Campaign for a Hydrogen Economy: "Renewable Energies" at MMU 21 March 2005
Mike Koefman: The Case for Hydrogen

I

The case for hydrogen is the mirror image of the case for carbon...

...especially the carbon which is embedded in all fossil fuels: coal, oil, gas

In recent years (2000 onwards) humankind has been releasing over 6 billion tonnes pa. of fossil carbon (= approx. 22 tonnes carbon dioxide) into the atmosphere. At least 2 billion tonnes of this carbon accumulates in the atmosphere each year.

The cumulative effect of this augmentation has been to raise the concentration of carbon dioxide in the atmosphere from the stable pre-industrial level of **280** parts per million to **380** parts per million. This level will almost certainly rise to **400** ppm by the year 2015, and possibly to **500** ppm by 2050.

The immediate effects of this excess are manifold :

1. **A now undeniable worldwide rise in average surface temperatures, by about 0.6 C over the twentieth century – and continuing.**

2. A disproportionate rise in average air and ground temperature in several regions of the world (as predicted by recent climate models), including the Arctic, the Antarctic Peninsular, southern Spain, parts of Australia and Africa.

3. A rise in the temperature of the upper "mixed" layer (approx. 100 metres) of the world's oceans.

4. A generalised matching increase of the climatologically significant heat content of nearly all soils, lakes and oceans.

5. A marked lowering of the hitherto stable pH of the oceans and of the world's fresh water bodies, ie a general acidification **of the world's water.**

II

The consequences of this excess are varied, interrelated and in every case disruptive of the natural systems and subsystems of the earth:

1. All ice masses are under threat (except, for the moment, inner Antarctica). For example, the recent (November 2004) report of the Arctic Climate Assessment Report is without ambiguity: the Arctic climate and habitat is changing with dangerous rapidity. Most of the world's glaciers (but not all) are showing signs of retreat.

2. This loss of ice is self-reinforcing: it constitutes a ***positive feedback***, and will lead to further warming.

3. Rain cycles and previously predictable seasonality are now being measurably affected all over the world, in ways which cannot be explained by natural variation and oscillations.

4. Agriculture, forestry and fisheries (whilst in some cases benefitting temporarily from carbon enrichment) are under permanent longterm threat.

5. Human health and welfare is under threat, reversing the great progress which has been made in the twentieth century by the richer nations, and further hindering the efforts of poorer nations to improve their human development. For example, there is now unimpeachable evidence that the lung function of millions is being damaged by fossil emissions (as well as by overuse of smoky biomass).

6. It is not possible to predict exactly what will happen to the earth system over the next few decades, although further warming is now inevitable. Qualified observers agree that there are "surprises" in store, and that they will be unpleasant in nature.

7. If competition for resources is usually an element in human conflict (from the parochial level right up to the international level), then the desire for even more fossil fuels is likely to lead to a worsening of relations between all parties **in the supplier/user nexus – as well as to a worsening of climate stress itself.**

III

Some illustrative carbon arithmetic: the story of a gallon of petrol:

<u>The fuel</u>*, *derived from concentrated biomass originating 300 million years ago -

1 gallon petrol ? 4.5 litres ? 3 kg carbon ? 10 kg CO_2 ?

5 cubic metres carbon dioxide

<u>The atmosphere</u>*, *from which the fuel derives its co-reactant oxygen, and into which it dumps its exhaust gases for a sojourn of c. 100 years -

Pre-industrial CO_2 load:	**280 ppm (vol)**
Present CO_2 load:	**380 ppm (vol)**
Overall increase to date:	**100 ppm (vol)**
Climatologically significant increase :	**50 ppm (vol)**

***<u>Conclusions</u>*: 50 : 1 000 000 :: <u>1 : 20 000</u>**

Therefore: 5 cubic metres CO_2 alter 100 000 cubic metres air
And (1 tankful): 50 " " " " 1 000 000 " " "

Therefore 1 000 tankfuls (in the "life" of a car) are able to alter . . . . .
. . . . .1 cubic kilometre of atmospheric air (at std temp and pressure).

And the present, 500 million (?), worldwide number of road vehicles is able in a decade to affect each cubic kilometre of the total area (500 million sq km) of the earth's first kilometre-depth of the atmosphere.

*If only we could forsake fossil fuels in their entirety, if only we could escape the **carbon conundrum**, whereby the very source of our commercial and industrial energy, so necessary for our survival, carries such weighty disadvantages . . .*

IV

Hydrogen, the only feasible alternative to fossil fuels and their embedded carbon

Why hydrogen?

1. The Periodic Table of the elements shows us that there are only two members which (a) readily combine with atmospheric oxygen to furnish heat (and hence power), and (b) exist in large enough quantities to be of use to human society: carbon and hydrogen.

2. The combustion of carbon with air necessarily produces *carbon dioxide*. The combustion of hydrogen with air necessarily produces *dihydrogen oxide* – ie. water, with little or no accompanying pollution.

3. The water produced by the burning of hydrogen cannot affect to any large extent the functioning of the earth system - land, fresh water, oceans, the atmosphere and all living things.

Even though water vapour is itself the most powerful of the greenhouse gases, it already exists in the atmosphere in such quantities (as 13 000 cubic kilometres of water equivalent) that any addition by human action would be imperceptible in its effects.

4. If hydrogen were to be produced exclusively by the electrolysis of water, its combustion would return all of the originating water to the land and oceans, via the rain cycle, within ten days of emission.

5. Hydrogen can fulfill all the tasks demanded of an energy source:

energy store

energy vector

combustion energy

electrical energy

mechanical energy

6. The worldwide sourcing of renewable electricity to produce hydrogen would give us all a chance to escape from the conflict-ridden market for fossil fuels.

Some hydrogen arithmetic:

(a) 1 cubic metre (= 1 tonne) of water contains 110 kg of "locked in" hydrogen.

(b) 10 tonnes of water contain 1.1 tonnes of hydrogen.

(c) 1.1 tonnes of hydrogen embody as much chemical energy as 2.5 tonnes of oil, which is the average annual per capita "ration" for some present day "advanced" economies.

(d) Conclusion: The hydrogen abstracted from 10 tonnes of water would grant a "modern" standard of living to one inhabitant of such a country for one year.

(e) By the year 2050 the world's population will probably peak at, or below, 10 billion. For each of these citizens of the future ten tonnes of electrolysed water (=1.1 tonnes of hydrogen "=" 2.5 tonnes of oil) will suffice to grant an adequate standard of living.

(f) On these assumptions, how much water will have to be electrolysed each year to keep every world citizen supplied with energy on this scale?

10 billion x 10 tonnes

= 100 billion tonnes

= 100 cubic km (= approx. Lake Geneva)

(g) These quantities are large and challenging, but compared with projections for a carbon-based future they do offer a feasible (though difficult and expensive) way to a sustainable energy society.

(Consider the carbon alternative: if the whole world of 2050 has attained the present UK government's target, for the UK, of "only" 1 tonne of carbon per capita per year, the total world population will be burning 10 billion tonnes per year – 40 % more than at the beginning of this century: a disaster which can only be precluded by the almost universal adoption of hydrogen.)

Hydrogen – some challenges:

1. To source it in ways which do not harm the environment and which do not entrain conflict, coercive measures or loss of rights to vulnerable people.

For example, if Europe (including the UK) should decide to negotiate for the use of areas of the Sahara Desert to produce solar electricity and solar hydrogen for its own use, such negotiations should be conducted so as to minimise threat and to maximise benefits to the producing countries.

For example, if Australia (the continent with the most intense solar regime in the world) should decide to explore the solar hydrogen option, full negotiating right should be given to the tribal peoples whose land may be affected.

Similar equality should be given to the tribal peoples of North and South Dakota when American investors weigh up the promise for wind hydrogen in these states.

2. To develop the research base which will hasten the adoption of hydrogen. Such a base must be international in scope, and recruit membership from countries outside the G8: the reign of TRIPS – trade related aspects of intellectual property rights – may encourage innovation in the short term, but threatens to hold sun-rich but cash-poor developing nations in permanent intellectual and financial bondage.

The use of the concentrated talent of large numbers of researchers in a compact region of technically biased universities should be of particular interest to Manchester, a region rich in physics, chemistry, materials science and the more human sciences which will have to participate in the establishment of a hydrogen-based economy.

3. To imagine the shape of the hydrogen-based society to come, by constructing a range of plausible scenarios where the interplay of technical, political and human factors is envisaged.

For example, should hydrogen first be introduced into the UK economy as a transport fuel, in relatively pure form so as not to damage the low temperature fuel cells in which it is likely to be used, or should hydrogen be introduced in a "rough" form for use in households?

VII

Can renewably generated hydrogen do the job ?

Energy storage: There is no reason why hydrogen should not be as effective as carbon as an energy store, provided that at the planning stage provision is made for its low *volumetric* energy density, and for its corrosive effects on certain types of steel.

For example 10 million tonnes of hydrogen at 100 atmospheres pressure could be stored in a dispersed but interconnected reservoir totalling 1 cubic km. This represents an energy equivalent of 25 million tonnes of oil, about 4 weeks total primary energy use in the UK.

Hydrogen also has a supplementary advantage as an energy store: it can function as an *energy buffer*; ie. at sites where sun, wind and wave are producing electricity in excess of what can be used by the grid, this surplus electricity can be used to electrolyse water, thus producing hydrogen which can be used either as a fuel, or reconverted to electricity in a fuel cell when the grid demands it – functioning as the (in)famous *spinning reserve*.

Energy vector: Although gaseous hydrogen cannot be carried easily in bulk at feasible pressures, it can be piped in the same way as natural gas. A great deal of energy is needed to propel it through pipelines, but this energy itself could be provided along the way by renewable supplies. The piping of hydrogen on an industrial scale has been common practice for a hundred years, and its refinement for future local use should not be impossible.

Combustion: Wherever fossil fuels are presently used for their combustion potential (their main use, and the main source of the atmosphere's present excess carbon dioxide) hydrogen can function as an alternative.

?The "town gas" of 40 years ago was 50% hydrogen.

?Heaters, boilers, piston engines and turbines have all operated on hydrogen, and there is no reason to suspect that further improvements cannot be made.

?An example can be given of an apparently intractable challenge to hydrogen technology: aviation. Not only have Lockheed (1970s), Tupolev/Dasa (1980s) and Dornier/Fairchild (1990s) put thousands of serious design hours into hydrogen-powered aircraft concepts, but Rolls Royce itself concedes that if it was forced

by the market (or by legislation) it could produce a hydrogen turbine to match its present range of engines in all important respects.

VIII

Electricity: **Most of the world's electricity is presently generated by fossil fuels, and by 2020 it is expected that 80% of the UK's electricity will be generated by just one of these fuels, natural gas – with worrying implications for climate and geopolitical security. If renewably generated electricity should become available in the necessary quantities, together with its natural companion, renewably generated hydrogen, as a storable and transportable fuel, then a rational and longterm future for our energy security can be envisaged.**

With the use of fuel cells, which convert the energy stored in hydrogen into electrical energy for local use or for the grid, a complete system of electricity supply could be designed, with little impact on the climate.

The culture, machines and artefacts of modern society: **Would the culture and practices of modern industrial society be overturned by the full adoption of the "hydrogen economy" ?**

Altered, yes, but shattered, probably not.

The question of cultural adaptation is but one of many which will need pre-emptive study, since many factors, including the need for the society-wide careful husbanding of initially expensive hydrogen energy, will enter into the design and behaviour of a hydrogen -based economy. Institutions exist in Manchester which could approach these challenges.

Example: the hydrogen-powered car and motorcycle could be so quiet as to constitute a danger for some pedestrians and cyclists: what kind of technical/social interface is needed to solve such a problem ?

Example: how could the poorer and richer countries of the world be integrated into a hydrogen economy in ways which are to the advantage of both ? Would it be possible to work in such tightly collaborative ways that conflict over energy would in future become simply stupid?

Conclusion: **In the face of climate change, attendant global warming and the degradation of the natural environment, it is incumbent on informed citizens to**

work for the rapid and complete introduction of an energy economy based on renewable electricity and renewably generated hydrogen. As citizens of this town, this country and the world we should use all available resources – human, scientific, financial and industrial - to bring about this transformation.

The Campaign for a Hydrogen Economy: Indicative websites

Climate:

1. www.Realclimate.org *(a recently established and immediately essential research tool and educational resource – possible the best on the web)*

2. **www.tyndall.ac.uk** *(a serious and established climate information centre, research-rich, and with excellent links)*

3. www.SciDev.net *(one of the most comprehensive sites treating climate, environment and development as interlinked themes)*

4. www.ipcc.ch *(the key intergovernmental research body, supplying and updating information to all climate negotiating partners)*

5. www.ucsusa.org *(the site of the Union of Concerned Scientists – quite fierce on climate issues, but always on solid ground)*

6. www.ncar.ucar.edu *(a huge american resource, tapping into many of the world's best research institutions on climate, oceans etc.)*