ESTIMATING THE COST OF AN EV.

By Edward Booth.

Introduction.

This bulletin is intended to help the prospective builder of an electric vehicle (EV) by converting an internal combustion engine (ICE) powered car.

It is not exhaustive, but aims to help the builder to understand what they are embarking on, financially, at least.

Building an EV is not really very difficult (see previous papers on the website), but it is most disheartening to run short of funds midway through the project. The loss of momentum can cause the project to stall and never restart.

The prices quoted can quickly change, and are only valid for January 2009.

Importing vs. buying from a local firm.

Many parts need to come from overseas, and there can be lengthy delays in acquiring them. This is true even when the order is placed on an Australian firm, as the parts can be too expensive to stock.

The importation of goods can be quite expensive. If the goods are worth less than AU$1000, they usually come straight through customs with no charges or delays. US airmail is very quick. However, once the value of the package exceeds AU$1000, you are likely to be charged GST, duty and agency fees for customs clearance. These quickly add up.

The apparent difference between the listed prices, say in the USA, and the local price reflects these costs, plus, of course, the profit margin and stocking cost. Exchange rates play havoc with estimating!

If you intend to purchase two or more items worth less than $1000, but their combined value exceeds $1000, make sure that they are sent separately.

If we want a vibrant industry, which stocks parts on demand, we will need to buy from local firms.

Remember also, that it is much easier to make a warranty claim on an Australian company. You can lose all the savings of direct import (and then some!) if you need to return goods to overseas. The delays can be very long, also.

What you will need.

There are many bits and pieces that you will need, but the main ones are:

Vehicle.
Most builders will opt for a small, light car under 750kg. (See the paper on choosing a vehicle on the AEVA SA Branch website.)

Once the type of vehicle has been chosen, you will need to find one that fills your needs.

Small cars can be acquired from $100 (or less) up to $4000, depending on age and condition. You can, of course, spend much more, if you wand a very late model or something exotic.

Remember that the car will have to undergo a rigorous inspection, so cheap is not always better. It is necessary to factor in the cost of getting it right up to inspection standard.

All this means that you will be very lucky to have a good roadworthy car for less than $2-3000, no matter how little you pay for the starting vehicle.

Obviously, if you can find a good car with a blown IC motor, you might come out well in front.

Engineering.
You need to apply to the Department of Transport to modify a vehicle, and they will issue you with a Statement of Requirement, setting out what

they will be needing. This will very likely involve getting a consulting engineer to sign off on at least part of your work.

You can either engage the engineer before or after applying to modify, but it pays to have preliminary discussions early.

Depending on what you want to do, the engineer will cost you somewhere between $600 and $2000. (One of my conversions did not require an engineer at all, so I was well in front).

As a rule of thumb, the more you modify, the more it will cost.

Motor.
This is a "big ticket item". See the paper on choosing a motor for an EV on the AEVA SA Branch website.

The smaller DC motors start at around $1000 and the larger ones can come in around $4000.

An AC motor will cost more again, but should be available for under $6000.

Controller.
This is another major purchase, and will usually cost around the price of the motor that it controls. Allow $1000 for a small 72volt unit, and up to $3500 for higher voltages. (See the paper on choosing a DC motor and controller).

For AC systems, you will need an inverter controller, which will set you back around $4000+.

Throttle pot.
This little gizmo connects the accelerator to the controller. Allow around $80.

Batteries.
These will vary in cost dramatically depending on your choices.

Lead/acid batteries start at around $220 for wet-cell up to $300 for AGM and Gel cells. You can usually do a little better if you are getting 10 or more. I got 10 AGMs for $2200 plus $120 delivery, so shop around.

Lithium ion batteries cost about three times as much as AGMs, but they are lighter, last longer, and deliver more useable current.

It is common practice for builders to start with lead/acid batteries, and replace them with Li/ion at the end of their life. This spreads the cost a bit, but requires that battery boxes be built to take the two sizes of battery.

Included with batteries, are regulators. Both Lead/acid and Li/ion will last significantly longer with charging regulators that ensure that all the batteries receive a full charge, but are not over-charged. Li/ion batteries really must have regulators, while Lead/acid will return up to twice the life, if fitted with Rudman Regulators. There are other less effective regulators available (some much cheaper), but the Rudmans seem to be the best. Allow around $70/battery for Lead/acid, and $15/battery for Li/ion. There are many more Li/ion batteries to achieve the same voltage.

The 12volt auxiliary battery will usually perform quite adequately. It is not usually cycled very deeply, so will last quite well. It is usual (I think) to replace them with a deep-cycle unit when the time arises, but that (hopefully) is some way off.

Chargers.
Most builders elect to carry the traction battery charger on board. This means that they need a lightweight MOSFET charger.

Since America uses 110volt mains supply, we have to source our chargers from elsewhere. Fortunately, there are European units, of which Zivan is probably the best known. They are available in Australia for around $2500, and can be bought for most voltages and battery types.

Alternatively you can find much cheaper chargers, which weigh too much to carry on board, and require you to always charge at the one place. This can be very inconvenient (read embarrassing!).

You will also need a charger for the 12volt auxiliary battery.

Some builders use elaborate MOSFET chargers to run of the traction circuit, but I prefer to use a separate 12volt charger.

You can mount the charger on board, and run it off the same 240volt AC socket as that for the traction circuit.

A good MOSFET “smart charger” will cost a little under $100.

Switches and relays.
You will need a big fat isolator switch. These start at around $60 for low voltage/low current units, and go up to $250 for large double-pole units. Prices vary, so shop around.

You will also need a solenoid switch, which is actuated by the ignition key. This basically duplicates the function of the isolator switch above, but you will need both. These solenoids can be found for around $200.

You will need an assortment of relays or an interlock device. Relays come in at around $15 each, while interlock boxes can vary widely. Allow $90 for relays or $300 for an interlock box. The latter is better, but not essential.

Cables.
These fall into two main groups:

- High tension. These are heavy cables, capable of carrying high amperages with minimal resistance. Conventional wisdom says that 50mm2 is the size to use, although I used 25mm2 in my 72volt/450Amp system, and 75mm2 in my 120volt/500Amp system. Neither system gets hot. The cables will require lugs for the terminals. These are best crimped onto the cables. Cables and lugs will work out at around $800 at today's copper prices. You can sometimes pick them up second-hand for much less, but don't count on it.
- Low tension. These are all the 12volt wires (and a few low-current high tension, eg charger cables). There is a surprising amount needed. There are also all the terminals. Allow $150. Again, you can sometimes scrounge second-hand cable from a friendly motor wrecker for next to nothing. Make sure that gauges are adequate.

Fuse.
You will need a fuse in the high-tension traction circuit.

If the system is under 80volts, you can use a car-type fusion fuse (such as Mexico), but over 80volts, you will need a T-class fuse or circuit breaker. The former costs around $40 for the fuse and holder, while the latter will cost $80 for the fuse and holder or $200 for the circuit breaker.

Battery box.

There are quite strict rules applying to these, where they are mounted inside the cabin of the vehicle, which is usual.

There are also mounting constraints, which must be met. These do not require massive steel bars. Well-attached metal straps will suffice. The engineer can advise you, but 10mm bolts on each side of the battery, with a steel strap over the top, will usually do the job. Use bolts, not tek screws!

My battery box cost me around $100. It was made of folded and welded aluminium, with a bolt-on 10mm plywood lid. This was well sealed with paint, and had an impervious rubber seal around it.

If the batteries are not in the cabin, they do not need to be in a sealed box. They need to be well vented. Either way, allow $100 for mounting the batteries; more if you can't do your own welding.

Mounting plates and brackets.

The most difficult (and expensive) of these is the motor adaptor to join the electric motor to the transmission. This assumes that the builder will retain the original transmission, which is the easiest way for most modern front-wheel-drive cars.

The average builder will not have the equipment or know-how to make a conversion plate. It is ***essential*** that the shafts are concentric and straight on to each other, or high wear and other damage will quickly occur.

My own adaptors cost less than $700 each, but I have heard that most people have had to pay much more. Shop around, but allow $1500-$2000 in your estimate.

Other brackets and mountings are:

- The controller. This needs to be mounted firmly and out of harm's way, yet close to the motor to keep cables short. It won't be very difficult, but will require materials, cutting and welding. If you can make it yourself, it will cost around $20, but to have it made, expect to pay up to $100.
- The throttle pot. This needs to be mounted where the accelerator cable can reach it without undue kinks. It must be firm, or the throttle control will be vague or jumpy. Allow $20 to do it yourself, or $100 to have it made.

- Relays, interlock box, fuses, inertia switch, etc. These can usually be bent up out of sheet steel or aluminium. Builder's strap (hoop iron) is very useful here. Allow $20.

Ducting.
The rules require that all high-tension cables must be protected, and entry points into the sealed battery box must also be sealed. This requires ducting. I found that the stuff from electrical suppliers did the job. Allow $50.

You will also need to pipe gases away from the box, and fresh air into it. The duct can be PVC plumbing fittings (about $50), and a small fan will cost around $20. (Use an induction motored fan to eliminate sparking).

Vacuum brakes.
If the car originally had vacuum assisted brakes, it must still have them after the conversion.

There are all sorts of systems available. I don't think I have seen two alike.

I chose to use a vacuum pump from a turbo Volvo. This pump is adequate to evacuate the system without a vacuum reservoir or pressure switch. It runs off the throttle-off switch on the throttle pot. Allow $80-$100.

Power steering.
This is best avoided by choosing a car without it. However, if the original car had it, you must retain it.

Power steering will need a small electric motor to drive the pump. You cannot run it off the drive motor, as it will not be running when you need it most! It will obviously reduce the range of your vehicle as it pulls current from your batteries.

Electric power steering would be better, but would come at a price.
I really cannot give any idea of cost for this item, but I suspect it would be several hundred dollars.

Heater demister.
The converted car must have a demister. The heater is optional.

There are many ways of doing this. Small ceramic heaters, hair driers and similar devices have all been used.

I found that a single-bar radiator coil running off the high-tension circuit, and mounter inside the original heater box worked well. You will have to fabricate insulated brackets (for heat and electricity). You will also need a relay so that the heater element cannot run unless the fan is also running.

These demisters only pull a few Amps, so they make little difference to the driving range (say 2%).

Allow about $100, although you might do it for as little as $20.

Gauges.
Most EV owners want to know what is going on “in there”.

When the car is first built, it takes a while to get a feel for the current used in acceleration and cruising. This needs an ammeter.

To connect the ammeter, you will need a shunt, or calibrate the resistance in your longest traction cable, then adjust the resistance on the gauge. The latter is not for the faint-hearted, but creates less resistance in the circuit.

If you elect to use a shunt, I suggest that you use two 50Ohm shunts back to back, or you will probably lose performance.

It is pretty useful to know how much charge is in the batteries (both traction and 12volt auxiliary). This will need two voltmeters.

Motor revs can be measured by using a calibrated voltmeter across the motor terminals. The motor will run at a fixed number of revs/volt.

Gauges usually cost around $30 each, and shunts $40 each.

Contingencies.

This is the box where you put all the little items not covered above. It also includes the blow-out on some items, the fluctuations in exchange rates, postage and couriers, petrol for running around, phone calls (occasionally international), paint to make parts pretty, etc.

I suggest about 10% of the total of the above. It should be well in excess of your need, but better safe than sorry.

So! What does that all come to?

If you have been keeping up, you will see that the best case comes to about $12000 for a simple 72volt DC small car, up to nearly $34000 for a the full bells and whistles, with AC power and Li/ion batteries.

This is for guidance only, but should be enough. There will be builders who have done it more cheaply (my little Subaru only cost $8000, and a friend with a machine shop built a 48volt car for $5000), but to claim that anyone can do it for less would be misleading.

My advice is to budget using the above as a guide, then scrounge and save as much as possible. Do as much as you can yourself without compromising safety.

Beware of cheap second-hand bits! They might be fine, but maybe not. The smaller items might be worth a gamble, but the larger items can really set you back. By this, I mean $1000 for a dud used motor is a big disappointment, and can set you back badly. Believe me. I know.

I also suggest that you use the help of members of AEVA and visit the excellent website. You can save yourself a lot of heartache.

As a final comment: make sure that your partner is on side. There will be times when you might need all the support you can get. A project like this can test a relationship.

Good luck!

This paper is prepared using the best information that I can find, and is based on personal experience from building two cars. There will be others who have greater experience, and others who disagree with my opinions. That is fine. Feedback is welcome. We can always improve guidelines, and should try to do so.

I also acknowledge the unstinting support of my wife, who has indulged me through the long, sometimes difficult, but very rewarding process.