Strategic consultants
in sustainable energy

HYDROGEN : TOO BIG TO MISS ?

SHARED IDEAS

December 2012

Hydrogen:
Too big to miss ?

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1. Why hydrogen as an energy carrier?

Hydrogen has been in use for decades in several key industry sectors such as oil refining, ammonia production, food processing, glass manufacturing, electronics and metal production. In 2010, *Markets and Markets* estimated the size of the global market for hydrogen at 53 million metrics tons with a total value of $82.6 billion.

In contrast, the use of hydrogen as a fuel for power generation or transport has faced a number of challenges. Over the past decades, many have sought to promote the development of hydrogen as an energy carrier, which, especially if combine with fuel cells, provide a clean and efficient alternative to conventional fuels. A key challenge is that although hydrogen enjoys a high energy-content per unit of mass (which explains its use in the space industry), it has a very low volumetric energy density compared to other fuels. Hydrogen must therefore be compressed, liquefied or even integrated in solid structures to make it more convenient to handle and transport.

Hydrogen is also a potentially convenient medium for storing energy from intermittent renewable energy sources, through water electrolysis. In that case, hydrogen is a fully decarbonised energy carrier. When used in a fuel cell in combination with oxygen from the air, it enables the production of electricity, in an energy efficient manner and with no emission other than water. Fuel cells find a very wide range of applications in many different fields, from stationary power and heat production to automotive powertrains, and as a power supply for mobile electronic devices.

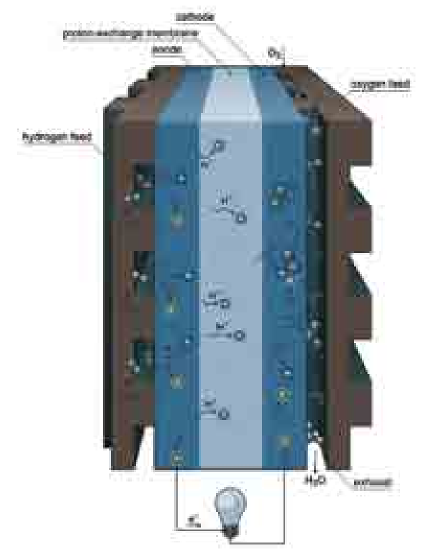


Figure 1 – Schematics of a PEM fuel cell stack

Among this range of applications, the passenger car remains one of the most attractive. Here, hydrogen and fuel cells offer a complete value proposition directly addressing the inherent limitations of battery-powered electric vehicles (BEVs), which continue to suffer from limited driving ranges, and long recharging times (15-20 minutes with fast charging, several hours with conventional power outlets). In contrast, the performance and user experience of fuel cell powered vehicles (FCVs) is comparable to conventional vehicles, but with the high efficiency and zero emissions of BEVs. In fact the two technologies are complementary; it is noteworthy that a small number of OEMs are trying to combine the best of both technological worlds by hybridizing BEVs with a 5-10kW fuel cell that serves as an on-board recharging device, thus extending the driving range.

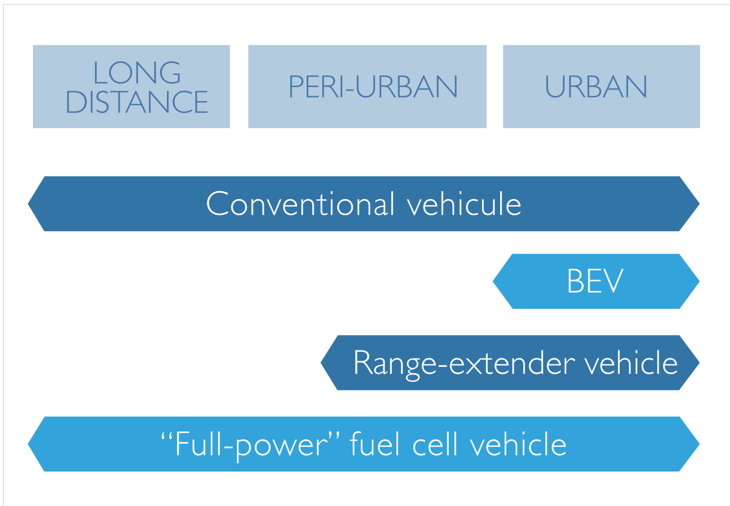


Figure 2 - Synergies between batteries and fuel cells for e-mobility (source: Hinicio)

Finally, it is worth mentioning that hydrogen can also be used in thermal applications (both stationary and mobile), whether pure or mixed with natural gas. In the transport field, natural gas vehicles, in particular buses, could be fuelled with natural gas-hydrogen blends. For example, Hythane®, a mix of 80% natural gas and 20% of hydrogen (in volume) developed by GDF-Suez, enables CO2 emission reductions of around 9% as demonstrated by the GDF-Suez-led Althytude project in Dunkerque (France).

All these arguments make hydrogen a prime candidate for complementing electricity in tomorrow's energy system, contributing to solving the energy and climate crisis.

2. Exploring the hydrogen value chain

Hydrogen is not a primary energy source freely available in nature but rather an energy carrier that needs to be produced from an external source of energy by separating the hydrogen atoms from other atoms in complex hydrogen-rich molecules, such as water, hydrocarbons or biomass. Once produced, it has to be delivered to the point of use, which means that the hydrogen agenda is fundamentally a systemic challenge, involving the coordinated roll-out of a brand-new energy production and distribution infrastructure and associated energy conversion devices such as fuel cells.

There may be lessons to be learned in this regard from the industrial hydrogen value chain, which is already well established and optimized for industrial users. Today's hydrogen market is largely dominated by so-called "captive hydrogen" producers. According to a recent report by *MarketsandMarkets*, 88% of all hydrogen consumed in the industry is generated on-site, thus eliminating delivery constraints. This option is often preferred for very large quantities, typically in refineries, even though smaller scale distributed generation has been gaining market share in recent years. The remaining 12% share is the merchant hydrogen market, where hydrogen is generated centrally and delivered to the point of consumption by industrial gas companies, such as Air Liquide, Air Products or Linde. Various delivery options are available including hydrogen pipeline, tube trailers and cylinders. Pipelines will be preferred when the quantity is sufficiently high to justify the significant initial capital investment required. Air Liquide owns for instance a network of hydrogen pipelines covering the North of France, the Benelux and Northern Germany regions, which are home to many large-scale industry consumers.

Figure 3 – Example of hydrogen pipelines owned by Air Liquide (source: Air Liquide)

For smaller quantities of hydrogen, such as for glass manufacturing, electronics or food processing, delivery is usually made by tube trailers or cylinders carrying hydrogen in gaseous form, under 200 bars for tube trailers (with 500-bar trailers soon to become available). Hydrogen is sometimes liquefied for longer distance delivery, in particular in the USA, but this practice is less commonly found in Europe, due to generally shorter distances in Europe combined with the high investment cost associated with a liquefier.

Figure 4 - Example of hydrogen truck (source: Linde)

Looking at current production practices, over 95% of all hydrogen is generated from fossil fuels, in CO2-intensive processes. Steam Methane Reforming (SMR) is presently the dominant production method in the world, ahead of partial oxidation of petroleum oil and steam gasification of coal, due to the low cost and easy availability of natural gas. However, SMR generates today around 10 tons of CO2 per ton of hydrogen produced and if hydrogen is to become one day part of the low-carbon energy system, CO2 emissions will have to be drastically cut along the entire value chain from cradle to grave, in particular at the production level where most emissions currently occur.

Reducing greenhouse gas emissions at the production level: how to do it?

Our research shows that drastic emission reductions are possible, and that alternative production technologies are already starting to emerge. Carbon Capture and Storage (CCS) is a natural candidate for "greening" steam reforming of natural gas, although significant uncertainties remain concerning its economic viability in the absence of an adequate carbon price signal. The current revision of the EU ETS may in this regard generate a positive impact in the mid-term. The social acceptance of the technology remains an issue, although we believe that once project developers get the economics rights, the social barrier could be overcome with adequate risk management standards and educational programs for the public at large.
Biogas reforming, which is essentially the same process as natural gas reforming but using a biomass based energy source, will likely be easier to implement in the mid-term and should become available on the market place shortly after 2015, provided that appropriate incentives are put in place. Demonstration projects involving industrial gas companies should start very soon in Europe.
Ultimately, our team firmly believes that water electrolysis offers a very promising path for producing "green" hydrogen while facilitating the integration of renewables in energy markets. Water electrolysis is in fact the exact opposite reaction than the one occurring in a fuel cell: electricity splits the water molecule into oxygen and hydrogen. Past projects have shown that while both the technology and economics still need to be optimised, water electrolysis may become one of the preferred technological options for storing excess power from renewables in the form of hydrogen, especially if the hydrogen can be utilised in the transport or industry sectors.

Indeed the electricity grid has never been designed to cope with high levels of variability at the production level. In a 100% renewable scenario, the hydrogen would be totally carbon-free. As we underlined in the French Hydrogen and Fuel Cell Roadmap, in France, where the carbon content of electricity averages 90gCO2/kWh, the production of one ton of hydrogen generates 4.3 ton of CO2, which is already a significant improvement compared to hydrogen production via SMR. In countries where the electricity mix is more carbon-intensive, the environmental performance of hydrogen deteriorates. Clearly, just like the electric vehicle, the development of hydrogen and fuel cells applications, in particular in the transport sector, will only be relevant in a general move towards decarbonized electricity systems.

HyUnder

Hinicio's team is currently working with Shell, Solvay, E.on Gas, KBB, CEA and other European partners to demonstrate the techno-economic viability of hydrogen underground storage to enable the storage of large quantities of intermittent renewable energies. In the course of 2013, preliminary results should determine the conditions under which such schemes may become viable, identify geographic locations across Europe suitable to launch demonstration projects, and relevant business models in 6 European countries (France, Germany, the UK, Romania, Spain and the Netherlands).
For further information, please visit the project website: www.hyunder.eu

Relatively less mature production processes are also being explored by researchers and engineers to produce low carbon hydrogen, including high-temperature water electrolysis using heat sources such as a nuclear reactor, biomass pyrolysis, thermochemical water decomposition or even biological processes. In this regard, "cleantech" investors could be well advised to scout possible future game changing technologies.

Interestingly, several sectors such as the chlorine or the petrochemical industry involuntary generate large amounts of by-product hydrogen. Most of the time, it is being sold to local industries or mixed with natural gas and burnt to generate heat usable in the process itself, thus proportionally decreasing natural gas consumption. However, in some instances, it is simply flared or vented into the atmosphere. Based on our experience, we can reasonably say that under certain conditions, hydrogen could instead be purified for use in stationary or transport applications, thus potentially enhancing the economics and environmental performance of the plant.

In 2011, Hinicio assisted the energy service company COFELY GDF-Suez in the evaluation of valorisation routes for large quantities of hydrogen by-product in a production facility of Akzo Nobel, a leading global chemical company. Various valorisation options were analysed, including on-site uses (in stationary fuel cells, gas or stream turbines, internal combustion engines), and off-site uses (injection into the natural gas grid, use in fuel cell vehicles or Hythane® vehicles, etc.).

In the latter case, an adequate infrastructure (clean-up and storage units, trailer trucks, distribution station) would have to be deployed to ensure proper delivery and distribution of hydrogen to end-use applications.

As an example, a throughput of 1000Nm3 per hour of hydrogen, which is typical in several industrial sectors, would be enough to supply hydrogen to approximately 100 hydrogen buses, 900 Hythane® buses, or 500 forklift trucks, a 1.5MWe stationary fuel cell or a 1.2MWe gas turbine.

The challenge of deploying a hydrogen infrastructure at an acceptable societal cost

As noted, a transport and distribution infrastructure is needed to ensure the supply of hydrogen from the point of production to end-use applications. This has been business-as-usual practice for industrial gas companies for decades. However, the deployment of hydrogen energy applications, in particular in the transport sector, will require the development of a brand-new infrastructure in parallel to the one already in use for industrial purposes, as well as the current transport fuel infrastructure.

In the short-term, truck delivery will probably remain the preferred option for both technical and economic reasons. In such a configuration, hydrogen stations very similar to existing gasoline stations would be supplied by trucks filled with pressurized hydrogen. Cars can then be refuelled with hydrogen compressed at 700bar, which appears to become the preferred standard for the car industry. In the longer-term, as the demand for hydrogen increases, the construction of dedicated pipeline networks could become economical. The deployment strategy should start first with economies of scale (volume) through the deployment of refuelling stations in a limited number of (peri) urban hotspots, in cities early adopting the technology, thus allowing the optimisation of the use of assets and invested capital.

Figure 5 - Air Products hydrogen filling station in Hempstead, Long Island (source: Air Products)

Altogether, deploying an adequate infrastructure remains admittedly a significant barrier in terms of investment cost. Meanwhile, the natural gas infrastructure is already in place in most countries and could very well be utilized for transporting large quantities of hydrogen, thus avoiding part of the investment cost in hydrogen infrastructure development, as least until mass markets are achieved. Synergies between hydrogen and natural gas are very promising and this is precisely why the concept of "Power-to-Gas" is being tested on the field, as a primary option from storing excess renewables from the Northern Seas. Around 20 projects are currently beginning to be implemented in Germany.

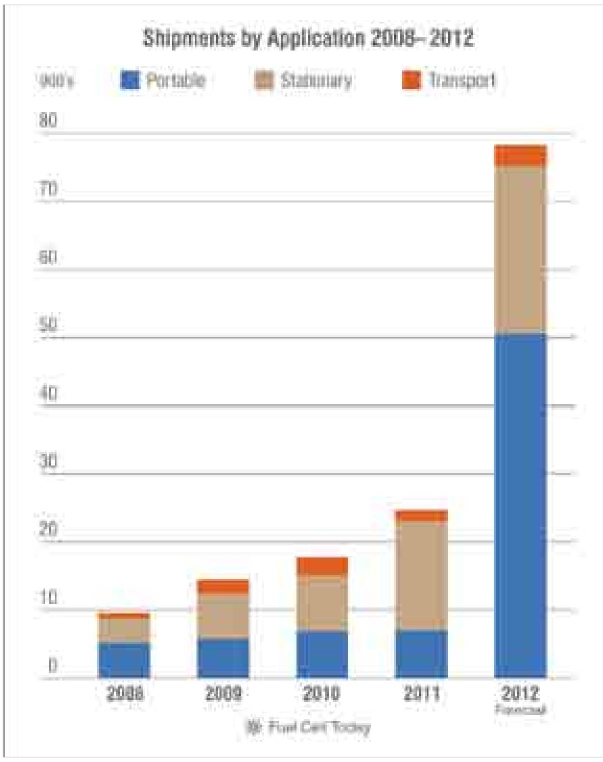
The concept here would be to produce massive amounts of hydrogen from excess renewable electricity and inject it into the natural gas grid. This would help reduce the carbon content of natural gas in downstream applications, such as domestic boilers. The separation of hydrogen and natural gas could also be envisaged using dedicated membranes. The European project NATURALHY has demonstrated that up to 20% of hydrogen in volume could theoretically be mixed with natural gas in pipelines without any major technical obstacle.

An alternative option consists in producing hydrogen from variable renewable power and combining it to CO2 captured on a large emitting industry site to produce synthetic natural gas that could be directly fed into the existing network.

3. Global emergence of hydrogen and fuel cell markets: Dream or reality?

In the past few years, the fuel cell market appears to have entered a new phase of market take-off, in particular as far as so-called "early adopter markets" are concerned. For those market segments the value proposition of fuel cells is already close to competitiveness with conventional technologies, while they often offer superior environmental or functional performance (autonomy, recharging time, noise, etc..). *FuelCellToday* recently reported that despite difficult economic conditions, especially in Europe, the global fuel cell industry had reported a 39% growth in sales in 2011 compared to 2010. **Nearly 24,600 fuel cell units were shipped in 2011, thus breaking the 100MW-mark for the first time in history.** North America and Asian emerging countries are currently the most dynamic markets. The stationary segment in particular experienced an astounding triple-digit growth, with over 16,000 units shipped, amounting to 80MW. Continued growth is expected in years ahead in this segment. It will probably remain the main growth component in terms of installed capacity. At the same time, the number of units shipped is probably about to further increase, driven by the portable segment, with the commercial launch of several mainstream products in 2012 such as battery chargers by myFC's from Sweden and Japanese manufacturer Aquafairy.

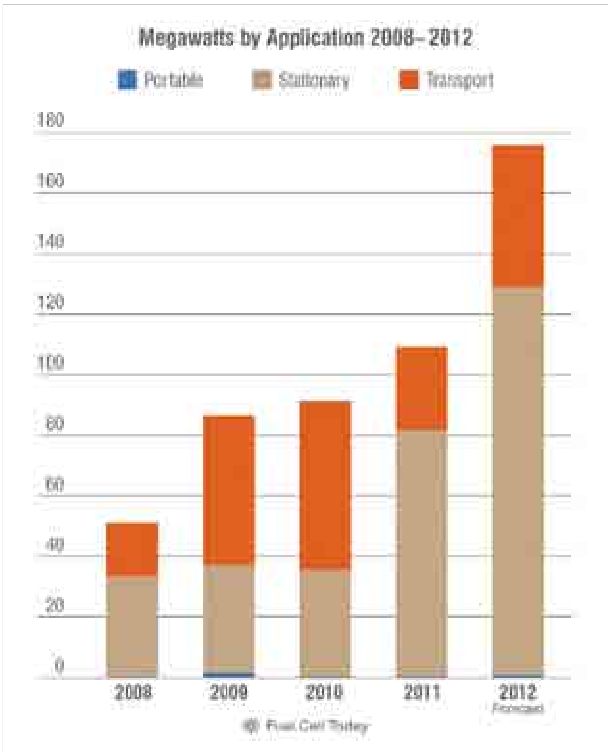
We at Hinicio estimate that the global fuel cell market should total between EUR 1 billion and EUR 5 billion by 2015 depending on the evolution of the global economic context.



Source: FuelCellToday, 2012

Hinicio has recently assisted a fuel cell manufacturer in addressing a growing sub-segment of portable fuel cells for recreational vehicles and leisure boats market where the fuel cell is used as an on-board battery recharger.
Several mainstream products are already available and have gained sizeable market shares in recent years, with a value proposition based on increased autonomy, reduced space requirements, noise and emissions.
The current market leader is German company Smart Fuel Cell, with its EFOY ("Energy For You") product line.

Source: World Sport Boat



Source: FuelCellToday, 2012

Stationary early-markets such as back-up and off-grid power supply for remote locations or critical applications in the telecom sector for instance, make particular sense in developing countries where the electricity grid coverage and reliability are limited. This is being confirmed by market data with the rapid take-up one can witness in some countries such as China and India. In environments requiring longer backup capacities the business case for fuel cells appears to be relatively attractive, mainly due to inherent limitations of batteries (lifetime, maintenance, fixed storage capacity) and generator-sets (maintenance costs, fuel cost, exhaust, noise and spillage issues) and generally resulting in a lower TCO (Total Cost of Ownership) over the system lifetime.

In the micro-CHP sector, over 13,000 micro fuel cells, running on natural gas, are already in operation in households in Japan, Germany and South Korea.

The megawatt stationary segment is less mature, although a number of headline projects have been recorded or are in the pipeline, particularly in North America and South Korea, where manufacturers such as Bloom Energy or FuelCell Energy are currently dominating the market. Early-adopters include Coca Cola, AT&T, NTT, eBay and Apple, which find in fuel cells an attractive value proposition for securing the electricity supply of their data centres.

In the field of logistics, the material-handling vehicle market is clearly gaining market traction primarily in North America, supported by a federal tax credit on capital expenditures under the Recovery and Reinvestment Act ($3,000 per forklift and $200,000 per hydrogen filling station) and not existing yet in Europe. Several fleet operators including the Department of Defence, Coca Cola, Wal-Mart and General Motors have rolled out fuel cell forklift trucks fleets in their facilities, supplied by on-site hydrogen filling stations, in replacement for battery-powered material-handling vehicles. Industrial gas companies such as Air Liquide, Linde, Praxair or Air Product are actively promoting the technology, positioning themselves as suppliers of hydrogen. The current leading supplier of forklifts is the US-based company Plug Power, which has recently announced a Joint Venture with Air Liquide to address the growing European market for material-handling vehicles with a complete value proposition. First projects are now being implemented in Europe, notably in IKEA's warehouses in Southern France.

Figure 6 - Example of fuel cell forklift trucks
(source: H2Logic)

Interestingly, the main driver for such markets is productivity, most notably with a reduced recharging time (minutes compared to several hours with batteries) and human labour requirements. A fuel cell based platform also avoids many constraints related to the use of batteries (dedicated space for switching batteries, security issues, etc.). Overall we estimate productivity gains can average up to 10% depending on the fleet size and characteristics of the operations.

APPLICATION SEGMENTS	VALUE PROPOSITION	MAIN CHALLENGES	MOST PROMISING MARKETS	LONG-TERM MARKET POTENTIAL	KEY PLAYERS
Fuel cell passenger cars	Extended range Reduced refueling time Zero tailpipe emission	Costs Infrastructure Availability of green hydrogen Competing technologies (BEVs, hybrids)	Germany, Japan, USA	+++	Daimler, Honda, Huyndai, Toyota, GM
Fuel cell buses	Extended range Reduced refueling time Zero tailpipe emission	Costs Lifetime Availability of green hydrogen	Europe	+	Daimler, Vanhool
Forklifts trucks	Improved productivity Lower TCO	Competing technologies Investment costs	North America	+	Plug Power, H2Logic, Hydrogenics
Backup-up power	Lower TCO Storage capacity Reduced needs for maintenance	Investment costs Fuel logistics	USA, emerging countries	+	FutureE, Dantherm Power, ReliOn, IdaTech, Altergy, Hydrogenics
Micro CHP	Improved electrical efficiency	Costs Lifetime	Japan, South Korea, Germany	++	Panasonic, Baxi, Ceramic Fuel Cells Limited
Portable fuel cells	Improved autonomy	Fuel conditioning and availability Safety	Worldwide	++	SFC Energy, myFC, Aquafairy, Horizon Fuel Cell Technologies
Large scale stationnary	Improved electrical efficiency Lower emissions	Costs Competing technologies Lifetime	North America, South Korea	+	Bloom Energy, FuelCell Energy, Ballard, Nedstack

Figure 7 - Fuel cell market development overview by application segment (source: Hinicio)

Fuel cell cars: ready, set, go in 2015?

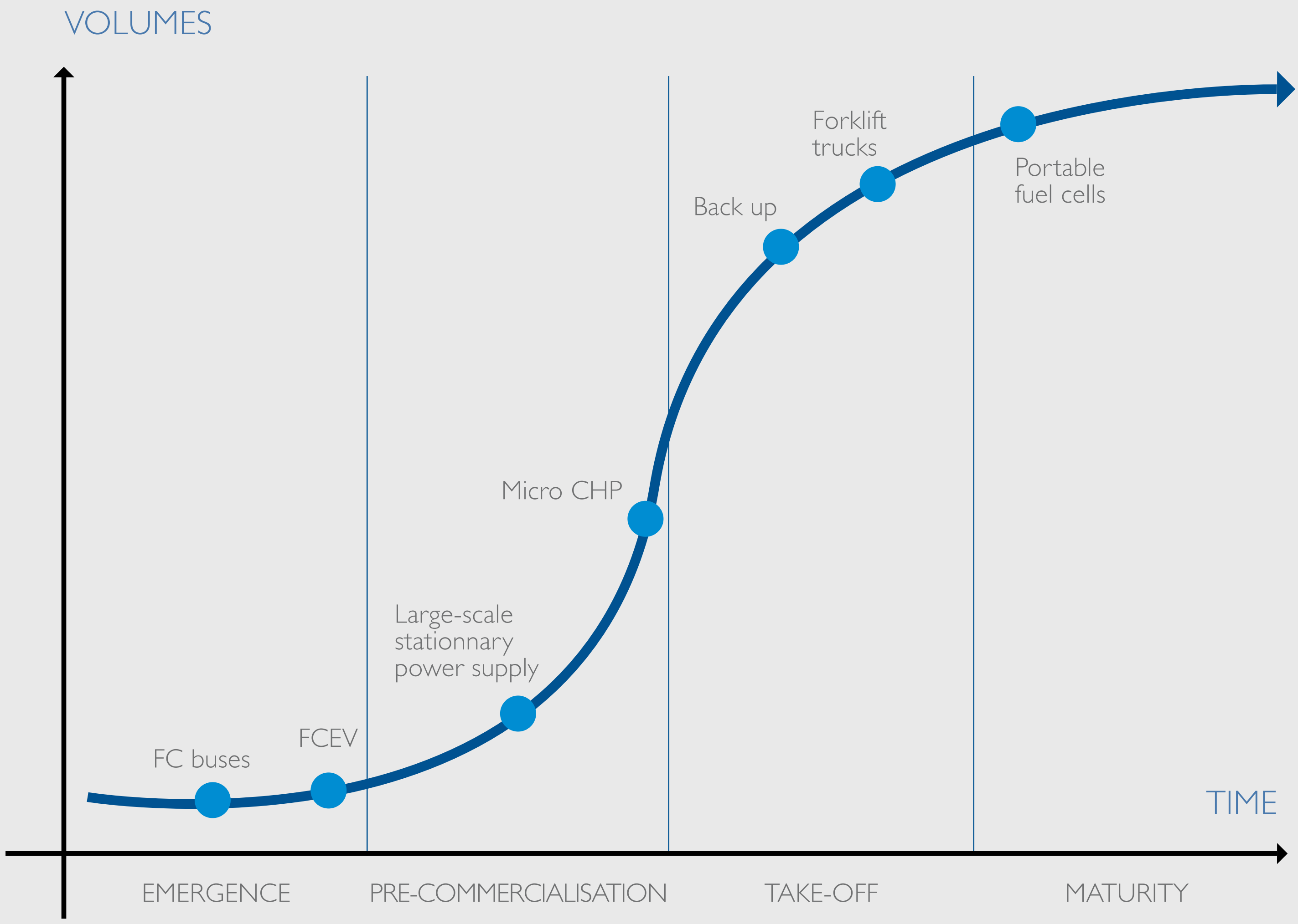
Last but not least, the passenger vehicle market has clearly the greatest potential in the long term both in terms of economic and environmental impacts. This segment remains the most demanding in terms of cost reduction and performance improvement. It is also the most challenging as far as infrastructure roll-out is concerned. Germany is undoubtedly leading the way in Europe with the H2Mobility program involving major oil companies, energy utilities and industrial gas providers (Air Liquide, Linde, Total, Vattenfall, Shell, etc.).

Figure 8 - Mercedes-Benz Class B F-CELL (source: Daimler)

Initiated in 2009, this program has the common goal of putting on the ground the necessary infrastructure to support the commercial deployment of fuel cell vehicles from 2015 onwards. Japan has similar plans and the United States, particularly California also shows interest, with its existing "hydrogen highway". On the vehicle side, although most global OEMs appear to be developing fuel cell vehicles, Hyunda-Kia and Daimler seem to lead the race in terms of commercial product launches, planned as early as 2013 and 2014 respectively.

Other manufacturers such as General Motors/Opel, Honda, Toyota, Ford and Nissan have also released roadmaps for hydrogen vehicles with commercial releases planned for around 2015. **While past statements used to suggest that hydrogen FCVs would always be 10 years off, it seems that 2015 could be the real turning point for the entire industry.** Of course, this will only be the beginning of a long transition period. As with BEVs, the uptake of FCVs is expected to be slow for some time.

MATURITY OF THE DIFFERENT MARKET SEGMENTS



(source: Hinicio)

4. Addressing the remaining barriers

Infrastructure deployment: overcoming the chicken and egg dilemma

The hydrogen sector has been confronted with a chicken-and-egg dilemma for many years. On the one hand, OEMs are reluctant to invest in manufacturing fuel cell cars if no hydrogen refuelling infrastructure is in place, because consumers would obviously not adopt them. On the other hand, energy companies and industrial gas companies are not prepared to roll-out the necessary hydrogen infrastructure before hydrogen cars hit the road as they would go through a "death valley" of several years before seeing any profit at all. The costs are indeed significant and **the EU Coalition report published in 2010 estimates at EUR 20 billion the investment required in infrastructure up to 2020 Europe to enable the deployment of 1 million fuel cell cars.** While such an amount may appear to be daunting, it is in line with other on-going energy infrastructure investments, such as in electricity and natural gas. However the current economic crisis in Europe could seriously jeopardise the timely adoption of such investment decisions.

As in the case of BEVs, the solution lies in a coordinated approach between infrastructure players, OEMs and public authorities at global and local levels to ensure that hydrogen production, delivery and distribution capabilities are deployed in a synchronised manner with sales of FCVs. The H2Mobility initiative, as well as the symmetrical developments in Japan are good examples of how government and private sector cooperation could help overcome the chicken-and-egg challenge.

Over 200 hydrogen refuelling stations are currently operating worldwide. Current developments in Germany, Japan and California, which have announced over 200 stations on the ground between now and 2016 on an aggregate basis, are suggesting that the infrastructural barrier is slowly but surely being overcome by the industry, at least in early adopting countries.

Addressing the technological barriers while reducing costs

While costs have been reduced significantly and technological performance improved in the last decade, significant technical and economic hurdles still remain along the entire hydrogen value chain, from the hydrogen production down to end-use applications.

At the production level, the economic feasibility of CCS remains to be confirmed and seems to mostly depend on a strong-enough carbon price signal that is highly unlikely at least in the mid-term. The reforming of biogas is facing integration and optimization challenges which once addressed should lead to significant cost reductions. Meanwhile, the costs of electrolysers also have to come down by several orders of magnitude and their durability and tolerance vis-à-vis input variability must seriously improve.

In order to become competitive in the mass transport sector, a hydrogen production cost at a maximum of 5€/kg will probably be required, given current energy prices. This appears feasible in the short term with conventional SMR technologies but will be much more challenging for very low carbon emission pathways.

In the field of fuel cells, various barriers are worth mentioning including reduced use of expensive precious metals such as platinum, lifetime and reliability improvements, resistance to corrosion, better integration, heat management and overall system simplification. Unsurprisingly, fuel cell costs are also still very high but combined with system simplification and the adoption of cheaper materials, economies of scale should help address the cost issue in the longer term. In the meantime, carmakers manufacturing fuel cell vehicles appear to be targeting in priority high-end segments with high customer expectations, for which superior performance, range and refuelling experience could offset some of the price differential.

Everything leads us to believe that fuel cell technical and cost barriers should be overcome by manufacturers before 2020. As displayed in figure 9, the EU Coalition study forecast a 90% decrease in system costs between 2010 and 2020.

Setting up appropriate incentive schemes

As applications continue to mature and become competitive, the supporting regulatory framework will need to move progressively from a demand-push research-focused paradigm to market-pull instruments, targeting end-users and aiming to stimulate the demand.

As far as early markets are concerned, applications tend to be characterized by a high investment cost, which can be compensated over time by lower operating costs. Supporting mechanisms should be designed to specifically address this barrier and close the initial investment gap. For instance, fiscal incentives have proven to be effective in the United States to facilitate the take-up of fuel cells in early adopter market niches, which provide a bridge towards larger markets such as passenger cars.

Dedicated instruments will also be needed at the hydrogen production level to ensure that the carbon footprint of hydrogen is progressively reduced to become consistent with our climate objectives. Realistically, the production of "green hydrogen" will remain more expensive than hydrogen produced from SMR in the short-to-mid-term, partly because of the low cost of natural gas but also because technologies such as PEM electrolysis will need time to reach maturity and become fully competitive. The creation of dedicated Guarantees of Origin and Green Certificates for hydrogen, similar to what has been implemented for years in the renewable energy field, could for instance be explored.

Specific incentive mechanisms to support energy storage and reward its added value emission-wise are currently being largely discussed by policy-makers. Some countries are already taking initiatives.
Hinicio has recently supported a leading global industrial gas company in analysing the regulatory framework applying to energy storage using hydrogen in several countries.
Our team has also been evaluating a variety of business models for commercialising innovative hydrogen storage solutions to address several renewable energy storage market segments.

This is not to mention a carbon tax or an extended carbon market that would automatically and progressively rebalance the gap of competitiveness between conventional and clean hydrogen productions.

In general, the current structure of electricity markets and price-setting mechanisms act as a barrier for the development of energy storage. Feed-in tariffs in particular transfer all the risks and costs associated to renewable intermittency to the network operator, which is, at least in Europe, not allowed to own and operate storage assets as laid out in the Third Energy Package. Feed-in tariffs, as currently operating, are therefore obstructing the deployment of energy storage. We believe that, as the share of renewable electricity continues to rise, feed-in tariffs will have to be reformed to better take into account the constraints posed by the intermittency of renewables and promote energy storage.

Consumer perception and public acceptance

Finally, public acceptance is generally seen as a major barrier to the mass-adoption of hydrogen as an energy carrier. It is often perceived as dangerous by the general public mainly because of its gaseous form and perceived risks of explosion.

The reality is somehow different. Over the years, fuel cell cars have cumulated millions of kilometres and no major accident has been registered.

Rather than the issue of safety, which will be addressed by the public and private sectors though normative processes, it is our conviction that the public perception of the technology in general should be addressed as a matter of priority as very little is being done in this regard at the moment to prepare a fertile ground for growing future seeds.

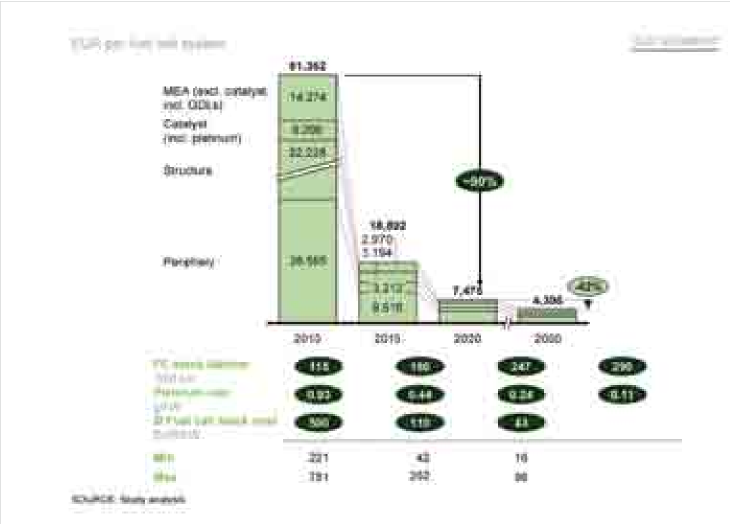


Figure 9 - Forecasts of fuel cell system costs (source: EU Coalition)

At a more industrial level, mass production will require the emergence of an entirely new supply chain. This challenge should not be underestimated in our opinion as significant bottlenecks may appear at some point in time if Tier 1 OEM suppliers fail to embrace the technology in a dynamic manner. Unlike the case of electric vehicle batteries, there are no companies experienced or equipped in the mass production of fuel cells or hydrogen storage systems at this point in time.

Gaining political support

Political support, intra-firm and intra-industry coordination mechanisms, and shared risk management strategies will be critical to establish a positive investment environment for hydrogen and fuel cells and ensure that the first-movers that take sizeable one-off investment risks are appropriately rewarded.

All levels of political decision-making have to be involved and supportive, from local authorities to national governments and European institutions that should stimulate pan-European visions and infrastructure deployment. Like any sector heavily depending on infrastructure developments, the hydrogen and fuel cell industry crucially needs to be part of a long-term transport and energy agenda, including support schemes. In particular, it will be vitally important to avoid "stop-and-go" approaches, which would be very detrimental to the industry at large and discourage long-term private commitments and investments.

While it is true that a great part of the investments will have to come from the private sector, the public sector has an important role to play in terms of setting up innovative risk-sharing facilities in order to leverage private investment with a limited amount of public finance. Certain public-private financing vehicles provide a good example of best practice in this regard. As an example, the European Fuel Cell and Hydrogen Joint Undertaking is a unique EUR 1 billion public-private initiative between the European industry and the European Commission supporting collaborative demonstration projects and leveraging investment from industry.

While we see this initiative as a very promising one for Europe, political support for hydrogen and fuel cells by governments and global policy makers is still missing. It is indeed the responsibility of the political sphere to define clear orientations for industry, to make sure that hydrogen and fuel cells will deliver the expected environmental performance while contributing to sustainable economic development, job creation and societal improvements. Recent joint efforts between public authorities and the private sector in several countries and regions across Europe to define clear roadmaps and ensure consistency of industrial development with our long-term energy and climate objectives have to be praised.

Hinicio has been involved in several strategic road-mapping projects in France both at the national and regional level since 2009, including in the Rhône-Alpes, Nord-Pas-de-Calais and Midi-Pyrénées regions. In particular, our team has supported ADEME, the French environment and energy agency, in elaborating the French Hydrogen and Fuel Cell Roadmap [1] in cooperation with a broad range of industry and research stakeholders. A "2020 vision" is articulated around 5 priorities:

1. Fostering the synergies between renewable energy and hydrogen
2. Fuel cell vehicle and the second generation e-mobility;
3. Hydrogen and fuel cells for sustainable cities;
4. Supporting early-markets;
5. Implementing the adequate supporting measures

[1] The document can be downloaded at : http://www2.ademe.fr/servlet/KBaseShow?sort=-1&cid=96&m=3&catid=24277#thm1tit6.

5. Conclusion: hydrogen is just too big to miss!

At Hinicio, we have been following very closely the development of hydrogen and fuel cell technologies over the last couple of years.

We have supported fuel cell companies in defining sophisticated routes to premium and early markets.
We have helped investors evaluate and support innovative fuel cell and hydrogen startup companies. We have analysed the next generation of electric mobility, where hydrogen and fuel cells come in to complement battery electric vehicles, enabling much longer driving ranges, much faster refueling and a resulting enhanced customer experience, while maintaining very high levels of environmental performance. We have also assisted leading industrial groups generating large amounts of by-product hydrogen to identify the best options to valorize this wasted asset, while improving their environmental performance. We are now studying the conditions for the emergence of innovative large-scale storage of renewable electricity through hydrogen.

We have challenged and trained public authorities officials and laid out the necessary steps including regulatory frameworks to support the emergence of hydrogen and fuel cells. We have supported local, national and European policy makers, helping them define shared visions in which hydrogen and fuel cells play a role in addressing global energy, mobility and climate change challenges.

We are now firmly convinced that the best is about to come. 2015 will most likely be the turning point and see the beginning of the commercialization of hydrogen fuel cell vehicles in Europe, Japan and in the USA.

Stakeholders across the board, whether energy utilities, gas companies, OEMs, entrepreneurs, cleantech investors, large energy users, policy makers, regulators, teachers or environmental NGOs should engage a thorough analysis as to whether and to what extent the emergence of hydrogen as an energy carrier could have a positive or negative effect on their activities in the mid-term, and question whether their strategy could be positively impacted should they decide to actively embrace the emerging technological transition.

The emergence of hydrogen as an energy carrier should be regarded as a major growth opportunity as its economic and environmental impact could potentially be massive.

Hydrogen is just too big to miss!

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sustainable energy projects and strategies

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