

EUROPEAN INTEGRATED HYDROGEN PROJECT PHASE II [EIHP2]

REGULATIONS FOR HYDROGEN VEHICLES AND HYDROGEN REFUELLING

- AIMS AND ACTIVITIES -

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EC-CONTRACT N°: ENK6-CT2000-00442

PROJECT COORDINATOR: L-B-Systemtechnik GmbH

CONTRACTORS:

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Air Liquide SA	FR
Air Products Plc	UK
Bayerische Motoren Werke AG	DE
BP Amoco	UK
Commissariat à l'Energie Atomique	FR
DaimlerChrysler AG	DE
National Centre for Scientific Research Demokritos	EL
Det Norske Veritas	NO
EC-Joint Research Centre	NL
Ford AG	DE
Forschungszentrum Karlsruhe	DE
Vandenborre Technologies NV	BE
Instituto Nacional de Técnica Aeroespacial	ES
Messer Griesheim GmbH	DE
Norsk Hydro ASA	NO
Shell Research Ltd.	UK
AB Volvo	SE
Raufoss ASA	NO
Linde AG	DE

DURATION: 36 MONTHS
(01FEB2001-31JAN2004)

1. Project Summary

1.1 Objectives:

Provide inputs for regulatory activities on an EU and global level to facilitate harmonised procedures for the approval of hydrogen fuelled road vehicles (with both internal combustion engine (ICE) and fuel cell drive trains), hydrogen refuelling infrastructure and the relevant interfaces between the vehicle and the filling station.

Ensure safe development, introduction and operation of hydrogen fuelled road vehicles and hydrogen filling stations throughout the EU and also on a global scale.

By achieving the above objectives one of the commonly perceived barriers for the introduction of hydrogen fuelled vehicles, i.e. the approval of vehicles for operation on public roads with publicly accessible infrastructure, shall be achieved.

1.2 Summary:

Draft regulations for the approval of hydrogen fuelled road vehicles have been developed during the first EIHP phase and are in the submission process to the relevant European regulatory bodies. These draft regulations shall be developed to such a level that they can be harmonised on a global level, initially between the EU and North America. By applying these draft regulations to the design and approval of fuel cell and internal combustion engine vehicles with direct onboard hydrogen storage they will be validated by taking into account not only hydrogen related vehicle components and systems but also safety requirements, refuelling procedures and periodic inspections.

For the relevant hydrogen refuelling infrastructure components and systems, for which existing standards, codes of practice and regulations are only partly identified, the applicable national standards and regulations will be identified and necessary requirements for new draft standards and possibly draft regulations for approval will be developed. These activities among others will also comprise refuelling procedures, safety aspects, periodic inspections and the layout of refuelling stations. The interface between the refuelling station and the vehicle (receptacle and nozzle) will be an important issue. The eligibility for EU-wide harmonisation will be checked. It will also be investigated to what extent certain elements of the refuelling systems are suitable for harmonisation on a global regulatory scale, e.g. components.

Comparative risk and safety analyses with respect to the release of hydrogen in confined and semi-confined environments, such as tunnels, garages, refuelling stations, and inner city streets will be undertaken. These shall provide data in sufficient depth in order to enable the partnership to define the required inputs for hydrogen related standards and regulations.

1.3 Results to be achieved:

- Development of a world-wide harmonised regulation for hydrogen fuelled road vehicles.
- Development of procedures for periodic vehicle inspections (roadworthiness).
- As far as possible development of a world-wide standard or regulation and of periodic inspection procedures for the relevant refuelling infrastructure, subsystems or components.

These draft regulations and standards will enable vehicle and infrastructure industry to save enormous resources in bringing hydrogen fuelled fuel cell vehicles onto the road. Many countries will for the first time have the legal basis to approve the operation of hydrogen fuelled vehicles on public roads and refilling at public refuelling stations. In addition, the access of vehicle and infrastructure component manufacturers to the EU market as well as the North American market will be facilitated in the medium and long term.

2. Major industrial objectives of the project are among others:

Work Package 2 'Refuelling Station'

- Overview of existing regulation and international standard and codes for natural gas, gasoline, diesel, LH₂, and CGH₂.
- Develop a refuelling station layout requirement and decide where harmonisation would be beneficial.
- Analysis and quantification of health, environment and safety risks associated with on-site equipment and performance of HAZOP studies for different refuelling station scenarios (link to WP5 'Safety', sub-tasks 5.2 and 5.5)
- Listing of main components and sub-systems, proposal where harmonisation and standardisation is regarded beneficial, and development of new draft standards, codes of practice or regulations for refuelling infrastructure systems.
- Assessment of the requirements for maintenance and periodic inspection of vehicle related refuelling infrastructure, including monitors and automatic safety systems.
- Adjustment and incorporation of refuelling procedures for fleet vehicles and cars developed in WP3 into the layout of the refuelling station (link to WP3 'Refuelling interface').

Work Package 3 'Refuelling Interface'

- Identification of optimum on-board storage pressure levels for CGH₂
- Development of requirements for international standardisation of interfaces (CGH₂ and LH₂)
- Approved LH₂ and CGH₂ refuelling interface/ connector
- Investigation of refuelling procedures for CGH₂ and LH₂ dispensing, putting particular emphasis on new and innovative techniques that allow fast and economic refuelling of very high pressure and of liquid hydrogen storage tanks

Work Package 4 'Vehicle'

- Validation of the EIHP I draft through the development and realisation of hydrogen components and vehicles according to the EIHP draft
- Monitoring of draft proposal from EIHP I in order to achieve a valid regulation
- Establish a global technical regulation
- Create a procedure for the necessary periodic inspection for hydrogen vehicles (amending directive to directive 96/96/EC)
- Validation of design rules or safety requirements, including definition of a procedure for the calculation and the design of safety valves for vehicle applications

Work Package 5 'Safety'

- *Compilation of existing data* on the safety of hydrogen and comparative fuels
- Performance of *HAZOP* of different refuelling station layouts in order to identify cases to become input for the quantitative risk analysis (QRA). Frequencies of accident causes and accident consequences (including CFD simulations of gas dispersion and explosion) related to refuelling infrastructure (including transportation of necessary raw materials to the stations) will be estimated. A comparison will be made with the risks represented by traditional refuelling stations (close collaboration with WP2 and WP 3). Identification and

evaluation of risk reducing measures, eliminating causes and reducing consequences. These will serve as inputs to other WPs.

- To estimate the consequences related to hydrogen release scenarios for CGH₂ vehicles, e.g. tunnels and inner city streets, and in comparison with CNG, numerical simulations of hydrogen dispersion and combustion processes will be performed. The results of the simulations will be integrated into a consequence analysis in the study of CGH₂ vehicles. The numerical simulations will also be used to provide data for sub-tasks in other WP's, including for example, the optimum on-board storage pressure study in WP3.
- Numerical simulation tools will be validated by *experiments*. The experiments will cover conditions and scenarios relevant to vehicular use.
- An overall *comparative study of risk to health, safety and environment*, associated to hydrogen and other fuels will be conducted, using the results obtained in sub-tasks 5.2 and 5.3.
- *Support of safety issues* in work packages WP4 'vehicle', WP3 'refuelling interface' and WP2 'refuelling station'.

WP5 activities will contribute to safety optimised design of vehicles and infrastructure and will provide information towards authorities and the public enhancing the credibility of hydrogen as a safe vehicle fuel, thus reversing the present negative perception.

Work Package 6 'Links EU-USA and Other Cluster Activities'

- Maintain relations to California Fuel Cell Project, to NHA's international hydrogen infrastructure steering committee, to DoE's Blueprint for Hydrogen Fuel Infrastructure Development, to SAE, to the Hydrogen Joint Working Group (HJWG) of the Americas and the Pacific Rim, etc.
- Attend plenary meetings and working groups 5 & 6 meetings of ISO TC 197 "Hydrogen Technologies"
- This package will try to establish and maintain links between the EIHP2 and other cluster activities (Several comparable activities already have started in the EU and further activities are likely to start in the area of regulations, infrastructure and demonstration of hydrogen fuel cell vehicles, as well as in general safety aspects of vehicles and infrastructure) in order to ensure the flow of information between the different groups, to avoid double work, to identify common goals and to develop increased strengths for these initiatives.
- Identification of comparable initiatives in Japan and establishment of first contacts.
- Ongoing collection and systematic editing of information available from selected other project activities.
- Dissemination of results achieved to interested experts/ target groups among others in workshops to be held with selected European, US and Japanese experts.
- Development of a network structure plan for hydrogen infrastructure implementation in the EU

3. Level of technical risk

There are various areas of technical risk in the proposed project. For infrastructure components, subsystems and systems it cannot yet be predicted to what level EU or even global harmonisation efforts could be successful. In the course of the project, it may be that the implementation process for entire refuelling systems could not be suitable for harmonisation on

EU or global levels, but only on component and subsystem level, and comprise only the development of requirements for standards and codes of practice, rather than for regulations.

Refuelling procedures for extreme high-pressure hydrogen refuelling (e.g. up to 70 MPa) may not be technically feasible to the extent desired.

The comparative risk analysis might show, that hydrogen in certain applications or environments could be more dangerous than conventional fuels already in use. In this case practical abatement measures would pose additional restrictions to hydrogen fuelled vehicles compared to the relative freedom in use of conventional fuels today. An identification and evaluation of risk reducing measures, including cost effectiveness analysis of measures might become necessary in this case. Recommendations for decision making about what risk reducing measures to implement and how, may have to be developed additionally.

4. Project Work Plan

4.1 Introduction to methodology and approach

Work Breakdown Structure

WP1 Overall Coordination	WP2 Refuelling Station	WP3 Refuelling Interface	WP4 Vehicles	WP5 Safety	WP6 Links "EU- USA" + other Cluster Activi- ties
<ul style="list-style-type: none"> • Overall Coordination of Work • Liaison Office • Public Relations (including project related website) • Mid-Term Meeting and Workshop • Report Compilation 	<ul style="list-style-type: none"> • Listing of existing standards, codes, regulations • Scenario descriptions • Description of components to be harmonised • Procedure for maintenance, inspection, operation, refuelling • Procedure allowing the introduction of new station layouts • Final reporting 	<ul style="list-style-type: none"> • Identification of optimised storage pressure(s) for CGH₂ • Development of requirements for international standardisation of interfaces (CGH₂ and LH₂) • Presentation of approved refuelling connectors for LH₂ and CGH₂ 	<ul style="list-style-type: none"> • Monitoring of draft regulation • Establishment of global technical regulation • Development of periodic inspection • Validation of EIHP1 draft regulation • Validation of design rules or safety requirements 	<ul style="list-style-type: none"> • Compilation of existing data on the safety of H₂ and comparative fuels • Definition of relevant scenarios in H₂ refuelling infrastructure • Performance of risk analyses • Numerical validation calculations based on experimental data, Comparison with accident reports / theoretical considerations • Comparative study of risk to health, safety and environment. 	<ul style="list-style-type: none"> • Information exchange with US-activities • Information exchange with EU cluster activities • Establishment of first contacts with comparable Japanese activities • Organisation of workshops with experts/target groups • Development of a network structure plan for hydrogen infrastructure implementation in the EU

To increase efficiency the work content of the project has been divided into 6 interrelated work packages (WP) which are depicted above and described below.

In **WP1** the administration, coordination and monitoring of the project is performed by the coordinator. Furthermore, general communication of project contents and publishable progress results are undertaken by the coordinator via a public project homepage. The coordinator organises regular project meetings (approx. every half a year), calls for specific work package related work group meetings, and monitors progress via the collection of bi-monthly status reports and 6-monthly progress reports from each project partner. The primary means of communication used are e-mails, phone conversations and a secure project internal non-public homepage, to which only the consortium partners and the European Commission has access.

In **WP2** the consortium develops inputs to ongoing work activities on new draft standards and codes of practice for refuelling station infrastructure systems, sub-systems and components. This comprises among other things refuelling station layouts, periodic maintenance and inspections protocols for refuelling stations as well as implementation of refuelling procedures. Prerequisites for the completion of WP2 activities are the work contents of WP3 (validation of standards for nozzle and receptacle and definition of refuelling procedures) and the safety scenario and risk analyses and HAZOP studies performed on different refuelling station layouts in WP5. Efforts for the harmonisation for refuelling infrastructure systems, sub-systems and components are also undertaken within the framework of this WP.

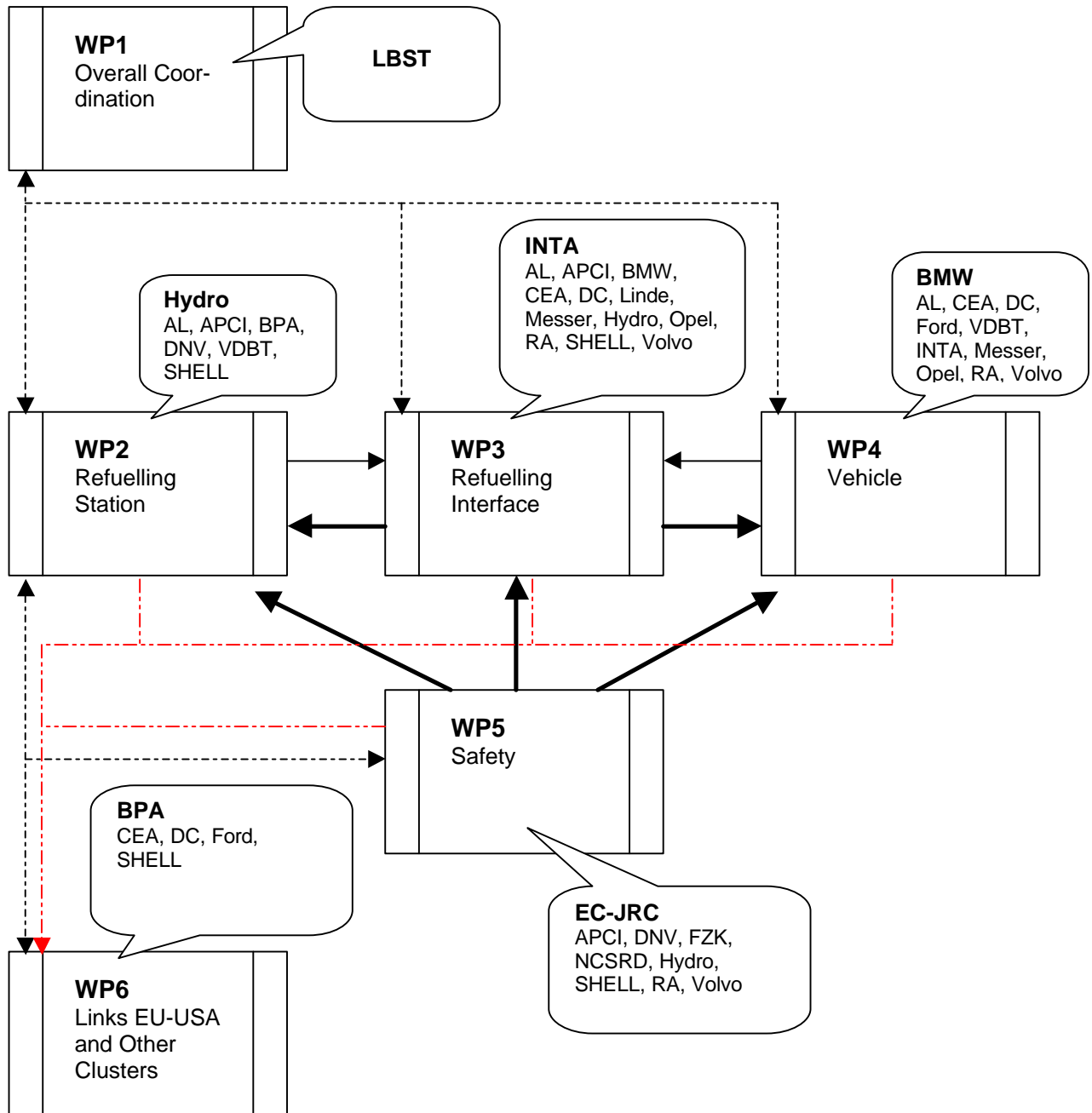
In **WP3** the consortium develops requirements for new draft standards of the refuelling interface 'vehicle – refuelling station'. This directly applies to the receptacle (vehicle based) and the nozzle (refuelling station based) and will have to take into consideration also items such as optimum storage pressure for CGH₂ storage and prerequisites of CGH₂ and LH₂ refuelling procedures. Validation of the interfaces shall ensure compliance with the elaborated standard and functional operability. Standardised on-board storage pressure(s) will be vital to the safe and commercially viable introduction of CGH₂.

In **WP4** the consortium advances the existing draft regulations for compressed gaseous hydrogen (CGH₂) vehicles and for liquid hydrogen (LH₂) vehicles developed in the first EIHP by monitoring them in the committee discussion process. They are improved further by validating one partner's internal combustion engine (ICE) hydrogen vehicles in real scale approval processes in Germany. Also a CGH₂ ICE bus and a CGH₂ fuel cell passenger car are used for validation of the regulations within this WP. Also included in WP4 are efforts for a global harmonisation of the vehicle related regulations.

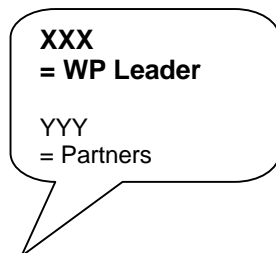
In **WP5** the consortium covers the safety and risk relevant issues. Accident scenarios for hydrogen release are identified for scenarios involving vehicles, for different hydrogen refuelling station layouts, and for the interface between vehicle and refuelling equipment. The risks of accidents and the consequences of such accidents are estimated using risk analysis tools (e.g. RRR, QRA, HAZOP), numerical simulations (e.g. CFD) and experiments. Comparisons are made with other well-known fuels as to the relative risk and accident consequences. WP5 is a supporting work package to the work packages 'vehicle' (WP4), 'refuelling interface' (WP3) and 'refuelling station' (WP2).

In **WP6** the consortium establishes and maintains links between EIHP2 and comparable activities in the USA as well as it has established first contacts to similar Japanese activities. Furthermore, the approaches adopted, progress achieved and further activities to be developed are communicated to external groups (also from US and Japan) active in related fields via workshops. A network structure plan for hydrogen infrastructure implementation in the EU has been developed.

4.2 Relationship between elements (Pert diagram)



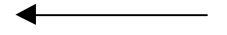
Explanation:



Supportiv Contribution



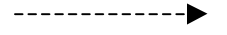
Delivery of Requirements or Inputs



International Info Exchange



Internal Info Flow



4.3 Work package overview

WP	Title	WP Leader	Person Months	Deliverable No.
WP1	Overall Coordination	LBST	19.9	1.1-1.6
WP2	Refuelling Station	Hydro	50.8	2.1-2.5
WP3	Refuelling Interface	INTA	76.6	3.1-3.7
WP4	Vehicle	BMW	89.6	4.1-4.6
WP5	Safety	EC-JRC	98	5.1-5.9
WP6	Links EU-USA and Other Clusters	BPA	12	6.1-6.6
	TOTAL:		346.9	

4.4 Deliverables list

WP - Deliverable No.	Deliverable	Type	Delivery Date
1-1	Progress, mid-term, mid-term Draft-TIP and final reports including joint cost statements and TIP to the EC	R	Months 7,13,19, 25, 31, 37
1-2	Consortium Agreement	DOC	Month 3
1-3	Internet sites (internal project partner site and external information site)	INT	Month 3, Month 5
1-4	Specification Document on EU- and US-Networking Activities	R	Month 5
1-5	Organisation of dissemination workshop(s)	A+R	Month 19
1-6	Delivery of reports (6-monthly, 12-monthly, mid-term, final, TIP, etc.)	R	Months 7,13,19, 25, 31, 37
2-1	List of existing standard, codes regulations for conventional fuels and hydrogen	R	Month 6
2-2	A document describing required station components to be harmonised	R	Month 18
2-3	A procedure or protocol for maintenance, inspection, operation and refuelling procedure	R	Month 32
2-4	Develop a procedure that allows introduction of new layouts and technologies	R	Month 34
2-5	Final report including H2 specific industrial codes of practise on H2 refuelling stations (36 month)	R	Month 36

WP - Deliverable No.	Deliverable	Type	Delivery Date
3-1	Proposal of identified optimum CGH ₂ on-board storage pressure(s)	R	Month 36
3-2	Definition of CGH ₂ refuelling procedures	R	Month 30
3-3	Approved high pressure CGH ₂ connector	H	Month 36
3-4	Recommendation of requirements for CGH ₂ interface to standardisation committees (e.g. ISO TC197)	R	Month 24
3-5	Approved LH ₂ connector (according to existing German and other regulations)	H	Month 36
3-6	Definition of LH ₂ refuelling procedures	R	Month 30
3-7	Recommendation of requirements for LH ₂ interface to standardisation committees (e.g. ISO TC197)	R	Month 24
4-1	List of deficits in rules and regulations including proposals for modifications	R	Month 3
4-2	Accepted ECE Regulation	R	Month 36
4-3	Global Technical Regulation for hydrogen fuelled vehicles in the Global Registry	R	Month 36
4-4	Draft for an amending directive to 96/96/EC	DR	Month 21
4-5	Approval for components and vehicles or an evaluation of necessary major modifications in existing components or vehicles	H + R	Month 30
4-6	Standard for calculation of safety valves for vehicle application	DS	Month 6
5-1	Report on compilation of existing data on hydrogen and comparative fuels (sub-task 5.1)	R	Month 3
5-2	Risk assessment of hydrogen infrastructure (sub-task 5.2)	R	Month 27
5-3	Report on safety study of CGH ₂ commercial vehicles (sub-task 5.3)	R	Month 36
5-4	Report on dispersion and combustion simulation results (sub-task 5.3)	R	Month 36
5-5	Description of the test facility design including instrumentation and agreed test matrix (sub-task 5.4) [test facility will be constructed by FZK]	H+R	Month 9
5-6	Experimental data base including data for hydrogen, methane and propane, under various test conditions. (sub-task 5.4)	R	Month 36
5-7	Report on CFD code validation and verification by the obtained experimental results (sub-task 5.4)	R	Month 30
5-8	Report on comparison of hydrogen with other fuels (subtask 5.5)	R	Month 36
5-9	Input to other WPs (sub-tasks 5.2 and 5.3)	A	Month 4-15

WP - Deliverable No.	Deliverable	Type	Delivery Date
6-1	Briefing notes on the latest developments in California and elsewhere in the USA	R	Month 6, 12, etc.
6-2	Briefing notes on the latest developments in the EU	R	Month 6, 12, etc.
6-3	Briefing notes on the latest developments of ISO TC 197 and SAE	R	Month 6, 12, etc.
6-4	Preliminary information about comparable developments in Japan	R	Month 6, 12, etc.
6-5	Draft of a network structure/ plan for hydrogen infrastructure implementation in the EU	R	Month 24
6-6	Workshops for target groups from around the world	A+R	Month 11, 23, 35

Explanation of Type of Deliverables:

A = Action; DOC = Document which is not a Report; DR = Draft Regulation; DS = Draft Standard; INT = Internet Presentation; H = Hardware Component; R = Report

5. The following mid-term results have been achieved by summer of 2002

TECHNICAL ACHIEVEMENTS SINCE PROJECT START:

WP 2:

- Overview of existing regulation and international standard and codes for natural gas, gasoline, diesel, LH₂, and CGH₂.
- Development of a refuelling station layout requirement and decide where harmonisation would be beneficial.
- Analysis and quantification of health, environment and safety risks associated with on-site equipment and performance of HAZOP studies for different refuelling station scenarios (link to WP5 'Safety', sub-tasks 5.2 and 5.5)

WP 3:

- Identification of optimum on-board storage pressure levels for CGH₂ [Partly achieved]
- Development of requirements for international standardisation of interfaces (CGH₂ and LH₂) [Partly performed for CGH₂]

WP 4:

- Monitoring of draft proposal from EIHP I in order to achieve a valid regulation [ongoing]
- Establishment of a global technical regulation [ongoing]
- Creation of a procedure for the necessary periodic inspection for hydrogen vehicles (amending directive to directive 96/96/EC) [development of procedure progressed, draft for amendment to be started]

- Validation of design rules or safety requirements, including definition of a procedure for the calculation and the design of safety valves for vehicle applications

WP 5:

- Compilation of existing data on the safety of hydrogen and comparative fuels
- Performance of HAZOP of different refuelling station [significantly progressed]
- Estimation of consequences related to hydrogen release scenarios for CGH₂ vehicles, e.g. tunnels and inner city streets, and in comparison with CNG will be calculated
- Support of safety issues in work packages WP4 'vehicle', WP3 'refuelling interface' and WP2 'refuelling station' [ongoing]

WP 6:

- Established contacts to US activities (a.o. NHA, SAE, DoE, CFCEP)
- Established contacts to comparable EU cluster activities
- First contacts to comparable Japanese activities established
- Participation in scheduled plenary meetings and working groups 5 & 6 meetings of ISO TC 197 "Hydrogen Technologies"
- Ongoing collection and systematic editing of information available from selected other project activities [ongoing]
- Dissemination of results achieved to first interested experts/ target group
- First steps in developing a network structure plan for hydrogen infrastructure implementation in the EU
- First briefing notes on US, EU, Japan, ISO activities delivered