Hydrogen civilisation concept: historical and all-planetary aspects

Victor A. Goltsov*

International Association for Hydrogen Energy, P.O. Box 248266, Coral Gables, FL 33124-0622, USA

and

Donetsk National Technical University, 58, Artyom Street, 83000 Donetsk, Ukraine
E-mail: goltsov@physics.dgtu.donetsk.ua
*Corresponding author

T. Nejat Veziroğlu

International Association for Hydrogen Energy, P.O. Box 248266, Coral Gables, FL 33124-0622, USA

and

UNIDO-ICHET, Sabri Ulker Sk. 38/4, Cevizlibag, Zeytinburnu, 34015 Istanbul, Turkey
E-mail: veziroglu@unido-ichet.org

Lyudmila F. Goltsova

International Association for Hydrogen Energy, P.O. Box 248266, Coral Gables, FL 33124-0622, USA

and

Donetsk National Technical University, 58, Artyom Street, 83000 Donetsk, Ukraine
E-mail: goltsova@fem.dgtu.donetsk.ua

Abstract: This paper discusses the novel Hydrogen Civilisation (HyCi) concept of the International Association for Hydrogen Energy. The HyCi concept states that at this demanding period in history, humanity still has the ability to save the biosphere and make the continuation of the human race possible. This objective can be achieved only by way of all-planetary cooperation along the direction of the ecologically clean vector 'hydrogen energy → hydrogen economy → hydrogen civilisation'. The HyCi concept includes three constituent, mutually conditional parts: industrial–ecological, humanitarian–cultural and geopolitical–internationally legislative. The legislative–economical mechanism of the transition to HyCi is formulated, and the most important stages are indicated and discussed. Special attention is paid to the future noospheric role of the world scientific–cultural community, to the fundamental importance of purposeful forming 'hydrogen–ecological'

mass consciousness, to the role and responsibility of international and regional legal and political organisations, national parliaments and governments.

Keywords: hydrogen civilisation; hydrogen economy; hydrogen energy; historical aspect.

Reference to this paper should be made as follows: Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2006) 'Hydrogen civilisation concept: historical and all-planetary aspects', *Int. J. Nuclear Hydrogen Production and Applications*, Vol. 1, No. 2, pp.112–133.

Biographical notes: Victor A. Goltsov is a member of the Board of Directors of the International Association for Hydrogen Energy (IAHE), a member of the Honorary Editorial Board of the *International Journal of Hydrogen Energy (IJHE)*, Chairman of the Physics Department and Head of the Donetsk State Hydrogen Laboratory of the Donetsk National Technical University. Over a period of several decades he has been elaborating hydrogen-materials problems and general questions of hydrogen energy (http://donntu.edu.ua/hydrogen). As a Chairman of the triennial IAHE special international conference 'Hydrogen Economy and Hydrogen Treatment of Materials' he represents IAHE and *IJHE* long-term goals and activities in Eastern Europe and North Asia (countries of Community of Independent States).

Turhan Nejat Veziroğlu is a founder and President of the International Association for Hydrogen Energy, Director of UNIDO International Center for Hydrogen Energy Technologies (http://www.unido-ichet.org), Editor-in-Chief of the *International Journal of Hydrogen Energy*, a founder and Honorary Chairman of the biennial IAHE World Hydrogen Conferences, and a key leader in the world hydrogen movement. Being a world-renowned scientist in the field of hydrogen energy and environmental problems, he has been an invited lecturer and/or consultant on energy research and education to many universities and research organisations all over the world.

Lyudmila F. Goltsova is a Leading Scientist of the Donetsk State Hydrogen Laboratory of the Donetsk National Technical University, a member of International Association for Hydrogen Energy, and Associate Editor of an informative-scientific, analytical and scientific–technical journal *Bulletin of Hydrogen Economy and Ecology*. She is a specialist in the field of informetric analysis of the world progression of hydrogen energy and the hydrogen economy, and of the development of the world hydrogen movement. She was the first scientific analyst to work out and publish (in *IJHE*, 1990) the informational structure of hydrogen energy as a novel large-scale scientific problem.

1 Introduction

The development of human civilisation and historical alternating epochs are usually classified by a leading method (material) of manufacture, determining the achieved level of the development of a society and of the technical culture of humanity (Copper Age, Iron Age, etc.). During the last centuries, development of civilisation was generally determined (and is determined) by the energy carrier used. A change of energy carrier

is always problematic and takes a long time. The transition from firewood to coal lasted about two centuries. From the middle of the 20th century natural gas occupied the power niche and continues to gain favour in industry nowadays.

In the 20th century, the economics founded on fossil fuels (first of all on oil and natural gas) was completely formatted. The technical advantages of these economics are widely known and irrefutable. Nevertheless, simultaneously with permanent achievements, the economics of oil and gas gradually and inevitably is leading to worldwide ecological catastrophe (greenhouse effect and climate deterioration, ozone holes, acid rain, etc.), and to global geopolitical shocks, because of limited oil stores and an inadequate perception of the state of the world in ecological terms.

In the first half of the 1970s, thanks to the enthusiasm of conscientious representatives of the world scientific community (Bockris, 1971, 1972, 1975; Gregory, 1973; Marchetti, 1974; Ohta, 1974; Veziroğlu, 1975a,b,c; Veziroğlu and Basar, 1974), the fantastic idea of the great French writer Jules Verne was revived. This idea was firstly written in Verne's *A Mysterious Island* in 1875. It consists of the opportunity for future humanity to heat itself with water, dissociating it into hydrogen and oxygen and then burning hydrogen. Indeed, as is well known, hydrogen burning does not pollute the atmosphere. One can find reviews of this era in Bockris (2001, 2002) and Veziroğlu (2000a,b).

In 1974, the International Association for Hydrogen Energy (IAHE) was established (Veziroğlu, 2000a,b) with its headquarters in the Clean Energy Research Institute of Miami University (USA). IAHE began publishing the *International Journal of Hydrogen Energy* (*IJHE*), and started organising the biennial World Hydrogen Energy Conferences (WHEC) to provide a platform for forming the Hydrogen Energy community (Veziroğlu, 1976; Hydrogen, 2004).

During the same time in the USSR, owing to the activity of Valery Alexeevich Legasov (Legasov, 1976), Anatoly Nickolaevich Podgorny (Podgorny et al., 1977) and their scientific adherents (see Legasov, 1977), hydrogen energy started to be intensively researched. A wider energy-technological version of the hydrogen energy concept, namely 'Nuclear Hydrogen Energy and Technology' was steadily worked out by the Institute of Atomic Energy, named by I.V. Kurchatov, and some other scientific and technological organisations (V.A. Legasov – key leader). The application of hydrogen as a fuel for car engines and using hydrides for its storage were worked on by the Institute of Mechanical and Engineering Problems (A.N. Podgorny – key leader). Hydrogen as a fuel in aviation and all other aspects of hydrogen energy also came to the attention of the hydrogen community of the USSR. In 1975, at the All-Union Scientific and Technological Seminar 'Gases and Metals' (Donetsk, Ukraine, 1975; Chairman V.A. Goltsov) hydrogen energy was thoroughly discussed, and for the first time, it was pointed out that: 'Hydrogen-Materials Problem and Materials Safety are an integral part of Hydrogen Energy concept'. From then on regular All-Union conferences and seminars (Moscow, Donetsk) and All-Union schools for young scientists were organised (Donetsk, Ionava, Tula, etc.), each of these attracting 250–500 participants (scientists, engineers, and industrial managers). Every year collections of analytical reviews and scientific–technological works (Legasov, 1978–1988), were published (every book consisted of 250–300 pages). As a result, there was an official acceptance of the concept and the USSR joined the IAHE.

Based on the decision of the USSR State Committee on Science and Technology – in 1977 the Donetsk State Hydrogen Laboratory was established at the Donetsk Polytechnic Institute (nowadays Donetsk National Technical University), for steadily developing the hydrogen-materials problem (Hydrogen in Metals, 1982; Goltsov, 1997, 1999, 2000, 2001a; Goltsova and Alimova, 1988) and for scientometric analysis of world hydrogen energy development ('Fundamentals of ecologically clean technologies', 1991; Goltsov, 2000; Goltsova et al., 1987, 1990). In accordance with the agreement between T.N. Veziroğlu and V.A. Legasov, the Donetsk State Hydrogen Laboratory and the Institute of Atomic Energy prepared *IJHE* annual reports about the 'hydrogen' works published in the Soviet Union (Alimova et al., 1983–1994). A partnership for ongoing scientometric investigation of the development of hydrogen energy (Fundamentals of Ecologically Clean Technologies, 1991; Goltsova et al., 1990) and the world hydrogen movement was established (Goltsova, 2000).

2 The last quarter of the 20th century: from hydrogen energy to hydrogen economy, origination of the IAHE hydrogen civilisation concept

The late 1970s and 1980s were years of very rapid progress in the development of hydrogen energy. It is impossible to mention all the important works of that period (see Legasov, 1978–1988), and we cite here only some references to research which made, in our opinion, a noticeable effect on the developing hydrogen movement (Awad and Veziroğlu, 1984; Bockris and Veziroğlu, 1983; Chen et al., 1982; Goltsov, 1978; Legasov, 1988; Legasov et al., 1978; Ohta, 1978; Shpilrain et al., 1984; Stolyarevsky and Chuvelev, 1988).

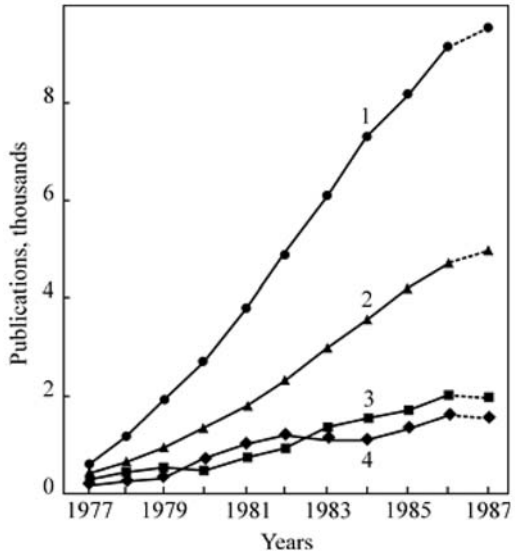
Scientometric studies of world hydrogen energy development between 1977–1988 have been reviewed in Goltsova et al. (1990). A file of 10,573 units was analysed. It was found that investigation of hydrogen energy had been carried out in 39 countries and information had been published in 21 languages. Therewith publications in English, Russian, Japanese, German and French amounted to ~98% of the total. The core group of journals included two international journals, namely *International Journal of Hydrogen Energy* and *Journal of the Less-Common Metals* (nowadays known as *Journal of Alloys and Compounds*), and the Soviet journal *Voprosy Atomnoi Nauki i Tekhniki. Ser. Atomno-Vodorodnaya Energetika i Tekhnologiya* that carried about 30% of the total publications on the problem.

World hydrogen energy development during 1977–1987 is presented in Figure 1. One can see a very rapid progress for this period represented by: the world total volume of publications (curve 1), the volume of periodicals (curve 2), patent documents (curve 3) and conference reports (curve 4). The growth of the world hydrogen community was reflected in 250 symposia on hydrogen energy and related problems held during these years (Goltsova et al., 1990).

In this work (Goltsova et al., 1990), an informetric analysis had been carried out and the scientific-information structure of hydrogen energy had been systematically studied and substantiated. It had 211 rubrics including nine rubrics of the first level, 40 rubrics of the second level, 66 rubrics of the third level, 85 rubrics of the fourth level, nine rubrics of the fifth level and two rubrics of the sixth level (see Appendix of Goltsova et al., 1990).

This classification served as the basis to draw the subject boundaries and was the basis for the information retrieval system on the scientific problems of hydrogen energy.

Figure 1 Database on hydrogen energy and technology (Goltsova et al., 1990): (1) the total number of publications; (2) periodicals; (3) patent documents; (4) conference reports



It is important to keep in mind that the term 'hydrogen energy' contains information about two aspects of the problem. On the one hand, a new rapidly advancing trend in science and engineering termed 'hydrogen energy' had been sculptured in the 1970–1980s as a large-scale unified scientific–technological problem having its own subject matter, structure, aim and tasks (Goltsova et al., 1990). On the other hand, 'hydrogen energy' had already been proposed as a new large-scale concept pointing to a new environmently friendly vector for industrial development (Legasov, 1988; Veziroğlu, 2000b).

In short the 'hydrogen energy'structure comprises:

- hydrogen production from water using non-renewable energy sources (coal, natural gas, oil, atomic energy and in the far future thermonuclear energy) and renewable energy sources (sun, wind, hydroelectric, biomass, and others)
- hydrogen delivery, transportation and storage
- hydrogen utilisation in industry, transport (land, water and air) and home
- problems of materials and safety.

The world hydrogen movement that was generated grew very quickly (see Bockris, 2001, 2002; Goltsova et al., 1990; Veziroğlu, 2000a,b and references in them) and that was how matters stood in the late 1980s.

Since the world economy runs on energy, the term 'hydrogen economy' (Bockris, 1971, 1972; Gregory, 1973) has received a wider usage in the last decade of the 20th

century. Then, as a result of the beginning of commercialisation of the hydrogen technique and technology, the concept of the hydrogen economy emerged (Bockris, 2001, 2002; Veziroğlu, 2000a,b).

By and large, the results of the hydrogen energy and hydrogen economy development within the last quarter of the 20th century are summed up in Bockris (2001, 2002) and Veziroğlu (2000a,b). The results are impressive. Some countries had adopted national programmes and/or initiated large hydrogen projects (e.g. Japan, Germany, USA and some others). Some companies had already begun to commercialise hydrogen technologies, hydrogen know-how and hydrogen energy systems, e.g. automobiles running on hydrogen fuel, fuel cells, improved electrolysers, hydrogen–nickel batteries, and so on. A stable hydrogen scientific community had been formed. They had begun to study the prospects of developing separate aspects of the hydrogen economy up to 2020, 2050, and even up to 2100 (Abdallah et al., 1999; Arnason and Sigusson, 2000; Contreras et al., 1999; Kruger, 2000; Lima and Veziroğlu, 2001). The research being carried out covered either a region and/or certain technical aspects of the hydrogen economy. For example, there were studies, which were pertinent to the USA, Brazil, Spain, Egypt, Iceland, etc. They were studying prognostic problems of the hydrogen energy system requirements for the future, the electrical energy required for hydrogen production, and other similar questions. From an engineer's viewpoint, such an approach is fully justified; it makes it possible to forecast and later on solve the important technical and economical problems of hydrogen economy.

At the end of the 20th century it became absolutely clear for the specialists, that an epoch-making replacement of the general energy carrier would take place in the 21st century. Fossil fuels will be step by step substituted by a new environmentally friendly energy carrier – hydrogen. Simultaneously the human way of life will necessarily be subjected to fundamental transformations: to industrial and spiritual ones. Thinking on the basis of Vernadsky's doctrine about this planetary process (Vernadsky, 1929, 1945, 1988, 1991) has originated a novel large-scale IAHE concept of a *Hydrogen Civilisation* of the future (Goltsov, 2001a,b) (furthermore, the HyCi concept). For the first time, the main aspects of a move by humanity into the era of an ecologically clean hydrogen civilisation were being considered. Some biospheric and noospheric consequences of this transition were analysed and the tasks of the world hydrogen movement discussed.

3 The first years of the 21st century: hydrogen economy progression and IAHE HyCi concept development

3.1 HyCi concept development

During previous years, the hydrogen economy has been gathering force in all possible directions: fuel cells, hydrogen cars and hydrogen refueling stations, Me–H-batteries, improved electrolysers, other hydrogen technologies and hydrogen energy systems. This has been demonstrated with a rapid growth of the amount of worldwide hydrogen refueling stations. In 2003 there were about 40 hydrogen refueling stations in the world, but 220 were operating by 2005. One can find full information on the internet, in the public press, in scientific journals, in proceedings of international

hydrogen conferences (see, for example, *Proceedings, Fourth International Conference 'Hydrogen Treatment of Materials. HTM-2004', 2004; Proceedings, International Hydrogen Energy Congress & Exhibition, 2005 and references therein; The Hydrogen Planet, 2002)*.

A very important point is that in many countries the hydrogen economy problem is being considered at governmental and inter-governmental levels. The Japanese government is planning to increase fuel cell production rapidly (Inui et al., 2004). To 2010, 2020 and 2030 there will be produced cars with fuel cells 50,000, 5,000,000 and 15,000,000, respectively. Stationary energy systems with fuel cells will have power 2200 MW, 10,000 MW and 12,500 MW, correspondingly.

The USA and Europe have their own ambitious plans for support of the hydrogen economy (Chalk, 2004; EHIP, 1999). In 2003 in Washington, 17 countries established an 'International Partnership for the Hydrogen Economy' to accelerate the transition to hydrogen economy. By creating the IPHE, the Partners have committed to accelerate the development of hydrogen and fuel cell technologies, to improve their energy security, environmental security and economic security.

Hydrogen economy advancement has provided the necessary practical background for the further development of a novel large-scale IAHE HyCi concept (Goltsov, 2001b) aimed at promoting a better understanding of the distant future of humanity.

Now let us note some milestones in the development of the HyCi concept. In 2001, the first worldwide international discussion on the HyCi concept was presented by V.A. Goltsov and T.N. Veziroğlu (2001a) during the Third International Conference 'HTM-2001' (Donetsk, Ukraine, May 14–18, 2001). Scientists and industrialists from Russia, USA, UK, Ukraine, Japan, France, Poland and other countries discussed the HyCi concept and accepted the 'Memorandum on the Transition from Fossil System to Hydrogen Economy and then to Hydrogen Civilisation'. The Memorandum was published in a Special Issue of *IJHE*. It called:

> "all the members of the hydrogen energy and ecological movements, everybody who cares for the ecological well-being of the humankind, preservation of the Earth's biosphere and ecosystem, to consolidate the efforts and to contribute to the approaching of the era of hydrogen civilisation, the only ecologically clean and worthy civilisation of the future." (Memorandum, 2002)

The views of the HyCi concept on the future of humanity on a global scale were published in *IJHE* in 2001 (Goltsov and Veziroğlu, 2001b). Further development of the HyCi concept was realised in Goltsov and Goltsova (2003a,b); Goltsov and Veziroğlu (2002); Goltsov et al. (2002, 2004a,b,c, 2005a,b, 2006a,b); Ohta (2004, 2006).

On June 12, 2002 at the meeting of Board of Directors of IAHE held in Montreal (WHEC-14), the presentation of a novel IAHE HyCi concept to the world hydrogen movement at the 15th Hydrogen Energy Conference in Yokohama was recommended. This decision was fulfilled in the 30th anniversary year of the IAHE during the 15th World Conference on Hydrogen Energy (Yokohama, Japan, June 27–July 2, 2004) (Hydrogen, 2004). The concept was presented at the Plenary

Session (Goltsov et al., 2004b,c) to an audience of 2000 delegates from 52 countries. Following this, the concept was widely presented to the scientific community at other international meetings (Goltsov et al., 2005a,b, 2006a).

The HyCi concept consists of three interdependent and interrelated component parts: industrial–ecological, humanitarian–cultural and geopolitical–internationally legislative.

The *industrial–ecological* part of the HyCi concept encompasses progress towards the hydrogen economy progress and the historical scientific viewpoint on interrelated development of the world ecological situation and hydrogen industry on a global scale. Being based on Vernadsky's studies concerning the biosphere, the HyCi concept leans in its analysis upon synergetics, a modern science about the development of complex self-organising systems, of which the biosphere is an example.

The *humanitarian–cultural part* of the HyCi concept emerges from Vernadsky's studies about the noosphere and his cultural–philosophical heritage. In its development, this part of the HyCi concept is guided by the humanities: modern philosophy, culturology and others. In particular, the HyCi concept comprehends and exposes the question about correlation and interrelation between the theory of hydrogen civilisation transition and universe synergetic concept (Malyshev, 2003). The historical task of the HyCi concept in its humanitarian–cultural aspect consists of the formation of mass hydrogen–ecological and noospheric consciousness of some peoples, and then of all humanity. This mass consciousness will afford an opportunity to accept a new paradigm of life quality and will serve as a humanitarian–cultural basis for introducing into the life of humanity a legislative–economical mechanism of transition to the era of hydrogen civilisation.

The *geopolitical–internationally legislative* part of the HyCi concept states the correctness and inevitability of generating global and local geopolitical and geoeconomical contradictions in the world community during the period of transition to the hydrogen civilisation era. The HyCi concept requires the involvement of legislation for resolution in frames of legislative field elaborated by world and regional international organisations, first of all under the aegis of UN and its structural organisations (UNIDO, UNESCO, etc.).

4 The global aspect of the concept

4.1 Vernadsky's biosphere and noosphere doctrine – groundwork of the HyCi concept

On a planetary scale, the HyCi concept is based on Vernadsky's studies about the biosphere and the noosphere (Vernadsky, 1929, 1945, 1988, 1991). The biosphere, in accordance with Vernadsky's doctrine, is an '. . .organised, specific crust envelope of the Earth associated (mated) with life.' So, the biosphere is bounded first and foremost by the region where life exists, and living matter and humanity is the primary driving force of the evolution of the biosphere over geological and historical timescales. A very important point is that the biosphere is permanently in a state of energy and matter exchange with outer space, with the rest of the central part of the planet Earth and with its upper atmosphere.

The noosphere, according to Vernadsky (Vernadsky, 1945, 1988, 1991), is a special stage in biosphere development when a dominant driving force of its self-development is science, with human intellectual activity as a general planetary phenomenon.

Now let us look at the Earth as a heavenly body which exchanges energy and matter with outer space. Matter reaches Earth as meteorites, space dust, microparticles, elementary particles of solar and space wind, etc. The Earth derives energy first of all in the form of solar radiation, and, to a smaller extent, from other space objects in the form of electromagnetic radiation, microparticle energy, etc. Solar radiation is certainly the foremost factor in the existence and functioning of the biosphere, and in what follows, we shall consider just this energy source.

The entire solar energy the Earth derives can be divided roughly into certain parts. One part is the Earth's thermal radiation. Basically, this is long-wave electromagnetic radiation. It passes partially through the Earth's atmospheric shell and proceeds into outer space. Some of this Earth-based radiation is blocked, speaking figuratively, by the atmospheric shell as if by an atmospheric 'blanket'. The Earth–space energy exchange results in steady-state conditions, and our planet is warm (in comparison with space temperature) and supports the life forms on it. The other part of the solar radiation the Earth derives is converted by the biosphere (mostly, through the work of plant life) into storable forms of chemical energy.

According to the scientific knowledge of his time, and even ahead of it, Vernadsky has elaborated in detail all aspects of biosphere functioning during geological and historical periods of time. He had particularly identified and analysed in every detail the cycles of chemical elements – components of alive substances (living matter). Vernadsky had shown that these cycles, in modern terms, are self-sustainable stationary ones. Thermodynamically they are not closed and, for example, over the course of geological time, a part of the matter and energy leaves them, being stored in the crust and forming such deposits as coal, oil, etc.

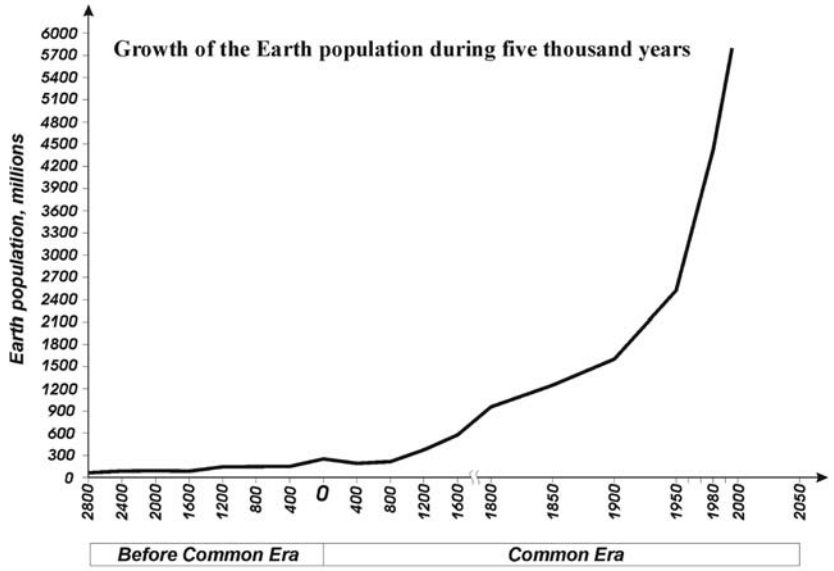
In the context of the HyCi concept, the carbon cycle is of particular interest. In this cycle, carbon dioxide, being a general cause for the greenhouse effect, plays a great role. It is emitted into the Earth's atmosphere through the industrial and vital activities of human life and through the vital activity of animal life, and is absorbed and processed by plant life (with the release of oxygen into the atmosphere). It is involved in the formation of minerals on land and in the aquatic environment.

Vernadsky perceived both the geological waste caused by human activity and the unpredictability of its consequences. He wrote (Vernadsky, 1991): 'We observe a more and more dramatic influence of a human intellection and collective mind on geochemical processes'; 'Of special interest and a characteristic fact in the history of carbon is the fact, that carbon dioxide quantity increases during the civilisation progress'; 'In this way a civilized person disrupts an established earth equilibrium'. He exclaimed: 'Where will this new geological process stop? And will it stop or not?'. Rather emotionally Vernadsky emphasised: 'Here human beings behave not like *Homo sapiens* but like *Homo sapiens faber*.'

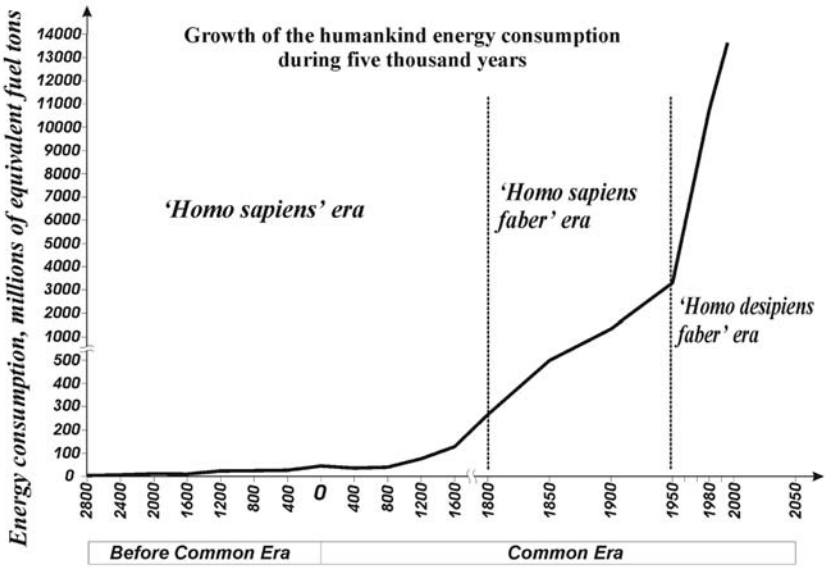
Slightly more than six decades since the great thinker's death, we see that answers to his questions are negative. Really, the population of the Earth (Slivko, 1999) has continued to grow more rapidly than in Vernadsky's times. That is clearly demonstrated in Figure 2a. And at the same time a dramatic growth of energy consumption has taken place (Figure 2b). So, during 5000 years the population of the Earth has grown 144 times, but energy consumption has increased by 2650 times. One can feel this difference is of fundamental importance. With a sad irony it has been said (Goltsov, 2001b) that during the last decades humanity has been acting not like '*Homo sapiens faber*',

but like '*Homo desipiens faber*' (working person without mind). Really, we live already in the Era of '*Homo desipiens faber*' (Figure 2b)!

Figure 2 Growth of the Earth's population (a) and energy consumption (b) over 5000 years



(a)



(b)

4.2 Irreversible catastrophe or hydrogen civilisation?

In the light of what is written above, a key question arises: is world ecological catastrophe possible or not? And, if it is possible, then what time do we have left to prevent this catastrophe? Another important question, connected to the above is: how will the biosphere develop in the future, depending on whether or not the hydrogen civisilation is established? In this context, the HyCi concept inpinges on the new interdisciplinary science of synergetics (Haken, 1983a,b, 1991; Vorstemke and Lefevr, 1984) and the now rapidly progressing synergetic view of the historical development of the humanity (Zubkov, 2003).

Synergetics describes the behaviour of *highly nonequilibrium*-dissipated systems (physical, chemical, technical, biological, economical, sociological, etc.). These systems consist of a multitude of subsystems and are in permanent exchange of energy and matter with the outside world. It is possible that the changing of some conditions (operational parameters) may bring about regular evolution and self-organisation processes in these systems.

A characteristic property of synergetic systems is that in their development there may exist so-called bifurcation points (periods), wherein the possible system development routes may fork. An important point here is that at such a time the system is in an unstable state and small random disturbances can lead to global impacts: the system could irreversibly progress in the direction of one of the earlier possible routes which can be absolutely and fundamentally different from the other probable variants of development.

The biosphere is a synergetic, to a highest degree, nonequilibrium self-organising system. As said above, it exchanges energy and matter with outer space, with the rest of the central part of the planet Earth and with its upper atmosphere. With regards to a geological scale of time, the biosphere has stayed in a stationary state and has evolved at the same time.

During its development the biosphere has come through various bifurcation periods and has undergone transformations by different mechanisms. For example, let us examine one of the most large-scale bifurcation biosphere transformations, which took place in the geological past. About 2 billion years ago a so-called Pre-Sinian catastrophe occurred (see Zubkov, 2003, pp.27 and 65). Before this catastrophe there existed large-scale 'reducing' forms of life and a huge quantity of pro-bacteria had been living on the surface of seas and land. Their vital functions consisted in reduction of iron oxides. The oxygen was released into the atmosphere and permanently poisoned the reducing environment.

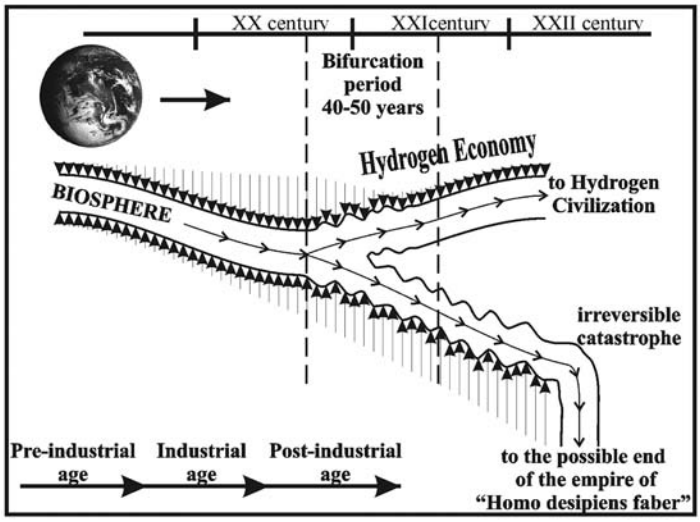
As a result, a dramatic eco-catastrophe took place and 'reducing' forms of life were wiped out. Then, during the next geological period of time, as a result of the oxygen content in the atmosphere, the biosphere started to be self-organising in a new way of evolution: an oxidative form of life was spontaneously generated and began its evolution, and still exists today. As is well known, most living organisms live by oxygen consumption and humans are the most important component of the living matter of the biosphere.

So, from the synergetic viewpoint, it is not surprising that, according to scientific expectations, the evolution of the modern biosphere could be terminated by a new and much more dramatic catastrophe, the result of which would be that the form of Earth life now existing would be wiped out as a result of the actions of '*Homo desipiens faber*'.

A diagram of modern and possible future biosphere development showing the current synergetic viewpoints and knowledge is given in Figure 3. It can be seen that during the transition from the pre-industrial period to an industrial one, biosphere loading,

caused according to Vernadsky by '*Homo sapiens faber*' activity, grew permanently and heavily. In the post-industrial period this loading became super heavily polluted and, speaking in images, humans became '*Homo desipiens faber*' (Goltsov, 2001b). According to the evaluations of some (Zubkov, 2004), in the present time the biosphere has already entered a bifurcation period (or will enter it soon).

Figure 3 Two possible ways of biosphere evolution



According to the IAHE HyCi concept two ways of biosphere evolution are possible in the future (Figure 3). The first one is the biosphere irreversibly entering a track leading to the catastrophic end of the '*Homo desipiens faber*' empire. The second is a transition of humankind from the hydrogen economy to the hydrogen civilisation (Figure 3). Consideration of this question is of greatest importance, and the main noospheric task for the world scientific community involves a scientific, systemic elaboration of synergetic biosphere evolution scenarios within the nearest 50–100 years.

The situation is dangerous! Indeed, we need to know how much time humanity has before a possible irreversible catastrophe hits the biosphere. So, this point must receive the attention it deserves, and the following HyCi concept scenarios of possible biosphere development require urgent consideration and closer examination.

Scenario 1: consider biosphere development for conditions when the amounts of CO_2 and other harmful effluents continue to increase. What will be the impact on the biosphere at different rates of effluent increase for different intervals (in 25, 50, 75, 100 and more years)? Such a global scenario should elaborate on the consequences for all biosphere biogeochemical cycles for all interacting biosphere subsystems, and for humanity and its habitat.

The knowledge of the general laws of synergetics and the possibilities of the existence of bifurcation points provide fundamental ideas for investigations of this kind. From the HyCi concept standpoint, it is of prime importance to establish how much time humanity has before the biosphere and ecosystem enter an irreversibly catastrophic phase of development.

Scenario 2: biosphere development when there are realised global and regional programmes of a progressive, at first partial, and then complete, replacement of hydrocarbon fuels by hydrogen at different rates of hydrogen energy introduction and for different time intervals (vis., 25, 50, 75, 100 and more years). There has been an initial and encouraging study showing how hydrogen is already being turned to proper use firstly for biosphere conservation, and then for transforming the biosphere into a new state.

Let us now highlight some *a priori* visible global peculiarities for the developments under this scenario. As noted above, hydrogen economy development is largely based on the expansion of the use of renewable energy sources, namely, solar energy and its derivatives. This means that there will appear a new factor changing the existing conditions of thousands of years of a stationary distribution of solar energy, which is immediately 'used' by the Earth and given back to outer space. So, with the use of hydrogen as an energy carrier, a decrease in emissions in technogenic effluents into the atmosphere, and an increase in direct use of solar energy will result in change in the existing conditions on Earth and the biosphere as global, highly non-equilibrium systems. Humanity must certainly calculate the consequences: if these factors are essential, how many other factors will also be essential, and what will be the new stationary dynamic state of the biosphere, and how fast will this state come into being? Undoubtedly, the regional stationary states for all biogeochemical cycles, including the carbon cycle, will also undergo changes. What will these changes be?

It is evident from the above statement that a movement from hydrogen economy to hydrogen civilisation will not only solve the world's environmental problems, but will also produce changes in the biosphere and its functioning over historical and geological scales of time.

Thus forecasting and estimating the future development of the biosphere in various conditions, and the prediction of possible irreversible universal and/or local catastrophes, are tasks of fundamental global importance for human thinking.

4.3 Inevitability of geopolitical contradictions – an attendant problem of transition to a hydrogen civilisation

Let us consider now the geopolitical – internationally legislative component part of the IAHE HyCi concept. In this regard, the concept is based on the incontestable proposition that historical transformation of such a scale like 'humankind transition to the hydrogen civilisation era' will permanently pose changes in the world geopolitical situation. Therefore, in the HyCi concept there are at least two large-scale factors which would play the role of driving forces behind the geopolitical changes, and these two factors would affect the fundamentals of existence in the life of particular states (groups of states).

The first one arises from *the inadequate perception of various states of the world environmental catastrophe jeopardy*. Really, even short-term, 'soft' methods of solving these problems contain the principal geopolitical antagonisms. For example, world community efforts to realise the Kyoto agreement (1997) clearly demonstrate this fact. Thanks first of all to Japan, Europe and Russia, the Kyoto agreement came into force. However, such an approach turned out to be unacceptable for the strongest world economies of the USA (pointed out already in Goltsov and Veziroğlu, 2001b), for the actively growing economies of China and India, which aim at future world domination.

It is unlikely that such an approach will satisfy poor countries for which the prohibition to increase energy consumption amount to a requirement to live in perpetual poverty.

The HyCi concept of IAHE does not undermine the Kyoto agreement. At the same time the HyCi concept shows the primary source of its restriction that generates geopolitical-scale intergovernmental contradictions. The restriction of the Kyoto agreement is conditioned by complex reasons (Goltsov and Veziroğlu, 2001b): geopolitical, economic, technical, scientific, etc., but the main reason is that the plan was to solve a very complicated and complex worldwide environmental problem by a simple and short-term method of attack, namely, by a basic undertaking of some obligations by countries, in the form of quotas, to reduce harmful emission into the atmosphere.

To put it precisely, any attempt to resolve the greenhouse effect and to avert a world environmental disaster by restricting energy consumption and by freezing economic growth will have no prospects of success. It is pertinent to note that Vernadsky stressed that any call for a return to a primitive life (such calls, both in a direct and veiled or mild form, were always put forward) is not well-grounded and cannot be realised in practice. Such an idea, speaking figuratively, is a 'still-born' idea.

Amplifying this, we can say (leaning upon Vernadsky's thought) that a 'Forward to primitive existence!' slogan is inconvenient to the human race. Therefore, let us repeat: the lines of attack for solving the biospheric problems 'à la Kyoto agreement' will always serve as a basis for geopolitical antagonism.

Now, let us point toward another large-scale factor, namely, the limitation of world oil and gas resources. Oil and gas are the basis for the modern world economy and will be the most important energy sources during a prolonged change-over period of transition to a hydrogen economy and to hydrogen civilisation. But, nowadays in the beginning of the 21st century, the world oil and gas problem has become an extraordinarily pressing one. For example, the specialists' estimations show that the world's proved reserves of oil do not compensate for the increase in oil consumption. This problem provokes already negative geopolitical decisions. The prognosis is that the world economy will be faced with a real, considerable deficiency of oil and gas by about 2030. Therefore, energy security is beginning to dictate to some countries the necessity of a rapid 'transition to hydrogen' (the USA – the 'hydrogen security' politics).

So, transition to a hydrogen economy and then to a hydrogen civilisation will undoubtedly be accompanied by permanent global and/or local geopolitical and geoeconomical contradictions. In particular, changes in the national interests of many countries will take place – 'old' and 'new' energy resource owners, changes of geoeconomical interests of transnational energy companies. A polarity reversal might arise in the sphere of geopolotical and geoeconomical attractions and the like.

According to the IAHE HyCi concept, the above problems are just around the corner and thought needs to be given to work under legislative (not by force) governing of possible negative tendencies on the road to hydrogen civilisation.

5 The stages and mechanisms of a movement on the historical track: 'Hydrogen Energy→Hydrogen Economy→Hydrogen Civilisation'

As indicated above, the noosphere, according to Vernadsky (Vernadsky, 1945, 1988, 1991), is a special stage of biosphere development when a dominant driving force of

its self-development is science, with human intellectual activity as a general planetary phenomenon. Following the spirit of Vernadsky's doctrine it is possible to say that transition to the hydrogen civilisation era will inevitably occur as a result of a natural biogeological phenomenon. This transition will be realised by the noosphere self-organisation conditioned by the human intellectual activity. A transition of such scope and significance cannot be realised over a short period. However, it will be realised by humanity in the historical period of its rational activity.

The IAHE HyCi concept formulates the stages and mechanisms of transition to the era of hydrogen civilisation that will be put into operation in the 21st century. Let us consider these stages, *which may take place successively and/or concurrently*, and where it is necessary, let us stress their noospheric character.

- The stage of a systemic study of changes of the biosphere, its sub-systems and, in particular, the Earth's ecosystem, which (being induced by humanity) are as a result of change-over (or not changing-over) to a new energy carrier – hydrogen. This stage is noospheric indeed, and an important segment of the world scientific community will take part in it. The germ of such a community is already in existence in the form of the world hydrogen movement and the environmental community of analysts, who are studying the greenhouse effect, its disastrous environmental, economical, political and other impacts. The integration of efforts by these scientific communities is a modern task. Scientific results available at this stage have to provide the humanity with real, highly plausible, accurate, comparative and predictive estimates of biospheric, environmental and other consequences of a wider use of energy carriers in question, i.e. fossil fuels and hydrogen.
- The stage of formation of a new environmental and noospheric consciousness of the general public of all the countries. This new consciousness (intellection) cannot be based, figuratively speaking, on the idea of 'moving ahead to the primitive living' by putting vetoes on energy consumption. This new consciousness will be based on scientific and highly reliable predictions about the manner and rates of humanity's change-over to the environmentally clean energy carrier – hydrogen. It is very important that the current world hydrogen scientific community permanently pays great attention to this 'unscientific' but absolutely necessary activity, without which a transition to hydrogen civilisation is impossible. The role of the general public of highly industrialised countries is especially important, because most of the world's science is concentrated in these countries, and at the same time these countries pollute the environment most. It is obvious that humanity has a right to expect, from these countries, the largest intellectual and financial contributions to enable transition to environmentally friendly hydrogen civilisation. The general public in both the countries of transforming economics and in the developing countries have to be fully involved in this process. In accordance with the HyCi concept, just a new mass consciousness will serve as a basis for acceptance and successful functioning of the legislative–economical mechanism, which will supply a realistic possibility of transition to the hydrogen civilisation era.

- The stage of an official consideration of the prognosis and perspectives of transition to an era of hydrogen civilisation by the international organisations (first of all by the UN and its substructures) and by the regional political and economics organisations. At this stage, the international legislative standards regulating the procedure needed to solve geopolitical, geoeconomical, regional political and economical problems will be elaborated and accepted. The framework laws (recommended to the national parliaments and governments), which would outline scientifically and economically founded ways and mechanisms for the transition to hydrogen civilisation would also be accepted. The work at this stage may lead to more effective international cooperation.
- The stage of consideration by the parliaments of the framework laws and recommendations suggested by the international and regional organisations as to the transition to hydrogen civilisation regarding specific conditions of individual countries. The living standards of each country and its economic state, scientific potential and environment and so on, should all be considered. The designing and adoption of laws should follow for the regulation of financing and the establishment of comprehensively organised national enterprises, which would encourage the use of hydrogen, investment of private capital and the establishment of a competitive market for hydrogen energy.
- The stage (historically this will be a prolonged stage) of a scientifically, legislatively and economically ensured transition to hydrogen civilisation. According to the HyCi concept, in the beginning of this long stage *the legislative–economic mechanism of* transition to hydrogen civilisation will be elaborated in detail and will enter into 'the play' like a noospheric rule. Historical necessity and the main principles of this mechanism of transition to the era of environmentally friendly hydrogen civilisation are as follows.
    - The economics of the 20th century was based on the permanent initiation of human needs in 'things and services'. The consumption of more and more quantity of 'things and services' was and is considered to be an equivalent of life high *quality*.
    - Progressively increasing production – outrunning consumption (demands), is the 20th century central economics dilemma, which still determines life nowadays. Correspondingly, *to have more 'things and services' is the modern paradigm of life* .

However, during the last decades, integral indications of real life quality have gradually reduced more and more (Zubkov, 2003). To mention just a few: the World Health Organization (WHO) data show that 6% of all deaths are the direct result of environmental pollution. This problem, undoubtedly, will be aggravated and, as was discussed above, a great probability of irreversible ecological catastrophe leading to the heaviest and irreversible consequences for humanity exists. All this means that the operating paradigm of life quality must be changed on the other one.

According to the HyCi concept, in the 21st century humanity will assume a new paradigm: a high quality of life will be associated (and perceived) as an optimal combination of a good, ecologically friendly habitat with a rational satisfaction of

necessary life needs. Established on this paradigm a new mass consciousness will serve as a humanitarian–cultural basis for a legislative–economical mechanism of transition to hydrogen civilisation. On these grounds, international organisations will accept and pass in national parliaments, the international legislative standards and corresponding framework laws recommending ecological taxes to be put to use.

Under these conditions some ecologically active countries with suitable humanitarian–cultural and economical conditions will pass national laws regulating the transition to hydrogen civilisation. These countries will initially implement light ecological taxes. Then, gradually they will enforce increasingly high ecological taxes for using fossil fuels and polluting technologies. Along with aforesaid hydrogen technologies will be steadily improved on one hand, while on the other hand, because of the limitation of the world resources, the price of oil and gas will continue to go up. All the above factors will make the production of hydrogen energy and its increasingly wide use in transport, industry, private life etc., to be profitable. According to the HyCi concept, this is a matter of a legislative–economical mechanism, which will guarantee success in progression along the vector 'Hydrogen Energy→Hydrogen Economy→Hydrogen Civilisation'.

The concept affirms that the prolonged nature of the transition means that HyCi will spread in an uneven, fragmented manner in geographical and geopolitical spaces in humanitarian–cultural and industrial–ecological spheres, in separate branches of engineering and technology, production and so on. This feature of the HyCi concept is subject to future comprehensive elaboration. One fundamental point is detailed further below.

It is well known that industrial megalopolises play an extremely important role in modern economics. However, these are very adverse habitats. With imagination, industrial megalopolises may be said to be the ecological black holes of the biosphere. They permanently draw in to themselves the manpower and material resources of the planet and cause ecological problems. However, whereas in space, black holes do not put out even light (photons), the ecological black holes are, on the whole, characterised by permanent and intensive emission of environmental pollution into the biosphere.

According to the IAHE HyCi concept, the ecologically load-carrying megalopolises, such as California in the USA, Ruhr in Germany, Donbass in Ukraine, Moscow, Ural and Kuznetsky regions in Russia, Shenyan region in China, will have to play a leading role in the transition to the hydrogen civilisation era. Without any doubt in the megalopolises alone, there will be certain factors to be overcome before the practical realisation of the legislative–economical mechanism of HyCi-transition, primarily their own ecological problems. At the same time the megalopolises will provide good examples and experimental fields for their own countries and for all humanity in the efforts focussed on sustainable development and a sustainable future.

6 Conclusions

The fundamentals of the novel International Association for Hydrogen Energy Concept for the future transition to the era of hydrogen civilisation are already established. Obviously, the concept has a programme nature.

The HyCi concept states that humanity can preclude world ecological catastrophe and conserve the biosphere's ability to sustain life only by movement along the vector: 'Hydrogen Energy→Hydrogen Economy→Hydrogen Civilisation'. Historically prolonged movement in this direction will lead to global transformations in all aspects of human existence, human mentality, human society, the mode of political and international thought, environment and industry friendly development. Correspondingly, the HyCi concept consists of three interrelated basic component parts: industrial–ecological, humanitarian–cultural, and geopolitical–internationally legislative ones.

The HyCi concept uncovers the legislative–economical mechanism of the transition to hydrogen civilisation. The HyCi concept formulates the stages of transition to the era of hydrogen civilisation that will be put into operation in the 21st century accenting an attention on the world scientific–cultural community future noosphere role, on the principal importance of purposive forming 'hydrogen-ecological' mass consciousness and on the role and responsibility of international and regional legislative and political organisations, national parliaments and governments.

Further HyCi concept development and detailed elaboration must firstly be (and will be) a product of joint collective efforts of the world hydrogen movement, and then would be needed the noosphere efforts of all the world scientific and cultural community (Goltsov et al., 2004, 2005a).

In summary we shall emphasise that the IAHE HyCi concept is an optimistic one serving as a guide for an optimistic vision of the future of humanity. According to the HyCi concept (Goltsov et al., 2005c), during transition to the era of hydrogen civilisation, a paramount life self-organisation will take place with an inevitability of a geological process, as in such cases Academician Vladimir Ivanovich Vernadsky liked to say with respect to the biosphere and noosphere processes.

Dedication

Dedicated to the memory of Valery Alexeevich Legasov and Anatoly Nikolaevich Podgorny

References

Abdallah, M.A.H., Asfour, S.S. and Veziroğlu, T.N. (1999) *International Journal of Hydrogen Energy*, Vol. 24, pp.505–517.

Alimova, R.F., Begicheva, T.S. and Goltsova, L.F. et al. (1983–1994) 'Bibliography on hydrogen energy and technology' (USSr) *International Journal of Hydrogen Energy,* 1983, Vol. 8, No. 8, pp.645–668; 1984, Vol. 9, No. 10, pp.873–884; 1985, Vol. 10, No. 12, pp.861–874; 1987, Vol. 12, No. 3, pp.187–204; 1988, Vol. 13, No. 2, pp.111–124; 1989, Vol. 14, No. 1, pp.53–64; 1990, Vol. 15, No. 3, pp.219–234; 1991, Vol. 16, No. 2, pp.147–158; 1992, Vol. 17, No. 2, pp.153–170; 1994, Vol. 19, No. 12, pp.969–989.

Arnason, B. and Sigusson, T.I. (2000) *International Journal Hydrogen Energy*, Vol. 25, pp.389–394.

Awad, A.H. and Veziroğlu, T.N. (1984) *International Journal of Hydrogen Energy*, Vol. 9, pp.355–366.

Bockris, J.O'M. (1971) *Environment*, Vol. 13, p.51.

Bockris, J.O'M. (1972) *Science*, Vol. 179, p.1323.

Bockris J.O'M. (1975) *Energy: The Solar-Hydrogen Alternative*, Sydney: Australia and New Zealand Book Co.

Bockris J.O'M. (2001) *Hydrogen Treatment of Materials: Proceedings, The Third International Conference 'HTM-2001'*, Donetsk, Ukraine, pp.33–52.

Bockris J.O'M. (2002) *International Journal of Hydrogen Energy*, Vol. 27, Nos. 7–8, pp.731–740.

Bockris J.O'M. and Veziroğlu, T.N. (1983) *International Journal of Hydrogen Energy*, Vol. 8, pp.323–340.

Chalk S. (2004) *Hydrogen 2004: Proceedings, 15th World Hydrogen Energy Conference*, Yokohama, Japan, CD, No. 28Pl-03.

Chen, D.Z., Guerkan, I., Sheffield, J.W. and Veziroğlu, T.N. (1982) 'Effective cost of fuels: comparison of hydrogen with fossil fuels', *Hydrogen Energy Progress IV*, Vol. 4, pp.1523–1538.

Contreras, A, Carpio, J, Molero, M, and Veziroğlu, TN. (1999) *International Journal of Hydrogen Energy*, Vol. 24, pp.1041–1052.

EHIP (1999) 'Preliminary results and validation of methodology' *Proceedings, Workshop on Dissemination of Goals*, European Commission DG XII, Brussels, Belgium, available from: www.ehip.org.

'Fundamentals of ecologically clean technologies' (1991) *Collection of Abstracts. 'Tekhnoekologiya - 91'*, Conference, Donetsk, 92 pp.

Goltsov, V.A. (1978) *Atomno-Vodorodnaya Energetika i Tekhnologiya*, No. 1, pp.193–230 (in Russian).

Goltsov, V.A. (Guest Ed) (1997) *Proceedings of the Selected Papers of the First International Conference on Hydrogen Treatment of Materials,* 'HTM-95', *International Journal of Hydrogen Energy*, Vol. 22, Nos. 2/3.

Goltsov, V.A. (Guest Ed) (1999) *Proceedings of the Selected Papers of the Second International Conference on Hydrogen Treatment of Materials*, 'HTM-98', *International Journal of Hydrogen Energy*, Vol. 24, No. 9.

Goltsov, V.A. (2000) *Hydrogen Energy Progress XIII*, Z.Q. Mao and T.N. Veziroğlu (Eds), Beijing, China, Vol. 1, pp.127–138.

Goltsov, V.A. (Ed) (2001a) *Progress in Hydrogen Treatment of Materials*, Donetsk-Coral Gables: Kassiopeya, 543 pp.

Goltsov, V.A. (2001b) *Proceedings, International Scientific Conference 'Vernadsky's Creative Heritage and the Present'*, Donetsk, Ukraine, pp.386–392 and 433–439 (in Russian).

Goltsov, V.A. and Goltsova, L.F. (2003a) *Proceedings, Third International Scientific Conference 'Vernadsky's Creative Heritage and the Present'*, Donetsk, Ukraine, p.203–204.

Goltsov, V.A. and Goltsova, L.F. (2003b) *Noosphere, Collection of Philosophical Articles*, Donetsk, pp.195–198.

Goltsov, V.A. and Veziroğlu, T.N. (2001a) *Proceedings, Third International Conference 'Hydrogen Treatment of Materials. HTM-2001'*, Donetsk–Mariupol, pp. 53–64.

Goltsov, V.A. and Veziroğlu, T.N. (2001b) *International Journal of Hydrogen Energy* , Vol. 26, pp.909–915.

Goltsov, V.A. and Veziroğlu, T.N. (2002) *International Journal of Hydrogen Energy*, Vol. 27, Nos. 7/8, pp.719–723.

Goltsov, V.A., Goltsova, L.F., Alimova R.F. et al. (1982) 'IAE named by I.V. Kurchatov', *Voprosy Atomnoi Nauki i Tekhniki. Atomno-Vodorodnaya Energetika i Tekhnologiya*, Moscow, No. 3, pp.18–19 (in Russian).

Goltsov, V.A., Goltsova, L.F. and Veziroğlu, T.N. (2005c) *Proceedings, Fourth International Scientific Conference 'Vernadsky's Creative Heritage and the Present'*, Donetsk, Ukraine, pp.25–28 and pp.107–109.

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2002) *International Scientific Journal for Alternative Energy and Ecology*, No. 4, pp.7–16.

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2004a) *Bulletin of Hydrogen Economy and Hydrogen Ecology*, No. 1, pp.19–29.

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2004b) *Hydrogen 2004, Abstracts. 15th World Hydrogen Energy Conference*, Yokohama, Japan, p.58.

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2004c) *Hydrogen 2004, Proceedings, 15th World Hydrogen Energy Conference*, Yokohama, Japan, CD, No. 30Pl-03.

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2005a) *Proceedings, International Hydrogen Energy Congress & Exhibition*, Istanbul, Turkey.

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2005b) *Proceedings*, *International Symposium on Hydrogen Energy*. Moscow, Russia, pp.20–27 (in Russian).

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F. (2006a) *Proceedings, International Forum 'Hydrogen Technologies for Energy Production'*, Moscow, Russia, pp.38–40 (in Russian).

Goltsov, V.A., Veziroğlu, T.N. and Goltsova, L.F (2006b) *International Journal of Hydrogen Energy*, Vol. 31, No. 2, pp.153–159.

Goltsova, L.F. (2000) *Hydrogen Energy Progress XIII*, Z.Q Mao, T.N. Veziroğlu (Eds), Beijing, China, Vol. 1, pp.122–126.

Goltsova, L.F., Alimova, R.F. and Garkusheva, V.A. (1987) 'IAE named by I.V. Kurchatov', *Voprosy Atomnoi Nauki i Tekhniki. Atomno-Vodorodnaya Energetika i Tekhnologiya*, Moscow, No. 1, pp.29–31 (in Russian).

Goltsova, L.F., Alimova, R.F., Garkusheva, V.A. and Goltsov, V.A. (1990) *International Journal of Hydrogen Energy*, Vol. 15, No. 9, pp.655–661.

Goltsova, L.F. and Alimova, R.F. (1988) *Metal Science and Thermal Treatment of Metals*, No. 11, pp.63–64 (in Russian).

Gregory, D.P. (1973) *Sci. Amer.*, Vol. 227, No. 1, pp.13–21.

Haken, G. (1991) *Information and Self-Organization, Macroscopic Point of View on Complicated Systems*, Moscow: Mir.

Haken, H. (1983a) *Synergetics, An Introduction*, 3rd edition, Berlin, Heidelberg, New York: Springer.

Haken, H. (1983b) *Advanced Synergetics, Instability Hierarchies of Self-Organizing Systems and Devices*, Berlin: Springer-Verlag.

Hydrogen (2004) *Proceedings, 15th World Hydrogen Energy Conference*, Yokohama, Japan (CD).

Hydrogen in Metals (1982) *Abstracts, Third All-Union Seminar*, Donetsk.

Inui, M., Fukuda, K. and Iwabuchi, H. (2004) *Hydrogen 2004: Proceedings, 15th World Hydrogen Energy Conference*, Yokohama, Japan, CD, No. 28A-01.

Kruger, P. (2000) *International Journal Hydrogen Energy*, Vol. 25, pp.1023–1033.

Kurchatov, I.V. (1977) *Voprosy Atomnoi Nauki i Tekhniki. Atomno-Vodorodnaya Energetika i Tekhnologiya*, Moscow, Vol. 1, No. 2 (in Russian).

Legasov, V.A. (1976) *Kommunist (Communist), Universal Possibilities of Hydrogen*, No. 1, pp.72–75 (in Russian).

Legasov, V.A. (Ed.-in-Chief) (1978–1988) *Atomno-Vodorodnaya Energetika i Tekhnologiya*, Moscow: Atomizdat, Nos. 1–8.

Legasov, V.A. (1988) *Atomno-Vodorodnaya Energetika i Tekhnologiya*, Moscow: Atomizdat, No. 8, pp.3–15 (in Russian).

Legasov, V.A., Ponomarev-Stepnoi, N.N., Protsenko, A.N., Popov, V.K. and Trotsenko, N.M. (1978) *Atomno-Vodorodnaya Energetika i Tekhnologiya*, Moscow: Atomizdat, No. 1, pp.11–36 (in Russian).

Lima, de L.C. and Veziroğlu, T.N. (2001) *International Journal Hydrogen Energy*, Vol. 26, pp.39–45.

Malyshev, Y.M. (2003) 'Wisdom of the Earth-Home. About the world outlook of the 21st century, *Ecogeosophic Almanac*, Issue 4–5, Saint-Petersburg-Donetsk, pp.90–110.

Marchetti, C. (1974) *J. Brit. Nucl. Energy Soc.*, Vol. 13, No. 4, pp.353–362.

Memorandum (2002) 'Memorandum on the transition from the fossil system to hydrogen economy and then to hydrogen civilization', *International Journal of Hydrogen Energy*, Vol. 27, Nos. 7/8, pp.725–726.

Ohta, T. (1974) *Proceedings, Hydrogen Economy Miami Energy (THEME) Conference*, Miami Beach, Florida, March, pp.15–19.

Ohta, T. (1978) *Solar–Hydrogen Energy Systems*, Oxford: Pergamon Press.

Ohta, T. (2004) *Proceedings, Fourth International Conference 'Hydrogen Treatment of Materials. HTM-2004'*, Donetsk-Svyatogorsk, Ukraine, pp.3–12.

Ohta, T. (2006) *International Journal of Hydrogen Energy*, Vol. 31, No. 2, pp.161–166.

Podgorny, A.N., Varshavsky, I.L., Makarov, A.A. and Mischenko, A.I. (1977) 'Usage of hydrogen fuel in internal-combustion engines', Preprint No. 45, Kharkov: IPME AS USSR, p.32.

Proceedings (2004) *Fourth International Conference 'Hydrogen Treatment of Materials. HTM-2004'* (2004) Donetsk-Svyatogorsk, Ukraine.

Proceedings (2005) *International Hydrogen Energy Congress & Exhibition* (2005) Istanbul, Turkey, CD.

Shpilrain, E.E., Malyshenko, S.P. and Kuleshov, G.G. (1984) *Introduction to Hydrogen Energy*, V.A. Legasov (Ed), Moscow: Energoatomizdat (in Russian).

Slivko, V.M. (1999) *Energetic Aspects of Development of the Most Ancient Civilizations*, Moscow: Galoil-Press.

Stolyarevsky, A.Y. and Chuvelev A.V. (1988) *Atomno-Vodorodnaya Energetika i Tekhnologiya*, Moscow: Atomizdat, No. 8, pp.244–259 (in Russian).

The Hydrogen Planet (2002) *Proceedings, 14th World Hydrogen Energy Conference*, Montreal, Canada, CD

Vernadsky, V.I. (1929) *La Biosphere*, Paris: Alcan.

Vernadsky, V.I. (1945) 'Biosphere and noosphere', *American Scientist*, Vol. 33, No. 1, pp.1–12.

Vernadsky, V.I. (1988) 'Biographic materials', in: *Prometei*, Moscow: Molodaya Gvardiya (in Russian).

Vernadsky, V.I. (1991) *Scientific Thought as a Planetary Phenomenon*. Moscow: Nauka (in Russian).

Veziroğlu, T.N. (1975a) *Proceedings, Symposium on Introduction to Hydrogen Energy,* Marcay, Venezuela, October.

Veziroğlu, T.N. (1975b) *Heliotechnique and Development*, Cambridge, Massachusetts: Development Analysis Associates.

Veziroğlu, T.N. (Ed) (1975c) *Hydrogen Energy, Proceedings, Hydrogen Economy Miami Energy (THEME) Conference* (Parts A and B), New York: Plenum Press.

Veziroğlu, T.N. (Ed) (1976) *Proceedings, First World Hydrogen Energy Conference (WHEC)* (3 Vols.), Clean Energy Research Institute, University of Miami, Coral Gables, FL.

Veziroğlu, T.N. (2000a) *Hydrogen Energy Progress XIII*, Z.Q. Mao and T.N. Veziroğlu (Eds), Beijing, China, Vol. 1, p.3.

Veziroğlu, T.N. (2000b) *International Journal of Hydrogen Energy*, Vol. 25, p.1143.

Veziroğlu, T.N. and Basar, O. (1974) *Proceedings, Hydrogen Economy Miami Energy (THEME) Conference*, Miami Beach, Florida, March.

Vorsthemke, V and Lefevr, R. (1984) *Noise-Induced Transitions, Theory and Applications in Physics, Chemistry and Biology*, Berlin: Springer-Verlag.

Zubkov, V.A. (Ed) (2003) *Wisdom of the Earth-Home*. About the World Outlook of the 21st Century, *Ecogeosophic Almanac*, Issues 4/5, Saint-Petersburg-Donetsk.