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Trends in Evaluation of Integrated Hydrogen Systems: IEA Hydrogen Task 18

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Abstract

Under the auspices of the International Energy Agency's Hydrogen Implementing Agreement, Task 18, Evaluation of Integrated Hydrogen Systems, has been underway since the beginning of 2004. During this time, numerous hydrogen demonstration projects from participating countries have been evaluated for technical performance and lessons learned. As the work program has progressed, various trends have been discovered, based on the projects considered. Among the trends are types, sizes and complexity of projects; project lifetimes and successes; technical performance and maturity of subsystems; modeling tools; permitting and progress in safety standardization; funding mechanisms; early and niche market development; social acceptance and policy issues; and hydrogen and energy sources. In this paper the objectives and accomplishments of Task 18 are discussed, the project portfolio, consisting of both refueling stations for hydrogen-fueled vehicles and stationary power systems are described, and the trends are reviewed. Lessons learned are summarized.

1 Introduction

Fifteen countries have participated in Task 18, bringing demonstration projects for evaluation. Tables 1 and 2 list the projects, which have been assessed in this Task. These fall into two major categories: refueling stations and vehicles, and stationary systems for power production.

Table 1: Portfolio of refueling station and vehicle projects [1].

Project / location	Vehicle / power plant	Station description
ECTOS buses / Iceland	(3) Citaro fuel cell buses with Ballard fuel cells	Shell / alkaline electrolzer, compressed gas storage
Pacific Spirit Station / Canada	(5) Ford Focus fuel cell vehicles	BOC (Linde) / waste hydrogen, compressed gas storage
Malmo, Sweden	City buses / NG engine with mixed NG / H2 fuel	Public station, PEM electrolyzer, compressed gas storage, mix at pump
Energy station / Las Vegas	Converted truck / IC engine	Air products electrolyzer, compressed gas storage
EXPO 2008 / Zaragosa, Spain	1 full size and 2 midi-buses, H2 bikes	Public station; Compressed gas storage
HyNor, Norway	10 converted Prius hybrid ICE	Public station; compressed gas stored underground
HydroGEM, Netherlands	Factory vehicle / PEM fuel cell	On-site at ECN
Clean Energy Partnership / Germany	Numerous fuel cell and ICE	Two public stations in Berlin; liquid storage
H2 Truck / Denmark	1.2 kW fuel cell powered factory loading truck	On-site; replaceable hydrogen canisters
Fuel cell boat / Amsterdam	Commuter boat / PEM fuel cell engine	Shell / multipurpose station for hydrogen fueling

Table 2: Portfolio of stationary projects.

1.1 Project / location	Hydrogen source / Grid connection	Fuel cell description / application	Storage
Residential fuel cell project / Japan	Small reformers / local grid	PEM / home water heating	Gas
HyLink / Totara Valley, New Zealand	Wind electrolysis / none	PEM, Residential power and water heating	Low pressure gas in pipeline
IHAVU (Single family home) / Spain	PV electrolysis / grid back-up	2 kW PEM, household power with hydrogen energy storage	Gas / MH
Hawaii Power Park / Kahua Ranch, HI	Wind / PV electrolysis / local grid	5 kW Plug Power stationary fuel cell / ranch operations office	Gas
RES2H2 / Canary Islands, Spain	Wind electrolysis / none	PEM; integrated with desalination plant	Compressed Gas
Hydrogen Office	Wind electrolysis / local grid	20 kW PEM / building heat and power; fuel cell test facility	Gas
RES2H2 / Greece	Wind electrolysis / local grid	PEM, wind interface testing	Gas / MH
Lolland Hydrogen community / Denmark	Wind electrolysis / local grid back-up	2 kW IRD PEM, Residential CHP	Gas

2 Refueling Stations and Vehicle Trends

The refueling stations in the portfolio have matured from true demonstration systems in early 2004 to fully operational stations today. Some of the trends include:

- a move from lower pressure to higher pressure for both storage and dispensing
- a move from exclusively above ground storage to innovative underground storage
- prevalence of stations with public access from restricted access locations

Figure 1 shows the German station at Berlin Messedamm, which has been open to the public since 2004 [2]. Stations in Sweden, Norway, the US and Iceland are also publicly accessible.

Figure 1: Hydrogen station at Berlin Messedamm, Germany.

Figure 2 is a system diagram of the layout of the HyNor station at Porsgrunn, Norway [3]. Here the hydrogen is stored in underground submerged tanks. Underground storage of liquid hydrogen is used in some locations in Germany, but is still not permitted in the US.

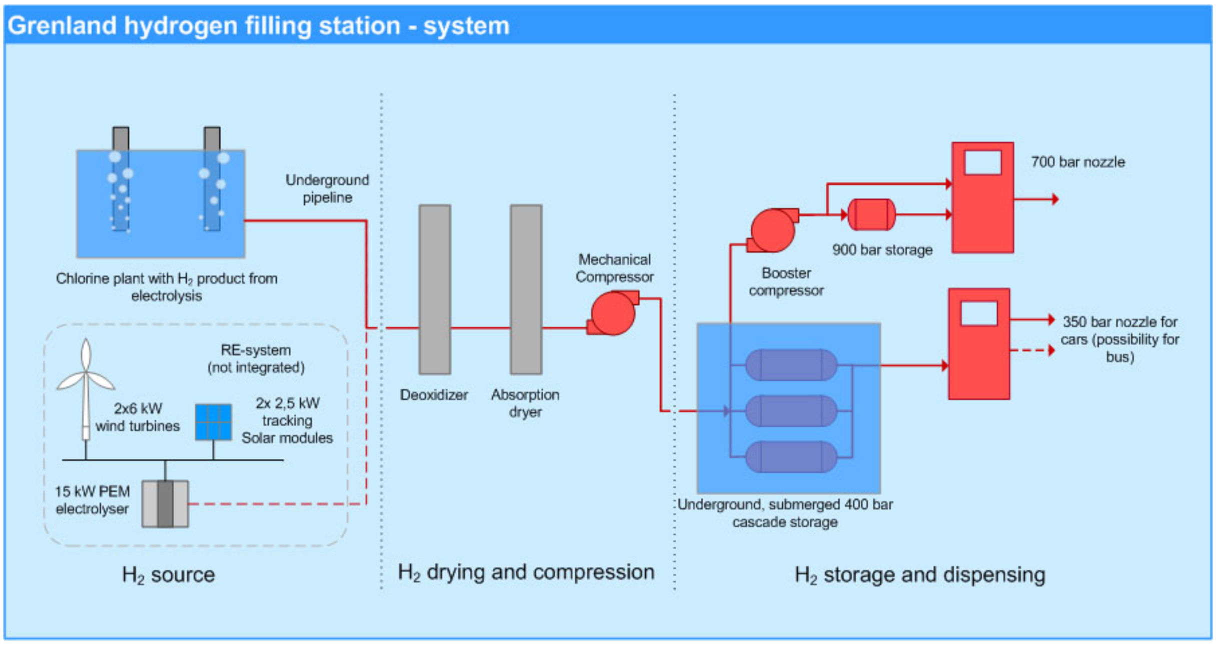

Figure 2: Grenland hydrogen filling station system diagram.

The move to on-board hydrogen storage pressure, from 350 to 700 bar has led to a significant increase in vehicle range. Other major trends in vehicle performance include better efficiency and longer life [4]. Figure 3 shows these trends the Honda FCX, while Figure 4 shows improvement in reliability for Daimler vehicles due to improved process control.

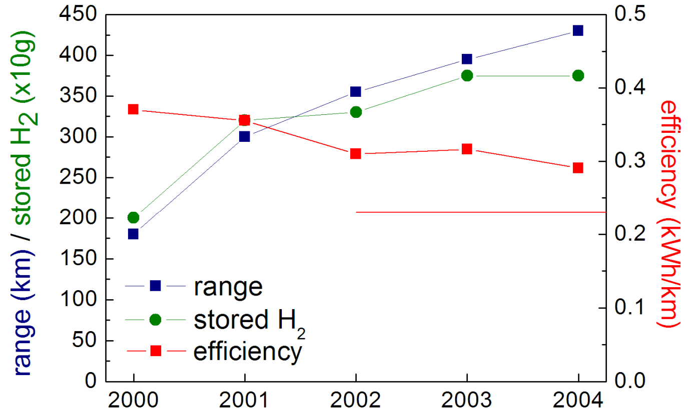

Figure 3: Trends in range, stored H_2 and performance.

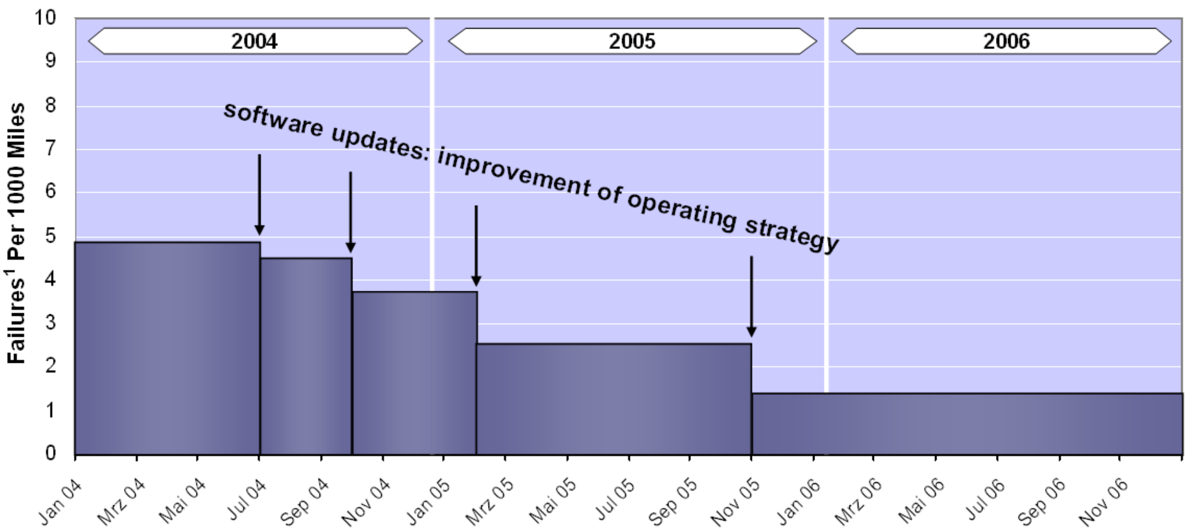

Figure 4: Vehicle reliability improvements (Source: Daimler).

The improved vehicle longevity is especially marked for the Canadian hydrogen highway project in British Columbia, to the extent that the demonstration Pacific Spirit Station, which is fueling seven different vehicle types, will remain open past its original plan to accommodate the vehicles [5]. With respect to buses, which were some of the first hydrogen vehicles on the road, more are in routine service (notably in California, Canada, London and Sweden) than simply in demonstration mode [6]. Sweden is moving toward mixtures of hydrogen and natural gas, while new hybrid (battery / fuel cell) buses are scheduled for placement in Hawaii in 2010 [7].

3 Stationary Systems

Stationary hydrogen systems, primarily for electric power production have predominated the Task 18 portfolio in the last few years. These tend to be somewhat small, individual, isolated projects focused on demonstrating subsystem performance, system integration and control optimization, more so than overall operation. As seen from the list in Table 2, the majority of projects combine renewable resources, primarily wind, with hydrogen production by electrolysis. Storage is mostly compressed gas, with some example of metal hydride storage, and electricity production using PEM fuel cells. A typical system diagram, for the Kahua Ranch power park demonstration in Hawaii, is shown in Figure 5 [8].

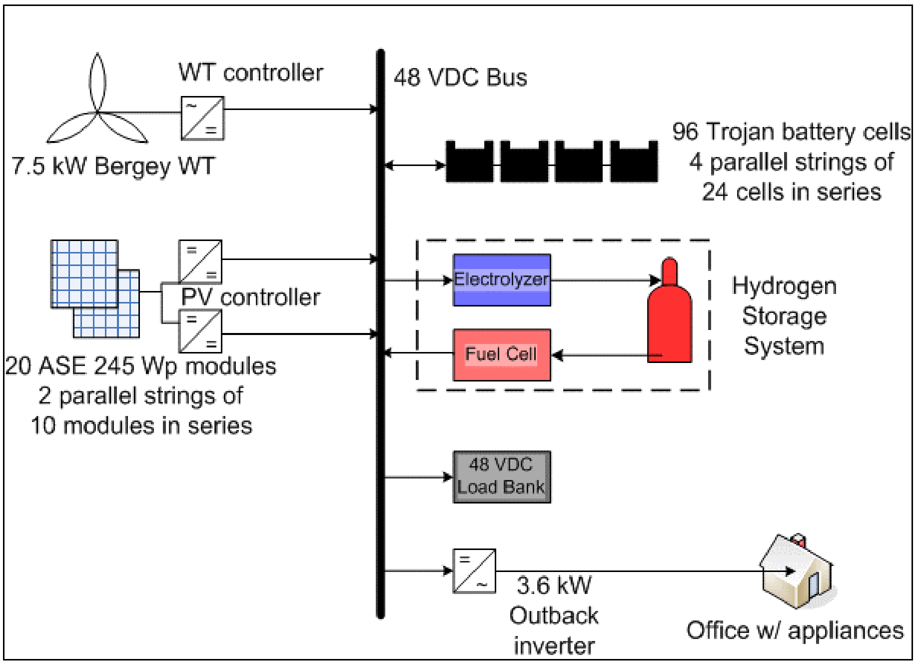

Figure 5: System diagram for Kahua Ranch system in Hawaii.

Several new trends in stationary systems are toward the use of mass-produced fuel cell systems for residences. In the Denmark community of Nakskov, combined heat and power units are being installed [9]. In Japan, several thousand homes have been outfitted with systems that provide power and hot water [10]. The Japanese system is shown in Figure 6.

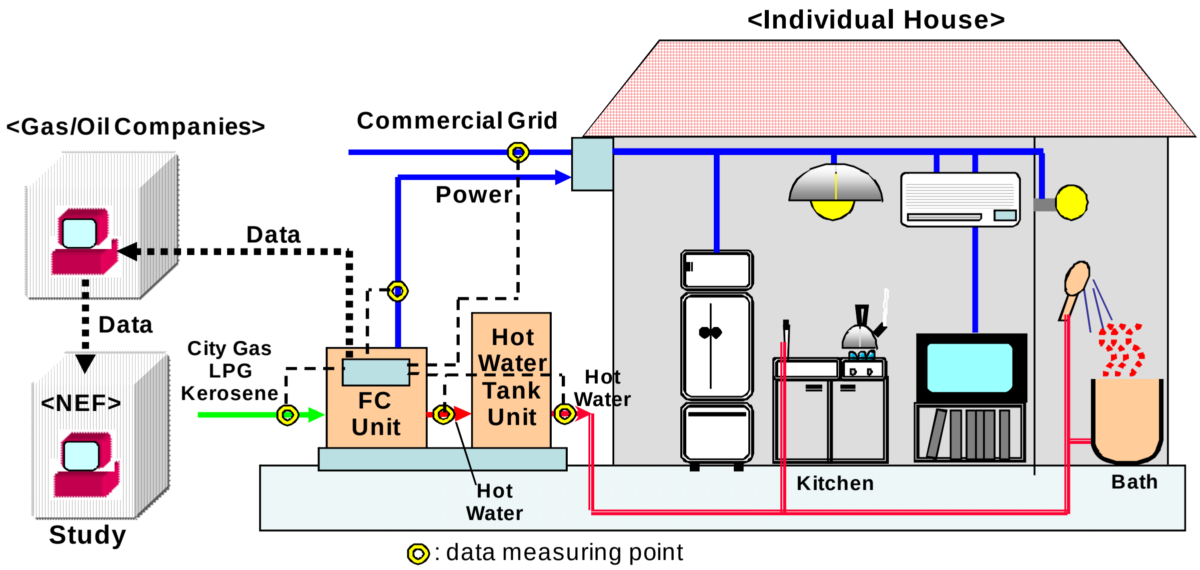

Figure 6: Domestic fuel cell system for power and water heating in Japan.

4 Project Technical Performance and Issues

The demonstration projects evaluated in this work have been primarily unique systems built from custom-made or first-of-a-kind components. While modeling and simulation have been performed, attempts to quantify operational performance, such as efficiency, has not been possible because of the intermittent and testing nature of the projects. In many cases, the hours of sustained operation have been limited, and hence the data sets are also limited. System and component failures have caused significant down time.

One area with recent extensive effort has been in the design and optimization of control systems. For both refueling stations and stationary power systems to be cost effective, not only must the subsystems be appropriately sized to be well matched, but the dynamic operation of all the various elements must also be optimized. In refueling stations, this is determined by the filling schedule of the cars or buses. In stationary systems, the operation depends not only on the schedule of the load, but also in some cases on the input energy from the wind or sun. Frequently the systems include batteries to control dispatch and charging the batteries becomes part of the equation. At the Kahua Ranch, a sophisticated control system has been refined, as shown in Figure 7. Similar design work has been done for the Italian hydrogen house, the HyLink project in New Zealand, and the IHAVU project in Spain.

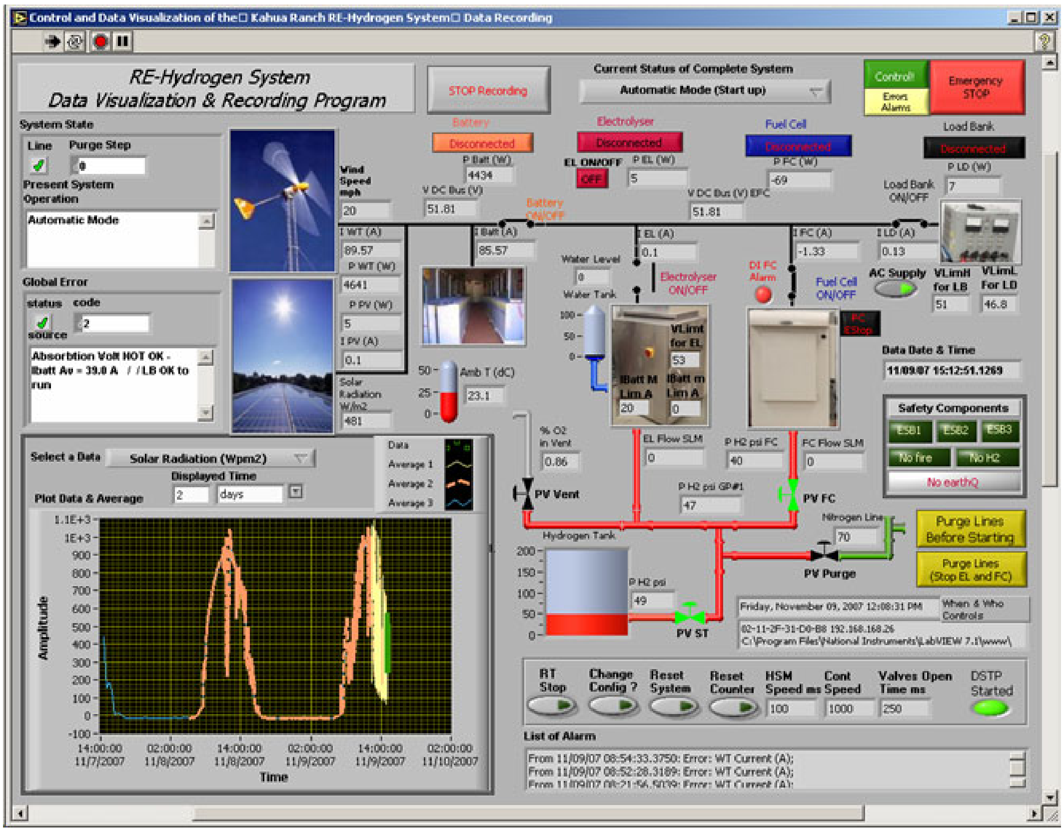

Figure 7: Control panel for Kahua Ranch project in Hawaii.

5 Social Benefits and Programmatic Issues

Throughout all of these projects, the communities involved have shown not only acceptance, but also a strong welcome for hydrogen and fuel cell technologies. The systems represent clean power and “green tech.” In remote locations, they can mean fuel price stability. A survey conducted by the Task 18 team found community pride in these systems and a source of jobs [11].

On the other hand, the projects have been plagued with discontinuities in government and private funding, leading to stops and starts in both planning and construction. Support for some projects to continue beyond the initial demonstration has been difficult to obtain. A funding survey by Task 18 members shows that industrial participation in the development of hydrogen leads to more success than government support alone, as indicated in Figure 8 [12].

Finally, permitting for system installation is still an issue, although major progress has been made since 2003, when every project was essentially acting alone to obtain permits. More recent projects have relied on established codes and processes as well as precedence

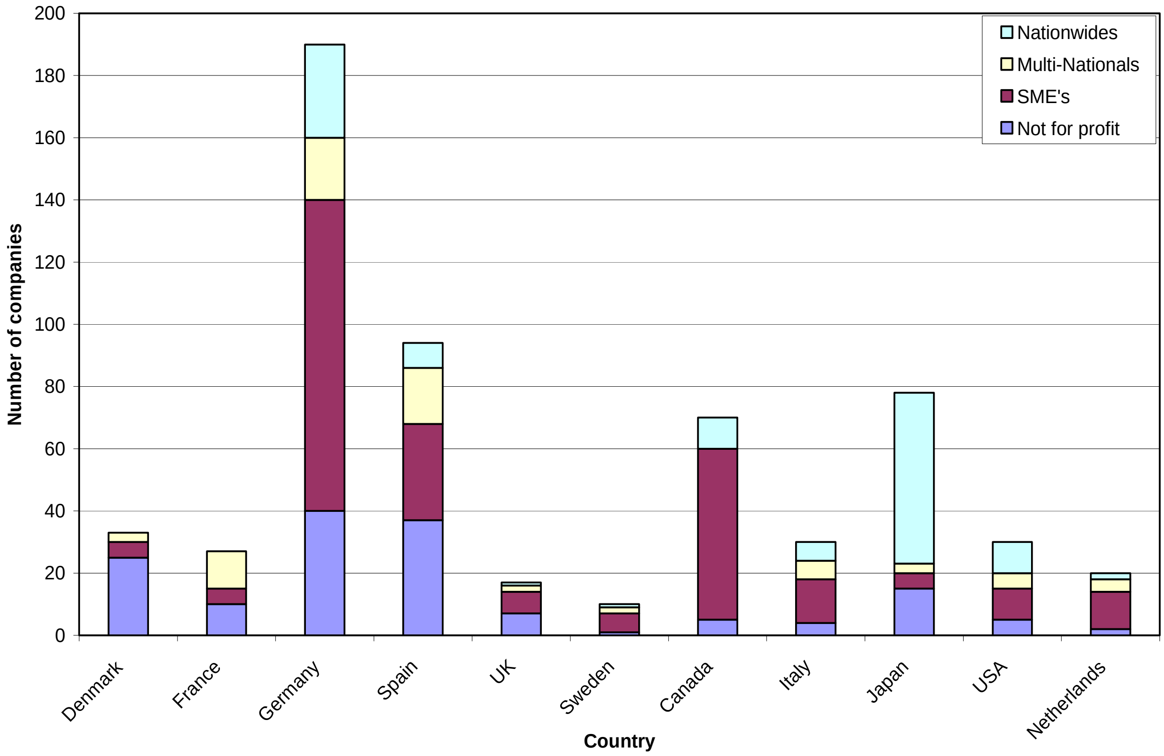

Figure 8: Hydrogen and fuel cell companies globally.

6 Conclusions

The work of Task 18 has illustrated some trends in hydrogen developments. Vehicles and refueling infrastructure are considerably more mature than stationary systems. A trend toward mass-produced systems for residences should aid in maturing such systems. The prevalence for using renewable resources for hydrogen production by electrolysis demands work on electrolyzers that can operate with time varying input. Control system design is of utmost importance. Ongoing funding to gather significant amounts of data are needed to optimize subsystem and system performance.

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