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Can Hydrogen Lead The Way to Decentralized Energy Supply?

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1. **Global energy consumption** will continue to rise in the coming years. At the same time global fossil fuel reserves are becoming scarcer and the **era of "cheap oil"** could **be over in just a few decades.**

2. **Hydrogen**, as a source of energy, and the **fuel cell**, as a converter of its chemical energy into electric current, could potentially help to solve this problem – without generating any CO_2 emissions. If the hydrogen is also produced from renewable sources, an **ecologically sound energy conversion cycle would be created.**

3. On this basis a scenario for the **decentralization of regional and global energy supply systems** could be drawn up: existing electricity end-consumers would **generate electricity to meet their own requirements** and feed any excess electricity into the grid; power companies could refocus their business on developing and operating the necessary infrastructure.

4. The **dependency** of the industrialized nations and the poorer countries **on fossil fuels would be reduced**. Third world countries with extensive renewable energy resources could become energy exporters. Global **CO_2 emissions** would also be **lowered**.

5. As things currently stand, **obstacles** include (1) the still **high cost of hydrogen** generated with the help of renewable energy sources, (2) the current **unidirectional structure of the grid**, and (3) the lack of **infrastructure for distributing hydrogen**.

6. In addition, most of today's **fuel cells** are still very **expensive**. The **range of applications** is **very promising**, meaning a large number of manufacturers is highly committed to fuel cell technology; however, only few products have actually been launched.

7. In spite of these obstacles **Iceland** has assumed a **pioneering role**, having taken concrete steps towards **changing over to a hydrogen-based power supply**. A similar, albeit more modest, initiative has been started in the US state of Hawaii.

8. The decentralization of energy supply offers **financial services companies** a **myriad of business opportunities** in the retail and corporate client segments. In order to anticipate and exploit this potential **the structures and dynamics of decentralization** need to be understood.

Water will be the coal of the future

Hydrogen is currently a highly topical issue. The world's biggest trades show for hydrogen as a source of energy and fuel cells as the means of converting it into electricity was recently held in Hamburg for the second time (2) . The US government announced increased funding of fuel-cell powered vehicles as well as of hydrogen produced with renewable sources. Various carmakers have stated that they will start delivering the first small batches of fuel cell vehicles to trial consumers in the coming months.

Jeremy Rifkin ultimately put all of this straight into macroeconomic and geopolitical context with his new book entitled *The Hydrogen Economy*: *The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth (3)* . He predicted nothing short of decentralization and democratization of our energy supply at the same time as capping the CO_2 emissions into the atmosphere and ending the dependency on imported oil. (NOTE) Rifkin is the author of a series of widely read, controversial books about technical, economic and social paradigm shifts.

Did Jules Verne over one hundred years ago put truly visionary words into the mouth of his protagonist Cyrus Harding? Below we shall expound on the main arguments presented by current advocates of a hydrogen-based energy supply and provide a brief insight into the current market situation for the key product: the fuel cell. To conclude, the potential implications of such a development for the financial sector will be addressed.

Fossil fuel reserves shrinking unevenly

Era of ”cheap oil” will end in coming decades

All today's industrial societies are dependent on oil that is old news. Their economic structure, despite the energy efficiency gains made following the oil price shocks, is geared heavily towards fossil fuels, not just oil but coal and gas as well. According to projections by the International Energy Agency (IEA), global energy consumption could rise by two-thirds between 2000 and 2030 . The IEA expects emerging markets to account for over 60% of this increase their development is founded to a great extent on fossil fuels. Owing to the economic frailty of third world countries, oil price fluctuations can quickly bring them to their knees.

Global oil reserves will, however, presumably be running low in a few decades. The decisive factor is less when the last drop will be produced but rather how much longer we will have access to ”cheap oil”.

Production of crude oil 2001: OECD 28%, Africa 11%, Latin America 10%, Asia ex China 5%, Middle East 29%, Former USSR 12%, China 5%

According to Rifkin and other observers (5), this phase will come to an end at the latest when global production levels no longer rise but instead start to fall – because fewer and fewer, smaller and smaller new deposits are being discovered and the rest of the major, known reserves will become increasingly difficult to tap. Part of the global demand might no longer be met or only at barely justifiable expense – the oil price would shoot up.

According to Rifkin, expert opinions about when this juncture will be reached can be divided into two camps: one expects global output to peak between 2030 and 2040, while the other forecasts this to happen between 2010 and 2020 at the latest. To be sure, it should not be forgotten that similar projections have been made many times in the past, but have then had to be revised subsequently. On the other hand, the oil price could raise considerably much earlier if, for example, production levels are deliberately kept down.

In addition to this scarcity, the remaining reserves are spread very unevenly around the globe. Two-thirds of known reserves can be presumed to be located in the Middle East (6). And by 2010 at the latest two-thirds of the petroleum on the global market will also come from the Gulf region, according to the US Energy Information Authority.

It is not only the current acute but also fundamental differences between Western industrialized nations and Muslim-oriented countries in the Middle East that suggest the West's crucial dependency on oil could result in increasingly frequent and serious conflicts.

Hydrogen and fuel cells: sources of hope

So what can be done? A frequently cited ray of hope is hydrogen – it is omnipresent and abundant. It constitutes three-quarters of the mass of the universe. Nevertheless, Jules Verne was not completely right. Pure hydrogen is found only rarely in nature; otherwise it is largely bonded in water and organic molecules. It is thus only a secondary energy source, which means that – unlike with the primary energy sources oil, coal, gas etc. – energy has to be used to release it from its respective compound.

However, once this has happened, it can be converted into electrical energy efficiently and cleanly (7). To do this so-called fuel cells are required in which hydrogen is combined with oxygen – the end products of this process are simply electricity and water (8).

There are a variety of ways of producing hydrogen. Roughly half of all the hydrogen currently produced is generated using the steam reforming method. Water vapor is reduced to hydrogen with carbon from natural gas, but carbon dioxide is also produced as a by-product. Thus, if the hydrogen produced in this way is used to generate electricity in fuel cells, the ecological efficiency of the whole energy conversion process is unsatisfactory. Steam reforming is, however, currently the cheapest method of producing hydrogen. It costs only one-quarter to one-third as much as electrolysis, in which water is broken down into oxygen and hydrogen with the help of electrical energy (9) .

From an ecological point of view, the best solution would be to obtain the electrical energy required for electrolysis from renewable sources such as the sun, wind, water, biomass or geothermic. Their energy could thus be stored in the form of hydrogen, transported in concentrated form (if need be) to the consumption site and ultimately converted into electricity when required without causing carbon dioxide emissions.

The above is undoubtedly an attractive scenario. However, as things stand today there are still the following, not insignificant obstacles to be overcome:

1. Electricity from renewable sources is still comparatively expensive (10) and along way from being sufficient to cover current electricity requirements – not including the amount needed to produce the hydrogen. On the other hand, 19% of global electricity demand is already met by hydropower (11) . And petroleum companies like Shell and BP estimate that renewable energy sources will have a market share of 30-50% (12) by the middle of the 21th century.

2. If renewable energy and fuel cells are used for stationary electricity supply, e.g. in residential properties – homeowners can fall back on the conventional electricity supply from the grid (13) when there are temporary peaks in electricity demand. If, by contrast, hydrogen and fuel cells are to power vehicles, the costly building-up of an infrastructure for distributing hydrogen will be unavoidable – at present it seems unrealistic to believe that hydrogen filling stations could produce sufficient hydrogen locally to meet customer demand.

3. Fuel cells are still comparatively expensive. Only intensive additional development work and higher volumes can bring prices down. In the case of fuel cells for vehicles there is a typical chicken-and-egg situation: demand for fuel cells can only be boosted if a hydrogen supply infrastructure is in place, but this in turn only becomes economically viable once a critical number of fuel cell vehicles are in use. A solution is only possible if unilateral moves are made – several carmakers are taking the first step by investing huge amounts in fuel cell development. Another possibility would be corresponding efforts by the public sector.

Diversification in the fuel cell market

Fuel cells of different sizes and outputs, powered by hydrogen or other ox disable substances, are currently being used in a wide range of applications but largely in prototypes up until now. Brief summary (14) :

Large stationary fuel cells: Non-residential stationary electricity supply is the most developed application area for fuel cells. Most of the world's 530 or so installations are located in Japan and the US, where state- funded field studies have been conducted for years. The majority of these systems are powered by natural gas. They are used predominantly in facilities that require an additional low-fluctuation source of electricity that is independent of the grid. The leading maker of commercially available equipment is UTC Fuel Cells (US).

Fuel cells for residential properties: This segment has experienced the strongest growth in the last two years. Worldwide around 550 of these smaller-scale systems are being operated in homes and comparable situations, most of them in the US. To date, however, no manufacturer has brought out commercially available systems. Most of these cells are powered by natural gas, as is the case with the big stationary fuel cells.

Fuel cells for vehicles: Carmakers such as DaimlerChrysler, General Motors, Ford, Toyota and Honda have been investing heavily in this segment for years. They have recognized that developing alternative propulsion systems is vital to their survival – the fuel cell is seen as a very promising option (15) . At the end of 2001 there were some 100 prototypes in use around the world. This summer Daimler Chrysler, Honda and Toyota announced the delivery of their first small fleets of fuel-cell-powered vehicles to test customers.

Despite their commitment carmakers do not expect to be selling large volumes of such vehicles Ford (16) or 2020 Honda (17) , for example. The main obstacles are seen to be the still very high price of the vehicles, their short range and the lack of a nationwide fuel supply infrastructure. A fuel-cell-powered car made by Ford (the Focus FCEV) currently costs about EUR 2 m. The biggest manufacturer of fuel cells for this application is Ballard Power Systems Inc. (Canada), which supplies cells to companies such as Ford, Daimler Chrysler and Toyota.

Fuel Cell Today forecasts that hydrogen will be the dominant source of energy for fuel cell vehicles both in the near future (few, mainly locally used fleet vehicles with their own on-site hydrogen supply) and again in a few decades (many fuel cell vehicles, developed hydrogen infrastructure). In the intervening period – with growing numbers of such vehicles and an inadequate hydrogen infrastructure – they see petrol or natural gas as the dominant fuel (infrastructure already in place, on-board conversion into hydrogen).

Portable and micro fuel cells: There are more manufacturers operating in this segment today than in all the others the micro fuel cell in particular is forecast to be widely used in electronic equipment such as mobile phones and laptop (18) . Future portable equipment will use much more electricity than today‘s units; fuel cells would then be more suitable than conventional rechargeable batteries. At the moment, however, there are only about 1,700 of them in use, largely in military applications or as prototypes. More and more manufacturers are banking on methanol as an intermediary source of energy for micro fuel cells, as it can be stored more easily and safely than hydrogen. Most of these developments will not be ready to hit the market until 2004 or 2005. Fuel Cell Today has identified just three companies worldwide whose fuel cells are already commercially available.

Overall, the commitment, range of applications and projected market potential are extensive. But the majority of fuel cell types are still in the development phase, so products have come to market only in exceptional cases up to now.

The vision of decentralized power supply

Let us now leave the present for the already broached scenario of a hydrogen-based power supply. The ideal conjured up by advocates goes far beyond purely switching over to hydrogen as the main source of energy. Their declared objective is to decentralize the entire power supply as comprehensively as possible. In achieving this, today’s energy end-users are to be transformed from pure consumers into ”prosumers”. The scenario is roughly as follow (19) :

- Every household, every office building, every electricity user generates electrical energy for their own use with fuel cells and hydrogen. The hydrogen required would constantly be generated on-site – without causing any CO_2 emissions – using electrical energy from renewable sources.
- There will be at least a few end-users that need to obtain additional electricity from larger utilities. The latter, however, are switching over at least partly to renewable energy sources, hydrogen and fuel cells and are thus decentralizing within their own grid. This in turn favors

smaller utilities and promotes competition in the energy market. In addition, the utilities lease fuel cells to end-users (20) .

- If the end-user temporarily or permanently generates more electricity than he consumes (or can store locally in the form of hydrogen production), this surplus can be fed into the grid. Electricity fed into the grid is netted with electricity taken from the grid. This is made possible by developing the power grid from its old ”broadcasting” concept into a multidirectional energy infrastructure.

- Besides being linked to the power grid all hydrogen prosumers would also be linked with one another and the utilities by means of information and communication technologies (ICT) to enable automated coordination of the energy exchange. The internet would be ideal for this. With the aid of this networking and using technologies that allow specific, directed ”dispatching” of defined energy loads via the grid (21) , regional differences in electricity supply and demand could also be evened out. Development and operation of this dual network are the key economic pillars of the former major utilities.

- Finally, parked fuel-cell-powered vehicles can be used as supplementary generators in the stationary grid, if its energy conversion capacity should be insufficient.

A dream: the dependency of the economy – and society as a whole – on fossil fuels would be greatly reduced and CO_2 emissions cut substantially. Rifkin in fact argues that even the poorer nations could reduce the degree of their dependency on external energy supplies, which he regards as an important weapon in the battle against the debt crisis that is suffocating many of them. And ultimately third world countries with extensive renewable resources could themselves become energy exporters.

As things stand today, it is clear that many years are required to create the conditions for such a scenario – several obstacles have already been addressed. Shifting our energy supply in this direction depends a great deal on significant technological advances. State involvement for example with subsidies for R&D costs or financial incentives to build out the necessary infrastructure could speed up the process. All in all, a gradual evolution seems more likely than a revolution.

However, it can already be seen that decentralized power generation can also make economic sense. Rifkin regards the springing up of small power plants for distributed generation in the U.S. as a step in this direction. And in 1999 the management consultancy Arthur D. Little came to the following conclusion in a report on the US market: DG [distributed generation] has the potential to play a major role as a complement or alternative to the electric power grid under certain conditions. The range of DG technologies suggests that DG could provide power supply solutions in many different industrial, commercial, and residential settings across the United States (22) .

The boldest hydrogen plan, however, is advocated by Iceland, which has ample hydropower and geothermal energy and would like to exploit this potential more extensively. In 1999 the announcement was made there that in the next 20 years Iceland plans to switch its entire economy over to hydrogen and stop using fossil fuel (23) . A joint venture between Shell, DaimlerChrysler, Norsk Hydro and six Icelandic partners were charged with the implementation of this plan (24) . In the first stage, all vehicles (including fishing boots) are to be converted to hydrogen fuel; in the second, the entire electricity supply system.

Similar plans – though more modest to date – exist in the US state of Hawaii (25) . There, too, greater use is to be made of the local sources of renewable energy – geothermal, wind and solar energy above all – in order to reduce the state's reliance on fossil fuels. Nearly 90% of energy consumption is derived from oil, which is imported solely by sea. Hydrogen and fuel cell technology are being incorporated into planning as potential new ways to provide energy (26).

Implications for financial services providers

It looks like a rethink has started, at least in parts of the world. And with good reason: even if it should take decades for oil production levels to peak – and thus for black gold to become more scarce – the structural changes that have to be made to the power supply system need to be addressed now. Fuel cells will not be improved overnight. Power grids cannot be transformed into multidirectional infrastructures in the twinkling of an eye. We also need to start considering the potential implications for the financial sector. Here are a few examples:

- If the end-users of energy are to become electricity ”prosumers” in the course of decentralization, households will need appropriate financing. A conceivable arrangement – in an early phase of decentralization – would be a combination with state subsidy program (similar to the German government's "100,000 roofs" solar energy program).
- The structural upheavals in the power supply sector that decentralization would entail would be huge. The reworking of the market and its participants needs to be financed and advice on its implementation has to be provided, valuation criteria for companies have to be adapted. A broad area for investment banking and asset management.
- Consideration also needs to be given to the valuation criteria for the transportation sector, if alternative propulsion concepts are to gain the upper hand. Who is well prepared in research, development, and marketing? Could totally new mobility patterns emerge? How important will cooperation with other transport providers be, and how important across sectors, e.g. with energy suppliers and financial services providers?
- In addition, there is potential for changes in the information and communication sector. ICT networks would become the lifeline of our energy supply, which could lead to massive shifts in interests and thus power in the information business. Here, too, there would thus be a learning curve and business opportunities for the financial sector.
- Ultimately our power supply system could encounter problems triggered by factors other than Middle East crises and oil price fluctuations. The technical and logistical complexity of a broad decentralized power supply system will bring with it dynamics previously unheard of in this sector. Its processes have to be analyzed and its weaknesses recognized in order to enable economic events to be understood and anticipated at an early stage. The ability to soon identify the winners and losers in this competition among countries and regions will be of the

essence.

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1. Verne, J. The Mysterious Island, Middletown: Wesleyan University Press.

2. H_2 Expo, further information available at www.H2expo.de

3. Rifkin, J. The Hydrogen Economy: The Creation of the Worldwide Energy Web and the Redistribution of Power on Earth. Penguin Putnam.

4. World Energy Outlook 2002, International Energy Agency. Only those consumption- relevant political guidelines and measures that had been approved or implemented by mid-2002 were factored into the estimate of global energy consumption.

5. Deffeyes, K.S. (2001). Hubert's Peak: The Impending World Oil Shortage Princeton. Princeton University Press. Deffeyes and other experts base their forecasts on a model for estimating future output levels unveiled by M. K. Hubbert in 1956. Hubbert, a Shell employee at the time, forecast with his model that the US oil production would peak in the early 1970s. His forecast was not taken seriously at first, but he turned out to be right: US oil production did peak in 1970.

6. Youngquist, W. (1997). GeoDestinies: The Inevitable Control of Earth Resources Over Nations and Individuals. Portland: National Book Company. See Rifkin, J. (2002), op. cit.

7. The theoretical maximum efficiency of a hydrogen fuel cell is higher than 80%. The efficiency of real PEM (Proton Exchange Membrane) fuel cells ranges between 40% and 70% in most cases. This means that for the propulsion of vehicles – if hydrogen itself is carried on board rather than methanol as an intermediate source of energy – the overall efficiency of the process of converting H_2 into mechanical energy is about 32-56%, given the roughly 80% efficiency of the electrical motor. By contrast, a conventional petrol-driven internal combustion engine (where chemical energy is converted into mechanical energy) has an efficiency of only about 20%.

8. Fuel cells can in principle directly process – without converting it into hydrogen – every other oxidisable liquid apart from hydrogen. However, a by-product of the direct processing of carbon fuels such as natural gas or methanol is carbon dioxide. Toxic carbon monoxide can also be deposited in the fuel cell.

9. Padró, C. E. G. and Putsche, V. (1999). Survey of the Economics of Hydrogen Technologies, Technical Report. Golden: NREL.

10. For example, Hamburgische Electricitäts-Werke AG (HEW) charges 19.50-euro cents/ kWh (EUR 4.30 basic charge per month) for its ”new power” electricity product generated solely from wind, solar and hydro energy. HEW‘s cheapest ”non-eco” product costs no less than 14.96-euro cents/kWh (EUR 5.30 basic charge per month). Yellow Strom, in contrast, charges only 13.20 euro cents/kWh (EUR 6.60 basic charge per month). Each stated price is a standard tariff (with no difference between day and night tariffs) as at 30.10.2002.

11. Hoffman, P. (2001). Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for a Cleaner

Planet. Cambridge: The MIT Press. See Rifkin, J. (2002), op. cit. Comparing this figure with the figures in the chart on page 4 shows that in several non-EU countries a far larger share of energy than the EU average comes from renewable sources.

12. See also: Shell International, Global Business Environment (2001). Energy Needs, Choices and Possibilities – Scenarios to 2050; Rowel, J. (1999). An Oil Man's Conversion. People & the Planet, 8/3.

13. In addition, at times of low network load – e.g. at night – cheaper electricity can be obtained from big utilities, converted into hydrogen and during the day – when power from the grid is expensive – reconverted locally into electricity in a fuel cell (if this strategy becomes more widespread, of course, eventually electricity would be no cheaper during the night than during the day).

14. The following information is, unless stated otherwise, taken from a series of reports published between November 2001 and September 2002 in the online portal www.fuelcelltoday.com. Fuel Cell Today is operated by Johnson Matthey plc. a manufacturer of fuel cells, and seeks to promote the commercialization of this technology "without bias towards any single organization, fuel cell technology or application".

15. Not all carmakers are putting their money on the fuel cell. BMW is instead developing conventional internal combustion engines that can run on hydrogen. And Ulrich Eichhorn, Volkswagen AG's head of research recently revealed his fundamental skepticism with regard to the generation, distribution and storage of hydrogen (Interview with Ward's Auto World, 2002).

16. Rudolf Kunze, Chief Technical Officer at the Ford Research Centre in Aachen (in: Der Spiegel, October 2002).

17. Yozo Kami, head of the Honda Motor Co. Ltd fuel cell project. (in: Ward's Auto World, August 2002).

18. Casio, the electronics manufacturer, for example unveiled a fuel cell the size of a laptop's rechargeable battery which provides electricity for four times as long as a high-grade rechargeable battery. It is powered by methanol, from which a postage- stamp-sized unit generates hydrogen, and is to go on the market in 2004. Motorola, the mobile phone manufacturer, and the start-ups MTI Micro Fuel Cells und Poly Fuel are also active in this segment.

19. See, for example, Rifkin, J. (2002), op. cit.

20. Chambers, A. (2001). Distributed Generation: A Nontechnical Guide. Tulsa: Penn- Well. See Rifkin, J. (2002), op. cit.

21. The US Electric Power Research Institute is actually developing a technology called FACTS, which is designed to make precisely this (Silverman, S. (2001). The Energy Web. Wired Magazine, 9.07).

22. Arthur D. Little. Distributed Generation: Understanding the Economics. White Paper.