Hydrogen as a fuel or fuel supplement – What technologies are emerging?

Some frequently asked questions and case-studies on the use of Hydrogen as a renewable fuel and the Hydrogen Economy

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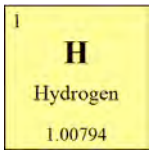
Firstly, what is hydrogen?

Hydrogen is the first element in the Periodic Table of Elements. It is rarely found in elemental form, but is rather combined with another hydrogen atom to make the compound H_2.

Hydrogen was discovered by Henry Cavendish in 1776 and named by Lavoisier; hydrogen is the most abundant of all elements in the universe. From the Greek words **hydro** and **genes**, which together mean "water forming."



Hydrogen is a colourless and highly flammable gaseous element; the lightest of all gases. Used in the production of synthetic ammonia and methanol, in petroleum refining, in the hydrogenation of organic materials, as a reducing atmosphere, in oxy-hydrogen torches, and in rocket fuels.

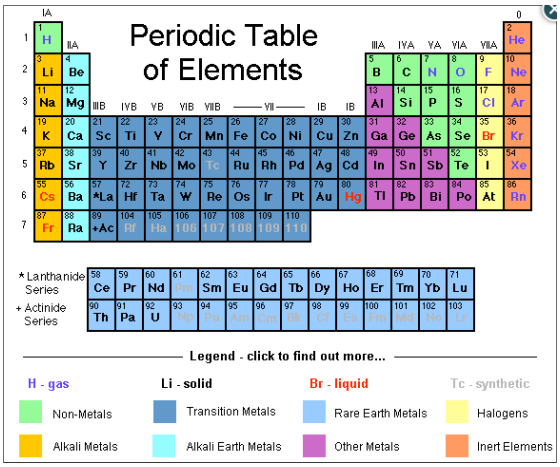
The most common uses of Hydrogen are in Hydrogen Peroxide, Fuel Cells, Fuel, Hydrogen Generators and Hydrogen Powered Cars.

While very small amounts of H_2 are present in the atmosphere, this molecule is usually bound to 1 oxygen atom to make H_2O or dihydrogen monoxide, more commonly known as water.

Composed of a single proton and a single electron, it is estimated that 90% of the visible universe is composed of hydrogen.

The bond between hydrogen and oxygen is very strong, requiring a lot of energy to separate them. However, hydrogen and oxygen give off a lot of energy when they are united, either by combustion or in a fuel cell.

Scientists have always admired hydrogen for its simplicity and its energetic nature. Unfortunately, these properties make hydrogen in its gaseous form difficult to store and transport. One kilogram of hydrogen (equivalent to a gallon of petrol or diesel) occupies 431 cubic feet of space (16 m3) …about the half the volume of a small office cubicle.



Up to now to store and transport hydrogen efficiently, it must be compressed or turned into a liquid. Compression to 350 to 700 times atmospheric pressure (5,000 to 10,000 pounds per square inch) is common for automotive applications. Compression requires a lot of energy, and the storage tanks to safely contain these pressures are heavy and expensive.

Traditionally liquefying hydrogen takes even more energy, since hydrogen does not turn into a liquid until it reaches a temperature that

is only 17º above the temperature of interstellar space. Hydrogen liquefies at 20ºA (above absolute zero) and interstellar space is 3ºA. Storing liquid hydrogen requires a very high technology Thermos bottle called a 'Dewar Flask' to prevent the hydrogen from turning back into a gas.

Both storage techniques are expensive. The base cost of hydrogen is multiplied by factors of 5 to 8 to purchase these expensive bottles and delivery vehicles required by the high pressures and low temperatures.

Why are people interested in hydrogen in the first place?

As the world becomes more aware of the potential harm that can be caused by carbon dioxide (CO_2) in the atmosphere, there has been a renewed effort to replace the complex hydrocarbons in petrol (gasoline) and diesel fuel with simpler compounds such as methane (CH_4 consisting of 1 carbon and 4 hydrogen atoms) and hydrogen itself.

Hydrogen can be burned in internal combustion engines, or it can be combined with oxygen in a fuel cell. Over 99% of the exhaust output is simple water vapour (H_2O).

Since combusting a gallon of petrol produces over 20 pounds of CO_2, (20 lb = 9.1 kg) replacing that gallon of petrol with hydrogen is environmentally very appealing. The United States Department of Energy Web Site (www.fueleconomy.com) has details.

What is the Hydrogen Economy?

The Hydrogen Economy is a proposed system of delivering energy using hydrogen. The term was coined by John Bockris during a talk he gave in 1970 at General Motors (GM) Technical Centre promoting hydrogen as a potential fuel for motive power (including cars and boats) and the energy needs of buildings and portable electronics.

What is the Hydrogen Highway? Hype or Happening?

As planners explored the benefits of hydrogen as a transportation energy source, they began to explore rolling out hydrogen fuelling stations along particular high traffic routes that became known as Hydrogen Highways.

There are six major initiatives that have been launched around the world in these areas: Japan, Scandinavia, California, Florida, British Columbia and Western Europe - principally Germany.

In the UK (2010), the M4 Motorway in South Wales is to become a "hydrogen highway", with alternative energy refuelling points, then Welsh Secretary, Peter Hain, announced.

The scheme, to extend into South West England, is aimed at making hydrogen and electric-powered vehicles a viable alternative to petrol-driven machines.

Under the plan, Wales will lead in developing alternative fuels, including hydrogen from renewable sources.

Hasn't hydrogen use been discredited?

It was not the use of hydrogen that was discredited, rather, scientists realised that the infrastructure to support the Hydrogen Economy would be very expensive. In fact, the US Department of Energy published an estimate of $500,000 million for infra-structure costs. Other factors that dampened the initial enthusiasm for hydrogen were the stubbornly high costs of fuel cell technology, and the difficulty of finding low-cost methods to store and transport hydrogen.

How will hydrogen impact the environment?

Every kilogram of hydrogen that replaces a gallon of petrol or diesel fuel will save the environment over 20 lbs (9.1 kg) of CO_2. Dramatic reductions of emissions of NOx (nitrogen compounds), SOx (sulphur compounds,) and soot (unburned carbon nanoparticles) have been shown in the laboratory.

Since the United States alone burns 20.7 million gallons of petroleum products per day, any substitution of hydrogen will have a beneficial effect on the environment.

(www.greencarcongress.com/2006/01/us_petroleum_co.html)

The lowest cost way to make hydrogen at the moment is to use steam to reform methane. However, the carbon atoms in methane (CH_4) become CO_2, so the overall CO_2 savings would be reduced to a net of 10 pounds or (4.6 kg). Micro Hydrogen generators or home units will reduce emissions to virtually zero as electrolysis units become affordable and more efficient.

Of course, using wind or solar energy to electrolyse water releases zero CO_2.

HYDROGEN AS A FUEL OR FUEL SUPPLEMENT

Can we get hydrogen from wind and solar power?

Converting green energy from wind and solar power to hydrogen is the goal of the alternative energy industry. Substantial investments are being made into electrolysers to break water apart into hydrogen and oxygen.

When will fuel cell vehicles be available?

Despite over a decade of promises regarding affordable fuel cells and thousands of millions of dollars being spent by government and industry, we are still another decade away from reaching the goal of $100 per kilowatt of electrical output. The problem is simple: without a breakthrough in science and high volume production, the fuel cell will remain very expensive.

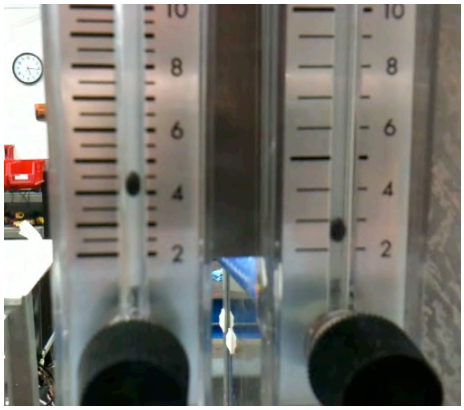
Vehicles designed for highway use require at least 50 kilowatts of energy to accelerate to 60 mph in less than 12 seconds (96.6 kph). Even when we reach the goal, the fuel cell alone in these vehicles will cost $5,000 — hardly a mass-market price point.

The push to cost-reduce fuel cells is driven by two primary attributes: zero pollution (all water vapour) and high efficiency. Fuel cells convert chemical energy to electrical energy with 60% efficiency. This is almost twice that of a gasoline engine (32%) and higher than internal combustion engines designed to run on hydrogen (42%).

What is the technology out there?

HHO or Brown's Gas generators produce both Hydrogen and Oxygen simultaneously through the process of electrolysis.

A typical HHO generator setup consists of a water/electrolyte reservoir, one or more electrolyser cells connected to or mounted inside the reservoir and an induction line from the top of the reservoir to the air intake. The electrodes are connected to the battery and alternator through a relay and current limiting electronics. When the engine is running, the relay switches power to the electrodes to begin the production of hydrogen and oxygen. The negative pressure created by the engine over the water line draws in these gases in a safe and efficient manner. When water is introduced to a DC electrical current it will become excited and divides into its primary elements of Hydrogen and Oxygen.



Some generators systems separate the Hydrogen from the Oxygen. Picture shows ratio of 2 to 1

The produced Hydrogen and Oxygen are now in a gaseous state from the liquid water. This can be fed into the engine intake or in the illustration below to feed a fuel cell though often this is done outside the vehicle and stored in-vehicle pressure tanks.

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When referring to an engineers' opinion, a high percentage will say that the technology is a fallacy. Their main argument is that in the creation of HHO within the vehicle will demand more energy that it releases. The principle being something to do with the law of physics and that it is impossible to get out more than you put in. (Faraday Efficiency). In our experience there is a constant 3 - 5% energy loss or drain but the gains are greater. There are thousands of testimonials to that effect by early adapters and their reports are of increased mileage even without definitive reasoning. You can produce HHO with as little as 1.5 volts DC and an amp of current.

The principle is to produce as much HHO as possible with the least amount of electrical input energy. In reality, once the HHO generator has been charged up it actually acts like a wet cell battery. It holds a charge of 1.5 - 2.0 volts DC and can operate when charged with the power switch turned off, until the remaining capacitive charge is dissipated. The vacuum created by the vehicles engine inlet manifold pulls the HHO into the engine for combustion purposes. The system is an 'on demand' system, "NOT" a pressurised storage system; the HHO generator only produces what the vehicle's engine may call for and nothing more. However, it is a good idea not to produce HHO if the engine is turned off. Good quality systems will have a device that confirms the engine is running.

Can an engine idle on pure HHO?

The answer is absolutely, but to actually operate the vehicle under normal driving conditions the current technology is not quite there yet. Currently there are claims of drivers seeing from 35 - 45% average fuel savings. Airmax has not documented that, but with 7 to 10 litres per minute of HHO we are seeing a constant 25%. This must be seen as a supplemental fuel.

To get better and more consistent results is down to the software in the vehicles engine management system. The language refers to Piggy Back ECU, Effie, CANbus and ECU.

The process is as follows, you start with water and an electrolyte NaOH or KOH. You add a DC current, the H_2O breaks down into H_2 & O [we just call it HHO]. It is introduced into the engine by use of the engine's vacuum. The HHO combines with the diesel or petrol and air in the combustion chamber and is burnt. Once burnt, it converts back to H_20. It's now going to absorb the inner heat from the engine normally at 350 - 400F (177 – 204C) and turn into super heated steam. This super heated steam is now expanding, thus creating an additional force to add too the previous combustion process. Then it's pushed out during the exhaust stroke and out the tail pipe. There it condenses back into water vapour and eventually collects back into water. So you start with water and end with water.

It is also advised that you understand your vehicles mechanical setup or have a professional mechanic with the expertise and qualifications to install the HHO generators. Many of the newer vehicles come with a sensor that is used for mass air intake, this sensor has a fine wire that actually glows like a filament in a light bulb and is located in the air intake system usually between the air filter box and the intake manifold. On those vehicles you MUST locate the HHO fuel outlet directly into the engine's intake manifold or as close to the engines throttle body as physically possible or by doing both. It is also advised that the system be controlled by the ignition key or preferably, an engine confirmation system, in conjunction with the provided power on/off switch. The reason being is that the user can forget to turn the unit off and flood the engine with an HHO fuel when the vehicle is not running. It also will allow your battery to run down if forgotten.

So what are our results?

First and foremost, a really odourless exhaust, lowered CO_2 emissions, and NO_2 emissions go almost to 0. In short, the exhaust emissions drop off the scale, as you know them and you produce water vapour from your vehicle's tailpipe.

Why vapour instead of water?

The hydrocarbon fuel, diesel, produces enough heat during combustion to keep the burnt HHO in a water vapour state, so it will totally condense into water outside of the exhaust system [lowering or even eliminating any internal corrosion].

Important facts to remember using HHO Hybrid

- You do not need to make any major alterations to your vehicle. NB, Pure Hydrogen may need some changes as it can harden metal.

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- All late model vehicles are already computer controlled.
- Your vehicle computer will fight against the new oxygen intake and so you need to add an ECU controller.
- You must have an automatic shutoff to turn the unit off when not running your vehicles engine.
- For cold weather climates use a fibre-glass foil backed pipe insulation wrap, or, you can use some of the higher end units, like The Cell, Inc, that supply preheated and controlled hoses designed for extremely cold climates.
- All models come with a liquid/gas flash back safety valve.

Some good reasons why you need a HHO generator for your vehicle

1. Fuel Efficiency

HHO is known to be at least 3 times more potent than petrol, supplementing it and improving its combustion; thus producing more power output. HHO or Brown's gas generators can improve your fuel efficiency dramatically, boosting its mileage.

2. Small investment goes a long way

For a small amount of money you pay for the generator kit, you get all your money's worth in the long run. As an HHO generator for your car works only on water and very little electricity from the vehicles battery, its initial price is the only investment that goes into it. These costs will be paid off with a good ROI.

3. Perfectly safe for you and your passengers

HHO generator system is absolutely safe. In fact, it is much safer to use than your conventional fuel tank. HHO is not a new invention. A small amount of power is used out of your vehicles' charging system to separate the water into the gas HHO. It burns completely and provides a great amount of energy and safe power for your vehicle.

4. No harmful chemicals emitted from this system

With the HHO gas burning the excess carbon in the combustion process, your vehicle's emissions become much cleaner and less harmful for the environment. The HHO gas produced turns right back into water. The engine takes less fuel and burns more completely. The overall effect is a great reduction in harmful emissions. Definitely this is one of the great benefits of an HHO generator for your car.

5. Reduce engine temperature

The engine of your car enjoys a lower temperature and so protects the environment from global warming while you drive, too. It keeps your vehicle cooler and quieter. Engine life will be extended as well due to the lower running temperature and cleaner process.

6. Better performance and less trips to the mechanic's shop for repairs

Vehicle owners who use HHO have testified that with a hydrogen generator vehicle, they experience a smoother drive and gearshifts and a better performance with less flat zones. Not to mention cleaner and longer lasting engine oil.

7. Reduces air pollution and decreases noise pollution too

With improved efficiency, your vehicle will have fewer emissions that pollute the air. Of course, the smoother running of the engine will make the drive quieter and thus noise pollution is reduced.

Can today's vehicles be modified to burn hydrogen?

Over 80% of today's vehicles could be modified for hydrogen use.

Diesel engines are classified as compression ignition engines, since the heat and pressure of the compression stroke is what ignites their air/fuel mixture. Currently, a 50% replacement is seen as the upper limit for diesel use.

Spark ignition vehicles (most car and light trucks on the roads today) are easier to modify, since the timing of the ignition spark relative to the engine rotation can be controlled. Initially, these engines would be boosted with hydrogen, but ultimately hydrogen would replace 100% of their fuel.

So who's working with Hydrogen?

Hydrogen cars are not the future, they are here now.

When hydrogen cars become the status quo, countries can lessen dependence upon foreign oil, achieve lower prices at the fuel pumps and cut down on the greenhouse gases that produce global warming. The future of

hydrogen cars is not a pipe dream, as there are already many hydrogen fuel cell cars and H2ICE vehicles on the roads. California, Japan and the European Union (especially Germany) have many hydrogen fuel cars being used as fleet vehicles now.

However, there are issues for the early adaptors for both electric hybrid and conversion on both petrol and diesel units:

- Cost of the OEM equipment
- Cost of conversion for ICE engines
- Range of vehicles
- Hydrogen in vehicle storage is bulky
- Infrastructure and distribution
- Servicing including issues with metal brittleness
- Taxation and congestion zone approval issues need clarity especially for retro's
- HHO conversions
- OEM warranty
- Vehicle insurance
- Health and Safety for chemical handling and waste disposal

BMW Hydrogen engine reaches top level efficiency

Specialists from BMW, HOERBIGER, the Graz University of Technology, and HyCentA developed a hydrogen combustion process, which achieves remarkable efficiency for internal combustion engines for passenger cars.

Munich. The BMW Group Forschung und Technik, in cooperation with researchers in Graz and Vienna, Austria, has succeeded in developing a dedicated hydrogen combustion engine with diesel-like geometry and progressive H2 high-pressure direct injection technology. The result is an efficiency level of up to 42%, on par with that of the best turbodiesel engines. Partners in the H2BVplus project, which is sponsored by Austria's Federal Ministry for Transportation, Innovation and Technology (BMVIT), are the Institute for Internal Combustion Engines and Thermodynamics at Graz University of Technology, HyCentA Research GmbH in Graz, as well as HOERBIGER ValveTec GmbH in Vienna.

"In light of the limited availability of fossil fuels and the rising environmental impact from harmful emissions, we are convinced that the H2 combustion engine will assume an important position in the product portfolio of future alternative drive concepts. It will crucially contribute to safeguarding our individual mobility at the high level the customer expects," said Professor Dr. Raymond Freymann, Managing Director of BMW Forschung und Technik GmbH.

H2BVplus Hydrogen Combustion Engine

The newly developed combustion system combines the strengths of spark-ignition and diesel concepts, while utilising the favourable combustion properties of hydrogen, and thereby achieves efficiency values that easily bear comparison with even those of state-of-the-art turbo diesel engines. In the process, the engineers based their work on the joint EU HyICE project, during which maximum specific powers of up to 100 kilowatt per litre of displacement were demonstrated for a spark-ignition hydrogen combustion process.

"The demonstration model of the new free-form tank being presented marks an important step forward into the hydrogen future. Filled with ten kilograms of hydrogen, it could allow a range well in excess of 500 kilometres in a future vehicle."

Thanks to its innovative concept, the weight of the entire tank system can be reduced to a third compared with conventional cylindrical steel tanks. Its adaptable form lends it a high degree of flexibility, allowing for significant energy savings. The subsidiary systems, moreover, are integrated inside the tank's casing, which means the tank takes up less room in the car and maintenance is also made much easier. The inner tank is designed on a modular basis, simplifying the production process in comparison with existing hydrogen tanks.

Prof. Dr.-Ing. Raymond Freymann, Director of BMW Group Forschung und Technik: "The demonstration model of the new free-form tank being presented marks an important step forward into the hydrogen future. Filled with ten kilograms of hydrogen, it could allow a range well in excess of 500 kilometres in a future vehicle."

There's another hydrogen technology on the horizon by Asemblon

Asemblon is a research company based in Seattle, Washington. It currently employs 15 full-time and 2 part-time people, including 3 Ph.D. chemists and 8 other advanced degree holders. Asemblon was founded in 2002, and has been developing its products aggressively since 2005. It holds one United States patent and several foreign patents, with many more in the pipeline. Asemblon has extensive laboratory space, with advanced instrumentation for qualifying and quantifying its products and experimental developments. Asemblon specialises in products used for surface engineering and renewable energy research.

How did Asemblon get into the hydrogen business?

The fact that certain compounds give up some of their hydrogen in the presence of heat and a catalyst was a serendipitous discovery by Asemblon's scientists.

Asemblon scientists quickly recognised that having energetic hydrogen bound onto a chemical at standard temperature and pressure would provide enormous benefits for hydrogen storage and transportation.

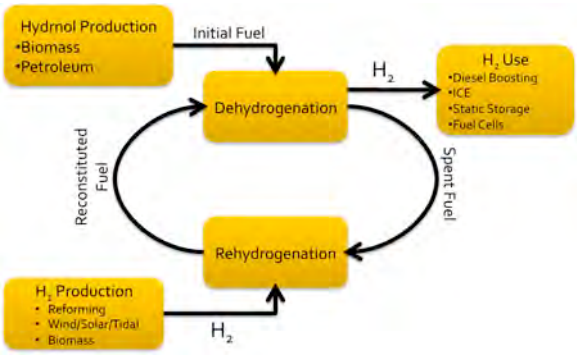
Asemblon's hydrogen technology, the N136™ Carrier, solves these issues in a very elegant way. While the lack of affordable fuel cells is likely to be an issue for another decade, hydrogen can be used with great effect to co-combust with petrol or diesel in existing vehicles. Pollution, including carbon soot, can be reduced substantially at reasonable cost while engine power and efficiency are actually increased. Hydrogen is not expensive to produce. Large volume purchases at the source can be made for less than $1.50 (£1.30) per kilogram. Whereas the cost to deliver this same kilogram is an additional $3.50 (£2.40) and $6.00 (£4.10) using compressed or liquid hydrogen, the cost to deliver it using the N136 Carrier is about $1.00. (£0.68).

What is the N136 Carrier?

The term, N136 Carrier, refers to a class of molecules that contain nitrogen where some hydrogen that can be stripped off by the application of heat and a catalyst. In order to be useful, the energy obtained from the hydrogen has to be much greater than the energy required to extract it. With the N136 Carrier, that is the case.

Since there is a family of these liquids, it is difficult to describe them all, but they generally have the density and viscosity of water, are clear, are liquid between -96ºC and 136ºC, and have flammability ratings between gasoline and diesel.

The best analogy for the N136 Carrier is that it is like the haemoglobin in our blood. Oxygen binds to the haemoglobin, is transported to our tissues where it is needed, and exchanges the oxygen for carbon dioxide. In the lungs, the process is reversed.



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The analogy to blood is not precise because there is no gas exchange. When some of the hydrogen atoms are stripped from the N136 Carrier, the molecule changes its chemical form and becomes Spent N136. To put more hydrogen onto this recyclable molecule requires a different catalyst, but little or no outside heat, as the reaction is exothermic (gives off heat) once initiated.

The N136 Carrier runs through a Reactor where it comes in contact with a heated catalyst that releases some of the hydrogen. Once the hydrogen is released, it becomes a dehydrogenated organic liquid that needs to be recycled and have hydrogen put back in it.

Estimates of the number of times the N136 Carrier can be recycled is over 100. That is not a limitation of the chemical process, but rather the 100-year experience of the petroleum distribution business in terms of losses in the system for liquid spills and vapour losses.

How is the N136 Carrier made?

Since N136 refers to a class of similar but different molecules, there is no single answer for how each will be made cheaply and efficiently. Several are based on petroleum by-products, some are alcohol based (ethanol and butanol feed stocks,) and others would be best made in plants specializing in fertilizer production.

All the methods used to make the original N136 molecule are based on well-known process chemistry. The cost of the original molecule is not important, since it will be recycled 100 times or more.

Can ethanol be used to make the N136 Carrier?

Ethanol is a fine starting material for several of the N136 molecules. In fact, the ethanol does not have to be dried before it can be processed into N136. The hydrated ethanol or 120 proof (60% ethanol and 40% water) is significantly less expensive because the costly heating of the liquid to drive off the water for producing 190 proof (95%) ethanol can be avoided.

Using ethanol and butanol to make N136 is an easy way to silence the critics who complain of the impact of these alcohols on the sharp rise in food prices. Since N136 can be recycled over 100 times, one can imagine expanding the supply of ethanol by 100 or reducing the food crop input by 99%.

Does N136 meet the DOE goals for hydrogen storage?

N136 already exceeds the 2015 goal five years ahead of schedule.

Can hydrogen compete with petrol or diesel on price?

Hydrogen is not expensive to make. It comes out of the typical steam reformer at slightly elevated temperature and 175 psi (11.9 bar). Asemblon's recycling process couples the hydrogen directly onto the Spent N136 Carrier. This avoids the cost of compressing or liquefying the hydrogen. It also avoids the cost of having to ship the hydrogen in special tankers or store it in expensive storage vessels.

The N136 Carrier can be transported in standard tank trucks and petroleum pipelines, unlike its compressed or liquid counterparts. Asemblon expects to be able to deliver a kilogram of hydrogen to a vehicle at a fuelling station for $2.50 (£1.71)

As petroleum becomes more and more difficult to find, extract, and refine, petroleum prices are expected to rise above $100/barrel in 10 to 15 years.

How long does it take to refuel an N136-powered vehicle?

The US DOE has set as their goal a three-minute refuelling time. Asemblon has designed a dual-channel fuelling nozzle to meet that goal. It allows fresh fuel to be pumped in while the spent fuel is withdrawn.

Can I fill up with hydrogen at my home?

Honda has designed a home fuelling station for their Clarity fuel cell vehicle. It connects to a natural gas supply and electricity, and steam reforms the methane to hydrogen. The hydrogen is compressed and stored in a tank ready to be transferred to the vehicle. There are two problems: the Clarity will cost $100,000 in 2015, and the home fuelling station will add another $50,000. So, yes, you can fill up with hydrogen at your home but it will be very expensive. What is really needed is the same approach as the brewing industry. We need micro generators and this is where the inexpensive HHO generators may play a part; especially if the oxygen is striped out at source.

Can I fill up with hydrogen on the road?

In the USA, there are proposals for fuelling stations to be built in local areas. Stations will be highlighted on Google Maps so that you can find the closest one to your current position. Hydrogen will be generated at large, central facilities and carried by truck, pipeline, or rail car to fuelling depots. From there, trucks would bring it to your local station. This is by far the most economical model for hydrogen fuelling.

Hydrogen Service Station with Dual Pumping Option

Can conversion to a hydrogen infrastructure be cost effective?

Asemblon is working with the Federal and State Governments to assist financially and to clear the regulatory hurdles to establishing a hydrogen infrastructure. Asemblon offers the capability to do this for less than 10% of the cost anticipated by the DOE.

Is the hydrogen released from N136 pure enough for fuel cells?

Fuel cells require very pure hydrogen. The specification usually calls for 99.999% purity (so-called 5 nines purity). A further requirement is that compounds that could damage the fuel cell must be at extremely low levels: 4 parts per billion for sulphur, for instance.

Asemblon certifies its hydrogen to meet both of these requirements.

How dangerous is N136?

Hydrogen bound to the N136 Carrier is much safer than free hydrogen in a gaseous or liquid form. In fact, N136 can be shown to be as safe to store, transport, and handle as gasoline or diesel fuel. To minimise any potential danger, free hydrogen is generated only at the time and place of use.

Can N136 make wind farm energy more valuable?

In most places, wind blows most strongly from the evening to the early morning (6 PM to 9 AM.) Electrical demand is the highest from 2 PM until 6 PM. The marginal rates for electricity mirror this demand cycle. If wind energy could be stored in the evening and early morning when rates are low and put back on the grid in the afternoon when rates are three to eight times higher, utilities could maximize the return on their investment in wind energy.

Asemblon is working with several of the most forward thinking electric utilities to test the economic feasibility of this time-shifting technique.

Who is leading the way in hydrogen adoption?

Surprisingly, all the major automobile manufacturers have hydrogen powered internal combustion vehicles as well as fuel cell vehicles. Of the major manufacturers, BMW (Series H700 sedan), Honda (Clarity fuel cell vehicle) and Ford (F-150 pick-up truck and hydrogen airport bus) are leading the way.

California and Germany are the governments that are out in front in terms of planning and financing the infrastructure build-out. Not far behind are Japan, Norway and Iceland.

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The three of us get together Airmax, Asemblon and The Cell.

Being able to produce and manage the engine's management system to maximise the fuel efficiency is a great start. Indeed early adaptors such as City Link and FedEx are installing The Cell, Inc's HHO units and shaking down the systems under controlled conditions. The Cell is already achieving in excess of 20% fuel efficiencies.

Airmax is developing a ubiquitous ECU to allow on-board and remote control of systems management.

Just imagine three further new initiatives as a result of this technology trilogy and company cooperation:

1. Fuel on demand within the vehicle as seen by the installation of the City Link Renault
2. Home production of hydrogen (in the micro brewery sense).
3. Hydrogen storage on-board thus is eliminating the need for compressed cylinders and expensive installations.

- **Airmax Group.** A leading innovator in telematics solutions and automotive engine management systems. (www.airmaxgroup.com)

THE CELL INC

- **The Cell Inc**. A company that has been working on hydrogen technology and produces its own hydrogen generating cell. (www.thecell.com)

- **Asemblon**. A company that has ground breaking technology that enables hydrogen to be stored and poured at room temperature. (www.asemblon.com)