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Investigation of challenges to the utilization of fuel cell buses in the EU vs transition economies

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Abstract

In the urban environment, residents' health is damaged seriously due to fossil-fuel combustion, among the pollutants most are created from transport vehicles. Fuel cell buses fuelled by hydrogen appear to be a promise solution to environment, energy and public health problems that we face today. Studies worldwide point towards the technical feasibility of hydrogen as an energy carrier in the transport and stationary sectors, but several non-technical barriers need to be overcome or removed before hydrogen can be deployed in energy systems. This paper expounds a previous country-specific analysis by contrasting the challenges arising at EU level and those faced by transition economies, using China and Brazil as case-studies to identify the key barriers and potential impact on hydrogen fuel cell buses applications. The evaluation criteria used are described. Lessons on the critical conditions for a successful introduction of fuel cell buses and hydrogen into society and the establishment of a hydrogen infrastructure arise from the above analyses.

Keywords: Fuel cell buses; Non-technical barriers; European union; Transition economies

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1. Introduction

Our economic development has depended on fossil fuels for a long time, resulting in a series of problems concerning the environment, human health, and sustainable development in general. Hydrogen is an attractive energy carrier for reducing the emissions of greenhouse gases and pollutants in our fossil fuel-based society. Studies worldwide indicate the technical feasibility of hydrogen as an energy carrier in the transport and stationary sectors, but several non-technical barriers need to be overcome or removed before hydrogen can be deployed in energy systems. A project, 'HySociety, the European Hydrogen (based) Society'[1] has been funded by the European Commission 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, economic challenges and the uncertainties surrounding the changing trends in industrial structures and in the European economy.

The project, being undertaken by a consortium of 20 European institutions, focuses on hydrogen-related projects in the 15 EU member states plus Norway and Iceland as well as selected examples in the USA, Canada, Japan, China and Brazil. The main objectives are to quantify the technological, social, economic and environmental impacts of the introduction of hydrogen in the European society and to propose an Action Plan to overcome the identified barriers. To achieve these goals, the work has been divided into three phases, the first being the preparation of a database of existing projects accompanied by an analysis of the challenges that they pose in the dimensions described above. The subsequent phase analyses current technologies, future hydrogen scenarios and their economic, social and environmental impacts, and the final phase will integrate all the information to formulate an overall Action Plan to overcome the challenges identified.

It is evident that there has been a great deal of interest and investment in hydrogen related research in the European Union. 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 [1]. 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. Research on hydrogen in the Sixth

[1] www.hysociety.net

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. The total budget for these 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.

Within the last two years there have been attempts to kick-start the hydrogen economy in some of the developing and transition economies. In order to speed up the commercialisation of fuel cells technologies in these countries, the Global Environment Facility (GEF) has a program to fund five demonstration projects on fuel cell buses and related refuelling systems in São Paulo, Mexico City, Beijing and Shanghai, Cairo, and New Delhi, which are the largest public transport markets using buses in the developing world [2]. The potential major expansion of the transport sector, both public and private, and the corresponding increased contribution to global greenhouse gas emissions is of real concern. The developmental goal of the program is therefore to reduce the greenhouse gas emissions discharged by municipal transportation in these countries, as well as the amelioration of local pollution.

The present paper makes use of the detailed analysis performed on two EU-wide demonstration projects and two projects that epitomize the efforts currently underway in transition economies. This is a loosely defined term that refers to the dramatic emergence of new market economies over the last two decades: examples are China, Brazil, India, Russia and several former Soviet states, some of which joined the EU in 2004. The challenges concerning the development of the hydrogen society in these countries are contrasted with those faced by the European Union in an attempt at extracting lessons for the future.

The study contrasts four hydrogen projects, two ongoing programs in transition economies, China and Brazil, and two EU-supported projects. A description of these projects is given below.

The project 'CUTE-Clean Urban Transport for Europe', is currently the largest hydrogen fuel cell bus demonstration programme worldwide. Trials are being conducted with a fleet of 27 hydrogen fuel cell buses in regular service for a proposed period of two years in 9 cities in Europe [3–5].

The program of 'EIHP II, the European Integrated Hydrogen Project' addresses standards and regulation for vehicles, safety issues for hydrogen vehicles and standards for components for fuel infrastructure related to the interface with vehicles. It also includes a discussion of the advantages and disadvantages of low and high pressure hydrogen systems [6].

The main purpose of the project 'Brazil: Hydrogen fuel cell buses for urban transport' is to promote the development and application of fuel cell buses through accumulating operation and management experiences of fuel cell operated bus fleets in Brazil, speeding up the commercial production of fuel cell buses with lower costs for the developing world [7].

The 'China: Demonstration for fuel cell bus commercialization' project deals with greenhouse gas emission reduction by using fuel cell buses in urban transport. It will investigate the technical and economic possibilities of operating fuel cell buses in China with related fuel systems and proposes to increase technical capacity of industry and the awareness of the public as well as policy makers with respect to fuel cell buses [8–10].

2. Methodology

The aim of the first phase of HySociety was to identify the critical conditions for a successful introduction of hydrogen into society and the establishment of a hydrogen infrastructure in the near term, medium term and long term. To this end the analysis of the aforementioned database would primarily be a qualitative assessment of the existing and potential impact of identified challenges on the uptake of hydrogen as an energy carrier. Where possible, a quantitative assessment would also be carried out. This assessment will be used to develop proposals under subsequent project phases for fiscal, legislative and other measures that would significantly enhance the potential for hydrogen to be used in a variety of circumstances.

The methodology was based on *transition theory* [11] as explored in Mourik et al. [12]: In this theory a technological transition is defined as 'a gradual and lengthy process (25–50 years) of change in which a society or a system changes fundamentally. These transitions often coincide or start with the breakthrough of several radical innovations from their niches. The nature of these innovations challenges existing technological conventions, regulatory frameworks, and established relations between consumers and producers. Technological transitions concern changes in the technological dimension, but also in the infrastructural, political and institutional, ecological, cultural and economic dimensions'.

Hysociety recognizes that technological transitions need to be managed, through all stages and in all dimensions. As transition theory has demonstrated, a transition takes a lot of coordinated efforts of many different actors and accurate timing and coordination: 'The superiority of a new technological option and market mechanisms are simply not sufficient to guarantee success, however, this is a perspective on transitions that many policy-makers and also innovators seem to have' [12]. In current descriptions of pathways dealing with the production of hydrogen, attention to the relevant actors and end-use practices is lacking, as well as attention to the necessary coordination of efforts and actors to make a widespread, i.e. global, production and use of hydrogen possible.

Having defined the theoretical backdrop, the framework for data collection was built via discussions among the institutions involved. Data was collected for individual countries as well as for EU-wide programs and GEF programs. These two international initiatives are selected for analysis in the present paper.

In this first phase of HySociety care was taken to provide accurate definitions of the concepts such as dimensions, stakeholders, and to avoid duplication and ambiguity of results. The proposed definition of 'challenges' not only referred to obstacles but also to opportunities that were not but should be taken. To refer to both the actions and the necessary actors to overcome a challenge, and to identify the exact moment or time frame within which an action had to be undertaken the term 'change' was developed. A standard table format was chosen for constructing the database and conducting the in-depth analysis of challenges and changes. Only demonstration projects were analyzed in the in-depth study, since these projects promised to expose most non-technical challenges.

The in-depth study of each project identified several challenges and elaborated on the changes necessary to overcome these challenges. It was decided to differentiate between different segments relevant to the hydrogen energy chain (production, distribution, storage, conversion and end-use). Differentiating between segments would give a picture of the challenges which were most likely to occur in relation to specific segments and hence allow for an analysis of the kind of challenges more likely to occur in specific combinations of segments, i.e. specific technological paths.

3. Results and discussion

The potential barriers to the introduction of fuel cell buses in society include technological, economical, social cultural and political issues. In this analysis the critical conditions for a successful introduction of fuel cell buses into society are examined within each of the four projects selected.

3.1. Technological barriers

In terms of the technological dimension, the fuel cell buses themselves are a common challenge for both developed and developing countries. The technologies relevant to fuel cell buses are clearly more advanced in Europe so the problems that appear in their programs differ somewhat from those in developing countries. For instance, the first commercial fuel cell power instrument in China, a 200 KW PAFC UTC fuel cell, was set up in late 2001 [13]. For China and Brazil, there is lack of large-scale experience in driving, fuelling, maintaining and repairing hydrogen fuel cell buses. It will therefore be necessary to conduct thorough tests to ensure the viability of fleets of fuel cell buses to meet the conditions of China and Brazil [7,8–10]. In Europe there is a lack of operating experience on a broad basis and under different operating conditions including operation for longer periods of time. Furthermore there is a shortage of global technical regulations for hydrogen vehicles [5].

In order to remove the barriers in developing countries, the following actions should be tackled: (1) enhancing scientific, technical, and industrial capacity in developing countries relating to the manufacturing and utilization of fuel cell buses; (2) accumulation of a substantial amount of knowledge on the reliability, failure modes and opportunities for improving the design of fuel cell buses; (3) minimizing the technological risks. To address the problems that exist in Europe, the following tasks need to be done: test and improve fuel cell systems technologies; development of hydrogen safety regulations and infrastructure supply technology; establishment of a global technical regulation for hydrogen vehicles.

3.2. Infrastructure challenges

In terms of the infrastructure for fuel cell buses, there is a need to stimulate the mass production of supply system elements and to promote their widespread deployment. Information from the two GEF projects indicated clearly that total fuel cell buses and hydrogen supply systems used for projects need to be bought from the other countries rather than to be produced by China and Brazil themselves [7,8–10], contrasting with the project ‘CUTE’ in which the different elements could be produced by partners, so the infrastructure, technical preparation and their cost are greater challenges to fuel cell buses introduction in developing countries.

There is a need for locally available qualified technicians capable of performing the basic instrumental analyses in the search of mechanical failure. It is also desirable that basic materials and equipment for maintenance be manufactured by Chinese and Brazilian companies including specific devices for maintenance that could be produced by the present industry (metallurgical, i.e: joints, hoses, filters, etc). Other requirements in the transition economies include a minimum storage buffer of key equipments for maintenance, like fuel cells, controlling system, specific tools, spares kits, etc; a strategic plan for growth in the local economy to enable companies to supply, in the medium term, the most important items and so decrease the maintenance cost. From the operational point of view, it is also necessary to provide a network of competency able to perform the maintenance without loss of the warranty of the equipment.

3.3. Economic problems

In the economic dimension the cost of the fuel cell buses being used in the project 'CUTE', is approximately 11 times higher than the cost for a standard diesel bus. The reason for the high cost is that fuel cells are still in a pre-development stage and are produced on an individual basis [5]. There is a need for the evaluation of fuel cell vehicles in terms of testing, certification, standardisation and in the implementation of the fuel cell system in a regular service bus. Furthermore mass production and further optimisation of design are effective ways for cost reduction. There is also a need for vehicle manufacturer's to have uniform legal requirements throughout the world to speed up development and to reduce costs.

The same challenge occurs to a greater extent in developing countries. Studies of the project in Brazil shows that only after a large number of fuel cell engines have been produced and the buses begin to be assembled in Brazil will the cost of fuel cell buses fall to a level that makes their life cycle operational costs competitive with those of modern diesel buses [7,8–10]. In China there is a great potential market for fuel cell buses. An analysis of the Chinese situation indicates that mass-production of fuel cell buses will be cost-competitive with diesel buses. It is nevertheless necessary to accumulate data and knowledge that will enable improvements to the design and reduction in the cost of fuel cell buses.

3.4. Social– cultural issues

A number of socio-cultural issues are identified in China and Brazil, including lack of awareness and acceptance of fuel cell technology among the general public and part of the policy makers; not many private actors are involved in R&D and Demonstration [13]. Activities are not operated widely because of the limited investment in research. Significant efforts need to be made to increase awareness and acceptance of fuel cell buses among policy makers, news media, investors and the general public. In developed countries socio-cultural concerns concentrate more on safety and reliability issues of fuel cell buses [7–9].

3.5. Political barriers

With regards to the political dimension, there is a lack of awareness and acceptance of fuel cell technology among policy makers, and the policy and planning capacity in the public transport sector in China is weak [8,9]. About fuel cell development strategy, before 1999 the Chinese government put huge investment focus on battery and electric motors; only after 1999 fuel cell technology obtained more attention, but with lower funding. The funding was used by wide distribution to many organizations covering various technologies rather than focusing on increasing the potential of the fuel cell [13]. The present situation is that very few large projects on fuel cells and hydrogen have been deployed in China. Most R&D on fuel cell and hydrogen technologies is still at an early development stage and not technically mature. So far national energy supply heavily depends on fossil fuels, especially coal and petroleum, which attract a large amount of the funds for research. As an example, in the '973 Program', the Chinese National Basic Research Program, from 1998 to 2002, fifteen energy key projects are funded in which five projects are related to coal combustion and other three focus on petroleum exploration. Only one project is about hydrogen and fuel cells. Furthermore, hydrogen and fuel cell studies are not included in the Supporting Plan of 973 in 2004 for important energy projects, development of coal, petroleum and electricity dominate the national energy strategy [14]. One of aims of the project 'China: Demonstration for fuel cell bus commercialization' is to improve planning and policy-making capacity among publictransport policy makers at the national and municipal levels as well as within the bus companies in Beijing and Shanghai. A number of political drivers such as the Kyoto Protocol are strongly counterbalanced by the political and regulatory barriers concerning hydrogen vehicle manufacture.

4. Lessons learned

Today, energy crisis and environmental decay pose a great challenge and transition from fossil fuel to the environment friendly substitutes is a common issue for both developed countries and transition economies. Developing countries face more challenges on the path towards sustainable development due to the limitation of both financial supports and effective energy technologies. From this paper the lessons from developed countries could provide some useful guidelines for the transition economies.

Firstly, technological transfer is an opportunity to harness the potential of energy R&D in emerging economies; Second, the political dimension and public perceptions present stronger challenges in emerging economies; and third, the strategy level and ability of policy makers is very important, determining the speed and quality of introduction of hydrogen and fuel cell buses into society.

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