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The Feasibility of Battery Electric Cars in New Zealand

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**ABSTRACT**

Several challenges are facing road transport including the depletion of cheap oil reserves, increasing congestion, localised pollution, the need to reduce carbon emissions and develop sustainable transport solutions. A long term transport solution could be the introduction of cost competitive, comfortable, attractive, energy efficient battery electric vehicles (BEVs). This paper first discusses the barriers that have hindered the development of this type of electric vehicle and secondly, how they can now be overcome.

The paper then discusses the development of the NZeco-Ultracommuter (NZ-U), a BEV currently under construction at the University of Waikato. The aim of the NZ-U project is to investigate the feasibility of BEV use in a ‘post oil’ New Zealand. It is intended that this vehicle will travel 250km per battery charge and so the technical features and predicted performance of the NZ-U are presented and discussed.

The technical specifications of the NZ-U were applied to two other BEVs, namely a single seat commuter vehicle and five seat family car. The performance and energy use of all three BEVs was subsequently calculated and compared with that of a conventional ICE (internal combustion engine) petrol car and an ICE car converted into a BEV. The results show that, depending on the BEV type, energy use is between 6 and 15 times less than that of a conventional ICE car when operating under the same conditions.

Finally the electrical energy required to charge a mixed fleet of 2 million BEVs was conservatively calculated. Ideally, electricity from renewable generation technologies should be used for battery charging and in this paper it was assumed that wind turbines will be used even though this technology is not yet widely utilised in New Zealand.

The results show that 464 x 3MW wind turbines would need to be installed to supply 2 million BEVs in New Zealand.

1. **INTRODUCTION**

The use of fossil fuel oil as a source of energy for personal transportation will decrease relative to other fuels during the 21st century. However, it is difficult to predict the rate at which this will occur, the magnitude of the change or what alternative fuels and technologies will replace oil derivatives. Currently, a number of alternatives are under investigation; bio-fuels, hybrid ICE-electric vehicles (HEV),
hydrogen fuel cell vehicles (FCV) and Battery Electric Vehicles (BEV) are presented as contenders for the future of transportation.

1.1 HYBRIDS

The term hybrid generally refers to vehicles which are powered by an internal combustion engine and an electric drivetrain. ICE-electric hybrid vehicles (HEVs) use less fuel than comparable ICE vehicles and have been the subject of recent attention through their commercial development by a number of motor manufacturers including Toyota and Honda. Hybrid vehicles however, can be viewed as an intermediate solution prolonging the use of fossil fuels before fuel cell vehicles (FCVs) or BEVs are widely available.

1.2 FUEL CELLS

First invented in 1839, fuel cells were developed by NASA for the Gemini and Apollo space programmes in the 1960s. While the majority of fuel cells are used in stationary applications their use in vehicles is comparatively recent, unlike BEVs which have a long history and have been used for more than a century.

Fuel cells that convert hydrogen to electricity for powering electric vehicles have received significant attention; particularly in the US where the government is aiming for near independence from oil imports in the first quarter of this century (Whitehouse, 2006). Various organisations are promoting hydrogen FCVs as the replacement for conventional ICE vehicles, and some have stated that they will be marketed by 2010 (Brooke, 2006).

Many academics researching a hydrogen economy however, have identified many issues that question this assumption. Various reasons are cited why hydrogen might not be the best alternative transport fuel, including safety, cost and overall efficiency (Shinnar, 2003 and Chalk and Miller, 2006). Ross (2006) noted that hydrogen storage is one of the major problems facing fuel cell cars and a practical, safe solution faces major technical barriers. Furthermore, hydrogen production from electrolysis would require a significant increase in electricity generation, in fact almost double the existing capacity for the US alone (Grant, 2003). In addition, the overall efficiency of FCVs is much lower compared to BEV’s (Eaves and Eaves, 2004 and Hammerschlag and Mazza, 2005).

Despite the many obstacles and efficiency issues related to hydrogen FCVs the fact that their travel range is comparable to that of conventional ICEVs could make them the preferred long term option (Chan, 2002 and Chan and Wong, 2004). Even though the overall efficiency of hydrogen fuel cell vehicles is inferior to that of directly charged battery electric vehicles, the current high levels of investment mean that this fuel and technology could eventually replace fossil-fuelled ICE vehicles.

1.3 BATTERY ELECTRIC VEHICLES (BEVs)

Battery electric vehicles were invented around the same time as internal combustion engine vehicles (ICEVs) 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 (Schiffer, 1994).

BEVs were thus, and still are, perceived as inferior to ICEVs despite the fact that recent improvements in battery chemistry, electric drive train technologies, and body and component materials mean that the range of a typical production model has increased to an average of 80km on one charge. This easily meets the requirements of many drivers in NZ for example where the average daily travel distance is approximately 40 km (Charlton et al, 2002).

For many years the majority of major automotive manufacturers stated that the public’s poor perception of BEVs meant that the potential market would not be large enough to be profitable; however, the results of a Californian study showed this not to be the case. In this study it was calculated that the initial market for BEVs in California to be between 150,000 and 225,000 p.a. rising to 10 million (EV World, 2001). Using similar criteria, 33% of the ‘second’ car market, potential annual sales in the UK alone would start at approximately 190,000 rising to a total of 2 million, thus justifying investment in manufacturing plant (Andrews et al, 2001).

History shows us that interest in small cars and BEVs has increased when fuel is in short supply, (e.g. during WWII), and/or when oil prices are high, as seen in 1956 and the early 1970s (Quandt, 1995). Interest in these types of vehicle has again increased in response to concerns about the environment and economic factors, although many recent and/or current models may be regarded as ‘niche market’ rather than mass-market vehicles. Examples include the Sparrow, the Think City, the G-Wizz (which is known as the Riva in some countries), the NICE Megacity and the Zap Xebra. While the Sparrow and Think City are no longer in production the latter examples are either now in production or will be within the foreseeable future.

For several years it was acknowledged that, in order to appeal to a wide market, the public must be convinced that BEVs can fulfil daily travel requirements and they must therefore look as though they can satisfy these requirements. Battery electric vehicles should be at least as aesthetically pleasing as comparable ICEVs and even if they have ‘character’, like the Smart Fortwo, they need to avoid being seen as an impractical solution to passenger transportation (Andrews et al, 1999). In 2006 this approach was realised by Tesla Motors who launched the Roadster, a two-seat sportscar with a travel range of 400 km (250 miles) per battery charge. The intent of Tesla Motors was to develop a car that ‘looks gorgeous’ and ‘is thrilling to drive’ in order to change public perception about battery electric vehicles (Tesla Motors, 2006). Although initial production is limited, demand for the cars is exceeding availability and the favourable press reports suggest that the company has indeed begun to fulfil their intent, which should stimulate the market for additional models.

If the transport issues outlined earlier are to be addressed there are several compelling reasons why the BEV warrants further consideration. BEVs have substantially higher well-to-wheel efficiency than ICEVs and when their electricity supply is taken from low carbon emitting sources such as wind, hydro, solar or natural gas they are an optimum solution to urban mobility (Van Mierlo et al, 2006). BEVs could be charged from mains power or use a battery replacement system. The infrastructure in New Zealand already exists to accommodate the introduction of BEVs and could be expanded with the introduction of, for example, wind farms for the required increase in electricity.

1.4 BATTERIES
A key factor that led to the predominance of the petrol car over the battery electric car is that the energy density of petrol is the 300 times greater than that of Pb-acid batteries, thus giving the ICEV superior range. This coupled with cheap and abundant oil meant BEVs were relegated to niche markets such as milk delivery floats, golf buggies and mobility scooters. However, recent improvements in battery performance mean that BEVs could become a mainstream vehicle technology.

Figure 1 shows that the energy density of rechargeable (secondary) batteries has increased significantly since electric vehicles were first introduced. The earliest BEVs used Pb-acid batteries, which have an energy density of approximately 30-40Wh/kg. Batteries such as Ni-Cad and Ni-MH have superior energy density but are lower than state of the art battery technologies such as Lithium-ion and Lithium-polymer that have energy densities ranging from approximately 100 - 200Wh/kg. Other technologies such as zinc-air and aluminium-air offer the potential for higher energy density than lithium batteries but would require a battery exchange system and reprocessing. This latter process however would also require significantly more energy than recharging.

![Figure 1 Energy Density of Batteries](image)

Emerging battery and other recent technological developments present a great opportunity for New Zealand to be an early adopter of BEVs and to demonstrate use of these technologies on a wider scale. It is unlikely that New Zealand will be a major car manufacturing nation but there is potential for it to develop low volume BEV production for domestic and export markets.

2. A DEMONSTRATION BEV: NZeco-Ultracommuter

In 1987 the first World Solar Challenge initiated the development of high performance solar/electric racing vehicles. By 2005 the best solar race cars averaged over 100 km/h and new regulations were required to slow them down (WSC, 2007). The best solar cars incorporated all the elements necessary for high performance battery electric vehicles:

- Low aerodynamic drag
The NZ-U design incorporates Li-ion batteries, a light-weight aluminium honeycomb chassis, in-wheel motors and an aerodynamic body shell. The two motors in the rear wheels could supply a combined power of 100kW but in the first version will be limited by the motor controller to 50kW. The top speed is calculated as 120km/h. The range of the car when travelling at 100km/h is designed to exceed 250 km. The car also aims to challenge the once ‘traditional’ image of BEVs as slow, unattractive and having a poor travel range.

The NZ-U is currently under construction and for the purpose of this study two other theoretical models were also investigated to demonstrate the potential of different types of BEV, a small single seat commuter vehicle and five seat family car. The single seat vehicle could be designed mainly for commuting because approximately 70% of commuter cars in NZ are used by the driver only (Sullivan and O'Fallon 2003). A lightweight battery electric family car that could have a range of over 300km on a single charge is also investigated. The combined analysis of these three BEVs represents a potential mix of personal passenger vehicles that could satisfy New Zealand’s car needs in a ‘post oil’ world.
3. **BEV PERFORMANCE**

To investigate the feasibility of high performance BEVs, an understanding of their energy requirements was compared to that of conventional ICEV’s and ICEVs converted into BEVs. The latter investigation highlights the need for vehicles to be designed specifically as BEVs rather than incorporating the technology into existing models.

The energy analysis undertaken in this work is relatively straightforward: the BEV specifications shown below in Table 1 were used to calculate the energy required for propulsion when driving on a highway at a constant speed of 100km/h. A simulation of UQ’s Ultracommuter predicted a cruising power of 7 kW at 100 km/h equating to an energy consumption of 70 Wh/km. For urban use, UQ researchers used the Advanced Vehicle Simulator (ADVISOR) software and predicted an urban energy consumption of 67Wh/km (Simpson et al, 2005). The two methods give similar energy consumption per kilometre and therefore the simpler, constant 100km/h method is used in this work.

3.1 **POWER TO PROPEL VEHICLES**

The power required to propel the three cars at a constant speed was calculated and used to determine the distance that they could travel using either the energy stored in the batteries or petrol. To simplify the analyses, information regarding acceleration, braking, cornering, hills and headwinds was not considered. The analyses are based on a vehicle speed of 100 km/h, which simulates highway driving. The power required to propel a vehicle travelling at constant speed on a straight, flat road with no headwind is given by equation (1):

\[
Pc = \frac{Cd A \rho V^3}{2} + M g RR V
\]

Where:
- \(Pc\) = Power to propel car (W)
- \(Cd\) = Drag coefficient
- \(A\) = Frontal area (m²)
- \(\rho\) = Air density (1.2 kg/m²)
- \(V\) = Speed (m/s)
- \(M\) = Mass (kg)
- \(g\) = Gravity (9.81m/s²)
- \(RR\) = Rolling resistance

3.2 **VEHICLE DATA**

The input data for the mathematical model of the five vehicles is shown in Table 1. For a typical ICEV, specification data was obtained from a number of sources such as Internetautoguide (2005). It was found that the \(Cd\) value of a typical ICEV saloon is between 0.3 and 0.4. An ICEV suitable for conversion to battery power was assumed to have a \(Cd\) of 0.31 as this would offer the best performance. A computational fluid dynamic analysis of the NZ-U BEV predicted a \(Cd\) of 0.25. It is assumed that the \(Cd\) of the single seat BEV and five seat family BEV will be the same.
Table 1 Vehicle Data

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Mass No Battery (kg)</th>
<th>Mass occupants (kg)</th>
<th>Mass luggage (kg)</th>
<th>Mass batteries/Petrol (kg)</th>
<th>Mass total (kg)</th>
<th>Frontal area (m²)</th>
<th>Cd</th>
<th>RR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 seat BEV</td>
<td>200</td>
<td>80</td>
<td>20</td>
<td>90</td>
<td>390</td>
<td>1.2</td>
<td>0.25</td>
<td>0.008</td>
</tr>
<tr>
<td>2 seat BEV (NZ-U)</td>
<td>400</td>
<td>160</td>
<td>30</td>
<td>270</td>
<td>860</td>
<td>1.7</td>
<td>0.25</td>
<td>0.008</td>
</tr>
<tr>
<td>5 seat BEV</td>
<td>700</td>
<td>300</td>
<td>100</td>
<td>510</td>
<td>1610</td>
<td>2.3</td>
<td>0.25</td>
<td>0.008</td>
</tr>
<tr>
<td>ICEV (battery)</td>
<td>1000</td>
<td>300</td>
<td>100</td>
<td>510</td>
<td>1910</td>
<td>2.3</td>
<td>0.31</td>
<td>0.014</td>
</tr>
<tr>
<td>ICEV (petrol)</td>
<td>1150</td>
<td>300</td>
<td>100</td>
<td>30</td>
<td>1580</td>
<td>2.3</td>
<td>0.31</td>
<td>0.014</td>
</tr>
</tbody>
</table>

Furthermore, it was found that the frontal area ($A$) of a typical ICEV was $2.3 \text{ m}^2$. The NZ-U was ascertained to have a frontal area of $1.7 \text{ m}^2$ using CAD modelling software, and the single seat and family car BEV frontal areas estimated as $1.2 \text{ m}^2$ and $2.3 \text{ m}^2$ respectively. In addition, it was assumed that a typical ICEV has a curb weight (no fuel, luggage or occupants) of 1150 kg, whereas the mass of the purpose-built BEVs ranges from 200 kg to 700 kg. The total mass of the NZ-U (including 270kg Li-ion batteries, a passenger and driver - 160kg - and 30 kg luggage) is 860 kg. In the simulation for the ICEV converted to battery power, it was assumed that the same batteries as the five seat BEV would be used and that the mass of this vehicle (including batteries, luggage and occupants) is 1910 kg.

For all vehicles the rolling resistance (RR) is dependent on tyre type, speed, pressure, road surface and condition and is usually between 0.01 and 0.02 (Bosch, 2004). The RR of a typical ICEV was therefore conservatively assumed to be 0.014. The BEVs however were assumed to be fitted with low rolling resistance tyres with an RR of 0.008.

### 3.3 POWER AND ENERGY ANALYSIS

As discussed earlier, several different types of battery are currently available for BEVs including Pb-acid, NiMH, NiCad and Li-ion. In this work, commercially available Li-ion batteries developed for electric vehicles were used in the analysis. The energy density of the Li-ion batteries used in the model was 96Wh/kg. Although this is considered low in comparison with some Li-ion batteries (the energy density of which is claimed to be 180 Wh/kg) the cost of those used in the model was approximately 20% of this latter type. It was assumed that the vehicles would only discharge 80% of the available battery capacity as a repeated 100% battery discharge would significantly reduce battery life. The manufacturer also claim that the batteries could be 80% discharged over 2000 times. As depth of discharge would normally be less than this, it is possible that the batteries could last over 10 years or the life of the vehicle.

It was also assumed that the electrical energy for the BEVs was converted to drive by a motor and controller with an overall efficiency of 0.9. Such efficiencies arise from the use of brushless DC motors built into the wheel of the vehicle, which eliminates the need for a gearbox and transmission. A typical ICEV has an overall petrol-to-wheel conversion efficiency of approximately 0.18 (Ahman, 2000). In this work an overall value of 0.2 was used to take into account increased efficiency for constant speed driving at 100km/h. Finally, the ICEV converted to battery power was assumed to have an overall efficiency of 0.8 because it would not include brushless in-wheel motors and therefore, losses would be incurred in transmission.
Table 2 shows the calculated power required to propel the various BEVs, an ICEV and an ICEV electric conversion vehicle at 100km/h. \( P_c \) is the power required by the car, \( P_a \) is a nominal auxiliary power required for fans, lights etc. \( P_s \) is the power from the supply source, either battery or petrol. The range of the BEVs on one charge (80% battery discharge) and for the ICEV 40 litres of petrol is also shown.

### Table 2 Vehicle Power and Energy Requirements at 100km/h

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>( P_a ) Power (W)</th>
<th>( P_c ) Power (W)</th>
<th>Battery or Petrol Energy (kWh)</th>
<th>Overall Effic.</th>
<th>( P_s ) Power supply (W)</th>
<th>Range (km)</th>
<th>Annual Distance (km)</th>
<th>One car annual energy (kWh)</th>
<th>Total Number Cars (000s)</th>
<th>Total Energy (GWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 seat BEV</td>
<td>100</td>
<td>4708</td>
<td>6.9</td>
<td>0.9</td>
<td>5331</td>
<td>104</td>
<td>5000</td>
<td>333</td>
<td>400</td>
<td>133</td>
</tr>
<tr>
<td>2 seat BEV NZ-U</td>
<td>300</td>
<td>7340</td>
<td>20.7</td>
<td>0.9</td>
<td>8456</td>
<td>245</td>
<td>10000</td>
<td>846</td>
<td>600</td>
<td>507</td>
</tr>
<tr>
<td>5 seat BEV</td>
<td>500</td>
<td>10904</td>
<td>39.2</td>
<td>0.9</td>
<td>12816</td>
<td>310</td>
<td>15000</td>
<td>1892</td>
<td>1000</td>
<td>1892</td>
</tr>
<tr>
<td>ICEV (battery)</td>
<td>1000</td>
<td>16456</td>
<td>39.2</td>
<td>0.8</td>
<td>21570</td>
<td>182</td>
<td>15000</td>
<td>3235</td>
<td>2000</td>
<td>6471</td>
</tr>
<tr>
<td>ICEV (petrol)</td>
<td>1000</td>
<td>15197</td>
<td>390.0</td>
<td>0.2</td>
<td>76985</td>
<td>507</td>
<td>15000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From Table 2 it can be seen that the NZ-U uses only 8.5 kW from the battery compared to 77kW from petrol for the ICEV. This factor of nine for the NZ-U highlights the compounding effect of high efficiency in-wheel motors with no gearbox and transmission losses coupled with low rolling resistance and aerodynamic drag. The single seat commuter BEV uses approximately fifteen times less source energy than an ICEV and a five seat BEV about six times less. This highlights the benefits of purpose-designed low energy and high efficiency BEVs. Furthermore, it can be seen that converting a typical late-model petrol car to battery requires almost twice the source energy compared to a specifically designed five seat BEV.

For a single seat short to medium distance commuter, a range of 100 km is considered adequate. This would reduce the battery requirements and hence the purchase price of the vehicle. The single seat BEV requires 6.9 kWh battery storage (80% discharge) with a total battery mass of 90kg. The cost of this battery pack was quoted as $5000 and it is expected that this battery pack would last the life of the vehicle. The range of the NZ-U was calculated as 245 km, giving adequate commuting range but also allowing for longer distance driving: for example a return trip from Hamilton to Tauranga. This range could be extended by the addition of more batteries.

The five-seat BEV would be capable of over 300km suitable for a return trip from Hamilton to Auckland. In comparison with the same energy input the ICEV converted to battery only travels 182km. It should be noted that these ranges could be achieved using existing commercially available Li-ion batteries. Future batteries will have higher energy densities and subsequently the range of the BEVs will increase proportionately. A range of 500 km for a five-seat BEV of the future should be possible making it comparable to conventional ICEV’s.

### 4. ELECTRICITY SUPPLY

New Zealand has approximately 2.2 million registered cars (LTNZ, 2005). It was assumed that if BEVs were to replace ICEVs for personal motorised transport, a similar number would be required. However in a New Zealand where BEVs replace ICEVs, car travel could be reduced as more people work from home and/or travel by...
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public transport, walking and cycling. Nevertheless in this study a hypothetical mix of 2 million BEVs is proposed. This mix comprises:

- 400,000 single seat BEV commuters with an annual distance of 5000 km equating to approximately 250 days commuting with a daily distance of 20km
- 600,000 two seat (NZ-U)'s with an annual distance of 10,000 km and
- 1 million five-seat BEVs with an annual distance of 15,000 km.

Future vehicle requirements are difficult to predict and so these values are indicators to enable resource consumption in a range of areas including electricity supply to be estimated.

It is proposed that the electricity to charge two million BEVs be supplied by renewable energy sources. Wind energy is considered the most likely option as it has the potential to supply over 7,900 GWh/yr by 2015 and 100,000Gwh/yr in the long term (EECA, 2001). It is expected that the batteries would act as a smoothing capacitor for the variable output from wind. In New Zealand, well-sited wind farms are a cost effective producer of electricity with an efficiency of over 40% (WEL, 2006), which indicates that it is feasible to supply the electricity for the two million BEVs investigated in this work.

From the travel distances and numbers of BEVs given above, the annual source energy required was estimated as shown in Table 3. The fleet of single seat BEVs would require 133GWh/yr, the NZ-U 507 GWh/yr and the five seat BEVs 1892GWh/yr. This gives a total of approximately 2500 GWh/yr excluding supply losses. Transmission losses are conservatively assumed to be 10% and the overall Li-ion battery charging/discharging efficiency was estimated in the worst case to be 90% although it has been found by the author and other researchers to be over 95% (Kennedy et al, 2000).

An urban driving factor of 1.3 was included to account for the probability that the motor/controller will run less efficiently at low speeds. A simulation of the HybridAuto BEV predicted that urban energy use will be 67Wh/km compared to that of highway driving at 70Wh/km (Simpson et al, 2005). However, until testing can resolve the actual energy use of the NZ-U BEV for highway and urban driving, it was assumed in this work that urban driving consumes 30% more energy and is in line with the urban/highway fuel consumption ratio of existing petrol cars (Internetautoguide, 2005). Unlike conventional ICEVs, braking energy is mostly recouped through regenerative braking (the motor is used as a generator) and the BEV uses no motive energy when stationary. Furthermore, a contingency factor of 1.2 was added to account for issues such as turbine down time through maintenance, or the over estimation of BEV efficiency.

The required energy for charging two million low energy BEVs is therefore conservatively estimated as 4900GWh and equates to 464 x 3MW turbines. Therefore 62% of the potential 2015 wind generated electricity capacity would be required by the hypothetical fleet of BEVs presented. New Zealand generated approximately 40,000GWh of electricity in 2006 (New Zealand Statistics, 2006) and the energy needs of two million BEVs equates to 12% of this generation. It should be noted that while wind energy is the most likely renewable energy supply for the BEVs, other forms of renewable such as projected geothermal programs could supply a considerable proportion.
Table 3 Electricity Supply for BEVs

<table>
<thead>
<tr>
<th></th>
<th>BEV ELECTRICITY REQUIRED</th>
<th>WIND TURBINES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total BEV Energy (GWh/yr)</td>
<td>Rated power 1 turbine (MW)</td>
</tr>
<tr>
<td>133</td>
<td>0.9</td>
<td>3</td>
</tr>
<tr>
<td>507</td>
<td>0.9</td>
<td>977</td>
</tr>
<tr>
<td>1892</td>
<td>0.9</td>
<td>3645</td>
</tr>
<tr>
<td>2533</td>
<td>0.9</td>
<td>4878</td>
</tr>
</tbody>
</table>

Wind generated electricity has natural fluctuations and seasonal output variance which has been cited by some as a major reason for its limited penetration in the national grid. However, Ford and Milborrow (2005) found that there are no technical barriers to prevent wind generating 20% of total grid.

Some individuals believe that wind energy will only supply a small proportion of New Zealand’s future electricity needs and that this will only offset the expected growth in electricity demand (Leyland, 2004). This is questionable however as it assumes continual long term growth in demand, regardless of the political changes and/or availability of resources. Concerns about climate change and scarcer and more costly energy resources mean that measures to reduce consumption will be inevitable. Examples include the use of solar hot water heaters, home insulation, double glazing, low energy light bulbs, low energy vehicles and changes in working and travelling arrangements.

5. FUTURE WORK - NZeco-Ultracommuter

The NZ-U is currently under construction and will be completed by September 2007. The vehicle will be used as a research tool to assess a range of BEV issues including; performance, manufacturability in New Zealand, battery technologies including battery exchange, lightweight materials, natural fibre materials, vibration of low mass vehicles and public perception. The NZ-U will be also be demonstrated in the Commuter Class of the 2007 World Solar Challenge where it will be driven 500 km per day.

6. SUMMARY AND CONCLUSION

New Zealand transport faces a number of challenges in the coming decades; depletion of finite oil reserves, rising petrol prices, congestion, local pollution and the need to reduce green house gas emissions. For passenger cars, alternative vehicle technologies and fuels such as BEVs, hybrids, biofuels and fuel cells are being widely investigated for the eventual replacement of conventional ICEVs.

Battery electric vehicles are one possible solution but in the past they have failed due to poor travel range, high battery cost and inappropriate design. This study showed that BEVs should be designed specifically as electric vehicles rather than being conventional ICEVs converted to battery. They must be lightweight, aerodynamic and
have a high battery to wheel efficiency as employed by the NZeco-Ultracommuter. As such, the NZ-U would use approximately one ninth of the source energy compared to a conventional ICEV under the same operating conditions.

Applying NZ-U technology to different size BEVs gives similar, reduced source energy requirements compared to that for conventional ICE cars. High energy density battery chemistry such as Lithium-ion enables well designed BEVs to have a range of 250-300km with existing technology and double this with improved Lithium batteries. It is possible that the Lithium batteries would last the life in service of the vehicle.

A conservative estimate for the electricity to charge two million BEVs in New Zealand is 4900GWh/year. This could be supplied by approximately 464 x 3MW wind turbines. This figure is based on the requirements of a hypothetical fleet of two million battery electric passenger cars comprising 1 million family cars, 600,000 two seat and 400,000 single seat vehicles, (which address the low occupancy rate of commuter cars).

This study indicates that in a ‘post-oil’ world, New Zealand has the potential to operate a fleet of 2million BEVs charged from sustainable energy wind sources.

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