The Oil Drum: Europe
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

Saving 20 million barrels a day. The 100mpg hybrid car should be here, now!

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Introduction

There is an urban legend that goes "car companies are withholding the 100 mpg car". It might not have been true before... and now while not withholding it, the 100mpg is ready - they're just being very very slow to make it and sell it!

For many years the car companies have said the "the batteries aren't ready" (here and here *) and I'm sick of reading it. They are in fact so "ready" that within a few months to a year 3 relativley small automakers (further details below) will be thumbing their noses at the big 4 auto companies as they bring to market electric cars (and a pickup) with 300-700hp electric motors, 100mph+ top speed and 100-200+ mile ranges per charge. Which might lead many to ask, "why are car companies saying the batteries not ready". Meanwhile, several groups of people such as Calcars have been converting various hybrids into Plugin Hybrids capable of in excess of 100mpg (in combined city/highway driving). The technology easily exists for the 100mpg production car. Please, "big auto" just make some yourselves!

* This page at Calcars lists where the various car companies are on PHEVs.

But why do we need the 100mpg car?

Before the Model T Ford became the huge mass production success it was there were apparently more electric cars than hydrocarbon (petrol/diesel) vehicles on the roads (Source). What happened though was improvements in the ICE (Internal Combustion Engine) far outpaced battery technology. However, we are at the dawn of a new age of electric and hybrid electric vehicles that should begin reversing this trend. The technology is here, now. We just await the car companies to put it together into a production car that will give us what we and the World needs a 100mpg+, ordinary looking, reasonably priced, car. If it doesn't happen soon we're going to be in serious trouble as Peak Oil catches Joe Public with their pants down, the proud owner of their crossover SUV pulling into a petrol station with a big "No Fuel" sign in their path. If this happens we're going to see catastrophic economic depression. We in the OECD (Europe, Japan, America, etc.) are rich nations and complain about petrol prices. But in other parts of the World biofuels are replacing food crops (or ancient forests); riots are occuring as governments try to pass on costs to the public; poorer people can't afford oil for their cooking stoves and generators run short leading to blackouts. Capitalism and the market are king - this will happen. Time is limited. The 100mpg car will save us around 20million (Source #1 below) of the 85million barrels a day we use and buy us time, precious time to do whatever else we need to find renewables and alternatives for oil.

Peak Oil will happen. All countries are producing at or near

"Innovations such as the plug-in

capacity causing price rises this summer to approach past highs when hurricanes devastated US Gulf Coast refining production. Replacing the entire fleet of fuel thirsty cars is going to take 10-20 years (time to build the cars and get sufficient take-up to make a massive difference). An often cited report by Robert Hirsch, requested by the US Department of Energy before being buried has already stated we need to act 10-20 years before Peak Oil to prevent an "unprecedented risk management problem". So I beg you, auto-companies, policy makers, governments, read this and other articles here, and act now!

> *hybrid should not have been sitting on the shelf for so long"*
> Rep. Ed Markey, the Massachusetts Democrat who has proposed a fuel economy standard of 35 miles per gallon by 2018 - source

As many commentators have said before, the only thing inhibiting the plugin-hybrid / electric car has been the battery - and as this article will illustrate - the batteries are indeed ready. Electric motors are, after all, now so powerful they rival gas turbine engines for the same weight (gas turbines are so light and powerful you'll find them used in something where weight is even more important than cars - helicopters). As an example, the Tesla Roadster (a car capable of 0-60mph in under 4 seconds) has a motor the size of a watermelon that weighs only 70 lbs (33kg). Electric motors have only one moving part (unlike a car's Internal Combustion Engine (ICE)) are brushless (so no friction, wear or maintenance), relatively inexpensive, and are greater than 90% efficient (a petrol engine is only about 30% efficient #2 source below, pdf .

Tesla Roadster, available Autumn 2007, has an electric motor no bigger than a watermelon

PHEVs would also not strain the grid despite the large amount of electricity it would take to charge one (aprox 10kWh for 30 miles range) as nightly off-peak demand (when people would most likely charge them) is far less than the afternoon / early evening peak time. It has been cited that as many as 4 million PHEV (Plugin Hybrid Electric Vehicles) could be charged in California (source #3 below). In fact, instead of worsening grid conditions PHEVs could actually help balance out the load from the grid. See 'Grid Balancing' below.

Batteries are key - the rise of the Electric Car

Experts say, "The battery is key". So, this as I see it is the path to the electric car, they are big flashing signs telling automakers how good batteries have become. The following is a path to the electric car that shows how increasing battery reliability is taking over from the ICE...

1. Fossil fuel powered cars (a single 12V battery is only powerful enough to run the starter motor)
2. Hybrid cars (comparatively weak batteries, powers car at low speeds only). The Prius is already 10 years old

3. Plugin-hybrid cars (battery powers car at greater speeds). ICE only needed at highway speeds. Even then the electric motor and battery still contribute. First Plugin Prius made in 2004 although Felix Kramer of CalCars has been building them for years before that.
4. Charge depleting hybrid - a smal petrol/diesel engine is not used to drive the car, it is only or primarily used to recharge the battery which in turn drives an electric motor. This is the concept behind the Chevy Volt (corporate site).
5. The electric car. The GM EV-1 made a brief appearance in the 90s. It was produced in limited quantities, never sold, only leased, and then destroyed by its creators as oil prices fell to $10 a barrel / petrol to $1 a gallon and a California zero emission vehicle mandate was killed. While not a big issue for many it was capable of a top speed of 80mph and had a range of around 70 miles on lead acid batteries, or 120 miles on NiMH batteries. It was also a relatively compact 2 seater.

However, the electric car is back with a vengeance... There are at least 3 electric cars in production now - The Tesla Roadstar, the British made Lightning and the Phoenix SUT. There's also a clever 3 wheeled plugin hybrid car/motorbike called the VentureOne that looks nifty. There's even an electric car (with EV-1 performance) due in 2009 from a company based in China - for only £15,000 - that might be enough to scare the big 4 into action! Motorbikes are also getting the electric treatment - there's The Enertia from Brammo, The Vectrix and several others. Creators of small, 2 seater "city" electric cars are also beginning to replace standard lead-acid batteries with the "new" better batteries.

So we're already at stage 5 - and where are the plugin-hybrids and electric cars from the big four automakers? Toyota may have one as early as 2008 (but for some unfathomable reason it apparently uses old technology NiMH batteries). Recently Peugeot-Citreon have announced they may have a diesel hybrid by 2010 which will get a claimed 69mpg, greater than the standard Prius ... but it won't be a plugin. GM however have embarked on some serious green washing after their green credentials got dragged through the mud by last years hit documentary "Who Killed the Electric Car". It didn't help that as recently as 2005 their Vice Chairman Bob Lutz had dismissed hybrids (here, here and especially here) with no thought about the fuel saving (Toyota reckons plugins have saved 215million gallons). But GM *may* now have a "plugin" one in showrooms by 2010 - the so-called Chevrolet Volt which has gained much interest at recent Auto shows. If you do less than 40 miles (and charge it every day) they claim it will never need to be filled up with fuel. GM also claim an incredible 150mpg when driven 60 miles a day. This is pretty revolutionary.

Important note - the Tesla and Lightning electric cars only cost a lot ($92,000+) as they are limited production sports cars - using more batteries than a production electric car would need, and many times more than a plugin hybrid would need. As batteries get cheaper with mass production more batteries could be included in future plugin-hybrids, increasing the range from around 40 miles to 100 miles+ and reducing the ICE to less than 1 litre (the Volt only uses a 1.0 litre 3 cylinder engine to recharge the battery). If you could go 100 miles on an electric charge, and at speeds up to 65mph you would only use the ICE for over-taking / hill climbing, long journeys and on empty motorways.

The "new" lithium batteries... the battery *is* ready!

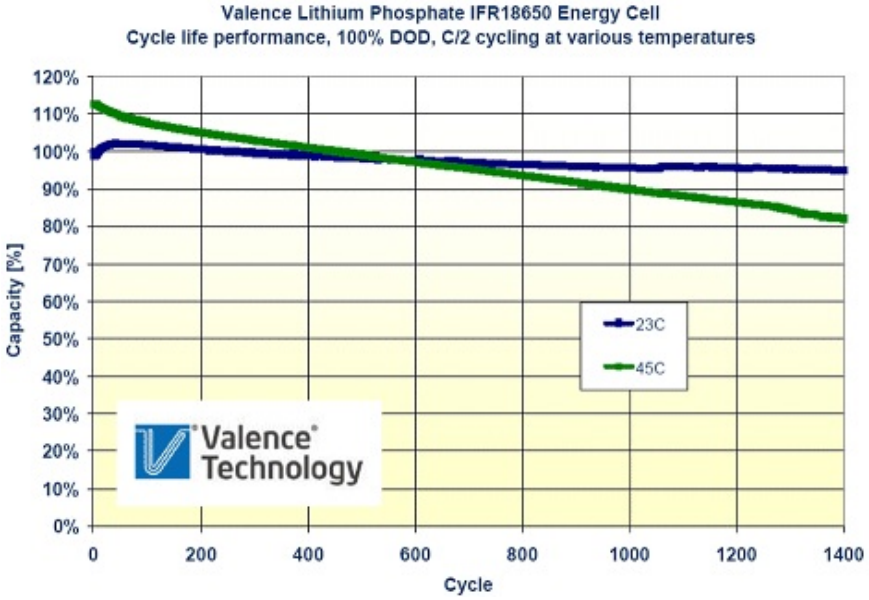
Driven by investment in laptops, mobile phones and other portable devices battery technology has accelerated rapidly in the last two decades. It has now reached a point where at least 3 companies have come out with batteries that are ideal to be used in the production of electric and plugin hybrid cars now, yes now!

These batteries are not your standard laptop or ipod lithium batteries! Standard lithium batteries use Cobalt Oxides ($LiCoO_2$). The Cobalt - Oxygen bond is weak, which can lead to thermal runaway (resulting in the inevitable fire or explosion). Special circuits are found in all of these batteries that carefully monitor charge levels. Errors in production have led to the recall of

literally millions of units after some serious battery fires left some users with second degree burns. Many site this excuse as a reason why they haven't been used in cars yet they seem to forget cars carry flammable fuels and can catch fire in accidents.

The new battery chemistry uses Lithium, Iron and Phosphate and Oxygen ($LiFePO_4$) as the cathode material. The Fe-P-O is far stronger than in the standard battery - they are also more structually stable (see here for further reading). The batteries go by several names depending on the company; Nano Phosphate, Lithium Iron Phosphate or Lithium Iron. I like the double meaning of LiFe myself (an acronym of the chemical name of Lithium and Iron). This Science News article proves that the technology has been around for over five years now.

The first one of the three companies I actually came across was Valence Technology and their patented "Saphion Lithium Iron" technology. The graph below is taken from their updated tests (which they kindly supplied me with). At 230C (probably typical Northern Hemisphere temperatures) you can see the capacity is still around 97% after 600 charges and 95% after 1400 charge cycles. You can read more about the vehicle sized cel packs here.



Valence U-Charge battery performance. Source, pdf

The A123 Systems battery can charge to 90% capacity after approximately 2300 charges (86% after 3800) according to this graph.

These numbers are revolutionary. Even if your car has a small battery pack (plugin hybrid with 40 mile range) and you only drive it in town as an electric vehicle your battery is going to last 40x2300 miles (an amazing 86,000 miles on PHEV power alone) and the car will *still* go to 90% of the distance it could on a charge when new (36 miles instead of 40)! It seems the battery will outlast the life of the typical car on the road today. If your car is an electric car (with more batteries) and you can do 150 miles a charge it will be 90% as good-as-new after an astounding 345,000 miles! 2300 charges at one charge a day is also more than 6 years. The Phoenix SUT uses Altair Nano's battery and is expected to last 250,000 miles / 12+ years.

The Segway company adopted Valence's battery technology and it more than doubled the range to 24 miles of their electric, 2 wheel vehicle while halving the weight *and* the charge time. Valence's batteries, like the other 3 companies, are also safe. Very safe. You can *seriously* abuse them (pierce them with a nail, crush them, shoot them, etc) with no risk of fire or explosion! Valence's website has a video on its site demonstrating their batteries alongside standard lithium batteries. The standard ones look like a cross between a fire cracker and a flame thrower when damaged!

Valence has been around 15 years and may be in the lead currently with their batteries in plugin hybrids and electric motorbikes, but its competitors Altair Nano and A123 Systems are snapping at their heels. A123 seems to have serious industry backing and has signed major contracts with GM for the Volt.

Their batteries have the safety and life of Valence's but boast:
a. an incredibly fast recharge times of as little as 1 or 5 minutes to around 90% capacity!
b. a charging/operating temperature range from -30C to 65C (exceeding the -10C to 50C of Valence) - easily good enough for the coldest winters and hottest summers)
c. even greater capacity and current (though Valence has a newer generation in development with twice the power/duration of the original packs).

You won't believe how powerful these batteries are. The Killacycle motorbike using A123 Systems batteries claims the battery pack weighs only 161 lbs but delivers over 350hp from a 1575 amp battery pack with 7.5kWh of storage. There's a nice video on YouTube of it doing the quarter mile from a standing start to 155mph in 8 seconds!

The plugin hybrid - the 100mpg+ car/SUV

The plugin hybrid is a normal looking car which can achieve in excess of 100mpg on a "typical" mixed city/highway journey. People have already modified the standard Prius to prove it and are reporting mpg from 100mpg to as high as 250mpg. 135mpg is quoted at this source. But 100mpg is typical with a typical 20-30mile range battery pack people have been installing.

The plugin hybrid has the advantage that it can be both an electric car (zero emission, quiet, cheap to run, and non-oil dependant) and at the same time, a normal petrol car. If your commute is at non highway speeds and under 20 miles a day then you may hardly ever need to fill up with petrol. The exact speed and distance will only depend on the balance of engine size to battery size. Put in more batteries and you can get a purer electric car. Put in fewer and you might be limited to a 50mph (light acceleration) 20 mile electric range only ... before the petrol engine seamlessly kicks in. If you don't charge it then it would perform the same as a normal hybrid car and only charge itself via regenerative breaking - running the motor backwards to charge the battery when you press the brake lightly (note if you slam on the brake it has normal brakes too!). On the other hand if you charged it daily, ONLY drove short distances at non-highway speeds, didn't floor the accelerator it would be a pure electric car with an almost infinite mpg - comparable to the Chevy Volt!

Note - as well as regenerative breaking, hybrids save gas in two other ways. They turn the engine off when the car is not moving, even when the AC is on. As idling wastes approximately half a gallon an hour (1 gallon for trucks, pdf) this can be significant in long jams. Thousands of cars trying to flee New Orleans in the path of Katrina ran out of gas in stationary traffic! In slow moving traffic / gentle acceleration they also don't need to run the ICE making them "light" EVs.

Plugin Hybrid Stage 1

The Hidden EV Mode

Hybrids such as the Prius and Lexus RX400h can run in all electric mode. The Prius sold in Asia and Europe has a button labelled "EV" which causes the car to run for about 1.5 miles as an electric vehicle without triggering the ICE to come on first (useful for tiny trips, parking, crawling traffic, etc). Now 1.5 miles is pretty rubbish. Some clever folks figured out that all 2004 and later Prius models could do this, you just need to follow this guide.

The low mileage is because the NiMH battery pack is both under-powered (1.3kWh) and deliberately crippled to only use some of its capacity. The reason is not some conspiracy to stop

people saving fuel, it's apparently done to ensure battery life (source A and B). So as to guarantee the hybrid synergy drive (including the batteries) for 8 years and 100,000 miles it can only run the battery down to 40% (from only 80% max) capacity before it tells itself too much of this will hurt the longevity of the battery. It's also of course underpowered to save on weight and cost and as it's only really designed to power the car at very low speeds (limited electronically to 34mph max).

Plugin Hybrid Stage 2

28x the range of a Prius battery - same volume, same mass!
Calcars wrote some battery management software, added a charging socket and replaced the standard 1.3kWh NiMH pack with some lead acid batteries (later 9kWh worth of Valence's Saphion® battery) - a battery not much bigger than the NiMH one but obviously more energy dense, and equally lightweight which can use nearly ALL of it's available capacity so called "deep discharge/cycling" or cycling which damages ordinary batteries. New lithium batteries can run from 0-100% DoD (Depth of Discharge) without damage to the battery life/capacity.

The standard NiMH battery cannot deep discharge and only uses 0.3kWh of it's available capacity. So what you get is a factor of 4 gain (the percent used) multiplied by the increased capacity (9 / 1.3 = 7) 4x7 and you get a battery about 28x as powerful. Your 1.5 mile range car now goes 30-40 miles in electric mode!

The electric motor is still the same, with a rating of 67hp / 50kW (kilo-watt) so it is limited to about 35mph in electric mode before the engine kicks in.

Toyota were apparently so impressed when they heard about the work of CalCars on improving their car they borrowed it for a week, flying it to their lab in Japan to test before returning it intact.

After market companies like EnergyCS, AmberJac and others will fit a 9kWh, 230volt, 40Ah battery pack to a standard Prius. This site has a table comparing the different after market companies. Calcars also lists these companies that will enhance your Prius for you... turning it into a full PHEV vehicle!

Toyota - Very good and very stupid

Yes, they are developing a plugin-prius - there are pictures and even some video from Japanese TV on YouTube.

You can read the mixed feedback on this blog - The feedback is mostly bad as although they're doing a PHEV they're still using the now "rubbish" NiMH batteries. In fact, two sets of the same battery pack, just connected in parallel!

They're not using any of the above "wonder batteries" and not surprisingly they're getting poor performance (a rather feeble 8mile range) but a top electric-only drive speed of 62mph (though I suspect this means accelerating very very slowly to prevent the ICE kicking in). Maybe NiMHs are dirt cheap now. I understand the battery company is part of the same parent company. Maybe, as this is just a new model Prius, they don't have the engineering budget to try anything too new, like better batteries. Or maybe being a big corporation, it "turns" like the proverbial oil tanker and they are being too cautious. Hopefully they'll wake up, soon! They seem to have competition from GM coming their way.

Okay, we can give some credit to Toyota for coming out with the Prius, popularising hybrid cars, proving the technology can work, coming out with some remarkable innovation while being very reliable (if it wasn't they wouldn't give a 8 year, 100,000 mile warranty on the battery and the

hybrid system!). However the car achieves only the same mpg rating as some small sized diesels in Europe (where diesel vehicles make up to 50% of new car sales).

What's interesting is that the Hybrid Synergy drive is now being used besides engines far larger than the Prius one (1.4 litres). It's alongside a 2.4 litre one in the Camry, and a still larger one in Toyota's sister company inside the Lexus RX400h. Instead of improving the battery and shrinking the petrol engine it's now just being used to make even more marginal reductions in fuel economy and to increase horse power. I'd like to see them putting the technology in their smaller cars alongside a diesel engine - otherwise they're going to find themselves overtaken by European rivals.

Fast charging. The "Gas" station does not need to be a relic of the 20th Century...

Due to the low current capabilities of the domestic electric grid, charging a battery as big as a car's in an incredibly fast 5-10 minutes (as the Lightning, and Phoenix both claim on their site) isn't possible at home. You would need to have a circuit capable of 100s of amps and most home circuits in the UK run on 13 amps and upto 45 amps if you have a separate cooker or electric shower circuit. You could trickle charge the car at home overnight and fast charge it at a charging station. I imagine green-field office sites, car parks and petrol stations would be ideal locations, maybe even some motel stations would install one to encourage motorists to stop there.

However, with a pack even as small as the typical PHEV's 9-10kWh charging in 5 minutes would require a massive load of 120kW! That's the same as 1200 100watt light bulbs or 40 kettles all running at once. It's also the average use of about 90 houses (averaging 1.5kW) - and that would be to charge just one car at once! Imagine a filling station with 10 of these and the demands on the local grid might be quite heavy. So I would assume a petrol station located near an electricity sub-station would have an advantage! On the other hand once enough petrol stations and other sites installed quick-charge stations the limited electric range of electric cars quickly vanishes as an issue.

Also a charge time under 5 minutes is about the same as an average person spends fuelling a car and paying for it, which makes forecourt charging of electric cars a real possibility. Other people have suggested that the batteries could be interchangeable at gas stations (take out the flat one, put in a charged one) but personally I could never see this working for everything from warranty reasons to the customised location, shape, make and capacity of batteries.

Grid balancing - is there nothing the electric car can't do?

Given the remarkably high density of energy in the batteries it could be possible to run your household electricity supply off the car during times of brownouts / blackouts. You could also sell electricity back to the grid during peak times and help "load-balance" the grid if you wanted to make money. V2G (Vehicle-to-Grid) will become increasingly necessary in the future as electric grids are put under strain from reduced fossil fuel availability.

Some people with solar / wind-power units such as the WindSave have devices installed by the electricity company that enables them to do just that.

Peak electricity demand is met by the most expensive power stations making peak-demand electricity expensive and something grid companies may be happy to buy back.

Nuclear and coal power plants can't increase or decrease their demand quickly and of course these are the ones now being considered in many countries as oil and gas (which can respond quickly to demand) first increase in price then run out. Electric car / plugin-hybrid could both smooth out the troughs in the grid (charge the car during cheap, off-peak times raising demand)

and help with the peaks (supply the grid during peak hours), lowering demand. The grid already uses a method of storing capacity and releasing it in the form of 'Pumped Storage' hydroelectric dams. These draw electricity during off-peak time, pumping water uphill into a reservoir - then at peak times they flow normally.

The evolution of batteries

- Lead Acid - used in 1920's electric vehicles is very old, heavy (due to the lead)
- Nickel Cadmium (NiCad) - Lighter. Cadmium is classed as a heavy metal (not weight, just toxicity). Has a "memory effect" which means capacity can be reduced if not charged/discharged correctly. Found in cheap portable devices.
- Nickel Metal Hydride (NiMH) - Better than NiCad, no heavy metals and a much reduced memory effect problem. Capacity has been increased with each new generation (typical AAs now are rated at 2500mAh, earlier ones were below 1000mAh). Found in the standard Prius.
- Lithium Ion / Lithium Polymer - Very energy dense and powerful. But highly flammable and explosive if abused. Lithium polymer batteries are small Require a small circuit to control charge. Found in laptops, new mobile phones, ipods, etc.
- Lithium Iron / Nano Phosphate (aka: LiXxx) - Energy density similar to Lithium Ion, safe when physically abused, light, exceptional life and deep cycle charge capability, large operating temperature range

"Forget hydrogen, forget hydrogen, forget hydrogen"

James Woolsey, former head of the CIA (source)

The reasons for this have been covered in other articles, but to summarise the key points:
1. Hydrogen despite being one of the most abundant elements in the Universe exists nowhere naturally on Earth as pure hydrogen!
2. Hydrogen needs to be stored in a solution or under extreme pressure, around 5000psi (pounds per square inch) to store enough to make it go a comparable distance to a normal car, eg. the Honda FCX concept car.
3. It exists in massive quantities on this planet but not in ways we can get at without expending more energy that might as well be used to fuel vehicles
4. Hydrogen is the smallest element so it is a devil to keep stored and literally leaks out of everything through the tiniest hole. The engineering quality and sealants need to be exceptionally engineered to keep the leaking to even a moderate level! These are the two processes for making hydrogen:
1. from water - which requires electricity.
2. hydrocarbons (fossil fuels).Until we have abundant almost free electricity or abundant fossil fuels (as if) we're not going to see a hydrogen economy! It's that simple. Both processes of producing hydrogen are not very energy efficient (about 50%). Storing electricity in a battery is >90% efficient. However, the reason hydrogen is still mentioned as a possible fuel can be summed up as follows:
1. Oil companies love hydrogen. The main source of hydrogen is natural gas. Oil companies own natural gas fields. Hydrogen could be sold from the typical forecourt filling station the same way as petrol is so they don't lose their business model if hydrogen succeeds.
2. Car companies like hydrogen. The technology needed to overcome so many hurdles to be economically viable means they don't need to consider it seriously.
3. It sounds green. When burned, it combines with oxygen to produce only water!
4. Car companies can reassure current gas guzzler wanting consumers that they're working on it, and "when oil runs out" we'll use hydrogen - but it's 20 years away (ie. at least the length of time you're going to own the 4x4 I'm trying to sell you).
Note - even recently, car companies such as BMW have been touting hydrogen as the future.

FAQ - Answering common questions

Q. What is the cost of electricity compared to filling up at a gas tank?
A. Tesla Motors site the cost of charging their car at a very cheap $0.02 a mile. Pluginpartners quote a per gallon price of about $1.00. So, about 1/3rd the current price per gallon. This is actually the highest estimate I've seen. As the electricity grid is less dependant on imported oil the price differential is not likely to decrease in this author's opinion.

Q. Won't power from the grid (to charge the cars) produce additional emissions?
A. What people call "well-to-wheel" emissions for grid-powered vehicles is far lower than gasoline (source), even for the US grid (which is 42 percent coal). Cars charging off-peak will use power from plants that may not be able to turn off at night. Also many parts of the country get most of their power from cleaner sources like natural gas and hydropower (and arguably nuclear). It's also far easier to improve the emissions of a few centralized power stations than millions of aging cars. Plug-in hybrids recharged from clean energy companies or domestic rooftop photovoltaic / wind systems will be true zero emission vehicles.

Q. What about the weight of the batteries?
A. The batteries will not add much to the weight of a car. Lithium technology batteries are very light. Steel and the engine are the heaviest thing in cars, and the engine and gas tank wouldn't need to be as large in a plugin-hybrid. Also note that 1 litre of fuel weighs about 1kg. 20gallons of "gas" in a gas tank is around 170lbs / 80kg of deadweight. The batteries would weigh about the weight of an average passenger and be low down, increasing stability. The Killacycle motorbike has a 10kWh pack (which would give a 30-40mile EV range in a car at 200-300Wh/mile) and it weighs 161lbs (75kg). A full EV vehicle may have a much larger pack but it dispenses with other heavy components such as the engine, gas tank, gears, starter motor, and other things you'd find under the bonnet of your average car. This page lists the additional weight of various battery packets after-market companies are fitting to the Prius.

Q. But won't two engines and other components increase the cost and weight of the vehicle?
A. This is not necessarily true. There are many things a hybrid / plugin hybrid doesn't need. The Prius does not need a clutch, step gear box, torque control, separate starter motor or alternator. As mentioned earlier, the existing engine and fuel tank would also not need to be as large. Hybrids are currently fitted with smaller engines than their petrol-only equivalents saving weight, space, fuel and cost. In plugins such as the Chevy Volt which have a larger battery pack the engine would be rarely used. Electric vehicles have few moving parts and therefore require almost no maintenance (spark plugs, oil changes, etc) so service costs will be less. The thousands of pounds in fuel savings of a full plugin hybrid are likely to offer a quick payback period.

Q. Why not put solar cells on the roof? Won't they help?
A. You'd need a roof larger than a house to get enough charge to move the car at low speeds. Solar cells are also energy intensive to produce and therefore costly. Solar cells convert only about 15% of the suns energy that falls on them. A whole day in the sun would barely trickle charge the car enough to give you a single mile of additional range. Until efficiency improves and cost falls solar cells are very inefficient with a long payback period.

Q. They're only in sports cars - so the batteries must be expensive!
A. Sports cars cost a lot as they are made by companies producing only a few hundred a year. They have limited "economies of scale" as nothing can be "mass produced", a lot is built by hand. They are also over-powered (being sports cars), using more batteries than a consumer car would need, and far more than a plugin hybrid capable of 100mpg would need. The batteries aren't the main cost in these $100,000 cars.
Mass production (if a big 4 automaker adopted the technology) would help the price fall rapidly. There is, of course, the running cost to consider. While the car may cost more, you would save

money every time you drove past a petrol/gas station when you would normally be filling up.

Q. So roughly, how much do the batteries cost?
A. Probably around $5000, £2500. Although that would depend on the electric range you need, and this is before mass-production. Currently companies charge about $12,000 / £7000 to convert a standard Prius to a Plugin-Prius (and make it a 100mpg+ car). But that covers their time and expenses and replacing the old batteries, installing the new batteries, some new battery management equipment and adding a plug-socket.
Remember that while adding a hybrid drivetrain costs money there will be other cost savings (beside the savings at the gas station). The petrol/diesel engine doesn't need to be even half the size and car engines are heavy (electric motors have incredible torque that starts at 0rpm. This helps with fast acceleration and the highly important 0-60 time).

Q. Would an electric heater or AC be too much for the battery?
A. An electric heater rated at "half a bar" 0.5 kW/hour would run down a typical battery of 9kW in 18 hours - but that is far more than would be needed to keep the passengers warm (a car is a very small, insulated room). I also imagine that just like with conventional cars they'll run a heat exchanger around something warm (the electric motor or battery instead of the exhaust) to direct heat to the passengers if required. The Prius can run its AC unit without the engine being on - and that has a tiny battery (40% of 1.3kW usable).

Further Sources

#1. Note - 9.2 million barrels (388 million gallons) a day of America's 21 million barrels a day oil consumption is used for vehicle transport. Source, MSNBC.
America uses 1/4 of the World's 85 million barrels a day. It is therefore logical to assume at least three times that amount is used in total throughout the rest of the World (aprox 30 million barrels+ in vehicle transport). Increasing fuel economy from 20mpg (USA average) and 30mpg Europe/Japan average to 80mpg would save 2/3rds of that 30 million barrels.

#2 http://www.hydrogenassociation.org/general/fleet_Module4.pdf
Gasoline ICE Efficiency Rule of Thumb: 30% output power, 30% heat loss in exhaust, 30% heat loss to coolant, 10% heat loss to radiation.

#3 http://www.sonyclassics.com/whokilledtheelectriccar/electric.html
Finally, some energy experts and utility analysts contend that millions of plug-in hybrid electric vehicles could be added to California's fleet without substantially impacting the state's current energy grid, since most of the charging for the plug-in hybrid electric vehicles could be done during off-peak hours, at night. [29] . It's estimated that 5,000 plug-in hybrids charging at night would represent less than 0.1 % of peak electrical demand in the state. [30] Moreover, they would also have strong beneficial environmental impact, since a plug-in hybrid vehicle that gets its energy from the grid during off-peak hours is thought to produce one-third the carbon dioxide emissions of an exclusively gas-powered car with a fuel efficiency of 24 mpg.

Note the Tesla uses approx 6800 standard laptop batteries, not batteries from any of the 3 (Altair, Valence, A123) battery companies mentioned. However, it uses various systems to increase the safety so if a single cell failed others wouldn't.

Additional Reading

- http://www.calcars.org/carmakers.html Calcars summary of what the various automakers are doing on PHEVs.
- http://www.evworld.com/ A site listing developments in Electric Vehicles
- http://www.pluginpartners.org A grass-roots campaign site, bringing together companies who

want PHEV fleet vehicles
- 'The Guardian' article on the Tesla car.
An article in a UK tabloid recently about the Lightning "*The electric car that's faster than a Ferrari*".
- BBC article on the revival of the electric car: EV1, Tesla, X1 http://news.bbc.co.uk/2/hi/programmes/click_online/6940007.stm
- Excellent resource about the inner workings of the Prius: http://www.ecrostech.com/prius/original/Understanding/PowerTrain.htm
- Brilliant, eye-opening article about the rise of the SUV during the late 1990s when oil prices and fuel economy fell, and how (no joke) cup-holders are essential to perceived safety.
- Google and YouTube - search for things like PHEV, Plugin, Plugin Prius, etc. Google also has news alerts you can subscribe to on any keyword. It will trawl the news sites each day and email you the top stories matching keywords you're interested in. I recomend this for keeping up on new developments.

PS. I do not currently own shares or have any financial interest in any of the companies listed here.

PPS. I don't own a Prius. I own a 10yr old Vauxhall Astra 1.6, it gets about 40mpg
One day I hope to replace it with an affordable 100mpg+ PHEV