Market Introduction of Hydrogen Technology: the Evolution of the Global Education and Vocational Training Markets

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Market Introduction of Hydrogen Technology: the Evolution of the Global Education and Vocational Training Markets

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1 Introduction

In the coming years the rising demand for energy security – driven by the international struggle for resources, the increasing scarcity of fossil fuels and energy security, as well as concerns about global warming and pollution - will continue to expand the market for green energy in general and hydrogen energy in particular. These trends are reflected in the increasing number of financial investments in this field from both state agencies and corporations around the world.

Hydrogen technology is particularly well-positioned because of its ability to complement other emerging clean technologies such as wind and solar power, which have seen immense increases in the last 5-10 years worldwide. Hydrogen technology can be the all-important “buffer” which allows energy to be generated when possible, stored until needed, and used without producing harmful emissions.

Many governments provide incentives for green technologies, and make a point of including fuel cell technology, which is widely seen as a bridging technology between today’s fossil fuel economy and any future hydrogen economy. In other words, fuel cell technology is already seen as being fuel agnostic, environmentally friendly, economically efficient, and technologically flexible. Fuel cell products are in the early stages of commercialization, as witnessed by the availability of consumer products such as auxiliary power units for camping, and products based on military prototypes. In general, hydrogen technology can be readily applied in portable and stationary applications, in many cases making use of the existing gas network, and of course – in perhaps its most visible application – in the automotive and transportation sector.

Yet in order to be a viable complement to and ultimately a replacement for fossil fuels, a future hydrogen economy needs further breakthroughs and wider popular adoption of the technology; hydrogen technology is both fuel flexible and application flexible. In certain jurisdictions, principally Japan, the USA, and Germany, education is leading these developments. The sales data for educational products are highly correlated with the numbers of demonstration programmes and early-stage commercial products that are sold in regions that have strong government support for the technology.

The introduction of hydrogen technology will affect aspects of education at many levels. Occupational opportunities will expand. Key aspects of curriculum content in schools and universities will be adapted to new challenges. Advanced vocational training and research will have to supply answers to the challenges posed by hydrogen technology. The presentation will review the past decade of development and offer an introduction to the rapidly expanding market for educational and demonstration fuel cell products – primarily by

means of a case study of the German company h-tec Wasserstoff-Energie-Systeme GmbH (h-tec Hydrogen Energy Systems).

2 h-tec

h-tec Hydrogen Energy Systems was founded in February 1997. At that time, the technology for industrial fuel cell applications was aimed at small, highly-specialized markets and required substantial funding. While studies had shown that, in theory, fuel cells could provide a new energy supply, this was economically impractical. Therefore, the initial batch of custom-made fuel cells and electrolysers was created with the educational market in mind.

At the Hanover Fair in April 1997, h-tec gave the first public display of its first full array of fuel cells and electrolysers. Today, the multifaceted educational product lines subsequently developed by the h-tec Education division still constitute the core business of the company. h-tec was the first company to offer fuel cells and electrolysers based on proton exchange membrane (PEM) technology, and h-tec's products are exported worldwide to be used in schools, colleges, technical colleges, universities, and by companies and institutes to demonstrate this new technology to their customers and to the public. In 2009 h-tec sold about 11,500 products, of which 85% were exported.

In 1999, development work started on the business division of industrial applications (h-tec Industrial). To this end, fuel cells and higher performance electrolysers have been developed, with the goal of being able to offer the best price/performance ratios and associated high quality standards in targeted service areas and markets.

3 Evolution of Hydrogen Technology Education Markets

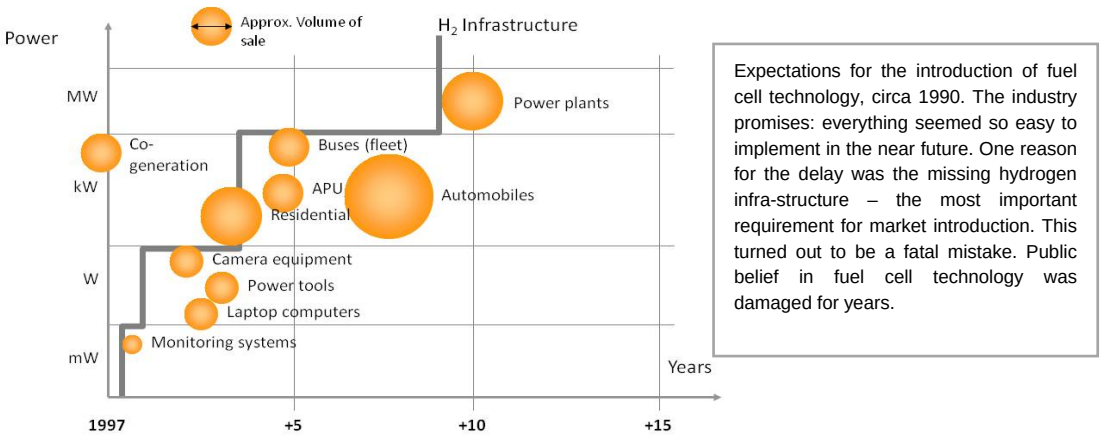


Figure 1: Expectation in the fuel cell market in 1997.

Interest in fuel cell technology increased rapidly throughout the 1990s. Automobile manufactures sought an alternative low-emission, high-efficiency energy conversion device that could be implemented at a reasonable price. In addition, heating system manufacturers

became interested in alternatives to heat engines. In 1997, conventional wisdom held that in six years fuel cell technology would be ready for markets and available in cars, heating systems, and many other applications in daily life.

However, at this time, fuel cells were little more than laboratory prototypes. Nevertheless, the growing interest in fuel cell technology generated a need for educational and demonstrational products. The first teaching systems were customised products, mainly for public outreach events run by institutions such as municipal utility companies.

Bespoke production led to high unit prices: e.g. €3,500 for an alkaline solar hydrogen system with one watt output. Today a solar hydrogen system with the same output costs about 170 €, a fall in price of some 95%.

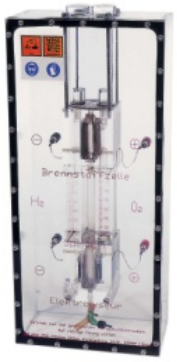


Figure 2: **Teaching system of 1995 with alkaline electrolyser and fuel cell(Source: h-tec GmbH).**

Figure 3: **State-of-the-art Solar-Hydrogen-Model for classroom instruction (Source: h-tec GmbH).**

Figure 4: **Sales partners h-tec worldwide.**

Today the market for educational hydrogen technology systems is highly competitive, with multiple participants from Germany, and a recent entrant from Singapor with production in China. Furthermore, there is a tendency towards more and more specialisation and a fragmentation of the target market into subcategories: e.g. fuel cell systems for schools, for universities, for vocational training of automobile mechanics, for the toy market, etc.

4 Correlation of Education and Outreach with Successful Implementation of Hydrogen Economy

h-tec experience has shown that the market for educational and demonstrational fuel cell systems correlates very closely with market development for industrial fuel cell technology. For instance, major industry players in North America, Asia and Europe are currently preparing for market introduction of commercial fuel cell products, and as can be seen in Figure 5 below, the level of market interest and penetration correlates with the historical sales figures of educational systems. Clearly, this correlation reflects a relationship with at least two sides: societies with interest in hydrogen technology are more likely to fund purchases of educational fuel cell materials, and societies where students have been trained with fuel cell technology are more likely to be able to support such an industry. There are undoubtedly other interrelationships as well, but the overall correlation is quite striking.

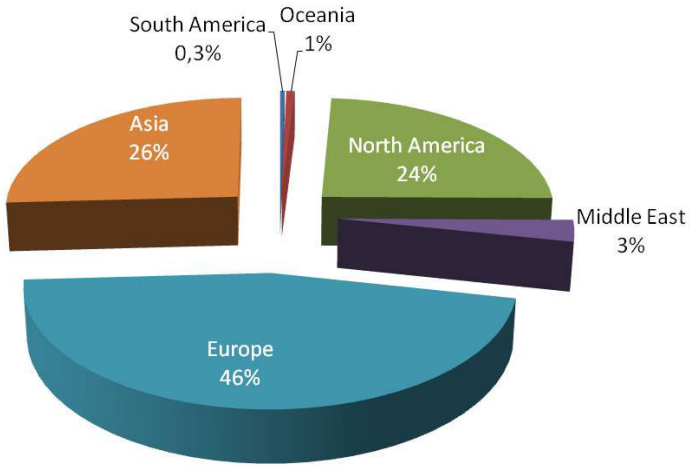
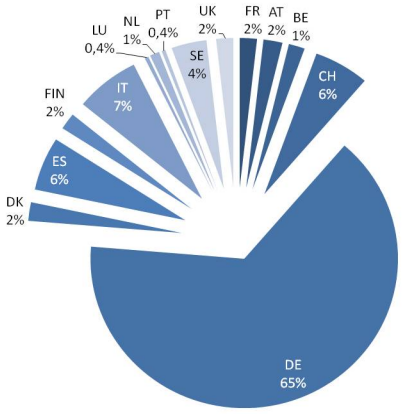


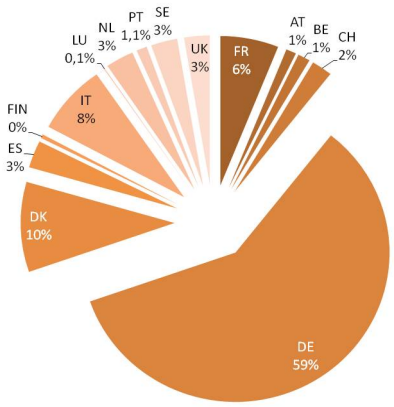
Figure 5: **Geographical sales breakdown of h-tec education products.**

This correlation is particularly interesting, given the difficulty of finding accurate indicators about commercial fuel cell technologies. Companies in this field are typically highly restrictive with information when asked about, for example, manufacturing capability or a breakdown of development and production costs. However, h-tec has found that to get an impression of the economic situation regarding the progress of fuel cell industries worldwide, it is sometimes also meaningful to have a closer look at the market for educational systems and services in specific countries. The number of educational systems sold is strongly correlated with the state of the industrial reality and finally with the number of commercial units that are actually installed.

As seen in the Figure 6 below, within the European market Germany is far ahead in the research and development of fuel cell systems and fuel cell powered applications. There is a particular concentration of expertise in North-Rheine-Westphalia, as this region is supported by an exceptionally well positioned network which supports its industry with a wide range of outreach activities, not to mention industrial support programs.



Installed FC in Europe - Rated Power (kW)
Source: http:/www.coretecventures.com



Sold Educational Systems of h-tec in Europe
Source: h-tec GmbH

Figure 6: Correlation of Installed stationary systems and markets for educational products.

5 Conclusion

In conclusion, our experience with the educational and industrial markets for hydrogen technology shows that the demand for technical education and demonstration products correlates strongly with the state-of-the-art technology, local and state government support, significant academic activity, and not least the amount of installed capacity. There is clearly a feedback loop between the educational and commercial worlds: interest in a technology drives demand for teaching, and interested students with a strong technical background go on to become the engineers and developers of the next phase of technological innovation. We have already seen this, even in the relatively young field of commercial fuel cells. The renaissance of fuel cell technology in the 1990s and increasing public awareness of the technology generated a demand for educational products for use in schools, universities and vocational training. At the same time, organizations realized the need for public education and the demonstration of hydrogen technology in general for companies' PR activities. h-tec stepped in to fill that demand. And now, the first generation of hydrogen researchers trained in the 1990s and early 2000s are contributing to the next wave of hydrogen technology development and commercialization. Proving causality is difficult, but if educational fuel cell activity really is a leading indicator for the commercial fuel cell industry, investment in the educational market should be an effective method of encouraging future adoption of hydrogen technology, and analysis of the educational market could show where to expect untapped commercial potential.