The Grand Challenge of the Hydrogen Economy: A Challenge Too Far?

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1. Introduction

Irrespective of the monumental events of the past few weeks centered on the global financial climate, the future of humankind still depends upon us achieving sustainable development. The concept of sustainable development has been defined in various ways, but a concise definition is "…*development that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

Sustainable development necessitates continued growth in energy supply in our developing world. In Figure 1, taken from Kolasinski [1], we plot the human development index (HDI) against per capita energy consumption with energy expressed in units of kg equivalents of oil. The HDI is composed, amongst other things of contributions from life expectancy, adult literacy, and gross domestic product. There is a strong correlation between people's standards of living and energy consumption.

Increasing energy demand in a developing world is inevitable as countries strive to enhance their population's standard of living. This must mean depletion of fossil fuel reserves, and the burning of fossil fuels will also exacerbate the environmental threat posed by the CO_2 they inevitably produce. Without significant new sources of sustainable energy (more correctly new sources of sustainable power), world development must stall, and conflict will increase.

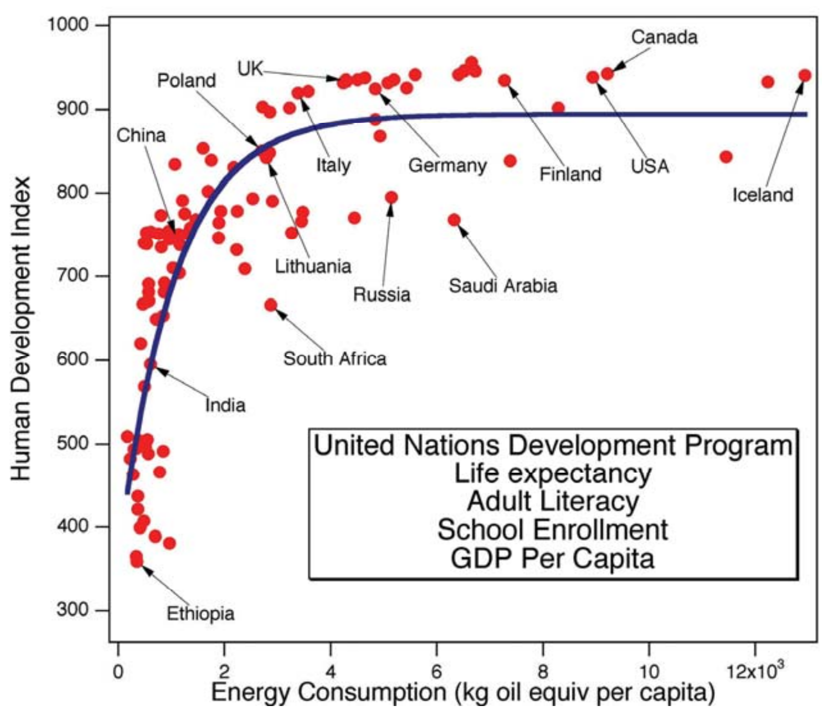

Figure 1. Human development index (HDI) against per capita energy consumption, with energy expressed in units of kg equivalents of oil [1].

2. The Carbon Economy

The development of our global economy has been based on the existence of large reservoirs of carbon-based fossil fuels, which we now routinely utilize as primary energy sources for electricity, heat, industry and transport. To take just one example of such a fossil fuel, think of our use of and reliance upon petroleum. Worldwide, we pump in the region of 90 million barrels of crude oil per day, equating to more than 3.5 billion gallons per day, and each and every single drop is used, either for fuel, or as feedstock for the petrochemical industry. As noted recently, the scale – and complexity – of this activity is almost incomprehensible [2] (Figure 2).

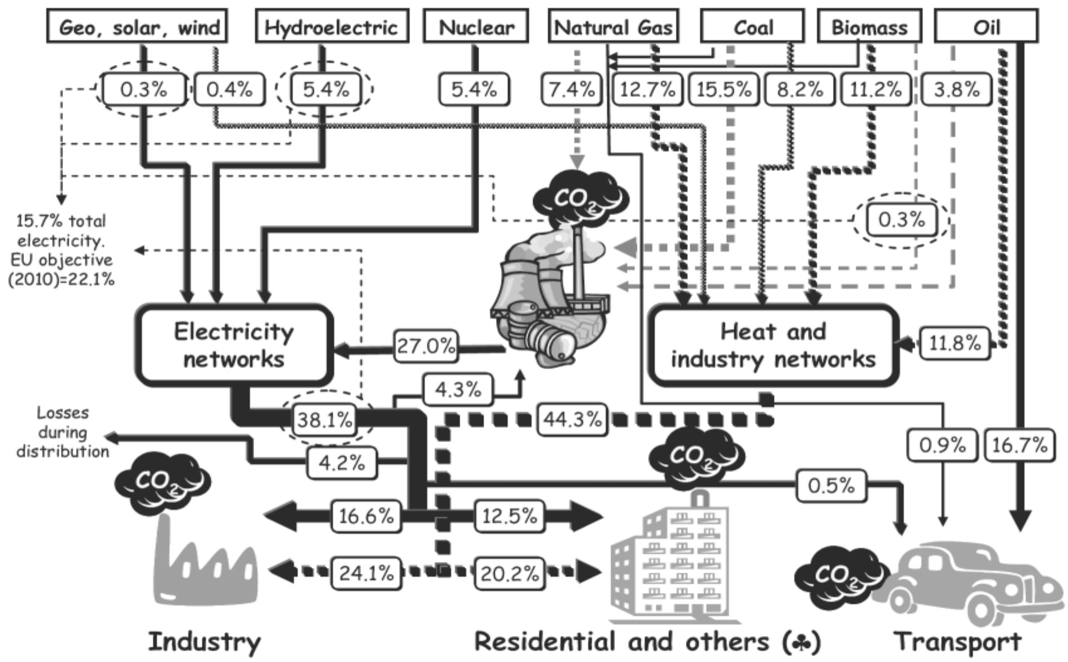

Figure 2. The Carbon Economy [2].

It is therefore necessary to begin (rapidly!) to paint a picture of how the world's voracious demands for energy can be made compatible with the concept of sustainable development, and this is the heroic task of this Energy 2030 Conference.

These goals can be accomplished by improving the efficiency with which fossil fuels are transformed and consumed, and by shifting to alternative fuels, especially from carbon-rich to hydrogen-rich fuels. Technologies to remove CO_2 from fossil fuels are being developed, as are methods – as yet untested - on the massive scales for CO_2 sequestration required.

3. A Hydrogen Economy

Hydrogen could be one attractive alternative to a carbon-based energy economy [3]. Hydrogen is not a primary energy source, but rather an energy carrier which is first produced using energy from another source and then transported for future use where its latent energy – stored in the H-H chemical bond - can then be fully utilized.

This key aspect of hydrogen as an energy carrier underlies part of its attraction in that it can be produced from diverse resources, both renewable (hydro, wind, solar, biomass, geothermal) and non-renewable (coal, natural gas, nuclear).

Hydrogen can then be utilized in high-efficiency power generation systems, including fuel cells, for both vehicular transportation and distributed electricity generation. Fuel cells convert hydrogen, a hydrogen-rich fuel and an oxidant (usually pure oxygen or oxygen from the air) directly into electricity using a low temperature electrochemical process.

A schematic, idealized representation of a possible Hydrogen Economy is outlined in Figure 3; here a wide range of primary energy sources are utilized in an energy mix which is closely dependent upon each locality, depending on its needs and resources.

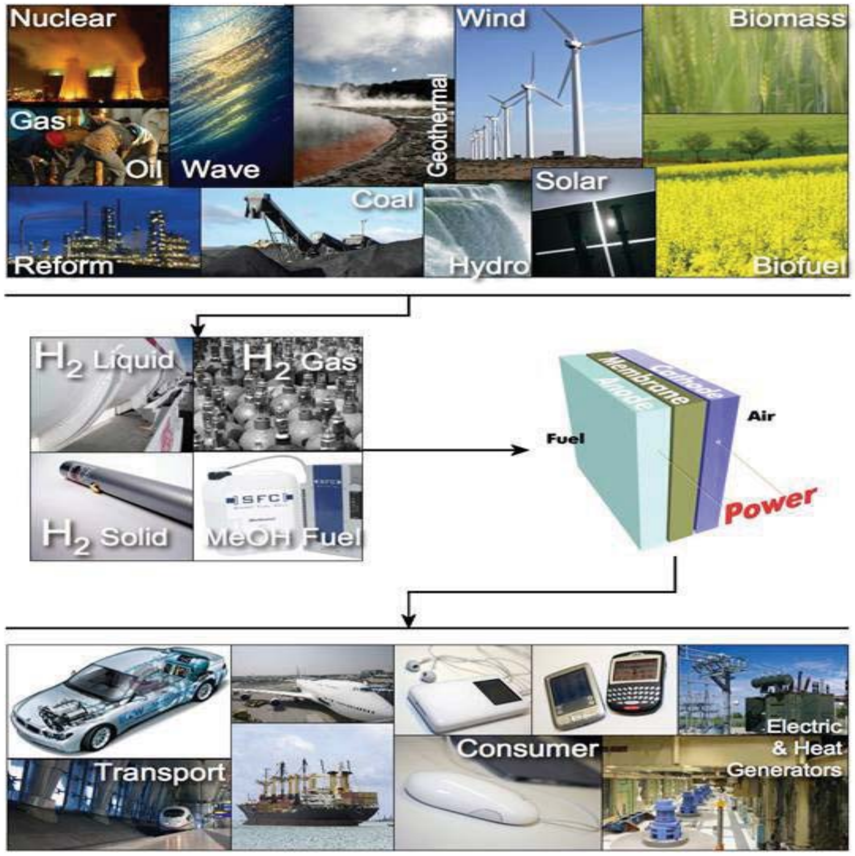

Figure 3. Schematic, idealized representation of a possible Hydrogen Economy.

However, any such transition from a carbon-based (fossil fuel) energy system to a hydrogen-based economy involves significant scientific, technologies and socio economic barriers to the widespread implementation of hydrogen and fuel cells as clean energy technologies for the future.

4. Conclusions

This Talk aims to capture, in brief, the current status, key scientific and technical challenges for hydrogen within a Sustainable Energy 2030 scenario. I will attempt to present a review of the many and varied challenges facing a possible transition to a Hydrogen Economy; the critical question is, therefore, how one might realize such a transition. The more potent enquiry, perhaps, is *"Can we ever realize a Hydrogen Economy, or, are the challenges just too daunting?*

5. References and Bibliography

1. Kolasinski, K. W., *Curr. Opinion in Solid State and Materials Science*, Vol. 10 (2006), pp. 129-131.
2. Marbán, G. and Valdés-Solis, T., *Int. Journal of Hydrogen Energy*, Vol. 32 (2007), pp. 1625-1637.
3. Edwards, P. P., Kuznetsov, V. L. and David, W. I. F., *Phil. Trans. Roy. Soc.*, Vol. A365 (2007), pp. 1043-1056.

Speaker's Biography

Peter P. Edwards was born in Liverpool. He graduated from Salford University; B.Sc. (1970) and Ph.D. (1974). He was then involved in collaboration with Sir Nevill Mott at the Cavendish Laboratory, Cambridge before taking up a British Fulbright Scholarship concurrent with a National Science Foundation Fellowship with Professor Mike Sienko at the Baker Laboratory of Chemistry, Cornell University (1975 – 1977). He then returned to the UK, to the Inorganic Chemistry Laboratory at Oxford, to work with Professor John B. Goodenough as SERC Fellow and Ramsay Memorial Fellow (1977 – 1979). He moved to Cambridge in 1979 to become Demonstrator, and then Lecturer, in Inorganic Chemistry and Director of Studies in Chemistry at Jesus College, Cambridge. During his period at Cambridge (1979 – 1991) he was also BP Venture Research Fellow. In 1987, with colleagues in the departments of Physics, Materials Science and Engineering, he established the first Interdisciplinary Research Centre in the UK, that in Superconductivity. During the period 1984 -1986 he was also Visiting Professor at the Baker Laboratory, Cornell University. In 1991 he moved to Birmingham to take up the Chair of Inorganic Chemistry, becoming Head of Department there from 1996. In 2000 Edwards became the holder of first Chair in Chemistry and Materials at Birmingham.

Edwards was elected Fellow of the Royal Society in 1996 and in 2003 he was awarded the Hughes Medal of the Royal Society for "…*Seminal contributions to fields including superconductivity and the behaviour of metal nanoparticles, and for the advancement of our understanding of the phenomenology of the metal-insulator transition*." He has also been the recipient of the Corday-Morgan, Tilden and Liversidge Medals of the Royal Society of Chemistry. Edwards' research interests are centered on the nature of the metal-insulator transition, the phenomenon of high temperature superconductivity and, most recently, the issue of hydrogen storage in solids, a key enabling technology for any future Hydrogen Economy. He is also Coordinator of the UK Sustainable Hydrogen Energy Consortium.