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The Potential for Battery Electric Vehicles in New Zealand

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Abstract

Several challenges are facing personal transport in New Zealand; the need to reduce carbon emissions, the depletion of cheap oil reserves, increasing congestion, localised pollution and the need for long term sustainability. One possible solution to replace petrol/diesel cars could be the mass deployment of cost competitive, comfortable, attractive, energy efficient battery electric vehicles (BEVs). This paper first discusses the social and technical barriers that have hindered the development of this type of electric vehicle and secondly, how they can now be overcome. The electricity supply for a New Zealand fleet of 2 million battery electric cars is also discussed.

Introduction

In New Zealand there are over 2.3 million licensed cars of which approximately 90% are petrol and 10% diesel (LTNZ, 2007). There are 2.6 million drivers of which men drive on average approximately 13000km per year and women 9000km (MOT, 2007). The average fuel consumption for a petrol car in New Zealand is 9.4litres/100km and for diesel, 8.3litres/100km (MOT$_1$, 2008). Therefore the total petrol plus diesel fuel consumption for passenger cars in NZ is in the region of 2700 million litres per year. This simplistic analysis highlights that even for a relatively low population country such as NZ, that because of the scale of dependency on conventional ICE cars and the subsequent fuel requirements for transportation it will be a considerable time before alternatively fuelled vehicles replace them.

However, NZ car users already face many challenges including; rapidly increasing fuel cost, the need to reduce carbon emissions, increasing congestion, localised pollution and the need for long term sustainability. The Ministry of Economic Development's 2050 energy strategy focuses on the need to reduce carbon emissions from transport (MED$_1$, 2007) and includes the in-principle decision to halve carbon emissions from domestic transport by 2040 and for New Zealand to be one of the first countries to widely deploy electric vehicles. However, the recent fuel price increases might be a greater motivator for transport change than reducing carbon emissions. To address both these issues, within the next few years there will have to be the start of a shift from conventional internal combustion engine (ICE) cars to alternatively fuelled cars.

Recently the NZ government established the Vehicle Energy and Renewables Group (VERG) with the aim of promoting biofuels and battery electric vehicles in NZ. This group recognised that one possibility for NZ to lead in the deployment of BEVs is to convince a major automotive company to use NZ as a ‘test bed’ for their new electric vehicles. This deployment model is currently being adopted by Israel, in partnership with Renault and Nissan (Project Better Place, 2008). To date there has been no evidence that VERG has progressed in finding a willing automotive partner, however if Israel succeeds then so could NZ.

The alternative is that NZ will follow rather than lead and have to wait for used BEVs from for example Japan or even Israel. For the latter scenario, it will be many years before BEVs become common on NZ’s roads. As an alternative to this, it is possible that NZ could become a BEV manufacturing nation. Investment capital and plans for a BEV company based in NZ are already in place to exploit the technology used on the UltraCommuter BEV discussed later in this paper. A NZ led consortium plans to develop electric cars for initially the low volume market and then move to mass production as demand for BEVs increases (Macrae, 2008).

Future Fuel Options for Cars

Currently, a number of alternative fuel systems are being investigated as a replacement for conventionally fuelled ICE cars; bio-fuels, hybrid ICE-electric vehicles (HEV), hydrogen fuel cell vehicles (HFCV) and Battery Electric Vehicles (BEV). It is likely that a mix of these technologies will be required and there are many arguments for and against each one. However, the focus of this paper is on BEVs as they are probably the best compromise between, performance, cost, land use and energy efficiency. BEVs have substantially higher well-to-wheel efficiency than ICE cars and their electricity use can be offset by renewable sources such as wind, hydro, solar, tidal or geothermal. BEVs could also be charged from mains power, use inductive charging or battery replacement system. Even though in need of upgrading, the electricity infrastructure in NZ already exists to accommodate the introduction of BEVs, unlike hydrogen, and could be expanded with the introduction of, for example, wind farms or pump storage for the required increase in electricity.

Battery Electric Vehicles

Battery electric vehicles were invented around the same time as internal combustion engine cars (ICEs) and in 1898 the electric ’Le Jamais Contente’ became the first car to exceed 100 km/h. Production models readily competed with early petrol cars because they travelled at an equivalent speed. They were also the preferred choice for many women drivers because they did not require a crank for starting and so the public's perception of BEVs was initially positive. A combination of prolonged battery charging time and developments in internal combustion engine technology (including the invention of the electric starting motor in 1911) meant that by 1915 petrol and diesel engine cars predominated.

There was a brief resurgence of interest in BEVs during the 1990's when the emissions reduction legislation of the California Air Resources Board (CARB) led to the development of several BEVs including GM's EV1 project. Unfortunately, the resurgence did not last due to CARB policy changes and the EV1's were reclaimed by GM and destroyed. More recently there has been interest in 'short' range commuter BEVs in cities such as London where they are exempt from congestion charges, vehicle tax and parking charges (in selected areas). Examples include the the G-Wiz, the NICE Megacity and the Zap Xebra. Other commuter BEVs under development are the Myers Motor NmG (formerly the Sparrow), the Th!nk City and Smart EV. Though suitable for city driving they have a limited range of typically 80km.

This meets the average requirements of most drivers in NZ, where for example the mean daily travel distance is less than 40 km (MOT, 2007). However, an issue the current generation of BEVs do not address is that many journeys in NZ are much longer than the daily average and BEVs should be capable of a range far greater than 40km. As an example, in rural areas the mean daily driving distance is 51km but 10% of the journeys are over 90km (MOT_2, 2008) and beyond the range of the average contemporary BEV. Unlike many countries such as those of the European Union, NZ does not have a well-developed public transport infrastructure; therefore New Zealander's are, and will continue to be for the foreseeable future, far more dependent on their cars for both short and long journeys. To achieve a level of comparable mobility, long range BEVs with a performance similar to existing ICE cars will be required to satisfy NZ's mobility needs.

Latest Generation of BEVs

Further improvements in Lithium batteries, motors, controllers and materials is leading to the development of a new generation of BEVs designed for longer range and better all round performance. Although nearly all automotive manufacturers have BEVs under development very little is known about their actual performance so it is difficult to assess their suitability for NZ. In 2006, Tesla Motors previewed the Roadster, a two-seat battery electric sports car with an estimated travel range of 400 km per charge, thus giving it a potential performance comparable to an ICE car. Although not yet proven, the Tesla will provide information as to the feasibility of long range BEVs.

Long Range BEVs

In 2007, The University of Waikato in partnership with HybridAuto Ltd demonstrated the two seat UltraCommuter (UC) BEV prototype that incorporated all the features necessary for a long range BEV; +95% efficient 'in wheel' motor, +97% efficient programmable motor controller, lightweight (630kg), low aerodynamic drag (Cd=0.25) and Lithium-iron-phosphate batteries with an energy density of 96Wh/kg. When tested, the UC had a range of 180km when driving at 85km/h, using 10.4kWh battery energy. Based on the actual performance, it was calculated that with double the battery pack, giving 20.7kWh when 80% discharged the UC would be capable of 260km range when travelling at 100km/h as shown in Table 1, (Duke et al, 2008).

Further calculations based on the testing, showed that a five seat family BEV with a range of over 300km was possible and would cater for 99% of all NZ car journeys. This suggests that BEV technology is already available and if properly packaged, would give BEVs the range and performance required by New Zealanders. It was also found that converting existing ICE cars to electric was a far from optimal solution and should be avoided.

Vehicle type	Power Car (W)	80% Batt. Energy (kWh)	Overall Effic.	Power from Batt. (W)	Range (km)	Wh/km	Equiv. L/100 km	Annual Distance (km)	Annual Energy 1 car (kWh)	No Cars (000s)	Total Annual Energy (GWh)
1 seat BEV	4708	6.9	0.9	5331	104	53	0.59	5000	267	400	107
UC Calculated	7329	20.7	0.92	7967	260	80	0.88	10000	797	600	478
5 seat BEV	10904	39.2	0.9	12616	310	126	1.39	12000	1514	1000	1514
ICEV (battery)	15063	39.2	0.8	19829	198	198	2.19	12000	2380	2000	4759
ICEV (petrol)	15197	367.2	0.2	76985	477	770	8.50	12000	9238	2300	21248

Table 1 BEV Performance and Energy Use at 100km/h

Single Seat BEVs

Over 68% of car journeys in NZ are driver only (MOT, 2007) and rises to well over 70% for commuting (Sullivan and O'Fallon, 2003). Table 1 shows the energy use of a well designed, low cost, single seat BEV (SSBEV) with a range of over 100km when 80% discharged. Table 1 shows that the energy use of the SSBEV is approximately 53Wh/km. Comparing this with a typical ICE car, which uses about 770Wh/km, the SSBEV uses about 15 times less energy to fulfill the same function. This highlights the energy wasted in transporting a single person by conventional car and in a future where energy for transport is constrained and costly the wide spread deployment of SSBEVs is a logical if not publicly popular development. This is an area where NZ could develop its own industry.

How to get BEVs in New Zealand?

There are several scenarios for the mass deployment of BEVs in NZ; Wait for the mass production of BEVs by the major automotive manufacturers and start the gradual market driven replacement of the current fleet. Adopt the Israel model and make a partnership with a major automotive manufacture to use NZ as a ‘test bed’ market. Offer financial incentives that encourage the uptake of BEVs such as free parking and charging, especially in major cities. Develop a NZ industry for low cost two and single seat BEVs that meets the demand for economic transport but is not in competition with the products of the major automotive manufacturers. Wait for used BEVs to become available from for example Japan and in effect continue the current system but with BEVs instead of ICE cars.

It is difficult to know which scenario or combination of scenarios will eventually occur, but it will take many years for the 2.3million licensed cars in NZ to be replaced with BEVs. As an example if 100,000 BEVs per year were deployed it would take over 20 years to replace the fleet, even in the unlikely assumption that the older BEVs were still operating. There are however, presently only a handful of manufacturers making only a few thousand BEVs, and even if NZ does become a ‘test bed’ for BEVs, it will be many years before they appear in significant numbers.

Energy for a Fleet of BEVs

Assuming BEVs do eventually become deployed in mass, their electricity requirements must be estimated. In this work, a scenario is investigated where there is a mixed fleet of 2 million BEVs and that the total annual distance driven is lower than the current average distance. The lower figure is due to the expected increase in use of public transport, cycling and walking. It also assumes that single and two seat BEVs will be widely used in NZ as they are more energy efficient and cost effective for most journeys. As such the scenario has 400,000 SSBEV with an annual distance of 5000 km equating to approximately 250 days commuting with a daily distance of 20km and 600,000 two seat UltraCommuter type BEVs with an annual distance of 10,000 km. There are also 1 million five-seat BEVs with an annual distance of 12,000 km to cater for family use.

Table 1 shows that the annual electricity from the batteries to run the BEV fleet is approximately 100GWh for the SSBEV, 500GWh for the two seat UC and 1500GWh for the 5 seat BEV giving a total of about 2100GWh. If it is assumed that the battery charging efficiency is 90%, transmission efficiency from the electricity generator to the charger is 90% and an urban driving factor of 1.3 is included, then the total electricity generation will be approximately 3400GWh. This is under 10% of the 40,000GWh generated in 2006 (MED_2, 2007). However, Table 1 also shows that if 2 million conventional ICE cars are converted to BEVs and driven similar annual distances as today, they will require approximately

4800GWh from the batteries and with the charge, transmission and urban driving losses will require 7700GWh of electricity or about 20% of NZ's present electricity generation. This highlights how well designed low energy BEVs can significantly reduce electricity demand.

Conclusion

The mass deployment of battery electric vehicles could be a long term solution to NZ's fuel price and carbon emissions issues. However they need to be capable of long range to meet the needs of New Zealand conditions. For mass introduction of BEVs, NZ could follow the same model planned by Israel and become a 'test bed' for BEVs. Alternatively NZ could establish a single or two seat BEV industry that would be able to cater for the vast majority car journeys. In regard to electricity generation, If a mixed fleet of 2 million well designed BEVs was deployed they would require less than 10% of current electricity generation, but poorly designed BEVs would require approximately 20%.

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