

FURTHER EXPERIENCES IN PERMITTING AND SAFETY OF INTEGRATED HYDROGEN SYSTEMS

S. Schoenung¹, M. Weeda² M. Argumosa³ B. Simonsen⁴ H. Iskov⁵
J. Linssen⁶ I. Aso⁷ A. Gardiner⁸ M. Gillie⁹ E. Stewart¹⁰

Abstract

Under the auspices of the International Energy Agency's Hydrogen Implementing Agreement, a working group has been evaluating and comparing experiences with integrated hydrogen demonstration systems, including a comparison of permitting requirements and safety designs. The group, Annex18 "Evaluation of Integrated Systems," has considered recently developed projects for both vehicle refueling stations and also fuel cell power systems with hydrogen as energy storage medium and fuel. This evaluation is a continuing effort and one important observation is that more standardization is evolving in the applied regulations, especially in Europe and Canada, and also in the US. Specific projects include new hydrogen vehicle fueling stations in Germany, Spain, the Netherlands and Norway, and new domestic power systems in Denmark, New Zealand and the United Kingdom, along with custom, multi-purpose applications in Spain. These experiences are compared with approaches in the United States. In general the processes for safety design and permitting have become somewhat more routine than several years ago, although there are still significant local variations. The various permitting experiences and codes or standards applied are described in this paper.

1. Introduction – International Energy Agency Hydrogen Implementing Agreement and Task 18 – Evaluation of Integrated Systems

Annex 18 has been underway since the beginning of 2004, and is scheduled to operate through 2009. The overall objective of Annex 18 is to provide information on progress in the hydrogen economy. Other objectives are to assess integrated hydrogen demonstration projects in member countries and to provide lessons learned and design guidelines. Integrated hydrogen systems, by definition, include a minimum of two hydrogen components. Most of the systems evaluated in Annex 18 consist of a source of hydrogen (generated by electrolysis or reforming), hydrogen storage, and an end use system (either stationary fuel cell or vehicle power plant). In Annex 18 there are currently fifteen member countries and three subtasks:

- Subtask A: Information Base Development
- Subtask B: Demonstration Project Evaluation
- Subtask C: Synthesis and Lessons Learned

¹ Longitude 122 West, Inc., Menlo Park, CA, USA

² ECN, The Netherlands

³ INTA, Spain

⁴ IFE, Norway

⁵ Danish Gastechnology Center, Denmark

⁶ Research Center Julich, Germany

⁷ Hidrogena Aragon, Spain

⁸ IRL, New Zealand

⁹ EA Technology, UK

¹⁰ Sandia National Laboratories, Livermore, CA, USA

While the Annex 18 experts have evaluated many aspects of system performance, one area of focus has been permitting and safety experiences and public acceptance. In general the experiences have been positive, with high visibility and good public acceptance.

2. Integrated Hydrogen Demonstration Systems

During Phase 1 of Annex 18, nine systems were evaluated in some detail.[1] Permitting experiences were described previously.[2] During Phase 2, an additional nine projects are being evaluated in detail. These cover the spectrum of system types, including vehicles, refueling stations, grid-connected systems, and stand-alone renewable-powered systems. Fuel cell uses include buses, cars, telecom power, building heat and power and grid power. The systems under evaluation in Phase 2 are described briefly in Table 1.

Table 1. Integrated Hydrogen Systems evaluated by IEA HIA Annex 18, Phase 2

Project / location	Hydrogen source	Application
Zaragosa fueling station / Spain	Grid electrolysis	City shuttle mini-buses
Norwegian hydrogen highway / Norway	Renewable electrolysis	Hydrogen Prius and Mazda vehicles
Amsterdam / Netherlands	Steam reformer / electrolyzer	Fuel cell canal boat; vehicle (truck) refueling
Clean Energy refueling / Germany	Industrial reformer	Public refueling station
RES2H2 / Gran Canaria / Spain	Wind electrolysis	Desalination, power, vehicle fuel
Hydrogen community / Lolland / Denmark	Wind electrolysis	2 kW micro-fuel cell residential heat and power
Hydrogen Office Demonstration Centre / UK	Wind electrolysis	5 kW fuel cell for building power
Totara Valley / New Zealand	Wind electrolysis	7.5 kW, CHP for 5 farm houses
Hawaii hydrogen park / Hawaii	Wind electrolysis / Geothermal electrolysis	Stationary power, shuttle bus fuel

3. Permitting and Safety Experiences

For the hydrogen systems analyzed to date in Annex 18, various characteristics have been evaluated, including permitting and safety requirements and approaches, including the application of standardized regulations or templates. The projects fall roughly into the categories of vehicle refueling stations and stationary power systems. The challenges are similar, with some unique features.

3.1 Refueling stations and vehicles

Zaragosa, Spain

In Zaragosa, Spain, a refueling station was built in 2008 to fuel a variety of vehicles for the world's fair: EXPO 2008. The vehicles included several powered bikes, one fuel-size city bus,

and several small shuttle buses.[3] Since the EXPO closed in September 2008, the shuttle buses have remained operating in the city of Zaragoza. The permit for the station was approved by the local municipality, the Industrial regional supervisor, and the Zaragoza Council. The local station stores 57 kg gaseous hydrogen, at 350 bar. The design of the station followed the recommendations of the European ATEX* code. The keep-out distance from the hydrogen storage system is 5m.

The station has been in operation since June 2008, with no major incidents reported. Over 250 fillings occurred during the EXPO, dispensing over 1550 kg hydrogen.

HyNor Project

Two refueling stations opened in 2008 at nodes on the Norwegian hydrogen highway at Stavanger and Porsgrunn. As part of the HyNor project, the new stations required permitting from:

- Directorate for Civil Protection and Emergency Planning
- Local government

Other official institutions contacted included:

- Norwegian Metrology Service (for measurement and sale of H₂)
- Norwegian Public Roads Administration
- Local police- and fire department

The station at Stavanger is part of a public filling station. Safety measures include:

- A separation of 5m between the hydrogen and gasoline dispensers, and 2 m from the public road
- Crash barrier between H₂ dispenser and road
- Clear markings at the dispenser site
- Detailed safety procedures for personnel at station and local emergency preparedness

The station at Porsgrunn in Grenland is unattended. Hydrogen is provided by pipeline to the station from a local industrial site. Safety features include:

- A 3m high steel fence in a 5m radius safety zone around H₂ storage.
- Underground H₂ compression and storage
- Dispenser open to public.
- Clear markings at the dispenser site
- When filling, person is approximately 2m away from H₂ nozzle, filling activated on the side of the dispenser.

Two other stations on the Norwegian highway, in the vicinity of Oslo are due to open in 2009.

Clean Energy Partnership

The Clean Energy Partnership in Germany has successfully opened two public hydrogen fueling stations, one built and operated by Total, the other by ARAL. [4] The second is now closing, to be replaced by a Shell station. These first two stations were pioneers in Europe – open to the public to dispense hydrogen to local vehicles. The TOTAL station stores cryogenic liquid hydrogen. Many authorities and regulations were involved in the permitting. The component manufacturer had to certify that their components work in a safe way by safety analysis and complying with existing directives and standards. There is no new directive or standard for

* ATEX = European Commission safety standards for hazardous gases; ATEX is named after the French "ATmosphère EXplosible"

hydrogen filling station on the way because in the industry sector in Germany, hydrogen handling is common. For the verification of the safe operation of components and filling stations in Germany the national authorities (e.g. Technical Control Board, so called TÜV) checks the compliances with existing directives and standards. At the station, exclusion zones are as indicated in Figure 1.

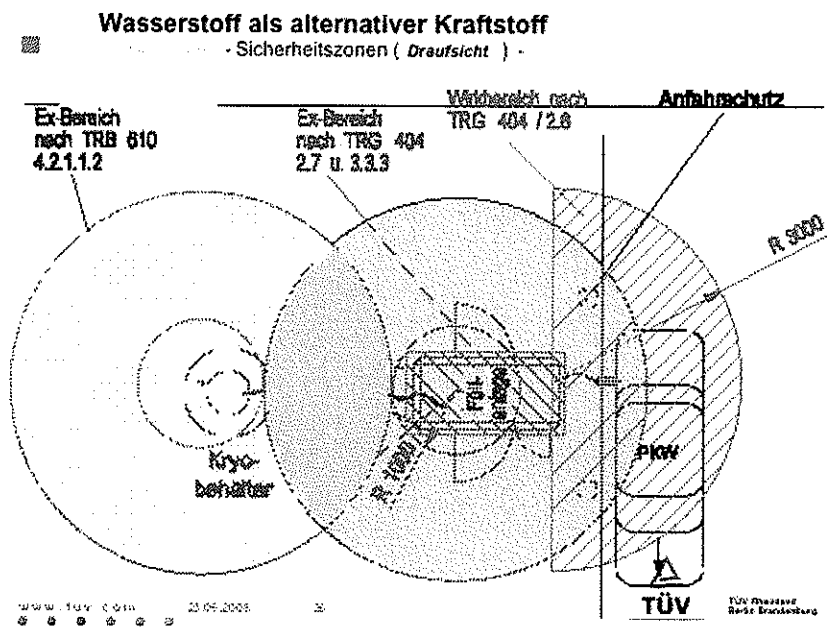


Figure 1. Exclusion Zones for Refueling Station in Berlin

In Germany a set of directives and standards exists for hydrogen applications e.g.

- technical directive of the ministry of environment (BMU-SFK)
- statutory order on hazardous incidents
- Device Safety Act
- Pressure Equipment Directive
- Technical directive conduits
- National standards
- Directives of the DVGW (German Technical & Scientific Association for Gas & Water)
- EU directives etc.

This is a manifold of standards and directives. It is not easy to decide which ones are applicable and have to be taken into account. This is more a question of learning and experience.

Amsterdam

Finally, Shell operates a hydrogen refueling station in Amsterdam. Based on the design for the station built originally to fuel a CUTE bus, the new station provides fuel for several trucks and a fuel cell canal boat, recently put into touring service. The boat has a storage of 24 kg of H₂ in composite cylinders at 35 Mpa. The safety requirements for the boat are handled as follows:

- o The Transport and Water Management Inspectorate is contacted for boat type registration and approval
- o The Port of Amsterdam authority is contacted to obtain a permit for operation of the boat on the river IJ

- The Inland Waterway Management authority of the city of Amsterdam is contacted to obtain a permit for operation of the boat in the canals. This authority consults the Fire Department for advice.
- The Fire Department includes the Quantitative Risk Analysis (QRA) performed for the boat in its advice.
- Safety features include separation of H₂, fuel cell system and electronics (as well as passenger) in different compartments by placing the H₂ storage in the back of the boat.
- The Transport and Water Management Inspectorate has adopted advises and guidelines developed by the Maritime Service provider Germanischer Lloyds (www.gl-group.com) for storage and use of hydrogen on board of ships.
- Furthermore future EU safety guidelines for boats (not yet implemented) known as ROS-R-guidelines are consulted and followed.

The requirements process for the station are summarized in Figure 2 below.

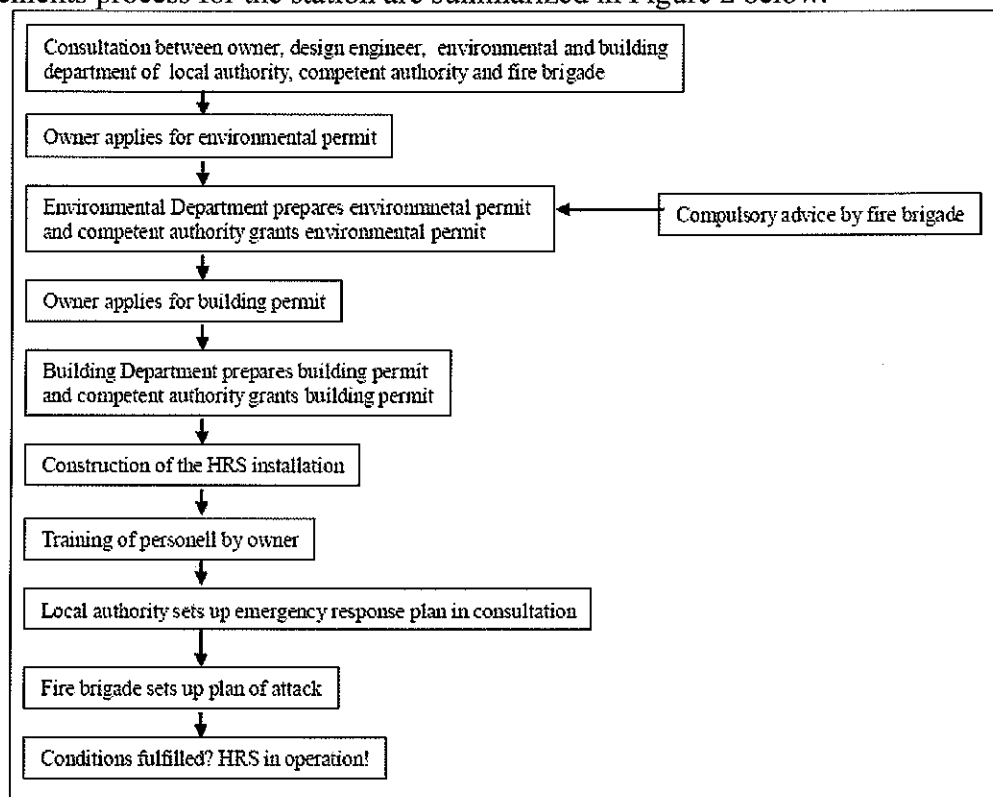


Figure 2 Flowchart of approval process for a hydrogen fuelling station in the Netherlands.

The safety requirements for the fuelling station are handled as follows:

Permits required:

- Building permit
- Environmental permit
- User permit

Authorities involved are:

- City of Amsterdam
- District authorities Amsterdam-Noord

- Fire Department
- The QRA has been performed by DNV (Det Norske Veritas). For the first fueling station (CUTE), 2 QRA's were performed by two institutes independent of each other.
- Both stations have been designed by Linde and comply with all relevant industrial safety regulation with respect to explosion safety, zones etc. (ATEX 137 guidelines).
- The permits provide a framework, which guides through all relevant aspects. H₂ is not treated as such, it is just a flammable or dangerous gas with risk of explosion. Regulations, codes and standards and safety features follow from there.

3.2 Stationary power systems

A number of other projects under evaluation as part of Annex 18 are renewables-based electrolysis systems.

ITC, Gran Canaria, Spain

In Gran Canaria, in Spain, the abundant wind resource is being used to provide much of the power on the island, including the desalination plant that delivers fresh water to the residents. The RES2H2 hydrogen project, funded by the EU, and constructed by the Instituto Tecnológico de Canarias (ITC), is an electrolysis system intimately connected with an innovative desalination approach. Permitting for the hydrogen system (electrolyzer, storage and fuel cell) was the responsibility of the local authorities (not national). The safety design is according to both Spanish and European law.[5] The security distance is 4 meters to the nearest building, 1.43 m free space around; risk analysis was carried out before the final design, and the fire protection is via dry chemical powder extinguisher. European ATEX and EIGA regulations were applied. Numerous Spanish regulations were also applied.

Lolland, Denmark

In Denmark, the small island community of Lolland has built a hydrogen pipeline to a number of houses in the village.[6] In each house, the hydrogen fuels a 2 kW fuel cell, providing both electric power and home heating. Approval of the design, equipment and installations was by both municipal and national authorities. These included the Danish Safety Authority, the Danish Working Environment Authority, and the Danish Emergency Management Authority. Among the regulations applied were the Pressure Equipment Directive and the ATEX directive, related to explosives. The community hydrogen storage tank is fenced, about 1 m from the nearest installation. The documentation needed to be extremely detailed because at the time there were no relevant codes or standards for some of the components, or for some applications CE-marking was not available, so that the suppliers were forced to do their own risk analysis. The installed fuel cell and outdoor pipe connection are shown in Figure 3.

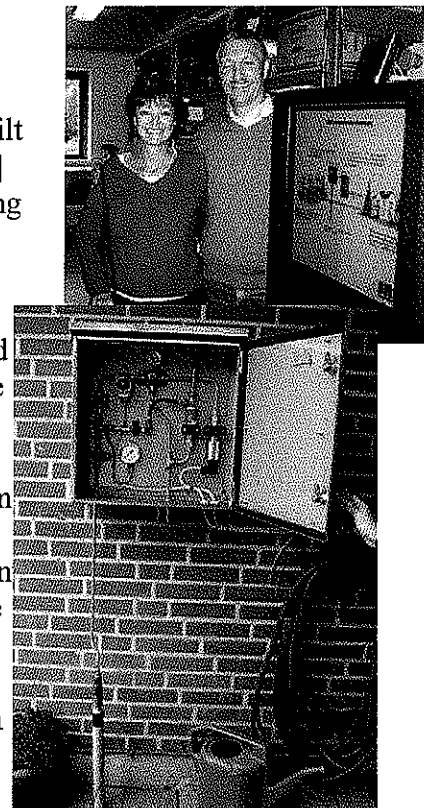


Figure 3. Hydrogen pipeline and fuel cell installation in Lolland, Denmark.

Totara Valley, New Zealand

In New Zealand, a wind turbine, electrolyzer, hydrogen pipeline, and fuel cell were installed, to serve a community of five farmhouses.[7] The arrangement is shown in Figure 4. The project developers addressed a number of issues, including hydrogen safety, environmental protection, and the electrical grid connection. Hydrogen safety was the responsibility of the local regional council, and approval for installation of the pipeline and hydrogen conversion equipment was obtained after an application, which showed that the scheme complied with relevant Hazardous Gas Regulations, which are based on International Standards. Approval for the wind generator installation was required under the Resource Management Act. Again this is the responsibility of the local regional council as the consenting authority, and was obtained after an application was lodged with written agreement from “affected” parties (residents in the region who could see the hilltop) and which showed that the scheme resulted in less than minor effects in the many potential areas of impact. Permission for grid connection is the responsibility of the local electricity distribution company (the lines company) under the Electricity Act, which can refuse permission to connect if they are concerned that the equipment is unsafe, or could degrade their system performance in any way.

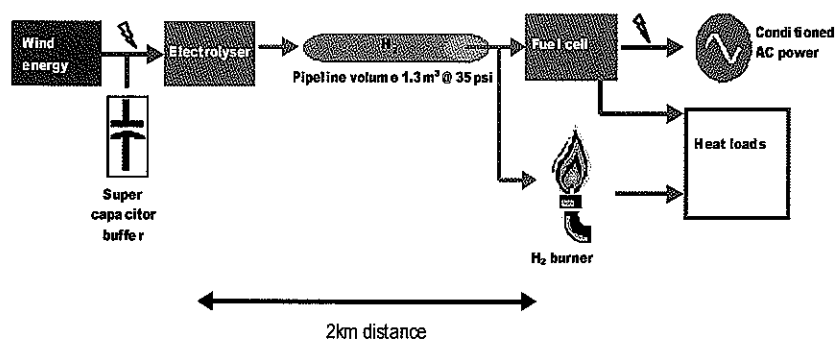


Figure 4. Totara Valley, New Zealand, Hydrogen System Arrangement

Big Island, Hawaii

In Hawaii, a wind-hydrogen system has been operating since 2007. Figure 5 shows the different locations at Kahua Ranch illustrating a general diagram of the final installation.[8] Concrete pads were poured in the hydrogen room and the gas tank location, and a firewall surrounds the hydrogen storage, tank which acts as a heat shield between the hydrogen storage tank and the facility. Fences also protect the area to keep out horses, sheep, and unauthorized humans.

HNEI state that guaranteeing safety in a demonstration hydrogen project is essential for their sustainability and public acceptance. The overall design criteria for the installation design was based on the safety requirements listed in the following U.S. codes and standards publications:

- NFPA 55: Standard for Storage, Use, and Handling of Compressed Gases and Cryogenic Fluids in Portable and Stationary Containers, Cylinders and Tanks
- NFPA 583: Installation of Stationary Fuel Cell Power Systems
- ASME B31.3: Process Piping
- CGA G-5.4: Standard for Hydrogen Piping
- CGA-5.5: Hydrogen Vent Systems

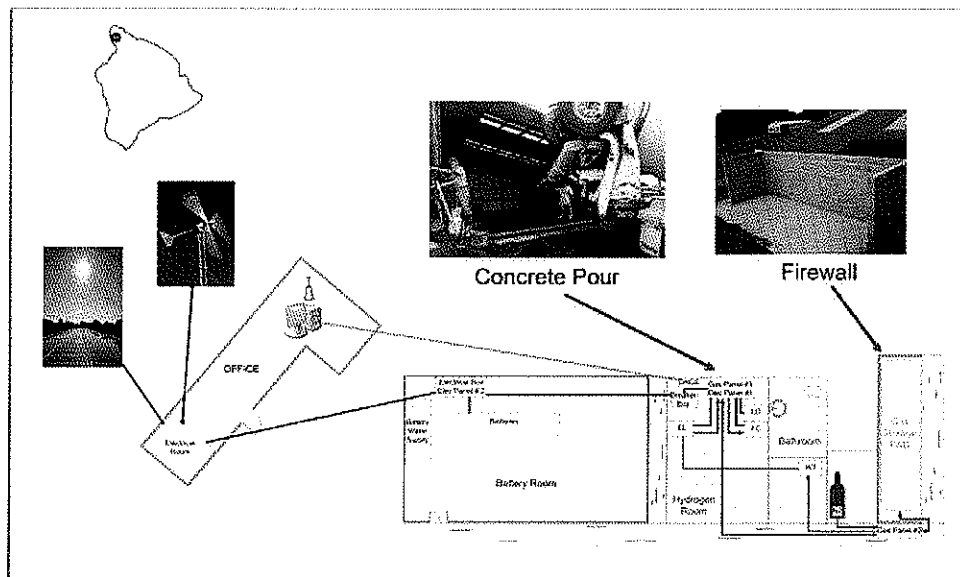


Figure 5: Kahua Ranch Layout

Safety control components were included in the installation including a hydrogen fire sensor, a hydrogen sensor, and an oxygen concentration sensor for controlling hydrogen purity. Three (3) emergency stop buttons identified by large signs are situated at different locations on the site. Many essential measurement sensors were duplicated in order to insure that gas leaks or component failure would be detected. A brick firewall was built surrounding the hydrogen storage. Warning signs identify restricted areas including the hydrogen storage area and the hydrogen room.

Other essential safety features included in the design are intended to address unattended events such as losing system control due to a DACS power shortage or a depressurization of the pneumatic line. In order to avoid hazardous situations, the interface was designed as a fail-safe system meaning that in such unattended events, the system stops safely: 1) all components are disconnected, 2) the gas storage is isolated, and 3) the gas lines are depressurized. The design was subjected to a safety analysis based on Fault Tree Analysis methodology.

Hydrogen Office, UK

In Fife, Scotland, the Hydrogen Office Demonstration Centre endeavours to accelerate the development of the hydrogen industry in a variety of ways. Its aim is to demonstrate the technology in commercial applications by

- increased access,
- showing reliability and robustness,
- verifying performance.

The project has been in development for several years, building on the experience of the PURE project in Unst. The project involves the installation of a wind tower, electrolyzer, hydrogen storage, and a fuel cell, all designed to provide power to a two-story office building. Permitting for this project this has been a truly ground-breaking activity.

Planning permission was required for each part of the Hydrogen Office (the office building and plant building, the hydrogen storage tank, and the wind turbine). Once planning permission had been achieved, and the energy system designed, the plans were presented to the Health and Safety Executive (HSE) for comment. Risk assessments were undertaken during the system design work, and an overarching risk assessment and safety management plan has now been developed. An application has also been submitted to the local network operator (Scottish Power) for a connection agreement to the public electricity network.

The Hydrogen Office Ltd has secured insurance for the project, though it is keen to continue to engage the insurance market to ensure that underwriters are fully aware of the issues involved in developing hydrogen energy systems for domestic and commercial hydrogen applications, with the aim of minimizing the risk premium resulting from a lack of understanding of the technology.

Consent was granted for the energy system and hydrogen storage tank before the consent for the wind turbine. There were a number of objections over the fuel cell and use of hydrogen, though the main opposition to the project was aimed at the application for the wind turbine.

Further discussion with the Health and Safety Executive is required with regard to the safety management systems, and the operating plans for the project. The experience of working with the Health and Safety Executive and carrying out the risk assessments to date has demonstrated the value of a standard format targeted for small scale domestic and commercial applications and a clear list of design guidelines. The current position requires developers to adopt the full range of safety precautions typically required for a larger system to reduce the risk that the system may have to be amended post installation at a prohibitive cost. It is important to learn from other European cities and work with the different stakeholders to establish guidelines and standards appropriate for this type of installation.

Discussions had to be held with the local fire brigade advisory service and the Council's Health and Safety officers. Because councils are unfamiliar with hydrogen, the responses vary from one council to another. A lot of education is therefore required and the process becomes long and drawn out with detailed designs and risk assessments. They also do not want to sign everything off before the equipment is bought so expensive changes could have been required further down the line. The Hydrogen Office was treated as a 'one off' and did not set a precedent. The Hydrogen Office worked with PURE from Shetland as they had experience of working through the issues with their council. Even without a UK standard there needs to be guidelines and best practice disseminated.

Summary

The experiences gathered from Annex 18, Phase 2 project evaluations are summarized in Table 2. Various permitting experiences and codes or standards applied to hydrogen demonstration projects have been described in this paper. Currently, Annex 18 is synthesizing key lessons learned from these experiences. A standardized approach is recommended for future projects.

Table 2. Permitting Experiences for Projects in IEA Hydrogen Implementing Agreement Task 18

Country	Projects	Location / Site Description	Hydrogen Storage	Permitting authority:	Safety Requirements / Codes and Standards
Refueling Stations / Vehicles					
Spain	Hydrogen filling station at Expo 2008 (grid/electrolysis)	Zaragosa / Public fair grounds; city operation through 2016	Compressed gas, 350 bar	Zaragoza City Council	ATEX codes*
Norway	Hydrogen filling station (grid/electrolysis), HyNor node	Stavanger, Porsgrunn public fueling stations; Prius vehicles	Compressed gas at 200, 350, and 850 bar	Directorate for Civil protection and Emergency Planning	Crash barrier between dispenser and road, fence around storage
Netherlands	Fuel cell tour boat	Amsterdam, city depot	Compressed gas, 35 MPa	City of Amsterdam	For the boat: Germanischer Lloyds guidelines and EU ROS-R; EU HyApproval
Germany	Clean Energy Project	Berlin	Cryogenic liquid	Federal government	TUV
Grid-connected or stand-alone power systems / some CHP					
Spain	RES2H2 (combined wind power and desalination)	Gran Canaria / industrial laboratory facility	500Nm ³ compressed gas, 25 bar	Regional authorities	ATEX codes
Denmark	Island power	Lolland / residential community	Gas storage, 6 bar	Danish Emergency Management Agency	ATEX Directive
UK	Hydrogen office	London office building	Gas storage	Health and Safety Executive	European codes
USA	Hydrogen power park (RE)	Kauhua Ranch / wind farm	Compressed gas, small volume	Local fire marshall	Public keep-out / NFPA
New Zealand	Renewable hydrogen pipeline / CHP	Totara Valley	Compressed gas	Local council	International codes

4. Toward Standardization

Within the various countries and regions, activities over the last few years have made significant moves toward establishing routine permitting guidelines, especially for refueling stations. Also, the recent formation of international activities such as HYPER (Hydrogen PERmitting), for example, is accelerating the move toward consistent permitting processes. [9] In January 2009, HYPER published the "Installation Permitting Guidance for Hydrogen and Fuel Cells Stationary Applications."

Europe

Many European projects are now referencing ATEX 137 and IGC 15/06 E in the designs of their hydrogen systems. ATEX is the European Commission safety standard for hazardous gases;

* ATEX = European Commission safety standards for hazardous gases; ATEX is named after the French "ATmosphère EXplosible"

ATEX is named after the French "*ATmosphère Explosible*." Regulation 137 applies directly to safety zones.

EIGA is the European Industrial Gas Association, similar to CGA Compressed Gas Association (USA) EIGA is a safety, quality and technically oriented organization representing the vast majority of European and also non-European companies producing and distributing industrial, medical and food grade gases. The member companies closely co-operate in safety, quality and technical matters to achieve the highest level of safety and environmental care in the manufacture, distribution and handling of gases. IGC 15/06 E is the revision of the original of 1996. It is a Code of Practice that has been prepared for the guidance / best practices of designers and operators of gaseous hydrogen stations. Its application will achieve the primary objective of improving the safety of gaseous hydrogen station operation.

Canada

In Vancouver, the Pacific Spirit Station is located on a federal site. Permitting was from the BC Safety Authority. In Victoria, the new station is located at a public transit facility. Permitting was also from BC Safety Authority, the Municipality and local fire department; the latter requires an emergency response plan. At Powertech, the hydrogen components are located on private property - an industrial site. HAZOPS and FMEA processes are applied. Although it was not in place for the design of these stations, the *Canadian Hydrogen Installation Code* has now been adopted for future stations on the Canadian Hydrogen Highway.

"The CHIC, which is the first of its kind, fills a gap and provides Canadian industry and regulatory authorities with a much needed tool for use with hydrogen installations." The need for such a code had been recognized from the outset by the Governments of Canada and Québec, which both sponsored the development of the new code. "Through the ecoACTION initiatives, our Government is committed to supporting the development of clean energy sources such as hydrogen." "This new code will further facilitate the commercialization of hydrogen and fuel-cell technologies as well as help build consumer confidence in the use of hydrogen as a clean, safe source of energy." As an example, the CHIC defines the installations requirements of hydrogen refilling stations that dispense gaseous hydrogen, whether the hydrogen is produced on site by water electrolysis or natural gas reforming or delivered by truck in a liquid or a gaseous form. It also provides the guidelines for the installation of fuel cells and internal combustion engines that provide emergency or back-up power to commercial buildings and residential homes.

United States

In the US, the Department of Energy leads the effort to develop standardized approaches to permitting and safety, and participates in the discussions of codes and standards. To date, many projects have followed the guidelines of the National Fire Protection Association (NFPA) for hydrogen storage. Guidelines for permitting hydrogen vehicle fueling stations have been drafted, as have some guidelines for stationary systems. The DOE has actively engaged communities in workshops and discussions to educate local permitting personnel.

In the US the Hydrogen Industry Panel on Codes (HIPOC) serves as an on-going forum to exchange information concerning the public safety aspects of the transition to hydrogen while developing and supporting the changes to codes and standards that are necessary to harmonize

the International Codes developed by the International Code Council (ICC) and codes and standards developed by the National Fire Protection Association (NFPA) affecting or relating to the storage, dispensing, use and handling of gaseous (GH₂) and liquefied hydrogen (LH₂) in ways that facilitate this transition.[10]

Global

With regard to standardization around the globe, there has recently been progress on getting harmony between the U.S. hydrogen codes and standards as far as separation distances.

A new table of separation distances is going into NFPA 55 and NFPA 2 and this table will also be put into NFPA 52. HIPOC voted in November 2008 to have the International Fire Code also reference this new NFPA 55 table for separation distances. The HIPOC group is currently trying to get the same processes used for NFPA to be used in the development of a table for hydrogen fueling stations in the ISO code.

5. References

1. Øystein Ulleberg, et al, "Hydrogen Demonstration Systems Evaluation," Task 18 Phase 1 Report; <http://www.ieahia.org/page.php?s=publications&p=technical>; 2008.
2. Susan Schoenung, et al, "Pioneering Experiences in Permitting and Safety of Integrated Hydrogen Systems." Proceedings NHA, 2007.
3. Ismael Aso, et al, "Urban Transport with Hydrogen Technologies at the International Exhibition: EXPO Zaragoza," Proceedings of the World Hydrogen Energy Conference, Brisbane, Australia, June 2008.
4. Clean Energy Partnership; <http://www.cleanenergypartnership.de/index.php>; 2009.
5. European Directive N° 1999/92/CE
6. Jesper Krogh Jensen and Jesper Bech-Madsen, "Utilization Of Hydrogen And Fuel Cell Technology For Micro Combined Heat And Power Production," <http://www.hydrogen-community.dk/>, 2008.
7. <http://www.irl.cri.nz/newsandevents/innovate/Innovate64/Distributedenergyprojectafirstforruralcommunities.aspx>; 2006
8. Emma Stewart, et al, "Analysis of Load, Hydrogen Control Systems and Economics for the Hawaii Hydrogen Power Park," Proceedings, this conference, 2009.
9. HYPER website; <http://www.hyperproject.eu/> 2009.
10. HIPOC website; <http://www.hydrogenandfuelcellsafety.info/hipoc/index.asp>; 2009.