HYDROGEN MOBILITY
More than just a vision

Dr. Hugo Vandenborre

Printed in The Netherlands

Printed and bound by: Blurb, Eindhoven, The Netherlands
First published in Belgium, March 2016
Consulting, Art Direction, Lay-out and Styling: Katrien Hermans

HYDROGEN MOBILITY

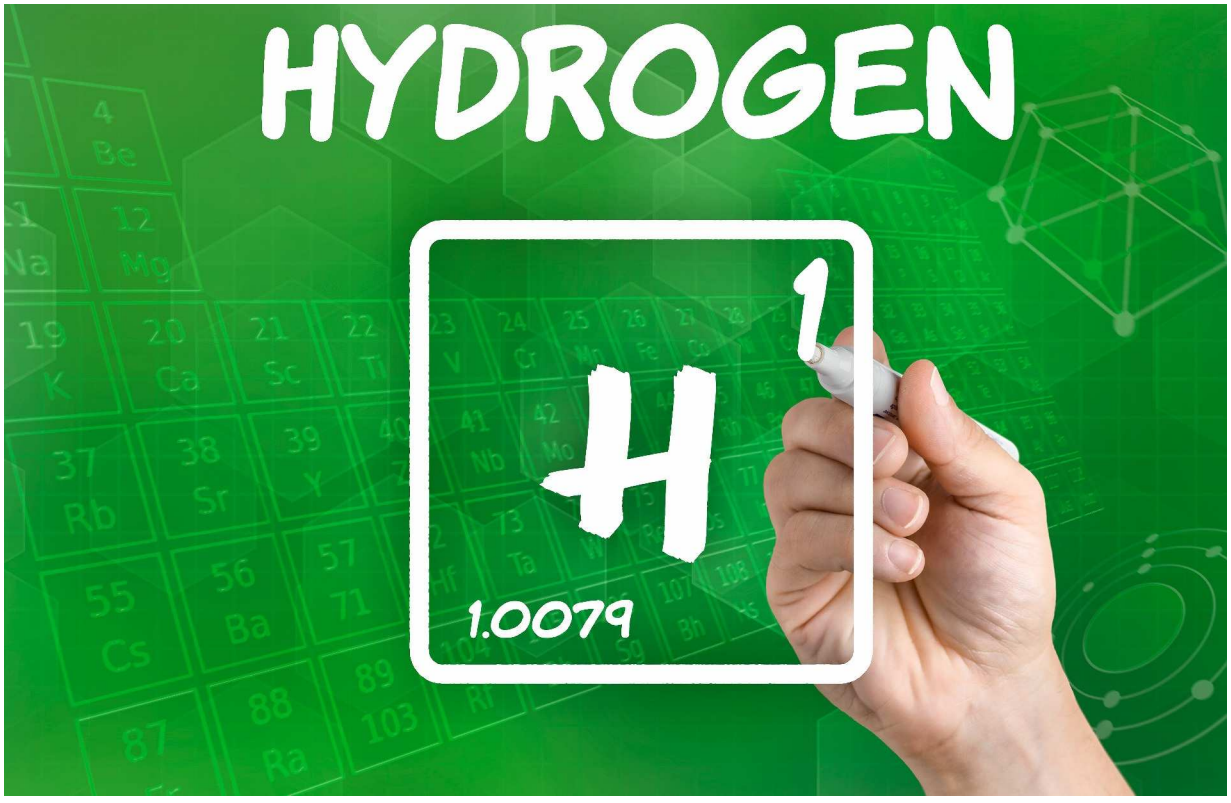
More than just a vision

Dr Hugo Vandenborre

'A world based on a green and blue energy system, sustainable energy and water might not just be a dream for my grandchildren Kaat, Janne, Joke, Laura, Toon, Jonas, Roos en Floor. It will be my gift for their future and the future of everyone.'

Dr. Hugo Vandenborre

Driving the future in a Honda Clarity



Composed of a single proton and a single electron, hydrogen is the simplest and most abundant element in the universe. It is estimated that 90% of the visible universe is composed of hydrogen. Hydrogen is the raw fuel that most stars 'burn' to produce energy.

It is colorless, odorless, tasteless and non-toxic. Hydrogen, just like gasoline and natural gas is readily flammable and can therefore be used as a fuel.

Hydrogen is by definition a ZERO emission fuel.

Contents

Preface

We cannot change our transportation and energy system overnight, but with the right strategy we can gradually bring about an evolution in the way we use our transportation system, store our energy and heat our homes and buildings.

Many of the technological breakthroughs to enable this future already exist - and a gradual transition to hydrogen as a fuel could begin today. Improvements to current technologies and new technological discoveries will undoubtedly continue to evolve, but the political will is needed to start a real transition as of now.

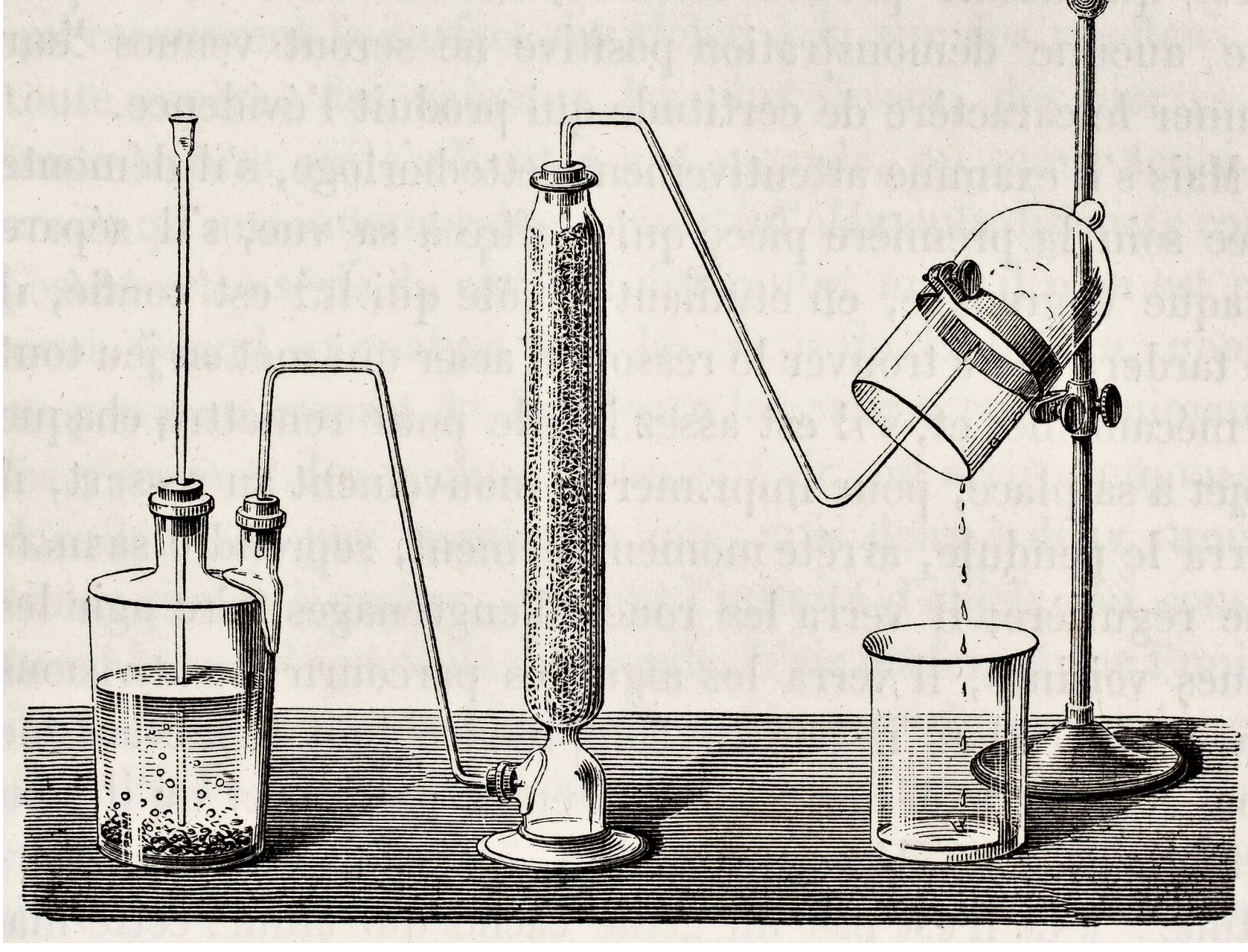
By making the right decisions today, hydrogen can stimulate economical growth and make our world cleaner, more livable and sustainable.

However, there is still a fear of hydrogen. Fears about its safety and physical properties, but more than anything, this is fear of the unknown. A fear we need to overcome.

This is the first in what set to become a series of books on the reality of a hydrogen society and a plea for its speedy adoption.

Dr. Hugo Vandenborre

An image of the ix35, Hyundai's current hydrogen production car



Old illustration demonstrating that in hydrogen combustion, the only exhaust is droplets of water. Published in L’Eau, by G. Tissandier, Paris, France, 1873.

Hydrogen in history

In his 1874 work, *L'ile mystérieuse,* Jules Vernes wrote: 'I believe that one day water will be used as a fuel, that the hydrogen and oxygen of which it is composed, will supply an inexhaustible source of heat and light'.

Hydrogen is the most common element in the universe. For over 500 million years, plants have been using solar energy to convert carbon dioxide and water into oxygen and carbohydrates through photosynthesis. The organic material was then covered with a layer of sediments and converted into hydrocarbon and fossil fuels through heat and pressure. It would take millions of years before people would learn how to use them.

The Chinese are technically the first users of oil. In 2000 BC, they already used a type of refined crude oil to light and heat their houses. The Greeks on the other hand established the foundations for our current knowledge about hydrogen, electricity and solar energy.

In 500 BC, the philosopher Heraclitus described a world in which there is a constant interaction of 'fluxes' between earth, fire and water - the basic elements known at the time. And even though renewable energy generation through hydro power, wind and solar was known for centuries before our modern calendar began - people still used fossil fuels first.

In 1776, the British scientist Henry Cavendish discovered that hydrogen is a specific element. He described it as 'highly inflammable air'.

In 1780, the French chemist Antoine Lavoisier gave Cavendish's 'inflammable air' its final name, hydrogen. The name was chosen because the gas can be extracted from water and it turns into water again upon combustion.

But it was the Dutchman Adrien Paets van Troostwijck who in 1789 succeeded in extracting hydrogen through the electrolysis of diluted acids.

English scientist and lawyer William Grove discovered in 1850 that it was possible to generate power by combining gases over a catalyst. This made him the inventor of the present-day fuel cell.

One hundred years later, in 1960, NASA first used fuel cells in space missions. The oil crisis of the 1970s prompted the development of alternative energy technologies, including hydrogen fuel cells for conventional commercial application.

I started my own research into a new hydrogen membrane in 1977, after I became fascinated by the concept of the fuel cell during my studies in the US.

In 1985, I discovered how a membrane could be made from inorganic ion exchangers to split water into hydrogen and oxygen with an efficiency of over 90%.

Today we are still burning fossil fuels - which took millions of years to be synthesized - and pollute our planet. Why this is the course that history took, continues to surprise me today.

Antoine Lavoisier (1743-1794) gave the name 'hydrogen' to the gas which was referred to before as 'inflammable air'. Published in The Gallery Of Portraits With Memoirs encyclopedia, United Kingdom, 1835.

'Don't go where the path of fossil fuels may lead;
go where there is no path and leave a TRAIL'

Dr. Hugo Vandenborre

Hydrogen infrastructure

It is clear that Hydrogen fuel offers the largest potential benefits in terms of reduced emissions of pollutants and greenhouse gases. But the development of a hydrogen infrastructure is often seen as a technical and economic barrier. A widespread hydrogen distribution infrastructure does not currently exist, although the technologies to produce, store and distribute hydrogen to vehicles are commercially available today.

But imagine that in the future, you could drive your hydrogen car into your garage and gas it up at your own home hydrogen fuel station. Solenco Power - a start-up recently founded by Dr. Hugo Vandenborre, is focusing on making this concept a reality. The system - using their trademark Solenco Power Box - does not only refuel a hydrogen car, it can also power a home through electricity and heat.

This is how it works. Solar panels act as the sole source of energy input. Electricity needs are covered by the solar panels during day time and only the surplus is sent to the Solenco Power Box. This unit then splits the water molecules and produces hydrogen. The latter is stored as a pressurized gas. When there is no sunshine, electricity is produced from the stored hydrogen and at the same time heat is produced at 95 % efficiency. The heat covers hot water needs for heating and sanitation. If the production of heat is higher than requested, heat will be stored in a hot water tank. In case the requested heat is higher than production, extra heat will be produced through a catalytic hydrogen burner. This is a high efficiency (97%) burner without flame using

hydrogen as fuel.

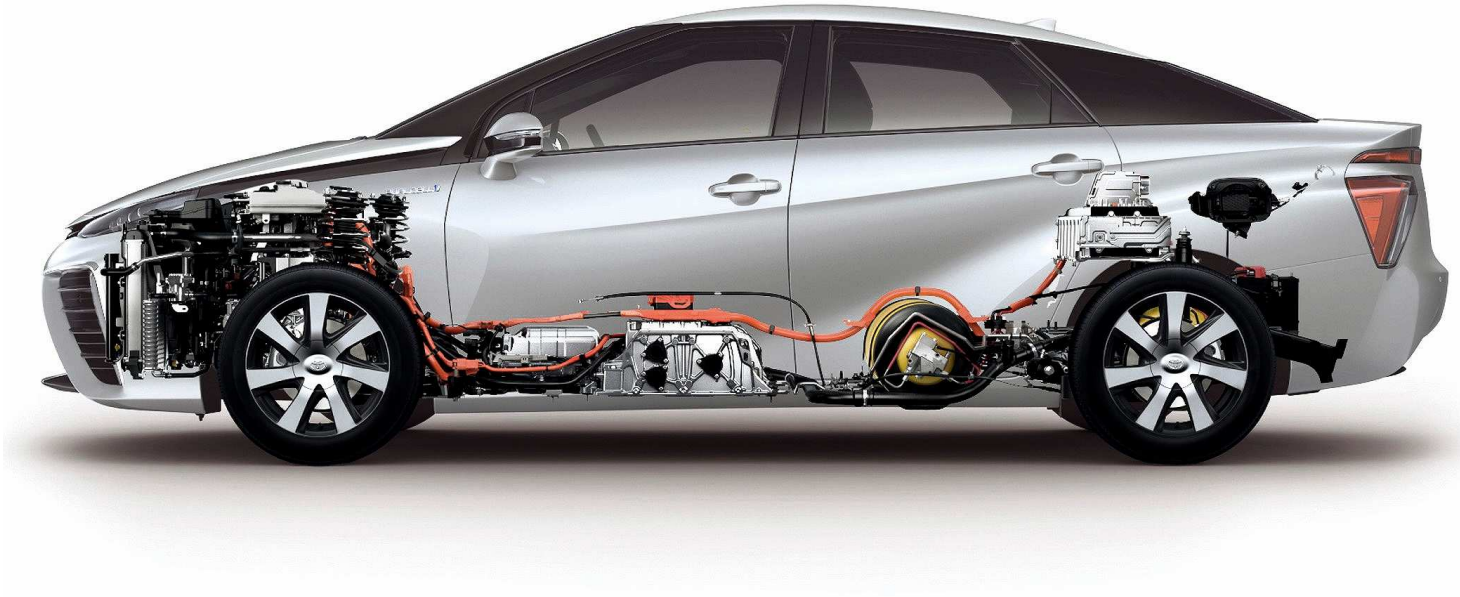
In the framework of a demonstration project financially supported by the European Commission, a similar system will be installed at Borkum Island, Germany in the course of 2016.

Hydrogen from water and renewable electricity

Hydrogen is strictly speaking not an energy source like natural gas, oil, coal or wood. In fact, it is an energy carrier. In this respect, hydrogen can be use the same way as electricity, to transport energy or to store energy.

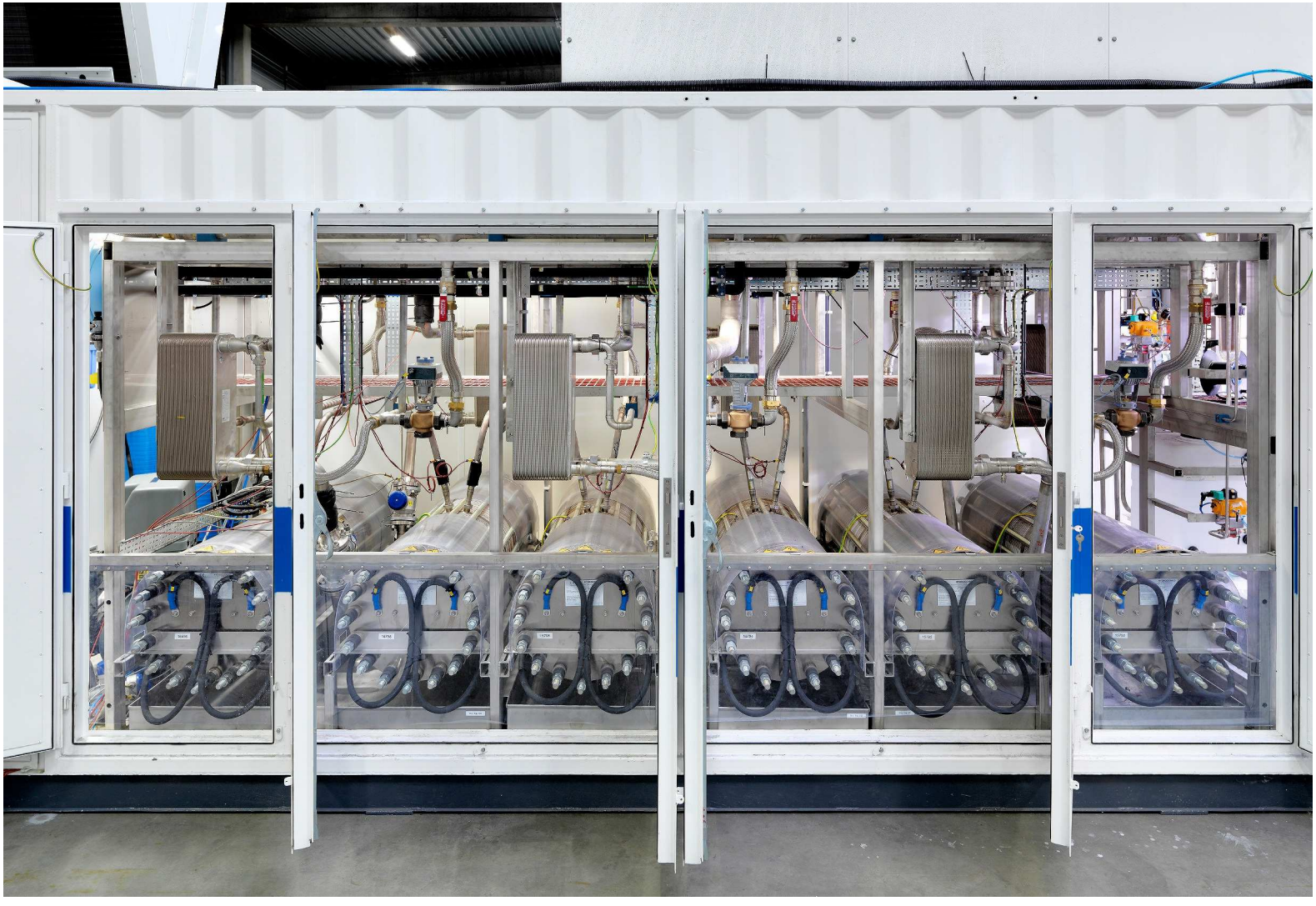
It is also a very flexible fuel. It can be used both in an internal combustion engine (mechanical energy), in a fuel cell (electric energy) and in catalytic combustion (thermal energy). When hydrogen is produced through water electrolysis, the only other by-product is oxygen and as a consequence is fully 'green'. In the case of hydrogen as a by-product of natural gas, oil or coal, CO2, the creation of the much-feared greenhouse gases is inevitable. This is referred to as 'brown hydrogen'. But even when produced through this method, it is more environmentally friendly than oil.

Once hydrogen is produced, how can it be stored? The biggest challenge is volume. Hydrogen is the lightest gas in the universe and is eleven times lighter than the air we breathe. Whereas it has high energy density when it comes to weight, hydrogen takes up sizable dimensions under normal atmospheric pressure.



Internal working of a Toyota Mirai

Image courtesy of Toyota Europe



Hydrogen production through electrolysis

Image courtesy of Hydrogenics Europe N.V.

As we move towards higher levels of hydrogen mobility, storing and transporting hydrogen efficiently becomes crucial. There are several ways to make hydrogen transportable. The easiest and most efficient way to decrease the volume of hydrogen gas is to increase its pressure.

In order to cover a distance of around 500 km between fuel stops, around 5 kg of hydrogen is needed. In terms of volume, this would mean 55m3, or around the size of a bus. As with any gas, the easiest way to decrease its volume is to increase its pressure at constant temperatures. Currently, steel cylinders with hydrogen stored at 200 bar are already available. 200 bar means 200 times normal atmospheric pressure. Hydrogen in cars is currently stored at 700 bar. At this pressure, our 5 kg of hydrogen fits in a 125-liter tank, roughly twice the size of a conventional fuel tank.

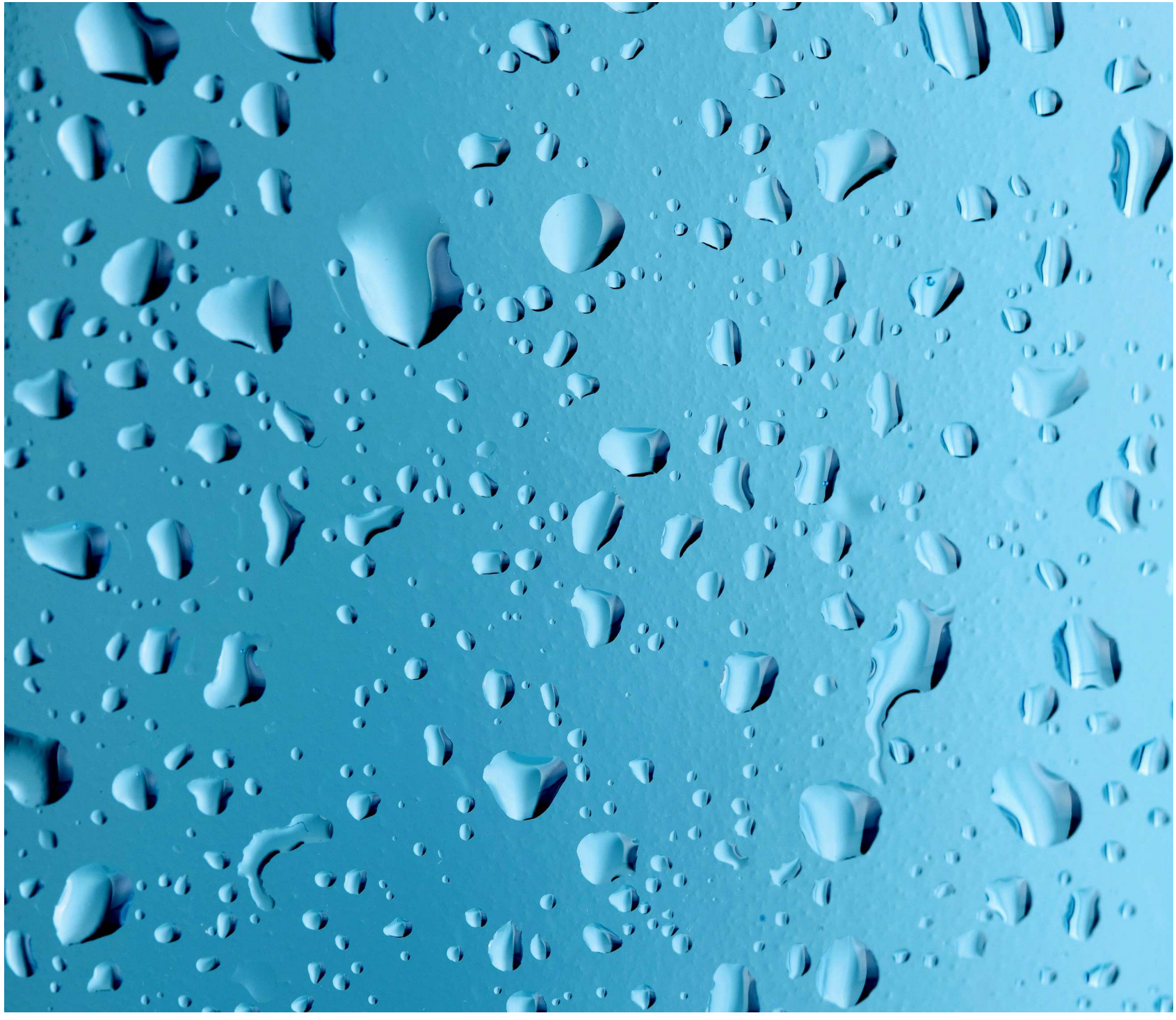
Is Hydrogen Fuel safe

Like any other fuel, the right safety regulations must be observed when using hydrogen. Hydrogen is highly inflammable and very explosive. Hydrogen ignites with a 4% concentration in air and is explosive at 18%.

Safety, as for any combustible substance, means that users must be aware of the so-called fire triangle - for combustion, three elements are necessary, i.e. the fuel, an oxidant and an ignition. Fire only occurs if the three elements are present. The oxidant is usually oxygen that already accounts for 20% of the air. Safety preferably means excluding two of these elements, e.g. no smoking when refueling or handling hydrogen and avoiding contact with air.

Also, let us not forget that we use gasoline, diesel or other fossil fuels every week, if not every day. It has become routine and we do not dwell on the fact that 40 liters of gasoline has as much energy as 300 kilos of TNT. If we compare the safety of gasoline to that of hydrogen, 'hydrogen actually comes out better' (as quoted by Ford motor Company). Hydrogen gas of course is more flammable and more explosive than gasoline, but it is also much more volatile. In the most exceptional case of a fire in the gasoline tank, the gasoline will spread underneath the car, because it is heavier than air. Gasoline also burns longer than hydrogen and produces suffocating gases.

So safe storage of hydrogen is absolutely necessary, preferably under pressure, to prevent mixing with air.



Bangkok - March 26, 2015 : Toyota Mirai, Hydrogen Engine Vehicle, On Display At 36th Bangkok International

For over 40 years, hydrogen has been used in industry in vast quantities as an industrial chemical and fuel for space exploration. During that time, the industry has created an infrastructure to produce, store, transport and utilize hydrogen safely.

An experiment at the University of Miami, Florida, revealed that at 60 seconds after ignition, the hydrogen flame began to subside, while the gasoline fire was intensifying. Dr. Swain from the University of Miami explains, 'After 100 seconds, all of the hydrogen was gone and the car's interior was undamaged (the maximum temperature inside the back window was only 19.5°C!). The gasoline car continued to burn for several minutes and was completely destroyed.'

One of the reasons hydrogen used to (wrongfully) have a bad reputation is because of the so called 'town gas', commonly used to heat homes until the first half of the 20th century. Town gas or 'coal gas' was a mix of around 50% hydrogen mixed with methane, carbon dioxide and carbon monoxide - made from coal. The gas was used for heating and lighting people's homes before the supply and transmission of natural gas became widespread from the 1940s onwards. In the UK, town gas as used throughout the 19th century for street lighting. Unfortunately, the gas was sometimes also used for a more ill-fated purpose, namely to commit suicide. However, hydrogen was not to blame, they died from carbon-monoxide poisoning.

The new engine, based on the Hydrogen Fuel Cell

The fuel cell is a device that converts chemical energy into electrical energy. Hydrogen is combined with oxygen (mostly obtained from the air) within a fuel cell to electrochemically produce electricity, water and heat.

The heart of the fuel cell generally consists of three primary parts: an anode, a cathode and an electrolyte. The electrical current flows from the cathode to the anode. There are different types of fuel cells depending on whether they are used in stationary, portable or mobile applications. In mobile (car or forklift) applications the fuel cell is composed of a proton exchange membrane which acts as the electrolyte and is referred to PEM-Fuel Cell.

The anode is coated with a catalyst (mostly noble metal based) which helps to split the hydrogen molecules into positively charged protons and negatively charged electrons. The electrolyte membrane allows only the protons to pass through this membrane to the cathode. The electrons cannot pass through this membrane and as a result, they flow in the form of an electrical current through an external circuit to get to the cathode. Oxygen supplied at the cathode then combines with the protons to form water.

Individual fuel cells are combined into a so called fuel cell 'stack'. The number of fuel cells in the stack determines the total voltage (1 fuel cell is typically 0.7 Volt). The surface area of each fuel cell determines its total current - typically 0.5 to 1.0 Ampère/ cm^2. Multiplying the voltage by the current yields the total electrical power generated, measured in kilowatts.

Fuel cell stack by Ballard Power Systems Inc.

Image courtesy of Ballard Power Systems Inc.

PARIS, November 30th 2015 - Prince Charles at the COP21 in Paris

Who is at the forefront of implementation

The COP21 in Paris at the end of 2015 turned out to be the largest ever single-day gathering of heads of state. This illustrates how critical the climate issue really is. Transport emissions account for a quarter of all of the EU's total emissions of carbon dioxide (CO2), the main greenhouse gas. Drastic measures are needed to reduce this.

The post-Kyoto United Nations negotiations have led to the agreement to have 'net zero emissions' during the second half of the century. This would mean drastically reducing emissions and any CO2 produced would need to be captured and disposed of or be neutralize by planting massive amounts of trees.

The summit has not missed its mark. Countless green initiatives are emerging worldwide. Bill Gates and other billionaires announced their breakthrough Energy Coalition in Paris in parallel with the COP21.

CHIC(Clean Hydrogen in European Cities) - a zero emissions bus initiative - is the next step towards full commercialization of Fuel Cell Hydrogen powered buses. The project gathers the results of 56 hydrogen buses, emitting nothing but water vapor. CHIC is already operational in 5 locations across Europe and has saved over four million liters of fuel and 6,000 tonnes of greenhouses gases (which amount to the annual fuel consumption of 91 diesel buses).

The initiative proves that the world is ready for a shift to hydrogen mobility in urban centers.

JAPAN

Hydrogen powered cars are a reality and the demand for fuel cells as well as hydrogen as fuel will surely rise over the next few years. We can expect Japan to be an interesting market for fuel cell manufacturers. The market potential for clean energy will be massive in Japan due to the steps taken by the government. The Japanese Prime Minister, Shinzo Abe, suggested he would be giving an 18 000€ subsidy for fuel cell vehicles since these vehicles are currently more expensive than electric and hybrid cars.

Major car manufacturers like Toyota and Honda have been leading the race to introduce the next-generation zero-emission hydrogen vehicles. Neil Spires, Mirai product manager for Toyota believes mainstream electric vehicles are not quite there yet. He thinks that electric cars are perfect for inner city use, but that the future belongs to hydrogen cars. Toyota has produced 700 of their Mirai hydrogen engine vehicle globally in 2015 and production will go up to 3,000 in 2016. Most of the vehicles will be for sale in Toyota's home market of Japan. The Mirai has a range of 550 km, has a 114kW motor, a nickel-metal hydride battery and a price tag of 80 000€.

Honda has created its own production fuel cell vehicle called the FCV Clarity (4th generation) with a range of an impressive 700 miles, a 130kW motor and lithium-ion battery. The FCV Clarity will be ready for sale in the European market in 2016.

Image of the Toyota Mirai

Image courtesy of Toyota Europe

View of the engine of a Toyota Mirai fuel cell car. The Mirai model is a vehicle equipped with a fuel cell that generates electricity through the chemical reaction between hydrogen and oxygen to power the motor driving the vehicle.

Image courtesy of Toyota Europe

Japan is the first country to give subsidies for fuel cell vehicles and other governments are bound to take similar steps once car manufacturers decide to launch zero-emission hydrogen vehicles.

The country is particularly focused on increasing the use of hydrogen fuel cells to limit carbon emissions. The country has devised a twenty five year plan in order to increase the use of hydrogen and fuel cells. One hundred new hydrogen fuel stations have become operational in the most populated areas of the country in 2015. During the period of 2020-30, the country plans to have 5.3 million fuel cells providing energy to the residential customers. By 2040, Japan aims to produce hydrogen in a carbon-neutral manner and scale back the dependence on the fossil fuels for its production.

United States

Another interesting application of fuel cells is in material handling through forklifts. The American company Plug Power has joined forces with Wal-Mart to supply not only fuel cell units, but the infrastructure to supply hydrogen. Repeat customers - as well as the addition of new sites - show that the technology is getting traction and customers are seeing the benefits of fuel cell powered forklifts.

Wal-Mart's decision to increase its fuel cell powered fleet suggests the benefit to the retailer is substantial. The company might even convert its entire forklift fleet to fuel cell powered vehicles in the future. The initial cost of the fuel cell systems is substantially higher than the cost of traditional batteries - however, if we take into account the replacement costs and the refueling costs - fuel cell powered forklifts give considerable savings to the business. Furthermore, the saving in the loss of productivity is a major issue as well because it brings efficiency to the operations of the company. According to Wal-Mart's study, the fuel cell powered forklifts can provide savings of up to 24% to a warehouse employing 230 forklifts - and the payback period for such a project will be just one year.

It is clear that the retailers see measurable benefits from the use of fuel cell powered forklifts. Along with these measurable benefits, the intangible benefits of using fuel cells are considerable - fuel cells do not cause pollution and these are preferable especially in the warehouses - less pollution will have a positive impact on the employees' health which should allow the retailers to have savings from insurance as well as better image with activists.

Alt Car Expo

SANTA MONICA CA - SEPT 26 2015: Force Fuels custom built Hydrogen Fuel Cell powered Hummer H2 at the Alt Car Expo. The Expo provides an outlet for alternative vehicles.

Audi h-tron Concept

DETROIT MI/USA - JANUARY 12 2016: Audi h-tron concept car at the North American International Auto Show (NAIAS), one of the most influential car shows in the world each year.

On April 18th 2015, another major hydrogen landmark was achieved in the US. Representatives from Ballard unveiled the the first zero-emission fuel cell bus serving the University of California, Irvine (UC Irvine) transit system, called the Anteater Express. The UC Irvine bus is the 5th American Fuel Cell Bus (AFCB) delivered in California.

Especially in places like California, hydrogen also has a significant celebrity backing, with the likes of former governor of California Arnold Schwarzenegger endorsing hydrogen powered vehicles.

Germany

At the new Berlin Brandenburg Airport, Total recently started operation of a multi-energy fueling station, including fuel cell electric vehicle. In addition to refueling fuel cell electric vehicles, a combined heat and power plant with generatively produced hydrogen is in operation.

More than 50 cars and buses in Berlin are already being refueled with hydrogen in the context of the 'Clean Energy Partnership' between industry and the federal ministry of transport. The aim is to test the every day use of hydrogen technology, and in particular the interface between vehicle technology, infrastructure and hydrogen production. The partnership, referred to as CEP is Europe's largest demonstration of hydrogen mobility. By the end of 2015, CEP will create a network of 50 hydrogen fueling stations across Germany.

At the 2016 Detroit Motor Show, Audi unveiled its h-tron Quattro concept, which is a

hydrogen vehicle based on the e-tron Quattro presented at the Frankfurt Auto show in 2015. The h-tron promises clean, quiet driving and can reach a 124-mph top speed and claims to use about a kilogram of hydrogen every 62 miles.

Belgium

Ms Annemie Turtelboom, Vice-Minister-President of the Flemish Government and Flemish Minister for Budget, Finance and Energy has acknowledged that hydrogen is an important part of the journey towards creating a more sustainable society. Minister Turtelboom strongly supports the construction of a hydrogen infrastructure in Belgium. On October 2nd 2015, construction started on the very first public hydrogen station in Belgium. The station will be operated by Air Liquide and is to be installed on land owned by Toyota Motor Europe.

Toyota Belgium will commercialize its Toyota Mirai from first half 2016 in Belgium, making it the fourth country in Europe to commercialize the first mass-produced fuel-cell sedan vehicle.

Belgium-based retail giant Colruyt group has been the first Belgian company to use cars running on hydrogen. In July 2013, Colruyt ordered the first hydrogen Hyundai ix35. Previously, the retailer had already experimented with forklift trucks running on hydrogen, and in 2012, the group invested in the production of hydrogen through green energy. which led to significant savings and reduced emissions. The company has its own hydrogen service station on site at its distribution center in Halle.

Van Hool already has 49 hydrogen buses in operation and is continuously adding more to its fleet

The Forze IV hydroelectric race car, which beat the lap record set by the Tesla Roadster by 5.45 seconds

Image courtesy of Rick Everaert

Belgium has been no stranger to pioneering hydrogen-based technologies. NASDAQ-listed Canadian hydrogen giant Hydrogenics was formed through the merger of Belgian Company Vandenborre Hydrogen Systems and Canadian Stuart Energy. And continued trail blazing work is being done through start-ups like Solenco Power, which has developed a hydrogen-based residential energy storage system; and organizations such as WaterstofNet, a group which recognizes the hydrogen potential of the Flanders - Southern Netherlands region. The area has a clear market for end users and is home to several important players in the industry. Projects carried out by WaterstofNet have included the opening of the first hydrogen fueling station, the building of a megawatt fuel cell plant at the Antwerp port and the conversion of two vessels to run on hydrogen fuel-cells.

The Netherlands

The first public hydrogen fuel station was unveiled in 2010 and in the meantime, the Netherlands has its own hydrogen racing team. On 16 November 2015, the Forze VI hydrogen-electric race car from the Delft University of Technology beat the lap record set by the Tesla Roadster by 5.45 seconds. Team Zero's car vehicle has an electric drive train, but the car generates the power on its own, with hydrogen and oxygen in a PEM fuel cell. Compared to the fully electric Formula E races, where 2 cars need to be used for each team to prevent from having to recharge the battery mid-race - hydrogen has the big advantage that it can be refueled just like regular fuel.

United Kingdom

In 2016, hydrogen cars are no longer purely a theoretical concept, but are becoming part of daily traffic. And even though the first commercial hydrogen car is yet to be sold in the UK, the first steps have been made.

Testament to this are organizations such as Transport for London, who currently have 8 hydrogen buses running on their London routes. Certain London taxi firms initiating hydrogen taxis in their fleet and Bristol City Council event even commissioned the UK's first commercial fuel cell ferry in 2010.

During the 2012 Olympic Games, hydrogen fuel cell black cabs were used to transport VIPs around London. These new generation taxis are fuel cell electric hybrids, combining a fuel cell system with a battery pack to drive the electric motor, reaching 0-60mph in 13 seconds.

But as in most countries, the major challenges are around infrastructure and wide scale adoption. Currently there are only four public refueling stations in the UK, with 2 stations in London. At present, these hydrogen stations rely on hydrogen deliveries by tankers. But the Sheffield station has a wind turbine that produces hydrogen from water through electrolysis. And more thought is going into creating an environmentally sustainably hydrogen refueling infrastructure. The number of stations is projected to rise to up to 10 by the end of 2016.

LONDON - Red double-deckers with tourists and taxi on a street in London, England. Transport for London has secured 5,67 million euros to expand hydrogen bus project

Close up of a hydrogen fueling dispenser for vehicles

What makes hydrogen the perfect alternative for fossil fuels

Hydrogen clearly has many advantages over fossil fuels. But even when compared to electric vehicles, hydrogen comes out superior in most aspects.

To start with, 'the only exhaust of a hydrogen car is water, either as water vapor or droplets, so you have no CO2, no NOx, no particulates,' as quoted by Robin Hayles, manager of sustainable fuel development at Hyundai. Fuel cells operate like batteries to create electricity through a chemical reaction, there is no combustion, and therefore no emissions.

Hydrogen has the same advantages as petrol and diesel when it comes to range, performance and refill times, without the having the huge disadvantage of having a detrimental impact on the environment.

At the same time, it has the same smooth drive of an electric vehicle, zero emissions and instant torque. But whereas charging an electric battery takes a minimum of 30 minutes, a hydrogen vehicle can refuel in 3 minutes - similar to a regular fuel stop.

When we zoom in on range, there is a significant difference between hydrogen cars and electric vehicles. Whereas the average range of an electric car is around 100 miles, a hydrogen car can cover a distance of over 360 miles - similar to a petrol fueled car.

Models with a combustion engine resemble conventional petrol cars with respect to their driving characteristics. So-called bivalent combustion engines can even alternate between hydrogen and petrol drives at full speed and without jerking. This way they can cover great distances, even when no hydrogen refueling station is nearby. Regarding energy efficiency however, fuel cell vehicles have the edge. They are fundamentally electric cars - the only difference is that instead of a battery, the fuel cell provides the necessary power (electricity). Fuel cell vehicles are ideal for inner city transport - quiet, quick to accelerate and totally emission-free.

The majority of large car manufacturers now have prototypes or close-to-production model with hydrogen drive in their portfolio. Even fuel cell of hydrogen combustion engine buses are already operational in several European cities.

The most prohibitive factor in the adoption of hydrogen powered cars is currently cost. You can purchase an electric Nissan Leaf for around 27 000€, whereas the Toyota Mirai costs triple that amount. And the cost of refueling an electric car is a fraction of the cost of fossil fuels, but refueling a hydrogen vehicle is at present still similar to the latter.

But it is worth noting that electric vehicles have been in commercial production for far longer than hydrogen vehicles and - as with any new product - it needs volume production to reduce cost. Thirty years ago, computers were a luxury reserved for the lucky few and now a staple of nearly every household.

Public fueling station in Rotterdam, The Netherlands

Jonas Vandenborre, the youngest heir of the family, looking into a bright hydrogen future

Personal thoughts

The Stone Age did not end because the stones ran out

For decades we have exhausted and polluted the earth with fossil fuels. Today we are faced with an evolution comparable to the transition from horse and carriage to an internal combustion engine-powered car.

That evolution -which took place over a hundred years ago- was surrounded with many doubts about the safety of the fuel and its availability. In the beginning, there was no fuel infrastructure and fuel had to be taken from the pharmacy - as it was seen as very toxic.

Critics denounced the loss of jobs in the horse-breeding and cart-building sectors. But gasoline and diesel vehicles prevailed and quickly they fundamentally changed our transportation system and our way of living and working.

Nowadays, we are equally aware of the disadvantages of a transportation system based on fossil fuels- our towns and our environment have been seriously damaged. Moreover, the earth's oil reserves are not infinite and are often located in political flash points, which makes price and availability very unstable.

Hydrogen and Fuel Cell Technology offer us a new approach to the supply of energy. It does not make sense to try and resolve the major environmental crisis with binding emission targets. We need a new development paradigm, a development model that will lead to an healthier world.

I do hope that large-scale implementation of state-of-the-art hydrogen and fuel cell technology combined with future developments will lead us to a world based on a green (sustainable) and blue (water) energy system.

In the wake of the latest emission scandals - which brought the truth to light about the NOx pollution emitted by diesel engines and caused nearly 1m tonnes of air pollution every year- alarm bells have gone off wold wide. Facts are emerging about startling numbers of premature deaths from pollution worldwide. Global leaders have no other choice than to turn to alternatives for fossil fuels. And hydrogen has never been so ready to take that place.

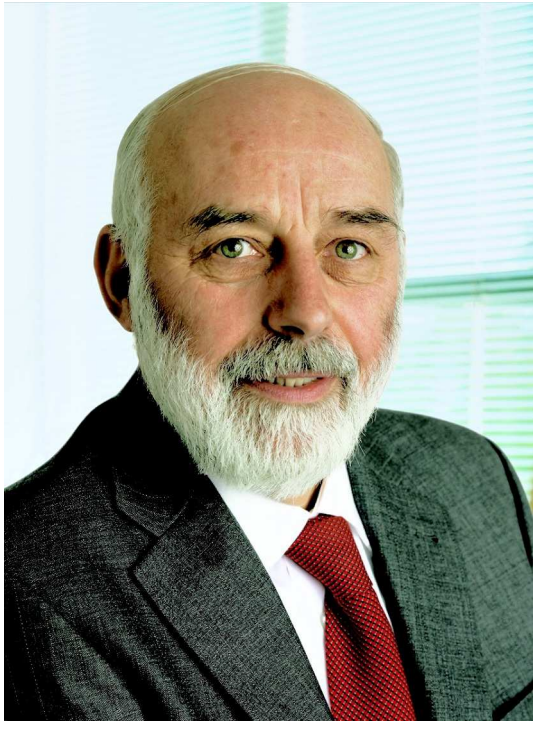

D A M
NEW
ART+
DESIGN
MUSEUM
atomium
I ♥ atomium

Bibliography

http://ec.europa.eu/clima/policies/transport/vehicles/index_en.htm
http://www.independent.co.uk/environment/climate-change/cop21-four-things-you-need-to-know-about-the-paris-climate-change-treaty-a6771931.html
http://www.hyer.eu/2014/clean-hydrogen-in-european-cities-chic-fuel-cell-buses-project
http://www.waterstofnet.eu/nl/home
http://www.c2es.org/international/negotiations/cop21-paris/summary
http://www.theguardian.com/environment/2015/nov/04/the-future-is-here-mass-market-hydrogen-cars-take-to-britains-roads
http://www.hydrogen-planet.com

Useful links and relevant websites

Arno A. Evers http://www.hydrogenambassadors.com
European Hydrogen Association http://www.h2euro.org
Fuel Cell & Hydrogen Energy Association http://www.fchea.org
Fuel Cell and Hydrogen Joint Undertaking http://www.fch.europa.eu
Fuel Cells 2000-FaQ http://www.fuelcells.org
Fuel Cell Today http://www.fuelcelltoday.com
Hydrogen and Fuel Cell Exhibition http://www.h2fc-fair.com
Hydrogen and Fuel Cell Safety http://www.hydrogeandfuelcellsafety.info
Hydrogen Fuel Cells and Electro Mobility http://www.hyer.eu
Stadwerke Borkum http://netfficient-project.eu
Toyota Europe http://toyota-europe.com



Dr. Hugo Vandenborre is President and CEO of Solenco Power NV - a new venture he founded in 2015. With the help of joint shareholders Solvay SA and Giacomini SpA, the company focuses on residential energy storage based on hydrogen technology.
Among various other positions, Dr. Vandenborre was Chairman of the European Electrochemical Engineers and the International Hydrogen Energy Association. He is a founding member of HYNET, the European Thematic Network on Hydrogen; Marine Hydrogen & Fuel Cell Association; Joint Undertaking of the European Commission and Masterplan & Implementation WaterstofNet.
He was part of various European and International Committees and was selected as one of the 12 members of the High Level Group who wrote the pathway towards Hydrogen and Fuel Cells for former European President Romano Prodi.
He was Chairman and Executive VP of Stuart Energy, a public company listed on Toronto Stock Exchange. After a merger, he became vice Chairman of Hydrogenics Corporation, a NASDAQ listed Company (HYGS).

He obtained his Doctorate of Science in Physics (maxima cum laude) at the University of Leuven, Belgium after completing his studies at the Institute of Science in Jülich, Germany and Brookhaven National Laboratory, New York , US.
He was keynote speaker at various international hydrogen conferences and has published over 200 international articles. He has over 55 patents to his name.

In 1969, he married Grete Van den Troost and had three children - Bieke, Hans and Dorien. He has two sons-in-law - Pieter and Manu - a daughter-in-law Kathie and eight grandchildren.
He was born in Kampenhout and lives in Kasterlee, Belgium.