Hydrogen

Alternative to Conventional fuels

It is the air you breath

Keep it clean

Hydrogen
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Primary energies

Fossil energies emitting greenhouse gases		81 %
Crude oil	35%	
Natural gas	22%	
Hard coal	13%	
Lignite	11%	
Nuclear power plants producing nuclear waste		12 %
Renewable energies		11 %

To change to sustainable energy economy decarbonisation of fuel and reduction of nuclear energy is imperious.

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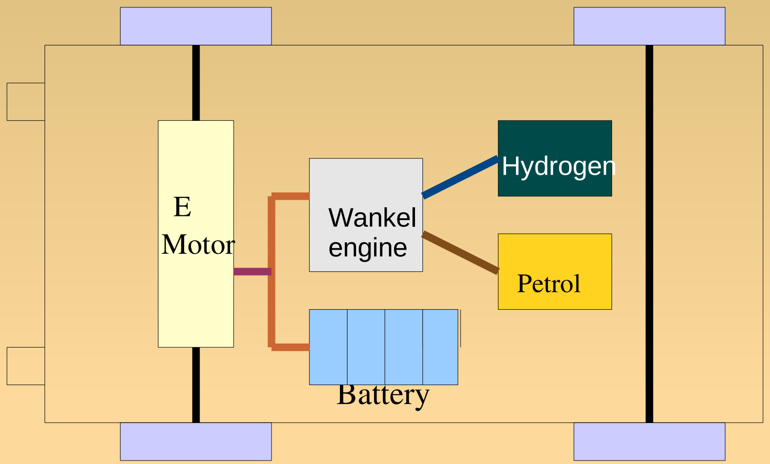
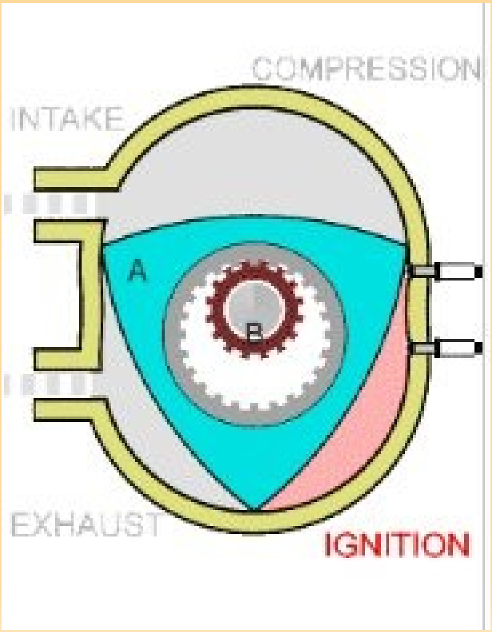
The Mazda Hybrid



There are some options to avoid air pollution.

The Mazda hydrogen version uses a Wankel engine which works on hydrogen and optionally on petrol.

The Wankel Engine



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Alternatives?

Lithium ion storage battery

Li-Tec, Daimler and Evonik build a giant lithium-ion battery to stabilise short fluctuation s of the electric grid resulting from the feed in of wind and photovoltaic power.
Solar thermal systems
Technologies to store energy for a short time are well developed, such as flywheels or giant capacitors may absorb short time fluctuations. A series of batteries like the lead-acid battery, the lithium-ion battery, or the redox-flow battery in which the electrolysis liquid is kept in a separate tank, leading to a greater energy storage capacity.

Pumped storage hydro power station

The pumped storage hydro power stations in Germany may supply energy for only few hours.
To comply with the demands of Europe enormous water reservoir would have to be created, together with their collecting lakes. The amount of water would be equal to two to eight times the volume of the lake Constance.

Compressed air

Compressed air stored in underground caverns would require 3,000 to 15,000 compressed air generators.

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Steam reforming

Industrial production is mainly from the steam reforming of natural gas, and less often from more energy-intensive hydrogen production methods like the electrolysis of water. Most hydrogen is employed near its production site, with the two largest uses being fossil fuel processing (e.g., hydrocracking) and ammonia production, mostly for the fertilizer market.

Space shuttle take off with liquid hydrogen

Hydrogen can embritel metals

Hydrogen is a concern in metallurgy as it can embrittle many metals, complicating the design of pipelines and storage tanks.

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Energy

Hydrogen gas (dihydrogen) is highly flammable and will burn in air at a very wide range of concentrations between 4% and 75% by volume. The enthalpy of combustion for hydrogen is –286 kJ/mol:

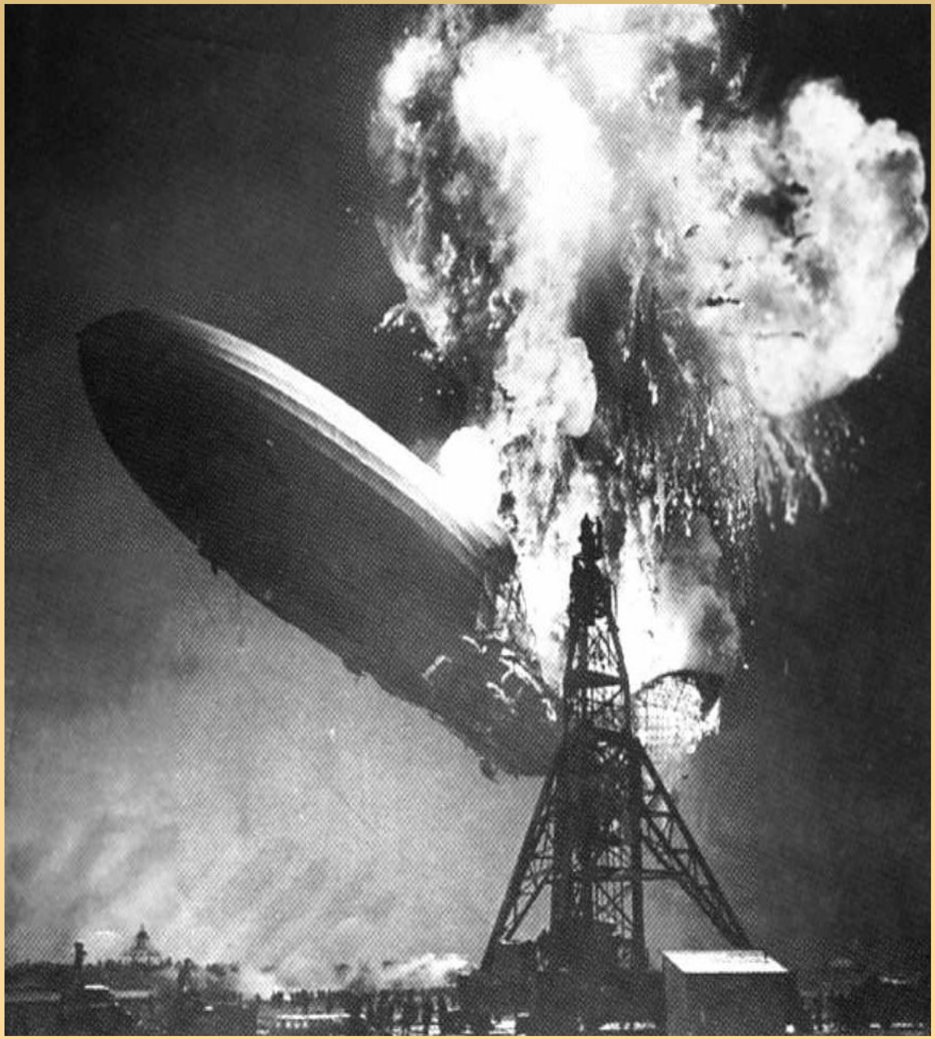
$$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O + 572\ \text{kJ}\ (286\ \text{kJ/mol})$$

286 kJ/mol: energy per mole of the combustible material (hydrogen)

Safety

Hydrogen gas forms explosive mixtures with air in the concentration range 4-74% (volume per cent of hydrogen in air) and with chlorine in the range 5-95%. The mixtures spontaneously detonate by spark, heat or sunlight. The hydrogen autoignition temperature, the temperature of spontaneous ignition in air, is 500 °C (932 °F).
The destruction of the Hindenburg airship was an infamous example of hydrogen combustion; the cause is debated, but the visible flames were the result of combustible materials in the ship's skin.[12] Because hydrogen is buoyant in air, hydrogen flames tend to ascend rapidly and cause less damage than hydrocarbon fires. Two-thirds of the Hindenburg passengers survived the fire, and many deaths were instead the result of falls or burning diesel fuel

The Hindenburg dirigible disaster May 6, 1937



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The best option to store energy [1] [2]

Hydrogen is seen as the best option to store energy. However, the infrastructure is not yet established. Siemens says that 50 to 200 salt caverns would be necessary to have a good storage to feed the powerstations of Europe for weeks. CCS, however, wants to reserve these places for its future activities of the coal industry. [1]

Hydrogen to methane to store wind energy using the natural gas infrastructure

Michael Sterner, from the Fraunhofer-Institut IWES in Kassel/Germany, presented a technology to produce hydrogen by splitting water in H2 and O2 and Hydrogen is the transformed in methane addig CO2 from the air. The resulting methane can be handled with the local infrastructure of natural gas which also consists mainly of methane. Solar fuel already has a running pilot plant of methane using hydrogen from hydrolisis of water.

Walter Scheer from Eurosolar stresses that the old economy always have to hold on past investments. New emerging companies could embrace such new technologies and are not bound to old fade out strategies.

[1] Wohin mit dem Windstrom? 27.12.2009
http://www.wir-klimaretter.de/content/view/4432/340/
[2] EuroSolar
http://www.eurosolar.de/en/index.php?option=com_content&task=view&id=391&Itemid=112

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Laboratory

In the laboratory, H_2 is usually prepared by the reaction of acids on metals such as zinc with Kipp's apparatus.

$Zn + 2\ H^+ \rightarrow Zn^{2+} + H_2$

Aluminium can also produce H_2 upon treatment with bases:

$2\ Al + 6\ H_2O + 2\ OH^- \rightarrow 2\ Al(OH)_4^- + 3\ H_2$

The electrolysis of water is a simple method of producing hydrogen. A low voltage current is run through the water, and gaseous oxygen forms at the anode while gaseous hydrogen forms at the cathode. Typically the cathode is made from platinum or another inert metal when producing hydrogen for storage. If, however, the gas is to be burnt on site, oxygen is desirable to assist the combustion, and so both electrodes would be made from inert metals. (Iron, for instance, would oxidize, and thus decrease the amount of oxygen given off.) The theoretical maximum efficiency (electricity used vs. energetic value of hydrogen produced) is between 80–94%.[70]

$2H_2O(aq) \rightarrow 2H_2(g) + O_2(g)$

In 2007, it was discovered that an alloy of aluminium and gallium in pellet form added to water could be used to generate hydrogen. The process also creates alumina, but the expensive gallium, which prevents the formation of an oxide skin on the pellets, can be re-used. This has important potential implications for a hydrogen economy, since hydrogen can be produced on-site and does not need to be transported. [1]

[1] Venere, Emil (May 15, 2007). "New process generates hydrogen from aluminum alloy to run engines, fuel cells". Purdue University. http://news.uns.purdue.edu/x/2007a/070515WoodallHydrogen.html. Retrieved 2008-02-05.

Hydrogen

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Industrial
Main article: Hydrogen production

Hydrogen can be prepared in several different ways, but economically the most important processes involve removal of hydrogen from hydrocarbons. Commercial bulk hydrogen is usually produced by the steam reforming of natural gas.[72] At high temperatures (1000–1400 K, °C;700–1100 °C or 1,300–2,000 °F), steam (water vapor) reacts with methane to yield carbon monoxide and H_2.

$$CH_4 + H_2O \rightarrow CO + 3\ H_2$$

This reaction is favored at low pressures but is nonetheless conducted at high pressures (2.0 MPa, 20 atm or 600 inHg) since high pressure H_2 is the most marketable product and Pressure Swing Adsorption (PSA) purification systems work better at higher pressures. The product mixture is known as "synthesis gas" because it is often used directly for the production of methanol and related compounds. Hydrocarbons other than methane can be used to produce synthesis gas with varying product ratios. One of the many complications to this highly optimized technology is the formation of coke or carbon:

$$CH_4 \rightarrow C + 2\ H_2$$

Consequently, steam reforming typically employs an excess of H_2O. Additional hydrogen can be recovered from the steam by use of carbon monoxide through the water gas shift reaction, especially with an iron oxide catalyst. This reaction is also a common industrial source of carbon dioxide:

$$CO + H_2O \rightarrow CO_2 + H_2$$

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Other important methods for H_2 production include partial oxidation of hydrocarbons:

$$2\,CH_4 + O_2 \rightarrow 2\,CO + 4\,H_2$$

and the coal reaction, which can serve as a prelude to the shift reaction above:

$$C + H_2O \rightarrow CO + H_2$$

Hydrogen is sometimes produced and consumed in the same industrial process, without being separated. In the Haber process for the production of ammonia, hydrogen is generated from natural gas. Electrolysis of brine to yield chlorine also produces hydrogen as a co-product.

Thermochemical

There are more than 200 thermochemical cycles which can be used for water splitting, around a dozen of these cycles such as the iron oxide cycle, cerium(IV) oxide-cerium(III) oxide cycle, zinc zinc-oxide cycle, sulfur-iodine cycle, copper-chlorine cycle and hybrid sulfur cycle are under research and in testing phase to produce hydrogen and oxygen from water and heat without using electricity. [1]

A number of laboratories (including in France, Germany, Greece, Japan, and the USA) are developing thermochemical methods to produce hydrogen from solar energy and water. [2]

[1] Al Weimer: Development of solar-powered thermochemical production of hydrogen from water. 25 May 2005
http://www.hydrogen.energy.gov/pdfs/review05/pd28_weimer.pdf

[2] Robert Perret. "Development of Solar-Powered Thermochemical Production of Hydrogen from Water, DOE Hydrogen Program, 2007
http://www.hydrogen.energy.gov/pdfs/progress07/ii_f_1_perret.pdf

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Hydrogen production using solar thermal technology

Solar Thermochemical Hydrogen Cost

Our current estimate for the cost of hydrogen from a solar driven hybrid sulfur cycle is $3.90-$4.90/gasoline gallon equivalent (gge). Our current estimate for the cost of hydrogen from the zinc oxide cycle is $4.60- $6.85/gge. [1]

[1] Robert Perret. "Development of Solar-Powered Thermochemical Production of Hydrogen from Water, DOE Hydrogen Program, 2007 http://www.hydrogen.energy.gov/pdfs/progress07/ii_f_1_perret.pdf

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North Field-DOY82, H10
125 m tower
7881 m² (5.3 acres land)

In
4.9-5.9 Mwth
η=62-74%

Out
3.9-5.2 MWth-
η=79-88%

Technical Targets
Solar-Driven High-Temperature Thermochemical Hydrogen Production [1]

Characteristics	Units	2006 Target	2012 Target	2017 Target
Solar Thermochemical Hydrogen Cost	$/gge H_2	10	6	3
Solar Thermal Capital Installed Cost	$/m^2$	180	140	80
Process Energy Efficiency	%	25	30	>35

[1] Robert Perret. "Development of Solar-Powered Thermochemical Production of Hydrogen from Water, DOE Hydrogen Program, 2007
http://www.hydrogen.energy.gov/pdfs/progress07/ii_f_1_perret.pdf

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Solar thermal energy for high temperature processes (T <1,300°C) is being studied using a solid particle receiver (SPR) concept that accumulates directed solar energy from a field of heliostats.

The net yield of Zn was ~36%. The reaction occurs only on the surface of the particles, Therefore small particles as aerosol are proposed.

The Zn/ZnO hydrolysis kinetics experiments also showed that reaction rates were faster in aerosol configurations than in stationary configurations.

Solid particle receiver

Uses sintered bauxite proppans for heat collection and storage.
-Directly illuminated curtail of fallinmg particles. High heat flux capacity. Non-corrosive.
Sintered bauxite suitable to 1000°C
Zircon suitable to 1200°C

Hydrogen

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The best choice

Photovoltaic and wind turbin bring immediate results in production of hydrogen. Both technologies are scalable. They can start in minute size without investment risk. Solar thermal energy is not scalable. It must follow a rigid initial construction plan. Hydrolysis of water is the best renewable fuel of the future.

The End

Keep your world clean. Choose the best way.
Don't take the cheapest choice