HyApproval

SES6 019813

HyApproval

Handbook for Approval of Hydrogen Refuelling Stations

Specific Targeted Research or Innovation Project

Priority [1.6] Sustainable Development, Global Change and Ecosystems

Final Publishable Activity Report

after 24 months

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Project coordinator organisation name: Ludwig-Bölkow-Systemtechnik

Revision [draft 8]

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Rationale and Summary

Why do we need hydrogen?

Hydrogen is an energy carrier with zero carbon content. Just like electricity, hydrogen can be produced from all energy resources, like biomass, wind and solar energy, nuclear energy and clean fossil fuels. It can be converted to power and heat with high efficiency and zero emissions, especially when used in fuel cells. It improves security of supply due to the de-coupling of demand and resources, allowing each European member state to choose its own energy sources. Within the HyApproval project, a Handbook for the Approval of Hydrogen Refuelling Stations has been developed.

Why do we need a solution for the harmonised approval of hydrogen refuelling stations?

On one side, the number of hydrogen fuelling stations is steadily growing worldwide as the number of hydrogen-fuelled vehicles increases. On the other side, Hydrogen refuelling stations are currently subject to very disparate requirements and permitting procedures from one country to another, or even, from one station to another within the same country,. These processes are often complex and lengthy, with a highly uncertain outcome. This results from a combination of two factors:

- The regulatory framework for Fuelling stations is still mostly determined at national level
- Due to the absence of specific requirements and regulation, there is significant variability with regards to the technical and regulatory references that will be invoked, as well as to how exactly they will be applied (as these did not specifically consider hydrogen refuelling stations when created)

Due to the range of issues that may be considered for permitting, the multiplicity of actors involved, and the absence of pre-defined requirements, the duration, the cost, and the prospect of success of a permitting procedure for a hydrogen fuelling station are very unpredictable (see ***Figure 1***).

Such a situation constitutes an obstacle to the deployment of the network of hydrogen refuelling stations that is required for introducing hydrogen fuelled vehicles.

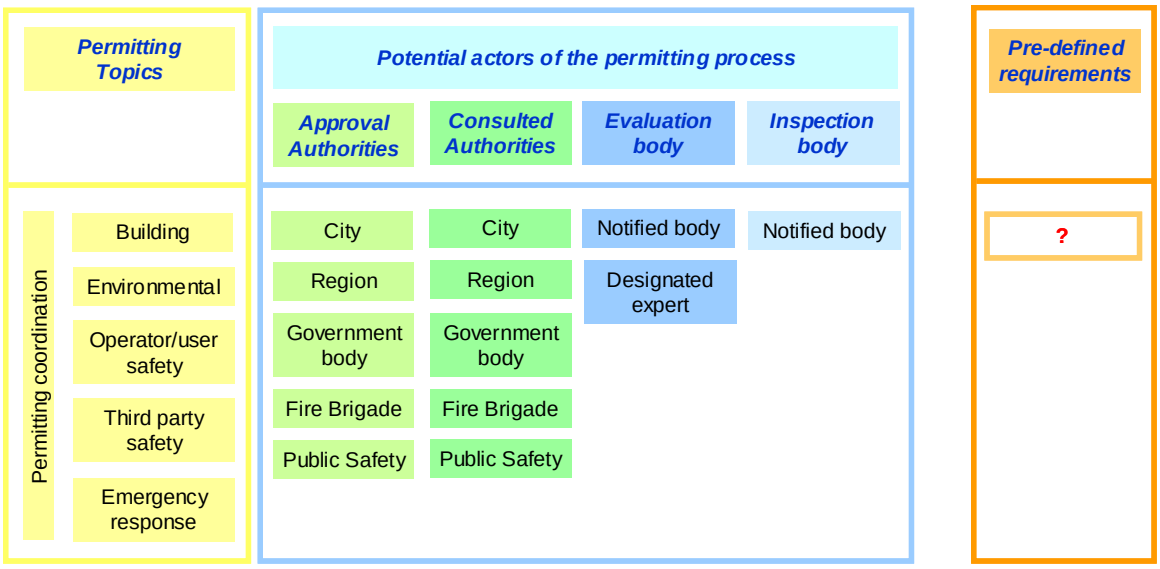

Figure 1: Potential permitting process complexity

Efforts towards developing a regulatory framework for hydrogen vehicles (EC type approval) must therefore be accompanied by similar efforts regarding the hydrogen fuelling stations.

Main recommendations

The key recommendation is to develop an EC regulatory framework for hydrogen refuelling stations based on the proven combination of Essential requirements, Harmonized standards, and Notified bodies. This could be most efficiently achieved through the development of an EC Regulation (as opposed to an EC Directive).

Such a framework, which allows to address the key safety issues without impeding continued technological development, would establish a very streamlined EU 27 uniform permitting process (see ***Figure 2***).

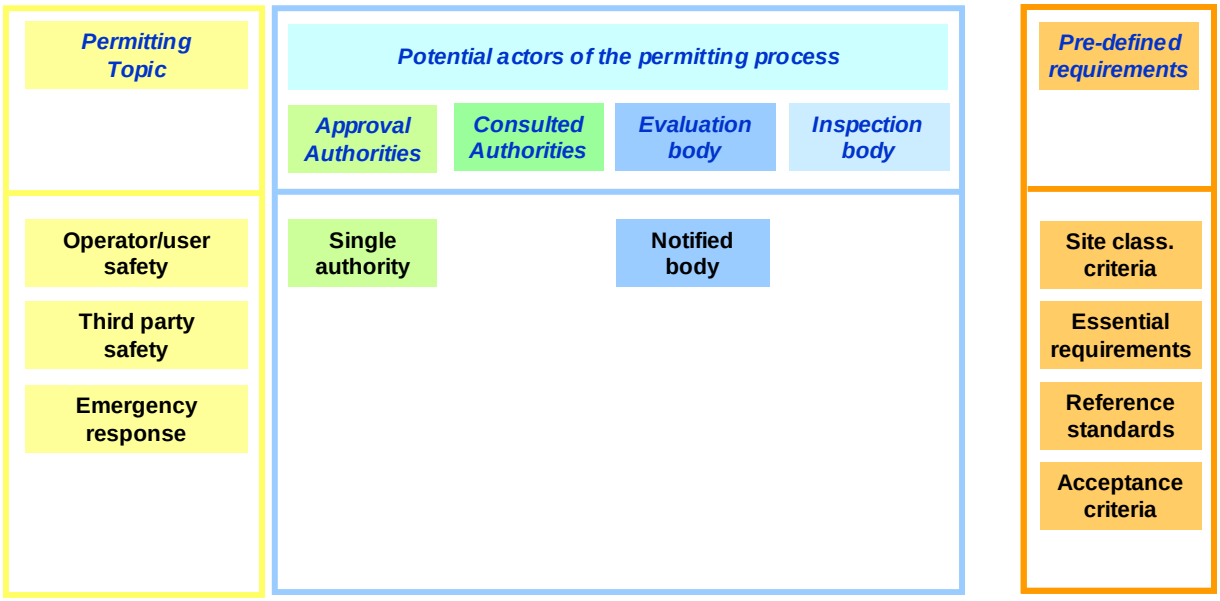

Figure 2: EU27 uniform permitting process

Going a step further, such a framework would allow for a mechanism of **fuelling station "type approval"** (similar to that of road vehicles), allowing a given station design to be approved for deployment in number in all EU 27 countries.

Until such a framework is fully established at EC level, national authorities are encouraged to adopt a permitting process structured similarly: one single authority, relying on the evaluation of one expert body, and referring to pre-established set of requirements and approval criteria.

International standards (ISO, IEC), developed considering the essential requirements set out in regulation, **are the framework of choice for developing and providing fuelling station design rules and criteria** allowing to meet regulatory and permitting requirements.

Whereas as regulation is developed at the initiative of the concerned EC regulatory bodies, standards are developed mostly through the contribution of industry. **However, due to the link between regulation and standards that needs to be established,** a key fea-

ture of the proposed regulatory framework, **close cooperation between actors of both worlds is necessary**.

Finally, in parallel to the development of the adequate regulatory framework, **guidance and support needs to be provided to the stakeholders** regarding the applicable standards and regulation, explaining how to apply these as well as providing the underlying knowledge base.

Providing this type of guidance is a key objective of the HyApproval handbook, the content of which needs to be continuously updated. Also the fast growing environment of evolution of knowledge and experience requires a mandatory and frequent update of the Handbook. Thus the Handbook for some time will constitute a Living Document.

1. Work Package Activities

1.1 General project objectives

HyApproval was an EC co-financed Specific Targeted Research Project (STREP) to develop a Handbook facilitating the approval of Hydrogen Refuelling Stations (HRS). The project, started in October 2005, was be performed over 24 months by a balanced partnership including 25 partners from industry, SMEs and institutes which ensure the critical mass and required know how for obtaining the identified project goals and finished in September 2007. Most partners have extensive expertise from HRS projects. Key partners from China/ Japan/ USA provide an additional liaison to international regulations, codes & standards activities. HyApproval was the first and only project of its kind.

The project goals were to finalise the HRS technical guideline started under EIHP2 (European Inte-grated Hydrogen Project) and to contribute to the international standard under development at ISO TC197 WG11 and in first line to provide a Handbook, which assists companies and organisations in the implementation and operation of HRS. The Handbook is based on best practices reflecting the existing technical know-how and regulatory environment, but also includes the flexibility to allow new technologies and design to be introduced at a later stage.

In order to meet these goals, best practises were collected from or developed from project experience (CUTE, Hy-Fleet:CUTE, ECTOS, EIHP1&2, HySafe, ZERO REGIO, CEP) and partner activities.

In 5 EU countries (F/D/I/E/NL) and in China the HyApproval process included a Handbook review by country authorities to pursue "broad agreement" and to define “approval routes”.

After finalising the Handbook process the developed requirements and procedures to get “Approval in Principle” are expected to be sufficiently advanced to seek approval in any European country without major modifications. Not only infrastructure companies, HRS operators/ owners and local authorities but also the EC will profit from the Handbook that is deemed to contribute to the safe implementation of a hydrogen infrastructure.

HyApproval comprised 7 workpackages including ‘HRS Definitions & Requirements’, ‘Handbook Compilation’, ‘Infrastructure & Deployment’, ‘Safety’, ‘Dissemination & Public Awareness’, ‘Vehicle Requirements’ and ‘Project Management’.

HyApproval was to assist in building alliances between industry, governments, authorities, research and SMEs in order to establish best practises mechanisms and to take the approval in principle further to a recognised and established approval procedure. It can furthermore serve as a future platform for the exchange of all HRS approval and implementation relevant issues in Europe and internationally.

The results of HyApproval will be communicated in widespread dissemination activities including various national and international workshops and publications.

The project complied with earlier EU’s R&D and energy policies, which aimed at the introduction of 5% hydrogen as motor fuel by 2020 respectively assists in obtaining HyWays hydrogen vehicle introduction scenarios for 2020, envisaging between 1 million and 5 million hydrogen vehicles in the market at this time.

1.2 Project objectives per work package

1.2.1 Work package 1:

In the first phase, the objective of WP1 was to define a “virtual” hydrogen refuelling station (HRS) with essential components of a uniform design and required safety features which could be approved in France, Germany, Italy, The Netherlands and Spain. WP1 will deliver input to WP2 (Handbook).

In the second phase, the objective of WP1 was to digest the findings of ST1 and ST2 into one single document, describing three different sizes of HRS (small, medium and large). The original task was to define a "generic" HRS which could be certified in any European country. It was found that this task is nearly impossible to achieve because of the great differences throughout Europe's certification processes and different safety philosophies.

1.2.2 Work package 2:

The objectives of the WP2 were:

- To write a Handbook for facilitating the installation of refuelling station in Europe
- To finalise the draft guidelines of hydrogen refuelling station initiated in EIHP2

The following actions should be performed:

Issue D2.2: Final version of the Handbook for hydrogen refuelling station approval
Include D2.3: Final regulation of hydrogen refuelling stations in the Handbook
Issue D2.5: List of applicable regulations, codes and standards
Submit the draft Handbook to the different local authorities
Include the feedback from local authorities in the Handbook

1.2.3 Work package 3:

Identify the requests of the responsible authorities (central, regional, local and fire brigades) for the approval of HRS in the five selected EU member states with respect (i) to the safety approach that the authorities will apply in the approval process and (ii) the refuelling station infrastructure in order and to come to a future "uniformised" HRS and the definition of a uniformised safety assessment process and safety features required for the approval of HRS in the member states.

1.2.4 Work package 4:

The objective of this work package is to develop a uniform approach based on 'best practice' experiences to give guidance to developers and regulatory authorities on public safety issues related to design, construction and operation of hydrogen vehicle refuelling stations.

In order to reach the objective, inputs from HySafe and other industry safety studies involving simulations and demonstrations will be utilised. The major involvement of research, certification & testing organisations contributed to the Handbook for agreed public safety standards and permitting issues.

The output was included into the WP2 Handbook.

1.2.5 Work package 5:

The main objective of WP5 has been to identify and inform European, national and local decision makers dealing with fuel station approval processes and international standards institutions about the Handbook for HRS and to involve them in the verification process of this Handbook. To reach this objective intense collaboration with national hydrogen associations has been established to create customised models to facilitate effective local dissemination. In addition more intense collaboration has been established with members of the CTIF the International Federation of Firefighters to discuss the use of the Handbook in training courses of fire fighters and emergency response personnel.

1.2.6 Work package 6:

The objective of this work package was to identify the requirement for refuelling stations from the vehicle side. Because of different requirements of various tanks systems there is the need to establish strong collaboration to define the interface requirements for both fuels, liquid as well as compressed hydrogen at the available filling pressures. The OEMs had to define suitable conclusions.

As long as no final standards were available it was decided to established *technical information reports* (TIRs).

1.3 Contractors involved

Ludwig-Bölkow-Systemtechnik GmbH (Germany), Air Products PLC (UK), Air Liquide Division des Techniques Avancées (France), BP Gas Marketing Limited (UK), Chinese Academy of Sciences, Techical Institute of Physics and Chemistry (PRChina), COMMISSARIAT A L'ENERGIE ATOMIQUE (France), NATIONAL CENTER FOR SCIENTIFIC RESEARCH DEMOKRITOS (Greece), Det Norske Veritas AS (Norway), Eni S.p.A. (Italy), Forschungszentrum Karlsruhe GmbH (Germany), Adam Opel GmbH (Germany), Federazione delle Associazioni Scientifiche e Tecniche (Italy), Norsk Hydro ASA (Norway), Icelandic New Energy Ltd. (Iceland), Institut National de l'Environnement Industriel et des Risques (INERIS), Joint Research Centre (The Netherlands), Linde AG (Germany), Hydrogenics Europe N.V. (Belgium), Shell Hydrogen B.V. (The Netherlands), TNO (The Netherlands), Total (France), National Renewable Energy Laboratory (USA), Health & Safety Executive (UK), Engineering Advancement Association of Japan (Japan)

1.4 Coordinator contact details

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1.5 Work performed and end results

1.5.1 Work package 1:

- ST1 (Hydro): Analysis and definition of the basic functional HRS requirements (basic HRS technologies) completed.
- ST2 (DNV): **Analysis and definition of the most basic safety equipment and safety distances arising from the equipment itself (H2 generation or delivery, compressor, liquid & compressed gaseous hydrogen storage, dispenser), disregarding the national expectations on safety equipment and distances.** An important work was the definition of the "best engineering practice" related to HRS currently existing in the field in different locations, industrial and public. Additional value could be created by taking into consideration the input from China, Japan & USA
- ST3 (HYGS): Integration of ST1 and ST2 into three "generic" HRS sizes →Draft Design Paper (DDP) established. The Intermediate Design Paper (IDP) has also been finalized and posted on the project web-page. These two papers have been used as one basis for the development of the Handbook. The Final Design Paper (FDP) although providing some good examples of three different sizes of HRS turned out to have much less content than originally anticipated since all important information is now contained in the Handbook. This on the other hand is regards a positive achievement as the HB will be a living public document disseminated to all relevant regulatory and standards organisations in Europe.

  [Remark: The original task was to define a "generic" HRS which could be certified in any European country. It was found that this task is nearly impossible to achieve because of the great differences throughout Europe's certification processes and different safety philosophies.]

- ST4 (ENI): Review of international RCS approaches.(existing ones and those under development). Especially the EIHP2 draft, the HyFleet:CUTE deliverables and the ISO TC197 WP11 draft have been used for revision and the best practice could be identified. Analysis of *already existing HRS* and the RCS according to which they have been built. Particular emphasis was laid on the acquisition and review of information obtained from projects like HyFleet:CUTE, ECTOS, ZERO REGIO and CEP.
- ST5 (LINDE): Development of a liquid hydrogen (LH2) refuelling station draft (in analogy to the gaseous hydrogen refuelling draft developed in EIHP2)
- The WP1 partners have performed well and worked out substantial documents, reflecting the today's HRS landscape. These documents have been taken as basis for the further development of the DDP, IDP and finally FDP. From WP1, substantial input was forwarded to WP2, being embedded in the content of the HB.

The deliverables are: 1.1 Draft design paper, 1.2 Intermediate design paper and 1.3 Final design paper.

1.5.2 Work package 2:

In the course of the project, it has been decided to merge the two main outputs of WP2. the Handbook and Final Design Paper into a single stand-alone document. Only those contents which could not be integrated into the HB are now contained in the Final Design Paper (overviews of small, medium and large HRS layouts and an overview of different HRS parameters).

Many of the most skilled European experts in hydrogen refuelling stations were involved in WP2. The compilation of the Handbook was an iterative process along the two years of the HyApproval project. More than ten intermediate versions of the Handbook were produced and submitted to the consortium for review. Moreover some comments have been collected from experts outside the HyApproval consortium.

Therefore one of the main challenges for the WP2 was to compile a great number of inputs into a single stand-alone document, which needs to be easy to read, be as complete as possible but without repetitions. A huge number of inputs had to be treated, coming in various formats (e.g. modifications of an existing documents, new paragraph or list of comments/recommendations) and from various organizations.

The deliverables are: D2.1 - Draft version of the Handbook for hydrogen refuelling station approval, D2.2 - Final version of the Handbook for hydrogen refuelling station approval, D2.3 - Final regulation of HRS, D2.4 - Suggested safety scenarios to WP4 and D2.5 - List of applicable regulations, codes and standards.

1.5.3 Work package 3:

The first two steps in order to identify the requests of the responsible authorities were to locate the representative bodies and to put questions in a uniformed manner.

By selecting the responsible authorities that were involved in the various hydrogen demonstration projects (for instance the CUTE project) the interviewing parties met authorities that already had some experience regarding hydrogen approval projects and were familiar with problems of various nature.

By developing a standard questionnaire the interview process in the five selected EU member states and the USA has been geared as much as possible.

For Italy and the Netherlands the interviews give a clear impression of the actual approach regarding the approval procedure for HRS's and the requirements regarding the safety approach for the near (0-5 years) and intermediate (5-10 years) future.

All interview results (from interview round 1) were collected and reported in deliverable 3.1. Conclusions and recommendations with respect to the draft HRS definition were reported in deliverable 3.2

A draft version of the Handbook was presented to the same authorities as those in the first interview round (NL, D, F, E, I, USA and China) together with a specially prepared evaluation questionnaire, for their comments and suggestions for improvements and additions. These findings were presented in WP2 meetings for inclusion in the final version of the Handbook. Results were also reported in WP3. Findings were also reported in deliverable 3.3

The deliverables are:

D3.1 Report with conclusions and recommendations with respect to the requirements for the safety assessment required for the approval of an HRS (input to WP4), D3.2 Report with conclusions with respect to the draft HRS definitions and requirements and the Handbook and recommendations for improvement and D3.3 Presentation of HB, consultation with authorities of the 5 selected MS, EIGA, CEN, etc. and sense check of the revised HB in the 5 selected MS.

1.5.4 Work package 4:

In period 1 of the project, a comprehensive Risk Assessment Workshop was convened by INERIS in Paris to review HRS accident scenarios and select simulations for CFD modelling. The RA Workshop confirmed the accident scenarios for CFD modelling as had been identified and proposed by the energy and gas merchant companies in the original HyApproval DoW.

Information on HRS safety incidents was received from the CUTE Project to be used as background information for risk assessment of HRS safety.

The Research Organisations (CEA, ENI, FZK, JRC & NCSRD) have performed work on CFD simulations on the accident scenarios identified by the Risk Assessment Workshop organised by INERIS.

NREL have provided the US DoE document entitled ‘Guidance for Safety Aspects of Proposed Hydrogen Projects’ (October 2005), which was used to prepare deliverables D4.7 & D4.10 as the information is seen as a very good example of best practice exchange between the HyApproval partners in promoting international harmonization for the development of hydrogen infrastructure projects. Only the specific references to US DoE hydrogen project solicitations, local US codes and standards and terms have been changed from the original US DoE document.

After time consuming discussions in period 1 on the accident scenarios and the simulations, WP4 has provided the required input to WP1, WP2 and WP3.

The objectives, being to develop a uniform approach based on “best practice” experiences to give guidance to developers and regulatory authorities on public safety issues related to design, construction and operation of hydrogen vehicle refuelling stations have been met.

The deliverables are: D4. 4.1 - Established safety matrix, D4.2 - Established best practices for safety, D4.3 - Agreement on safety documentation for Handbook and actions to complete HRS documentations, D4.4 Identification and critical review of reliability data from past data collections and risk studies, D4.5 - Agreement on required safety documentations, D4.6 - Agreement on required modelling tools & techniques for risk assessments and simulations, accident scenarios, credible leak rates, D4.7 - Safety documentation for Handbook & Guidance for Safety Aspects of Hydrogen Infrastructure Projects & Hydrogen Refuelling Infrastructures: Safety Plan Checklist, D4.8 - Development of simulation scenarios based on present HRS systems, D4.9 - HAZOP/ QRA/ FMEA/ Risk Ranking (including Appendix A: Risk analysis of hydrogen refuelling stations - assumptions and study basis, Appendix B: Risk analysis of hydrogen refuelling stations - consequence assessments, Appendix C: Risk analysis of hydrogen refuelling stations - description of example case study HRS, Appendix D: Risk analysis of hydrogen refuelling stations - frequency assessments and Appendix E: Risk analysis of hydrogen refuelling stations - event tree assessments, D4.10 - Agreement on safety documentation, D4.11 - Matrix table of accident simulations & scenarios, risk assessment studies, D4.12 Risk assessments & accident simulations as per matrix table and D4.13 Compilation of a report detailing all the research activities and results generated in WP4.

1.5.5 Work package 5:

The main objective of WP5 has been to identify and inform European, national and local decision makers, dealing with refuelling station approval processes and international standards institutions, about the HB and to involve them in the HB verification process. To reach this objective intense collaboration with national hydrogen associations has been established with the support of the European Hydrogen Association, EHA, to create customised models to facilitate effective local dissemination. In addition collaboration has been established with national members of the CTIF, the International Technical Committee for the Prevention and Extinction of Fire, especially with their national members in Belgium, German and Austria to discuss the use of the HB in training courses for fire fighters and emergency response personnel.

In the information collection phase national hydrogen and fuel cells associations and platforms have been contacted to solicit contact information of HRS authorization officials and industries involved or interested in hydrogen infrastructure development. In addition literature and event searches were conducted to establish a database of venues to present the project. WP5 also suggested to include a question in the questionnaire and interviews of WP3 on how the HB format should look like and how it could best serve information dissemination in an authorization organisation.

Through an in-depth verification of past and current dissemination activities in EU projects recommendations were formulated to establish effective national dissemination models (D 5.1). To complement the dissemination models a study was completed with the support of CEA and INE in the form of a matrix of acceptability and awareness levels of local officials and the public in general of hydrogen applications (D5.2). It was found that very few studies exist and that more studies are needed to adapt information on hydrogen and fuel cell applications to key actors in the HRS approval process. It was suggested to study the difference between experts' and the general public's awareness where surveys have been conducted. In this way an education and training plan for specific officials on technical regulatory and safety aspects of the use of hydrogen could be developed.

On the basis of the feedback received on WP3 interview results regarding the format of the HB, a general questionnaire was developed to facilitate the final Handbook verification process by CEN, EIGA, CTIF, ITRE. (D 5.3); this questionnaire will be send with the final Handbook to inform and involve relevant European organisations and decision makers in future HB updates.

As it became clear that only the dissemination of a more complete version of the Handbook would result in concrete feedback of the target audiences and that therefore dissemination activities would risk to fall outside the project duration, not only a general seminar outline, including a national calendar of presentations for each partner country and seminar calendar for industry specific audiences was developed, but a head-start was made with the organisation of several presentations at relevant events (D5.4, D5.6 and D5.8).

The feedback of those presentations plus valuable contributions of BP on their experiences at local level with authorization officials and the general public, formed the key input to the Dissemination models for different countries (D5.5)

Dissemination packages for EU authorities and organisations have been developed; graphic outline and format of HB and brochures are ready for print when final HB content is approved (D 5.7).

The reports "Report of seminar results" in non-participating EU countries have been completed for Austria, and Poland. Sweden, UK and Greece are planning their national seminars after 30 SEP 2007 as they requested presentations of the final HB version.

The deliverables are: D5.1 - Verification of existing studies and formulation of suggestions to create dissemination models and a table on European projects, D5.2 - Matrix of acceptability and awareness levels of different aspects of hydrogen fuelling stations, D5.3 - General questionnaire to facilitate the verification process by CEN, EIGA, EFA, ITRE and List of contacts to European fire brigades, D5.4 - "Safety Review" workshop – HB review by external refuelling station experts and other risk and safety experts from HySafe in 2006 and 2007, D5.5 - General seminar

outline and seminar calendar for industry specific audiences, D5.6 - Dissemination models for different countries, D5.7 - A national calendar of presentations and deadlines for each partner country, D5.8 - Dissemination packages for EU authorities and organisations at the identified key events and in key publications, D5.9 Organisation of Seminars in the following non participating EU member states: Austria, Greece, Poland, Sweden and UK, D5.10 - Report of Seminar results, D5.11 - A database of contacted agencies and officials on European level will be established, D5.12 - A database of contacted national agencies and officials will be established, D5.13 - Sending Handbook to responsible authorities in non-participating EU member states and collect feedback (will be performed after closure of HyApproval via EHA) and D5.14 - European Handbook Workshop (will be performed after closure of HyApproval via EHA in coordination with EC RTD & FCHInStruct [JTI])

1.5.6 Work package 6:

A good progress was done. The collaboration with other OEM's was accommodated to define common parameters and thresholds.

It is mandatory to have a common General interface Description in order to prevent a situation as we currently have with country codes for refuelling interfaces. All dispensers at HRS's, shall have the same interfaces in the EC and worldwide.

Therefore the Interface Description shall follow the SAE standards. According to SAE, the vehicle receptacle geometry is already standardized.

Subtask-related activities comprised:

- General interface description for LH_2 and CGH_2:
  Contend discussed, coordinated with other OEM's which are not participating in the project

  CGH_2 35 MPa: According to SAE J 2600, the receptacle is already standardized. Most of the existing HRSs use already the SAE Standard. This standard is also available as and identical ISO standard 17268. The interface description and also the related link to the SAE, has to be delivered to the handbook.

  CGH_2 70 MPa: A *technical information report (TRI)* which specifies a guideline for the hardware requirements considering fuelling of a hydrogen vehicle with 70 MPa is available. This SAE TRI J2799 is to enable harmonized development and implementation of the hydrogen fuelling interface and will be utilized for the hydrogen field evaluations until enough information is collected to enable final standardisation. This TRI will be subsequently superseded by J2601 in the 2009 timeframe.

  LH_2 Coupling: Consortium of BMW/GM/Linde has developed a new coupling. Opel and BMW had collected the data of the validation process of the new coupling. SAE published a Technical Information Report SAE TRI J2783. WP6 will follow the TRI and provided the description to the Handbook.

- Data exchange vehicle and refuelling station
  Content discussed, coordinated with other OEM's which are not participating in the project

  The vehicle-to-station communications between gaseous and liquid hydrogen vehicles requires a standardized data communication surface for both CGH2 and liquid refuelling.

  LH_2-Interface: The Data protocol is harmonised between BMW and Opel. Car ready confirmation is required. Not finalized is the physical interface. The existing solution will not be the long term solution. Both, BMW and Opel are trying to find a more appropriate interface for LH_2 HRS.The interface description is included in the SAE TRI 2783.

  CGH_2 IR-interface: DC and GM/Opel are developing the IR-interface. Validation is ongoing. HRS part is at the moment unclear. The data protocol at vehicle side is available. The IR-Interface is communicated to SAE 2601, the protocol is also defined and distributed to the SAE and considered in SAE-TIR 2799. Validation of the physical interface at the vehicle side is done. Discussion between OEM's and HRS manufacturers has to be established.

The Handbook describes the wireless interface via an Infrared Communication interface for the CGH_2 storage vehicles and the galvanic interface for liquid storage vehicles.

- Refuelling process LH_2, CGH_2
  Content discussed, coordinated with other OEM's which are not participating the project

  Together with the involved partners the interface data exchange for LH_2 and CGH_2 vehicles were validated in order to come up with a standardisation for the data interface.

  For LH_2 (cryogenic filling) the active operation of the refuelling valves in the station and in the vehicle is necessary. Therefore an exchange of an enable signal between station and vehicle is mandatory.

  For LH_2 the refuelling process as a general description is implemented. Further information regarding liquid refuelling the involved OEM's will inform about the details for refuelling of a Liquid hydrogen storage system.

  For CGH_2 a temperature monitoring of the vehicle tank due to the use of composite tanks or the reaching of a maximum fill-up is necessary. Fast-fill and non-communication-fill scenarios need to be considered.

  For 70 MPa refuelling a technical information report which specifies a guideline for the hard-ware requirements considering fuelling of a hydrogen vehicle with 70 MPa is available. This SAE TRI J2799 is intended to be utilized for the hydrogen field evaluations until enough information is collected to enable final standardisation.

  For CGH_2 the refuelling specification for the compressed hydrogen vehicles is finished. It will be posted at the HyApproval web page.

- Safety during refuelling
  Content discussed, coordinated with other OEM's which are not participating the project.

  No info about incidents from other OEM's is available. German TUEV-Statement for grounding is obtained. No additional grounding is required so far.

  The following questions have to be positively answered in order to ensure safe hydrogen refuelling:

  - Is a breakaway coupling installed with appropriate release force (or an equivalent protection system for LH_2)?
  - By what measures is proper grounding of the vehicle ensured?
  - Is the HRS pressure relief valve installed with the correct opening pressure?
  - What self diagnosis processes are performed during refuelling?
  - What measures are installed to detect severe leakages?
  - Drivers Training implemented ?

  A manual for the drivers instruction was established. This manual was recognized from other OEMs and other regions than the EU.

  The purpose of the HyApproval Handbook was also to share the requirements and performance expectations of vehicle manufacturers to aid station providers in designing stations in the period before a complete set of standards are adopted to ensure that vehicles can be designed to be fuelled at common fuelling stations, and to indicate performance targets for fuelling seen by drivers as competitive with conventional fuelling, and to guide future station performance. Most of the features identified herein are achievable today. Capacity and reliability targets are set forth to support expected growth in numbers of vehicles in cluster regions.

  For the CGH_2 70MPa refuelling process a detail description is included in the Handbook or provided under at following web page:

  http://nextenergy.org/industryservices/70MPa_Specification_Docs.asp

The deliverables are: D6.1 - General interface Description, D6.2 - Data Interface, D6.3 - Refuelling Process and D6.4- safety during refuelling.

1.5.7 Methodologies and approaches employed

Contributions required from all WP leaders. In a general way. Not necessarily WP by WP.

Hydrogen Refuelling Station (HRS):

The main source of information, were the partners with significant knowledge in building HRS. In several iterations, data of existing HRS has been collected and put into a table. From this table, the most important and relevant data has been chosen to be "reference data" for the further development of the Design Paper and its related information. Some of the information which has been collected has been supplied to WP2 for direct insertion into the HB.

Handbook Compilation:

The first task of the WP2 was to agree on a table of content for the Handbook. Based on this the various inputs needed were shared between the WP2 partners, depending on the expertise of each organization. In the course of the project the table of content was reworked, mainly to avoid repetitions and to improve readability of the final document. This led to small modifications of the task sharing.

Data were then collected to feed the various paragraphs.

Compilation of the Handbook was an iterative process. Draft versions of the Handbook were presented to the WP2 partners and discussed in review meetings.

In order to collect data and to improve the quality of the final document, WP2 interacted with the other HyApproval work packages, and with other CE-funded projects (e.g. HyFleet:CUTE, HySafe).

In total more than ten intermediate versions were submitted to the HyApproval partners or to external reviewers.

Infrastructure and Deployment:

To identify the responsible authorities in the selected countries, for each country a partner was appointed to make this selection. Those authorities willing to cooperate, were approached personally, by E-mail or by phone (this order of preference) with the aim to fill in a questionnaire, prepared earlier by a selection of WP3 partners, and approved by all WP3 partners.

Results were compiled by the WP leader (TNO), distributed for approval amongst WP3 partners and finally reported in deliverable 3.1. Conclusions and recommendations with respect to the draft HRS definition were reported in deliverable 3.2

To have the draft version of the Handbook evaluated an evaluation questionnaire was prepared in the same way as the first questionnaire mentioned above. This questionnaire was sent to the same authorities as those in the first interview round together with the draft of the handbook. Returned comments were compiled and reported in deliverable 3.3, again after a comment round amongst WP3 partners.

Safety:

By reviewing and evaluating RCS from existing projects, the Handbook establishes Best Practice for Safety.

The Research, Testing & Certifying participants, in conjunction with HySafe and Industry partners, have developed realistic accident scenarios and credible leak rates which were used in the different Risk Assessment methodologies. The identification and critical review of reliability data from past data collections and risk studies have forced Industry partners and Research, Testing & Certifying participants to find consensus on the data to be used in order to realise these Risk As-

sessments where the results reflect the safety requirements for future HRS's taking into account the technical and commercial feasibility of a Hydrogen Economy.

HyApproval Research, Testing & Certifying participants have developed simulation scenarios based on present HRS systems for which data have been released by the Industry Partners and on reports that have been generated based on interviews with authorities and other involved parties such as fire brigades.

The collaboration and data exchange between all different parties involved in the HyApproval project has generated Best Practise for the Safe implementation of a Hydrogen Station.

Dissemination, Public Awareness, Int. Cluster Activities:

To ensure broad and consistent dissemination to different target audiences in HyApproval partner countries and EU Member States a customized HyApproval Dissemination Model format was developed that can be updated and adapted to changes in authorization procedures and the position of responsible officials. Even during the course of the two year HyApproval project changes in responsible authorities and contact persons in national organizations were frequent. It also became clear that most target audiences were interested to review and contribute to a more complete version of the Handbook to confront the recommendations with current local practice. The HyApproval model therefore has been revised multiple times and will remain a living document as a practical instrument for dissemination at multiple levels in each country.

The HyApproval Dissemination Model contains information per country. Each country sheet is divided in different sections covering National government department, Fire Brigades, relevant national organizations, EU project contacts, media and event contacts. A separate section of EU contacts in the European Commission, the EU Parliament and European organizations is included as well.

Presentations of the Draft Handbook were instrumental to collect contact info of the main authorities and other key players. In addition contacts were established with national fire brigades who provided valuable information on local authorization procedures and key actors. The European Hydrogen Association's national member associations were instrumental in identifying suitable seminar dates and locations. The countries listed are covering a broader geographical area then anticipated in the initial description of the HyApproval project, as actors in those countries communicated contacts in their countries and requested to review the final version.

General recommendations for the use and maintenance of the HyApproval Dissemination Model

1. The model should be updated at least twice a year to keep up with changes in organization charts of target audiences. EU developments on new regulations and technology developments could be used to address all contacts on a regular basis;
2. Other current or future EU projects that deal with similar topics or area dealing with authorities should be informed about the HyApproval Dissemination Model in order to better coordinate communication and avoid application.
3. The model could be helpful for national associations in organizing and planning their events; speakers from organizations in other countries, experiences with similar events etc.
4. The model can be used to start identification of authorities and key players in countries that are not yet included ; the aim of the EHA is to cover all EU Member States;
5. The EHA has asked its national associations to become the national HyApproval Dissemination coordinators who will be responsible for their respective country contact information updates.

Automotive Interface – Vehicle Requirements:

The handbook focuses on the safety requirements for the Liquid and Compressed Hydrogen Refuelling Process at Hydrogen Refuelling stations.

The aim of the Handbook is not to describe the vehicle homologation process or the design criteria for a Hydrogen Refuelling Station, but it gives an overview about the safety related measures during hydrogen refuelling.

The collaboration of GM/Opel as a HyApproval contractor with other OEM's outside the project to collect their experiences was in the opinion of WP6 a very effective decision. Because a public HRS should be able to refuel all hydrogen vehicles in the same way.

Because of the definition of the parameters, the main task of WP6 during the project was to compare the data and parameters between GM, DCX and BMW. A good progress was achieved. The collaboration was accommodated to define common parameters and thresholds for a common refuelling process.

For further projects related to Hydrogen Infrastructure, deriving from this positive experience it shall be mandatory to include at least one partner of the automotive industry to implement the knowledge and experience of the vehicle OEM's to the project.

1.5.8 Achievements of the project vs. state-of-the-art.

WP1 - Hydrogen Refuelling Station Definitions and Requirements:

In WP1, a good progress could be achieved. At the kick-off meeting in Paris (16NOV2005) a large number of partners were present and the issues of WP1 were discussed, ST-leaders were elected and the team-spirit was strengthened. The work of ST1 and ST2 began with collecting data on already built and partly planned HRS in Europe but also in the US and China. The Subtask-leaders did a good job in collecting all necessary parameters and supplying them to the WP1 leader for further processing.

In the first TeleCon (02FEB2006) the further process was discussed and it was found, that the current working-progress is going fine. After the first draft collection of HRS information, a first DDP meeting was held in Stuttgart (16NOV2005). At that meeting, the first specific HRS sites which should be used as reference sites have been agreed upon. In order to ease the exchange of information with other EU-funded projects (CUTE, HyFLEET:CUTE, HarmonHy, …) the partners were asked (e-mail voting) if they would agree to "declassify" the upcoming IDP from the "PP" level to the "RE" level. A consensus could be achieved amongst all partners.

On 12JUN2006 a further WP1 meeting was held and it was found that the small reference station in "Montova" can not be taken as reference, as it is not built yet and it is not sure if it will be certified.

Instead of Montova station, Air Liquide offered to take their small transportable HRS, which was already operated in France as a reference for the small station.

It was further agreed, that the On-Site generation of H2 shall be integrated into the handbook (HB), as otherwise the HB will not be complete. It was also agreed, that the 70 MPa refuelling shall also be covered, as the car-industry is strongly supporting this high pressure for on-board storage of H2 in order to etend the range of the vehicles.

The task force "Housing density" was initiated and did some basic work but in the exchange with the other WPs (WP4), it could be seen, that the factor of the housing density should not be a limiting factor for the approval of HRS and so it was decided to discontinue the work of the task force.

It could be seen as a great support for the HyApproval project and also for the ISO197WG11 (Hydrogen Refuelling Stations) work, if a regular exchange of information could be achieved. So far, this exchange a regular exchange of information could not be achieved. Some further progress will be made by using the know-how of the partners active in both projects in order to bring the relevant content to the project and seek for gaps or deviations.

ST1, ST2 and ST4 have collected all necessary information for the definition of the three different HRS sizes: small, medium and large. The data collected give a very good overview on the exist-

ing HRS throughout Europe, the USA and China, indicating all relevant technical information such as capacity of H2 stored on site, implemented technologies and safety-related equipment installed on the HRS. It also give a good overview on the RCS according to which the respective HRS have been built. The collection makes it very clear that most of the existing HRS are medium size and that in some countries the approval procedure is much more difficult than in others.

WP2 - Handbook Compilation:

The main achievements of the Handbook (HB) compilation (WP2) are:

- Development and iterative update of D2.1 "Draft version of the Handbook for hydrogen refuelling station approval": 9 different versions produced along the period, and submitted to partners for comments
- Submission of the draft version to the different local authorities
- Presentation of two versions of the Handbook to the HySafe experts for review in NOV2006 and MAY2007
- Production of D2.2 "Final version of the Handbook for hydrogen refuelling station approval", including D2.3 "Final regulation of HRS"
- Development of D2.4 suggested safety scenarios to WP4
- Production of D2.5 "List of applicable regulations, codes and standards"

WP3 - Infrastructure and Deployment:

The main achievements in WP3 were:

Identification of the requests of the representative authorities involved in the approval process of hydrogen facilities. To achieve this:

1. Relevant authorities were identified
2. A questionnaire was compiled to structure the interview process and to obtain comparable results
3. Authorities were approached, appointments made and interviews held
4. Reports of interviews were made, send to partners and collected (i.e. those returned: from Italy and NL) by WP3 leader TNO

Development and finalisation of the following deliverables

- D3.1: "Requirements for the safety assessment for approval of HRS"
- D3.2: "HRS definition and recommendation for improvement"
- D3.3: "Presentation of the concept HyApproval handbook to authorities"

WP4 – Safety:

The main achievements of WP4 were the following:

A comprehensive Risk Assessment Workshop was convened by INERIS in Paris to review HRS accident scenarios and select simulations for CFD modelling. The RA Workshop confirmed the accident scenarios for CFD modelling as had been identified and proposed by the energy and gas merchant companies in the original HyApproval DoW.

D4.2: refers to the task of 'establishing best practices for safety' of hydrogen refuelling stations considered within the HyApproval Project DoW of the following:

- Available industry best practices to identify accident scenarios and mitigating factors
- Safety studies from HySafe and other sources as background for determination of other best practices for hydrogen safety

D4.3 & D4.5: refer to presenting a risk assessment methodology in order to identify a list of scenarios for a Hydrogen Refuelling Station (HRS)

D4.6: refers to the agreement between partners participating in WP 4 – Safety on numerical tools, techniques and the data necessary to perform safety analysis of relevant accident scenarios.

D4.7 & 4.10: refer to the Guidance for Safety Aspects of Hydrogen Infrastructure Projects

D4.8: has set up a proposed list of scenarios for the modelling task

D4.9: refers to the Quantitative Risk Assessment of Hydrogen Refuelling Station

D4.11 & D4.12: refer to Risk Assessments and Accident Simulations

D4.13: this document is serving as a report to the activities that have been published under the WP4 activity relating to deliverables D4.1, D4.2, D4.4, D4.7, D4.8, D4.9, D4.11 and D4.12. These deliverables incorporate the results generated by all research partners participating within the WP4 organization.

WP5 - Dissemination, Public Awareness, International Cluster Activities:

D5.1 Verification of existing studies in other EU projects and formulation of suggestions to create dissemination models: created database of dissemination activities in different EU projects regarding hydrogen and fuel cells specifically targeted towards dissemination to authorities. Suggested to include a question on best format of Handbook and dissemination model in WP3 questionnaire to include results in the models.

D5.2 Collect H2 Awareness data and dissemination models: FAST collaborated with INE and CEA to define how the data of different awareness surveys should be interpreted; few awareness studies included specific references to authorities. Final awareness matrix plus summary was submitted on March 10, 2006.

D5.3 Contact European Fire brigades and European organisations to verify handbook: established close collaboration with Hazardous materials Commission of CTIF, the International Association of Fire and Rescue Services, Feuerwehr Hamburg and Deutscher Feuerwehr Verband, EIGA.

D5.4 During the second reporting period it was decided to conduct a “Safety Review” workshop and HB review on respectively 30 NOV 2006 and 09 MAY 2007 by external refuelling station experts and other risk and safety experts from HySafe and from other projects in the EU (HyFLEET:CUTE, ECTOS, ZERO REGIO, CEP) providing comments for improvement of the HB. Experts were selected upon mutual agreement between EC and HyApproval. Travel costs for the experts have been covered by the original budget of WP5. The comments and suggestions of the workshop and review were communicated to WP2 to include them in the HB.

D5.5 General seminar outline and seminar calendar for industry specific audiences: developed EU 25 database containing contacts at national level, national fire brigrade level, as well as contacts at main national publications and events; the national firebrigades have all been addressed to include HyApproval presentations in upcoming events and publications.

The HyApproval dissemination model now includes the following deliverables:

D5.5 General seminar outline and seminar calendar for industry specific audiences

D5.6 Dissemination models for different countries

D5.7 A national calendar of presentations and deadlines for each partner country

D5.10 Organisation of seminars in the following non participating EU member states: Austria, Greece, Poland, Sweden and UK

D5.12 A database of contacted agencies and officials on European level

D5.13 A database of contacted national agencies and officials

D5.8 Dissemination packages for EU authorities and organisations at the identified key events and in key publications: all graphical work and the development of the final format have been completed and approved by the HyApproval Consortium at the last GA on 17 SEP 2007. Small

changes to the text of the brochure have been added. Final organisation of the events and key publications are pending on the decision of the European Commission and the partners.

D5.10 Report of seminar results: reports have been completed of seminars in Austria, UK and Poland. The seminar in Hungary was held on 24 OCT 2007. Presentations in Sweden and Greece have been re-scheduled to allow presentation of the final version of the HB.

D5.13 Sending Handbook to responsible authorities in non-participating EU member states and collect feedback: pending on final version.

WP6 - Vehicle Requirements:

During the project, it was the main objective of WP6 to force the "guests", i.e. other OEM's, to come to conclusions in regard of the standards for the interfaces. Even if no final standard was defined during the project period some TIR (Technical Information Report) could be written and coordinated.

The main achievements were

- DaimlerChrysler was participating in the deliverables related to the compressed hydrogen refuelling
- BMW was participating in the deliverables related to the liquid refuelling
- WP6 has defined a common specification for 35 MPa refuelling stations. The work was expanded to also have a specification for 70 MPa stations and a specification for a 70 MPa refuelling process
- WP6 defined a common refuelling process and the interface for liquid hydrogen refuelling
- WP6 made the project and the Handbook aware to other OEMs

In contrast to conventional fuelling stations hydrogen refuelling stations require a hermetically sealed interface between tank, dispenser, and vehicle storage tank. This affects e.g. the dimensioning of the receptacles, filling procedures and processes. Examples are:

- For CGH_2 a temperature monitoring of the vehicle tank due to the use of composite tanks or the reaching of a maximum fill-up is necessary. Fast-fill and non-communication-fill scenarios need to be considered.
- For LH_2 (cryogenic filling) the gaseous back-flow from the vehicle tank must be enabled to ensure a fast filling process within a closed system when no pressure increase during refilling is allowed.

Together with the outlined partners the interface description, data exchange and the filling procedure for LH_2 and CGH_2 vehicles was validated in order to come up with a standardisation for data interface, nozzle and receptacle.

It was essential to integrate WP6 experiences and lessons learned into the handbook compilation of WP2 as the set-up of filling station interfaces and hydrogen vehicle storage tanks must be subject to and based on the same codes and standards. This is to ensure the compatibility of all interlinking components and equipment. A handbook for refuelling stations without the knowledge of the vehicle requirement will not be really helpful for the set up of a hydrogen infrastructure. Therefore vehicle requirements were part of the handbook. WP6 had included the specific requirements for hydrogen vehicles to the handbook.

Part of WP6 had also included, in conjunction with WP4, the safety requirements during the filling procedures. WP6 put together best practice in handling gaseous and liquid hydrogen during the refuelling process. Also the coordination with other projects such as CaFCP and standards such as SAE took place.

1.6 Impact of the project on its industry or research sector

WP1 - Hydrogen Refuelling Station Definitions and Requirements:

The main result of WP1 was the definition of standard HRS for the approval process. The impact on the industry and research sector can be realised by the direct comparison of different realised HRS and the reference to those stations when planning a new station. Many examples are listed in the tables which have been taken as basis for the FDP. The reference stations explicitly show which HRS types have the highest chance to be approved in most of the EU countries. As WP1 has worked out the basis for the HB definition in WP2, the main use will be made of the HB rather than the deliverable of WP1.

WP2 - Handbook Compilation:

By nature the Handbook is the last Deliverable of the HyApproval project to be issued. The final version is still to be disseminated. Therefore impacts on the community are expected (see project objectives) but are not yet visible.

The partners having directly contributed to the Handbook compilation and review now benefit from the work achieved. The Handbook provides immediate access, in a synthetic way, for instance to best technical practices, list of applicable standards or current approval process in Italy, France, The Netherlands, Germany, Spain and China.

WP3 - Infrastructure and Deployment:

Results from WP3 clearly showed that authorities' demands and requirements vary considerably between countries or regions. In particular if experience with HRSs was limited authorities had a tendency to include requirements from all areas that were considered 'comparable', This will only change if exposure to and experience with HRS's increases and, secondly, if the technologies used will be further standardised. The latter will also allow standardisation of safety requirements as only a limited number of technological options is used. Hence industry and research organisations will need to increase the public's exposure to HRSs and keep demonstrating its safety (e.g. with the help of independent research organisations) and at the same time strive for standardisation as this will eventually make the approval process easier, quicker and cheaper

WP4 – Safety:

Existing HRS's have been built to a number of different regulations, codes & standards, primarily based on national and local specific requirements and some codes and standards have been derived from experiences with the CNG industry. The review of existing regulations, codes, standards and relevant technical references or guidelines that make use of recognized best practice industry experiences to set safety standards to design and construct HRS's have identified a number of regulations, codes and standards which set the base for further RCS development and do provide a clear overview to the regulators and Industry partners.

There are experiences from industry best practices related to on-site production of hydrogen, by water electrolysis or by natural gas reforming, to gaseous compressors, liquid hydrogen pumps, gaseous buffer storage and LH_2 storage tanks which are applicable and relevant to be considered, these best practises have been gathered in the Handbook and give the opportunity for the Industry partners to gather learning's on best practises and to take these into account on future HRS projects.

In the Quantitative Risk Analysis (QRA) potential hazards are identified, and the annual frequencies of the hazards are estimated based on historical incident data. Availability of relevant high-quality incident data is important for the quality of risk studies and in particular for general risk management of installations. A challenge when performing risk analysis of HRS's is the lack of historical incident data for such installations. The lack of data is mainly due to the fact that the use of hydrogen as fuel for transportation is relatively new, and the exposure data for HRS's is there-

fore scarce. The Industries have now a clear example of a QRA performed on a reference HRS and clear understanding of the issues related to the lack of reliable data, this again triggers the question of creating future global databases on HRS equipment.

Within the framework of WP4 partners CEA, ENI, FZK, JRC and NCSRD have performed consequence assessments of the H_2 accidental release scenarios identified earlier in the project through scenario selection workshops, see HyApproval deliverables D4.6. The consequence assessment was performed employing mainly the CFD methodology. A simpler integral modelling tool was applied in two of the scenarios. Engineering models are based on a simplified representation of the physics and on experimental data. This means that the models will have a limited range of applicability and caution must be exercised so as to not extrapolate the results of the model too far. Engineering models are widely used in assessing hazard consequences, they are quick and easy to use but they are not well suited to complex geometries. Increasingly, the more sophisticated CFD models are being used, as both the models themselves, and the computers on which they run, are rapidly improving. CFD models require expert users, but they do provide very detailed output that cannot be matched by simple engineering models.

As a conclusion we claim that Safe practices in the production, storage, distribution, and use of hydrogen are essential for regulatory approval and for the widespread acceptance of hydrogen technologies. A catastrophic failure in any hydrogen project could damage the public's perception of hydrogen and fuel cells and could also decrease the ability of hydrogen technologies to gain the approval of the local regulatory authority, a necessary occurrence for commercialization.

WP5 - Dissemination, Public Awareness, International Cluster Activities:

At the last General Assembly the HyApproval consortium agreed that the European Hydrogen Association, EHA, representing 14 national associations in Europe and the main industrial players, many being HyApproval partners, will facilitate the dissemination of the HyApproval Handbook after the project has ended in collaboration with FAST and the Italian Hydrogen and Fuel Cell Association, H2IT. This will ensure that the HyApproval Dissemination Model will be updated and completed overtime and that a broad range EU, national and local stakeholders involved in the installation and authorization of HRS will be informed about the Handbook in a continuous manner.

WP6 - Vehicle Requirements:

The number of hydrogen fuelling stations is steadily growing worldwide as the number of hydrogen-fuelled vehicles increases. Most of these vehicles are carrying a compressed hydrogen gas (CGH_2) or a liquid hydrogen (LH_2) storage system on board.

The OEM's have developed a common refuelling process. This document describes the targeted refuelling process based on vehicle requirements and also defines a series of detailed requirements (performance, hardware,…) for the vehicle interface at fuelling stations.

Because of the different thermal behaviour of different vessel types, all HRS should follow the refuelling specification. The specification is available at the web page:

http://nextenergy.org/industryservices/70MPa_Specification_Docs.asp

A communication interface between vehicle and HRS will be introduced, with the purpose of optimising the refuelling process. Both communication-fill (optimised) and the more conventional non-communication fuelling needs to be considered for development of the hydrogen infrastructure.

2. Main Challenges and Movers:

2.1 Moves by the European Commission:

The European Commission intends to take two important decisions, which should increase the potential of hydrogen as an energy carrier in Europe.

The first is the creation of a multi-billion euro public/private partnership for research, a ***Joint Technology Initiative***, to benefit the development of fuel cells and hydrogen. This will be the fifth such Joint Technology Initiative to be proposed by the Commission since the start of the 7th Research Framework Programme in 2007. It will start with an Interim Structure in fall 2007.

The second is a ***Regulation on motor vehicles using liquid or compressed gaseous hydrogen***. This will lay down common rules on the construction of these vehicles to ensure the smooth functioning of the internal market, high levels of public safety and the possibility of greener forms of transport in the future.

2.2 Findings by the European Industry and Research Community:

The results of the HyWays project quantify the expected hydrogen vehicle and refuelling station penetration in the European market.

Source: http://www.hyways.de/docs/deliverables.html

The HyWays project in agreement with the European Hydrogen and Fuel Cell Technology Platform (HFP) comes to the conclusion that the following numbers of road vehicles will be expected by 2020 if policy support is provided:

- 1 million (with high policy support and fast learning)
- 5 million (with very high policy support and fast learning)

HyWays has identified the following low and high scenario numbers for hydrogen road vehicle for 2030:

- 15 million (with high policy support and fast learning)
- 50 million (with very high policy support and fast learning)

HyWays has identified the following numbers of hydrogen refuelling stations for Europe:

- for an introductory “lighthouse project” phase (2010-2015) some 400 stations in selected urban centres and some 500 stations on selected inter-connecting highways between these urban centres
- for the phase of developing demand (2015-2025) between 13,000 and 20,000 stations
- for the massive rollout phase after 2025 the same station patterns as today for conventional fuels will be reached

3. Introduction to the Handbook

The HyApproval project aims to develop a uniform approach to installation and approval of Hydrogen Refuelling Stations (HRS) throughout Europe as well as attempting to define a typical “European” refuelling station, which could be installed in most of the EU27 countries.

For example the CUTE project has shown the need for harmonization of safety requirements and permitting process. This has made it difficult for the infrastructure companies to propose a cost effective standard for hydrogen refuelling station sites. The HyApproval HRS handbook addresses these issues.

In order to move towards the goal of enabling the development of cost effective hydrogen refuelling stations, subject to harmonized requirements, an "EU wide" approach needs to be implemented. As a first step, an EU draft guideline was initiated during the EIHP2 project. The HyApproval handbook builds on this project by compiling recommendations, good practices, and applies these to a reference station.

The main goals of the handbook are:

- To serve as a working document to help and support authorities to deliver permits to install and operate HRS in Europe
- To assist companies and organisations in the implementation and operation of hydrogen refuelling stations
- To contribute to the safe implementation of a hydrogen infrastructure by addressing key safety issues (safety distances, safe technical solutions, operation and maintenance)

Therefore the target readers are mainly the authorities, regulators and the hydrogen refuelling stations owners.

This document will enable infrastructure companies, in the future, to avoid developing country specific standards and sites designs, and instead promote EU uniform HRS layouts.

The present handbook has been written as a standalone document. It is based on best practices reflecting the existing technical know-how and regulatory environment, but it also includes flexibility to allow new technologies and design to be introduced at a later stage. Along the 2-year development phase is has been reviewed by authorities in 5 EU countries (France, Germany, Italy, Spain and The Netherlands) and in China to pursue "broad agreement" and to define "approval routes".

The handbook provides recommendations for an EU27 uniform approval process for HRS. The handbook is thereafter divided into two main parts:

- Part I: "Guidelines for design, operation & maintenance of a Hydrogen Refuelling Station" provides technical guidelines and best practices related to construction and operation of a hydrogen refuelling station. It includes the properties of hydrogen, and the list of regulations, codes and standards related to HRS. It also presents the methodologies for a risk assessment in the frame of a HRS approval.
- Part II: "Permitting process" proposes an approval route, which could be applicable all over Europe. It also highlights the HRS approval process differences between France, Germany, Italy, Spain, The Netherlands and China. It identifies the gaps between the various national processes. A feedback from the authorities is also included.

As hydrogen refuelling stations are still largely built as demonstration facilities, allowance for further technological development and new innovative solutions is necessary. The safety of these can be addressed by application of relevant risk assessment methodologies described in the HyApproval Handbook, and demonstrated in the reference HRS risk assessment also provided in the Handbook.

Disclaimer

The handbook is based on best knowledge and experiences of 2007 available in the HyApproval consortium. The design and system solutions presented in this document are selected on the basis of practice prior to 2007 and should not be understood as mandatory.

4. Main Conclusions and Recommendations:

The Handbook produced by the HyApproval consortium is a good starting point for establishment of an EU27 uniform approval process for hydrogen refuelling stations. It contains a large number of technical and regulatory information, useful for authorities, regulators and hydrogen refuelling station owners.

4.1 General recommendations derived from HyApproval

The key recommendation is to develop an EC regulatory framework for hydrogen refuelling stations based on the proven combination of Essential requirements, Harmonized standards, and Notified bodies. This could be most efficiently achieved through the development of an EC Regulation (as opposed to an EC Directive).

Going a step further, such a framework would allow for a mechanism of **fuelling station "type approval"** (similar to that of road vehicles), allowing a given station design to be approved for deployment in number in all EU 27 countries.

Until such a framework is fully established at EC level, national authorities are encouraged to adopt a permitting process structured similarly: one single authority, relying on the evaluation of one expert body, and referring to pre-established set of requirements and approval criteria.

International standards (ISO, IEC), developed considering the essential requirements set out in regulation, **are the framework of choice for developing and providing fuelling station design rules and criteria** allowing to meet regulatory and permitting requirements.

Whereas as regulation is developed at the initiative of the concerned EC regulatory bodies, standards are developed mostly through the contribution of industry. **However, due to the link between regulation and standards that needs to be established,** a key feature of the proposed regulatory framework, **close cooperation between actors of both worlds is necessary**.

Finally, in parallel to the development of the adequate regulatory framework, **guidance and support needs to be provided to the stakeholders** regarding the applicable standards and regulation, explaining how to apply these as well as providing the underlying knowledge base.

Providing this type of guidance is a key objective of the HyApproval handbook, which, as such, will need to be continuously updated.

4.2 List of Requirements for a Future Maintenance of the HyApproval Handbook

4.2.1 Suggested Structure and Tasks of a Handbook Maintenance Organisation

- An organisation for enabling service, support and maintenance of the Handbook should be nominated. This organisation preferably could have the capability to develop the Handbook together with the European Commission towards an EC regulation or directive at a later stage.
- One key task could be to develop a web-portal for the Handbook as has been done by the U.S. Department of Energy.
- The handbook web-portal should contain compiled helpful guidelines on where to find the latest technological information and lists of useful information sources for those who intend to review hydrogen facilities and issue permits. Permission to link such information sources should be harmonized to IEA, hydrogen implementation agreement, ISA working groups, ISO and other relevant working groups.

- Contact and co-operation with other key national organisations, e.g. DOE and ENAA should be formalised.
- The Handbook should be reviewed at least every 2 years.
- Establishing this activity as a "HRS Approval Industry Grouping" could be beneficial as positioning towards the future JTI activities.
- ISO has issued a first suggestion of hydrogen standards (e.g. ISO/PDTS 20012), restrictions and requirements in the handbook can be streamlined/ simplified by using these in cross-references and thus avoid mismatching/ contradicting information.
- In order to inform a broad group of stakeholders and local authorities at EU and Member State level collaboration with a European organisation active in the promotion of the use of hydrogen in transport applications is needed that could facilitate national and local dissemination of the Handbook. The European Hydrogen Association has offered to facilitate this dissemination in collaboration with HyApproval partner FAST and the Italian Hydrogen and Fuel Cell Association H2IT. This offer was accepted at the 5th General Assembly of HyApproval on 17 September 2007.

4.2.2 Consulting Group to the maintenance of the Handbook:

- Stakeholders not willing or able to make financial contributions and commitment. This group can contribute with valuable in-kind to the external review processes, e.g.:
  - "Fire Brigade representative, e.g. CTIF (the international association of fire and rescue services)
  - Other parties from Europe with practical HRS approval experience in e.g. Germany, Italy, Spain, Sweden, The Netherlands, UK or any other location were hydrogen refuelling stations have already been approved, preferably for public use and access.
- Research organisations e.g. coordinated by HySafe or a permanently installed European follow-up organisation
- Notified bodies, certification bodies and approval authorities; DNV has already offered to guard the Handbook maintenance process

5. Deliverables and milestones of the project

5.1 List of deliverables, including due date and actual/foreseen submission date

Deliverables list

Delivery no.[1]	Deliverable name	Lead participant	Nature[2]	Dissemination level [3]	Delivery date[4]
0.1	Provision of agreed and signed Consortium Agreement	LBST	O	CO	M2
0.2	Installed HyApproval website	LBST	O	PU/CO	M3
0.3	Intermediate report	LBST	R	PP	M12
0.4	1st annual financial statement	LBST	R	CO	M12
0.5	Final report	LBST	R	PU	M24
0.6	2nd annual financial statement	LBST	R	CO	M24
1.1	Draft design paper	HYGS	R	PP	M4
1.2	Intermediate design paper	HYGS	R	PP	M9
1.3	Final design paper	HYGS	R	PU	M15
2.1	Draft version of Handbook for Hydrogen refuelling station approval	AL DTA	R	PP	M12
2.2	Final version of Handbook for hydrogen refuelling station approval	AL DTA	R	PU	M24
2.3	Final regulation of hydrogen refuelling stations (continuation of EIHP2)	AL DTA	R	PU	M24

[1] Deliverable numbers in order of delivery dates: D1 – Dn

[2] Please indicate the nature of the deliverable using one of the following codes:

R = Report

P = Prototype

D = Demonstrator

O = Other

[3] Please indicate the dissemination level using one of the following codes:

PU = Public

PP = Restricted to other programme participants (including the Commission Services).

RE = Restricted to a group specified by the consortium (including the Commission Services).

CO = Confidential, only for members of the consortium (including the Commission Services).

[4] Month in which the deliverables will be available. Month 0 marking the start of the project, and all delivery dates being relative to this start date.

Delivery no.[1]	Deliverable name	Lead participant	Nature[2]	Dissemination level [3]	Delivery date[4]
2.4	Suggested safety scenarios to WP4	AL DTA	R	CO	M6
2.5	List of applicable regulations, codes and standards (taking into consideration EIHP2, HarmonHy, HFP-IG RCS, ISO)	AL DTA	R	PU	M6
2.6	Gap analysis of the different requirements from authorities	AL DTA	R	PU	M12
3.1	Report with conclusions and recommendations with respect to the requirements for the safety assessment required for the approval of an HRS (input to WP4).	TNO	R	PU	M12
3.2	Report with conclusions with respect to the draft HRS definitions and requirements and the Handbook and recommendations for improvement.	TNO	R	PU	M15
3.3	Presentation of HB, consultation with authorities of the 5 selected MS, EIGA, CEN, etc. and sense check of the revised HB in the 5 selected MS.	TNO	O	PU	M23
4.1	Established safety matrix	Shell	R	PU	M3
4.2	Established best practices for safety	Shell	R	PU	M3
4.3	Agreement on safety documentation for Handbook and actions to complete HRS documentations	Shell	O	PP	M3
4.4	Identification and critical review of reliability data from past data collections and risk studies	Shell	R	PU	M3
4.5	Agreement on required safety documentations	Shell	O	PP	M4
4.6	Agreement on required modelling tools & techniques for risk assessments and simulations, accident scenarios, credible leak rates.	Shell	O	PP	M4
4.7	Safety documentation for Handbook	Shell	R	PP	M8
4.8	Development of simulation scenarios based on present HRS systems	Shell	R	PP	M8
4.9	HAZOP/ QRA/ FMEA/ Risk Ranking	Shell	R	PP	M8
4.10	Agreement on safety documentation	Shell	O	PP	M9
4.11	Matrix table of accident simulations & scenarios, risk assessment studies	Shell	R	PU	M9
4.12	Risk assessments & accident simulations as per matrix table	Shell	R	PP	M12
4.13	Compilation of a report detailing all the research activities and results generated in WP4 (based on reports delivered under D4.1, D4.2, D4.4., D4.7, D4.8, D4.9 D4.11 and D4.12)	Shell	R	PP	M24
5.1	Verification of existing studies and formulation of suggestions to create dissemination models	FAST	R	PU	M12
5.2	Matrix of acceptability and awareness levels of different aspects of hydrogen fuelling stations	FAST	R	PP	M6

Delivery no.[1]	Deliverable name	Lead participant	Nature[2]	Dissemination level [3]	Delivery date[4]
5.3	General questionnaire to facilitate the verification process by CEN, EIGA, EFA, ITRE	FAST	R	PP	M12
5.4	"Safety Review" workshop – HB review by external refuelling station experts and other risk and safety experts from HySafe and from other projects in the EU (CUTE{+}, ECTOS, ZERO REGIO, CEP) providing comments for improvement of the HB. Experts will be selected upon mutual agreement between EC and HyApproval.	FAST	O	PP	M17
5.5	General seminar outline and seminar calendar for industry specific audiences will be developed to be translated by the national associations into a suitable local format	FAST	R	PU	M18
5.6	Dissemination models for different countries	FAST	R	PP	M18
5.7	A national calendar of presentations and deadlines for each partner country	FAST	R	PU	M18
5.8	Dissemination packages for EU authorities and organisations at the identified key events and in key publications	FAST	R	PU	M24
5.9	Organisation of Seminars in the following non participating EU member states: Austria, Greece, Poland, Sweden and UK	FAST	O	PU	M21
5.10	Report of Seminar results	FAST	R	PU	M22
5.11	A database of contacted agencies and officials on European level will be established	FAST	O	PP	M24
5.12	A database of contacted national agencies and officials will be established	FAST	O	PP	M24
5.13	Sending Handbook to responsible authorities in non-participating EU member states and collect feedback	FAST	O	RE	M24
5.14	European Handbook Workshop	FAST	O	RE	M24
6.1	General interface description for LH_2 and CGH_2	Opel	R	RE	M8
6.2	Data exchange vehicle and refuelling station	Opel	R	RE	M14
6.3	Refuelling process	Opel	R	PP	M14
6.4	Safety during refuelling	Opel	R	PU	M12

5.2 List of milestones, including due date and actual achievement date

Milestone no.	Milestone name	Work package no.	Date due (month) [calendar month]	Actual/ Forecast delivery date (calendar month)	Lead contractor
0.1	HyApproval website installed	0	3 [DEC2005]	OCT2005	LBST

Mile-stone no.	Milestone name	Work package no.	Date due (month) [calendar month]	Actual/ Fore-cast delivery date (calendar month)	Lead con-tractor
0.2	Report to EC concern-ing the status quo of the project	0	12 [SEP2006]	NOV2006	LBST
0.3	Final report to EC in-cluding the final version of the HyApproval Handbook	0	24 [SEP2007]	NOV2007	LBST
1.1	Draft design meeting	1	4 [JAN2006]	FEB2006	HYGS
1.2	Intermediate design meeting	1	9 [JUN2006]	JUN2006	HYGS
1.3	Final design meeting	1	15 [DEC2006]	DEC2006	HYGS
1.4	Presentation of “Agreed final design paper” as input to WP2 for the final version of the “Handbook”	1	16 [JAN2007]	JAN2007	HYGS
2.1	The first milestone will be the submission of the approval file including the Handbook to the different local authori-ties.	2	15 [DEC2006]	DEC2006	AL DTA
2.2	The second milestone will be the feedback from local authorities.	2	21 [JUN2007]	JUN2007	AL DTA
3.1	Interview protocol task 3.2	3	3 [DEC2005]	MAY2006	TNO
3.2	Draft report task 3.2	9	9 [JUN2006]	NOV2006 (in-cluding I and NL)	TNO
3.3	Final report task 3.2	3	12 [SEP2006]	DEC 2006	TNO
3.4	Interview protocol for task 3.3	3	10 [JUL2006]	JAN2007	TNO
3.5	Draft report task 3.3	3	13 [OCT2006]	MAR2007	TNO
3.6	Final report task 3.3	3	15 [DEC2006]	APR2007	TNO
4.1	Identification of acci-dental scenarios (safety matrix established in M3).	4	5 [FEB2006]	OCT2006	Shell

Mile-stone no.	Milestone name	Work package no.	Date due (month) [calendar month]	Actual/ Fore-cast delivery date (calendar month)	Lead con-tractor
4.2	Results of scenarios calculations	4	21 [JUN2007]	development of first scenarios OCT 2006; final results expected JUN 2007	Shell
4.3	Final contribution to the Handbook [The safety documentation for the Handbook will be delivered in M9. First results from circulation of the Handbook within the consortium will be available after M15.]	4	23 [AUG2007]	AUG 2007 [Del. 4.7 & 4.10 already circulated for being com-mented; final comments are required by 19 NOV 2006] Final contribu-tion to the HB expected in AUG 2007 as per milestone target	Shell
5.1	Matrix of acceptability and awareness levels of different aspects of HRS completed	5	6 [MAR2006]	Achieved 03APR2006	FAST
5.2	Verification of existing dissemination project results completed	5	12 [SEP2006]	Achieved 15OCT2006	FAST
5.3	General seminar outline and dissemination mod-els completed	5	18 [MAR2007]	Expected MAR2007	FAST
5.4	Databases of contacted agencies on European and local level com-pleted	5	24 [SEP2007]	Expected SEP2007	FAST
6.1	General interface de-scription for LH_2 and CGH_2	6	8 [MAY2006]	Best practice TIR available FEB2007	Opel
6.2	Data exchange vehicle and refuelling station	6	14 [NOV2006]	No milestone, draft available APR2007	Opel
6.3	Refuelling process	6	14 [NOV2006]	Draft available, Final document MAY2007	Opel
6.4	Safety during refuelling	6	12 [SEP2006]	Draft available MAR2007	Opel