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"HySociety" in support of European hydrogen projects and EC policy

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Abstract

Hydrogen is an attractive energy media for reducing the emission of CO_2 and pollutants in our fossil fuel society. Although studies worldwide have indicated the technical feasibility of the use of hydrogen as an energy carrier in the transport and energy sectors, there are several non-technical barriers which must be overcome or removed before hydrogen can be applied in energy systems. The project HySociety focuses on the 15 EU member states plus Norway and Iceland and addresses the non-technical barriers such as codes and standards for hydrogen infrastructure implementation, public safety concerns, social and economic impacts, changing trends in industrial structures and in the European economy. The project aims to provide an action plan for the successful introduction of a clean, safe and efficient hydrogen-based society in Europe.

Keywords: HySociety; Europe; Non-technical barriers; Impact; Action plan

1. Introduction

Concerns about climate change and energy security create a forum for the mainstream market penetration of hydrogen. In recognition of the greenhouse gas (GHG) emission reduction target set by the Kyoto Protocol [1] and the need for security of supply [2] the European Commission has developed several strategies, policies and new proposals to combat climate change and to increase the share of renewable in the energy and transport sectors [3–6].

It is against this backdrop that the European Commission has sponsored the project "HySociety—the European hydrogen-based Society". The main objective of the project is to support the introduction of a safe and dependable hydrogen-based society in Europe by providing an action plan that integrates political, technological, economic, social and environmental issues.

The programme addresses the non-technical barriers such as codes and standards for infrastructure implementation and public safety concerns, the social and economic impacts, changing trends in industrial structures and in the European economy and the information needs of the public, students, decision makers and business leaders about opportunities and progress towards establishing a clean, safe and efficient hydrogen-based society in Europe. The project will contribute towards the preparation of European policies on hydrogen-related issues through the development of a complete action plan for the introduction of hydrogen in European society. The work builds upon the results of existing EC funded research and technology development (RTD) and research, technological development and demonstration (RTD& D) projects and networks, national projects, industrial initiatives and programmes in other countries, mainly the USA, Canada and Japan.

This paper introduces the program of HySociety, the work tasks, details of the design of the activities planned by a consortium of 20 organisations that will aid the establishment of an enabling environment and facilitate the management of

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the transition from fossil fuels to sustainable renewable energy. In addition, the energy policy of the EU and important research programs on hydrogen development are reviewed briefly.

2. Research programs on hydrogen

As indicated from the papers of Veziroglu [7] and Momirlan [8], hydrogen energy has been developed significantly in the world since the early 1970s, and most of the main R & D programs contribute to hydrogen as a fuel and energy carrier as well as related technologies.

In the United States, the "Strategic Plan for Hydrogen Program" started in 1979, aims at promoting hydrogen as a cost-effective energy carrier for utilities, buildings and transportation [9]. The main purpose of the "Vision 21 Program" is to develop clean energy technologies with no environmental pollution including zero CO_2 emission by 2015 [10]. The Hydrogen Vision and Roadmap of DOE [11] presented in 2002 described where and how the transition from traditional fossil energy to hydrogen will be fulfilled by the year of 2030 and beyond in USA.

The USA and Japan have taken a leading role in fuel cell research with large investments, whereas efforts in the EU are under-funded and are not structured. For example in the US President Bush has announced the FreedomFUEL Initiative to complement the FreedomCAR Partnership Plan launched in 2002 [12]. The FreedomCAR initiative was to advance high-technology research needed to produce practical, affordable hydrogen fuel cell vehicles and the new FreedomFUEL initiative is to develop the technologies and infrastructure needed to produce, store and distribute hydrogen for use in fuel cell vehicles and electricity generation. The combined cost of the two programmes is $1.7 billion over the next 5 years.

In Japan the WE-NET project administered by the New Energy and Industrial Technology Development Organisation (NEDO) has allocated about $11 billion for a 28-year period running in three stages up to the year 2020. The main objective of the program is to develop basic technologies for achieving a hydrogen-based energy economy.

The international program of Euro-Quebec Hydro-Hydrogen Pilot Project (EQHHPP) is a very successful program for hydrogen energy development in the world, and many countries carry out similar projects to improve the capacities of hydrogen application [8].

A survey of European projects on hydrogen reveals that there were about 336 individual research, development and demonstration activities in hydrogen between 1988 and 1999 [13]. Nonetheless, research on hydrogen in the European Union is still perceived as fragmented and lagging behind the programs of the US and Japan. Overall funding for hydrogen fuel cell research in the EU is estimated to be between 50 and 60 million Euros a year. The total funding for fuel cell research in the 1997–2002 period was 120 million Euros. In recognition of these facts Romano Prodi, President of the European Commission governing the 15 member-state nations, introduced measures to change this situation. In a recent press statement Prodi indicated that "It is envisaged that the budget for research on fuel cells ... will be increased substantially" in the 2003–2006 period.

In order to speed up the commercialisation of fuel cells technologies in developing countries, the GEF funds five demonstration programs on fuel cell buses and related refueling systems in Sao Paulo, Mexico City, Beijing and Shanghai, Cairo, and New Delhi, which are the largest public transport markets using buses in the developing world [14]. The development goal of the program is to reduce the CO_2 emission discharged from the municipal transportation in GEF program countries. The total financial support of above projects is US$59.6 million and about US$36 million has already been approved. The demonstration activities were started in Sao Paulo, Mexico City, Beijing and Shanghai, whilst the programs for Cairo, and New Delhi are in preparation.

3. EU policies and instruments

3.1. EU policy

The Green Paper on strategy for the security of energy supply notes that "The Union imports 50% of its energy requirements and if no measures are taken within the next 20–30 years this figure will rise to 70%" [2]. This high dependence on external sources of energy poses considerable economic, social, ecological and physical risks to modern society, especially as the supply is often from politically unstable or unfriendly regions.

One of the main aims therefore, of the European Community's energy policy as described in the Green Paper of November 2000, is to ensure a supply of energy to all consumers at affordable prices while respecting the environment and promoting healthy competition on the European energy market [2]. These aims follow on from the Lisbon strategy "for the EU to become the most competitive knowledge-based economy of the world" and the Gothenburg conclusions on the EU strategy for Sustainable Development [15,16]. In June 2000 the Commission launched the European Climate Change Programme (ECCP) to identify and develop all the necessary elements of an EU strategy to implement the Kyoto Protocol [17]. The programme set an ambitious task for change involving the full range of stakeholders promoting horizontal integration of environmental policy across the Directorates General of the European Commission.

Similarly the White Paper on transport adopted by the commission in September 2001 proposed an ambitious program of some 60 measures by the year 2010 including a target of 22 percent of electricity from renewable sources by 2010 [5]. In the road transport sector the Commission proposed in November 2001, an action plan and new regulatory and fiscal legislation to promote the use of alternative fuels for transport [6]. The action plan for the 15 member states of the European Union outlines a strategy to achieve a 20% substitution of diesel and gasoline fuels by alternative fuels in the road transport sector by the year 2020. The plan recognised three options that would each appear to have the potential to achieve a volume of more than 5% of the total transport consumption over the next 20 years. Biofuels which are already available were considered in the short term, natural gas in the medium term and hydrogen and fuel cells in the long term. The first of the proposed directives would establish minimum levels of biofuels as a proportion of fuels sold, starting with 2% in 2005 and rising to 5.75% in 2010. The second proposed directive would give Member States the option of applying a reduced rate of excise duty to pure or blended biofuels, when used either as heating or as motor fuel.

The commitment of the EU is illustrated by the appointment in October of 2002 of a High Level Group on Hydrogen and Fuel Cells to "...assess the potential benefits of using hydrogen and fuel cells in EU transport, energy production and many other areas, and help pave the way for more focused EU action in this field" [18]. The group comprises top level representatives from major EU automotive and energy companies, public utilities, research institutes, transport companies and policy makers.

The aim of the European Commission is to bring industry, the research community and government together to map out the hydrogen future. The EU's scientific effort will be as important to Europe as was the space program to the US in the 1960s. and l970s. To meet these objectives a number of budgetary, industrial, regional and social policy measures are being implemented. It was against this background that the project HySociety was designed by a consortium of 20 European partners and accepted by the Commission as one of the last projects to be funded by the fifth Framework Program.

3.2. The framework programs

The Framework Programs of the European Union launched in 1984 were based on a Community Policy that, amongst others, would promote industrial competitiveness, strengthen Europe's science and technology base and coordinate Community and national activities by encouraging collaboration between industry and academia and between member states. Four Framework Programs were mounted between 1984 and 1998. In the Fifth Framework Programme (FP5) the priorities in the research, technological development and demonstration activities addressed the concerns of increasing industrial competitiveness and the quality of life for European citizens. An important difference in FP5 from previous programs is the focus on the major socio-economic challenges facing Europe. To maximise its impact FP5 focused on a limited number of research areas combining technological, industrial, economic, social and cultural aspects. The EU has identified hydrogen as a priority within this context.

Research on hydrogen in the Sixth Framework Programme (FP6) is included under "Sustainable development, global change and ecosystems", one of the seven thematic priority areas adopted by the Council of Ministers in June last year. The total budget for the seven priority areas amounts to 17.5 billion Euro for the period 2002–2006 and is intended to be used for a set of new instruments designed to focus and integrate research in Europe and to create a true "European Research Area" leading to an internal market for knowledge and new technologies.

3.3. Some hydrogen research projects in Europe

There are several major European-wide ongoing activities focussing on various aspects of hydrogen. These include the following projects:

- EIHP I and II—the European Integrated Hydrogen Project addressing standards and regulation for vehicles, safety issues for hydrogen vehicles, standards of components for fuel infrastructure related to the interface with vehicles and discussion of the advantages and disadvantages of low and high pressure [19].
- CUTE—clean urban transport for Europe: the largest hydrogen fuel cell bus fleet trial worldwide. A demonstration of 27 hydrogen fuelled fuel cell buses in regular service for 2 years in nine cities in Europe [20–24].
- RES2H2—Cluster Pilot Project for the integration of RES into European energy sectors using hydrogen. Hydrogen production from renewable sources is very important for sustainable development, this project demonstrates the feasibility of clean hydrogen generation and hydrogen storage on an industrial level [25,26].
- ECTOS—Ecological City Transport System which tests the fuel cell buses performance in the tough climate of Iceland, along with public acceptance [25].
- EURO-HYPORT—a feasibility study on exporting green hydrogen from Iceland to the European Continent [25,26].
- FEBUSS—Fuel Cell Energy Systems standardised for large transport, buses and stationary applications. The project is from 2002 to 2007 intending to develop an optimal fuel cell power module standardised to fit the applications for public transport and station [25–27].
- FUCHSIA, HYMOSSES, HYSTORY—the cluster of projects study advanced hydrogen storage materials. FUCHSIA, a project by the University of Birmingham for on-board storage of hydrogen in metal hydrides and carbon nano-structures; HYMOSSES and HYSTORY address different ranges of storage materials and application areas (stationary power generation and marine applications) [25,26,28].
- HYNET—a thematic network to develop strategies for the introduction of hydrogen and to facilitate its use as

an energy carrier on a pan-European level. The network addresses issues of hydrogen production, infrastructure, safety and regulation, socio-economic issues and the promotion of public awareness [29].
- ACCEPTH2—public acceptance of hydrogen transport technologies [25].
- CP2FCs—a workshop on critical pathways for promoting fuel cells [30,31].
- Land Transport by Fuel Cell Technology—the cluster including of nine European projects (FUERO, PROFUEL, BIO-H2, DREAMCAR, AMFC, PEM-ED, ASTOR, MINIREF and ACCEPT) with 50 partners from the car and supplier industry from 14 countries in Europe to meet specific key targets that lead to demonstrations of technologies suitable for exploitation [25].

Furthermore the International Energy Agency (IEA) has for more than 20 years had in its hydrogen program an implementation agreement for the purpose of advancing hydrogen technologies and accelerating the acceptance and widespread utilization of hydrogen. Canada, The European Commission, Japan, Lithuania, the Netherlands, Norway, Spain, Sweden, Switzerland and the United States participate in this implementation agreement. In addition several EU member states and other European countries have their own hydrogen programs (e.g. Denmark, Germany, France, Italy, Spain, Sweden, United Kingdom, Norway, Iceland and Switzerland).

The European activities described above are complementary to other worldwide programs in Japan, the USA and Canada and they demonstrate adequately the technical initiatives, the aspirations and the progress in the hydrogen sector. An important step in taking these actions to fruition is the assessment of the non-technical barriers that may confront the introduction of hydrogen as an energy carrier in European society. It is this aspect of the chain that the project HySociety addresses. The novelty of the present programme is the focus, in an integrated way, on the European Member states plus Iceland and Norway in order to propose a common and concerted strategy to accelerate hydrogen implementation and widespread utilization.

4. Overview of the HySociety project

As an overview of the general problem we have a base of technology covering a number of vertical issues such as production, storage, distribution and application (Fig. 1). Above that we have society, the end-user, with a number of horizontal concerns such like safety, codes and standards and the environmental impact. In between we have some ill-defined barriers. The objective of HySociety is to prepare an action plan to overcome the barriers and establish a hydrogen-based society.

HySociety is an accompanying measure financed under the "ENERGY" sub-program of the Fifth Framework Program. It is a short term measure of 2 years duration to complement other initiatives on hydrogen. HySociety will address some of the regional and social measures that need to be implemented by examining the barriers to the introduction of a hydrogen-based society and preparing an action plan for overcoming the identified barriers. HySociety will define the problem areas to be addressed in the introduction of hydrogen in the European Union. Good cooperation and minimal overlap with other programmes is assured as the key partners participate in other European projects. In particular, HySociety will work closely with HyNet, the thematic network on hydrogen, such that the outcomes of the project are likely to be the starting points of other activities related to hydrogen.

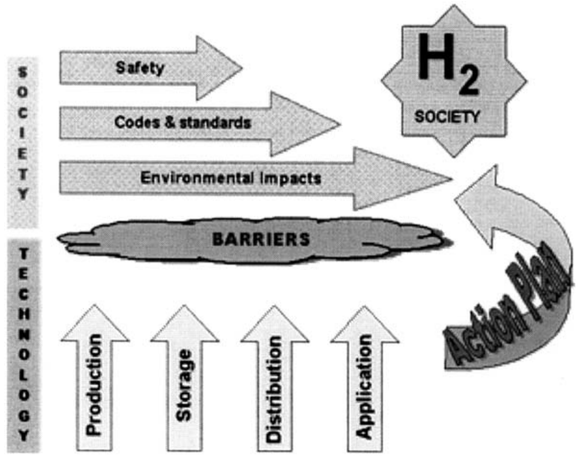

Fig. 1. Overview of the project HySociety.

4.1. Objective of the project

The project HySociety aims to support the introduction of a safe and dependable hydrogen-based society in Europe by addressing the non-technical barriers such as codes and standards for infrastructure implementation, public safety concerns, social and economic impacts, changing trends in industrial structures and in the European economy.

The main objectives are to propose an action plan to overcome the identified barriers and to quantify the technological, social, economic and environmental impacts of the introduction of hydrogen in European society. The project will foster broad public awareness and debate on the opportunities and challenges of the hydrogen society in order to stimulate dialogue with all interest groups and so facilitate the transition from fossil fuel energy systems to sustainable hydrogen-based energy systems.

In order to achieve the objectives, the project follows a simple working methodology:

- identification of barriers;
- establishment of guidelines to overcome those barriers;

Table 1
Consortium of partners

Austria	EVA	Austrian Energy Agency
Belgium	Ulg	Université de Liége
Belgium	VITO	Flemish Institute for Techn. Research
Europe	AVERE	European Electric Road Vehicle Association
Finland	VTT	Technical Research Centre of Finland
France	CNRS	Centre National de la Recherche Scientifique
Germany	ISI	Fraunhofer Institute Systems and Innovation Research
Germany	LBST	LB-Systemtechnik GmbH (subcontracted by IST)
Grammy	VGB	Power Tech
Greece	NTUA	National Technical University of Athens
Iceland	INE	Icelandic New Energy (subcontracted by IST)
Italy	ENEA	Italian Agency for new Technology, Energy and the Environment
Netherlands	ECN	Energy research Centre of the Netherlands
Norway	SINTEF	Energy Research
Portugal	IST	Instituto Superior Técnico
Portugal	SRE	Soluções Racionais de Energia, (subcontracted by IST)
Spain	INTA	Spanish Institute for Aerospatial Technologies
Sweden	Sydkraft	Energy Trading AB
Sweden	RF	Rogaland Research
UK	ICSTM	lmperial College of Science, Technology and Medicine

- in-depth investigation of the changes hydrogen will cause in society;
- definition of concrete measures, in the form of an action plan, to implement the hydrogen society.

4.2. International co-operation

The project is being undertaken by a consortium of 20 organisations from 14 countries in Europe. The geographic focus is on the 15 member states (Austria, Belgium, Denmark, Germany, Greece, France, Finland, Ireland, Italy, Luxembourg, The Netherlands, Spain, Portugal, Sweden and the United Kingdom). The consortium also includes Norway because of its policies and success as a world leader in terms of quality of life, and Iceland because of its commitment to the use of domestic renewable energy and their goal to create the first hydrogen-based economy in the world. Contact will also be made with the 10 candidate countries (Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia) scheduled to join the EU in 2004 and the three associate countries (Bulgaria, Romania and Turkey). The partners of the consortium comprise national energy agencies, national laboratories and major engineering schools (Table 1).

4.3. Project organization

The Project Co-ordinator IST (Instituto Superior Técnico, Lisbon, Portugal) has the overall responsibility for project management and for the supervision of the technical and administrative aspects of the project. The work to be performed is divided into five work packages, each with a work package leader, and consisting of a number of tasks.

The plan of work is arranged in a series of five work packages, Table 2. The work package consists of a number of tasks assigned to particular partners in the consortium.

In WP1 the creation of the enabling environment to establish the European hydrogen-based society involves three tasks: (1) the identification of on-going projects and programs; (2) the identification of barriers to the introduction of hydrogen; (3) the proposal of actions to remove and reduce the barriers.

The analysis in WP2 will involve five steps: (1) a study of the technological impacts of the hydrogen society with respect to hydrogen production (both centralized and non-centralized), storage, distribution, end use and applications (in combustion, fuel cells and processes and synthesis) and cost implications; (2) integrated system analysis of the design and operation of new infrastructure for production, transport, storage and end use of hydrogen, and an analysis of the impact and coordination with existing infrastructures; (3) evaluation of impacts on the global European economy due to the hydrogen society including a study of job migrations, industrial competitiveness and shift of business areas. The problems concerning security of supply as well as economic savings due to a reduction in CO_2 emissions and the role of the capital markets in financing the hydrogen business structure will be examined; (4) an assessment of the social impacts of society covering the problems associated with the potentially poor safety image that hydrogen has and the level of knowledge of the different market actors (policy makers, industry, educational entities and general public); (5) an environmental impact assessment of the

Table 2
Work packages

Work package and leader	Work package title
WP1-ECN	To create an enabling environment to establish the European hydrogen-based society by identifying barriers and proposing measures for their removal and reduction
WP2-FhG/ISI	Analysis of the technological, social, economic and environmental impacts of the introduction of a hydrogen society for both stationary and mobile applications
WP3-ENEA	Development of a complete action plan for the introduction of hydrogen into the European society
WP4-IST	Project management
WP5-IST	Dissemination

hydrogen society which establishes scenarios for comparison with conventional solutions using fossil fuels based on information obtained through a life-cycle analysis. The study will cover CO_2 emissions and urban air quality in the full hydrogen life cycle analysis—from production up to final consumption.

The action plan in WP3 addresses six topics: (1) recommendations for political and fiscal support measures including Government support for field trials, tax incentives, subsidies, government research and development grants and measures for the ratification of the Kyoto Protocol; (2) codes and standards required for the safe implementation and generalized use of the hydrogen infrastructure that is acceptable in all European countries; (3) public education and communication programmes for government agencies, decision and policy makers, industry, business leaders, schools and universities, engineering courses, the general public, NGOs and end user groups; (4) proposals for the integration of the hydrogen cycle within existing infrastructure including the existing urban setting and actions to promote the creation of new infrastructure for hydrogen production, storage, transport and end use. The importance of the automotive market will be reflected in this task as this sector has specific needs concerning supply; (5) human resources with specialised skills required for the anticipated high level of hydrogen integration in society. Although there is not yet a problem skills gap, actions must be taken with schools and education agencies to address this potential problem; (6) dissemination of information to Member States and candidate countries that are interested in hydrogen technologies and impacts.

WP4 covers the management of the project and WP5 deals with the dissemination of the results which will include: (1) dissemination brochures on the project and the hydrogen-based society to be distributed at appropriate venues. The contents of these brochures will also be distributed in promotional CD-roms. (2) Dissemination of information and results via a dedicated website http://www.hysociety.net. (3) A workshop within Clean Air 2003—The Seventh International Conference on Energy for a Clean Environment, which has already taken place in Lisbon on 7–10 July 2003. This workshop presented the preliminary results of HYSOCIETY to promote the discussion on the hydrogen society amongst the 279 specialists in energy technologies that attended the Conference. The dissemination activities of Clean Air 2003 are expected to reach about 5000 people around the world. (4) An open forum will take place at the end of the project, as a final event where all results will be formally and publicly presented and discussed. It will take place in Brussels, the heart of the European Union, and the press will be invited to cover the event, widening the target audience. It is envisaged that this event will become a preferred occasion to promote the work of the European Commission in the development of energy strategies for Europe. (5) An event in the 2004 Olympics in Athens such as the promotion of a hydrogen vehicle as part of the hydrogen society. (6) Attendance at International Conferences and presentation of communications on HySociety—as part of the current academic activity of the partner universities and research institutes, the results of project will be presented to the academic world. This activity will go on throughout the duration of the project and after it is completed, without a specific calendar. The conferences where participation is foreseen are those dedicated to hydrogen technologies and new energy technologies, energy policies, European energy strategy, socio-economic aspects of new energies penetration, and related energy issues. (7) An event at the European Energy Foundation to debate the results of HySociety in the context of the European energy future.

4.4. *Program outcomes*

The outcomes of the tasks in the work packages will include: (1) a set of important barriers to the hydrogen society; (2) a set of common and concerted policies and measures to remove and/or reduce the identified barriers; (3) assessment of major modifications in the technology field; (4) integrated system analysis of a European hydrogen infrastructure based on different scenarios; (5) review of changes in the European economy; (6) assessment of the social impacts of hydrogen; (7) assessment of the environmental impacts of the hydrogen society; (8) proposals for political and fiscal support measures; (9) proposals for codes, standards and measures for hydrogen; (10) dissemination strategies for the different stakeholders; (11) actions to be taken at European level for the hydrogen society infrastructure; (12) an action plan for training of workers and education of engineers in courses relevant to the hydrogen society as well as multi-disciplinary teaching programs for schools, economists (macro and micro) and environmental, social and political scientists; (13) an overall action plan for the introduction of a hydrogen-based society.

5. Summary

The novelty of HYSOCIETY is to propose a common and concerted strategy to accelerate hydrogen implementation and widespread utilization throughout Europe.

HYSOCIETY aims at increasing the public acceptance of hydrogen, at business leaders in order to debate the business opportunities of the hydrogen-based society, at all interest group (environmental, NGOs, consumer groups, associations, local communities) in order to stimulate the dialogue about the challenges and advantages of the hydrogen society and finally, at decision and policy makers.

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