Invented in the 1830s, the electric car antedates the gasoline powered car and the oil industry by decades. Today, due to a combination of the desire to reduce ones’ carbon footprint, climate change, oil at $150 US a barrel, and improving technology, there again appears a compelling argument for electric vehicles. To date, in order to meet that desire mainstream automakers have offered up a fare of Hybrid electric vehicles, and are just now beginning to re-embrace the concept of the all-electric vehicle. Currently these cars are relatively expensive, and despite having a strong environmental conscience the consumer who wants to drive an electric car will find it hard to justify the economic cost. One way to satisfy this desire and overcome the economic cost is to convert an ordinary gasoline powered car into an EV. This study aims to identify an Australian family sized car that is capable of accepting such a conversion and completing an average Canberran commute. In doing so the selected car must be able to achieve this at an economically justifiable cost. The initial research conducted has highlighted the different approaches to such conversions; specifically the power sources currently being used to power EVs around the world. These differences warrant further investigation. It is expected that the outcomes of this study will provide a comprehensive design of the selected vehicle that will enable a trained mechanic convert a vehicle in minimum time.

Nomenclature

ABS = Australian Bureau of Statistics
AC = Alternating current
ACT = Australian Capital Territory
AUD = Australian dollar
AWD = Michelin Active Wheel Drive
DC = Direct Current
EV = electric vehicle
HEV = hybrid electric vehicle; ICE gasoline powered motion with electric motor augmentation
ICE = internal combustion engine
NEV = neighbourhood electric vehicle
NiMH = nickel-metal hydride
PHEV = plug-in hybrid electric vehicle; electric motor powered car with onboard ICE to charge the batteries
RRP = recommended retail price

I. Introduction

In Australia today a key area of concern for individuals and all levels of government is climate change. The individual can contribute to the solution by reducing their own ‘carbon-footprint’. One of the biggest contributors to an individual’s ‘carbon-footprint’ is the personal motor vehicle. As climate-change forecasts become ever direr the renaissance of the EV gathers momentum by virtue of being seen as the only viable technology of delivering zero-emission private transport.¹

While the major auto-makers are currently committed to HEVs, and committing to making PHEVs, they do come at a significant cost. Until more people buy such vehicles, and market forces take hold, the costs of such vehicles are likely to remain high. What then does the ordinary Australian do if they want an electric vehicle? The short answer is to convert the family car into an EV. The challenge is then to create such a conversion that is

inexpensive and yet maintains all the desirable traits of the humble family car over an average daily commuting range. With the 2006 ABS census showing that over 107 thousand Canberrans drive their vehicle to work each day there is a large potential market for this project.

II. Project Scope

Without constraints on size or budget designing a functioning conversion for a gasoline powered car to an EV will present little problem to the student-engineer, or even the enthusiastic hobbyist; however, this project aims to provide an engineering, rather than scientific, solution. With constraints in mind the project must focus on what is achievable within an economically viable framework. Although cost is an important factor in the development of the project it must be considered in balance with environmental awareness. Environmental protection, and in particular zero emission transport, can be an emotive topic may give the project some room to move on a budget front. Acknowledging these concerns does not allow ignorance of reasonable costs, for even if environmental concern is a large driver the project will be doomed to failure if it delivers an unaffordable vehicle. Hence the project must balance these competing agendas when designing the finished vehicle. The design of this conversion will need to be comparable in cost to replacing the intended conversion car with a new EV, or variant of, or even a newer efficient ICE vehicle. In order to design a successful conversion to an EV this study will initially determine a suitable budget for such an undertaking, and determine the range required of the vehicle if it is to be used within the ACT. Once the cost and range have been determined it then allows for the selection of an appropriate car on which to conduct the conversion. After selection of the appropriate car the specific design can begin.

III. Aims

The specific aims associated with this project are:

1. Define the range requirement for an average Canberran commute.
2. Determine an appropriate budget for the conversion to an EV.
3. Select a suitable car from a list of Australian family sized cars.
4. Design a conversion that complies with all applicable laws and regulations pertaining to vehicle registration and operation within the ACT.
5. Provide a complete list of components, parts, and instructions that will allow a qualified mechanic to complete the conversion on the selected vehicle.

IV. Literature Review

The scope of the literature considered for this project was contained in three main areas: previously modified EVs, battery technology, and motor technology. Each topic was attempted to be covered from a historical, current, and future contexts. There have been some examples of major auto companies producing EVs which were essentially a converted ICE vehicle, and although not all are a retro-fit conversions, like the one envisaged by this project, they do offer some insight into attempts to convert the current paradigm with a secondary storage device, as opposed to a fuel cell. Perhaps the most significant area of EV research concerns the issue of energy storage, and its this area that offers the most hope to EVs and this project.

A. Previously Modified Gasoline Powered Vehicles

The previous second coming of the electric car was due not to concerns about climate change, but air pollution, (during the 1990s the California Zero Emission Vehicle regulation was first adopted)\(^2\), the cause may have been different, but the result was the same; with a number of vehicle manufacturers developing vehicles to meet the zero emissions requirement. These vehicles contained similar technology and represent a good point to study the recent past with respect to EVs. Californian laws were not the only reason that EVs were produced with some companies converting cars for their own economic or social reasons; the French company Heuliez is a good example. More recently smaller companies have arisen to carve a niche for themselves in this ‘new’ market. Some representative examples follow:

Initial Thesis Report 2009, UNSW@ADFA
i. Toyota Rav4-EV: the recent past

The Rav4-EV was one of the ‘first’ generation of EV developed in the late 1990s mainly in response to the California Air Resources Board Zero Emissions Mandate. It was based on an ICE variant of Toyota’s popular small SUV; which was then modified by the manufacturer prior to sale. It used a bank of NiMH batteries for energy storage, and was also equipped with regenerative braking in order to help extend the range of the vehicle; the vehicle had a range of approximately 200km. No aerodynamic modifications to the exterior of the car were undertaken, nor were any significant modifications made to the driving dynamics; it was essentially no different form the gasoline powered version except for some decals.

This vehicle is representative of the ‘first’ generation of the new EV which also included the GM EV1, the Ford Ranger EV and the Honda Plus. All of these have potential relevance to this project, but specifically the Rav4-EV is truly a converted gasoline powered car, has a range that meets or exceeds the likely requirement of this design. One aspect of the Rav4-EV that will not be appropriate to this project’s conversion is its charging mechanism. The Rav4-EV used a ‘Hughes’ type induction charger; this required specialised equipment to be installed in the home in order to recharge the vehicle. Due to the overarching umbrella of cost, this project envisages achieving battery recharge with a small on-board charger, and simply plugging into mains power; further research is required to see if this is possible with reasonable recharge times.

Also relevant to this project is the issue of cost of the vehicle. At the time of sale the Rav4-EV retailed for approx $40,000 US; various subsidies brought this price down to approximately $30,000 US. At the time this was still a large amount of money for a small SUV, but Toyota sold all that they could make; which does provide some evidence that the community are willing to pay more for such vehicles.

ii. Blade Electric Vehicles: current

Blade Electric Vehicles are a small Australian engineering firm that specialises in the conversion of gasoline powered cars to EVs. Their primary specialisation is the conversion the Hyundai Getz into an EV they call the Electron. The Electron is powered by a 40 kW motor; energy storage is via Lithium Iron Phosphate batteries; has a claimed range of 120km in an urban environment, with the aid of regenerative braking; a claimed top speed of 120 kph; and a seating capacity of four. Re-charging is claimed to be complete in 1 hour, 7 hours, and 9 hours, with 3 phase (32 amp), 240v 15 amps, and 240v 10 amps respectively. As with the Rav4-EV there have been no modifications to the aerodynamics of the vehicle.

The Electron has much relevance to this project with numerous technologies to be incorporated. The greatest relevance to this project surprisingly does not come from its engineering, but rather its pricing. The Electron is priced at $39500 AUD to purchase outright or $29000 to convert a previously owned Getz. This is significant to the project because the Hyundai Getz can be purchase new for $12990 AUD. Such a large price differential for a small car that would be perceived to be an efficient ICE vehicle provides evidence that the public is willing to part with significant amounts of money for a converted ICE vehicle to an electric vehicle. Notable differences with this project however are the size of the vehicle, and the seating capacity. With a larger vehicle mass and a greater capacity required, the power, performance, and range characteristics of the Electron will not be possible without significant rework of the Electron’s parameters.

iii. Heuliez: the future of cars (?)

Heuliez is a French company that specializes in niche market vehicles. They have been converting gasoline powered cars to EVs since the early 1980s. With its latest design, the WILL, Heuliez has the potential to revolutionise not only EVs, but the design of the car. The Will is the first car to be designed incorporating the Michelin Active Wheel Drive (AWD) concept. The Michelin Active Wheel design greatly simplifies the vehicle design process, by doing away with numerous components. Vehicles powered with the AWD system have no requirement for a gearbox, clutch, drive shaft, or shock absorbers. This dramatically decreases overall vehicular weight which can be substituted with additional energy storage devices thereby increasing range. Heuliez has not revealed any further information pertaining to energy storage, range or performance.

This particular design is cutting edge technology, and has
the potential to be the future of the automobile according to Dr James Moody, General Manager of Government and International Development at the CSIRO.\textsuperscript{11} If these particular wheels were available for purchase it would obviously represent the easiest way to convert an ordinary gasoline powered car into an EV; simply remove the old wheels and put on the AWD wheels. Then it would just be a simple controller matter. This particular possibility is some way off, but relevance can still be drawn from the weight reduction achieved by this particular design. Although this design reduces weight by by-product rather than design it does show how important weight savings are in the range-payload trade-off for EVs.

B. Energy Storage

There are two types of energy sources for the EV; batteries and fuel cells.\textsuperscript{12} Except for a small percentage of zero-emission vehicles most EVs are powered by batteries, because of this and a fuel cell’s increased complexity this project will also use batteries for energy storage. Because the size, weight and energy density of the battery affects almost all of the EVs characteristics, the battery becomes the most important and most limiting component in the EVs development.\textsuperscript{13} Additionally the fuel tank in a gasoline car is unlikely to wear out during the life of the car whereas an EV power source will wear out long before the rest of the vehicle wears out from rust or old age.\textsuperscript{14} It is these two important reasons that necessitate the study of energy storage in order to ensure the most appropriate battery is selected for this design.

Because EVs are not a new idea there has been considerable research into the best method of powering these vehicles; and during the last century there has been significant technological progress in battery technology. During the 1970s and 80s there was considerable research into the improvement and development of the humble lead-acid battery and, what were then considered alternative battery types, nickel-iron, nickel-zinc, zinc-halogen, molten salt, and non-aqueous batteries.\textsuperscript{15} Among secondary battery types there is lead-acid and the rest; Table 1 lists the common batteries to be considered and their specifications.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|c|}
\hline
System & Pb/PbO & Ni/MH & Na/NiCl₂ & Na/S & Li-ion & LPB \\
\hline
Operating temperature (°C) & <45 & <45 & 235-350 & 285-330 & <50 & 60-80 \\
Electrolyte & H₂SO₄ & KOH & β’-ceramic & β’-ceramic & LiPF₆ & Polyelester oxide \\
Cell OCV (V) & 2.0 & 1.2 & 2.1 & 4.0 & 4.0 & 100-120 \\
Specific energy (Wh/kg) & 25-35 & 40-60 & 100-120 & 110 & 80-120 & 100-120 \\
Energy density (Wh/L) & 50-90 & 120-160 & 160-200 & 135 & 200 & 200 \\
Specific power (W/kg) & 300-400 & 500-800 & 75 & 85 & 80 & 80 \\
Comments & Largest use & Up to 1000 & 150-180 & <75 & 50 & 100-120 \\
\hline
\end{tabular}
\caption{Battery Specification}\textsuperscript{16}
\end{table}

\begin{enumerate}
\item **Lead Acid Pb-A: past – future (?)**

Lead Acid batteries have long been used in automobile systems in the starting-lighting-ignition (SLI) role; however, they are generally limited in the traction battery role. Prior to the maturity of current battery technology the Pb-A battery was considered the best battery available when conducting a conversion to an EV.\textsuperscript{17} Undeniably its use in this role can be seen with a simple Google search. Pb-A batteries are also enjoying some resurgence in the NEV market with car makers such as ZENN Motor Co. (“zero emission, no noise”), Global Electric Motorcars, and ZAP! (“zero air pollution”) all offering cars that use traditional Pb-A batteries for traction drive.\textsuperscript{18} However, the cars offered by these manufacturers have major differences from the project’s application; principally, the NEV concept is for vehicles that travel at speeds less than 25mph (40kph), and hence have little in common with the envisaged conversion. The limitation of the typical Pb-A SLI type battery in its application to EV designs of greater demand stems from the demanding duty cycle environment placed on it in an EV.

Those batteries designed for SLI or deep-cycle use, quickly accumulate lead sulphate on the negative plate under such cycles, and to get around this problem the first HEVs made use of NiMH batteries. However there is some effort being applied in order to overcome this phenomenon with research conducted by/for the Advanced Lead Acid Battery Consortium (ALABC). The ALABC current research is focussed on the design and demonstration of carbon-enhanced lead-acid batteries for hybrid electric vehicle duty. The incorporation of elevated levels of certain types of carbon into the negative plates of lead–acid batteries can overcome the mechanism that is responsible for the accumulation of lead sulphate and this discovery has allowed the production of prototype lead–acid batteries that are capable of operating successfully in the HEV mode.\textsuperscript{19} Of all
the energy storage systems that employ lead–acid chemistry, that which has so far been most successful in the HEV application has been the Ultra Battery.\textsuperscript{20}

The Ultra Battery is a high performance, high power, and longer life alternative to the conventional lead acid battery; developed by the CSIRO. In order to overcome previously identified limitations a super-capacitor is integrated into the negative plate. The integration of a super-capacitor gives the Ultra Battery a life close to that of its competitive nickel-meta-hydride technology, but with greatly reduced cost.\textsuperscript{21} The CSIRO claims a life cycle four times longer than conventional Pb-A batteries; 50 percent more power than conventional Pb-A batteries; 70 percent less expensive than NiMH batteries; and faster charge and discharge rates.\textsuperscript{22}

The CSIRO’s involvement in this project gives great impetus to incorporation of this battery type into this project; however, the CSIRO is not involved in its manufacturing and distribution; it has licensed Ultra Battery technology for automotive applications in Japan and North America, but is yet to license it in Australia for automotive applications.\textsuperscript{23} Additionally, although the Ultra Battery has had significant success incorporated into a HEV\textsuperscript{24} it is yet to be incorporated into a PHEV or full EV. With a lack of an Australian licensee and further development still required for full EV usage, other battery types must be considered for this project.

\textbf{ii. NiMH: the current standard}

A more advanced nickel battery the NiMH was developed by the USABC in the early 1990s, and although these are somewhat more costly than lead–acid they are able to perform the duty without early failure and have a higher specific energy than Pb-A and other nickel based batteries.\textsuperscript{25} This battery type has become the most prevalent source of stored energy in the HEV market. The most popular HEV, the Toyota Prius, and the Honda Civic-Hybrid currently support this technology. Honda remains committed to this technology, for now.\textsuperscript{26} The NiMH battery may be the standard for HEVs but PHEVs and EVs have even more demanding operating cycles than HEVs. Plug in hybrids and full electric cars require batteries that can store lots of energy, recharge quickly and operate in diverse weather environments without overheat or failure, the NiMH battery fails to meet this criteria.\textsuperscript{27} NiMH is the current hybrid standard, but major auto manufacturers see lithium ion as the next step as they are smaller, lighter and pack more electricity.\textsuperscript{28} NiMH is also likely to be less competitive in the EV market if the Ultra Battery delivers as claimed.

\textbf{iii. Lithium: the future (?)}

Lithium is a light and very reactive metal that is good for electrochemical energy storage with a stable electrolyte, which was incorporated into re-chargeable batteries for mobile phones, notebooks, and similar.\textsuperscript{29} Development of this type of battery has progressed significantly in the last half century; in the late 1970s a bright future in military applications was envisaged for lithium batteries;\textsuperscript{30} by the early 1990s lithium derived batteries were being developed for space applications;\textsuperscript{31} in 1994 it was still considered exotic for vehicle application;\textsuperscript{32} and as under development in 2003.\textsuperscript{33} Whereas they have now begun to gain acceptance for EV design because of their high power and energy density,\textsuperscript{34} and it is now the future battery type for hybrid and full EVs.

This rapid development in the first decade of this century has occurred in no small part to the link with mobile phones and notebooks. The growth in these industries saw a need for a high power, high energy density, and light weight battery with a low life cycle cost, and the battery developed to meet those needs was the lithium ion.\textsuperscript{35} Acceptance of lithium ion as an energy storage source for EVs then happened due to sharing the same requirements for an energy storage capability with those of the communications industry.

Lithium derived batteries are being considered for use in new EV and HEV developments; however, there are still some problems that have caused some concern. Honda asserts that lithium technology is still too unreliable to warrant mass production;\textsuperscript{36} and as recently as 2006 Sony decided to undertake a recall of all of its lithium ion batteries used in Dell laptops, due to a danger of overheating and catching fire.\textsuperscript{37} As Tim Spitler of Altair Nanotechnologies points out, car makers can not sell cars that might very well ignite and burn up grandma and the kids sitting on half a ton of batteries. Toyota had planned to use lithium ion batteries in the new Prius, but safety concerns have pushed back the launch of lithium ion technology until late 2010-early 2011.\textsuperscript{38}

Addressing these concerns are several companies working on an iron phosphate derivative in an effort to create a lithium battery that is less likely to overheat.\textsuperscript{39} Companies such as A123 Systems, EnerDel Inc., and Valence Technology are all trying to get a piece of the lithium battery pie. Such LiFePO\textsubscript{4} batteries are currently available to the ordinary consumer and present an ideal opportunity to power any converted machine. The Electron uses LiFePO\textsubscript{4} sourced from Thunder Sky Energy Group. Thunder Sky has used these batteries in a prototype EV with a claimed battery life of 600,000 km. Due to their ease of procurement, high power and energy density, modularisation, and proven ability in similar applications these batteries provide a powerful
argument for inclusion in this design. Further highlighting the future for these batteries is a new study by MIT that discovered a new way to charge these batteries in a very short time.  

iv. Sodium Sulphur NaS

The highest energy densities are produced in high energy or high temperature batteries; it has long been hoped that these systems will provide a commercially feasible battery capable of delivering a driving range comparable to conventional vehicles. The potential of the sodium sulphur battery was known for some time prior to its first practical automotive development in the 1960s. Sodium sulphur is a high temperature battery that operates at temperatures at or above 350°C. Power density decreases occur below 275°C, and increases are possible above these temperatures, but are impractical as corrosion and sealing becomes a difficulty. These batteries have a high energy density: up to three times lead acid battery; have high efficiency: up to 89 percent dc efficiency with no self discharge; and have a long cycle and shelf life: more than 2500 full cycles. Despite all these advantages it is a particularly difficult technology to incorporate into an EV.

The difficulty arises not only due to the high operating temperature, but because of the permanent damage that will occur if the temperature drops below 200°C. Therefore it requires battery heating facilities to maintain the battery’s heat in periods of non-use, impractical for urban vehicles which may have extended periods of non-use. Another problem for the NaS battery is the loss in capacity after extended periods of charging/discharging this is associated with the build up of corrosion products. Originally the NaS battery was being developed for mobile and static use, but during testing it was found that the sodium and sulphur can react in an uncontrolled way and produce toxic gas, and therefore has most potential for static installations. Indeed the battery has been successfully used in large scale applications in static facilities such as electric power stations for use in load levelling. It appears the mobile platforms this battery is best suited for are naval powering surface and submarine vehicles. Some vehicle applications have been attempted with a NaS battery has been tested in a Bedford van by the UK Electricity Council in 1972, but generally EV applications appear far off.

C. Electric Motor Technology

Unlike the ICE the electric motor emits no pollutants, is inherently simpler and more powerful than ICEs and torque is available across the entire revolution range. Hence why electric traction drives have powered trams, trains, and subways for years. Like the progress of any electrical component motor technology has focussed on getting smaller, lighter, yet more powerful and efficient. Three types of motor are considered suitable for a conversion from gasoline power to electric power: the AC induction motor, the brushed DC motor and the brushless DC motor. All three types have been used in this application in the past, and all have their particular advantages and disadvantages. Electric motors are also extremely efficient with conversion of up to 90 percent of the input electricity available as output. The cage type induction motor has the advantage of simplicity of construction, light weight, speed range, and reduced cost. However, its downfall is the complexity and cost of the controller as compared to the DC equivalent. The DC machine has an advantage because the power source is a battery; controllers for DC motors are simpler, lighter, and less expensive. With no brushes to replace or commutator parts to maintain, brushless DC motors promise to be maintenance free with a long life, and are therefore a better economic choice than the brushed DC motors.

Switched Reluctance Machine have been touted as a possible EV motor type because of its low inertia, minimal losses on the rotor, and mechanical robustness which allow it to be driven at high speeds. Presently demand for SRMs is increasing as they offer superior performance with lower price. However, this technology has yet to become readily available.

D. Additional Reading

Appendix 1 contains a bibliography of additional reading conducted during the course of the initial research that helped shaped my ideas, but were not cited. The majority of this additional reading contains information that is duplicated in the cited references.

V. Anticipated Progress of Project

To successfully achieve all the aims of this project the tasks to be completed are listed below:
A. Range determination

Range of the vehicle is of critical importance to the design of the conversion. The required range determines the size of the required power source. This size then determines the type and number of the required batteries, which in turn influences weight of the battery pack. The range of the vehicle will be determined from statistical data gathered from the ABS, claimed ranges of other EVs, and from public survey. The ABS data presents annual average kilometres travelled for individual vehicles registered in the ACT. This annual kilometre reading will then be divided by 365 in order to gain an average daily figure for a car registered in Canberra. This figure will then be compared to the median range as determined by the public survey and the greater distance of the two will be adopted as the range. An additional 40% will then be added to this average daily distance travelled to get the final estimate for the required range of the vehicle.

B. Determine the budget

In order to start the conversion design the likely cost acceptable to a potential customer must be explored. The study will attempt to take in such subjective measures as desire to reduce personal emissions and dependence on oil, and although this project will design a full electric vehicle it is will be necessary to bench mark its price against current HEVs. Therefore, it is safe to assume that the cost could not be equal to or greater than the cost of a new Prius or Insight for example. Furthermore, to complicate matters, the cost must also take into account the cost of a new small ICE vehicle. Examining this cost is done because it is invariably less expensive to purchase a new ICE vehicle, and it may in fact pollute less than an EV, dependant on the EV’s re-charging source. Whilst conducting initial research into the conversion of gasoline powered cars into EVs it was un-surprising to find that the majority of retro-fit conversions of gasoline powered vehicles have been undertaken by the enthusiastic hobbyist with their progress/results often posted on individual websites. Although these do not present reliable scientific data on which to base design decisions they do provide costs which can be confirmed with rudimentary investigation and hence provide a resource for this project.

C. Selection of the vehicle to convert

The aim of this project is to convert a gasoline powered vehicle to an EV, but also to show the wider community that this can be achieved, and hopefully convince them to convert their cars. As far as the public is concerned an EV is a small car with little range that is slow and expensive. Therefore, in order to dispel some of these myths and to capture the widest possible audience, the selected car must have capabilities that the average Canberran desires, and currently possesses in their ICE vehicle. In order to meet budgetary requirements it will be necessary to convert a second hand car, but it must be sufficiently new that it will present an attractive option to the widest possible audience. The vehicle must also be Australian made; with the hope that a successful conversion may attract industry involvement.

D. Power Requirements

To determine the minimum power requirements of the converted vehicle the operational envelope of the vehicle must be examined; examination will reveal where the maximum power required will occur and how much power is required to keep the vehicle moving at a constant or acceptable velocity. Evaluation of this scenario will enable a trade study of performance versus range to be conducted; which in turn will enable the selection of the appropriate type and size of the power source. Establishment of the power requirements will then allow determination of the transmission requirements.

E. Select Battery Type

The principle reason EVs have limited range is that their energy storage devices typically have low energy density. After examination of the literature it appears that a lithium based battery is required; the task now is to find a suitable battery that meets the power requirement at a reasonable cost.

F. Select Motor

After the power requirements are determined the motor can be selected in an iterative process in conjunction with the batteries and controller. Although preliminary indications are that the range requirement for an ACT EV will not be large, the intent is to select a motor with regenerative braking capability for technological parity with other current designs.
G. Design the integration of the motor and control system
After the selection of the vehicle, battery, and motor the specific design to incorporate an electric drive can begin. This stage will comprise of a number of steps:
   i. Removal of superfluous components
      Not only will the required components need to be identified, but their weight and location must be determined. Any effect of removal on ride height and weight distribution must be carefully examined and minimised. Components certain to be removed are: the ICE; the fuel system; and the exhaust system. Components to be considered to be removed will include the transmission, the air conditioning, the SLI battery, ICE engine mounts, and the power steering.
   ii. Battery location
      After removal of superfluous components the battery location can be determined; an appropriate design for the restraint system must then be devised.
   iii. Motor mounts
      Regardless of the removal or not of the ICE engine mounts the motor will have to be adapted.
   iv. Battery management system
      In order to keep costs low the intent is to use a COTS solution, but a modification can not be ruled out.
   v. Regulatory Requirements:
      The goal of this project is to have a fully functioning EV capable of meeting the daily transportation requirement of the average Canberran. The converted vehicle must at least meet the requirements of the ACT laws and regulations pertaining to the use of motor vehicles. This task is a technical performance measure that will require continual monitoring when conducting each task.

H. Provide a complete list of components
By the completion of the design a complete list of components should be known, all that remains is to collate all parts by function into a useable document.

VI. Project Management
Included at Appendix 2 is the initial Gantt chart associated with this project. At this point physical risk assessment is not a great issue for this project as physical construction is not yet slated to occur; this obviously may change depending on the progress of the project. Technical risk is reduced by using a commercial off the shelf approach to the majority of preliminary design, some risk will have to be assumed by the project when designing/manufacturing the adaptor plate from the motor to the transmission housing should it be determined one is required. There is a substantial risk associated with the production of any adaptor plate in that design of this has not yet started and IAW the project’s Gantt chart the determination of its requirement is not scheduled to occur until 30 July 2009. By this date the workshop’s ability to produce the plate will be limited due to the large number of requests it will have already received; therefore in order to mitigate this risk the project will focus on the design of the adaptor and adopting a modified COTS approach to fulfilling this requirement if it is needed. Should any additional parts be identified that require manufacture the same approach will be taken.

VII. Progress to date
A. Ethics Approval Application
   In order to help determine range and budget of the project a short survey was conducted. The survey was initially sent only within the confines of ADFA, but a more representative study was desired and hence ethics approval was then required in order to conduct the survey outside the confines of ADFA. The survey is expected to produce results that will help determine the required range, size and age of vehicle, and the project’s budget. Ethics approval application was submitted on April 17th 2009, and is included as Appendix 3.

B. Range
   Motor vehicles in Australia travelled an estimated 209,405 million kilometres in the 12 months ending October 2006, with an average ACT registered car travelling approximately 13600km for the same period.\textsuperscript{60} This equates to approximately 38 kilometres per day. This range was also confirm by the survey The median range travelled as determined by survey was 40 kilometres the Although this figure suggests that a range of 40 kilometres would be sufficient for the project studies have shown that EV drivers only drive to 60 to 70% of the vehicles capacity because of the desire to not run out of charge.\textsuperscript{61} Therefore the minimum range required of the converted vehicle is
required to be approximately 67 kilometres. The other fundamental requirement that ties closely with range is top speed; because commuters in the ACT are faced with a posted limit of 110 kph the converted vehicle must be capable of reaching this limit. Despite the minimum range being 67 kilometres and the minimum maximum speed being 110 kph the project will aim for a range of 100 kilometres, in order to allow for multiple trips for the one charging period, and a maximum speed of 120 kph in order to allow a minimum emergency power capability.

C. Client Brief
The initial client brief is attached at Appendix 4.

VIII. Summary
The initial research suggests that despite an absence of a production EV from a major manufacturer for the better part of a decade the technology has not stagnated, and some enterprising new niche companies have emerged in their absence. These smaller players have been able to market their products despite a large price premium on the technology; despite this the project aims to remain realistic in the compilation of the final budget for the project. The study has also identified that lithium ion batteries appear to be the future of EV energy storage, but that position is not without challenge from the once humble lead acid battery. Electric motor technology is reduced to the three competing choices of AC, brushed DC, and brushless DC. Although AC appears to have a number of advantages its controlling technology is far more expensive than the equivalent DC controller; this then gives the front running in terms of design to a DC motor. Brushless then has the edge of the two DC motor types because of simplicity and reduced life cycle costs. With the budget, vehicle, and range all determined the project now has to focus on the power requirements in order to select battery and motor type before incorporation can begin.

Appendices
1. Additional readings
2. Project Management Charts
3. Ethics Approval application
4. Client Brief

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6. Leitmann, p217
7. ibid, p205
13. loc cit
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