H–Y2K

At the bigining of new Millennia, which is the 54rd anniversary of issuing the Chemical Industry Journal (in serbian "Hemijska industrija") we would like to thanks once again to all of our sponsors and financiers who has helped us in the recent and far past, not only financially, very often also and more with other useful information and support.

It can be now anounced that Yugoslav Association of Chemical Engineers is starting with publishing the "special issue of Chemical Industry Series" in the form of collected papers which cover special topics and problems extensively analyzed and published in several issues of Chemical Industry Journal. The main purpose of such, so called "special issue" is to give at one place the extensive informations on specific topic in the form of specially oriented and prepared review articles, opinions and futuristic views or in the form of original scientific results.

Preparation of this special issue of Chemical Industry Journal was started in 1998. We wish to express our deep gratitudes to the leading world authorities and distinguished authors who responded to our kind invitation to contribute to assemble such a complete illustrative matter in the field of Solar–hydrogen options, the present status and their further possibilities in the overall world and our domestic search for sustainable, reversible, clean, inexhaustible and renewable energy. However more contributions of specific results regarding hydrogen application were received and accepted after we were prepared No 12 in 1999, so the second issue of Chemical Industry covering hydrogen energy was published as No 3 in 2000. All the papers published in mentioned issues are content of this first special issue of Chemical Industry Jl. which is prepared as published materials for participants of the 13th World Hydrogen Energy Conference (WHEC–2000), Beijing, China, June 11–15, 2000. It has certainly a broader intention to introduce readers in contemporary problems and solutions in the Solar–hydrogen options.

Although we know now that the problem of computer bug (Y2K) was succesfuly solved, we are sure that H–Y2K, as symbol for hydrogen (H) energy in the future, shown on the front page of this special issue, will be the main interest of many researcher and scientific institutions in the World in finding right application and solution of hydrogen energy in the forthcoming years of this Millennium.

Taking into account all the positive implementation of the future role of hydrogen as a fuel and hydrogen as reactant and product in many different chemical processes, we have established Yugoslav Association for Hydrogen Energy in April 2000 and decided to continue with publication of papers regarding these and other hydrogen related topics and to publish them every years in one issue of Chemical Industry. Now, we are tooking a chance for calling all the authors and participants of WHEC–2000 to send their papers for publishing in Chemical Industry Journal – H–Y2K.

SOLAR–HYDROGEN ENERGY AND ECONOMY
HYDROGEN AS AN ENERGY CARRIER AND ENERGY VECTOR

There is a belief that God in the creation of the Universe first made hydrogen, and from it water, to start life upon the planet Earth. Another scientific statement is that Sunshine upon the Earth comes as radiation based on the nuclear reactions primarily of protium with continuous deuterium production. Hydrogen is an ideal fuel: the smallest atom and molecule producing more energy than any other chemical source. As a fuel, hydrogen is the cleanest, sustainable, renewable and reversible energy carrier able to promote worldwide economic development and hence to establish international harmony, since at least progressively less unproductive work would be required to undo environmental damages and maintain a clean living atmosphere. Hydrogen is the only energy source human kind knows capable and able of establishing a sustainable and reversible relationship between matter and energy on Earth: to return exactly what has been taken from nature – water to water! Hydrogen is the carrier and fuel in both directions. Even more so, to bring all countries and all nations in an equal position concerning energy resources and its in situ consumption – fuel independence for all people. As an energy carrier hydrogen is already in: space shuttles virtually represent hydrogen powered vehicles able to overcome gravitation and fly within interplanetary air free space, while supersonic jets could approach their maximal speeds only on hydrogen power. There are already many city buses running on hydrogen power in some metropolitan areas, where pollution by fossil fuels has approached critical concentrations. The International Association for Hydrogen Energy has already proclaimed the Transition to Hydrogen and has taken the year 2000 for massive hydrogen bus introduction in big cities all over the world, to start clean, sustainable and renewable energy in broader practice.

Contrary to hydrogen, fossil fuels are finite in amount and detrimental in their use, and within an already visible time period will be depleted, with a downturn in production expected to start early in the next century.

Existing civilization is already confronted with an enormous, irrational and exhaustible consumption of fossil fuels with all the negative consequences resulting therefrom within the visible future (Fig. 1). It is an alarming and seriously warning fact that the world growth of population, fossil fuels consumption, consequently, carbon dioxide accumulation in the upper layers of the atmosphere ("Green House Effect") causing growing damage to our Biosphere (the only known domain of the Universe to be supportive of life), follow the same shape of curves (Fig. 2). The apparent prospects consist of more environmental damages and further world climate changes. Thus, it is already prudent and even delayed to plan and begin conversion to the next alternative energy systems by making use of the remaining fossil fuel sources to achieve a smooth changeover, which is expected to take about half–a–century. Human kind is already aware that combustion products and their harmful effects do not stop at national boundaries and spread all over the Biosphere. Where is the solution?! In the solar–hydrogen combination. Hydrogen being an energy carrier and energy vector!

The problem is that while four fifths of the Earths surface consists of water, hydrogen does not exist in larger amounts in its elementary form. Thus, human kind must be aware that there is only one source of hydrogen upon the Earth – water and, consequently, search for its economically optimal production. Namely, one has to put and spend more energy to produce hydrogen from water by electrolysis, than we get back from its consumption, even in fuel cells with reversible electrocatalytic electrodes. All human kind really has inexhaustible on the Earth is the Suns shining energy and human creativity and inventive mind. Consequently, this is where we should search for the solution of problems associated with clean, sustainable and renewable energy. This primarily means, in conjunction between photovoltaic energy sources and water electrolysis, producing large amounts of hydrogen as a fuel. Relatively small areas of enormous and otherwise useless Equatorial deserts with continuous sunshine of twelve hours per day are ideal and able to solve definitely and permanently the whole worlds energy problems on a photovoltaic–hydrogen production basis. Solar–hydrogen interrelation! Prospects of such a perfect vision are illustrated by the well–known C.–J. Winter graphical prediction for the world energy future (Fig. 3). In its search for larger energy quantities, the world might now move from the Middle East to Africa! A pipeline between Tunisia and Italy already exists, while the problem of transport of liquid hydrogen in corresponding ship containers was technically solved long ago.

There is a need for two types of energy carriers: electricity, which meets about one–quarter of the demands at the customer end, and fuel, preferably hydrogen as a carrier, which meets about three–quarters of the demands.

All technical problems associated with hydrogen production and consumption in powered vehicles (motors with internal combustion and/or vehicles powered by mobile fuel cells) have already been solved, while certainly so far no new invention has been ideal to advance it further. In other words, photovoltaic cells can already produce large amounts of hydrogen, but still below comparable levels of other energy sources. Enzymatic catalysis is still far from a satisfactory solution, but very promising. Selective ion exchange membranes belong to the few most outstanding breakthroughs of the twentieth century, but the best of them based on perfluoropolymers are still extremely expensive for broader application in fuel cells, though they quite satisfy the technical requirements. There already exist satisfactory electrocatalysts for both hydrogen evolution and its (H_2/CO) oxidation in fuel cells, and science is just within the period of intensive and advanced production of extra–active nano–size electrocatalysts for hydrogen electrode reactions. Electrocatalysis for oxygen evolution and cathodic reduction have much more spare voltage room, especially at higher current densities for further advances and this is the most urgent and most stimulating electrocatalytic research area in contemporary electrochemical and material science. Unfortunately, so far electrochemists have been looking forward in the search for a synergetic solution on an intermetallic basis, though the solution lies in a reversible oxide layer, since oxygen never evolves from clean metal, but virtually always from oxide surfaces. Thus, one could conclude that existing science already has all the technical solutions available and ready, while almost all of them require and afford further possibilities and room for stimulating and continuous advances and improvements.

Milan M. Jakšić
Guest Editor

Figure 1. Shares of primary energy consumption of the world (after C.-J. Winter)

Figure 2. CO_2 in the Atmosphere (after C.-J. Winter)

Figure 3. The Development Phases of Solar and Hydrogen Technology in Future Decades

There are no more doubts: Hydrogen is an available and ideal energy source of the forthcoming world future: the smallest atom and molecule producing more energy than any other comparable chemical source. As a fuel, hydrogen is the cleanest, sustainable, renewable and reversible energy carrier able to promote world–wide economic development and, hence, to establish international harmony, since at least progressively less unproductive work would be required to undo environmental damages and maintain a clean living atmosphere. Contrary to hydrogen, fossil fuels are finite in amount and detrimental in their use, and will be depleted within an already visible time period, with downturn in production expected to start early in the next century. Besides one of the irrecoverable consequences of their consumption is the so–called "green house effect", and already registered climate changes all over the world. Hydrogen is an unique energy source known to mankind capable and able to establish a sustainable and reversible relationship between matter and energy on Earth: to keep and preserve the harmony of nature and return exactly what has been taken from its sources – water to water over the hydrogen energy cycle! Hydrogen, as an eternal fuel deprived of depletion in its water sources, has the privilege of being a sustainable energy carrier and fuel in both directions. Since energy and fuel are the main problems and subject of life and civilisation development, and even of human existence upon Earth, hydrogen has the unique opportunity and privilege to bring all countries and all nations in an equal position concerning energy resources and its *in situ* consumption – fuel independence for all people. The modern age has already been named the age of hydrogen and we live in times the features of which are based on the transition to hydrogen as a clean and sustainable fuel. These are the main reasons why two issues of the Journal "Chemical Industry" have been devoted to hydrogen as a fuel and accompanying problems associated with its production, properties and uses, as well as existing energy problems able to be resolved by such a sort of basic fuel, as well as inspiring facts that leading world authorities provided in their contributions with substantial treatment of governing problems arising and following therefrom.

There are two other significant alternative energy sources, which could be efficiently and usefully combined with hydrogen energy in our homeland. The geographic position, configuration and constitution of Yugoslavia, together with its specific climate, provide almost unpredictable possibilities of the combination of wind and hydrogen energy as well as solar energy and hydrogen production. This is the reason that within the Association of Chemical Engineers of Yugoslavia, we shall soon establish the **"Yugoslav Committee for Hydrogen Energy"**, thus becoming a member of the family of hydrogen associations all over the world, to use the benefits of that exchange of experience and facilities, and to unite domestic forces already working on hydrogen energy and hydrogen economy problems. We should be aware that the world will soon be organised in a hydrogen network, as the Internet or electrical power systems are already. The year 2000 has already been named the year of transition to hydrogen fuelled city buses. HIP–Pančevo and "Tehnogas" are already able to supply many lines of such buses in the city of Belgrade and show the benefits of reduced air pollution, silent drive and high energy efficiency. All humankind really has inexhaustible on the Earth is the Suns shining energy and human creativity and inventivity. Consequently, right there we should search for the solution of problems associated with clean, sustainable and renewable hydrogen energy, both in our homeland and all over the world.

In such respect, the present and former issues of the **"Chemical Industry"** Journal have the aim to review the introspects and prospects of the solar–hydrogen energy option, the present status and further possibilities in the world and our domestic search for sustainable, reversible, clean, inexhaustible and renewable energy, as well as possible overall energy harmony on the Earth that should be resulting therefrom. No detrimental and exhaustible fossil fuels, no nuclear energy sources, but instead, just the Solar–Hydrogen energy system based upon the reversible and renewable energy exchange between water and elemental hydrogen as its carrier. In the same context, we wish to express our deep gratitude to the leading world authorities and distinguished authors who responded to our kind invitation to contribute to assemble such a complete illustrative matter in the field of solar–hydrogen options. The whole issue is primarily prepared for participants of the 13th World Hydrogen Energy Conference (WHEC–2000), Beijing, China, June 11–15, 2000 and HYFORUM–2000, Munich, Germany, September 11–15, 2000, and certainly with the broader intention to introduce readers to contemporary problems and solutions in solar–hydrogen options.

Milan M. Jakšić
The Guest–Editor