

Battery Electric Vehicles (BEVs)

Submission to Automotive Review

What are the current options for replacing conventional vehicles with their capacity for Carbon Dioxide emissions? How can we move as quickly as possible towards zero transport emissions?

Mainstream alternatives

Most of the emphasis at present is towards hybrids. Normal hybrids proceed by using an electric motor and batteries to support the operation of an internal combustion engine. This means that though they are more efficient, they still run 100% on traditional fuel types, just in a more efficient way. Some hybrids will soon run on biofuel, which is a benefit, but such cars are still not ideal because they will not reduce demand on liquid fuel to a great enough extent. There is just not enough biofuel around. The improvement in efficiency is in the order of 15%, but they are still merely efficient cars (similar to the small efficient diesel) – there has been no big step away from internal combustion engines.

Fuel-cell hybrid cars

Fuel-cell powered hybrids are a popular longer term option. For this car, the recommended fuel is hydrogen. The consumption of hydrogen in a fuel cell releases water vapour rather than carbon dioxide.

Hydrogen does not naturally exist independently in nature (though it is very widespread), and has to be isolated using electrical power, whether through steam-reforming (obtaining hydrogen from natural gas), or via electrolysis (extracting it from water). It is sometimes called an *energy carrier* rather than an *energy source* for this reason. Electricity is also an energy carrier, fossil fuels are energy sources.

It seems, however, that hydrogen powered fuel cell vehicles have a number of important constraints. Solutions have to be found to store the hydrogen (it is difficult to contain), the components of the fuel cell itself are in limited supply (platinum, the active component, is very rare), and a successful method is required to obtain the hydrogen in large enough quantities to support a country's vehicle infrastructure. Probably the most important question is the following. Is it more efficient to use electricity directly rather than using it to create hydrogen which then powers a vehicle?

For an answer to this question, it is worth reading 'Carrying the Energy Future: Comparing Hydrogen and Electricity for Transmission, Storage and Transportation' by Patrick Mazza & Roel Hammerschlag (<http://www.ilea.org/downloads/MazzaHammerschlag.pdf>). This is a document which compares hydrogen power and direct electricity, and outlines some considerations on the future of transport. It models the various levels of efficiency of hydrogen and battery

power, and concludes that fuel-cells combined with hydrogen is less efficient as a transport option in comparison with using the electricity directly.

Biofuels – The fuel for food argument

Replacement fuels such as biodiesel, pure vegetable oil, and ethanol provide a zero net addition to the carbon dioxide in the atmosphere. This is because burning such fuels releases carbon that has been recently absorbed by living plants. This carbon is *not* from fossil fuels which have been sequestered over millions of years. Using fossil fuels adds *new* carbon to the cycle, using biofuels returns recently absorbed carbon back to the atmosphere. Biofuels can be used in existing engines, though sometimes these engines require minor modifications.

Unfortunately, these fuels are limited by land availability. Relying on biofuels to fuel all the cars in the USA, is reported to require 936000 hectares of land to grow the fuel crops, in addition to the 1.6 million hectares already growing crops for food. To supply the Australian requirement for biofuels, we would have to consume 26% of our arable land (<http://tasmaniantimes.com/index.php?/weblog/article/philll>). This is a very difficult task. We are struggling to grow crops for food given the dry climatic conditions, let alone extra amounts for fuel. If people were to move en-mass to biodiesel, they would consequently be limited by demand. Too many people wanting too little product.

Advantages of Battery Electric Vehicles (BEVs) and Plug-In hybrids (PHEVs)

Battery electric vehicles have been discussed before, and are usually dismissed because of limited range, slow charging times, and short battery life.

In the past, electric cars were essentially a curiosity, or were only used by dedicated electric car clubs. The only form of battery available for these cars were the well known, yet extremely limited lead-acid battery. These BEVs had an average range of 60 kilometres (though it could be extended to 100 kilometres with careful design), and an average maximum speed of 65 km/h, due to the power characteristics of the battery. In addition, the batteries

- required replacement every 2 or 3 years, at a cost of perhaps \$2000 each time.
- required recharging for at least 8 to 10 hours before the vehicle was able to drive again.
- were heavy and bulky
- had a ‘memory’ effect, which would lead to problems if fully discharged. The battery would not charge to the same extent next time
- contained significant quantities of heavy metals. (To some extent these were successfully dealt with by recycling programs.)

But this is changing. Electric vehicles now have the following characteristics.

- A much greater range. Some electric cars are reported to travel over 350 kilometres (<http://www.teslamotors.com>).
- Much higher top speeds are possible, at least 120 kph. Many electric cars can go much faster than this.
- Battery replacement is required at over 1000 cycles (discharge and recharge events), at least 7 years under typical usage patterns.
- The new lithium batteries are relatively expensive, however this is only due to economies of scale. The price is expected to drop significantly as lithium batteries become more widely used in the rapidly expanding hybrid vehicle market.
- These batteries are much less toxic than older batteries. Good recycling programs can significantly reduce the environmental impact.
- New and better battery technology is being producing very rapid charge times (90% charge in 5 minutes) <http://www.gizmag.com/toshiba-scib-super-charge-lithium-battery/8506/>
- The batteries have no memory effect.
- There is no need for a complex engine with large numbers of moving parts. An electric motor is extremely simple.
- In a practical sense the only work required on the car is maintaining the electrical system and transmission repairs and tyre rotation. There is no requirement for oil changes and filters, fuel tanks, fuel injectors, carburettors, or an exhaust system. There is no requirement for servicing and replacement of spark plugs, engine oil, oil filters, air filters, and timing belts. There is no need for emissions tests.
- Electric motors are probably the most efficient systems for propelling cars. They are between 85% and 95% efficient at using energy, whereas ordinary car engines are only 15 - 40% efficient at converting fuel energy to motion (See http://en.wikipedia.org/wiki/Internal_combustion_engine#Engine_Efficiency for more details). Modern electric motors utilise efficiency measures such as regenerative braking, which allows energy to be recovered during the braking process and returned to the battery pack. And, they consume no energy when the car is stationary, the motor does not run at all.
- There is no need for the costly and time consuming establishment of a complex refuelling infrastructure. Such cars can plug into any standard power point, and charge off the grid.

- These cars are ideally suited to urban stop-start driving, and have like good hybrids also have the capacity to recover energy usually wasted during deceleration or braking. ('Regenerative braking').

At present a battery vehicle that will drive 300 or 400 kilometres per charge is still too expensive to be appropriate for the mainstream consumer (though this could be possible as battery costs are reduced due to higher levels of demand, and as batteries continue to improve). However, a vehicle that will drive 150-200 kilometres per charge could be produced, and such vehicles would be eminently suitable for shorter range urban driving, where most people drive most of the time.

Plug-in hybrids

An alternative to a BEV is a Plug – in Hybrid EV (PHEV). This is a vehicle that runs for a short distance on battery power, before a liquid fuel powered generator switches on to charge the batteries. The total range of such vehicles could exceed 1000 kilometres per tank.

Unlike traditional hybrids (but similar to BEVs), these vehicles can be plugged in and charged from the power point as well, and in most cases would not need their liquid fuel backup. In general PHEVs (sometimes called REEVs or Range Extended Electric Vehicles) are almost as good as BEVs, though somewhat more complicated. If a biofuel was used, this would increase the benefits over existing hybrids still further, completely removing the need for a fossil fuel.

Where does the electricity come from?

People criticize these vehicle on the worse case scenario, that these vehicles can still be charged on coal-based electricity, which delivers little carbon benefit in comparison to existing vehicles.

However, it is interesting that this ability to run on electricity, which is an infinitely flexible fuel, is not seen as an *advantage*.

Given that electricity can be generated in different ways, BEVs will still run no matter what happens in the future in terms of power generation. It is not subject to a limitation like that of fossil fuels. The assumption is that power stations will become cleaner as time goes on, therefore BEVs will also become cleaner.

In contrast existing vehicles are the cleanest the moment they run off the production line, over their lifetime they emit more as their emission controls degrade. They are also *locked in* to one type of fuel, all of which emit carbon (whether the carbon is grown in plantations or removed from below ground deposits).

Powering electric vehicles from green energy delivers a zero-emission vehicle, both from the vehicle itself and from the power generation side.

Electric cars also have the capacity to be used as a distributed storage mechanism for grid power. People can connect their cars back into the grid when they are not being used, and supplemental electricity can be drawn back from them if the need arose. This is sometimes called a 'Vehicle to Grid' relationship (<http://www.udel.edu/V2G/>). This brings the concept of electric vehicles out of the domain of transport, and into mainstream power issues. What an impressive means of storing green power! It is a common criticism that green power cannot be stored effectively for when it is needed.

This also relates to off-peak power, for times when the power stations are running at a high level with little demand (often at night), the power can be stored by vehicles during their charging phase (also at night) for re-use during the daytime (often when people have finished driving and are at work). In this case, even if a coal-fired power station was supplying the power at night, this power would not have been used anyway. There is therefore a great benefit to the environment, as the owner of the BEV is driving on formerly unused power, and is not emitting carbon (in comparison to a internal combustion engine which would have polluted *in addition to* the grid).

Embedded energy of battery powered vehicles

It can be pointed out that batteries are energy intensive to manufacture, and that you have to prepare a total life-cycle analysis of electric cars before making a judgement about whether these cars are really effective in reducing emissions.

Such analyses have already been performed for hybrids.

Examples are drawn from a study where a Prius (containing a large battery pack) was portrayed as requiring more energy to produce and run than a large American gas guzzler (a 'Hummer'). For more details on this report, see *CNW Marketing - "Dust to Dust: The Energy Cost of New Vehicles From Concept to Disposal" 2006*

Unfortunately,

- the report is based on an assumption that a Prius will only drive 160,000 kilometres in its lifetime, whereas the hummers were reported to last 480,000 kilometres. Prius cars are lasting far longer than this, Prius taxis have driven over 300,000 kilometres
http://greenmesh.com/2006/09/prius_taxi_fleet_long_term_tes.php.
- the report assumes a far greater number of Hummers on the road than Prius hybrids, which skews the embedded energy requirements in favour of the hummers. But thousands of new hybrids are being produced every year.

- the assumption is that the vehicle construction phase requires a far higher energy input than the usage phase. However, most other studies contradict this (typically 20% of the total energy is expended in the construction and disposal phases, 80% in usage).

See this report for more details

http://www.pacinst.org/topics/integrity_of_science/case_studies/hummer_vs_prius.pdf.

Here is a comparative report on a number of vehicles, based on a system developed by the Argonne National Lab, called “The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model”.

<http://www.triplepundit.com/pages/askpablo-time-to-get-a-new-car-002538.php>

The argument is that cars with good fuel economy rapidly overcome vehicles with poor fuel economy, despite the extra energy involved in developing these cars. The example discusses hybrids, but the argument applies also to BEVs. And as pointed out above, retrofitting existing vehicles improves the equation even further, as most of the car body and a good portion of the internal parts are reused in a retrofit.

World developments

Most large manufacturers now are focused on fuel-cell cars, hybrid vehicles, and plug-in hybrids. Some BEVs are in the pipeline, though they will not appear for at least two years, and when they do arrive it will take a long time to make a dent in the vehicle fleet.

Larger companies

Some larger companies are working on electric vehicles.

Mitsubishi has a significant research arm developing electric vehicles. They are currently working on a number of concept cars, and have one production vehicle (the ‘MIEV i’) slated for sale in 2009.

http://www.mitsubishi-motors.com/corporate/about_us/technology/environment/e/miev.html

The advantage of this vehicle is that it is being developed in Japan, so it is already right-hand drive, which means that it could be sold in Australia as soon as it is ready for production. It is a good urban vehicle, and has a range of about 150 kilometres, though improvements in range are likely as time goes on.

Subaru is working on pure electric vehicles, as displayed by the Subaru R1e and Subaru G4e. The R1e may be released in Japan within a couple of years

<http://www.autobloggreen.com/2007/12/26/subaru-ev-could-arrive-as-early-as-2009>).

Nissan is working with **Renault** on a massive project in Israel, to introduce electric vehicles and electric vehicle infrastructure by 2011. A large network of charge points will be introduced, and vehicles will be paid for independently of the cost of the battery, which will be leased like a mobile phone.

http://www.nissan.com.au/news_pdfs/20080122_ProjectBetterPlace.pdf

Plug-in hybrids

General Motors Holden

The flagship vehicle for Holden is the Chevy Volt. Widely marketed as a Range Extended Electric Vehicle, this PHEV will drive for 60 kilometres on battery power alone. Subsequently, the generator (running on ethanol, petrol, biodiesel, or a small fuel cell stack) recharges the batteries, allowing for further driving (up to 1024 kilometres).

See the following website for more details : <http://www.chevrolet.com/electriccar/>

The Chevy Volt will be (hopefully) introduced to the world in late 2010.

Toyota

Toyota is working on a plug-in hybrid (<http://www.toyota.co.jp/en/news/07/0725.html>). Not as much is publicized about this vehicle, little is known about its release date.

Small companies

The speed of production of large companies is unfortunately dependent on the huge manufacturing processes of these companies to change for the new vehicles. An alteration in a manufacturer's mindset might take years to appear on the production floor. It is possible, however, to produce good new BEVs right now.

And many smaller car companies are developing such vehicles.

Europe

- http://www.greencarcongress.com/2005/10/sev_launches_fa.html
- <http://www.smithelectricvehicles.com>
- <http://www.goinggreen.co.uk/store/content/gwiz>
- <http://www.cleanova.com> (in French)

The USA

- <http://www.teslamotors.com>
- <http://www.phoenixmotorcars.com/>

The USA has a significant following for these vehicles, have a look at this website. <http://www.pluginamerica.com/>.

Brazil

- http://www.greencarcongress.com/2006/07/obvio_to_introd.html

Australia

- <http://www.revaaustralia.com.au>

Ways to support electric vehicle companies in Australia

At some point these commercial vehicles will be introduced to Australia. However, these vehicles will not replace the existing fleet, but will be introduced in addition to current vehicles.

Is this enough? Can we convert the current fleet to electric without waiting for new vehicles? Can we use the better battery technologies to start changing the fleet now?

Yes, we can. The motors and car mechanics are *simple*. Electric cars *can* be created through the process of converting them from traditional vehicles, without creating/purchasing new cars. The embedded energy of developing a new car is much reduced in a conversion. It also avoids the classification issues of introducing a new vehicle, converting an existing car means that the car body satisfies the Australian regulations.

How do we develop businesses that convert such vehicles?

The USA has a large number of small conversion companies removing internal combustion engines, and replacing them with electric motors and batteries. For an example, see <http://www.laweekly.com/general/features/whos-resurrecting-the-electric-car/13975/> .

The greatest stumbling block for a successful conversion business would be the image problem. The slow, short range 'Neighbourhood' electric car with regular expensive battery replacement (and resulting recycling issues) is not necessarily the case any more, but many don't know that. People still think that charging their car from a coal-fired station is just as bad as driving an internal combustion engine. This is just not true.

Some visible examples of electric cars, with strong enthusiastic proponents would do much to change opinion in this matter. The expensive nature of petrol would make cheap, low maintenance, versatile electric vehicles extremely attractive. Hopefully, with a bit of publicity, people would begin purchasing these cars in large numbers. 'Drive your car 300 kilometres for \$5.00!' This is a persuasive argument in the modern environment of expensive fuel costs.

Conversion companies in Australia

Knowledge about conversions, and the mechanical hardware in a BEV is widespread in Australia. Commercial electric vehicle motors, links to companies, example conversions, and kits can be found at many locations.

Australia does have an electric vehicle association. The Australian Electric Vehicle Association (AEVA) holds regular meetings, displays their cars at events, and has the capacity to help with practical advice and literature. See the following link for more details : <http://www.aeva.asn.au>.

There are a few companies that convert vehicles (Convert Your Car - <http://www.converturcar.com>, Blade Electric Vehicles - <http://www.bev.com.au>), however the high cost of lithium batteries makes the overall package relatively expensive and the general public are reluctant to purchase small converted vehicles at these perceived higher prices (in comparison with existing cars).

Options for government action

What can the government do to help?

1. Implement up front rebates, especially for retrofitted second hand vehicles (similar to the LPG conversion program, or the rebate for photovoltaics) California encouraged BEVs by mandates, 3% of all cars were to be zero-emission by 1998, 10% by 2003. (Some of this legislation was overturned during the demise of the General Motors EV 1). Laws like that (though controversial) would inspire ingenuity and much commercial development.

For zero-emission cars, England provides free on-street parking, no annual road tax, and exemption from the congestion charge.

2. A carbon tax on the embedded energy of new vehicles
3. Drivers of cars that have zero emissions (BEVs charged from green energy) should be able to claim carbon credits, for the carbon not emitted per kilometer driven. A difficulty is how to prove that a car is run from green energy. Perhaps this credit could only be available on people who are subscribed to a green energy scheme or have their own clean energy installation. The carbon credits could come from a carbon offset company that buys your carbon credit capacity
4. Governments to help by installing fast recharge points, powered by green energy
5. Governments should be supporting the incubation of regionally based conversion industries
6. Governments can support the training of engineers who are registered to convert vehicles

7. Governments should establish robust design standards for registering electric vehicle conversions
8. Governments should encourage motor companies to set up Australian based electric vehicle production facilities