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33124-0622, USA****INTRODUCTORY PAPER**

## SAGA OF HYDROGEN CIVILIZATION

After having my elementary and middle school education in Izmir, Turkey, and the high school education in Istanbul, I attended the Istanbul Technical University for year and a half. Then I entered the Imperial College, London, to complete my university education, where I received the Associateship of City and Guilds Institute "A.C.G.I.", B.Sc. Degree in Mechanical Engineering, Diploma of the Imperial College "D.I.C.", and, in 1951, Ph.D. Degree in Heat Transfer from the University of London. After my graduation, I did my military service in Turkey, in the Ordnance Division, working in the Office of Soil Products, first as a Consultant and then as the Deputy Director of Steel Silos, and in the management of a major construction company.

In 1962, I joined the Engineering Faculty, University of Miami, as an Associate Professor of Mechanical Engineering. My first research project involved the investigation of two-phase flow instabilities in nuclear hydrogen rocket engines for travel to Mars. Dr. Alan Stenning, Chairman of the Department of Mechanical Engineering, was the Project Director. We discovered three different instabilities in boiling two-phase flows and the precautions to be taken to eliminate them. This study lasted five years - from 1962 to 1967. During that time, I became quite familiar with the properties of liquid and gaseous hydrogen. It is the lightest fuel, and the best one for long-distance journeys.

In the 1960s, air pollution in cities became an important issue hurting the health of people. I became interested in environmental issues in general and the air pollution in particular. I started studying possible

vehicle fuels, with a view of determining the fuel which would cause little or no pollution. I particularly studied methanol, ethanol, ammonia and hydrogen, as well as the gasohols (*i.e.*, the mixtures of gasoline and methanol and/or ethanol). My investigation of fuels for transportation lasted five years (1967-1972). The result was that hydrogen is the cleanest fuel, and it is also the most efficient one. It would not produce CO, CO<sub>2</sub>, SO<sub>x</sub>, hydrocarbons, soot and particulates. If hydrogen was burned in oxygen, it would not produce NO<sub>x</sub> either. If it burned in air, there would be then some NO<sub>x</sub> produced.

Early in 1973, the energy crisis started. The petroleum-producing countries in the Middle East stopped exporting oil. The world economy almost came to a standstill. Some factories stopped and/or worked part time. Transportation was adversely affected. There were big lines at gas stations, few cars on the roads and air traffic was curtailed.

Since I always believed that engineers and scientists should strive to find solutions to the problems facing the humankind and the world, I established the Clean Energy Research Institute (CERI) at the University of Miami in 1973. The mission of the Institute was to find a solution or solutions to the energy problem, so the world economy can function properly and provide the humankind with high living standards. To find clean forms of energy was also the mission of the Institute, so that they would not produce the pollution and damage the health of flora, fauna and humans, as well as the environment of the planet Earth as a whole.

CERI started work in earnest. We quickly looked at all of the possible primary energy sources, including solar, wind, currents, waves, tides, geothermal, nuclear breeders and thermonuclear. They are much cleaner and would last much longer than fossil fuels.

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We began using fossil fuels with the start of the Industrial Revolution in 1860s. First, we used coal, and then we started using oil, and later natural gas. Petroleum companies expect that most of the fluid fossil fuels (*i.e.*, petroleum and natural gas) will have been used by 2060s. Coal, tar sands and shale oil might last another 100 years if a solution to CO<sub>2</sub> emission problem could be found. However, renewable energy sources will last as long as we have the sun - another five billion years!

Although the new primary energy sources would last much longer than fossil fuels and although they are much cleaner, these sources were not practical for use. They were not storable or transportable by themselves, except nuclear. They could not be used as a fuel for transportation by themselves, except nuclear for marine transportation. In order to solve the problem, it became clear that we had to manufacture a synthetic fuel using the new primary energy sources. As a result of my ten years of research and investigation (*i.e.*, from 1962 to 1972), I already knew that the best synthetic fuel is hydrogen. It is the lightest, the most efficient, the cleanest, and the best fuel for transportation. I decided to call the resulting energy system "Hydrogen Energy System" or "Hydrogen Economy", since energy is the locomotive of economy. I was quite sure this is the best solution to the depletion of fossil fuels and the global environmental problems they are causing, such as global warming, climate change, ozone layer depletion, acid rains, air pollution, oil spills, etc. I was convinced it is inevitable that sooner or later the Hydrogen Energy System would replace the present fossil fuel system.

In order to inform the scientific community about the proposed solution and get their reaction and input, I decided to organize an International Conference, to be named The Hydrogen Economy Miami Energy (THEME) Conference. I went to Washington, D.C., and explained my idea to the National Science Foundation. They donated the Clean Energy Research Institute \$70,000 to organize the Conference. We sent letters and brochures to all the scientists around the world, who were interested and/or would be interested to solve the energy and environmental problems facing the mankind. We worked overtime to organize the Conference in the shortest possible time, in about eight months.

The landmark THEME Conference was opened at the Playboy Plaza Hotel in Miami Beach on 18 March 1974, with the participation of more than 700 scientists from some eighty countries. At my opening address, I described and proposed the Hydrogen Energy System as the permanent solution to the depletion of fossil fuels and the global environmental

problems being caused by their utilization. After my opening address, we had a refreshment break. Some ten scientists from around the world came up to me. They said: "Dr. Veziroglu, we agree with you, the Hydrogen Energy System is the best possible system to replace the fossil fuels". That evening eleven of us met at the Penthouse of the Hotel, which was my residence as the Chairman of the Conference.

The eleven scientists, who were later recognized as "Hydrogen Romantics", represented almost all regions of the World. They were **Hussein K. Abdel-AI** of Egypt and Saudi Arabia, **John O'M Bockris** of the United Kingdom and Australia, **William J. D. Escher** of U.S.A., **Cesare Marchetti** of Italy and Austria, **Anibal R. Martinez** of Venezuela, **Tokio Ohta** of Japan, **Walter Seifritz** of Switzerland, **William D. Van Vorst** of U.S.A., **T. Nejat Veziroğlu** of Turkey and U.S.A., **Kurt H. Weil** of Germany and U.S.A., and **Robert M. Zweig** of U.S.A. At the Penthouse meeting, there was a passionate, yet deliberate, debate. It was agreed that the Hydrogen Energy System is an idea, of which time had arrived. It was the permanent solution to the depletion of conventional fuels. It was the permanent solution to the global environmental problems. Then, the discussion turned to whether there is a need for a formal organization. It was Anibal Martinez of Venezuela (incidentally the one who took part in establishing the petroleum cartel OPEC), who urged the founding of a Society dedicated to the crusade for the establishment of what seemed to be the gathering, and which later proved to be, the inevitable and universal energy system, the Hydrogen Energy System. It was ironic that he was proposing the establishment of an organization, which would make petroleum obsolete. As a result of the Penthouse meeting, the International Association for Hydrogen Energy (IAHE) was established by the end of the year 1974. I was elected the President of IAHE, William J. D. Escher was elected the Secretary, and most of the Hydrogen Romantics served in the Board of Directors.

IAHE started working enthusiastically. In 1975, we published two newsletters. I negotiated with Pergamon Press to start a scientific journal on hydrogen energy, and CEO of Pergamon Press, Bob Maxwell, agreed to be the publisher. The first issue of the International Journal of Hydrogen Energy (IJHE) - of which I became the Editor-in-Chief - was published in January 1976. For the first three years, IJHE was quarterly. Three years later, in 1979 it became bi-monthly, and three years later, in 1982, it became monthly. Last year IJHE published 18 issues. Starting in January 2008, IJHE became fortnightly, in keeping up with the growing importance of Hydrogen Economy.

In order to provide a platform for Hydrogen Energy scientists from around the world, we decided to organize the biennial World Hydrogen Energy Conferences (WHECs). The first one was held in Miami Beach in 1976. Thereafter the WHEC Conferences were held in Zurich, Tokyo, Pasadena, Toronto, Vienna, Moscow, Honolulu, Paris, Cocoa Beach, Stuttgart, Buenos Aires, Beijing, Montreal, Yokohama and Lyon, every other even year. The forthcoming WHEC Conferences will be held in Brisbane, Australia, in 2008, Essen, Germany, in 2010, and Calgary, Canada, in 2012.

Of course, no technology can take roots without standards, and no universal technology can be established without international standards. Gustav Grob of Switzerland approached the International Standards Organization (ISO) based in Geneva, Switzerland, requesting ISO to consider preparing International Standards for Hydrogen Energy Technologies. A meeting of interested ISO Members was organized in 1990, which I attended as the Head of the U.S. Delegation. As a result of this meeting, ISO/TC-197 Committee was established to prepare the standards. For several years, Switzerland hosted the Secretariat of this committee. Some six years ago, the Secretariat was moved to Canada. The Committee has already prepared nine International Standards for Hydrogen Energy Technologies, and is working on several others.

Because of the growing interest in Hydrogen Energy, IAHE Board of Directors decided that we should have technology-oriented meetings during the odd years. The first World Hydrogen Technologies Convention (WHTC) was held in Singapore, June 2005. The second WHTC was held in Monte Catini, Italy, in November 2007. They will be followed by WHTC 2009 in Delhi, India, and WHTC 2011 in Glasgow, United Kingdom.

It was clear that the Hydrogen Energy System is inevitable. Through the research carried out around the world, through WHEC Conferences and through the papers published in *IJHE*, the foundations of the Hydrogen Energy System were being established. It was time to start implementation. I decided that a United Nations Centre would be the best organization to implement the establishment of the Hydrogen Energy System throughout the world. In 1988, I proposed such Center to the United Nations Industrial Development Organization (UNIDO), for which I was the consultant on the Hydrogen Energy System.

The UNIDO Officials liked the idea. Now, it had to be approved by the UNIDO General Assembly. I, together with UNIDO representatives, visited many countries (including USA, Japan, China, India and EU) in order to explain the Center proposal and get their

agreement, which we did. The countries which we did not visit, including Russia, Ukraine, Brazil and Argentina, were invited to a meeting in Istanbul, organized by Engin Ture (who later became my deputy in the Center) on behalf of the Turkish Scientific and Technological Research Organization. At the end of this meeting, the participating countries also agreed to the Center proposal. In 1996, UNIDO General Assembly unanimously approved the establishment of the Center in Istanbul, Turkey, because of its central location between the developing countries and the industrial countries. After that, the negotiations started between UNIDO and the Turkish government for the final agreements. Yılmaz, Ecevit and Erdogan Governments, as well as the National Security Council, approved them. In October 2003, the Minister of Energy and Natural resources, Hilmi Guler, who strongly believes in the importance of Hydrogen Energy for Turkey and the World, signed the agreements with UNIDO in Vienna.

In April 2004, I took three-years leave of absence from the University of Miami, and was appointed the Founding Director of the Center, and started working vigorously in temporary facilities. In the ensuing three years, a truly International Center, UNIDO International Centre for Hydrogen Energy Technologies (UNIDO-ICHET), has been established, consisting of scientists and staff from many countries of the world, including Turkey, USA, UK, France, Croatia, Greece, Bulgaria, Kirgizstan, India, Pakistan and Egypt. The Center has been working to establish Hydrogen Energy Pilot Projects around the world. It also organizes international conferences, training courses and workshops. As my leave of absence from the University of Miami ended on 1 May, 2007, I left the Associate Director, Professor Engin Ture, in charge of the Centre. He is doing admirably well to fulfill the Center's mission to help convert the world to Hydrogen Economy.

It was not always smooth going. There were obstacles on the way - some of them formidable. When eleven of us established the IAHE, the petroleum interests became worried. They labeled eleven of us "Hydrogen Romantics". They said that we were dreaming and it could never happen. After the 1973 energy crisis, a bill was being discussed in the U.S. Congress to support electric cars, alcohol cars and hydrogen cars. Petroleum lobby made sure that "hydrogen cars" were taken off the bill. Then, petroleum companies established a Consortium to fight Hydrogen Energy. The purpose of the Consortium was to prove that fossil fuels is clean, and hydrogen is not feasible. They lavishly supported the research, which agreed with them. They claimed that the air pollution in the cities

is not caused by emissions from the cars, buses and trucks, but it is caused by volcanoes erupting far away; the smoke and dust the volcanoes produced would travel through the atmosphere and fall on the cities to cause the air pollution. They claimed that the global warming was not caused by CO<sub>2</sub> produced from burning of the fossil fuels but by regurgitating cows in meadows.

By the 1990s, most of the industry was considering hydrogen as the fuel of the future, and they started building prototypes to use hydrogen. There were prototypes of hydrogen cars, hydrogen buses, hydrogen air conditioning systems and hydrogen appliances. Aircraft companies were working on hydrogen-fueled airliners. However, there was one industry which was missing from the effort, and which seemed aloof to hydrogen. It was the petroleum industry.

From time to time, I would think about the absence of interest in Hydrogen Energy amongst the petroleum companies. During an Organizing Committee Meeting for the 12 WHEC Conference, the Conference Chairman, Dr. Juan Carlos Bolcich, and I looked into this problem and planned a strategy! As a result, I sent letters to the presidents of major oil companies, saying that in June 1998 we were going to have the 12 World Hydrogen Energy Conference in Buenos Aires, Argentina. At the Conference, we would have a session devoted to petroleum and we would like them to come to this session or send their representatives to tell us what they would sell when the petroleum deposits were depleted! None of the oil company presidents answered. I later heard that one of the presidents asked his advisors, if it was true that the oil deposits would be depleted. Although none of the oil companies answered, Shell Oil Company sent a handful of their engineers to the Conference in Buenos Aires. Two months after the Conference, in August 1988, Shell Oil Company left the Anti-Hydrogen Consortium of oil companies and, as the fourth Division in the Company, they established the Hydrogen Division, in addition to the Divisions on petroleum production, petroleum transportation and refineries. August 1998 was the date when the petroleum Companies saw the "light", and started jumping on the Hydrogen caravan. Shell Oil Company was followed by the British petroleum, after that the anti-hydrogen Consortium was dissolved, and all the petroleum Companies - large and small - joined the Hydrogen caravan.

Of course, economy is important. Cost of the fuel to energize the economy must be as low as possible. Amongst others, cost depends on the utilization efficiency of the fuel and the environmental damage the fuel causes. Our investigations at the Clean Energy

Research Institute have shown that hydrogen is the most efficient fuel. When one considers all the energy applications in the world at the consumer end to produce thermal energy, mechanical energy and electrical energy, hydrogen is 26 % more efficient than fossil fuels. The environmental and health damages that fossil fuels are causing worldwide through global warming, climate change, acid rains, ozone layer depletion, air pollution and oils spills add up to some six trillion US Dollars a year, and is constantly growing. When one takes into account the higher efficiency of hydrogen, and the environmental and health damages caused by fossil fuels, hydrogen is the most cost effective fuel.

I was invited to the United States Congressional Committee in Washington D.C., to testify about the Hydrogen Energy System as the permanent answer to the depletion of fossil fuels and the environmental damage they are causing. At the end of my testimony, the Chairman of the Committee, Congressman Brown of California, said to me: "Dr. Veziroglu, in the United States we have a free economic system. If hydrogen is such a good energy carrier, let it compete in the marketplace and win". My answer to the Congressman was: "Mr. Brown, the United States may have a free economic system, but it does not have a fair economic system. If you pass a law making all the goods responsible for their environmental and health damages, nobody will sell petroleum but hydrogen". In short, petroleum, natural gas and coal are relatively cheap, because they do not pay for their huge environmental and health damages. They are paid - directly and/or indirectly through taxes and insurance premiums, etc. - by the people.

As a result of the research and development activities around the world, World Hydrogen Energy Conferences, and the publication and dissemination of the research and development results through the International Journal of Hydrogen Energy, foundations of the Hydrogen Energy System were established during the quarter century from 1974 to 2000. Starting with the twenty-first century, the implementation of the Hydrogen Energy System began. Some hydrogen fuel cells became commercially available. All major car companies came up with various models of experimental hydrogen-fuelled cars. In several major cities of the world, hydrogen-fuelled buses started being operated on a trial basis. Airbus and Boeing Companies started programs for building hydrogen fuelled subsonic, supersonic and hypersonic passenger planes. Home appliances running on hydrogen have been built and tested. Hydrogen electric batteries have been commercialized.

At the Clean Energy Research Institute, we carried out a model study in order to determine, when the conversion to hydrogen economy could be completed under the existing laws, regulations and rules. For this business as usual case, our model study indicated that the conversion to Hydrogen Economy would take another three quarters of a century, *i.e.*, it would be completed by 2074.

Let us now have a look the planet Earth from a distance towards the end of the twenty-first century, after the Hydrogen Energy System has replaced the present fossil fuel system. There will be no pollutants, no chemicals to damage the ozone layer, no acid rains, no oil spills. Earth's temperature will return to pre-industrial levels. Global warming will end. Earth's climate will return to normal. It will be the most hospitable planet for flora, fauna and humans. Each country will be using the renewable energy sources available for manufacturing the fuel "hydrogen" it needs for its economy. As a result, the development of countries will be hastened, the population increase will le-

vel off and cease, they will achieve higher quality of life, and illegal immigration from developing countries to industrial countries will end. Petroleum wars will be history. The planet Earth will become a paradise. As Viktor Golstov of Ukraine foresaw it early in 2000, the ultimate has now been reached for the planet Earth and for its inhabitants, *i.e.*, **Hydrogen Civilization!**

*P.S.* I would also like to mention that the foundations for the Hydrogen Energy System were established and the conversion started due to the efforts of thousands and thousands of hydrogen energy scientists and engineers from many countries of the world. Those who have distinguished themselves have been honored with the coveted IAHE awards. I am very happy to mention that amongst them, there is a distinguished son of Serbia. Because of his important contributions to the science of electrocatalysts and their applications to fuel cells and electrolyzers, Prof. Milan M. Jaksic of the Belgrade University was bestowed with the IAHE Sir William Grove Award in 2006.



#### DR T. NEJAT VEZIROĞLU

Dr. Veziroğlu, a native of Turkey, graduated from the City and Guilds College, the Imperial College of Science and Technology, University of London, with degrees in Mechanical Engineering (A.C.G.I., B.Sc.), Advanced Studies in Engineering (D.I.C.) and Heat Transfer (Ph.D.). In 1962 - after serving in some Turkish government agencies and heading a private company - Dr. Veziroğlu joined the University of Miami Engineering Faculty. In 1965, he became the Director of Graduate Studies and initiated the first Ph.D. Program in the School of Engineering and Architecture. He served as Chairman of the Department of Mechanical Engineering 1971 through 1975, and was the Associate Dean for Research 1975 through 1979. He took a three years Leave of Absence (2004 through 2007) and founded UNIDO-ICHET (United Nations Industrial Development Organization - International Centre for Hydrogen Energy Technologies) in Istanbul, Turkey. At present, he is the Director of the Clean Energy Research Institute at the University of Miami. Dr. Veziroğlu organized the first major conference on Hydrogen Energy: The Hydrogen Economy Miami Energy (THEME) Conference, Miami Beach, 18-20 March 1974. At the opening of this conference, Dr. Veziroğlu proposed the Hydrogen Energy System as a permanent solution for the depletion of the fossil fuels and the environmental problems caused by their utilization. Soon after, the International Association for Hydrogen Energy (IAHE) was established, and Dr. Veziroğlu was elected president. As President of IAHE, in 1976 he initiated the biennial World Hydrogen Energy Conferences (WHECs), and in 2005 the biennial World Hydrogen Technologies Conventions (WHTCs). In 1976, Dr. Veziroğlu started publication of the International Journal of Hydrogen Energy (IJHE) as its Editor-in-Chief, in order to publish and disseminate Hydrogen Energy related research and development results from around the world. IJHE has continuously grew; this year it will publish twenty-four issues. He has published some 350 papers and scientific reports, edited 160 volumes of books and proceedings, and has co-authored the book "Solar Hydrogen Energy: The Power to Save the Earth". Dr. Veziroğlu has memberships in eighteen scientific organizations, has been elected to the Grade of Fellow in the British Institution of Mechanical Engineers, American Society of Mechanical Engineers and the American Association for the Advancement of Science, and is the Founding President of the International Association for Hydrogen Energy. Dr. Veziroğlu has been the recipient of several international awards. He was presented the Turkish Presidential Science Award in 1974, made an Honorary Professor in Xian Jiaotong University of China in 1981, awarded the I. V. Kurchatov Medal by the Kurchatov Institute of Atomic Energy of U.S.S.R. in 1982, the Energy for Mankind Award by the Global Energy Society in 1986, and elected to the Argentinean Academy of Sciences in 1988. In 2000, he was nominated for Nobel Prize in Economics, for conceiving the Hydrogen Economy and striving towards the establishment.