

**Development of H<sub>2</sub> Safety Expert Groups and due diligence tools  
for public awareness and trust in hydrogen technologies and  
applications**



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**Date of this document:**

27 February 2015

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## 1 Timing Release

The official H<sub>2</sub>TRUST website includes diverse information available to visitors, some of them are:

- description of the project aims and the benefits expected from the coordination and support action;
- general information about H<sub>2</sub>TRUST consortium and the activities carried out during the development of the project itself as well;
- updated news and events about hydrogen safety aspects, H<sub>2</sub> safety updates, events and international initiatives;
- online tools and features specifically developed for the purpose of the H<sub>2</sub>TRUST project;
- an online library, where references related to hydrogen are available;
- deliverables from the H<sub>2</sub>TRUST project (these deliverables will be uploaded once they are approved by the FCH JU).

The website is available at the URL <http://h2trust.eu/> since September 2013 (M4).

H<sub>2</sub>TRUST resources, findings and deliverables are made available on-line on the portal, which is being integrated as an extension of the FAST/EHA internet presence, with the intention of becoming the standard reference for safety matters in the FCH industry.

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## 2 Online portal structure

### 2.1 Home page

The Home Page represents the “landing page” of the project from external access and its main window to the outer world.

It contains the elements of the graphic representation of the project (project logo and graphics), as well as required EU-FCH Disclaimers.

The Home Page presents the main information of the project in a user-friendly manner, in order to facilitate navigation and of main contents.

Graphics have been studied since the beginning to be compatible and in line with EHA/FAST websites, where the H<sub>2</sub>TRUST will be integrated, with the view of ensuring sustainability and follow-up after the project duration.

Main parts of the Home Page are:

- **Menu**
- **H<sub>2</sub>ighlights**
- **Main body (central part of the Home page)**
- **Contacts Link**
- **Registration link**

In the following pages we explain more in detail each of the above-mentioned parts.

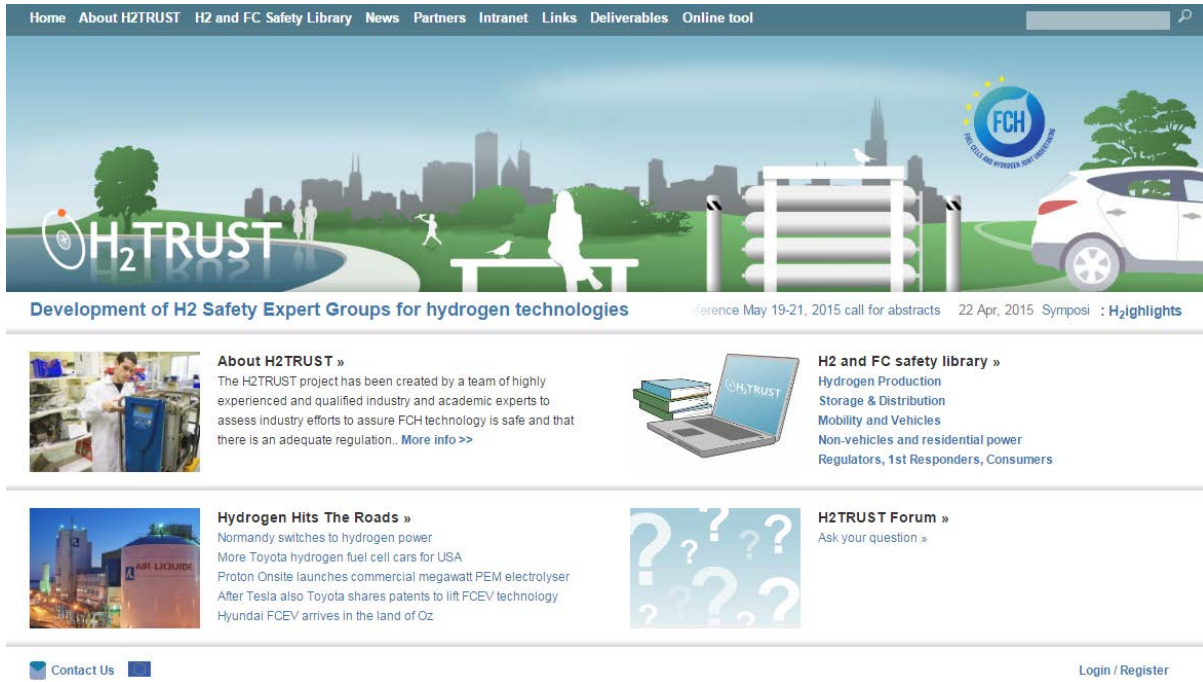


Figure 1. H<sub>2</sub>TRUST Home Page

## 2.2 Menu and Main sections

As stated at the beginning of this section, the H<sub>2</sub>TRUST online portal is composed by the Home page and the other main sections.

From the Home Page, visitors can use the **Menu**, placed horizontally on the top of the page, just below the header, to access the different sections and subsections.

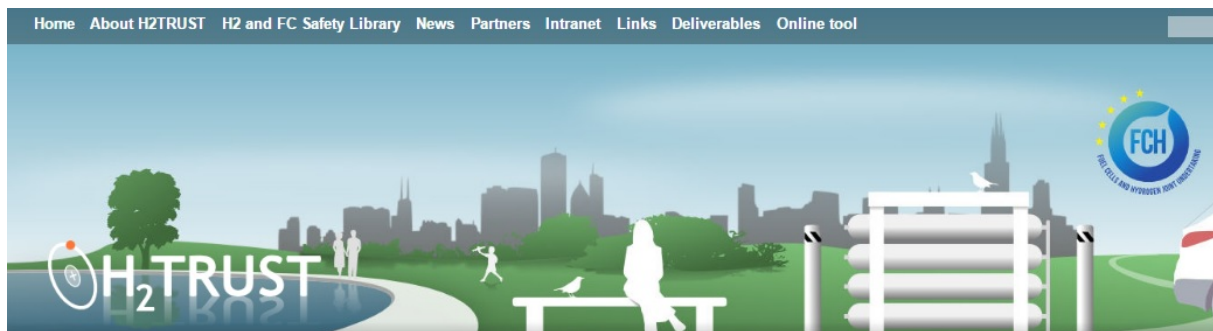


Figure 2. H<sub>2</sub>TRUST Menu

In the following of the paragraph the contents of each section of the Menu are described.

### 2.2.1 Section “About H<sub>2</sub>TRUST”

This first section describes the main content of the H<sub>2</sub>TRUST project, to let the user understand about general and specific project objectives and main goals.

Home About H2TRUST H2 and FC Safety Library News Partners Intranet Links Deliverables Online tool

**About H2TRUST** Symposium, Fuel cells – energy and transportation, Szczecin, Poland : H2highlights

Although many predictions for the hydrogen economy in the last decade have proven optimistic, the maturity of it is now increasingly evident by the substantial investments in R&D, demonstration and industrialisation made by public and private institutions in Europe. The USA and Japan are leading the hydrogen based energy infrastructure, becoming a mainstream solution for society's need to transition to clean, renewable and widely available energy sources.

To ensure that non-technical barriers to the deployment of Fuel Cell and Hydrogen (FCH) technologies are properly addressed, the H2TRUST project has been created by a team of highly experienced and qualified industry and academic experts with the following objectives:

- Assess industry efforts to assure FCH technology is safe and that there is an adequate regulation, hazard awareness, incident readiness and ability to respond to public concerns.
- Hazard and risk assessment in the FCH industry in each of the main application areas (H2 Production, Storage and Distribution, Mobility and Vehicles, Non-vehicles and residential power generation).
- Systematically map safety issues and assess how they are addressed.
- Compile information demonstrating safety due diligence and best practices.
- Seek input from previous, on-going and upcoming Fuel Cells and Hydrogen Joint Undertaking (FCH JU) demonstrations and pre-normative and training projects and from similar international activities.
- Make recommendations for further safety efforts by FCH community.
- Develop communications network to manage public reaction to incidents and give documented responses.
- Disseminate the results so as to create a long lasting culture of safety practices in the industry and a legacy of tools and knowledge serving to reinforce best practices and assure public confidence.

H2TRUST is a response to the FCH JU call for proposals in their Annual Implementation Plan of 2012, page 101(Topic SP1-JTI-FCH.2012.5.5: Assessment of safety issues related to fuel cells and hydrogen applications).

**Related Posts**

- Birmingham FC/H2 Conference May 19-21, 2015 call for abstracts  
Posted on 26 February, 2015
- Symposium, Fuel cells – energy and transportation, Szczecin, Poland  
Posted on 26 February, 2015
- Risk assessment  
Posted on 19 February, 2015

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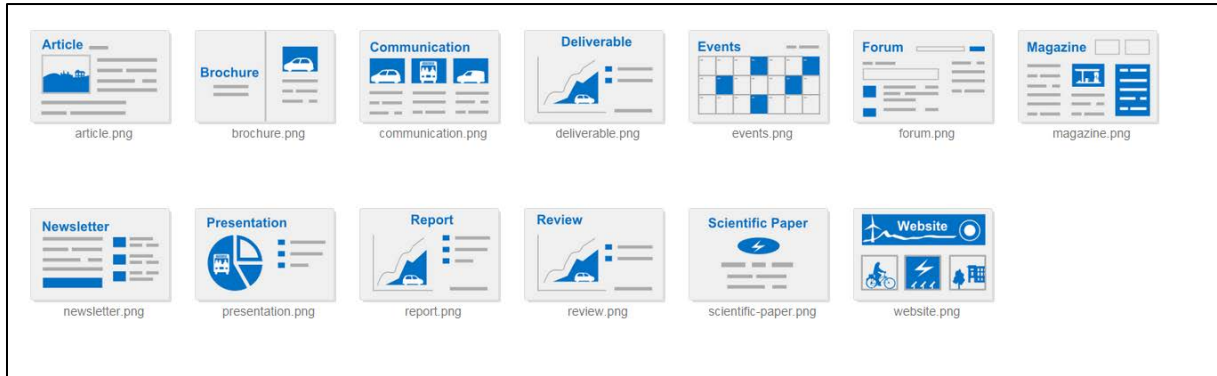
Figure 3. About H<sub>2</sub>TRUST

## 2.2.2 Section “H<sub>2</sub> and FC Safety Library”

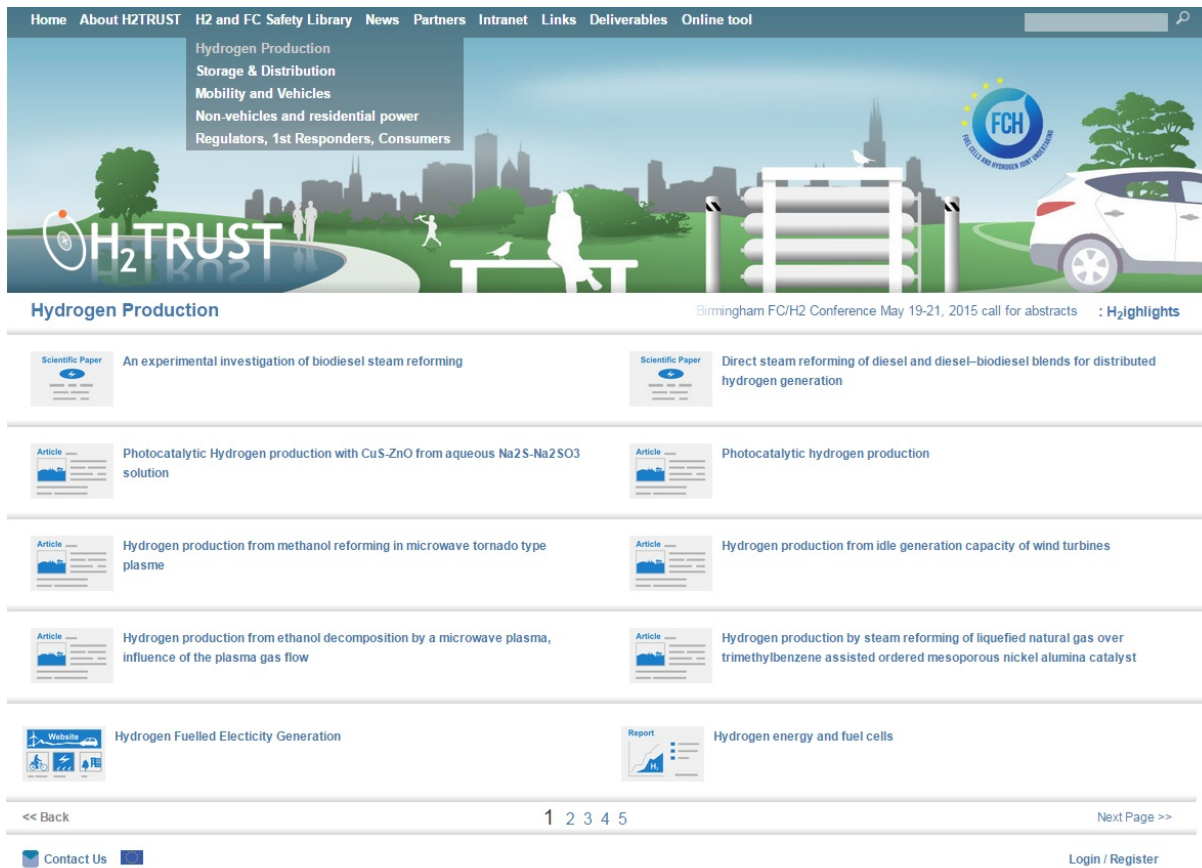
**Figure 4. H<sub>2</sub> and FC Safety Library**

In this section, hydrogen related documents can be found taking into account the following classification: Hydrogen Production, Storage & Distribution, Mobility and Vehicles, Non-Vehicles and Residential Power, and Regulators, 1<sup>st</sup> Responders, Consumers. By clicking in the corresponding section (“View all”), all the related references will appear (see Figure 5-9). The contents of the H<sub>2</sub> and FC Safety Library are connected with the task 2.3 Literature study and discovery, focused on the creation of the online project reference source. The on-

line library is including 145 documents. The layout of each section of the on-line library shows the title and an icon which explains the type of the document.



**Figure 5 Library - document types icons**



**Figure 6. Library - section Hydrogen Production**

Home About H2TRUST H2 and FC Safety Library News Partners Intranet Links Deliverables Online tool

Hydrogen Production  
Storage & Distribution  
Mobility and Vehicles  
Non-vehicles and residential power  
Regulators, 1st Responders, Consumers

**Storage & Distribution** 1, 2015 call for abstracts 22 Apr, 2015 Symposium, Fuel cells – er : H<sub>2</sub>ighlights

Optimization of hydrogen vehicle refueling via dynamic simulation	On optimal investment strategies for a hydrogen refueling station
Hydrogen Storage: Compressed Gas	Hydrogen refueling station costs in Shanghai
Hydrogen refueling infrastructure design for personal mobility devices using Frugal Engineering Approach	Hydrogen infrastructure for the transport sector
Hydrogen Fuelled Electricity Generation	Hydrogen energy stations: along the roadside to the hydrogen economy
Feasibility study on hydrogen refueling infrastructure for fuel cell vehicles using the off-peak power in Japan	Experimental and numerical study on temperature rise within a 70 MPa type III cylinder during fast refueling

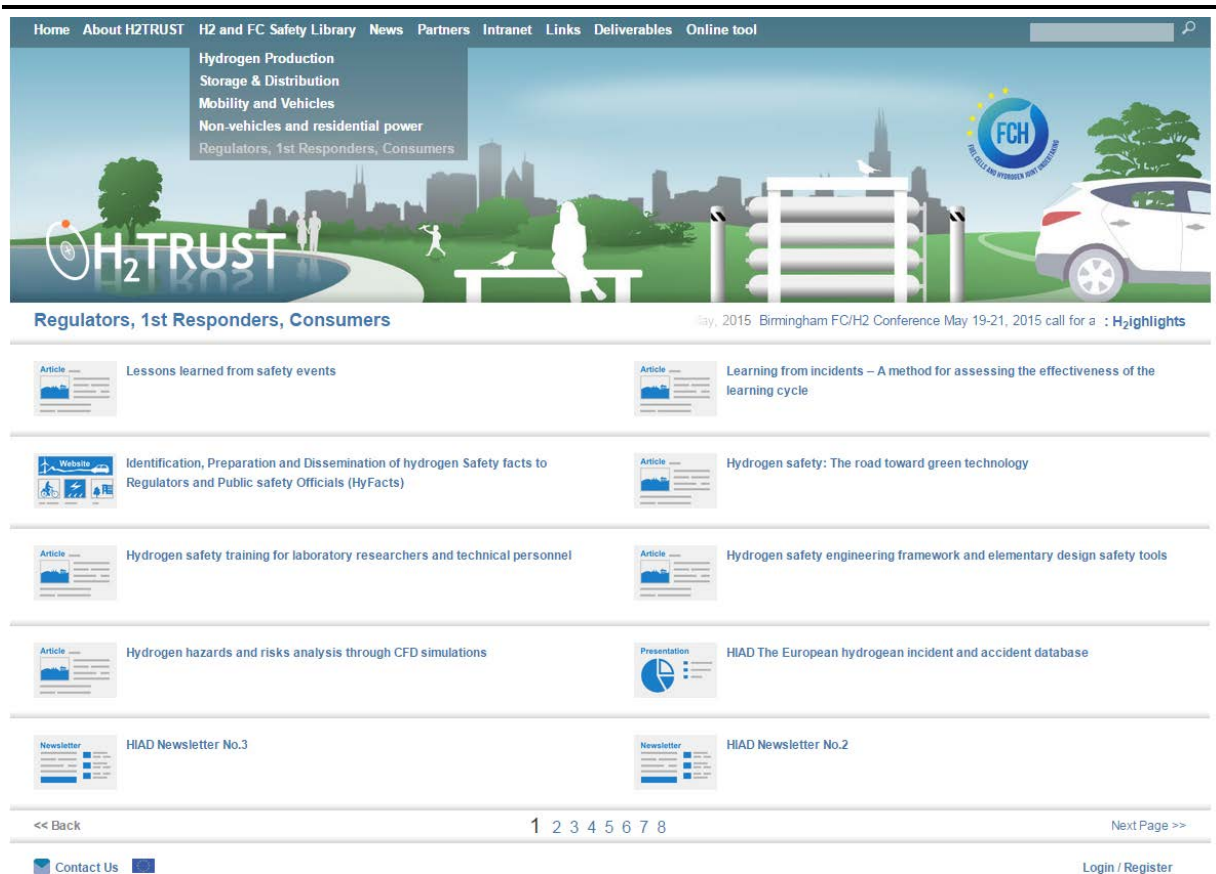
<< Back 1 2 3 4 Next Page >>

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Figure 7. Library - section Storage & Distribution

Figure 8. Library - Section Mobility and Vehicles

Figure 9. Library - Section Non Vehicles and Residential Power



**Figure 10. Library - Section Regulators, 1<sup>st</sup> Responders, Consumers**

Finally, by clicking in the title of the document you want to consult, you can see all the related information (Authors, Language, Link -where the document can be found-, Reference, Type of document, Year of publication and Keywords).



**Figure 11. Detail on the Article**

### 2.2.3 Section “News”

The News and event sections are updated sections with the latest news on Hydrogen and Fuel Cells and the upcoming related events. The News section is to report news of interest to the website visitors focusing on what is happening in fuel cell and hydrogen world on the academic level, industrial level and political level. As part of the “News” section on the H<sub>2</sub>TRUST website, a specific page is dedicated to News related to safety of Hydrogen and FCH technologies. (Fig. 12-15).



Figure 12. News

Home About H2TRUST H2 and FC Safety Library News Partners Intranet Links Deliverables Online tool

Events  
 H2 Safety Updates  
 Latest News

**Events** Conference May 19-21, 2015 call for abstracts 22 Apr, 2015 Sym: H2highlights

**Birmingham FC/H2 Conference May 19-21, 2015 call for abstracts**  
 The University of Birmingham Fuel Cell & Hydrogen Technical Conference 2015 will be held at the Millenium Point, Curzon Street, Birmingham, B4 7XG on the... [More info >>](#)

**Symposium, Fuel cells – energy and transportation, Szczecin, Poland**  
 Please find the agenda here

**Hypac Expo**  
 Hypac Expo, a pioneering hydrogen and fuel cell exhibition, will be organised in parallel with the Salon Bois Energie and Biogaz Europe... [More info >>](#)

**European Electric Vehicle Congress 2014**  
 The European Electric Vehicle Congress strenghtens its position as global platform to foster exchange of views between the R&D, the industry, the authorities, the end-users... [More info >>](#)

**FCH JU Stakeholders Forum 2014**  
 The Fuel Cells and Hydrogen Joint Undertaking is organizing its 1st Stakeholder Forum under the new European Research and Innovation Program "Horizon 2020". The achievements of the... [More info >>](#)

**The 6th International Conference on Hydrogen Safety**  
 The 6th International Conference on Hydrogen Safety (ICHS 2015) will be held in Tokyo, Japan on October 19-21, 2015 under the auspices of the... [More info >>](#)

**Workshop: How LCA Reports Can Contribute To Better Business Planning**  
 Workshop: How LCA Reports Can Contribute To Better Business Planning Brussels –11:30 – 13:00 Monday 10 November 2014 (times to be confirmed; this workshop will... [More info >>](#)

**Hyindoor Final Workshop 2014**  
 Hyindoor Final Workshop 2014 Date: 11 December 2014 – 9:00-18:00 Place: Les Loges-en-Josas, France (on the way between Paris and Versailles) Venue: Relais de Courlaunde Click here... [More info >>](#)

**5th International Conference on Hydrogen Safety**  
 The 5th International Conference on Hydrogen Safety (ICHS 2013) will be held in Brussels, Belgium on September 9-11, 2013 under the auspices of the International Association... [More info >>](#)

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Figure 13. News - Events

Home About H2TRUST H2 and FC Safety Library News Partners Intranet Links Deliverables Online tool

**Events**  
[H2 Safety Updates](#)  
[Latest News](#)

**H2 Safety Updates**
: H2ighlights

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*UL 2267 Standard for Safety: Fuel Cell Power Systems for Installation in Industrial Electric Trucks, is currently under revision.*

Scope of UL 2267: The requirements cover fuel cell power systems currently noted as intended to be installed in type E, industrial trucks used in locations as defined in the Fire Safety Standard for Powered Industrial Trucks including Type Designations, Areas of Use, Conversions, Maintenance and Operations NFPA 505, and the National Electrical Code NFPA 70. The scope only covers those systems that incorporate a permanently mounted pressure vessel containing compressed hydrogen gas for designs that are fueled without the pressure vessel being removed from the industrial truck (on board fueling). At this time, the standard is limited to systems with maximum pressures of 25 MPa or 35MPa.

The standard was published in May 2006 as an ANSI standard, and is available through UL. The document was recently revised to address those areas of UL 2267 affecting high pressure fuel containment to appropriately address safety concerns of current technology. Specific revisions to address the following concerns were recently completed:

- a. Develop cycling and other tests of high pressure systems as needed,
- b. Address instructions and markings, and
- c. Address End of Life Criteria

The revisions were developed by UL's UL 2267 Standard Technical Panel (STP) High Pressure Task Group which included members from the automotive sector, fuel cell industry, industrial truck industry, government, laboratories, and academia. These revisions include:

- scope changes to address current technology including limiting the scope to systems with maximum pressures of 25 MPa or 35MPa and onboard refueling;
- revision of high pressure system terms, addition of diagrams and a comparison table of high pressure terms to better harmonize with related standards;
- compliance of hydrogen pressure vessels to ISO TS 15869 for heavy usage industrial truck service (i.e. a minimum of 11,250 full fill cycles representing a 10 year life);
- restrictions on the types of materials that may be utilized for the hydrogen pressure vessels;
- revisions to the piping and component requirements for the high pressure hydrogen lines including reference to ASME B31.12 for hydrogen piping;
- a revised overpressure and over-temperature protection section to include requirements based upon current protection mechanisms for high pressure hydrogen systems; and
- nameplate and documentation for end of service life of the hydrogen pressure vessels.

The revised UL 2267 standard with the recent high pressure section changes is available for purchase on UL's website [www.ul.com](http://www.ul.com).

However, even though the work of the High Pressure Task Group has been completed, there is a current proposal bulletin out for balloting that addresses tank replacement markings, changes to vibration and other testing and additional proposals for the pressure vessel section. The ballot closing date is July 11, 2011. Follow up revisions to the standard such as replacing the "Type E" industrial truck designation with the new industrial truck "Type CGH" (compressed gaseous hydrogen) designation in accordance with NFPA 505 are planned, to address developments in the industry and the codes that affect it.

UL proposal bulletins are available to the UL STP members free of charge and are available to the general public for purchase at UL's website [www.ul.com](http://www.ul.com).

Additional background information on UL 2267 was presented in a short course at the 2009 Fuel Cell Seminar, and is available online at [www.hydrogenandfuelcellsafety.info/2009/dec/shortCourse\\_florence.pdf](http://www.hydrogenandfuelcellsafety.info/2009/dec/shortCourse_florence.pdf).

For additional information, please contact Laurie Florence [atlaurie.b.florence@us.ul.com](mailto:atlaurie.b.florence@us.ul.com).

**Related Posts**

**Birmingham FCH2 Conference May 19-21, 2015 call for abstracts**  
Posted on 26 February, 2015

**Symposium, Fuel cells – energy and transportation, Szczecin, Poland**  
Posted on 26 February, 2015

**Hypac Expo**  
Posted on 10 February, 2015

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Figure 14. News - H<sub>2</sub> Safety Updates

Home About H2TRUST H2 and FC Safety Library News Partners Intranet Links Deliverables Online tool

Events  
H2 Safety Updates  
Latest News

**Latest News** 15 Birmingham FC/H2 Conference May 19-21, 2015 call for abstrac : **H2ighlights**

**H2TRUST – Final workshop**  
Joint workshop will be organised by the projects: H2Trust, SUAV, Hycarus and HYPER and will take place on Wednesday 25th February.. [More info >>](#)

**European bus manufacturers and leading mayors step up for fuel cell electric buses**  
European bus manufacturers and city representatives announce the commercialisation of fuel cell electric buses for urban transport in Brussels On the occasion of the FCH JU.. [More info >>](#)

**Carbon Breakthrough: US, China Make Milestone Agreement to Fight Climate Change**  
President Barack Obama pledged deeper U.S [More info >>](#)

**H2FC European Infrastructure opened the sixth call for proposal**  
H2FC European Infrastructure is a European Research Infrastructure funded as a 4-years project by the European Commission within the frame of FP7 "Capacities" [More info >>](#)

**EU leaders agree to tough carbon regulations to spur renewable energy development and fight climate change**  
European Union leaders backed the most-ambitious carbon emissions goals of any major economy, in a bid to crank up pressure on the U.S [More info >>](#)

**The latest Eurobarometer survey results**  
Protecting the environment is important to Europeans The latest Eurobarometer survey results focusing on the environment have been released [More info >>](#)

**Sandvik Materials Technology Testing Fuel Cell Cars**  
On 16 September Sandvik inaugurated and Sandviken Municipality a month-long pilot project on fuel cell cars [More info >>](#)

**The 6th International Conference on Hydrogen Safety, first call for papers**  
The 6th International Conference on Hydrogen Safety, first call for papers - abstracts deadline is Dec [More info >>](#)

**First HyResponse Workshop on H2 safety training a success!**  
More than 70 participants attended the the first international HyResponse project workshop on hydrogen safety training for first responders co organized by FAST in cooperation.. [More info >>](#)

**World's First Post Graduate Programme in Hydrogen Safety**  
Competitiveness of hydrogen and fuel cell systems directly depends on their safety characteristics and professional provision of safety in facilities they are used [More info >>](#)

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Figure 15. News - Latest News

## 2.2.4 Section “Intranet”

This section of the portal (“back-end”) has the main purpose of creating an area of sharing of information and documents among project partners, EC officials and relevant accredited stakeholders.

A specific “Registration Form” has been developed as part of the H<sub>2</sub>TRUST portal, in order to allow encrypted access to this area by project partners and accepted users.

Figure 16. Intranet

### 2.2.5 Section “Links”

The Links section is including hydrogen and fuel cells third parties websites and blogs, where H<sub>2</sub>TRUST website link is published.

Home About H2TRUST H2 and FC Safety Library News Partners Intranet Links Deliverables Online tool

**Links** Symposium, Fuel cells – energy and transportation, Szczecin, Pol : H2ighlights

Full name of the project	Acronym	Website	More info
High Pressure Hydrogen All Electrochemical Decentralized Refueling Station	Phaedrus	<a href="http://www.phaedrus-project.eu">www.phaedrus-project.eu</a>	
Fuel Cell Based Power Generation	FOGEN	<a href="http://www.fogen.com">www.fogen.com</a>	
Pre Normative Research on Gaseous Hydrogen Transfer	HYTRANSFER	<a href="http://www.hytransfer.eu">www.hytransfer.eu</a>	
Material Testing and Design Recommendations for Components exposed to Hydrogen enhanced fatigue	MATHRYCE	<a href="http://www.mathryce.eu">www.mathryce.eu</a>	
High energy DEnsity Mg-Based metal hydride storage System	EDEN	<a href="http://www.h2eden.eu">www.h2eden.eu</a>	
Development of solid state hydrogen storage from fundamentals to application	BORASTORE	<a href="http://www.borastore.eu">www.borastore.eu</a>	
Marie Curie ITN ECOSTORE – Novel Composite Metal Hydrides for Efficient and Compact Storage of Renewable Energy as Hydrogen and Electricity	ECOSTORE	<a href="http://www.ecostore-itn.eu">http://www.ecostore-itn.eu</a>	
HyTIME	HyTIME	<a href="http://www.hy-time.eu/hytime">www.hy-time.eu/hytime</a>	
Hydrogen from RES: pressurised alkaline electrolyser with high efficiency	RESelyser	<a href="http://www.reselyser.eu">www.reselyser.eu</a>	
Improvements to Integrate High Pressure Alkaline Electrolysers for Electricity/H2 production from Renewable Energies to Balance the Grid	ELYGRID	<a href="http://www.elygrid.com">www.elygrid.com</a>	
New Method for Superior Integrated Hydrogen Generation System 2+	NEMESIS2+	<a href="http://www.nemesis-project.eu">www.nemesis-project.eu</a>	
Compact Multifuel-Energy to Hydrogen converter	COMETHy	<a href="http://www.cometry.enea.it">www.cometry.enea.it</a>	
Fuel Cell Coupled Solid State Hydrogen Storage Tank	SH2S	<a href="http://www.sh2s.eu">www.sh2s.eu</a>	
Hydrogen sensors for the safe use of hydrogen	H2SENSE	<a href="http://www.h2sense.calm.de">www.h2sense.calm.de</a>	
Construction of improved HT-PEM MEAs and Stacks for Long Term Stable Modular CHP Units	CISTEM	<a href="http://www.project-cistem.eu">www.project-cistem.eu</a>	
Fluid Management component improvement for Back up fuel cell systems	FLUMaBACK	<a href="http://www.flumaback.eu">www.flumaback.eu</a>	
SOFCOM Demonstration Plant	SOFCOM	<a href="http://www.sofcom.eu">www.sofcom.eu</a>	
Advanced Multi-Fuel Reformer for Fuel CELL CHP Systems	ReforCELL	<a href="http://www.reforcell.eu">www.reforcell.eu</a>	
Simulation based dimensioning and integration approach for fuel cells operated as domestic mCHP Systems	Asterix3	<a href="http://www.asterix3.eu">www.asterix3.eu</a>	
DiDOD Converter-based Diagnostics for PEM systems	D-CODE	<a href="https://dcode.eter.kit.edu/">https://dcode.eter.kit.edu/</a>	
STationary PEM fuel cells with lifetimes beyond five YEARS	STAYERS	<a href="http://www.stmf.no/Projectweb/Stayers">www.stmf.no/Projectweb/Stayers</a>	
-	LOTUS	<a href="http://www.lotus-project.eu">www.lotus-project.eu</a>	
Integrated low temperature methanol steam reforming and high temperature polyne	BeingEnergy	<a href="http://www.beingenergy.eu">www.beingenergy.eu</a>	
Integrated Hydrogen Power Packs for Portable and Other Autonomous Applications	HYPER	<a href="http://www.hyperportablepower.com">www.hyperportablepower.com</a>	
Direct Methanol Fuel Cells	DURAMET	<a href="http://www.duramet.eu">www.duramet.eu</a>	
Hydrogen Cells for Airborne Usage	HYCARUS	<a href="http://www.hycarus.eu">www.hycarus.eu</a>	
Novel CATalyst structures employing Pt at Ultra Low and zero loadings for Automotive MEAs	Catapuit	<a href="http://www.catapuit-fuelcells.eu/">http://www.catapuit-fuelcells.eu/</a>	
Solar To Hydrogen Hybrid Cycles	SOL2HY2	<a href="https://sol2hy2.eu/coord.com/">https://sol2hy2.eu/coord.com/</a>	
Assessing the potential, actors and business models of large-scale underground hydrogen storage in Europe	HyUnder	<a href="http://www.hyunder.eu/">http://www.hyunder.eu/</a>	
Technology Monitoring and Assessment	Temonas	<a href="http://www.temonas.eu/">http://www.temonas.eu/</a>	

**Related Posts**

Birmingham FCH2 Conference May 19-21, 2015 call for abstracts  
Posted on 26 February, 2015

Symposium, Fuel cells – energy and transportation, Szczecin, Poland  
Posted on 28 February, 2013

Risk assessment  
Posted on 19 February, 2015

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Figure 17. Links

## 2.2.6 Section “Deliverables”

In this section, all the public deliverables resulting from the H<sub>2</sub>TRUST project, will be uploaded in order to be disseminated not only for experts but also for the public in general.

These documents will be available once the FCH JU has approved them.

These deliverables are:

- D2.1 Framework and methodology
- D2.2 Reference Benchmark for H<sub>2</sub> production-storage-distribution technologies
- D2.3 Literature and Knowledge Base
- D2.4 Mirror groups organisation chart and Data gathering procedures
- D3.1 State of play H<sub>2</sub> issues (5 Chapters)
- D4.1 FCH Safety Issues, Industry Best Practices, and Recommendations
- D4.2 Safety Risk Assessment
- D4.3 Public Safety Assessment
- D5.1 Online portal
- D5.2 Assessment and Due-Diligence Tool
- D5.3 Demo, conference and trade fair kit.
- D5.4 Dissemination implementation measures checklist.

## 2.2.7 Section “Online Tool”

Beyond project deliverables, in order to contribute in a practical manner to safety and trust among FCH stakeholders and the general public, under this section the portal features the following relevant building blocks:

1. **Advanced Search engine:** It uses modern semantic web techniques and tools based on a series of funded EU projects (TechTeasy, InSearch) to continuously crawl the web to find relevant safety related literature to be structured within categories and a continuously updated searchable H<sub>2</sub> safety document repository. Pages crawled are indexed and processed so that the results displayed are ordered on the basis of their relevance.

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**2. Hazard and consequences Tables:** These Tables have been structured in Task 4.2 as a result of the development of the methodology for risk assessment performed by TU/e (see deliverable D4.2 for more information).

These tables are based on the identification of all possible hazard types related to the hydrogen process considered. Based on the list of hazard types, the suitable hazard identification method (e.g. HAZID + FTA, etc) can be applied for each type of hazard.

The final tables report the list of Hazard Type, Hazardous Event, Initiating Cause, Prevention Controls, Consequences, and Mitigation Controls.

The user can either scan the tables to identify the hazard type or navigate the tables by applying filters on the hazard type and hazardous event. These tables are also the starting point for the risk assessment tool (see also D 5.2).

**3. H<sub>2</sub> due diligence safety risk assessment tool:** Based on the H<sub>2</sub>TRUST FCH stakeholders and analyses model as well as the reference benchmark for production-storage-distribution technologies, a specific on-line tool (result from Task 5.2) is made available for whoever wants to use it to assess its safety readiness/adequacy.

It has to be noted that the tool is not intended to be an exhaustive tool for risk assessment, but more a “guiding instrument” in the hands of users to help them understand the steps needed to perform a solid risk assessment. To this end, the main parameters involved, the mathematical and physical models that regulate the different hazard situation and potential consequences, have been studied for several case studies, as well as how these are calculated and treated to evaluate the risk associated to a certain technology, process, plant, involving hydrogen.

The tool makes some assumptions in order to be user-friendly and shows them as well as the formulas used for the calculation, in a step-by-step flavour that should be very handy for users.

In the following Figures we show the screenshots of the “Online Tool” section Menu and the single building blocks. For a more detailed description of the H<sub>2</sub> due diligence safety risk assessment tool please refer to Deliverable 5.2.

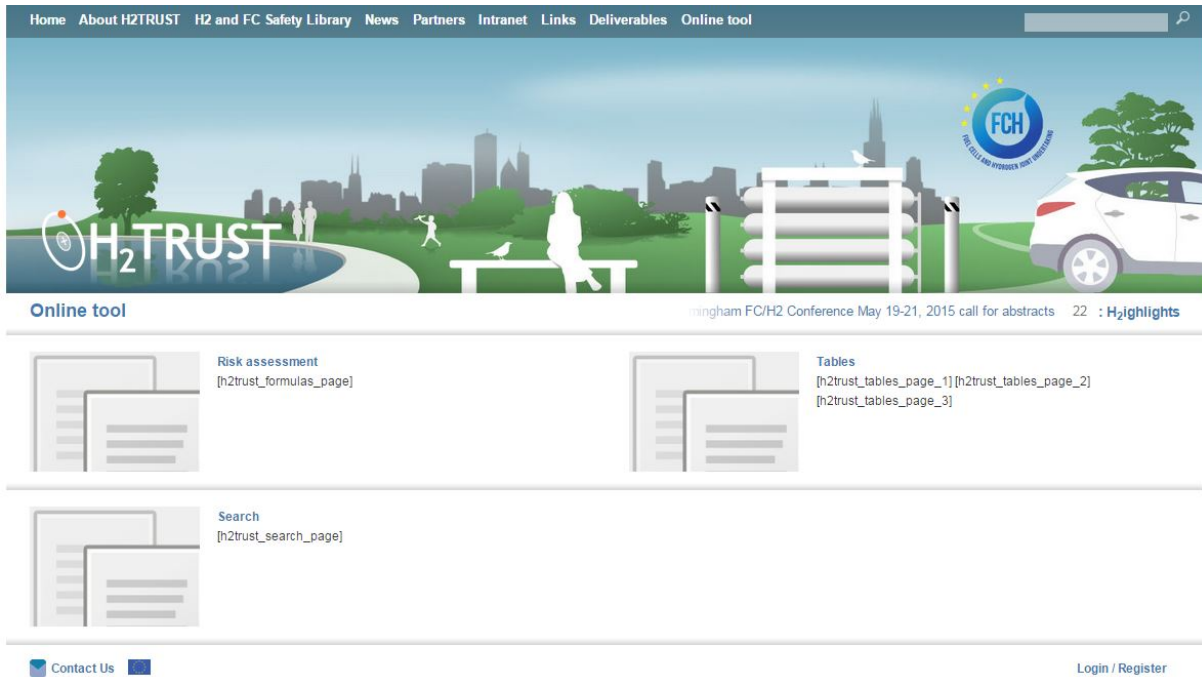


Figure 18. Online tool – main page

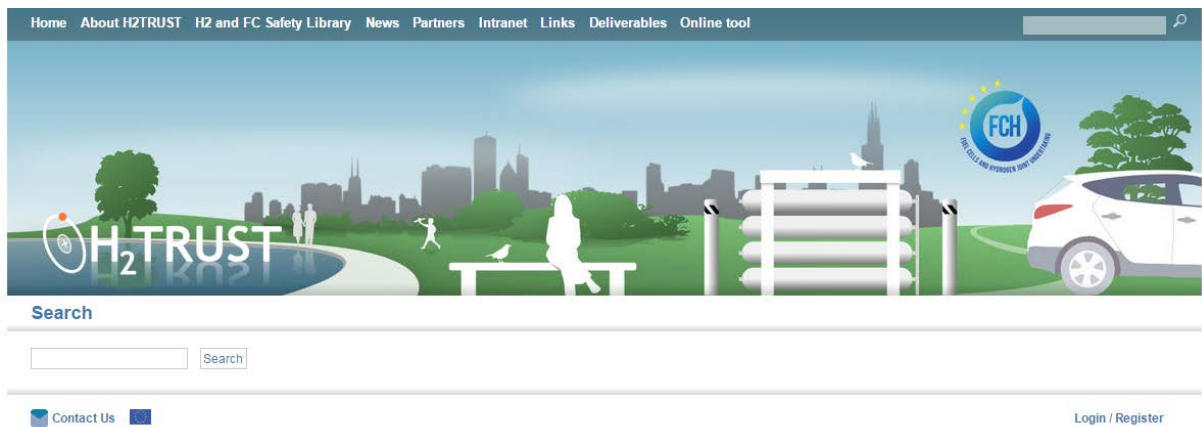


Figure 19. Online Tool – Search engine



Tables

Table D- 1: HAZID analysis table - Large scale SR of NG.

No.	Hazard Type	Hazardous Event	Initiation Cause	Prevention Controls	Consequences	Mitigation Controls
1	Hydrocarbons under pressure	Loss of containment	<ul style="list-style-type: none"> <li>⊖ Tube rupture inside the reformer</li> <li>⊖ Heavier H/C (C2+) presence in NG due to varying quality of natural gas.</li> <li>⊖ Coke formation</li> <li>⊖ Hotspots development on reformer tubes</li> <li>⊖ Deactivation of reformer catalyst</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Pre-reforming</li> <li>⊖ High S/C (steam/carbon) ratio</li> <li>⊖ Safety valves</li> <li>⊖ Design with low inlet temperature to reformer, short connecting lines to reformer</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Flammable gas release</li> <li>⊖ Flammable mixture fire/explosion</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Gas quality requirements to NG supplier.</li> <li>⊖ Regular inspection and maintenance</li> <li>⊖ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system</li> <li>⊖ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
2	Hydrocarbons under pressure	Loss of containment	<ul style="list-style-type: none"> <li>⊖ Tube rupture</li> <li>⊖ NG leak inside reformer</li> <li>⊖ Metal dusting (Disintegration of the affected metal into a powdery mixture of graphite and metal particles)</li> <li>⊖ Lower oxygen partial pressures and higher carbon activities.</li> </ul>	<ul style="list-style-type: none"> <li>⊖ High S/C (steam/carbon) ratio</li> <li>⊖ Protective coating (Aluminide coatings, alloying with copper)</li> <li>⊖ Safety valves</li> <li>⊖ Appropriate material selection (Alloys such as INCONEL alloy 600 and INCOLOY alloy 800H.)</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Flammable gas fire/explosion</li> <li>⊖ Flammable gas ignition</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Regular inspection and maintenance</li> <li>⊖ Explosion relief panels</li> <li>⊖ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system.</li> <li>⊖ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
3	Hydrocarbons under pressure	Loss of containment	<ul style="list-style-type: none"> <li>⊖ Large leak of flammable gas (NG/H<sub>2</sub>/CO) mixture inside container.</li> <li>⊖ Wear and tear</li> <li>⊖ Mechanical aggression/fatigue</li> <li>⊖ Failure of gaskets/joints</li> <li>⊖ Human failure</li> <li>⊖ Insufficient safety measures</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Explosion relief of containment</li> <li>⊖ Gas detection which activates:                             <ul style="list-style-type: none"> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> </ul> </li> <li>⊖ Safety valves</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Flammable gas mixture fire/explosion</li> <li>⊖ Flammable gas ignition</li> <li>⊖ Lost time injury</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Segmentation valves, located outside the container in an area with good natural ventilation</li> <li>⊖ Regular inspection and maintenance</li> <li>⊖ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system .</li> <li>⊖ Explosion relief panels</li> <li>⊖ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
4	Hydrocarbons under pressure	Loss of containment	<ul style="list-style-type: none"> <li>⊖ Leakage of NG feed line</li> <li>⊖ Wear and tear</li> <li>⊖ Mechanical aggression/fatigue</li> <li>⊖ Failure of gaskets/joints</li> <li>⊖ Stress corrosion cracking (SSC)</li> <li>⊖ Insufficient safety measures</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Gas detection which activates:                             <ul style="list-style-type: none"> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> </ul> </li> <li>⊖ Ventilation system</li> <li>⊖ Adequate inspection</li> <li>⊖ Protective coating</li> <li>⊖ Safety valves</li> <li>⊖ Appropriate material selection (Alloys such as INCONEL alloy 600 and INCOLOY alloy 800H.)</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Flammable gas mixture fire/explosion</li> <li>⊖ Hydrogen ignition</li> <li>⊖ Lost time injury</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Segmentation valves, located outside the container in an area with good natural ventilation</li> <li>⊖ Regular inspection and maintenance</li> <li>⊖ Explosion relief panels</li> <li>⊖ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system .</li> <li>⊖ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
5	Toxic/flammmable substances	Loss of containment	<ul style="list-style-type: none"> <li>⊖ Pipe failure</li> <li>⊖ Stress corrosion cracking (SSC)</li> <li>⊖ The presence of incompatible materials (KOH as promoter present in the SMR catalyst)</li> <li>⊖ Hydrogen embrittlement</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Protective coating</li> <li>⊖ Cathodic protection</li> <li>⊖ Piping specifications (Replacement of the SS 24-inch with 1-1/4 Cr 1/2 Mo alloy pipe that is corrosion-resistant to SCC)</li> <li>⊖ Adequate inspection</li> <li>⊖ Safety valves</li> <li>⊖ Adequate Hydrogen detection equipment</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Flammable mixture release</li> <li>⊖ Flammable mixture fire/explosion</li> <li>⊖ Ignition</li> <li>⊖ Damage of equipment near the event</li> </ul>	<ul style="list-style-type: none"> <li>⊖ Detailed hazard review and evaluation of all of the materials of construction in the hydrogen plant process to prevent changing several pieces of piping and equipment items in the SMR process.</li> <li>⊖ Regular inspection and maintenance</li> <li>⊖ Refresh and re-enforce personnel training on fire and gas identification and interpretation.</li> <li>⊖ Explosion relief panels</li> </ul>

6	Toxic/flammable substances	Loss of containment	<ul style="list-style-type: none"> <li>① Tube rupture inside reformer</li> <li>② Sulphur poisoning</li> <li>③ Deactivation of reformer catalyst</li> <li>④ Hotspots development on reformer tubes</li> </ul>	<ul style="list-style-type: none"> <li>① Cu-catalyst as sulphur guard in the bottom of ZnO bed (Protective coating)</li> <li>② Pre-reforming upstream reformer</li> <li>③ Safety valves</li> </ul>	<ul style="list-style-type: none"> <li>① Flammable gas release</li> <li>② Flammable mixture fire/explosion</li> </ul>	<ul style="list-style-type: none"> <li>① Gas quality requirements to NG supplier.</li> <li>② Regular inspection and maintenance</li> <li>③ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system.</li> <li>④ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> <li>⑤ Re-enforce personnel training on their roles to ensure that non-essential personnel are cleared from the area during startup.</li> </ul>
7	Gases under high pressure	Loss of containment	<ul style="list-style-type: none"> <li>① Pipe rupture</li> <li>② Failure of structure after startup.</li> <li>③ Hydrogen embrittlement</li> <li>④ Localized deterioration and hotspots</li> <li>⑤ High pressure</li> <li>⑥ High temperature</li> </ul>	<ul style="list-style-type: none"> <li>① Adequate inspection</li> <li>② Careful change in Procedures, equipment, or Materials</li> <li>③ Comply with correct Standard Operating Protocol (SOP)</li> <li>④ Safety valves</li> </ul>	<ul style="list-style-type: none"> <li>① Flammable mixture release</li> <li>② Flammable mixture fire/explosion</li> <li>③ Ignitimitigation_controls on</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Refresh and re-enforce personnel training on fire and gas identification and interpretation.</li> <li>③ Operation and management of the Steam/methane reformer unit should be strengthened to account for local corrosion.</li> <li>④ Explosion relief panels</li> </ul>
8	Hot or Cryogenic fluids	Loss of containment	<ul style="list-style-type: none"> <li>① Rupture of H2 pipe</li> <li>② Hydrogen embrittlement</li> <li>③ Excessive temperature</li> <li>④ Excessive pressure</li> <li>⑤ Failure of gaskets/joints</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Adequate inspection</li> <li>③ Gas detection which activates:</li> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> <li>④ Causes shutdown when exceeding max operation temperature</li> <li>⑤ Protective coating</li> <li>⑥ Appropriate material selection (Alloys such as INCONEL alloy 600 and INCOLOY alloy 800H.)</li> </ul>	<ul style="list-style-type: none"> <li>① Leakage of H2 pipeline before or after cooling</li> <li>② Flammable gas mixture fire/explosion</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> <li>④ Explosion relief panels.</li> </ul>
9	Utility facilities	Loss of function	<ul style="list-style-type: none"> <li>① Tube rupture</li> <li>② NG leak in heat exchanger</li> <li>③ Metal dusting (Disintegration of the affected metal into a powdery mixture of graphite and metal particles)</li> <li>④ Lower oxygen partial pressures and higher carbon activities.</li> </ul>	<ul style="list-style-type: none"> <li>① High S/C (steam/carbon) ratio</li> <li>② Protective coating (Aluminide coatings, alloying with copper and addition of steam)</li> <li>③ Improve design (use of boiling water and steam for cooling)</li> <li>④ Appropriate material selection (Alloys such as INCONEL alloy 600 and INCOLOY alloy 800H.)</li> </ul>	<ul style="list-style-type: none"> <li>① Flammable gas fire/explosion</li> <li>② Hydrogen ignition</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Explosion relief panels</li> <li>③ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system.</li> <li>④ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation</li> </ul>
10	Safety systems	Loss of function	<ul style="list-style-type: none"> <li>① Tube rupture during startup</li> <li>② Steam flow picking up water and carrying it into the furnace</li> <li>③ Entrained water impinges on hot catalyst and pipe wall and instantaneously flashes</li> <li>④ Winter shutdown operation (external impact)</li> <li>⑤ Operating error</li> <li>⑥ Hotspot development</li> <li>⑦ Extreme internal pressure</li> </ul>	<ul style="list-style-type: none"> <li>① Comply with Standard Operating Procedures</li> <li>② Adequate management of change</li> <li>③ Efficient decision making</li> <li>④ Provide adequate draining system to facilitate water removal</li> <li>⑤ Safety valves</li> </ul>	<ul style="list-style-type: none"> <li>① Flammable mixture fire/explosion</li> <li>② Shock wave development</li> <li>③ Lost Time Injury</li> <li>④ Generation of shrapnel and brittle fracture</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed guidance for verifying that the feed system is dry, and a formal sign-off by both operations and engineering personnel.</li> <li>③ A separate cold-eyes review by external experts is recommended as part of the pre-startup safety review.</li> <li>Refresh and re-enforce personnel training on their roles to ensure that non-essential personnel are cleared from the area during startup activities.</li> </ul>
11	Safety systems	Loss of function	<ul style="list-style-type: none"> <li>① Rupture of vent line</li> <li>② Mechanical aggression</li> <li>③ Corrosion</li> <li>④ Overpressure</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Adequate inspection</li> <li>③ Gas detection which activates:</li> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> <li>④ Protective coating</li> <li>⑤ Appropriate material selection (Alloys such as INCONEL alloy 600 and INCOLOY alloy 800H.)</li> </ul>	<ul style="list-style-type: none"> <li>① Flammable gas mixture standing flame/explosion</li> <li>② Hydrogen ignition</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> <li>④ Explosion relief panels.</li> </ul>
12	Safety systems	Loss of function	<ul style="list-style-type: none"> <li>① No proper purge system after removing and installing a vent valve</li> <li>② Maintenance error</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Adequate inspection</li> <li>③ Gas detection which activates:</li> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> </ul>	<ul style="list-style-type: none"> <li>① H2 vent line explosion</li> <li>② H2-Air mixture ignition from flare stack or static charge</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> <li>④ Explosion relief panels.</li> <li>⑤ Fenced site</li> </ul>

13	Instrumentation and Control systems	Loss of control	<ul style="list-style-type: none"> <li>① Pipe rupture</li> <li>② Valve failure</li> <li>③ Operating error</li> <li>④ Extremely high pressure (pressure explosion)</li> </ul>	<ul style="list-style-type: none"> <li>① Regularity requirements to suppliers of control system (PLC and valve operation).</li> <li>② Adequate system monitoring/inspection.</li> <li>③ Ventilation system.</li> </ul>	<ul style="list-style-type: none"> <li>① Flammable gas fire/explosion</li> <li>② Ignition</li> <li>③ Lost time injury</li> </ul>	<ul style="list-style-type: none"> <li>⑤ Fenced site</li> <li>① Remote operated process will reduce the probability of human failure.</li> <li>② Industry guidance on the type of pressure relief device materials in terms of their metallurgical makeup.</li> <li>③ Regular inspection and maintenance</li> <li>④ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system .</li> <li>⑤ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
14	Instrumentation and Control systems	Loss of control	<ul style="list-style-type: none"> <li>① Pressure disk failure in the regulator</li> <li>② Improper installation of check valves (backward installation)</li> <li>③ Deficiency in procedures</li> <li>④ Human error</li> </ul>	<ul style="list-style-type: none"> <li>① Proper installation of check valves</li> <li>② Adequate system monitoring/inspection.</li> <li>③ Visual inspection of check valves and equipment prior to pressurization</li> <li>④ Ventilation system.</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition</li> <li>③ Flammable gas fire/explosion</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
15	Dangerous equipment	Loss of function	<ul style="list-style-type: none"> <li>① Rotary PSA safety valve failure</li> <li>② Fatigue</li> <li>③ Wear and tear</li> <li>④ Failure of gaskets/joints</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Adequate inspection</li> <li>③ Gas detection which activates:                             <ul style="list-style-type: none"> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>① Flammable gas leakage</li> <li>② Flammable gas mixture standing flame/explosion</li> <li>③ Injury</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system .</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> <li>④ Explosion relief panels.</li> </ul>
16	Dangerous equipment	Loss of function	<ul style="list-style-type: none"> <li>① Burst of the PSA</li> <li>② Overpressure (external fire)</li> <li>③ Excessive pressure at reformer outlet</li> <li>④ Hydrogen embrittlement</li> <li>⑤ Mechanical aggression</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Adequate inspection</li> <li>③ Gas detection which activates:                             <ul style="list-style-type: none"> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> </ul> </li> <li>④ Protective coating</li> <li>⑤ Use sensors to identify the presence of oxygen or air ingress upstream and actuate alarms/emergency stop when concentrations exceed predetermined set point</li> <li>⑥ Purge the adsorber bed with an inert gas to reduce the risk of ignition if high oxygen concentrations are present.</li> <li>⑦ Appropriate material selection (Alloys such as INCONEL alloy 600 and INCOLOY alloy 800H.)</li> </ul>	<ul style="list-style-type: none"> <li>① Toxic gas dispersion</li> <li>② Missiles</li> <li>③ Fireball</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> <li>④ Explosion relief panels.</li> <li>⑤ Fenced site</li> <li>⑥ Pull a vacuum on the adsorber to remove any adsorbed oxygen before the adsorber is put back online</li> </ul>
17	Dangerous equipment	Loss of function	<ul style="list-style-type: none"> <li>① Leakage or burst of the H2 line to the compressor</li> <li>② Operating error</li> <li>③ Wear and tear</li> <li>④ Technical defect</li> <li>⑤ Errors in process controlling</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Adequate inspection</li> <li>③ Gas detection which activates:                             <ul style="list-style-type: none"> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valves</li> </ul> </li> <li>④ Protective coating</li> <li>⑤ Causes shutdown when exceeding max operation temperature</li> </ul>	<ul style="list-style-type: none"> <li>① Jet fire</li> <li>② Explosion</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
18	Dangerous equipment	Loss of function	<ul style="list-style-type: none"> <li>① Blow off of cylinder head</li> <li>② H2 compressor repair</li> <li>③ Error at assembly</li> <li>④ Discharge valve installed in intake position of compressor</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Adequate inspection</li> <li>③ Gas detection which activates:                             <ul style="list-style-type: none"> <li>d) Emergency ventilation,</li> <li>e) Opening of ceiling and/or walls</li> <li>f) Closure of segmentation valve</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② Fire/explosion</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
19	Dangerous equipment	Loss of function	<ul style="list-style-type: none"> <li>① Constant vibration of the process equipment (compressor)</li> <li>② Design flaw</li> </ul>	<ul style="list-style-type: none"> <li>① Hydrogen distribution lines should be designed and carefully inspected to ensure process equipment in the area is correctly and safely installed.</li> </ul>	<ul style="list-style-type: none"> <li>① The bolt rubbed a hole in the high-pressure suction piping, resulting in the release of make-up hydrogen.</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Equipment subject to vibration should not be placed in contact with hydrogen lines or with other equipment.</li> <li>③ If equipment is moved or rearranged, the hydrogen system should be re-inspected as per the above.</li> </ul>
20	Dangerous equipment	Loss of function	<ul style="list-style-type: none"> <li>① Incorrect installation of sized gasket at the suction line of a hydrogen compressor</li> <li>② Inadequate Venting Design</li> <li>③ Flammable Mixture in Confined Area</li> <li>④ Design Flaw</li> </ul>	<ul style="list-style-type: none"> <li>① Adequate inspection</li> <li>② Adequate System Monitoring/Oversight</li> <li>③ Adequate Hydrogen Detection Equipment</li> <li>④ Ventilation system</li> </ul>	<ul style="list-style-type: none"> <li>① H2 leak</li> <li>② Fire/explosion</li> <li>③ Human life</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system .</li> <li>③ Carefully revise the risk assessment process to evaluate any confined areas where hydrogen is handled.</li> <li>④ Separate the fire and gas detection alarm system from the process information to provide easy and clear identification.</li> <li>⑤ Retrain personnel on emergency procedures and enhance their understanding and awareness of risky, flammable, explosive, and/or toxic substances.</li> </ul>
21	Ignition source	Failure of safety systems	<ul style="list-style-type: none"> <li>① Tube rupture</li> <li>② Heat release</li> <li>③ Burn wires</li> <li>④ Short circuit in the electrical junction box in the vicinity of a H2 line</li> </ul>	<ul style="list-style-type: none"> <li>① Install circuit protection devices (e.g. Fuses, circuit breakers, ground-fault circuit interrupters)</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② Fire/explosion</li> <li>③ Hydrogen ignition</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>

22	General radiation, not ionized	External impact (welding)	<ul style="list-style-type: none"> <li>① Holes burned through the hydrogen tubing</li> <li>② Improper hot work performance in the vicinity of a charged flammable gas line.</li> <li>③ A short during welding caused the pinholes in the tubing containing the gaseous H<sub>2</sub>.</li> <li>④ Failure to follow Standard Operating Procedures</li> <li>⑤ Human error/Individual action</li> </ul>	<ul style="list-style-type: none"> <li>① Perform hot work only after the gas supply is verified closed (along with a lock and tag).</li> <li>② The system should be checked for leaks prior to turning the gas back on.</li> </ul>	<ul style="list-style-type: none"> <li>① H<sub>2</sub> leak</li> <li>② H<sub>2</sub> ignition</li> <li>③ Minor injury</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system.</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>
23	Surrounding-Related hazards	General facility damages (severe weather)	<ul style="list-style-type: none"> <li>① Usually calm weather</li> <li>② Cold H<sub>2</sub> gas vented through the stack into atmosphere</li> <li>③ Gas accumulation around the vent stack</li> </ul>	<ul style="list-style-type: none"> <li>① Check for weather conditions and adjust procedures</li> </ul>	<ul style="list-style-type: none"> <li>① H<sub>2</sub> release</li> <li>② H<sub>2</sub> ignition</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system .</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>

Table D- 2: HAZID analysis table - Alkaline electrolyzer.  
 -- Filter hazard type --  
 -- Filter hazardous event --

No.	Hazard Type	Hazardous Event	Initiating Causes	Prevention Controls	Consequences	Mitigation Controls
1	Toxic/Flammable substances Hazardous Materials	Leakage / Loss of containment	<ul style="list-style-type: none"> <li>① Lye leak through cells</li> <li>② Overpressure (External fire)</li> <li>③ Failure of gaskets/joints/fittings</li> <li>④ Excessive temperature</li> </ul>	<ul style="list-style-type: none"> <li>① Safety valves</li> <li>② Proper purging system</li> <li>③ H<sub>2</sub> detection system with shutdown</li> <li>④ Isolation valves closure</li> </ul>	<ul style="list-style-type: none"> <li>① Explosion</li> <li>② Jet flame</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Adequate venting design</li> <li>③ Exceeding max operation temperature causes shutdown</li> </ul>
2	Toxic/Flammable substances Hazardous Materials	Leakage / Loss of containment	<ul style="list-style-type: none"> <li>① Leakage from lye pipes</li> <li>② Hydrogen embrittlement (hydrogen corrosion)</li> <li>③ Overpressure</li> <li>④ Failure of gaskets/joints</li> </ul>	<ul style="list-style-type: none"> <li>① H<sub>2</sub> detection system with shutdown (Limit leak time)</li> <li>② Safety valves</li> <li>③ Isolation valves closure</li> </ul>	<ul style="list-style-type: none"> <li>① Explosion</li> <li>② Jet flame</li> <li>③ Injury</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Forced and emergency ventilation</li> <li>③ Proper purging system</li> </ul>
3	Toxic/Flammable substances Hazardous Materials	Leakage / Loss of containment	<ul style="list-style-type: none"> <li>① Lye discharge through vent line</li> <li>② Overpressure in hydrogen separator</li> <li>③ Low level in break tank</li> </ul>	<ul style="list-style-type: none"> <li>① H<sub>2</sub> detection system with shutdown (Limit leak time)</li> <li>② Expand vent line with water trap (Vent stack kept frost free by heating elements)</li> <li>③ Safety valves</li> <li>④ Isolation valves closure</li> </ul>	<ul style="list-style-type: none"> <li>① Explosion</li> <li>② Jet flame</li> <li>③ Injury</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Forced and emergency ventilation</li> </ul>
4	Toxic/Flammable substances Hazardous Materials	Leakage / Loss of containment	<ul style="list-style-type: none"> <li>① Lye pipe rupture</li> <li>② Hydrogen embrittlement (hydrogen corrosion)</li> <li>③ Excessive pressure</li> <li>④ Excessive temperature</li> <li>⑤ Welds and connections failure</li> </ul>	<ul style="list-style-type: none"> <li>① H<sub>2</sub> detection system with shutdown (Limit leak time)</li> <li>② Safety valves</li> <li>③ Exceeding max operation temperature causes shutdown</li> </ul>	<ul style="list-style-type: none"> <li>① Explosion</li> <li>② Jet flame</li> <li>③ Injury</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Forced and emergency ventilation</li> <li>③ Proper purging system</li> </ul>
5	Toxic/Flammable substances Hazardous Materials	Leakage / Loss of containment	<ul style="list-style-type: none"> <li>① Sludge deposits in the electrolyte passages</li> <li>② Inadequate flush water system to remove Sludge formation</li> <li>③ Electrolyte flow rate reduce caused by sludge blockage</li> <li>④ High temperature</li> <li>⑤ High electrolyte concentration</li> <li>⑥ Severe corrosion/erosion of cell electrodes and separator (Hydrogen embrittlement)</li> </ul>	<ul style="list-style-type: none"> <li>① Periodical flush the system with water to remove sludge formation.</li> <li>② Adequate Hydrogen Detection Equipment</li> <li>③ Continuous gas analyzer test of oxygen and hydrogen product purity.</li> <li>④ Supply supervision alarming.</li> </ul>	<ul style="list-style-type: none"> <li>① Physical breakdown of cell separators</li> <li>② H<sub>2</sub> and O<sub>2</sub> mixture</li> <li>③ Flammable mixture ignition</li> <li>④ Explosion</li> <li>⑤ Separator drum rupture</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Check on a routine basis the individual cell purity levels to monitor the deterioration of performance of individual cells.</li> <li>③ Carry out a risk assessment of the current LP purity analyzers to determine the level of risk associated with a loss of sample flow.</li> </ul>
6	Safety systems	Loss of functions	<ul style="list-style-type: none"> <li>① Technical defect</li> <li>② Operating error</li> <li>③ Discharge form safety relief valve to an unsafe location</li> </ul>	<ul style="list-style-type: none"> <li>① H<sub>2</sub> detection system with shutdown (Limit leak time)</li> <li>② Adequate venting design</li> <li>③ Location selection according to local regulatory authority</li> </ul>	<ul style="list-style-type: none"> <li>① Explosion</li> <li>② Jet fire</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance.</li> <li>② Detailed hazard review of all procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> <li>③ Location away from residence area</li> </ul>

7	Instrumentation and Control System.	Loss of control	<ul style="list-style-type: none"> <li>① Bursting disc ruptured</li> <li>② Air ingress in the system</li> <li>③ LP filter and LP dryer failure allowing air in the line.</li> <li>④ LP Pipe low point drain at LP gasholder blocked</li> <li>⑤ LP gasholder failure (sticking bell or mal-operation)</li> <li>⑥ Design flaw on inlet and outlet of gasholder</li> <li>⑦ Oxygen ingress form cells</li> <li>⑧ Low electrolyte level due to built-up of magnetite and other contaminants at the inlets leading to blocked water inlet pipes at the affected cells. (Blocked drain valves)</li> <li>⑨ Failure of welds and connections at the storage banks allowing hydrogen gas to be released in large quantities</li> </ul>	<ul style="list-style-type: none"> <li>① LP purity analyzer</li> <li>② Isolation transformer</li> <li>③ Supply supervision alarming</li> </ul>	<ul style="list-style-type: none"> <li>① Hydrogen release</li> <li>② Ignition</li> <li>③ Explosion in the hydrogen</li> <li>HP feed pipes</li> <li>④ Hydrogen self-ignited resulting in an explosion and fire in storage tanks.</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance.</li> <li>② Check on a routine basis the individual cell purity levels to monitor the deterioration of performance of individual cells.</li> <li>③ Replace the drain valves with open port ball valves to improve the drain operation and to allow effective cleaning of the cells.</li> <li>④ Replace the existing LP purity analyzer with a fail-safe model that ensures the vent valve is opened under the conditions described above.</li> <li>⑤ Carry out a risk assessment of the current LP purity analyzers to determine the level of risk associated with a loss of sample flow.</li> <li>⑥ Fit hydrogen purity analyzers that fail safe either between the stages of the compressor or immediately after the compressor.</li> <li>⑦ Fit pot type water seals with open trough water makeup as a replacement for the U tube and pot type seals.</li> <li>⑧ Remove the end sheeting from the building to increase ventilation</li> <li>⑨ An investigation be carried out into the feasibility of establishing a gas up station away from the hydrogen generation plant possibly near the CO2 plant to allow the units to be gassed from transportable pallets in an emergency</li> </ul>
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Table D-3: HAZID analysis table - GH2 storage system.

-- Filter hazard type --      -- Filter hazardous event --

No	Hazard Type	Hazardous Event	Initiating Cause	Prevention Controls	Consequences	Mitigation Controls
1	Liquids and Gases under high pressure	Leakages / Loss of containment	<ul style="list-style-type: none"> <li>① Massive GH2 leak due to pipe rupture</li> <li>② A pneumatically operated GH2 isolation gate valve failed in open position (overpressure)</li> <li>③ Absence of coating at the leak point</li> <li>④ Galvanic corrosion</li> <li>⑤ Pipe rupture when high-pressure gas was applied to the thin pipe membrane.</li> <li>⑥ GH2 was trapped in large quantities in sand and gravel under the apron surface (a 1-foot-thick concrete pad about 160 x 140 ft).</li> <li>⑦ GH2 entrance in the basement of the electrical control and instrumentation terminal building, located immediately adjacent to the facility, through penetrations in the basement wall, including cable ducts, cable pulls, and two 24-inch-diameter air conditioning ducts. GH2 was transported through the air conditioning ducts to a support building about 90 feet from the terminal building.</li> <li>⑧ The possible ignition source in the terminal building was considered to be an electrical arc from a sump pump.</li> </ul>	<ul style="list-style-type: none"> <li>① Active GH2 sensors should be installed and continuously monitored in all enclosed buildings near GH2 sources. All buildings near areas where hydrogen is used should be designed to preclude GH2 entrapment (e.g., sloping roof with ventilation at the highest point).</li> <li>② Underground carbon steel lines beneath concrete pad areas should not be used for GH2 transmission. All GH2 lines are now stainless steel and above ground.</li> <li>③ Any GH2 transmission lines buried underground should be proof-tested and leak-checked on a periodic basis.</li> <li>④ Any below-grade piping installation should be in open trenches covered by grating.</li> <li>⑤ Facilities should be protected from GH2, at a safe distance, by manual isolation valves. If remote-operated valves (ROVs) are required for operational isolation purposes, the ROVs should be in series with and downstream of the manual isolation valve.</li> <li>⑥ Valves repaired in the field should be subjected to functional and leak checks, including actuator and valve seals at simulated operating conditions. A written procedure should be prepared and used.</li> <li>⑦ Valves utilizing pneumatic actuators should have actuator piston and piston nut staked (or locked by other positive means) in the installed condition.</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition (an electrical arc from a sump pump)</li> <li>③ Flammable gas explosion</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② The pressure between isolation valves and stand shut-off valves should be routinely monitored on a daily basis.</li> <li>③ Field repair of mechanically severable valves in high-pressure systems should be eliminated.</li> <li>④ All high-pressure gas lines scheduled to be inactive for periods greater than 6 months should be physically isolated by blind flanges from active systems.</li> <li>⑤ Supply system status of pressure vessels and lines (pressure and/or quantity) should be recorded at the start and completion of operations each day. All reservoirs should be isolated at close of business each day, and before weekends and holidays.</li> <li>⑥ Corrosion protection systems for underground lines should be reviewed and tested to confirm the adequacy of the systems.</li> <li>⑦ Operational and support buildings at hazardous sites should be isolated (i.e., interconnecting air conditioning systems should be avoided). Buildings connected to hazardous sites by tunnels and/or conduits should be physically isolated by seals. If physical isolation is not practical, then positive air flow should be maintained in tunnels and conduits.</li> <li>⑧ Explosive gas detection meters should be included in the equipment carried by firefighters and emergency medical personnel.</li> <li>⑨ Fire alarm transmitters should be located at all hazardous locations.</li> <li>⑩ Emergency instructions for isolating GH2 and utilities for hazardous locations should be permanently posted with names and telephone numbers of key individuals to be contacted.</li> </ul>
2	Liquids and Gases under high pressure	Leakages / Loss of containment	<ul style="list-style-type: none"> <li>① Rupture of the H2 storage output line</li> <li>② Mechanical aggression (digger)</li> <li>③ Hydrogen embrittlement (hydrogen corrosion)</li> <li>④ External fire or overpressure (excessive temperature)</li> </ul>	<ul style="list-style-type: none"> <li>① Fenced site</li> <li>② Regular monitoring system</li> <li>③ Safety valve at the storage output (released by a fuse)</li> <li>④ Pressure reducer as close as possible to the high pressure source</li> <li>⑤ H2 gas detection system with shutdown if in confined ventilated space</li> <li>⑥ Flame detection</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition</li> <li>③ Flammable gas explosion or jet fire</li> </ul>	<ul style="list-style-type: none"> <li>① Work permit/Trained employees</li> <li>② Regular inspection and maintenance</li> </ul>
3	Liquids and Gases under high pressure	Leakages / Loss of containment	<ul style="list-style-type: none"> <li>① Release of of hydrogen through the pressure relief valve (PRV) line</li> <li>② External fire or overpressure/excessive pressure input</li> </ul>	<ul style="list-style-type: none"> <li>① Adequate gas detection system with shutdown</li> <li>② Pressure reducer as close as possible to the high pressure source</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition</li> <li>③ Flammable gas explosion or jet fire</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② PRV vent in a safe location</li> </ul>

pressure						
4	Liquids and Gases under high pressure	Leakages / Loss of containment	<ul style="list-style-type: none"> <li>① Burst of hydrogen tank</li> <li>② External fire</li> <li>③ Jet flame/impingement</li> <li>④ Overpressure (input line)</li> <li>⑤ Loss of mechanical properties (ageing, mechanical aggression, material defect)</li> <li>⑥ Chemical aggression</li> </ul>	<ul style="list-style-type: none"> <li>① Adequate gas detection system with shutdown</li> <li>② Avoid combustible materials used in design-housekeeping</li> <li>③ Location of vent outlet (open air, no congestion)</li> <li>④ Fenced site</li> <li>⑤ Compatible material use</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition</li> <li>③ Pressure wave+missiles+fireball</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Periodic control</li> <li>③ Work permittrained employees</li> <li>④ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> </ul>
5	Liquids and Gases under high pressure	Leakages / Loss of containment	<ul style="list-style-type: none"> <li>① Release of hydrogen through the vent line due to voluntary action / human error (maintenance)</li> <li>② voluntary emergency release (fire)</li> </ul>	<ul style="list-style-type: none"> <li>① Design: release hydrogen in a safe location</li> <li>② Adequate gas detection system with shutdown</li> <li>③ Refresh and re-enforce personnel training on abnormal phenomena identification and interpretation.</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition</li> <li>③ Explosion or jet fire</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Periodic control</li> <li>③ Work permittrained employees</li> <li>④ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> </ul>
6	Liquids and Gases under high pressure	Leakages / Loss of containment	<ul style="list-style-type: none"> <li>① Rupture of the H2 bundle manifold or of the manifold feed line due to mechanical aggression (drop of a heavy equipment, displacement of cylinders)</li> <li>② hydrogen embrittlement (hydrogen corrosion)</li> <li>③ external fire</li> </ul>	<ul style="list-style-type: none"> <li>① Detect / Limit the flow / quantity of H2 that can leak at the H2 bundle manifold or at the manifold feed line with isolation through fail safe valve</li> <li>② Limit manifold material to those that can withstand an ignited leak</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition</li> <li>③ Explosion or jet fire</li> </ul>	<ul style="list-style-type: none"> <li>① Regular inspection and maintenance</li> <li>② Periodic control</li> <li>③ Work permittrained employees</li> <li>④ Detailed hazard review and evaluation of all of the procedures in the hydrogen plant process gas system to prevent abnormal phenomena.</li> </ul>
7	Liquids and Gases under high pressure	Leakages / Loss of containment	<ul style="list-style-type: none"> <li>① A pressure relief device (PRD) valve failed on a high-pressure storage tube at a hydrogen fueling station</li> <li>② the use of incompatible materials in the manufacturing of the PRD valve,</li> <li>③ improper assembly resulting in over-torquing of the inner assembly</li> <li>④ over-hardening of the inner assembly materials by the valve manufacturer</li> <li>⑤ Gas ignition at the exit of the vent pipe</li> </ul>	<ul style="list-style-type: none"> <li>① adequate quality assurance/quality control procedures during the design and safety reviews.</li> <li>② it is likely that the vent stacks adjacent to the canopy would have been raised in order to avoid any damage in the event of a fire.</li> </ul>	<ul style="list-style-type: none"> <li>① H2 release</li> <li>② H2 ignition (Either static electricity or spark from escaping particle)</li> <li>③ Fire or Jet flame</li> <li>④ Property Damage</li> <li>⑤ Facility closure</li> </ul>	<ul style="list-style-type: none"> <li>① new and modified procedures were instituted to improve the timely communication of station status during emergency events.</li> <li>② Additional training of personnel focused on improving the response time and effective communication between employees, first responders, and the hydrogen equipment supplier.</li> </ul>

Figure 20. Online Tool – Hazard Tables

### 3 Online Forum Form

Based on the H<sub>2</sub>TRUST mirrors groups the Consortium has established and facilitates access to a permanent set of H<sub>2</sub> expert groups that may be consulted by public or private organisations for the purpose of develop adequate and informed public responses to H<sub>2</sub> safety issues. The users of the forum will have to register first before posting or participating in the forum.

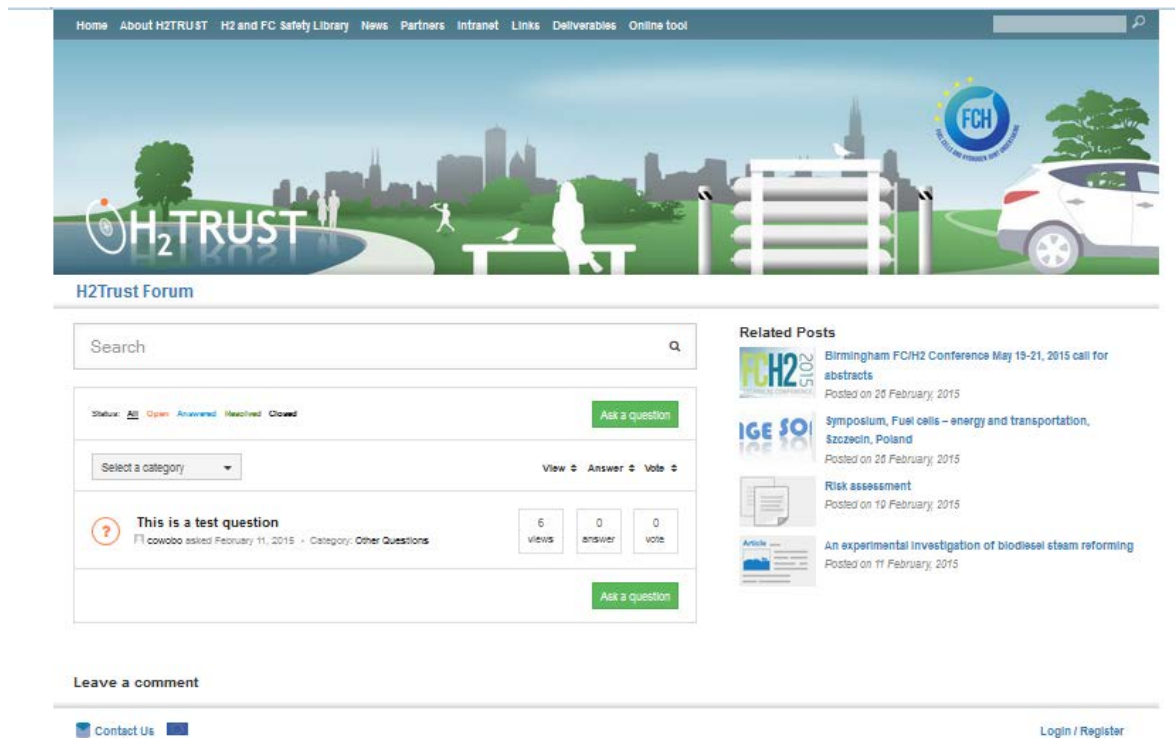


Figure 21. H<sub>2</sub>TRUST online forum form

## 4 H<sub>2</sub>ighlights

H<sub>2</sub>ighlights is a news bar under the main menu and the banner of H<sub>2</sub>TRUST website. H<sub>2</sub>ighlights is a fixed bar in all website pages and its objective is to highlight the important news or events in a visible way to the website visitors.

