Sustainable Energy Forum of Aotearoa[1]

Briefing note for the "Yes We can" symposium 31st May 2016

Proposal - Reverse the Greater Wellington Regional Council's decision to remove the trolley bus electricity distribution infrastructure from Wellington

Using New Zealand's mostly renewable electricity as an energy source for transport is five times less CO_2-intensive than using liquid fossil fuels.[2] The use of distributed electricity for inner city public transport is a well proven trolley system in 300 cities worldwide plus 400 cities have light rail electric public transport systems. These have the co-benefits of quietness and cleanliness and are the way of the future in a carbon-constrained world.

The decision by GWRC to "pull the plug" on the energy supply for Wellington's fleet of 57 trolley buses leaves Infratil company NZ Bus with a stranded asset and with the problem of providing a socially and environmentally acceptable public transport service for Wellington. In the absence of a continuous energy supply via trolley wires, the existing trolley buses must be made autonomous and carry sufficient on-board energy to meet the duty of a bus service.

The weight of on-board energy storage represents non-fare-paying passengers and needs to be minimised. Diesel fuel has an energy density of 45 MJ/kg. Lead acid batteries have an energy density of about 0.1 MJ/kg. State-of-the art laminated lithium ion batteries have an energy density of about 0.5 MJ/kg. New battery chemistries are still at the research stage. Battery weight limits the application of battery power in buses to niche applications.

Taking account of the electric motor vs diesel engine efficiencies, the on-board energy store for a battery bus with advanced batteries would weigh 30 times more per unit of energy than diesel fuel. Therefore retrofitting the existing trolley buses with sufficient batteries to have a sufficient range for a rush-hour shift would impose a significant weight penalty.

The existing trolley buses have some on-board battery capacity to enable the vehicles to be driven short distances off-wire. That capability is the basis of the retrofit that NZ Bus plans for the stranded asset of their trolley bus fleet, if the street wires are removed. The plan is to

[1] This briefing note is a compilation and development of on-line discussions by SEF members

[2] Assuming: - NZ electricity CO_2 emission factor as 150 kgCO_2/MWh; Trolley bus wire to wheel efficiency as 85%; Diesel fuel CO_2 emission factor as 70 kg CO_2/GJ; Diesel engine tank to wheel efficiency as 30%.

install on-board engine-driven battery-chargers for range extending. That scheme would allow the engine to be operated efficiently at constant speed. NZ Bus states that a battery charger would need to run 17% of the time to meet the duty schedule of a bus.

The use of an on-board engine as a battery charger means that the energy source for the converted trolley bus fleet would be mostly liquid fossil fuel instead of electricity. That retrograde step would be the exact reverse of the Government's declared policy to promote the transition of transport energy from liquid fuels to electricity.

The on-board battery charger could be powered by a commercially available constant speed clean (Euro 6) diesel engine. However, instead NZ Bus has entered into a contract to retrofit the trolley buses with the novel Wrightspeed gas turbine technology for range extender duty. Small open cycle gas turbines are intrinsically less thermally efficient than diesel engines. A small gas turbine delivering energy via a battery charger might produce 50% more CO_2 than a normal diesel bus on a tank to wheel basis.[3] However, the Wrightspeed gas turbine technology claims to be cleaner burning for a city street application.

Another promotional claim of the Wrightspeed gas turbine technology is that it could use renewable biogas, such as landfill gas as the fuel source. Biogas composition is typically 55% CH_4 and 45% CO_2, so its energy density is 17 MJ/kg. Biogas would have to be stored in pressure vessels, which might reduce the energy density of on-board biogas storage further to 9.4 MJ/kg[4], compared with 45MJ/kg for a tank of diesel. When the energy requirement for compressing biogas is also taken into account, the concept of using biogas as a bus fuel doesn't make sense. Landfill gas is better converted with an engine into electricity at source.

Regenerative braking, in which the electric motors are used as electricity generators when the bus slows down to a stop, presents a major energy efficiency improvement opportunity for any vehicle regardless of the source of primary energy. Existing diesel hybrid buses with regenerative braking gain that advantage. All new buses would be expected to include regenerative braking, including any new trolley buses. The existing trolley bus fleet does not have that technology but Wrightspeed also offer an all-wheel electric drive system alongside their gas turbine.

Retaining the trolley bus infrastructure in Wellington will require an upgrade of the electricity supply system. The cost of that upgrade has been independently estimated to be much less than the cost basis on which the decision to "pull the plug" has been made.

Replacing the overhead power supply to trolley buses with on-board Wrightspeed gas turbine battery chargers could increase the annual CO_2 emissions from 12 to up to 90 tonnes CO_2 per year per bus;[5] depending on the split between depot charging and on-road charging. Introducing fossil fuels onto trolley buses would negate other initiatives designed to support meeting NZ's Paris Agreement obligation to reduce NZ's CO_2 emissions.

Retaining and upgrading the trolley bus infrastructure in Wellington, with the adaptation of retained sections to provide pantograph fast charging of buses with more batteries, would be consistent with the Government's policy of electrification of transport.

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[3] Assuming tank to wheel efficiencies of about 30% for a conventional non-hybrid diesel bus and about 20% for a small gas turbine delivering electricity into a battery from which the energy is used via electric motors.
[4] A 45kg LPG bottle weighs 36 kg empty.
[5] Assuming 20 km/hr; 10 hours per day; 300days per year and 100 kg CO_2 per 100 km for a normal diesel bus together with the assumptions in notes 2 and 3. The addition of regenerative braking might give a 30% emission reduction for either energy supply system.