POLISH JOURNAL OF APPLIED CHEMISTRY
L, no. 1–2, 1–5 (2006)

Anna MARZEC

TOWARD A HYDROGEN FUEL – WOULD ITS MASSIVE USE BE SAFE FOR A CLIMATE? (A discussion paper)

Institute of Coal Chemistry, Polish Academy of Sciences, ul. Sowińskiego 5, 44-121 Gliwice,
e-mail: marzec@karboch.gliwice.pl

Published data on (i) carbon dioxide emission from the US transportation sector in 2002 as well as (ii) the amount of hydrogen that would be needed for the sector, if entirely fuelled by hydrogen, had been found. The (ii) data have been used for calculation of the amount of water resulting from hydrogen combustion in the sector. The case that the resulting water vapor is emitted into atmosphere has been considered. The carbon dioxide and water vapor emissions were compared using their molecular equivalents. The results show that approximately the same amount of water molecules will be emitted into atmosphere as carbon dioxide molecules eliminated by the use of hydrogen fuel in the transportation sector. Thus, the advantage of hydrogen fuel eliminating the carbon dioxide emission and its greenhouse influence, seems to be questionable since the water molecules (gas phase) possess also strong greenhouse properties.

Key words: transportation sector, carbon dioxide emission, hydrogen fuel, water vapor emission, molecular equivalents

1. INTRODUCTION

Carbon dioxide emission and its concentration in the atmosphere will significantly increase during the next decades [1,2]. There is an urgent need for a change in the energy production system if the dangerous global climate warming has to be avoided. One of the proposed ways of the change is a massive use of hydrogen as a fuel. The idea is presented in mass media as a "hydrogen economy".

According to the report of National Research Council [3], there are no realistic means for production of large commercial quantities of hydrogen fuel during the next 10–30 years. The same conclusion one may find in a Special Issue of Science journal [4] as well as in the paper of J.J. Romm [5]. Thus, decades are needed (i) to work out new technologies of hydrogen production eliminating carbon dioxide occurring as the side-product; (ii) to build the safe infrastructure of transporting and storing hydrogen gas, and (iii) to enroot the techniques of safe hydrogen use in the society. The conclusion is that hydrogen fuel does not represent a short-run solution, capable of suppressing global concentration increase of carbon dioxide in the atmosphere.

There are also doubts whether hydrogen fuel can be a long-term solution. One of the reasons is a high probability of hydrogen leakage into atmosphere from the future transport, storing and usage systems. Such hydrogen could destroy ozone layer in the stratosphere [6,7]. A possible rise in atmospheric hydrogen concentration may have an influence on complex chemistry among greenhouse gases occurring in atmosphere [8]. Various rates of hydrogen leakage – from 3% to 10% of a global hydrogen production – have been taken into consideration [7]. In any of the cases, the leakage would be far from being negligible if one takes into account a scale of hydrogen production predicted. For example, if 30% reduction in CO_2 emissions by 2020 is to be achieved by means of using hydrogen fuel, the global annual production of the gas [7] would be about 4.7 gigatons (4.7×10^9 tons/y), and its leakage into atmosphere would amount some hundreds megatons per year.

Another problem for the atmosphere protection creates the water vapor emission arising from combustion of hydrogen fuel. The aim of the present paper is to clarify the following subjects:

- an assessment of the order of water vapor emission due to hydrogen fuel combustion, and
- comparison of the amounts of water vapor emission with the carbon dioxide emission that could be eliminated by the hydrogen fuel use.

As an example, the calculations have been carried out for the US transportation sector.

2. CALCULATIONS

2.1. Hydrogen fuel demand and water vapor emission of transportation sector

Grant [9] stated that for operating the 2002 size transportation sector exclusively on hydrogen, one would need around 230 000 tons of hydrogen daily. It makes 84×10^6 tons per year (Table).

Table. Characteristics of the US transportation sector (2002 y) on the assumption that the sector is entirely fuelled with hydrogen

	Metric tons per 2002 year
Hydrogen demand	84×10^6
Water vapour arising from hydrogen combustion	756×10^6
Carbon dioxide reduced	1866×10^6
Molecular equivalent of exhaust water vapour expressed in carbon dioxide amount[a/]	1848×10^6

[a/] 756×10^6 tons of water contains the same amount of molecules as it occurs in 1848×10^6 tons of carbon dioxide.

It is worth to note that a future use of hydrogen just by a portion of US transportation sector (light-duty vehicles only) may reach 110×10^6 t/year in a few decades [3] (p. 83 and p. 118 in the reference). One can also find much higher future quantities of predicted hydrogen use, quoted by Eiler [7].

The calculation of water vapor amount resulting from hydrogen combustion is simple: one kG (or 1 ton) of hydrogen produces 9 kG (or 9 tons, respectively) of water. Thus, the combustion of 84 megatons/y of hydrogen would produce 756 megatons/y of water (Table) by the US transport sector of the 2002 size.

The data available for the US transportation sector makes possible an approximate calculation of the hydrogen amount needed for fuelling the entire global transportation sector. Since the US vehicle fleet represents the 30% share of the global fleet, a rough estimation of hydrogen amount for running the global sector (of the 2002 size) is 280×10^6 tones/y. Such amount of hydrogen would produce about 2.5×10^9 t/y of water vapor.

2.2. Carbon dioxide emission from the US transportation sector

Carbon dioxide emission from the US transportation sector [10] in 2002 was 1866×10^6 tons (see Table 10 in the reference) and accounted for 32% of the total US energy-related carbon dioxide emission in 2002. Using hydrogen fuel in place of hydrocarbon fuels (gasoline, diesel oil, jet fuel, *etc.*) this carbon dioxide emission would be eliminated (see Table).

2.3. Comparison of water vapor and carbon dioxide emissions

The contribution of a species to greenhouse effect depends on the radiative properties of the molecules of the gas and on its atmospheric content expressed in volume concentration (volume gas concentrations correspond to molecular concentrations). Therefore, one has to consider molecular equivalents of the two gases when one wishes to compare greenhouse effects of the water vapor arising from hydrogen combustion and of carbon dioxide that would be eliminated by the use of hydrogen fuel. The equivalents are amounts of two substances that contain the same numbers of molecules (for example, 18 tons of water contains the same number of molecules as 44 tons of carbon dioxide).

The present calculations have shown that the amount of water vapor in question *i.e.*, 756×10^6 t/year, generated in the hydrogen fuelled transportation sector, and 1848×10^6 tons of carbon dioxide (Table) contain the same amounts of molecules. The latter is close to the amount of the eliminated carbon dioxide emission which is 1866×10^6 tons. Hence, nearly the same quantity of water molecules replaces carbon dioxide molecules.

3. DISCUSSION AND CONCLUSIONS

Some questions referring to a future water vapor emission into atmosphere arising from massive use of hydrogen fuel should be discussed.

One of them is as follows. Water vapor from hydrogen oxidation (no matter whether fuel cells or internal combustion engines would be used) is not condensed in-situ in the cars and not piped away into natural water system. Then, the vapor would certainly enter into atmosphere. When the vapor penetrates an atmospheric space, which already had been saturated with moisture, clouds are formed. And clouds are known to have an influence on climate. Moreover, the formation of clouds is associated with a release of condensation heat by water vapor molecules when they change the phase to liquid state. The condensation heat rises the temperature of air and thus a concentration of water gas molecules in air is increased.

However, a significant part of atmosphere is not in the state of water vapor saturation [11]. In such atmosphere space, the additional stream of water molecules results in a concentration increase of the water in atmosphere.

Thus in both cases, there is an increase in water vapor concentration in the atmosphere. In fact, water gas molecules are strong GHG as compared with carbon dioxide molecules. The conclusion is that in the case the total amount of water (produced by the transportation sector) contributes to the concentration increase of water in atmosphere, the greenhouse effect could be enhanced instead of being weakened. The final effect (whether meaningful or weak) would depend on the amount of water vapor emission. The anticipated future emission of water vapor from the global transportation sector is about some billions (10^9) tons/y.

These additional water vapor emissions into air should be first of all explored from the point of view of probable change of weather conditions over regions of dense population and dense car traffic (for example, Europe). And then, consequences on global climate could be considered as a result of climate change in such regions.

Summing up, any expectation of future advantages of hydrogen fuel use, cannot disregard the fact that in place of one greenhouse gas (carbon dioxide) another even stronger GHG (water) would be emitted.

REFERENCES

[1] **Third Assessment Report of the Intergovernmental Panel on Climate Change; Summary, 2001.** IPCC Secretariat: Geneva, 2001, pp. 1–97.

[2] **a/International Energy Outlook 2002. Transportation Energy Use.** Energy Information Administration (EIA) of US Dept of Energy: Washington, DC, 2002. www.eia.doe.gov/oiaf/ieo/archive_ieo.html (search for Report Contents and then, Transportation Energy Use)
b/**International Energy Outlook 2003**. Energy Information Administration (EIA) of US Dept of Energy: Washington, DC, 2003. ww.eia.doe.gov/oiaf/ieo/archive_ieo.html.

[3] **The Hydrogen Economy – Opportunities, Costs, Barriers and R&D Needs, 2004**. National Research Council. The National Academies Press: Washington D.C., 2004, pp. 1–374.

[4] **Special issue: Toward a Hydrogen Economy; Special Issue.** Science 305, 957–974, 2004.

[5] J.J. ROMM, The Hype about Hydrogen. Issues in Science and Technology. Spring 2004. www.issues.org/issues/20.3/romm.html

[6] T.K. TROMP, RUN-LIE SHIA, M. ALLEN, J.M. EILER, Y.L. YUNG, Potential Environmental Impact of a Hydrogen Economy on the Stratosphere. Science 300, 1740–1745, 2003.

[7] J.M. EILER, T.K. TROMP, RUN-LIE SHIA, M. ALLEN, Y.L. YUNG, The Bush Administration and Hydrogen; Response. Science 302, 1332–1333, 2003.

[8] M.G. SCHULZ, T. DIEHL, G.P. BRASSEUR, W. ZITTEL, Air Pollution and Climate – Forcing Impacts of a Global Hydrogen Economy. Science 302, 624–627, 2003.

[9] P.M. GRANT, Hydrogen lifts off – with a heavy load. Nature 424, 129–130, 2003.

[10] **Emission of Greenhouse Gases in the United States. Carbon Dioxide Emission**. Report of US Dept of Energy. Environment Information Administration DOE/EIA – 0573 (2004). Washington, D.C. December 2005. www.eia.doe.gov/oiaf/1605/ggrpt/index.html.

[11] **National Research Council. Understanding Climate Change Feedbacks**. The National Academies Press: Washington, DC 2003, 166 pages.

Received November 12, 2006