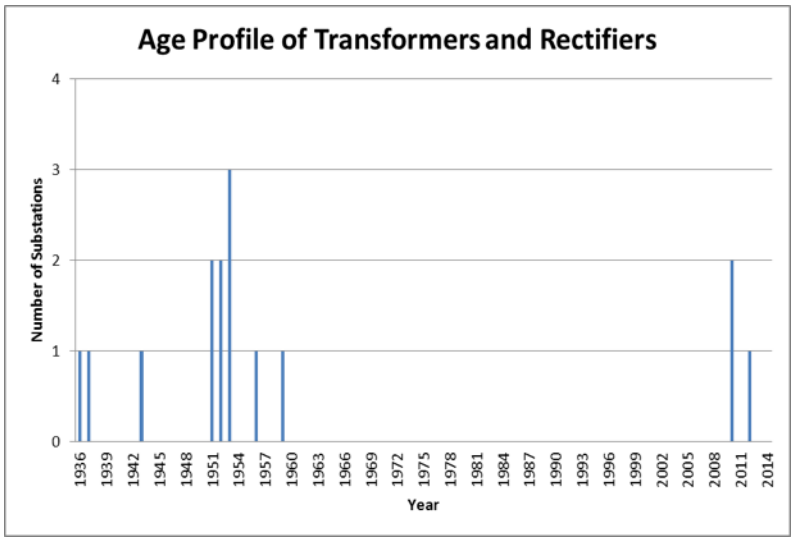
With the exception of recently replaced equipment (rectifier equipment at three of the 15 substations), the majority of transformers, rectifiers, cables and circuit breakers used to supply the trolley bus network are at end of life. The equipment ranges in condition from fair to poor for age, and these assets are operated and maintained to ensure they reach the end of the present contract (2017).

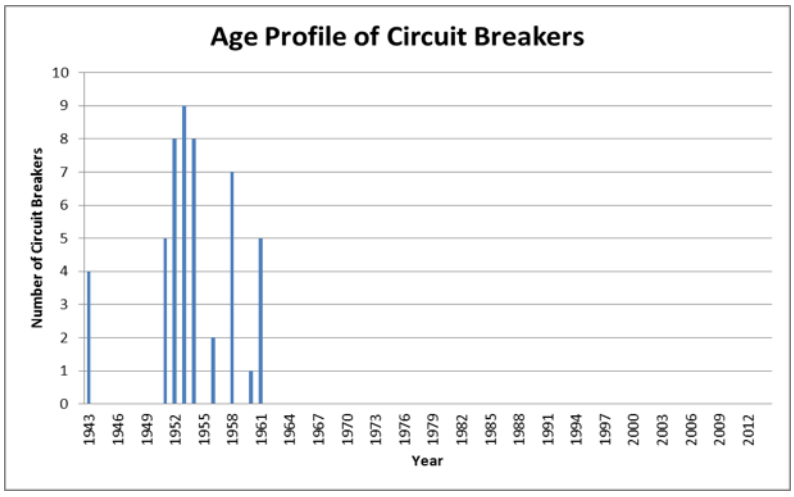
Several transformer and rectifier replacements have been undertaken to address risks at key sites since 2009, along with cable replacement (around 1 km of the 40 km total system length) where required.

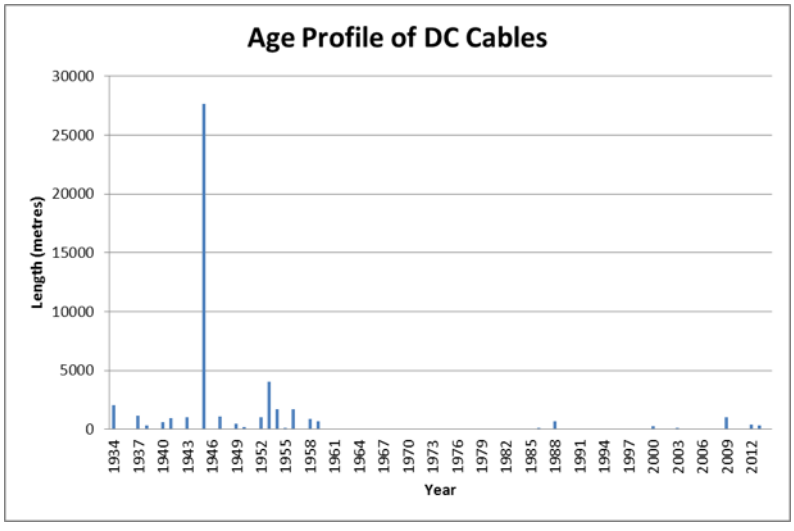
It is apparent from the age profiles below, that there has been no significant investment in the system since it was installed, and that the assets are now well past their end of life (typically 45 to 50 years for circuit breakers and transformers).

Asset replacement should have commenced in the late 1980s to address the earliest components (installed in 1939) and continued through until the early 2000s. This would have significantly smoothed the required investment over a period of 15 years. It is understood that since the split of WCTL and Capital Power from WCC in 1992, uncertainty over the future of trolley buses led to deferral of any major investment being made, and a minimal re-investment strategy taken by GRWC since this time, preferring a running down of the supply asset.

3.2 Age Profiles







4. Investment in the network to date

Since taking ownership of the network in 2008, WELL has undertaken a number of investments, within the funding arrangements of the 2007-2017 contract. These investments were to address immediate issues, or high risk sites, to ensure an appropriate service level was maintained until 2017. However, with limited capital replacement this has necessitated elevated levels of maintenance expenditure to keep the equipment in service and operating.

4.1 Major Plant Replacements

Transformer and Rectifier Replacement

Aged rectifiers have been replaced at 176 Wakefield Street and 92 Washington Avenue substations.

Aged transformers and rectifiers have been replaced at the Cable Car Lane and Duncan Terrace substations in conjunction with High Voltage switchgear replacement.

Cable Replacement

Cable has been replaced in the Cambridge Terrace to Elizabeth St area of Mt Victoria and the CBD. This was to address a fault that was present when the network was purchased. Approximately 950m of new cable was installed in 2009 at a cost of $520,000.

Minor cable replacements have also been undertaken in various locations around the CBD area to address condition concerns and to repair faults, although only short lengths have been required.

4.2 Network Augmentation

An extension to the DC cable network was undertaken from Victoria St to Manners St in 2011 to address the loading concerns and to reduce the number of trippings in the Manners Mall area. This was funded jointly between WCC, WCCL and WELL.

4.3 Routine Maintenance

In addition to these capital investments, WELL has undertaken Preventative and Corrective Maintenance programmes on the DC supply equipment over the period to ensure it remains in a serviceable and safe condition.

4.4 Health and Safety Improvements

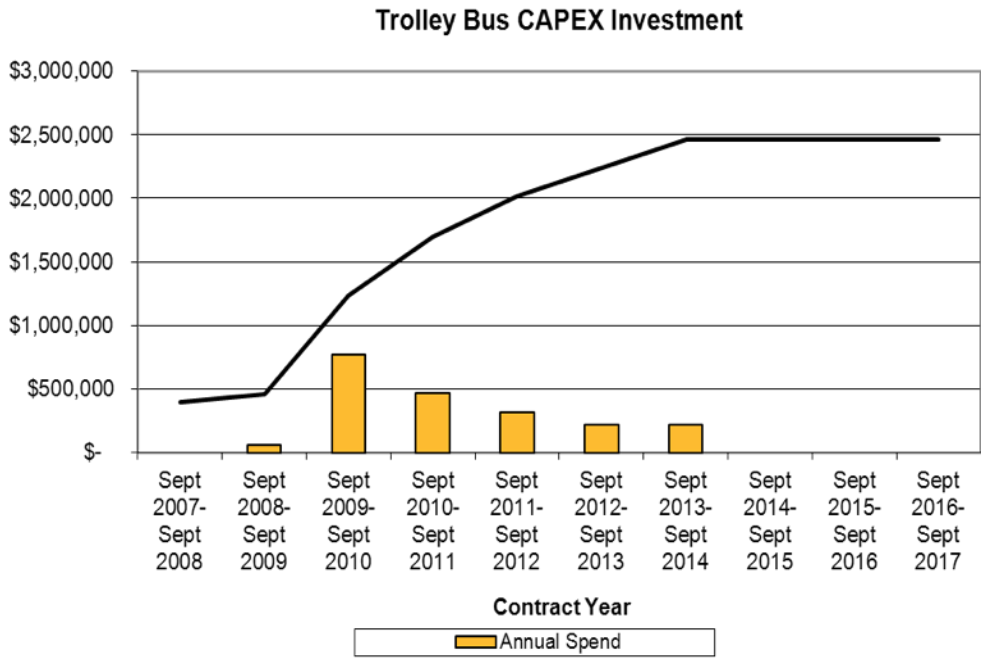
The age of equipment and changes in safety standards has necessitated Wellington Electricity undertaking two major projects to reduce the risk of keeping this older supply equipment in service.

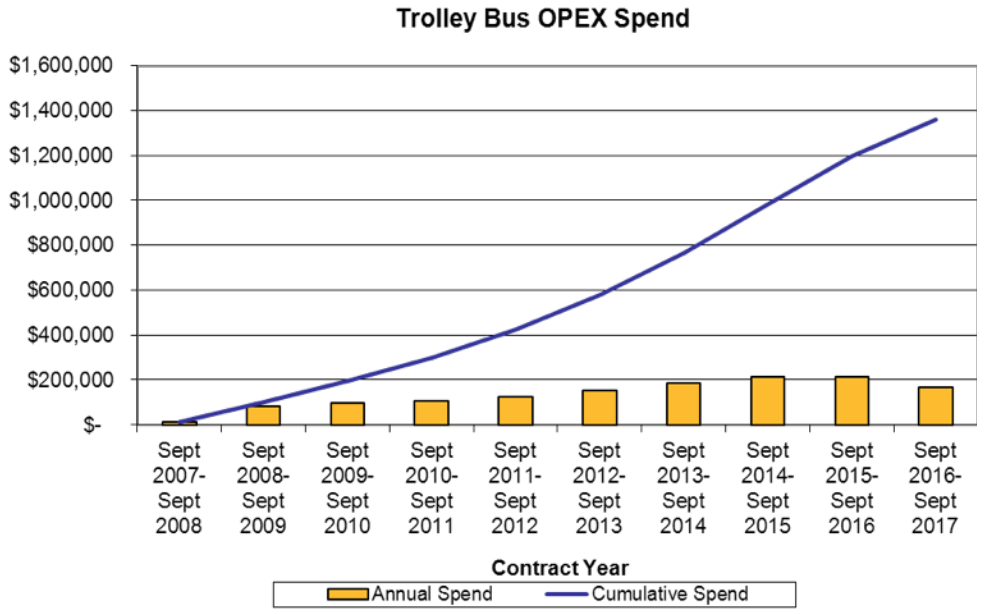
WELL has completed the installation of Perspex cover-up panels over the DC switchgear. This is to address safety concerns that personnel within substations could come in contact with live parts, common on older style traction switchboards over 50 years old. This work cost $60,000 across the 15 sites.

During 2011 WELL also replaced the asbestos arc chutes on the DC switchgear. This project was undertaken to reduce the risk associated with having a known carcinogen within the substations. This project cost $492,000 across the 15 sites.

4.5 Proposed Investment Profile 2007-2017

The following funding has been allowed for within the 2007-2017 supply contract, and Wellington Electricity has agreed an investment plan with the stakeholders on this funding, as shown below.





Spend Category	Funded 2007-2017	To Date	Remaining 2014-2017
OPEX	$1.36 M	$580,000	$780,000
CAPEX	$2.46 M	$1.99 M	$470,000

OPEX spend to date has been largely based upon routine maintenance and minor corrective repairs. It is forecast that in the latter third of the contract, 2014 to 2017, the requirements for OPEX will be greater as an increasing number of the assets experience end of life failures.

CAPEX spend to date has covered replacement of rectifiers and transformers, as well as larger cable replacements and safety improvements. The forecast spend for the period 2014-2017 includes allowance for replacement of one further rectifier and transformer, and a major cable replacement. This cable replacement has been tentatively reserved for the Hataitai bus tunnel cable replacement due to the age, condition and strategic reliance on this asset to maintain service.

5. Beyond 2017 - Replacement of the existing network

In order to continue operating the trolley bus network as it is presently configured beyond 2017, a complete network replacement would be required (with the exception of the equipment replaced since 2009).

The existing assets have reached, and are now well past the end of their technical life and have remained in service due solely to good maintenance and operational practice.

The network has been operated and maintained to reach 2017, within the funding arrangements covered by the present contract. The age and risk associated with operating this equipment beyond 2017 is generally unacceptable to WELL, or what would be considered good industry practice.

There are possible scenarios where the network could be operated beyond 2017 without significant investment; however an assessment of the risks would need to be undertaken, in particular:

- The likelihood of equipment failure is increased, with potential impacts on safety to public, personnel and property.
- Bus network performance may fall to unacceptable levels as equipment failure may be more frequent, and take longer to repair.
- The risks to personnel in WELL substations and operating the equipment may be too great to operate live, increasing the requirement for outages and extending repair times.
- Failed assets would need to be replaced by WELL, and funded appropriately to make a recovery of the asset value over the remaining life.
- Changes in Electricity Safety Regulations making past operating processes now unacceptable when considering current standards of good industry practice.

5.1 Overall system replacement costs

WELL provided high level information in late 2011 outlining a number of replacement items required to keep the system operating beyond 2017. This has been updated in the table below to show estimated replacement costs for the overall system.

High Scenario – Full system replacement (in 2014 $)

Equipment	Sites	Unit Cost (avg.)	Total
AC-DC Conversion Equipment	11	$370,000	$4.1M
DC Circuit Breakers	Large Switchboards (4)	$850,000	$3.4M
	Medium Switchboards (3)	$550,000	$1.7M
	Small Switchboards (8)	$350,000	$2.8M
DC Cabling	All feeder cabling (40km)	$750,000 / km	$30.0M
Project Design and Management Costs			$5.0M (est.)
Contingency		~10%	$5.0M
Total Upfront Capital Cost			**$52.0M**
Return on Capital			TBC
Total Lifetime Cost			**TBC**

WELL has subsequently explored alternative switchgear arrangements and could reduce the Switchboard cost ($3.4M+$1.7M+$2.8M) by around $3.5 million, to a revised total of $4.4 million using alternative technology. Further work however is required to confirm this is a viable option.

When compared to figures originally released, this table does not include the replacement of tie cables at $10.0 million (which have been found not to provide the security of supply and contingency benefits when compared to the more economic alternative of holding spare plant or commissioning a mobile substation), it makes allowance for two rectifier sites having been upgraded since the last disclosure of this information, and also includes a reduced contingency amount.

5.2 Minimum replacement to operate beyond 2017

In order to keep the system operating beyond 2017, WELL requires that the end of life circuit breakers and rectification equipment are replaced. These two asset classes present the highest risk to the system security, reliability and operator safety.

DC cabling (which represents more than half the asset replacement cost stated above) is aged, although can be operated in a run to failure mode and repaired or replaced as required, allowing a smoothing of cash flows over an extended period of time. This approach however would lead to lower service reliability than the complete replacement option as a number of cables could be unavailable for service as end-of-life attrition occurs.

Assuming replacement of all substation equipment, the following table outlines costs under this scenario. Annual CAPEX of $1.0 should also be allowed for to progressively replace aged or failing cables, as well as an increased OPEX allowance to cover the higher number of faults, fault locations and repairs.

Low Scenario – Major plant replacement, no cables (in 2014 $)

Equipment	Sites	Unit Cost (avg.)	Total
AC-DC Conversion Equipment	11	$370,000	$4.1M
DC Circuit Breakers	Large Switchboards (4)	$850,000	$3.4M
	Medium Switchboards (3)	$550,000	$1.7M
	Small Switchboards (8)	$350,000	$2.8M
Project Design and Management Costs			$3.0M (est.)
Contingency		~10%	$1.5M
Total Upfront Capital Cost			**$16.5M**
Return on Capital			TBC
Total Lifetime Cost			**TBC**

5.3 Alternative replacement scenarios

The replacement costs shown in the tables above are to replace key elements in a like for like situation, with or without cables. This approach is not recommended by Wellington Electricity as the system architecture should be reviewed for suitability of changing Public Transport needs, and which may result in a requirement for more, or fewer substations, or substations in alternative locations to provide the optimal electrical supply system.

Variants of these proposals could be considered, including keeping core inner CBD routes electrified with trolley buses, and convert outlying residential routes to alternative energy sources, etc. These options could reduce the number of sites in which major plant needs to be replaced, particularly the outer areas such as Island Bay, Seatoun, Miramar, Brooklyn and Karori which changes the electrical supply economics.

5.4 Summary of Estimated Replacement Costs

Scenario	CAPEX 2017-2022	OPEX Annual	CAPEX Annual	Service Level and Reliability
High Scenario Replace entire supply network	$47.0 M	$0.2 M	Nil for replacement	Good – all system elements replaced
Low Scenario Replace high risk substation equipment only, other assets run to failure	$16.5 M	$0.5 M	$1.0M	Low to Poor - More frequent and longer outages due to cable faults

Wellington Electricity, like any investor, requires a commercial return on and of capital invested in the network, and to manage any risk around early termination and potential asset stranding, as well as end of life decommissioning expenses.

6. Alternative supply arrangements – future options

The existing trolley bus supply network is based upon technology and network topography reflective of the 1960s trolley bus network in Wellington with minimal improvements made in the past 50 years.

Given the extent and cost associated with replacement of the existing trolley bus supply equipment, consideration must be made for alternative electric bus technology which has advanced dramatically in recent years.

Wellington Electricity is a utility infrastructure network operator and can provide electrical supply infrastructure to a range of alternative electric bus solutions based on a commercial return on investment being agreed.

If considering a "blank page" approach to future transport within the Wellington City area, the following ideas could be considered for development of a short list of costed alternative bus options.

"Green" Trolley Buses

There is a perception that Trolley Buses have a high level of environmental "friendliness". This is true in so far as they do not directly burn fossil fuels, and have no emissions along the routes which they run, making them ideal for urban centres. Consideration does, however, need to be made for the time that the electricity is used. The majority of trolley bus operations occur during the day time especially morning and evening peaks, which coincide with national grid peak demand. This increased demand is met through the use of fossil fuel-based generation sources. Indirectly, the power used by trolley buses at peak times is derived from fossil fuels.

Use of battery storage technology would allow for charging at low cost, off-peak times, when the generation mix is predominantly renewable, should be carefully considered.

Alternative supply voltages or currents

The present bus system operates on a 550V DC supply. This is a very old British standard supply voltage dating back to the tram era. It requires very large currents to provide sufficient power for large motors (power is a function of voltage and current). It is not recommended to make a significant investment in low voltage DC traction systems, and consideration should be made to using higher voltages (such as 750V DC), or alternating current (AC) which requires less costly conversion equipment and is easier to operate the modern protection and control systems which are required to comply with recent changes in safety legislation.

Stored charge electric buses

Battery powered and storage-type electric vehicles are emerging in private use passenger cars, and in a number of commercial fleets around the world. Battery technology is rapidly advancing and costs are decreasing. Wellington City has a compact CBD area and surrounding suburbs, with the short route distances making them well suited to battery storage technology. The advantage of this technology is night time charging during bus down time at depots, and potential access to low cost / low carbon energy from renewable generation sources makes this economically attractive.

Inductive charging electric buses

Technology is progressing quickly in the areas of contact-less charging for vehicles, including in road inductive charging loops. Buses could be charged as they drive along routes, or at regular stop points where they would pick up charge as the bus stops, topping up on-board batteries.

Supply points for bus charging

WELL operates a network of 33kV, 11kV and low voltage supplies around Wellington City. Installation of suitable charging point supply infrastructure is easily achievable and part of WELL's core business.

WELL estimates the cost to install capacity for charging points (based on current prices and use of standard equipment) to be in the order of $150,000 per 1 MW of demand. This is to supply a high capacity 50Hz AC connection, but does not include any special connection or conversion equipment required to charge the buses.

Total capacity would need to be calculated based upon a range of factors including charging requirements, number of connection points, number of buses, and similar.

7. Conclusion

The trolley supply system owned by Wellington Electricity is at the end of its technical life and is being managed to reach the end of the 2017 supply contract through a number of investments to mitigate key risks. These investments are fully funded and recovered within the existing supply contract.

Due to the extent of replacement work required to keep the trolley bus system operating beyond 2017, between $16.5 and $52 million worth of infrastructure investment is estimated to be required over the period 2017 to 2022 on WELL owned equipment. This equipment will have a 50 year life and WELL would expect a suitable commercial return, reflective of the risk and term, on this equipment.

Given this extensive investment required across the entire trolley bus supply network, and the advances in modern electric fleet technology, WELL would recommend that GWRC considers optimisation of the present system in conjunction with a range of alternative electric bus options, for which WELL could supply charging and connection infrastructure to at a more economic outcome than trying to replicate a largely superseded 50 year old technology.

Wellington Electricity welcomes the opportunity to explore alternative electric transport ideas and develop more detailed solution costing where possible.