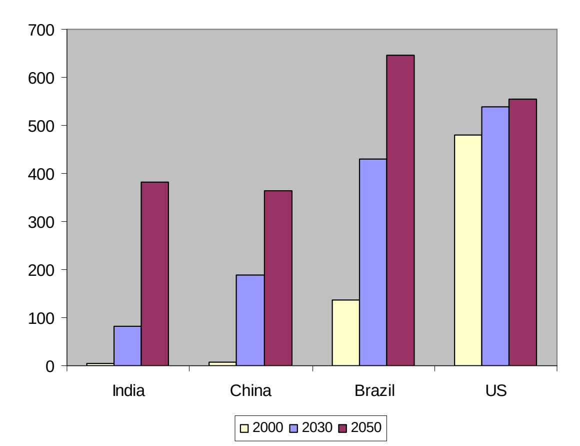
CLEANING THE CAR: A GUIDE FOR INVESTORS

Transport is the cause of a growing share of emissions, a trend that is expected to continue as car ownership grows in emerging markets such as Brazil, China and India (see figure 1). Next year is expected to see global vehicle sales of 72m units, according to General Motors. As a result, regulation to improve fuel efficiency and cut emissions is becoming more stringent. New Energy Finance examines the wide range of business and investor opportunities that will result.

Fuel for road transport is overwhelmingly petroleum-based and this is likely to continue in the short term, so the first measures will involve improvements to gasoline and diesel engines and developments in biofuels. Biofuels will only ever be a partial solution to transport's pollution and emission issues. Ultimately, electricity and possibly hydrogen will be important fuels for cars, with consequent knock-on effects on transport and power generation infrastructure.

Figure 1. Projection of car ownership per 1,000 people

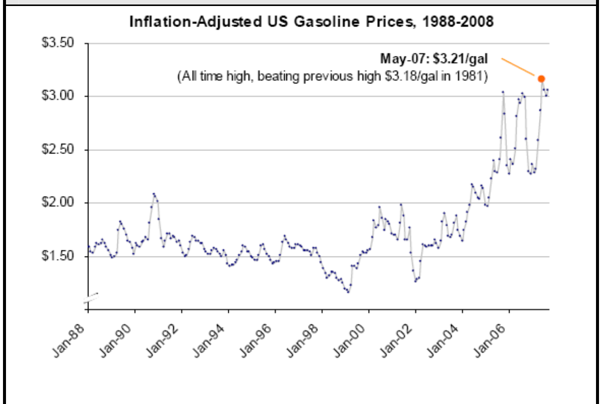


The King Review of Low Carbon Cars, 2007

Driving forces

- Car ownership is growing rapidly, particularly in emerging markets, at a time of increasing focus on the emissions caused by transport and increases in fuel prices.
- Regulations on emissions from cars are becoming stricter around the world, led by the EU and Japan, which is demanding emissions of no more than 120g/km CO_2 (equivalent to about 43mpg) by 2012. US CAFÉ standards are set to be revised sharply upwards in 2011 as part of the Energy Bill signed by President George W Bush before Christmas, while several states led by California are looking to impose even stricter standards.
- The overwhelming majority of cars are still powered by gasoline or diesel, so in the near term, improvements will come from refinements to internal combustion engines and the limited use of bioethanol (as a replacement for or additive to gasoline) and biodiesel (as a replacement for or additive to diesel).
- Improvement in fuel efficiency of up to 30% (a saving of $600-$1,000 per year for a 10,000-mile a year driver) could be gained by adding a range of measures costing $2,000-$3,000.
- In the medium term, hybrid technology will become more commonplace, both for gasoline and diesel engines. A number of analysts suggest that the most effective short-term technology for improving fuel economy will be diesel-hybrids.
- Plug-in hybrids provide a natural bridge to an electricity-fuelled transport future and, with the right policy support, could help to make the development of renewable energy sources more cost effective by increasing demand for electricity generated off-peak.
- The development of powertrain technology for plug-ins may produce a modest fillip for the cause of fuel cell cars. However it is not clear to what extent fuel cell and electric cars can co-exist in the long term. The infrastructure for electric cars is already in place and if electricity generation becomes decarbonised, why would anyone go to the expense of building a hydrogen infrastructure?
- The widespread adoption of electric cars is dependent on improvements in the weight, range and costs of batteries, however.

Figure 2. Real US gasoline prices 1998-2007



Source: Innovest Strategic Investment

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Context: a growing share of emissions

Transport is responsible for about 15% of global carbon emissions and as much as 30% of emissions in the US and Europe. As the world economy expands, vehicle sales are set to grow rapidly, particularly in emerging markets such as China and India. Even in places where growth is less spectacular, such as Europe, journey distances are growing and congestion is increasing. Road transport fuel is overwhelmingly petroleum-based (99% of road fuel in the UK is either diesel or petrol, for example). According to the King Report on Low Carbon Transport, a UK Government-commissioned report published in 2007, "[diesel and petrol] dominate because they meet most of the criteria for what makes a good fuel. They are energy dense, easily storable, non-corrosive and tend to be inexpensive relative to the alternatives. Moreover, decades of "learning-by-doing" have helped make the production, distribution and use of petrol and diesel increasingly efficient. However, because of their chemical composition, they produce CO_2 when burned."

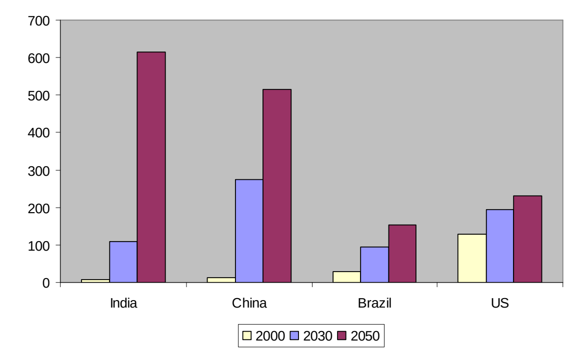
As a result, road transport is one of the fastest growing sources of emissions around the world, outstripped only by aviation.

In addition, the price of oil has not only soared, it is also incredibly volatile – in 2001 it was less than $20 a barrel, while 2007 saw it pushing $100, with a rise of almost $30 in one quarter. A variety of factors has pushed the price up and destabilised the market, including political instability in the Middle East, increased demand from the emerging giants of Asia, China and India and a lack of investment in exploration over the past decade as a result of low prices at the time. A further factor has been the depreciation of the dollar, but that has acted to limit the effect of price rises outside of the US. All industrialised countries have fears over energy security as a result of increasing reliance on unstable and potentially unfriendly suppliers in Russia, Venezuela and the Middle East.

Meanwhile, the concept of carbon pricing has, after a slow start, gained increasing prominence and major automotive markets either have, or are planning to introduce, some form of emissions trading. The EU Emissions Trading Scheme's second phase starts in 2008 and its scope is increasing all the time, with plans under way to bring aviation into the scheme within the next five years. A number of states in the US are also introducing schemes, notably two coalitions – one involving 10 north-eastern states (the Regional Greenhouse Gas Initiative, which initially will only include power producers), the other led by California and comprising seven states and the Canadian province of British Columbia. Even where road transport is not included, such schemes highlight the carbon footprint of the sector and increase pressure to mitigate it.

All of these factors make emissions from transport one of the most urgent issues for policymakers, car manufacturers, fuel providers and consumers. As a result, there are great opportunities to be had in reducing the fuel consumption of vehicles in the short, medium and long term.

Figure 3: Projection of total cars owned (millions)



The King Review of Low Carbon Cars, 2007

Technology	Advantages	Disadvantages	Timescale/investment opportunities
Gasoline	Established infrastructure and technology; cheap; further efficiencies to be gained through technological improvements and use of biofuels	Less efficient than other technologies, most directly affected by fuel price rises and efficiency regulations	Short-term, mainly for established, publicly-quoted carmakers
Diesel	20%-30% more fuel-efficient than gasoline. Big growth potential, particularly in US; opportunity for greater efficiencies through use of biofuels	More polluting than gasoline so subject to more stringent regulations and more costly. Some consumer resistance in US	Short/medium-term, mainly for established carmakers
Hydrogen Combustion	Zero emissions at tailpipe. Easy to convert gasoline engines to burn hydrogen.	Lack of infrastructure. Less efficient than fuel cells, and shifts CO_2 emissions to a central site as H_2 must still be produced from hydrocarbons or H_2O electrolysis.	Medium-term. BMW is chief proponent of this technology, with Honda and Mercedes also keen.
Gasoline hybrid	Established technology offering acknowledged mileage improvements. Makes best use of available infrastructure and overcomes many advantages of batteries. Proven sales potential – Toyota has sold more than 1m Prius units.	Still quite expensive – mileage improvements easier to come by through other measures and by driving smaller cars.	Short/medium-term. Established car-makers such as Toyota, Honda, Ford and GM. Still possibilities for VC/PE in battery technology, while many companies are likely to come to market
Diesel hybrid	Offers even bigger fuel savings than gasoline hybrids. Technology already in use on buses, railways and earth-moving equipment.	Some problems with noise and vibration. No cars yet commercially available.	Medium-term. Big carmakers and their suppliers, such as Peugeot, Bosch and Valeo
Plug-in hybrid	Offers possibility of massive mileage improvements. Can boost cost-effectiveness of renewable energy and electricity grid if transport seen as part of integrated energy system.	Battery performance, recharging time, range and infrastructure remain inadequate. Massive structural overhaul required.	Medium/long-term. Opportunities across the value chain from established carmakers to battery-makers to renewable energy providers.
Battery Electric Vehicles	No emissions, can be very low carbon if renewable energy is used to charge batteries, so could boost renewables industry. Ideal in cities.	Range, weight, low speeds and recharging time remain issues, as does cost. Lack of infrastructure is also a major barrier.	Medium/long-term. Opportunities for VC/PE investors and for small groups to make a breakthrough. Public markets opportunities likely in longer term.
Fuel Cells	No emissions, no pollution. Hydrogen could be a cheap, clean and plentiful replacement for fossil fuels. Technology has advanced greatly in recent years and is close to a breakthrough.	Lack of hydrogen infrastructure is a real barrier to development. Hydrogen produced from fossil fuels is no real solution.	Medium/long-term. Opportunities throughout the value chain, from carmakers to public companies such as Ballard to start-ups and early stage companies.

Table 1. Clean car technologies

New Energy Finance

1. Technologies

The urgency of the climate change problem, fears over the shortage of oil and a belief that the extent of regulation will become more stringent and more widespread has led to a number of technological solutions being put forward. Some are massively complicated, some are relatively simple. Because there is a global infrastructure devoted to the provision of petrol and diesel, solutions based on existing vehicles and fuels are easiest to implement. “Essentially internal combustion (IC) will be the dominant technology for many years to come,” says Dr Paul Nieuwenhuis, co-director of the Centre for Automotive Research at Cardiff University.

Simple solutions

The next round of car models, and, in some cases, current models, are likely to include some of the technologies below. The King report suggests that the average new vehicle could be 30% more efficient than the equivalent model today, at a cost of about $2,000-$3,000 per vehicle. This would save a driver travelling 10,000 miles a year $600-$1,000 a year, giving a payback of three to five years.

- stop-start – this cuts engine power when the car is at a standstill, and starts up the engine when the driver places the car in gear to pull away; Mercedes is among the companies involved in stop-start, planning to introduce it from late 2007, while at the other end of the scale, Citroens and Fiats will also use the technology.
- direct injection – this ensures that the fuel is burnt more efficiently; Bosch is one of the leaders in this field, although Mitsubishi was the first to introduce the technology in mainstream cars in the 1990s. Siemens VDO, Delphi and Denso are also involved. A joint venture between BMW and Peugeot has developed a range of direct injection engines, as has Porsche.
- variable valve actuation – this optimises the way in which fuel enters the combustion chamber of the engine; car parts maker is working on electronic variable valve actuation.

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- boosting (turbo/supercharging) – these technologies pressurise air in the fuel mixture to increase power. This means that the same power can be achieved with a smaller engine; the technology has been around for years.
- regenerative braking – this captures the energy otherwise lost as friction when a car slows down, in electrical form and it is already a key feature of many hybrids.
- electrical motor assistance – an electric motor provides assistance to the internal combustion engine, reducing the amount of petrol or diesel used.

A number of non-propulsion measures can also reduce fuel use.

- fuel additives – when added to an engine, these products, made by companies such as Oxonica, can improve fuel efficiency.
- lightweighting – using less steel and more aluminium, carbon fibre or other lightweight materials reduces fuel consumption. The easiest way to do it is to use a steel sub-frame and plastic outer panels. Ferrari has produced a lightweight concept, the Millechili (= 1000 kg). Compared with the current, and already legendary, Enzo, the new car is 1000mm shorter and 300kg lighter, which means it can use a smaller engine (V8 instead of V12, 550hp instead of 800hp) and still be faster than the current supercar. CO_2 emissions drop from 400g/km to 250g/km.
- low rolling resistance tyres. Michelin was among the pioneers of these products. Its Energy Saver tyres will be fitted to the new Peugeot 308.
- improved aerodynamics.

Table 2. Simple ways to cut fuel consumption

Technology	Efficiency saving	Cost per vehicle ($)
Direct Injection and Lean Burn	10-13%	**400-800**
Variable valve actuation	5-7%	**350-500**
Downsize engine capacity with turbocharging or supercharging	10-15%	**300-600**
Dual clutch transmission	4-5%	**800-1,200**
Stop-start*	3-4%	**200-400**
Stop-start with regenerative braking*	7%	**700-800**
Electric Motor Assist*	7%	**2,000**
Reduced mechanical friction components	3-5%	**Negligible**
Lightweighting	10%	**500-1,000**
Low rolling resistance tyres	2-4%	**100-200**
Improved aerodynamics	2-4%	**-**

*Figure quoted is for whole drive cycle. Savings are much greater in urban driving conditions.

Source: The King Review of Low Carbon Cars, 2007

There are also a number of companies producing equipment that enables diesel engines in trucks to be converted to run on mostly natural gas. While the problems of fossil fuel usage remain, companies such as Clean Air Power and Westport Innovations say their technology allows trucks to produce fewer emissions and run more efficiently. Westport also suggests that, through its Hydrogen-enriched Compressed Natural Gas technology – which improves combustion – it acts as a natural bridge to a hydrogen economy.

Internal Combustion Engines

As a result of fears over emissions and the trend for more stringent regulation on fuel efficiency, vehicle makers that are developing small, efficient powertrains, clean diesel engines, and petrol-electric and diesel-electric hybrids are best placed to gain market share, with emerging markets and Europe set to see growth in small cars while hybrids and clean diesel gain traction in the US. We expect small, traditional powertrains to see continued growth in Europe and the emerging markets, and hybrid and clean diesels to see the strongest growth in the US. "The auto industry must now rapidly retool to focus on fuel economy – an optimisation neglected for two decades while safety features, and size took centre stage. The traditional simple gasoline engine will be speedily phased out over the next two decades in favour of gas-electric hybrids, plug-in hybrids, and clean diesels," says Innovest auto analyst Dan Moran.

Gasoline

Opinions are mixed as to the future of the gasoline engine. The world's automotive fuel infrastructure is set up to serve petroleum power, which builds in a certain amount of inertia to the system. Dr Nieuwenhuis says: "Essentially internal combustion will be the dominant technology for many years to come." Ultimately, however, many analysts believe gasoline engines will disappear in the face of increasing fuel efficiency standards and high oil prices. However, there remain some efficiencies still to be teased out of the conventional internal combustion engine, from the measures outlined above. The preponderance of ethanol among biofuels, which can be blended with gasoline up to 10%, will also boost its staying power.

Case Study 1. Combining technological solutions

During 2007, the MINI has undergone a technology revision consisting of the following elements:

- Brake energy regeneration – combined with an intelligent alternator that engages only when required. The system also uses energy from the engine on over-run (braking or hill descent) to charge the battery.
- Stop-start – on manual transmission models
- Change point display – indicates to the driver the optimum point at which to change gear

The combination of these technologies allows the MINI Cooper D to return 72.4mpg with CO_2 emissions of 104g/km – the same as a Toyota Prius. This technology push is not cheap. BMW's R&D costs rose by nearly 40% to €835m ($1.12bn) in the second quarter of 2007, making its net profit fall 4.3% to €753m.

Source: Car CO2 Reduction Feasibility Assessment; Is 130g/km Possible? Paul Nieuwenhuis

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Diesel

Intrinsically more fuel efficient than gasoline, by 20-30%, diesel is the choice of more than 50% of new car buyers in the EU. There is no tradition of diesel cars in the US, where concerns over emissions have restricted the fuel to trucks and trains. However, improvements in technology have made diesels much more user-friendly and sales in North America, where diesels account for only 3.8% of cars at the moment, are likely to soar. However, diesel engines cost twice as much to make as petrol engines, the King Review says, and the efficiency differences are likely to reduce over time. Renault plans to have clean diesel cars on the market in Europe and emerging markets within two years, while Germany's VW is poised to be the first to have a clean diesel product that will meet US standards, followed by compatriots Daimler and BMW.

Hydrogen combustion

Hydrogen combustion produces zero carbon emissions at the tailpipe, and gasoline engines require minimal alterations to make them burn hydrogen. One kilogram of hydrogen is estimated to produce the same power as a whole gallon of gasoline. When the hydrogen is produced from low-carbon sources, it is a very low source of emissions. BMW is focusing strongly on this technology, and has 100 H2-combustion cars on the road, mostly in California. But there are a number of problems. Hydrogen combustion is only 30% efficient, while hydrogen fuel cells can capture 60% of the energy in hydrogen. It requires the same hydrogen infrastructure as fuel cells, so it would have to be substantially cheaper than fuel cells to be viable. "Functional fuel cells are not far off and hydrogen development is better targeted there," says Innovest. Furthermore, at the moment, the most common source of hydrogen is fossil fuels and using these to make hydrogen is considerably less efficient than just burning the fossil fuels. Storage is a problem because hydrogen is very light and hard to compress.

Hybrid technologies

Hybrid cars use two or more sources of power. Most hybrids today use a rechargeable battery and gasoline and they reduce the pollution effects of gasoline while overcoming the current shortcomings of current electric cars, which are not very powerful or fast, have only a short range and take a long time to recharge. Conventional engines are set up to provide the maximum power that will be needed, which is when a vehicle starts to move or goes up hills. But most drivers use this peak power less than 1% of the time. Hybrids have a smaller engine than a conventional car that is much closer to the average power output of an engine, while batteries help to get the car moving and to go up hills. In parallel hybrids, both the engine and the batteries can turn the wheels. In a series hybrid, by contrast, the gasoline engine turns a generator, and the generator can either charge the batteries or power an electric motor that drives the transmission. Thus, the gasoline engine never directly powers the vehicle. Series hybrids are likely to take over from parallel hybrids with the advent of 'plug-in' hybrids.

Critics of hybrids say that similar savings can be made using other technologies or simply from driving smaller cars, but they are likely to remain popular in North America, and Australia, where there is no small-car culture and travel distances can be very large. In addition, some of the technologies used in hybrids will be useful in other carbon reducing technologies such as fully electric cars, fuel cell vehicles and the hydrogen economy.

Gasoline hybrid

Toyota has sold more than 1m of its Prius hybrids in the US and there are projected to be 4m hybrids on the road by 2010, with Toyota's main competition likely to come from its Japanese rival Honda. As the technology becomes cheaper and with oil prices forecast to remain strong, hybrids are forecast to make up 14% of new car sales by 2012. Honda's now-withdrawn Insight was a classic parallel hybrid and focused on maximising mileage. The Prius incorporates technology that allows it to operate as a parallel hybrid or a series hybrid. Other models are available from Ford, GM and Nissan and Toyota subsidiary Lexus.

Diesel hybrid

Combining the fuel savings of diesel with the hybrid model provides significant savings in fuel consumption and CO2 emissions compared even with a petrol-electric hybrid and the technology is already in use on trucks, trains, buses and earth-moving equipment. Diesel-electric hybrid technology is currently used on trains, heavy earth-moving equipment and some light and medium trucks, as well as buses. It is therefore a proven technology, but there are currently issues over noise and vibration levels when it is used in cars. Valeo and Ricardo have developed a prototype and Peugeot Citroen says it will have a diesel-electric hybrid on the market from 2010, although some experts say 2012 is a more realistic deadline. Bosch is also working on diesel hybrids.

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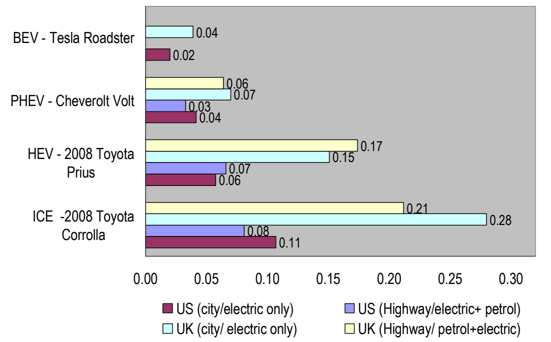
Plug-in hybrid

"For the greatest CO2 and efficiency benefits to be gained from hybrid technology, the battery will need to be charged by electricity from the grid rather than the internal combustion engine," says the King Review. Plug-in hybrids can be charged from the electricity grid. If the electricity is generated using renewable resources, it dramatically cuts the emissions profile of the car. As outlined in a previous Research Note, *Batteries: Driving Efficiency,* December 2007, plug-in hybrids are significantly cheaper to run than internal combustion engines and even than current hybrid cars, as well as offering much lower CO2 emissions. Unlike 'conventional' hybrids, they are designed to be driven significant distances on battery power alone. Some designs, such as GM's Chevrolet Volt, can drive on battery alone but once the battery runs out the gasoline engine turns on, recharging the battery. The Saturn Vue uses the engine to drive the car once the battery charge is depleted. Plug-ins overcome two of the key issues for pure battery electric vehicles – the distance they can travel and the weight of the batteries – while providing dramatically improved fuel consumption compared with internal combustion. Battery performance, recharging time, range and infrastructure will be the key issues for plug-ins. "For plug-in hybrids to become convenient for most users, batteries must be cheaper, with an energy density at least several times current levels, and charging that takes minutes rather than hours," according to the King Review.

Figure 4. Cost per mile ($) to drive ICE, hybrid and battery operated vehicles



Note: US gasoline price of $3/gal and UK of $7.84 (£1/ L); average residential electricity $0.10 kW/h in US and $0.18kW/h in UK; "electric only" refers to the Volt and Roadster "petrol + electric" refers to the combination drive mode of the Volt.

Source: New Energy Finance

A couple of three-wheeled plug-in hybrids have attracted interest from investors. Los Angles-based company Venture Vehicles raised $6m in series A funding backed by NGEN Partners and DVC Technologies, while Robert Q. Riley Enterprises says it is set to introduce its XR-3 three-wheeler plug-in. As well as the obvious weight savings leading to lower fuel consumption, three-wheelers are not subject to the same safety regulations as cars.

2. Beyond petroleum

Battery Electric Vehicles (BEV)

Purely battery-driven cars have no emissions at the point of use, so they cut air pollution compared with petrol and diesel cars. Moreover, "if the electricity is produced from renewables or other low-CO2 sources, such as nuclear or even fossil energy with carbon capture and storage, it can have low or even effectively zero CO2 emissions over its life cycle," says the King Review of Low Carbon Cars. The existence of the electricity grid means that the basic charging infrastructure for electric vehicles is essentially in place.

Most BEVs suffer from four key problems – range, weight, low speeds and recharging time. Some analysts believe that electric cars will only ever secure a niche market because of limitations in range and recharging and also because the development of a large-scale hybrid market will also make fuel cell cars more viable as many of the technologies needed are very similar.

However, as with plug-ins, they offer significant improvements in CO2 emissions and fuel efficiency. New Energy Finance has calculated that the Tesla Roadster, for example, would produce 18 tonnes of CO2 per 100,000 miles using coal-fired electricity, compared with more than 32 tonnes per 100,000 miles for a conventional Toyota Corolla. It is also five times cheaper per mile in the US and seven times cheaper per mile in the UK to run. With a range of 245 miles, a top speed of 135mph and fuel efficiency equivalent to 135mpg, it is beginning to provide comparability with the ICE, but a charging time of 3.5 hours and a cost of $100,000 suggest there is some way to go before battery cars become truly competitive. The first Roadsters are expected to roll off the production line in the first quarter of 2008.

Nickel-Metal Hydride (NiMH) is the technology of choice for the current generation of hybrid vehicles such as the Toyota Prius, but Lithium-ion (Li-ion) batteries could offer 400-500km (250-300 miles) of range per charge once problems around system integration and battery management are overcome. Volkswagen is heading up a €360m ($520m) German push to develop Lithium-ion batteries for hybrid and electric vehicles, along with BASF, Bosch, Evonik and Li-tech, with an additional €60m coming from Germany's ministry for education and research. Japan's Nissan and telecoms group NEC have also formed a Li-ion joint venture, while Toyota and Matsushita are developing NiMH batteries.

Progress is not restricted to the developed world. Indian electric car manufacturer, Reva Electric Car Company (RECC), raised $20m from Draper Fisher Jurveston (DFJ) and Global Environment Fund (GEF) in 2006, although a joint venture with IndianOil to make a hydrogen fuel cell car came to nothing.

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Fuel cells

Hydrogen fuel cells remain the elusive prize for carmakers – a hydrogen economy based on renewable sources of hydrogen production, or nuclear power – would cut not only carbon emissions but other forms of pollution from cars as well. There are a number of challenges, including establishment of a hydrogen infrastructure, the need for renewable sources of hydrogen, and finding a way to store the element at sufficient density to allow it to be used as a fuel. According to the King Review, "a large supply network is only likely to be developed if hydrogen emerges as a fuel that can be widely supplied in a low-CO2 way and at a reasonable cost, and if developments in battery technologies do not provide a more cost-effective electric alternative."

Producing hydrogen results in life-cycle emissions (LCE) that range from 100%-400% higher than petrol and diesel using coal-fired electricity, to 90% lower when using renewable or nuclear electricity. Using natural gas, when using natural gas, the LCEs of hydrogen are between 50% lower and 20% higher than petrol and diesel, although in future this could be improved through carbon capture and storage. Other non-electrical ways of producing hydrogen (for example, from biomass or through novel nuclear technologies) could also be very low-CO2.

The cost-effectiveness of hydrogen also varies widely depending on the production route. The most cost-effective current routes are from nuclear or wind electricity and wood gasification, with abatement costs ranging from $500 to $900 per tonne of CO2. "With the possible exception of electricity, these abatement costs are relatively high compared to other options for cutting CO2 in both road transport and the wider economy," says the King Review.

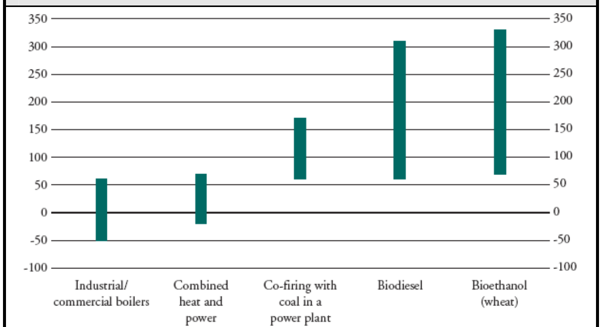
Honda will start limited marketing for its latest FCX fuel cell car, the Clarity in summer 2008. The company claims the FCX Clarity offers 68mpg, a range of 270 miles, a fuel cell powertrain close to the size of a modern hybrid-electric powertrain, which has led to an improved power-to-weight ratio.

3. Biofuels

Biofuels have created a stir out of all proportion to their role in cutting the environmental impact of cars. They are seen in certain quarters, not least the White House, as a partial answer to the problems of climate change and energy security, but the industry is currently facing a number of stiff challenges. These include the fact that there is simply not enough land available to supply more than a small fraction of the total fuel supply, a conflict between biofuels and food production, and concerns over deforestation in Asia to make way for palm oil plantations. There are also issues around the use of fossil-fuel derived fertiliser to grow the feedstock. Meanwhile, biofuels have become very politically charged because the important biofuel-producing regions in the US are also at the centre of current campaigning by US presidential candidates. Furthermore, the sector is already entangled with barriers to trade that impede the most energy efficient biofuel, ethanol from Brazilian sugarcane, from being sold in the US. There is controversy on the other side of the Atlantic because US subsidies allow producers to import biodiesel from Europe or the rest of the world, add a minimal amount of normal diesel and then export it to Europe, where it massively undercuts European biodiesel.

Critics argue that biofuels is a relatively inefficient use of biomass, maintaining that it would be more effective to use the biomass to produce electricity and use that to charge car batteries. But the biofuel bandwagon is likely to roll on, not least because of the various biofuel mandates in place around the world. Early in 2007, the EU set a target of 10% biofuels by 2020, but the German government has just announced a plan to lift the country's biofuel target from 5% to 10% by 2010, and to 20% by 2020, double the amount mandated by the EU. The US has a target of 28bn litres of ethanol to be produced by 2012 and latest proposals suggest 13bn gallons of biofuels by 2010, 20.5bn gallons by 2015 and 30bn gallons by 2020. Brazil already has 20-25% ethanol in the gasoline mix.

Figure 5: Comparison of CO2 abatement cost ranges for selected use of UK Biomass (£ per tonne CO2 abated)



The King Review of Low Carbon Cars, 2007

New Energy Finance predicts that biofuels demand will grow by more than 9% a year to 2030. The US market is likely to focus on ethanol, while biodiesel will be more important in Europe. In the long run, great store is set by various unconventional sources of biofuel, including new feedstocks such as jatropha and algae, the introduction of cellulosic ethanol, made from agricultural waste and other non-food crops, and new fuels such as biobutanol. Algae technology, which is about 10-15 years from commercialisation, shows great promise because it may be possible to get 30,000 litres of fuel per year from a hectare of land using algae, compared with 5,000 litres per year from palm oil. In the short run, cellulosic ethanol is likely to make traditional biofuels more viable by using material that currently has to be discarded to make fuel rather than replace them, say New Energy Finance analysts.

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While Asian countries such as Malaysia, Indonesia and Thailand push the development of their biofuels industries through their palm oil industries, China is unlikely to push the development of the sector too forcefully because of problems sourcing feedstock. Japan has just announced plans to introduce low-cost technology for producing cellulosic bioethanol by 2015 to help reduce its dependence on gasoline.

Europe's biofuels sector is relatively moribund – hit by US "splash and dash" subsidies – while the sector in North America is undergoing a period of consolidation after the fundamentals became less favourable after 2006's 'perfect storm' of investment drivers. The biggest growth area will be Latin America, where Brazil will lead the way, perhaps followed by Argentina, which is focusing on producing biodiesel from soybeans.

4. Investment opportunities

Infrastructure

Plug-ins, pure electric vehicles and hydrogen-powered cars could be a key driver for renewables by providing an outlet for rfenewable electricity generated off-peak, that would otherwise be 'spilled'. Ireland, for example, has a potential wind generating capacity of 12,000MW, but current demand is only 4,700MW. It has similar potential in marine energy. All this energy cannot be used by electricity consumers and, given Ireland's interconnections, it cannot easily be exported. Moreover, much of it would be generated at night, when electricity demand is at its lowest. However, it has great potential to be used to charge plug-in hybrids or electric cars or to produce hydrogen, drastically cutting fossil fuel consumption. Such a scheme requires a radical overhaul of energy infrastructure and requires a leap of imagination from government, consumers, the energy industry and the car industry. Nonetheless, it provides a viable model for a move away from a carbon economy, which could be rolled out first in small economies with large renewable resources. The first signs of infrastructure investment for electric or hydrogen cars are starting to emerge. Shai Agassi's Project Better Place has just raised $200m (see box), while ECOtality has bought fast-charging companies eTec and Minit-Charger in the last three months.

Hydrogen infrastructure is virtually non-existent, but that does not mean there are huge opportunities – most of the work on putting hydrogen refuelling facilities in place is likely to be done by oil companies or auto groups. In the last year, there were only two hydrogen deals in VC/PE, which raised a total of $10m. However, Quantum Fuel Systems Technologies is to supply three transportable hydrogen fuelling stations to General Motors, as a complement to the Quantum systems already used by the US automaker. GM will use the fuelling stations to supply its hydrogen-powered vehicles at vehicle proving grounds and public demonstrations.

US hydrogen supplier Air Products and the University of California, Irvine have launched a vehicle hydrogen fuelling station as part of the California Hydrogen Infrastructure Project (CHIP).

Case Study 2. Electric infrastructure for cars

In October, Shai Agassi, a former board member at software group SAP, announced he had raised $200m for an electric car infrastructure venture that will sell electricity to vehicle users on a subscription basis and will subsidise costs through leases and credits. Tests on prototype vehicles are due to start early in 2008, with commercial operations rolling out within two years. Agassi says that all-electric cars would cost about 7 cents a mile, less than one third the cost of a current gasoline-powered car, assuming batteries that can be charged 1,500 times. With fuel prices much higher in Europe, the economics of Agassi's scheme will be much more attractive there. Agassi envisions tens of thousands of recharging spots, where recharging would take about one minute for every minute driven. The system would be supplemented by car-wash-style stations where batteries could be swapped for immediate use. The system would be focused on "transportation islands" – densely populated regions where people drive less than 100 miles 99.5% of the time – where electric cars become viable.

Source: http://www.projectbetterplace.com

Batteries

A prerequisite of a successful electric car infrastructure is effective batteries that recharge quickly, are light and can power a car for significant distances at reasonable speeds. Such batteries are currently lacking. Current hybrid batteries are Nickel Metal Hydride (NiMH) – Panasonic and Sanyo dominate the NiMH market, with 85% of all sales. Panasonic EV Energy supplies Toyota, Hyundai/Kia, Lexus and Daihatsu and made more than 1m units in 2006, while Sanyo supplies Ford and Honda and raised $2.5bn in a 2006 secondary offering.

Lithium ion (Li-ion) is set to take over as the next generation technology, because it can provide the distance and the power to run a car solely on a battery. Companies such as A123 Systems, Altair Nanotechnologies and China's Advanced Battery Technologies are leading the way in Li-ion while Power Genix Systems produces a Nickel/Zinc battery that is supposedly lighter, smaller and safer than the alternatives. Japanese electronics group Toshiba plans to start selling a battery that can recharge to 90% of full capacity in less than five minutes. The company said its Super Charge ion Battery would go on sale from March 2008.

Other companies prominent in the sector include Canada's Advanced Lithium Power, which saw Quantum Fuel Systems Technologies take a 19.9% stake in 2006; Automotive Energy Supply Corporation, a Japanese joint venture in Li-ion batteries between Nissan and NEC; Cobasys (US) a NiMH JV between Chevron Technology Ventures and Energy Conversion Devices, which has an agreement with Panasonic EV Energy to solicit and sell NiMH battery products for North American transportation applications. US group Ener1's Li-ion

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battery division EnerDel is jointly owned with Delphi, the world's largest car parts maker, which has a 19.9% stake. The company has caught the eye in developing a plug-in version of the Toyota Prius.

Ultracapacitors

One way to smooth out the power requirements for an electric car is the use of ultracapacitors. These store, and can discharge a high amount of energy instantaneously. This can provide the energy needed to get the car moving, thus reducing the amount of power drained from the battery. Ultracapacitors also capture the energy from regenerative braking systems and can be used in conjunction with fuel cells to provide high power. Maxwell Technologies is the leading ultracapacitor company. Others include Smart Storage and of Australia, Canada's EPOD Industries and Axion Power, while Engen's nano-scale polymer technology has applications in ultracapacitors and Aerogel Composite produces its ENERGel Carbon Aerogel Ultracapacitor electrode material. Texas-based EEStor US high-density energy storage devices manufacturer EEStor secured $2.5m funding from electric cars provider Feel Good Cars for its ultracapacitor technology.

Fuel cells

To many people, fuel cells are destined to remain for ever 20 years from mainstream adoption – certainly their cash burn remains impressive. In 2006, nine publicly quoted companies spent $196m, against generated revenue of $113m suggesting that commercialisation remains some way off. However, Dr Paul Nieuwenhuis says that the achievements of the fuel cell industry – Ballard in particular – are impressive, with dramatic improvements in the cost per kW over the past 15 years or so. "In fact, in many respects the fuel cell car is competitive with the internal combustion-engined car even today," he says. There remain problems, however.

- Vehicle integration – fuel cells still take up too much space
- Materials cost – fuel cells need a lot of platinum, which is in short supply, and expensive;
- Fuel supply and production – because pure hydrogen does not occur naturally, it has to come from other sources. At the moment, the most convenient and lowest cost source is fossil fuels;
- Manufacturability – Ballard's former car transport arm, now owned by a Ballard-Daimler-Ford joint venture, is closest to setting up a manufacturing process for automotive fuel cells, envisaging a gradual increase in annual production in a single factory.
- Infrastructure. It has been estimated that building a hydrogen infrastructure would cost $5,000 per car and there is a chicken and egg situation in that manufacturers will not build fuel cell cars in large numbers unless the refuelling infrastructure is available, while there will be a reluctance to build the infrastructure without proven demand for fuel cell cars. There have been proposals in California and British Columbia for 'hydrogen highways' – corridors where hydrogen availability would be guaranteed at regular intervals – this is likely to require some kind of government assistance.

There are suggestions, however, that such thinking, based on the current way of delivering fuel, will be superseded. Hydrogen, like electricity, could be distributed at homes and offices and partly generated from renewable electricity. In the absence of a general hydrogen infrastructure, fuel cell vehicles are likely to be restricted to depot-based vehicles with fixed routes, such as buses and delivery vehicles. Fuel cells would seem to be competing with electric vehicles for the same resources from vehicle makers, infrastructure providers and governments.

Ballard has supplied fuel cell buses for trials in London, British Columbia, Washington DC and Sao Paulo. Meanwhile US-based fuel cell manufacturer Plug Power is trying to commercialise an on-board hydrogen fuel system developed by Exxon Mobil, QuestAir and Ben Gurion University under an agreement announced by Exxon. The technology, which converts liquid fuels such as petrol, diesel, ethanol or biodiesel into hydrogen on board the vehicle on demand without the need for storage, would first be fitted into fuel cell systems for fork-lift trucks by Plug Power.

Shanghai Auto Industry, meanwhile, claims to have developed a fourth generation hydrogen fuel cell car that can reach 150km per hour, accelerate from zero to 100km per hour in 15 seconds and run continuously for at least 300km. The company aims to be producing 50,000 cars by 2010.

VC/PE investment in fuel cells hit a record $571m in 2006, some $217m of it due to one PIPE deal, but it slowed considerably in 2007 to about $90m. The sector continues to attract investors on the public markets, however, with $268m raised in 2007.

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5. Regulation

Given the combination of fears over oil supplies, volatile oil prices on an upward trend and concern over climate change, it is unsurprising that regulation and restrictions are becoming tougher globally.

Europe

The European Union has voluntary agreements with vehicle makers' associations to bring in average fuel economy figures for their fleets of 140g CO_2/km (about 40 mpg) by 2008-9 and 120g CO_2/km (about 43 mpg) by 2012. The response of many European automakers that they will be unable to meet this standard has met with little sympathy and has prompted a regulatory response. Regulations (and voluntary agreements enforced by threat of regulation) have already been introduced in various European countries, including the UK and Spain, which would impose fines on automakers exceeding 120g CO_2/km after 2012, according to Innovest Strategic Investors.

The EU also has a target that by 2020, 10% of fuel sold in the bloc would be biofuels. The European Commission says it is confident that target will be met, even though previous targets have fallen by the wayside. Biofuels were meant to make up 2% of the fuel mix by 2005, but reached only 1%, rising to 1.5% in 2006. By 2010, the level should be 5.75%. One of the problems with the targets is that there are no real sanctions against those who fail to meet the targets.

A split has developed between the main European car-making nations, with French and Italian car makers – along with Japanese companies, which have also signed up to the agreement – managing to cut their emissions in recent years, while the more up-market German brands have increased the emissions from their vehicles (See Case Study 1).

The EU looks set to introduce a new petrol blend equivalent to the E10, allowing ethanol to be mixed with petrol up to a limit of 10%, after the idea passed a European Parliament vote without any problems. The amount of ethanol allowed in petrol is currently limited to 5%. The raising of the limit is likely to be backed by the whole Parliament in January and agreed by EU countries in 2008, allowing the new blend to be on forecourts as early as 2009.

US

Currently, cars must return 27.5mpg, with light trucks only needing to offer 20.5mpg, rising to 23.1mpg by 2010. However, this is set to rise sharply, thanks to new CAFÉ (Corporate Average Fuel Economy) regulations passed by Congress in late 2007. The Energy Bill signed by the President on 19 December raises the US corporate average fuel economy standard from the current 25mpg to 35mpg, in a stage process taking place between 2011 and 2020. The Bill also mandated that 36bn gallons of "alternative" fuels be mixed into the US fuel supply annually by 2022.

Separately, several states, led by California, are locked in a court battle to introduce more stringent fuel economy standards. The states have sued the Environmental Protection Agency to try to force it to rule on their efforts to introduce their own fuel standards. In 2002, California passed a law that called for a 30% cut in greenhouse gases over the entire fleet by 2016. Fifteen other states have said they would also adopt the standard, with another four considering them and a number of Canadian provinces also looking to get in on the act. However, carmakers are challenging the move in the courts, saying that only the Federal government can set fuel economy levels. If this is a constructive attempt to get a more stringent nationwide standard, it is a good sign, but the recent history of the US automotive industry suggests it is an attempt to avoid regulation until the last possible moment. If this is the case, the US auto industry will continue to lag behind the rest of the world in the face of what Innovest calls a "market-altering challenge to the auto industry".

Canada

Canada comprises 8% of the North American market, and its voluntary agreement mirrors its southern neighbour's. Under a 2005 agreement between the government and carmakers companies are committed to cutting GHG emissions by 5.3 Mt by 2010, which implies a 20% improvement in fuel economy.

China

At present, China's fuel economy standards for passenger vehicles are weight-based. Under Phase 1 standards (implemented in 2005) the lightest cars must achieve 38mpg, while vehicles over 5,500lbs must return 19mpg. From January 1 2008, Phase Two standards require 43mpg for light cars and 21mpg for vehicles above 5,500lbs.

Japan

The current fuel economy standard is 32mpg. There is a proposal that by 2015 fuel efficiency for gasoline-engine passenger vehicles should be 39.5mpg, for small trucks 35.8mpg, and for small buses 21.0mpg.

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India

India's major cities have standards that match EU emissions regulations, but there is still no national fuel economy mandate and it does not look likely to happen in the near future. The small cars and motorcycles popular in India already achieve high mileage, while LPG is popular in built-up areas since it offers high mileage (up to 58mpg in small engines) and near zero emissions. In most emerging markets air pollution is a bigger concern than GHG emissions.

Australia

Under a voluntary agreement, Australia's passenger car National Average Fuel Consumption is 28.6mpg, with a new voluntary standard committing manufacturers to improve that to 34.5mpg by 2010.

6. The journey ahead

The King Review suggests that future research should focus on overcoming key obstacles to alternative fuels use, including (but not limited to):

• developing batteries with longer ranges and faster recharging

• developing cheap and low-CO2 ways of producing, distributing and storing hydrogen

• improving crop yields to reduce the land requirements of biofuels, through either plant breeding or genetic engineering, and

• improving technology for converting biomass (in particular non-food biomass) into fuel.

For transport to become truly decarbonised, there also needs to be further regulation to encourage greater innovation away from petrol power. While market drivers are powerful, particularly the price of oil, the world's transport infrastructure is so geared to the internal combustion engine that price signals alone are unlikely to be enough. Further, the in-built bias for a system that looks as much like the current apparatus as possible may lead to the wrong focus. Biofuels with little or no advantage over petroleum are being encouraged for reasons that are more to do with strong agricultural lobbies, for example.

Transport has to be seen in the context of carbon emissions, energy provision and infrastructure as a whole – in places with more renewables potential than demand, such as Ireland or New Zealand, cars can provide impetus for massive investment in renewables, perhaps coupled with some kind of energy storage technology. Using renewable energy outside peak times to charge batteries for electric vehicles or to produce hydrogen could have a far greater impact in cutting emissions than using it just to produce electricity.

In the long run, all cars will be powered by electricity or fuel cells, or possibly a combination of both. Which technology emerges as the winner depends on the relative developments in battery technology, fuel cells and the infrastructure for electricity and hydrogen.

Table 1. Selected investments in clean car technology 2007

Company name	Type of investment	Sector	Amount
A123Systems	VC – further pre-IPO round	Li-ion batteries	$70m
ACAL Energy (UK)	VC/PE Series B	Fuel Cells	$3.1m
Acucar Guaranie (Brazil)	IPO	Ethanol	$358m
Amminex A/S (Denmark)	VC Series C	Hydrogen Storage	$9.7m
Amyris Technologies (US)	VC Series B	Biofuels	$70m
Brenco (Brazil)	Other	Ethanol	$200m
China Agri-Industries Holdings (China)	IPO	Biofuels	$413m
Cosan (Brazil)	IPO	Ethanol	$1,050m
Ener1 (USA)	PIPE	Li-ion batteries, fuel cell	$32m
Imperium Renewables (US)	PE – Asset Investment	Biodiesel	$113m
Intelligent Energy Holdings (UK)	VC Series D	Fuel Cells	$17m
Quantum Fuel Systems (USA)	Secondary offering	Hydrogen storage	$18.8m
Santelisa Vale (Brazil)	PE – Asset Investment	Ethanol	$221m
Venture Vehicles (US)	VC Series A	Electric Vehicles	$6m

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Selected Companies Mentioned in this Report		
Company	**Ownership**	**Relevant Sub-activities**
A123Systems	VC/PE-funded	Li-ion batteries
Advanced Battery Technologies	Private/family controlled	Li-ion batteries
Altair Nanotechnologies	Public	Nano-materials for batteries and fuel cells
Ballard Power Systems	Publicly quoted	Automotive fuel cells
Bosch	Publicly quoted	Direct injection
ECOtality	OTC-quoted	Fast-charging battery technology
Honda Motor	Publicly quoted	Fuel cell and hybrid cars
Maxwell Technologies	Publicly quoted	Ultracapacitors
Power Genix Systems	VC/PE-funded	Nickel Zinc rechargeable batteries
Project Better Place	VC/PE-funded	Electric car infrastructure
Tesla Motors	VC/PE-funded	Electric cars
Valeo	Publicly quoted	Diesel hybrid

Source: New Energy Finance

Disclaimer

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