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Survey of Support Mechanisms for the Development and Demonstration of Hydrogen Systems

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Survey of Support Mechanisms for the Development and Demonstration of Hydrogen Systems

by

Mary Gillie and Karen Platt

Summary

This report analyses the results of a survey taken to identify methods that successfully encourage the development of hydrogen systems. The work was carried out under the International Energy Agency (IEA), Hydrogen Implementing Agreement Annex 18. The survey concentrates on funding for demonstration projects rather than blue sky or academic research.

Successful methods can be characterised by effectiveness and efficiency. In this context, effectiveness is defined as achieving long term growth in hydrogen systems and efficiency is defined as the cost per kW of hydrogen system installed or per vehicle (e.g. car, bus or van). The work also aims to identify the systems for the management and co-ordination of projects and portfolios of projects that allow lessons to be learnt and hydrogen systems to develop effectively.

In general, the results of the survey show that the countries that are most successful are not necessarily the most populous or richest. Industrial and government co-operation are required to deliver a well managed programme of development. There should be a clear timetable with economic and technical targets and a rigorous method of evaluation of projects. Co-ordinating bodies should aim to publicise as much non-commercially sensitive information as possible. A range of funding mechanisms is useful to meet the range of applications for hydrogen and provide a smooth path from research to commercialisation.

Cross border co-operation provides momentum and has the potential to enlarge markets and increase the speed of taking products to market. For transport applications, extending filling stations network across borders is important to increase the range of travel.

Many of the attributes of a successful development programme for hydrogen also apply to other technologies. However, the flexibility and spectrum of hydrogen technologies results in a very large list of applications. This means that input and co-ordination is needed from a cross-section of areas of government from the environment through tourism and transport to science and technology. The associated services and public acceptance need to be developed alongside a product.

Contents

1 Glossary

GDP	Gross Domestic Product
HIA	Hydrogen Implementing Agreement
IEA	International Energy Agency
IPHE	International Partnership for the Hydrogen Economy
NREL	National Renewable Energy Laboratory
NRCan	National Research Canada
SME	Small or Medium sized Enterprise
UNIDO-ICHET	United National Industrial Development Organisation’s International Centre for Hydrogen Energy Technologies

2 Introduction

This project is part of the International Energy Agency (IEA), Hydrogen Implementing Agreement Annex 18. Annex 18's remit is to evaluate hydrogen demonstration schemes and disseminate the data and lessons learnt. In the present, Phase 2 work programme (running from March 2007 to the end of 2009), there is a focus on how demonstration schemes can be used as a basis to further develop the role of hydrogen within low carbon energy systems. This is not only a technical analysis but also looks at the economic and social benefits and barriers for hydrogen systems. It was noted that some countries have been more successful in developing hydrogen schemes and that this is not linked solely to the amount of money being spent by governments and their agencies. How funding is used and how projects are managed and co-ordinated seem to be key factors.

3 Purpose of the survey

The purpose of the survey is to identify methods that successfully encourage the development of hydrogen systems as alternatives to conventional power or fossil fuel technologies. Many of these techniques may also apply to the development of other new or advanced technologies. The survey concentrates on funding for demonstration projects rather than blue sky or academic research (the survey can be found in Appendix II).

Successful methods can be characterised by effectiveness and efficiency. In this context effectiveness is defined as achieving long term growth in hydrogen systems and efficiency is defined as the cost per kW of hydrogen system installed or per vehicle. An approach to funding could therefore be very effective but not efficient because of its high cost. Alternatively, a support scheme could be very efficient if the amount of money spent on each hydrogen systems was relatively low but not effective if the number of hydrogen schemes did not grow.

The second part of the survey is more qualitative. Its aim is to identify the systems of management and co-ordination of projects and portfolios of projects that allow lessons to be learnt and hydrogen systems to develop effectively.

As well as the data from the survey results, information from reports that member countries have made to the Annex 18 Experts' Meetings have been used to help build a more complete picture.

3.1 Exchange rates

All monetary values are recorded in Euros using one exchange rate for the five years. Although exchange rates have fluctuated over the 5 years covered by the survey (2003 – 2007), a single rate was used for each currency (see Table 1).

Table 1 Exchange rates used to convert to Euros

Country	UK (GB pound)	Denmark (Kroner)	Japan (Yen)	Canada (Canadian dollar)	USA (US dollar)
Exchange (to Euros)	1.3073	0.13421	0.0062	0.632	0.643

4 Limitations to the survey

Only open source data could be used for the survey. In many countries information is either incomplete or is dispersed in many different sources. It is therefore inevitable that some funding or projects will be missed. In countries where funding may come from international, national, regional or local government it is highly likely that some funding may be missed or some double counting may occur. Where funding covers a number of areas such as transport, residential, industrial and portable applications, it is very difficult to achieve a full survey of all activities.

5 Results

In the general, the results of the survey show that the countries that are most successful are not necessarily the most populous or richest (Figure 1 to Figure 3). Results are for the period 2003 – 2007. Figure 1 shows a comparison of the number of vehicles, filling stations and stationary kW of hydrogen power installed in different countries. Figure 2 shows a comparison of government spending over 5 years on demonstration hydrogen projects/GDP by country. Figure 3 shows a comparison of government spending over 5 years on demonstration hydrogen projects/population by country.

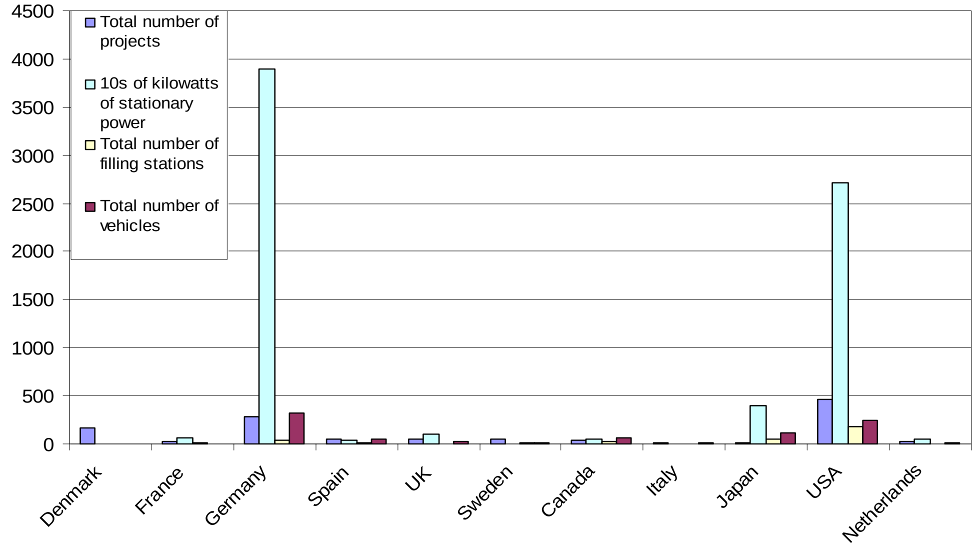

Figure 1 A comparison of the number of vehicles, filling stations and stationary kW of hydrogen power installed in different countries.

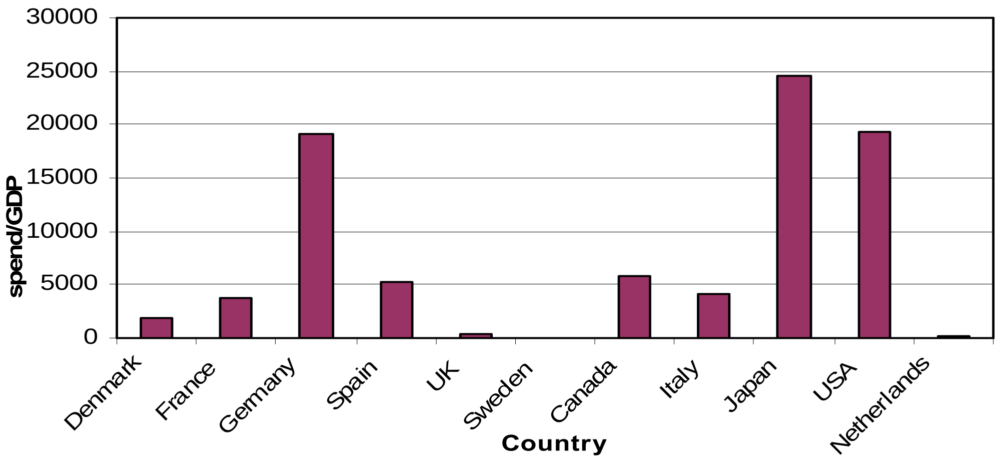

Figure 2 Comparison of government spending over 5 years on demonstration hydrogen projects/GDP by country [9].

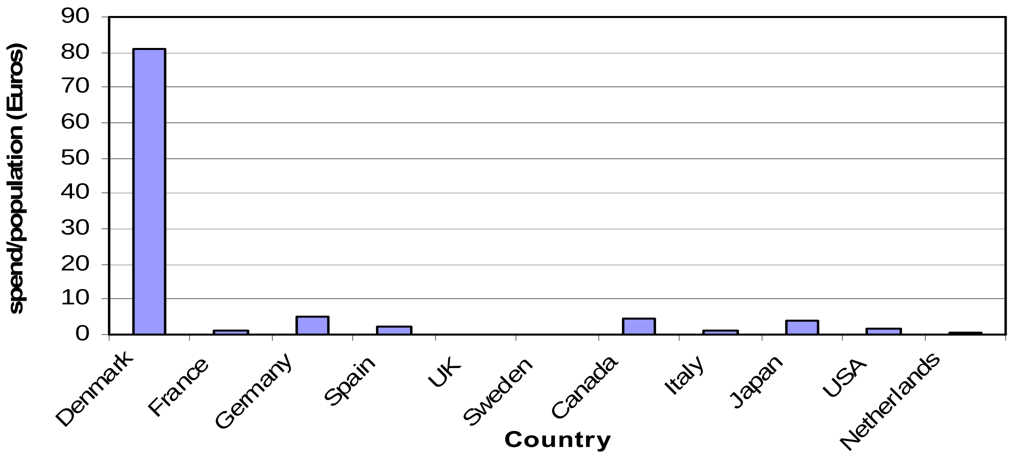

Figure 3 Comparison of government spending over 5 years on demonstration hydrogen projects/population by country [9].

There are some key themes that recur in countries that either have an effective (and in most cases efficient) process in place. These themes are:

- Cross ministry co-ordination within government.
- Strong management processes with heavy industrial involvement.
- International co-operation.

5.1.1 Companies Operating in the Field of Hydrogen

Countries gave an estimate of the number of companies or organisations involved in hydrogen. Figure 4 is a comparison of the results. Note however, that it is difficult to estimate the number of companies that are involved in hydrogen related activities but have other more significant business activities. It is clear that the number of companies does not reflect the wealth or size of the country. However, it should be noted that a number of nationwide companies or multinationals can generate a large amount of activity compared to many Small and Medium Enterprises (SMEs). For example, the 'Clean Energy Partnership' that is demonstrating hydrogen powered cars on a large scale in Germany requires the financial and wide ranging technical capabilities of the large car manufacturers, BMW, Daimler, Ford, GM/Opel and Volkswagen. The first stage has a budget of 33 million Euros. A similar example is the Hydrogen Fuel Cell Vehicle and Infrastructure Learning Demonstration in the USA. In terms of budget and demonstration units, an SME would struggle to manage such projects (although they may contribute to a large project).

It is still the case that SMEs play a very important role as they tend to be more efficient in developing innovative ideas and successfully commercialising them. A report from The Cambridge-MIT Institute showed that, in both the US and the UK, organisations with fewer than 100 employees were most efficient in terms of turning innovative inputs into commercially successful outputs compared to larger companies [10]. A large number of SMEs involved in hydrogen could therefore help a country stay at the forefront of the development of hydrogen systems.

For all sizes of companies it is clear that in terms of number of companies involved, countries such as Germany, Spain and Canada are performing much better than the UK or USA. From Figure 5, it is clear that Germany's funding strategy is by far the most effective in getting industry involved in the development of hydrogen systems.

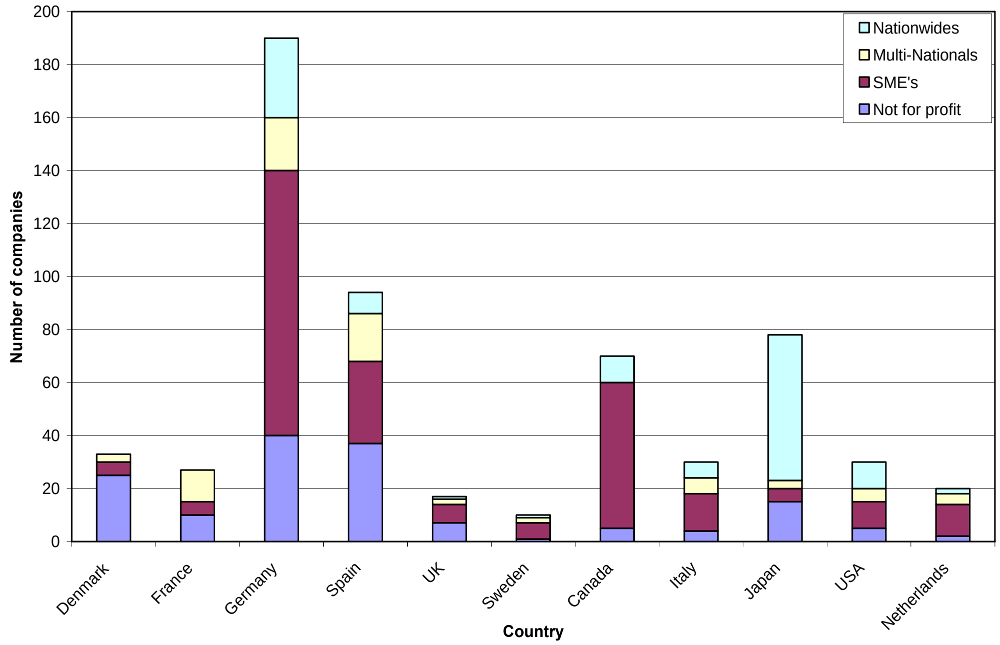

Figure 4 Graphs of the number of different types of company or organisation involved in hydrogen related activities by country.

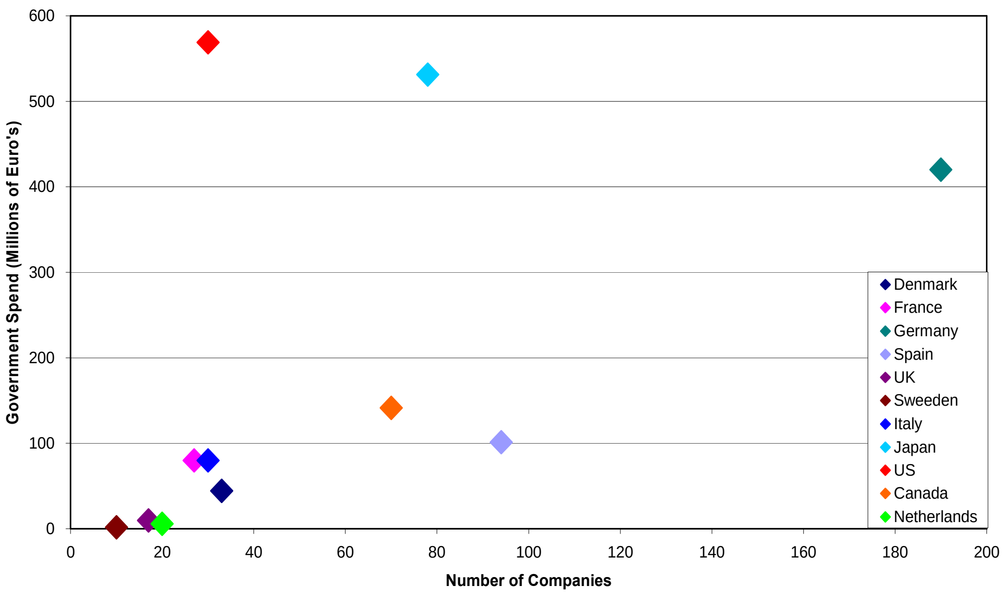

Figure 5 Comparison of the number of companies versus government spending on hydrogen.

For comparison Price Waterhouse Cooper reported that in 2006, the US has the most fuel cell companies listed but there was strong year-on-year growth of companies registered in Europe. Listings in Canada have been falling. However, this survey only covers fuel cell companies and in addition many of the public fuel cell companies have operations in a number of different countries and are not limited to the country in which they are registered.

Examples of this are:

- Proton Power is a UK holding company for a German firm.
- Zonshen is Canadian but operates primarily in China.
- Plug Power is American but has a significant European ownership.
- Ceramic Fuel Cells is Australian but is registered in the UK and has manufacturing sites in other countries in Europe.[11]

5.1.2 Types of Funding

There are many ways that government can support research, development and demonstration. It is notable that most of the countries that are most successful in terms of the number of active companies have a wide range of funding mechanisms Table 2. This probably reflects the range of applications for which hydrogen and fuel cells can be used and the different stages of development of different technologies involving hydrogen. Subsidies per kW and public/private partnerships may be particularly useful at the early commercialisation stage to reduce the risk of adopting new technology and supporting companies until they become profitable. In contrast, blue sky research often needs full or majority funding. With a range of funding mechanisms, it is probably more likely that a smooth path can be made from research to commercialisation.

Table 2 Types of support used by different countries.

	Denmark	France	Germany	Spain	UK	Sweden	Canada	Italy	Japan	USA	Netherlands
100% funding			*					*	*	*	
Part funding	*	*	*	*	*	*	*	*	*	*	*
Tax breaks				*							*
Investment/stake in start-up companies	*										
Subsidy per kW			*	*					*	*	
Public/private finance initiatives	*		*	*		*	*				

5.1.3 Industrial Involvement and Project Management

Most of the successful programmes have a co-ordinating body with clear aims and management and evaluation processes. Industry is heavily involved both in managing and carrying out programmes but with clear targets and reporting regimes. Germany, Canada, Spain and the US have some or all of these attributes. Examples of this are given in several case studies described below (1 to 3 and 5). There is normally a requirement to publicise data (whilst respecting the need for commercial confidentiality).

Denmark is also developing a structure where information can be shared between groups carrying out work on different areas of hydrogen development with an overall co-ordinating body [1].

Case Study 1 USA
The US Hydrogen Fuel Cell Vehicle and Infrastructure Learning Demonstration is co-ordinated by the National Renewable Energy Laboratory (NREL). Four vehicle manufacturers are part funded to develop small demonstration fuel cell vehicles fleets against performance targets. Targets are for vehicle range, fuel cell durability and fuelling cost. In return, data is received, compared and analysed by NREL and general results and progress reports are published. The projects are run by the manufacturers [2].

Case Study 2 Canada
In Canada there are various programs set up at the federal level. An example of a very successful model is the Canadian Transportation Fuel Cell Alliance (funded to March 2008). This alliance was managed by National Research Canada (NRCan) and consisted of a pot of funding as well as 5 working groups. Proponents were able to meet regularly to discuss their projects, meet potential partners and potentially get funding for their projects. The working groups consisted of

- Studies and Assessments
- Heavy Duty vehicle demonstrations,
- Light Duty vehicles demonstrations,
- Communications,
- Codes and Standards.

These working groups were well attended and it therefore meant that the funding and the projects were co-ordinated and there was no duplication.

The projects are managed by government but with input from the Project Advisory Committee that has representatives from regional and national government and as well as experts in the field. There are evaluation criteria to compare different transportation demonstration projects. These include criteria to evaluate the impact on the community and reduction in green house gases [3].

Furthermore, for hydrogen research and development in Canada most programmes have industrial advisory boards to ensure that the programmes remain relevant and these help guide public research. R&D projects undergo a rigorous selection process by multidisciplinary review panels. The federal government also has a Hydrogen and Fuel Cell Coordinating Committee to ensure that projects share information and eliminate duplication. It comprises of around 20 federal agencies from Health to Agriculture that provide information and advice.

There are also a variety of Technology Transfer Workshops put on either by the federal government or by the industry associations.

5.1.4 Cross Ministry Co-operation

Hydrogen has many uses and benefits, it can be used for power and heat production, transport and energy storage. Its benefits are environmental but systems can also:

- Bring additional tourism to an area,
- Help prevent 'brain drain' from remote communities,
- Reduce noise pollution,
- Reduce maintenance work and down time.

There should therefore be interest in hydrogen from a number of ministries in government covering areas such as, science and technology, education, transport, the environment and tourism. It is important that the different areas of government co-ordinate their activities. Case studies 2 and 3 show the impressive range of ministries involved in Germany's and Canada's development programmes. Spain benefits from the fact that tourism and transport are in the same department of government (Case study 4). This department collaborates with science and education but transport and the environment do not play an active role in hydrogen development.

French industry has identified the need to develop a platform to foster hydrogen development across the French economy but this has not been government led.

Case Study 3 Germany

In Germany the National Co-ordination Office Juelich for Hydrogen and Fuel Cells co-ordinates projects at a Länder and Federal level. A new national program 'The Hydrogen and Fuel Cell Technology Programme' has been put together by the Federal Ministry of Transport, Building and Urban Affairs (BMVBS), the Federal Ministry of Economics and Technology (BMWi), the Federal Ministry of Education and Research (BMBF) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The Federal Ministry of Education and Research has supplemented the funding. It will co-ordinate its work with the European Hydrogen and Fuel Cell Platform. All projects are part funded. It sees the development of hydrogen technologies as means to improving Germany's performance in Science and Technology as well as developing a low carbon energy system.

There are clear milestones and funding allocations for different applications in a detailed development plan. This breaks hydrogen activities into different applications and then into the developments that need to take place. It aims to combine research and development work with market-preparatory demonstration projects. Lighthouse projects represent a bridge between R&D and commercialisation. All potential stakeholders (supplier industries, manufacturers, users, approval bodies, authorities, etc.) are encouraged to be involved in Lighthouse projects. As this stage therefore the product must be usable and reproducible. Results are publicised but commercially sensitive information remains private. Related support services for the products must also be developed.

The management of the projects and reviews of the development plan are carried out by the 'NOW'. This is a co-ordinating body that comprises of a representative of each of the areas of activity and the government ministries involved.

Case Study 4 Spain

The Spanish Hydrogen and Fuel Cell Technological Platform Co-ordinates work of the Ministry of Education and Science, the Ministry of Industry, Tourism and Trade and the Spanish Hydrogen Association [4]. Funding calls from government insist that public institutions should work with industry.

5.1.5 Holistic Approach

As with all products, it is important to develop the services to accompany hydrogen technology otherwise customers cannot easily adopt it. For example, for hydrogen cars to be useful, enough filling stations are needed that the cars have a reasonable range. Countries where the number of filling stations has grown with the number of demonstration fleets appear most successful. This is illustrated in Figure 6 (for clarity only countries with a significant number of vehicles are included).

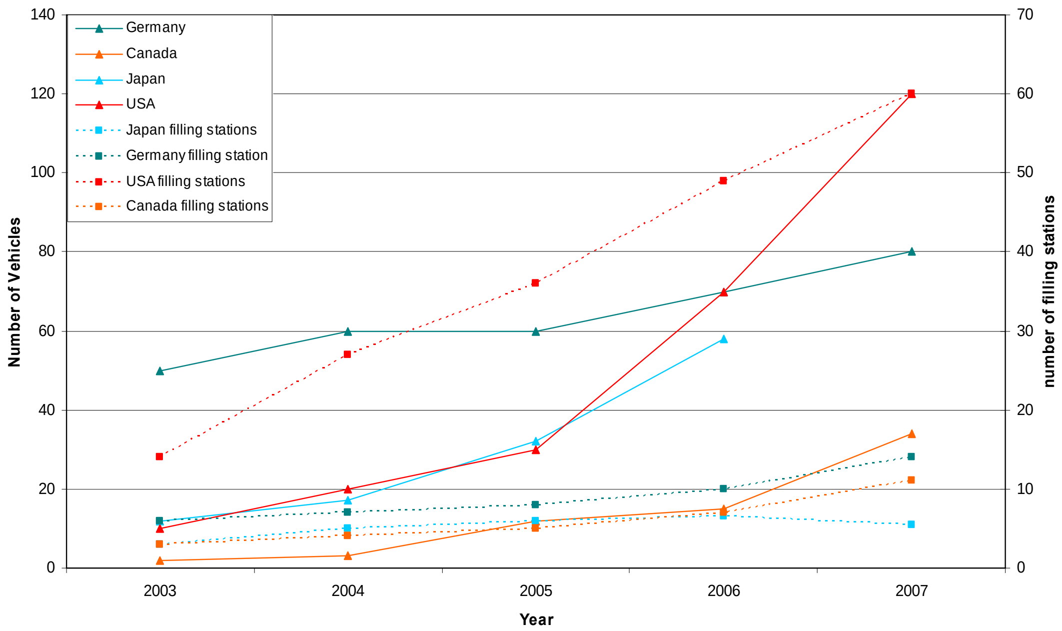

Figure 6 A comparison of the growth of hydrogen vehicles and hydrogen filling stations

It is also important to engage with the public to allay fear of the safety of hydrogen and for them to feel comfortable with a new technology. Japan has formally focused on public relations as part of their strategy (case study 5).

Case Study 5 Japan
The Japanese Hydrogen and Fuel Cell Demonstration Project [5] (JHFC) is organised by the Ministry of Economy, Trade and Industry of Japan, METI. Japanese Automobile Research Institute and the Engineering Advancement Association of Japan are the executive organisations with a joint steering committee to co-ordinate the project as a whole. Under the committee, there are 2 study groups for Small Vehicles and Public Relations Strategy. There are 5 working groups:

- Hydrogen Stations,
- Fuel cell vehicle fleets,
- Interface technology,
- Public relation and education,
- Technology research.

Participating companies belong to one of these groups.

5.1.6 International Collaboration

International co-operation is important as it can help maintain momentum and share knowledge. This helps develop whole systems ready to take to market and extends the potential market. This is important at present as products ready for commercialisation are urgently needed to convince commercial banks [6] that hydrogen systems and fuel cell companies are viable. Some examples of co-operation are:

- Canada, USA, Germany, Spain, Scandinavia are all involved in international or European projects.

- The Joint Technology Initiative on Fuel cells and Hydrogen is a joint EU, industry funded programme with most member states involved [7].
- The Scandinavian Hydrogen Highway Partnership has targets to build 45 filling stations and over 1000 vehicles to 2015 [8]. Links are now also being made with Canada.
- Canada is taking part in the International Partnership for the Hydrogen Economy (IPHE), as well as the IEA Hydrogen Implementing Agreement. It participates in technology transfer workshops through Asian Pacific Economic Co-operation, University of California Davis Sustainable Transportation Energy Pathways Program and other collaboration with the US.
- FuelCell Energy is targeting areas with high fuel prices across the globe such a California, Korea, Japan and Europe. [11]
- Ballard has an agreement with Shanghai Fuel Cell Vehicle Powertrain Company [11]

Co-operation is especially important for vehicle project in Europe where cross border travel is common.

5.1.7 Size of Projects

No conclusive evidence of large or small projects being more successful could be found from the results. However, for transport projects, it is notable that Japan, USA and Germany are most successful and have large vehicle manufacturers involved in developing demonstration fleets, as indicated in Figure 7 and Figure 8. For stationary projects, only Japan has a large scale stationary hydrogen generation programme but other countries have increased the amount of stationary hydrogen power installed (see Figure 9)

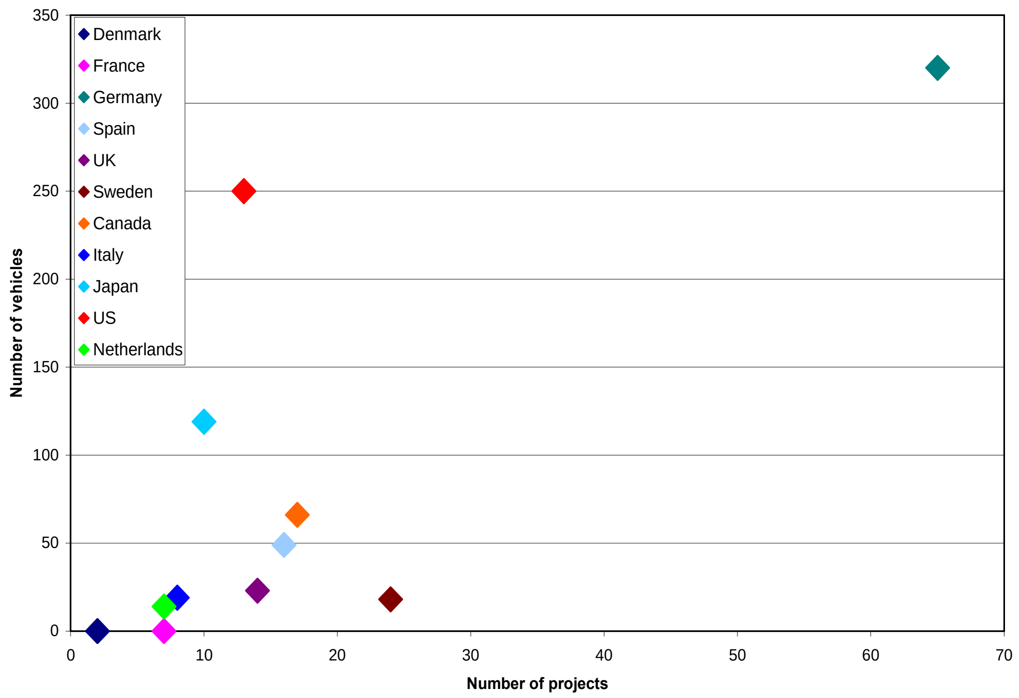

Figure 7 Number of vehicles against number of projects by country

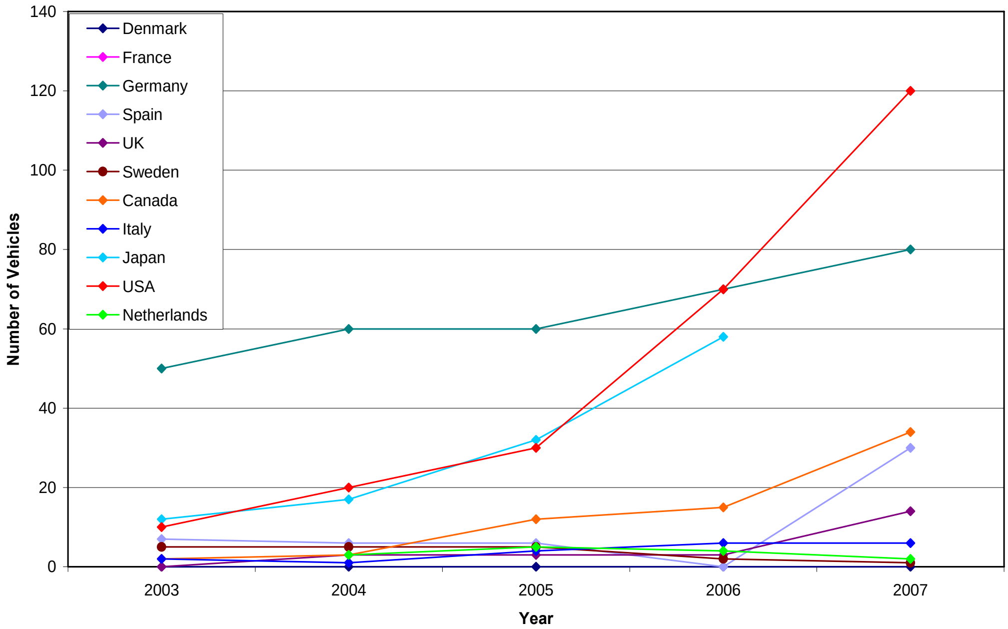

Figure 8 Growth in hydrogen vehicles by country

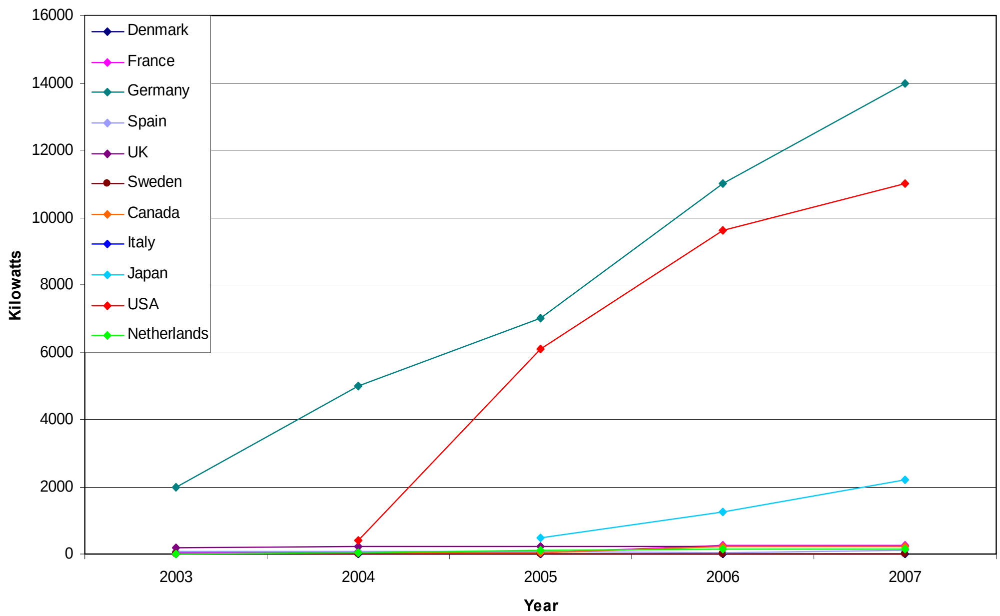

Figure 9 Kilowatts of stationary hydrogen power

6 Developing Countries

The cost of hydrogen infrastructure makes the development of hydrogen system in the developing world difficult. However, the United Nations Industrial Development Organisation's International Centre for Hydrogen Energy Technologies ((UNIDO-ICHET) will support 50% of project costs that are defined as:

- salaries for local experts
- consumable items
- equipment
- travel expenditures coverage.

ICHET can only loan equipment rather than donate it, but it encourages donor countries to donate equipment to allow projects to continue long term. This is a mechanism for developed and developing countries to collaborate. ICHET's first project is the sponsorship and support of hydrogen-fuelled 3-wheeler vehicles for Agra in India. It is also working on renewable hydrogen projects on Turkish islands.

Proposals for developing systems producing hydrogen from solar energy in North African countries and possibly transporting the hydrogen (or the electric power) to Europe are other examples of methods of collaboration between developing and developed countries.

7 Conclusions

In general, the results of the survey show that the countries that are most successful are not necessarily the most populous or richest.

Industrial and government co-operation are required to deliver a well managed program of development. There should be a clear timetable with economic and technical targets and a rigorous method of evaluation of project. Co-ordinating bodies should aim to publicise as much non-commercially sensitive information as possible.

A range of funding mechanisms is useful to meet the range of applications for hydrogen and provide a smooth path from research to commercialisation.

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Many of the attributes of a successful development programme for hydrogen technologies also apply to other technologies. However, the flexibility and range of hydrogen technologies results in a very large list of applications. This means that input and co-ordination is needed from a cross-section of areas of government from the environment through tourism and transport to science and technology. The associated services and public acceptance need to be developed alongside a product.

Appendix I

References

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Appendix II

Funding Mechanisms for Hydrogen and Fuel Cell Demonstration Projects

The aim of this questionnaire is to assess the different methods of government funding support mechanisms for hydrogen and fuel cell **demonstration** projects used by different countries, their efficiency and effectiveness.

Country:

Please concentrate on funding specifically for hydrogen and fuel cell related projects. If there is no specific funding please indicate this and estimate the proportions of general funds aimed at hydrogen and fuel cells.

Specific funds **Yes/No**

Please provide links or copies of any reports or websites that provide relevant information at the end of this questionnaire (question 10).

1. Please estimate how much funding your national and regional governments provide for Research, Development and Demonstration that is specifically for hydrogen projects in the last 5 years. Please state the currency.

	2003
	2004
	2005
	2006
	2007

2. Please indicate the types of funding mechanisms that are used:

	Type of funding
	100% funding of projects
	Part funding of projects
	Tax breaks
	Investment/stake in start-up companies
	Subsidies per kW installed
	Public/Private finance initiatives
	Other - please specify:

3. Please estimate the number of different types of companies/organisations developing hydrogen projects in your country (excluding universities).

Number	**Type**
	Not for profit organisation
	SME*s
	Multi-nationals
	Nationwide/large companies

***SME definition**
SME is defined as micro, small and medium-sized enterprises consisting of enterprises which employ fewer than 250 persons and which have either an annual turnover not exceeding 50 million euro, or an annual balance sheet total not exceeding 43 million euro.

4. Please list international hydrogen and fuel cell funding programmes in which your country participates (e.g. European framework programmes).

5. Please estimate the number of hydrogen and fuel cell stationary projects in your country for the last 5 years.

	2003
	2004
	2005
	2006
	2007

6. Please estimate the number of hydrogen filling station projects in your country for the last 5 years.

	2003
	2004
	2005
	2006
	2007

7. Please estimate the number of road, hydrogen vehicle projects in your country for the last 5 years.

	2003
	2004
	2005
	2006
	2007

8. Please estimate the number of electrical kW of stationary hydrogen fuelled generation in your country (this could include reformed natural gas/methane/biofuels).

	2003
	2004
	2005
	2006
	2007

9. Please estimate the number of hydrogen filling stations in your country for the last 5 years.

	2003
	2004
	2005
	2006
	2007

10. Please estimate the number of hydrogen vehicles in your country on the road for the last 5 years.

	2003
	2004
	2005
	2006
	2007

11. What process is used to co-ordinate hydrogen projects?

12. What process or success criteria are used to ensure the results of a project are fed into commercialisation/wider field trials or implementations or to ensure continuity between projects?

13. Please give any links to websites with relevant information or attach any relevant reports.

Please return to Dr Mary Gillie at EA Technology Limited by 29th February 2008.
mary.gillie@eatechnology.com