HYLIGHTS

Hydrogen for Transport in Europe

Monitoring & Assessment Framework (MAF) Handbook I at Demonstration Project Level for Large-Scale Road Transportation Demonstration Projects on “Hydrogen for Transport” under FP7/JTI

Report Status: Version 1.1
Report Date: 23 October 2008

Funded by the
European Commission

H2moves.eu

A Coordination Action to Prepare European Hydrogen and Fuel Cell Demonstration Projects on Hydrogen for Transport

Acknowledgement:
HyLights is financed by funds from the European Commission under FP6
Contract TREN/05/FP6EN/S07.53917/019990.

Disclaimer

This MAF Handbook is the result of a collaborative work between HyLights Industry and Institute partners. The results of the research were subsequently elaborated and presented in a coherent manner, which involved extensive stakeholder consultation in locations around the world as well as feedback from the “HyLights” Industry Partners.

The ideas presented in this Handbook were reviewed by certain "HyLights" project partners to ensure broad general agreement with its principal findings and perspectives. However, while a commendable level of consensus has been achieved, this does not mean that every consulted stakeholder or "HyLights" Industry Partner necessarily endorses or agrees with every finding in the Handbook. The producer of this Handbook is the sole responsible for its content and recommendations.

Title:	Monitoring & Assessment Framework Handbook I at Demonstration Project Level for Large-Scale Road Transportation Demonstration Projects	
Project:	HyLights	
Report Status:	v1.1 – Final report	
Report Date:	23 October 2008	
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*All **P**erformance **I**ndicators (PIs) are serially numbered, see the numbers in the brackets:*

*- Number of **P**roject Governance Indicator (PGI#),*
*- Number of **V**ehicle Performance Indicator (VPI#) and*
*- Number of Hydrogen **I**nfrastructure Performance Indicator (IPI#)*

Acronyms and abbreviations

CGH_2	Compressed gaseous hydrogen
CCH_2	Cryo Compressed Hydrogen
FC	Fuel cell
GHG	Greenhouse Gases
H_2	Hydrogen
HRS	Hydrogen refuelling station
I-#	Hydrogen Infrastructure Performance Indicator – number
ICE	Internal combustion engine
IPI	Hydrogen Infrastructure Performance Indicator
ISO	International Organization for Standardization
LB	Liaison Body
l_{ge}	Litre of gasoline equivalent
LH_2	Liquid hydrogen
MAF	Monitoring & Assessment Framework
NB	Neutral Body
NEDC	New European Driving Cycle
P-#	Project Governance Indicator – number
PC	Project Coordinator
PGI	Project Governance Indicators
RCS	Regulations, Codes & Standards
SAE	Society of Automotive Engineers
V-#	Vehicle Performance Indicator - number
VPI	Vehicle Performance Indicator

Introduction

This Handbook will be used as a guideline for data monitoring and assessment of future European large-scale hydrogen demonstration projects in the transport sector. This Handbook should support the demonstration project partners to negotiate their specific project with the JTI Program Office.

The "Monitoring & Assessment Framework"

The Monitoring & Assessment Framework (MAF) will be used by the EC as a guideline for the assessment of the EC funded large-scale hydrogen demonstration projects in the road transport sector. Its objective is to map the performance of these projects on a common basis, with concise definitions of how to monitor and later assess the data and information collected from each individual project.

Performance Indicators

Performance Indicators (PI) have been identified for the monitoring and assessment of the demonstration projects' progress and performance. They cover all data of interest for both hydrogen vehicles and hydrogen refuelling stations (HRS). The extent to which the project partners will report data is of course subject to individual project objectives and will need to be mutually agreed for each project individually at an appropriate level. All identified performance related data should be collected in templates, see examples in the Annex.

Other, more "general data and information" on hydrogen vehicles and hydrogen refuelling stations that are not addressed as Performance Indicators in this handbook should be collected separately in "general data" templates, attached at the end of this handbook, see Annex.

Strategic issues, such as the fulfilment of the EC policy goals (e.g. GHG emission reduction), the overall economy of the projects, the assessment of individual technology and performance issues etc will be addressed at program level.

This handbook covers the project specific assessment activities.

Key Performance Indicators

Key Performance Indicators (KPIs) are the most important and relevant Performance Indicators (PIs) for the vehicle customers.

Following “Key Performance Indicators” are identified by HyLights:

Vehicles	**Infrastructure**
Maximum speed	Availability (incl. reliability and incidents reporting)
Acceleration and elasticity	Hydrogen fuel costs
Driving range	Refuelling time
Vehicle and maintenance costs	Refuelling station siting
Load	Flexibility (different types of vehicles number)
Fuel consumption	
Approval and operational hurdles	
Availability (incl. reliability and incidents reporting)	

For industry and EC additional relevant performance indicators have been identified. This Handbook addresses all relevant “Performance Indicators” (PIs) for customers, industry and EC and described in the following chapters.

IPR Management

Project partners should ensure that all cumulative performance data are only be processed by electronic devices. At project level, all vehicle-related operational data and all relevant HRS data should be reported to the “Neutral Body” (NB) by the automotive manufacturers or HRS operators respectively.

The validity of all vehicle and HRS collected data should be verified by the automotive manufacturer and the HRS operator respectively before passing onto the NB.

The vehicle operator will be responsible for the collection of certain data that will not be deemed confidential and will be specified by the automotive manufacturers.

All hydrogen refuelling station (HRS) data that will not be deemed confidential will be reported to the NB by the HRS operator. It is recommended that data reporting is the responsibility of the HRS operator not the owner’s or constructor’s.

The "Neutral Body" (NB) and the "Liaison Body" (LB)

Each industry partner producing "foreground" information, i.e. project results, will collect and transmit the contractually agreed data and information to the NB of each individual demonstration project.

All data or information, which is reported to the NB by the industry partners has to be handled according to the following classification:

P	Public	Raw data provided by any one project partner that could be reported to other project partners and the public
I	Project Internal	Raw data provided by any one project partner that could be reported to other project partners but not to the public.
C	Confidential	Raw data reported by any one project partner that could neither be shared with other project partners nor reported to the public.

Table 1: Confidentiality levels of data reporting

Role of the Neutral Body

To ensure transparency, confidentiality and objectiveness when treating confidential and project level data, the "Neutral Body" (NB) will be an independent partner appointed by the project consortium of each individual demonstration project. Its role will be to centralise the "sensitive"[1] data collected and transmitted to it by the industry project partners. It will be responsible for the handling of "sensitive" data and the preparation of the reports to the project partners and the EC, containing such data. The NB will ensure that all "sensitive" data reported to the project partners and the EC as well as those disseminated to the public will be presented in an aggregate form, i.e. by presenting average, not individual values. This is needed in order to protect the intellectual property rights (IPR) of the industry partners and to impede the rise of IPRs concerns as "sensitive" information will be presented in a way that precise source cannot be extrapolated and the possibility of further use is excluded. "Sensitive" information will be identified as such by the industry project partners. The latter will have the possibility to exclude data or information from wider dissemination that if published could negatively impact their IP rights.

With regard to public dissemination of data collected throughout the life of each individual demonstration project, this data will remain the property the project partner, who collected this data, beyond the project duration within a predetermined timeframe identified by the project partners or complying with regulations set out in funding programmes i.e. FP7 as the case may be.

The NB of each demonstration project will provide all relevant data and information on project performance and safety (classified as "public") to the

[1] Data reporting by project partners: all data that are classified as "project internal" or "confidential" are defined as "sensitive" data and must be handled according to their classification, see Table 1.

Liaison Body (LB) of the overall demonstration program and will be appointed by the its custodian, e.g the JTI.

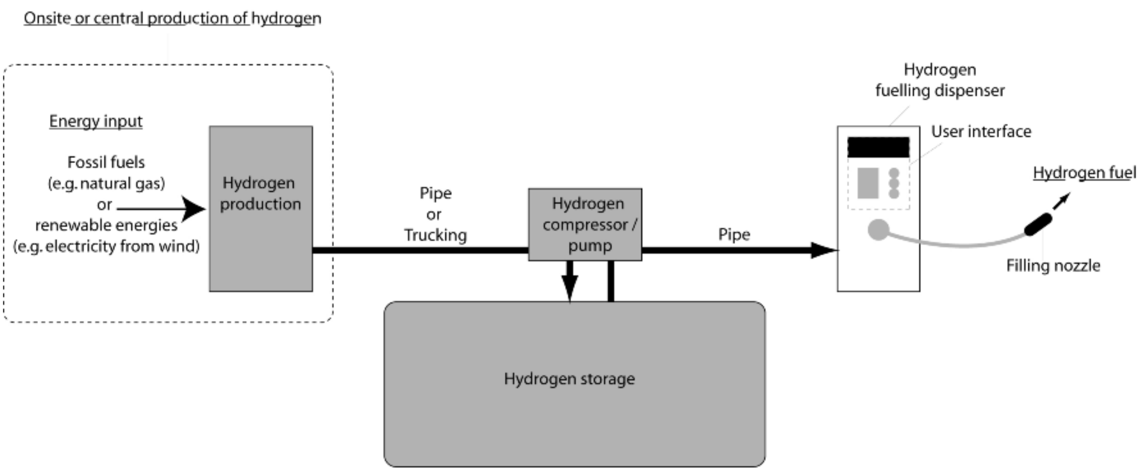
It is recommended that some specific performance issues will be analysed and evaluated at overall program level rather than by each individual demonstration project. These performance issues – to be handled by the Liaison Body are (see also Table 5):

- vehicle cost
- hydrogen fuel cost
- vehicle GHG emissions
- hydrogen fuel production GHG emissions
- public acceptance of hydrogen vehicles, hydrogen as a fuel and hydrogen refuelling stations

Both, the NB and LB should be financed on a 100% basis as part of the program monitoring activities, as they are typically non-profit activities.

Hydrogen refuelling station and its major components

The following figure shows the major components of a hydrogen refuelling station (HRS). Hydrogen is produced from fossil (e.g. natural gas, coal) or renewable energies (wind, solar, biomass) in onsite production units at the HRS or in central production plants. From central production sites, hydrogen is delivered via pipelines or trucks to the refuelling station. At the HRS the hydrogen fuel is stored in a hydrogen storage tank. For vehicle refuelling, the gaseous hydrogen is compressed by a compressor or liquefied hydrogen is pumped by a hydrogen pump via the dispenser unit and the filling nozzle to the hydrogen vehicle.



Scheme of major components of a hydrogen refuelling station

Identified Performance Indicators

Following Project Governance Indicators (PGIs) / Performance Indicators (PIs) identified for future European large-scale demonstration projects are summarised in Table 2, Table 3 and Table 4:

PI-#	Issue	Unit	Data basis / info supplied by	Confidentiality level
Project Governance Indicators				
Project management:				
(P-1)	scheduled development	report	Neutral Body	project internal
(P-2)	collaborations	report	Neutral Body	project internal
(P-3)	financing & budgeting	report	Neutral Body	project internal
Legal:				
(P-4)	contract negotiations	report	Neutral Body	project internal
(P-5)	liability	report	Neutral Body	project internal
(P-6)	Intellectual Property Rights	report	Neutral Body	project internal
Socio-economics:				
(P-7)	dissemination and visibility	report	Neutral Body	project internal
(P-8)	education and training	report	Neutral Body	project internal
(P-9)	business opportunities	report	Neutral Body	project internal

Table 2: Project Governance Indicators (PGI) to be reported by each demonstration project

PI-#	Issue	Unit	Data basis / info supplied by	Confidentiality level
Hydrogen Vehicle Performance Indicators				
Technical specifications:				
(V-1)	maximum speed	km/h	vehicle manufacturer	public
(V-2)	acceleration and elasticity	s	vehicle manufacturer	public
(V-3)	driving range	km	vehicle manufacturer	public
(V-4)	drivetrain power density	l per kW kg per kW	vehicle manufacturer	confidential
(V-5)	ambient temperature limits for vehicle operation	min °C max °C	vehicle manufacturer	confidential
(V-6)	maximum hydrogen storage capacity of the vehicle	kg of H_2	vehicle manufacturer	project internal
(V-7)	energy density of the hydrogen storage	wt% kg per liter	vehicle manufacturer	confidential
(V-8)	LH_2 storages autonomy time of the vehicle	days from 50% state of filling to remaining range of 20 km	vehicle manufacturer	confidential
Cumulative performance data:				
(V-9)	total travelled distance	km	vehicle manufacturer	public
(V-10)	hydrogen refuelled and consumed	kg per refuelling	vehicle manufacturer or refuelling station operator	project internal
(V-11)	vehicle availability	%	vehicle manufacturer	confidential
(V-12)	safety incidents reporting	report for each vehicle	vehicle manufacturer	project internal
(V-13)	vehicle efficiency fuel consumption	% kg_{H2} / 100 km l_{ge} / 100 km	vehicle manufacturer	confidential
(V-14)	vehicle emissions – regulated emissions	g per km	vehicle manufacturer	confidential
(V-15)	customer satisfaction	report	subcontracted	public
(V-16)	approval and operational hurdles of the vehicle	report	vehicle manufacturer	public
(V-17)	buses – number of passengers	number of passengers	manufacturer operator	public

Table 3: Vehicle Performance Indicators (VPI) to be reporting by each demonstration project

PI-#	Issue	Unit	Data basis / info supplied by	Confidentiality level
Hydrogen Infrastructure Performance Indicators				
Technical specifications:				
(I-1)	fuel dispensing capacity	kg per h kg per day # of dispensers # of nozzles	refuelling station operator	public
(I-2)	refuelling station siting	m*m descriptive	refuelling station operator	public
(I-3)	boil-off rate of the stationary LH_2 storage (at HRS)	g (H_2) per day	LH_2 storage equipment manufacturer	confidential
Cumulative performance data:				
(I-4)	refuelling quantity	kg per day kg (total)	refuelling station operator	public
(I-5)	refuelling time	min per kg	refuelling station operator	public
(I-6)	utilisation rate of the refuelling station	%	refuelling station operator	public
(I-7)	availability of the refuelling station	%	refuelling station operator	project internal
(I-8)	safety incidents reporting	report	refuelling station operator	project internal
(I-9)	fuel quality and composition	% of H_2 ppms of impurities	subcontracted by refuelling station operator	project internal
(I-10)	hydrogen losses at the refuelling station	%	refuelling station operator	confidential
(I-11)	quantity of delivered H_2 (central H_2 production)	kg per interval	refuelling station operator	public
(I-12)	produced H_2 (onsite H_2 production)	kg per interval	refuelling station operator	public
(I-13)	utilisation rate of fuel production unit (onsite H_2 production)	%	refuelling station operator	public
(I-14)	specific energy demand	kWh energy / kWh H_2	refuelling station operator	confidential
(I-15)	customer satisfaction of the refuelling station handling and opening hours of the station	report	subcontracted by the refuelling station operator	public
(I-16)	approval and operational hurdles of the HRS	report	refuelling station operator	public

Table 4: Hydrogen Infrastructure Performance Indicators (IPI) to be reported by each demonstration project

Program related performance issues

It is recommended that the following performance issues are addressed and analysed at demonstration program level and not by each individual demonstration project:

Issue	Comments
Vehicle cost	Methodology defined in MAF Handbook II at demonstration program level
Hydrogen fuel cost	Methodology defined in MAF Handbook II at demonstration program level
Vehicle GHG emissions	Methodology defined in MAF Handbook II at demonstration program level
Hydrogen fuel production GHG emissions	Methodology defined in MAF Handbook II at demonstration program level
Public acceptance of hydrogen vehicles, hydrogen as a fuel and hydrogen refuelling stations	Methodology defined in MAF Handbook II at demonstration program level

Table 5: Program level specific performance issues

Industry participating in the individual demonstration projects will commit itself to provide relevant inputs to the body responsible for carrying out the above tasks (e.g. for the calculation of the vehicle / hydrogen fuel cost or GHG emissions). This commitment will be anchored in the demonstration project contracts.

A. Project Governance Indicators

Apart from the technological and technical aspects of the LHPs, a number of other factors are important for the successful implementation and outcome of the large-scale road transport demonstration projects. These factors could be grouped under:

- *Project Management:* comprising the management structure; the financial & budgeting aspects of the project; internal and external collaboration issues; quality assurance.
- *Legal:* comprising the legal form of the consortium; the definition of intra-consortium IPR and liability issues.
- *Socio-economics:* dissemination and public outreach; education and training; business opportunities.

These factors are characterised as "**P**roject **G**overnance **I**ndicators (PGIs)" and should be monitored by each individual demonstration project to offer specific information alongside the technological and technical issues.

Each demonstration project should provide information on experiences gained and lessons learned during the different project phases (e.g. planning and execution phases). The objective is that each demonstration project contributes a set of recommendations for future projects to the demonstration program level.

At project level, information will be gathered by the "Project Coordinator" (PC) and transmitted to the "Neutral Body" (NB) of the project. Sensitive information will only be bilaterally discussed between these two bodies. The NB will ensure that information disseminated on the management performance of the project is treated in a way that no specific company information or any other information that the project partners consider as confidential can be tracked, especially with regard to the consortium agreements.

Project management

These PGIs will be used as an input for monitoring the project management performance and identifying the risks that are linked to management choices and could lead to project failure.

(P-1) Project development

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The PC will report to the NB lessons learned / findings and should give recommendations for future projects related to the necessary timelines, hurdles and opportunities during the project negotiation, planning and operation phase, as well as the strengths and weaknesses of the chosen management structure.

The Project Coordinator will report on:

- Identified weaknesses related to:
  - The pre-defined phases of the project (Have the phases been set or defined properly at the beginning of the project?, Did they match with the project's strategic objectives?, Did they reflect the partners' needs?, etc.) and
  - The defined milestones (Have the milestones been realistically identified? Have tasks and responsible partners been linked to milestones correctly to achieve the objectives?, etc.).
- What were the main reasons that generated the above mentioned weaknesses?
- Has a mechanism dealing with project management hurdles been put in place at the beginning of the project? How efficient was this mechanism in identifying problems, receiving feedback from different partners, developing and implementing ways to overcome these problems?
- What were the suggested measures to solve the problem(s) or to adjust the pre-defined phases or milestones?
- How successful was the implementation of the suggested measures and actions described above?

All collected information should serve as an input at the demonstration program level.

(P-2) Collaborations

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The Project Coordinator (PC) will report lessons learned / findings and should give recommendations for future projects related to project internal and external cooperation, on synergies with other demonstration.

The PC will focus on:

- Any problems and lessons learned regarding **project internal issues** related to:
  - The *project organisational structure*,
  - The *partners/industries* involved (missing of specific content or partners etc.)
- Details on collaborations with **external projects**, such as:
  - Co-operation with other European projects
  - International interactions (with non-EU projects).

All collected information should serve as an input at the demonstration program level.

(P-3) Budgeting & Financing

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The PC will report lessons learned / findings and should give recommendations for future projects related to budgetary and financial issues of the demonstration project.

Particularly, the PC will focus on:

- Experiences and lessons learned with respect to financing the demonstration project, e.g. the used financing model (e.g. Public Private Partnership (PPP)), the financial contribution of the partners, external financing pooled into the project, etc.
- Experiences and lessons learned with respect to the planned project budget and distribution compared to the actually required budget and distribution during project execution

All collected information should serve as an input at the demonstration program level.

Legal

(P-4) Contract negotiations

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The PC will report lessons learned / findings and should give recommendations for future projects related to the preparation phase including contract negotiation issues related to the demonstration project.

Particularly, the PC will focus on:

- General experiences and lessons learned from contract negotiations, such as partnership agreements, confidentiality agreements and other issues with respect to internal and / or external demonstration project partners
- General experiences and lessons learned with respect to the confidentiality of project internal data handling and reporting between the industry partners and the NB

All collected information should serve as an input at the demonstration program level.

(P-5) Liability

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The PC will report lessons learned / findings and should give recommendations for future projects related to information on liability issues.

Particularly, the PC will focus on:

- General experiences and lessons learned with respect to liability related issues of hydrogen and fuel cell hardware and handling, and insurance requirements.

All collected information should serve as an input at the demonstration program level.

(P-6) Intellectual Property Rights

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The PC will report lessons learned / findings and should give recommendations for future projects related to information on Intellectual Property Rights (IPR).

Particularly, the PC will focus on:

- General “rights for usage” principals to ensure IPR of individual project partners
- Any other experiences gained on IPR issues within the demonstration project.

All collected information should serve as an input at the demonstration program level.

Socio-economics

(P-7) Dissemination and public outreach

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The PC in collaboration with the responsible project “task force”/”work group” will report on dissemination and public outreach activities of the demonstration project and will give recommendations for future projects.

Particularly, the PC will report on:

- Implemented and proposed activities to support the visibility and public outreach of the demonstration project
- Details on implemented and proposed scientific dissemination actions.

All collected information should serve as an input at the demonstration program level.

(P-8) Education and training

Unit	Confidentiality level:	Data presentation:	Reporting:
Various channels reports, brochures, workshops, etc	**Public**	**Detailed**	**At project beginning or updated on demand**

The PC in collaboration with the responsible “task force/work group” will report on education and training related issues – if applicable to the project – and will give recommendations for future projects.

Particularly, the PC will report on:

- Implemented and proposed education and training activities on hydrogen and fuel cell technology
- Identified gaps in hydrogen and fuel cell specific education and training issues.

All collected information should serve as an input at the demonstration program level.

(P-9) Business opportunities

Unit	Confidentiality level:	Data presentation:	Reporting:
Report	**Project internal**	**Detailed**	**At each reporting, At project end**

The PC will report lessons learned / findings and should give recommendations for future projects related to business opportunities created by hydrogen and fuel cell technology.

Particularly, the PC will focus on:

- Experiences gained by the hydrogen vehicle operators and automotive manufacturers on hydrogen vehicles
- Economic benefits that the hydrogen and fuel cell technology offers for business partners
- Identified positive or negative impacts on the economic situation (e.g. employment).

All collected information should serve as an input at the demonstration program level.

B. Vehicle Performance Indicators

The **V**ehicle **P**erformance **I**ndicators (VPI) to be addressed by each individual demonstration project comprise two types of data:

1. **Technical Specifications**: The technical specifications comprise design specific data which are reported by the vehicle manufacturer **once,** at the beginning of each demonstration project. Should the vehicle specifications change during the project, the technical specifications must be updated.
2. **Cumulative Performance Data**: In contrast to the technical specifications, the cumulative performance data are measured and collected **continuously** during the project. The intervals of data acquisition are event or time specific, e.g. every trip with the vehicle, every refuelling, every incident or every six months.

Vehicle segments

Vehicle segments need to be defined and selected by the project partners at the beginning of each project. The selection of the segments depends on the type of vehicles and technologies deployed in the project.

Data monitoring within the demonstration projects should provide an information basis to assess the project performance on a technology basis. In order to avoid the possibility to relate specific data to a specific vehicle or technology, it is recommended that (if possible):

- more than two different vehicle manufacturers are represented within a vehicle segment (the calculation of average values and the presentation of lower and upper limits requires more than two different and independent inputs)
- more than two different developers of FC or ICE vehicles are represented within a vehicle segment
- more than two different vehicle manufacturers using LH_2 and/or CGH_2 storage technologies are represented per vehicle segment

Table 6 outlines the definition of different vehicle segments.

Vehicle segments		
A	Mini	Bikes, scooters
B		3 wheelers, others
C	Passenger cars *	
D	Light duty vehicles	
E	Heavy duty vehicles	Buses Trucks
F	Others	Others

Table 6: Vehicle segments

* The vehicle segment will be further distinguished into **small, lower medium, upper medium, MPV, minivan, executive**, if an appropriate number is available (see [ACEA]). Based on current experience, this will not be likely until commercialisation is reached. In any case, an average passenger car fuel consumption should be related to the definition of the cars which were involved in the specific demonstration project.

Technical specifications

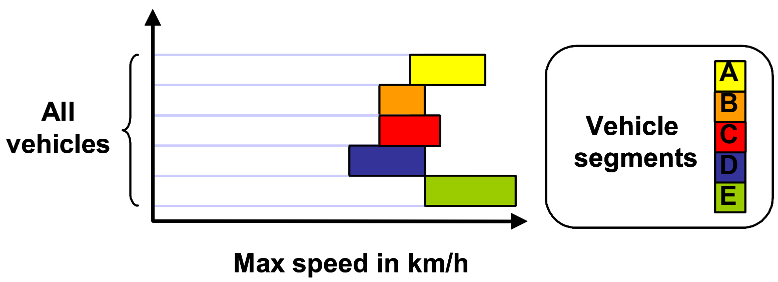
a) Vehicle

(V-1) Maximum speed

Unit	Confidentiality level:	Data presentation:	Data reporting:
km/h	**Public**	**Aggregated**	**At project beginning or updated on demand**

The **maximum constant speed** of the vehicle is reported to the Neutral Body (NB) by the vehicle manufacturers. The vehicle manufacturer reports whether the data provided is calculated or measured.

<u>Example for data presentation:</u> *Lowest and highest performance data for each vehicle segment which is reported by the vehicle manufacturers.*



(V-2) Acceleration and elasticity

Unit	Confidentiality level:	Data presentation:	Data reporting:
Seconds	**Public**	**Aggregated**	**At project beginning or updated on demand**

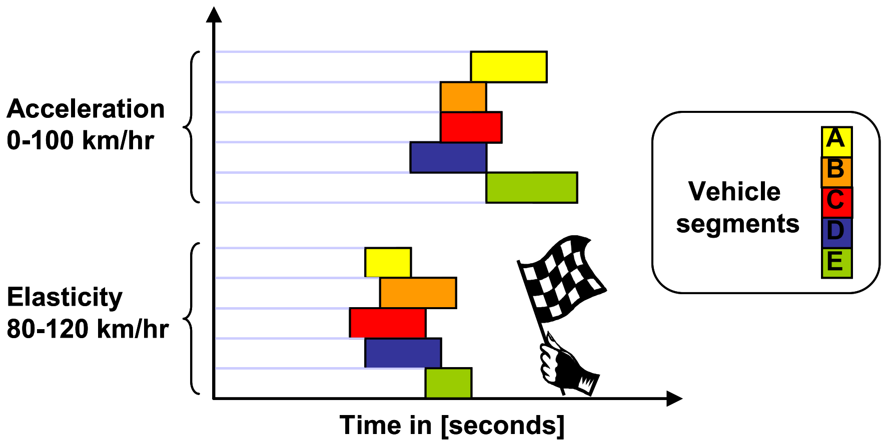
The **acceleration** and the **elasticity** of the vehicle is reported to the Neutral Body (NB) by the vehicle manufacturers. The vehicle manufacturer reports whether the data provided is calculated or measured.

It is recommended that a specific standard for buses is defined at demonstration project and program level.

Acceleration:	Elasticity:
0-50 km/h for cars in [seconds]	80-120 km/h for cars in [seconds]
0-100 km/h for cars in [seconds]	
0-60 km/h for buses in [seconds]	

Table 7: Suggested acceleration and elasticity tests for cars and buses [Concawe/TtW]

Example for data presentation: *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*



(V-3) Driving range

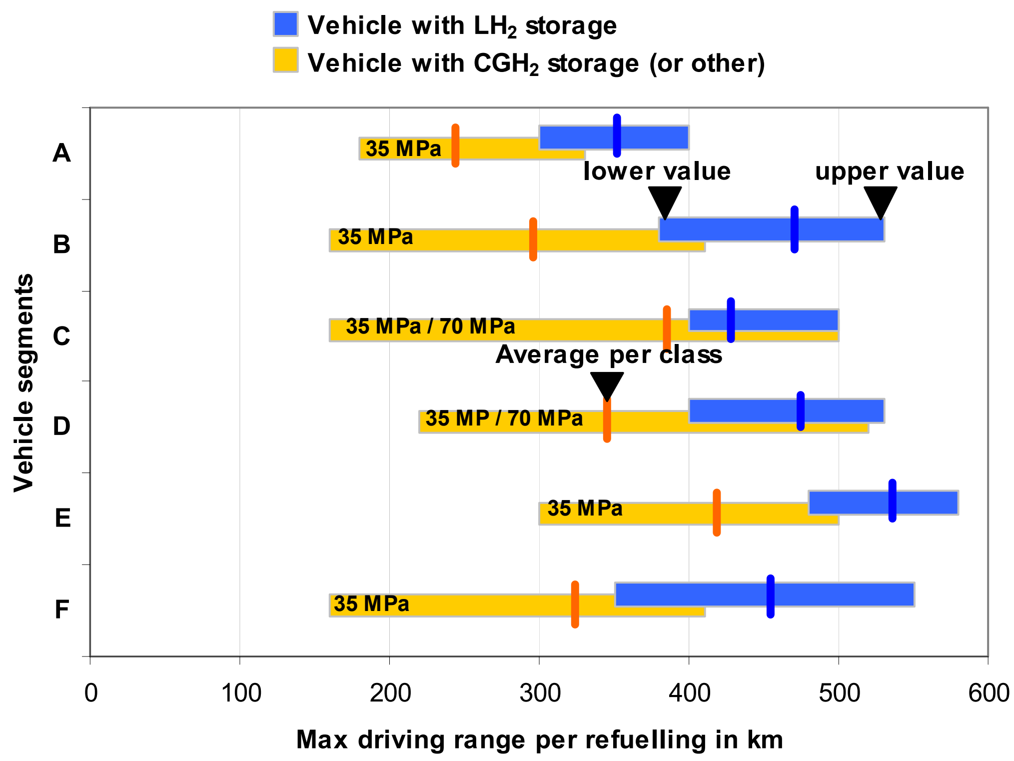
Unit	Confidentiality level:	Data presentation:	Data reporting:
km	**Public**	**Aggregated**	**At project beginning or updated on demand**

The **driving range** of a vehicle is reported to the Neutral Body (NB) by the vehicle manufacturers. The vehicle manufacturer reports whether the data provided is calculated or measured.

The driving range of a vehicle is based on the New European Driving Cycle (NEDC) and the full nominal storage capacity of the vehicle where it is necessary to specify the electrical state of charge of potential battery systems.

It is recommended that a specific standard for buses is defined at demonstration project and program level.

Example for data presentation: *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*



b) Drivetrain

(V-4) Drivetrain power density

Unit	Confidentiality level:	Data presentation:	Data reporting:
l per kW **kg per kW**	**Confidential**	**Aggregated**	**At project beginning or updated on demand**

The **volumetric power density** (litre per kW) and the **gravimetric power density** (kg per kW) of the complete propulsion system is reported to the Neutral Body (NB) by the vehicle manufacturers. The vehicle manufacturer reports whether the data provided is calculated or measured.

Definition: A **fuel cell (FC) propulsion system** comprises the complete power system including FC stack, balance of plant, additional energy storage devices (battery, super capacitors,…), inverters and controllers, electric motor & transmission, cooling systems and exhaust systems

Not included are:

- Hydrogen storage system and
- comfort features (e.g. air conditioning).

Definition: A hydrogen fuelled **internal combustion engine (ICE)** propulsion system includes the complete ICE engine (including gearbox, transmission, integrated electric motor and control units), additional energy storage devices (battery, super capacitors,…), inverters and controllers, cooling systems and exhaust systems

Not included are:

- Hydrogen storage system and
- comfort features (e.g. air conditioning).

Definition: Volume of a drivetrain

The **volume of a drivetrain** is defined as the immersed volume of the complete propulsion system.

Definition: Power of the system

The **power of a fuel cell or ICE system** is defined as the power provided to the wheels of the vehicle.

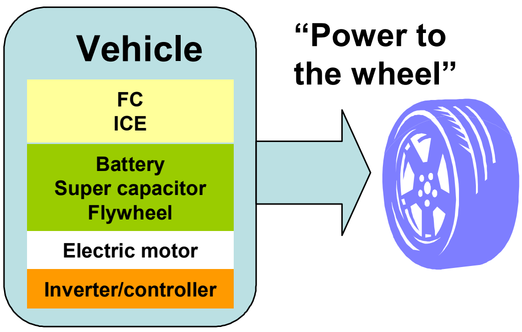
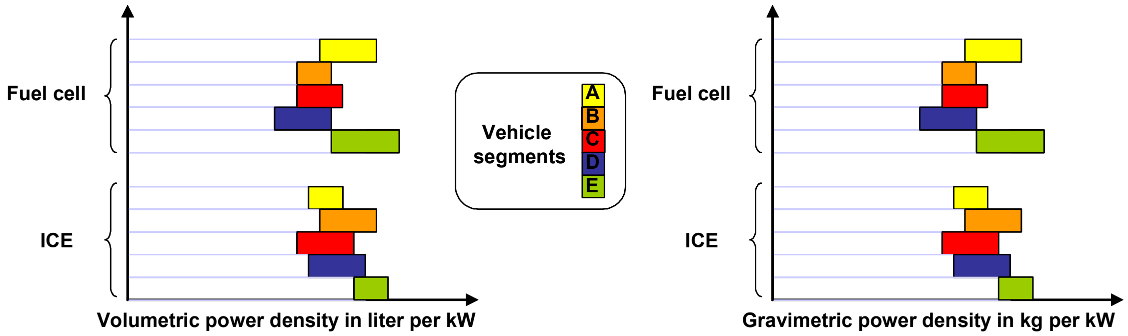


Figure 1: The definition of the power of a system comprises the FC or ICE, a battery, super capacitor, flywheel and the electric motor as well as the inverter/controller of the vehicle.

Fuel cell drivetrain power density: The volume and weight of the system is divided by the net power output of the FC / hybrid system provided to the wheels.

Internal combustion engine drivetrain power density: The volume and weight of the system is divided by the nominal power output of the ICE / hybrid system provided to the wheels.

Example for data presentation: *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*



(V-5) Ambient temperature limits

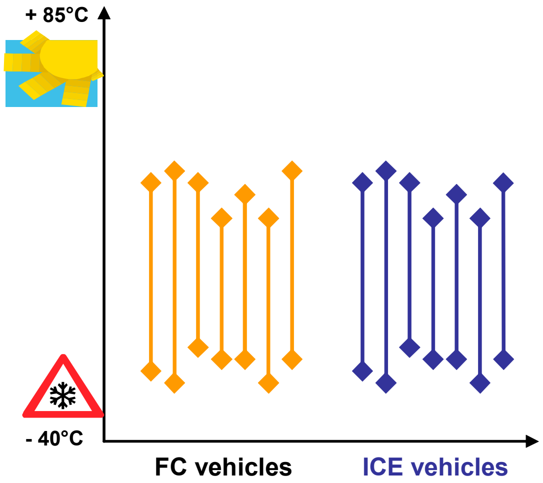
Unit	Confidentiality level:	Data presentation:	Data reporting:
min °C – max °C	**Confidential**	**Aggregated**	**At project beginning or updated on demand**

The ambient temperature limits of the vehicle show the approved temperature limits under which the hydrogen vehicle can be parked, started and operated by the vehicle operator (customer).

The minimum ambient temperature limit (**T_min**) indicates the **lowest start-up temperature** in °C. The maximum ambient temperature limit (**T_max**) shows the **highest ambient temperature under which the vehicle is operable**.

The temperature limits for conventional cars are -40°C and + 85°C. Ambient temperature limits for hydrogen and fuel cell vehicles that are reported to the NB by the automotive manufacturers should be presented in relation to the limits of conventional cars, see example below.

Example for data presentation: *Lowest and highest performance data for fuel cell (FC) and internal combustion engine (ICE) vehicles based on the figures reported by the vehicle manufacturers.*



c) Hydrogen storage

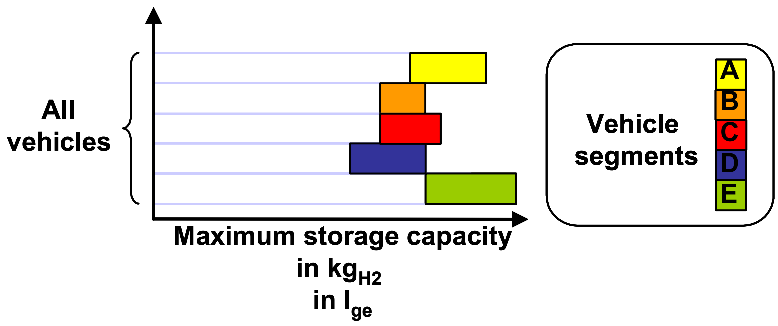
Liquid LH_2 and compressed CGH_2 hydrogen onboard storage are expected to be the only relevant storage technologies in the pre-commercialisation phase of hydrogen vehicles.

(V-6) Maximum hydrogen storage capacity

Unit	Confidentiality level:	Data presentation:	Data reporting:
kg of stored H_2 **litre$_{gasoline\ equivalent}$**	**Project internal**	**Aggregated**	**At project beginning or updated on demand**

The **maximum hydrogen storage capacity** of the vehicle in [kg of hydrogen] and in [litre of gasoline equivalent] is reported to the Neutral Body (NB) by the vehicle manufacturers. The vehicle manufacturer reports whether the data provided is calculated or measured.

Example for data presentation: *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*



(V-7) Energy density of the hydrogen storage system

Unit	Confidentiality level:	Data presentation:	Data reporting:
wt% **kg per litre**	**Confidential**	**Aggregated**	**At project beginning or updated on demand**

The **gravimetric hydrogen storage system energy density** (weight % = kg of stored hydrogen per kg of hydrogen storage system weight), and the **volumetric hydrogen storage system energy density** (kg of stored hydrogen per litre of hydrogen storage system volume) are reported to the NB by the vehicle manufacturers.

Definition: Hydrogen storage system

A hydrogen storage system comprises components such as valves, fittings, etc. The hydrogen storage system boundary is defined as the location where the hydrogen is completely conditioned to be fed to the FC or ICE.

Gravimetric hydrogen storage system energy density:

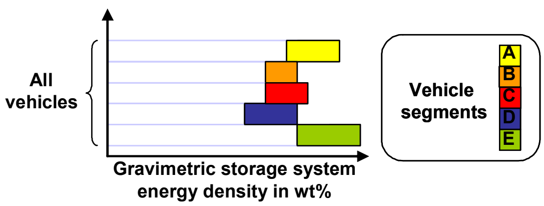
wt% = amount of stored hydrogen in [kg] / weight of hydrogen storage system (incl. H_2) in [kg]

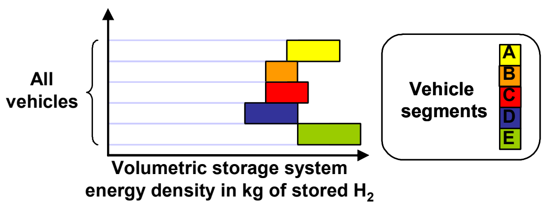
Volumetric hydrogen storage system energy density:

Amount of stored hydrogen in [kg] / volume of hydrogen storage system in [l]

The storage system volume is defined as the immersed volume of the complete hydrogen storage system.

Example for presentation of vehicle performance: *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*



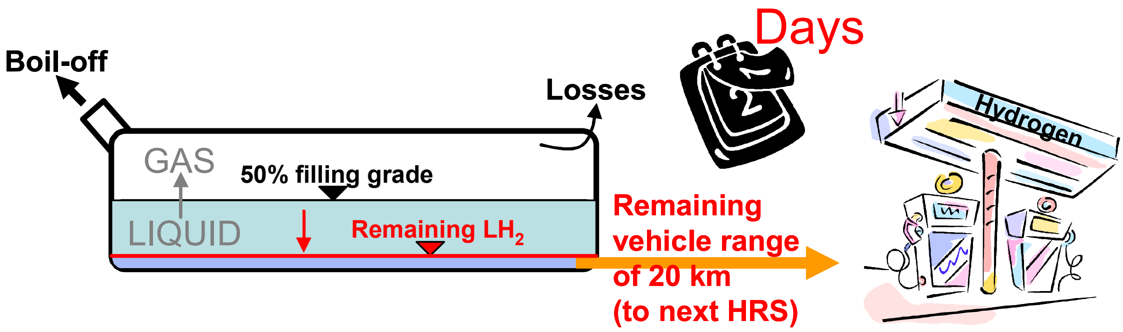


(V-8) LH_2 storages autonomy time

Unit	Confidentiality level:	Data presentation:	Data reporting:
Days from 50% state of filling to remaining range of 20 km	**Confidential**	**Aggregated**	**At project beginning** **Project end**

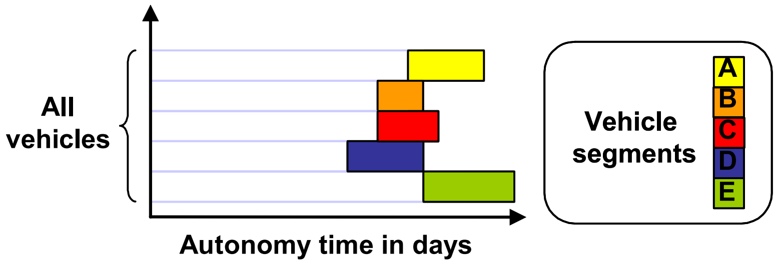
The **LH_2 storage autonomy time** is reported to the Neutral Body (NB) by the vehicle manufacturers.

The LH_2 storage autonomy time is measured for a 50% filled tank in a single test until the vehicle has reached a remaining minimum range to still get to a hydrogen refuelling station (HRS) (the remaining minimum range should be defined by each individual project, e.g. 20 km).



The autonomy time value indicates the maximum time interval before the storage of a parked vehicle is that much exhausted (due to H_2 boil-off and losses) that continued driving to the next HRS (defined range of e.g. 20 km) can no longer be secured.

Example for data presentation: *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*



Cumulative performance data

Methodology

a) Daily operating performance data

Following options are suggested for the collection of the **daily operating performance data of the vehicle** (e.g. driven km and operating hours per trip,…):

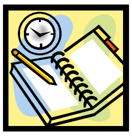
Option a) Manually filled templates

Data are collected on basis of **manually filled templates by the vehicle operator** for **each vehicle trip**.

Option b) Electronic driver's logbook

Data are collected automatically by an **electronic driver's logbook** for **each vehicle trip**.

Option c) No detailed data collection



Data are collected **over a time interval** and **not for each trip**. This option should only be considered, if options a) and b) are not applicable.

The methodology of data collection needs to be defined in the proposal phase of each project.

It is recommended that all collected data are reported in **regular intervals of six months** to the Neutral Body by the automotive manufacturers / vehicle operators.

Table 8 summarises the advantages and disadvantages of each of the suggested options.

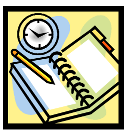
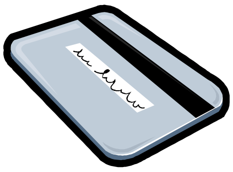
	Advantages	Disadvantages
Option a) Templates by operator 	- detailed data are collected for each vehicle trip - potentially lower investment cost (for data collection software & hardware) compared to option b) - more data collected compared to option c)	- continuity/quality of data acquisition may be limited due to missing data collection discipline - low level of confidentiality protection - manual recording reduces efficiency of further data processing - less details as compared to option b)
Option b) Electronic driver's logbook 	- detailed data are collected for each vehicle trip – constant data quality due to automatic data collection - efficient data management and processing (data available electronically) - more data and details available compared to option a) and c) (e.g. drive patterns, climate conditions,…) - high level of confidentiality protection - potentially lower operating cost, (depending on the quantity of data collected and the number of vehicles)	- potentially higher investment cost - potential lack of private data protection (customer)
Option c) No detailed data collection 	- no manual data collection by operator as compared to option a) - no additional cost as compared to option b)	- data collection only every six months - only cumulated data (km, refuelled hydrogen) - no detailed data collection for each vehicle trip possible

Table 8: Advantages and disadvantages of the different options for vehicle data collection

b) Vehicle refuelling data

It is recommended that the data assessment of each **hydrogen refuelling** of a vehicle is recorded by appropriate electronic methods like a **refuelling card**. The function of a refuelling card is described as an example:



A refuelling card should be the defined data interface between the vehicle and the refuelling station. This approach would dramatically simplify the procedure of data collection and handling within a project since the vehicle driver would not have to collect any refuelling data manually. The electronic recording of the refuelling data simplifies the processing of the collected data at the end of the project.

Each vehicle should be equipped with its own refuelling card. The vehicle driver inserts the refuelling card of the vehicle into the card terminal at the dispenser unit of the project related HRS before starting the vehicle refuelling process. To activate the filling process each driver has to enter a personal code for identification at the terminal. If a vehicle is refuelled at a non project refuelling station that does not support and accept the refuelling card of the vehicle, the vehicle operator has to collect the data manually.

<u>The following data should be collected for each refuelling at the filling station:</u>

- Date and time
- vehicle specific identification number
- refuelling station (identification number)
- refuelling time (coupling/de-coupling) and ambient temperature
- amount of refuelled hydrogen
- type of refuelled hydrogen (CGH_2 @ 35 MPa, CGH_2 @ 70 MPa, LH_2, CCH_2)

Date, time	Vehicle ID	Refuelling station ID	Refuelling duration [min]	Amount of refuelled H_2 [kg]		
				CGH_2 35 MPa	CGH_2 70 MPa	LH_2
1.1.2006; 14:00	xxx	yyy	3		2	

Table 9: Example: Type of data collected for each vehicle refuelling

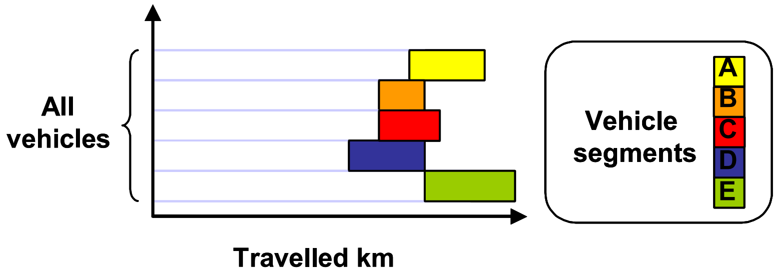
Cumulative performance data to be reported

(V-9) Total distance travelled

Unit	Confidentiality level:	Data presentation:	Data reporting:
km travelled since project start	**Public**	**Aggregated Composite data**	**At project beginning Every six months At project end**

The **total travelled distance** of the vehicle is reported to the Neutral Body (NB) by the vehicle manufacturers.

<u>Example for data presentation:</u> *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*



(V-10) Amount of refuelled hydrogen

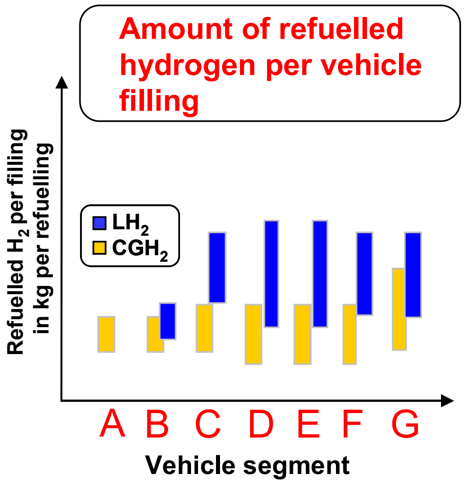
Unit	Confidentiality level:	Data presentation:	Data reporting:
Kg per refuelling	**Project internal**	**Aggregated Composite data**	**Each refuelling**

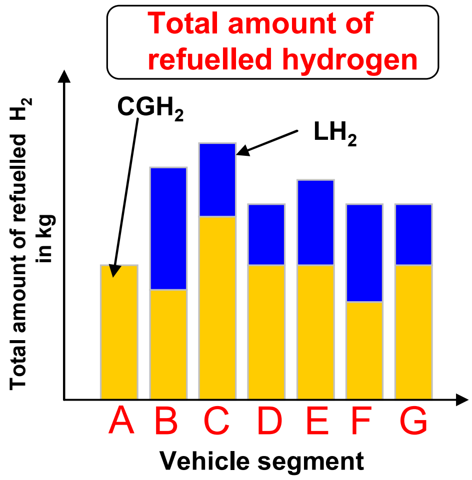
The **amount of refuelled hydrogen** per vehicle filling in [kg] is reported to the Neutral Body (NB) by either the vehicle manufacturer or the hydrogen refuelling station (HRS) operator. Before passing the collected data to the NB, the validity of the collected data must be verified and agreed by both industry partners (automotive manufacturer and HRS operator).

Additional data collected for each vehicle refuelling which are not registered by the fuelling cards but by manual filled-in templates are reported by the vehicle operator to the vehicle manufacturer.

The **NB calculates and presents** the average amount of refuelled hydrogen per vehicle filling and the total amount of refuelled hydrogen over a specified period of time.

Example for data presentation: *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers / HRS operators.*





(V-11) Vehicle availability

Unit	Confidentiality level:	Data presentation:	Data reporting:
%	**Confidential**	**Aggregated**	**Every six months** **At project end**

The **availability** of the vehicle is reported to the Neutral Body (NB) by the vehicle manufacturers. The vehicle manufacturers calculate the availability of the each hydrogen vehicle in [%]:

Availability in [%] = real operating time in [h] / potential operating time in [h]

with

real operating time in [h] = potential operating time in [h] - Σ down-times in [h]

and

potential operating time in [h] = maximum time of potential availability of the vehicle (e.g. 365 days per year – no consideration of vehicle incidents or maintenances)

Σ down-times in [h] = total time, no vehicle operation was possible due to incidents or repairs (= unavailability of the vehicle, see below)

Example 1: Private car

The maximum time of potential availability of a car could be 365 days per year (24 h per day / 7 days per week / 52 weeks per year) if no incidents and repairs are considered. The real availability is lower because of incidents and repairs during the year: e.g. 4 incidents and 2 major repairs with a total time of 17 days lead to a real availability of 348 days. Thus, the availability of the car is 348/365 = 95 %.

Example 2: Fleet operation

The maximum operation time (= maximum availability) of the fleet vehicle could be 8 hours per day (07:00 to 15:00), 40 hours per week (Monday to Friday) or 2,080 hours per year (52 weeks per year). Due to incidents and repairs during the year of a total of 200 hours, the real availability is 90%

The availability is calculated on the basis of the scheduled fleet operation times (Monday to Friday, 07:00 to 22:00).

Availability in [%] = 1,880 h/yr / 2,080 h/yr = 90%

with:

Actual operating time in [h] = 2,080 h/yr – 200 h/yr = 1,880 h/yr

Potential operating time in [h] = 8 hours per day * 5 day/week * 52 weeks/year = 2,080 h/yr

The definition of the **vehicle down-time** (=unavailability of the vehicle) **excludes incidents** that are **caused by the refuelling station**, i.e. unavailability to refuel the vehicle due to incidents or scheduled repairs at the refuelling station.

In general, if a hydrogen station is unable to refuel a vehicle (i.e. no H_2 refuelling is possible due to maintenance), the refuelling station operator should inform the vehicle manufacturer and operator within the ongoing project immediately (e.g. report the current operating status (green/red light) via appropriate communication means). The reported data should include information about the start (red light) and the end (i.e. problem solved = green light) of the unavailability to refuel hydrogen vehicles (see also (I-7), page 46).

Incidents reporting

As described above, the availability of the vehicle is derived from the potential operating time and the down-times. Down-times are due to certain incidents. Details on incidents will be reported by the vehicle manufacturers in regular project reporting meetings (e.g. every six months).

Any safety related occurrence must be handled according to (V-12) Safety incidents as well.

The incidents reporting by the vehicle manufacturer comprises the following information:

- Incident number
- vehicle identification
- date/time of out of operation
- date/time back to operation
- km reading of the vehicle @ the time of the incident
- operating hours
- scheduled repair (yes/no)
- if unscheduled, classification: Category A-E
- safety relevant (yes/no)
- if safety relevant, classification: Category 1-5
- comments

						unscheduled event						safety relevant				
incident #	vehicle identification	day/time out of operation	date/time back to operation	km reading of vehicle	operating hours	yes, category A	yes, category B	yes, category C	yes, category …	no	Comments	yes, category 1	yes, category 2	yes, category …	no	Comments
1	xxx	01/01/ 2007; 14:30	02/01/ 2007; 17:30	8000	160			X			FC stack exchanged				X	-
2																
3																

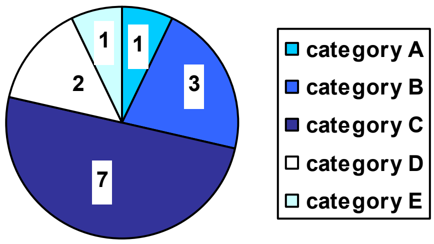
Table 10: Example: Template for incident reporting by the vehicle manufacturers

The following failure categories for incidents reporting are recommended:

Level	Description
A	Stack or ICE
B	Periphery (mechanical components, e.g. compressor, valves,…)
C	Electrical components (i.e. electric motor, inverter,…)
D	H_2 storage
E	High voltage battery

Table 11: Classification of failure categories

Example for data presentation: *Number of unscheduled incidents by category, to be presented for each vehicle.*



(V-12) Safety incidents reporting

Unit	Confidentiality level:	Data presentation:	Data reporting:
Report for each vehicle	**Project internal**	**Aggregated**	**Each incident**

Safety incidents must be reported at program level by each individual project participating in the program.

Each safety related incident of a vehicle or vehicle component has to be reported to the Neutral Body by the vehicle manufacturer. Basis for the reporting is the incidents template, as presented in Table 10.

The following safety incident categories are recommended:

Event Type	Vehicle incident	Description
This rating system is to be used to categorise Hydrogen Vehicle safety data potentially for statistical analysis.		
1	Vehicle incident/ injury/ H_2 release	Hydrogen Vehicle accident that resulted in injury. H_2 release has occurred.
2	Vehicle incident/ injury/ no H_2 release	Hydrogen Vehicle accident that resulted in injury. No H_2 release has occurred.
3	Vehicle incident/ without injury/ H_2 release	Hydrogen Vehicle incident that did not result in any injury but possible vehicle damage. H_2 release has occurred.
4	Vehicle incident/ without injury/ no H_2 release	Hydrogen Vehicle incident that did not result in any injury but possible vehicle damage. No H_2 release has occurred.
5	Near miss	An event that under different circumstances could have become an incident specified in category 1-4

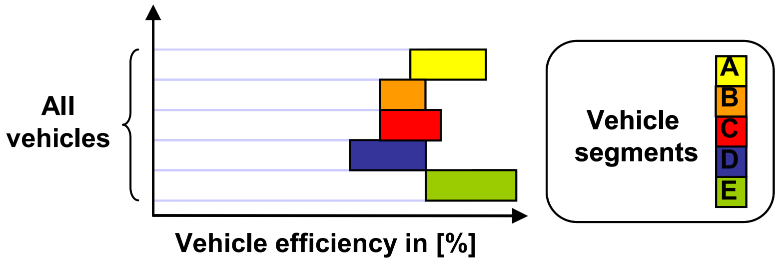
Table 12: Classification of safety incident categories related to H_2 vehicles

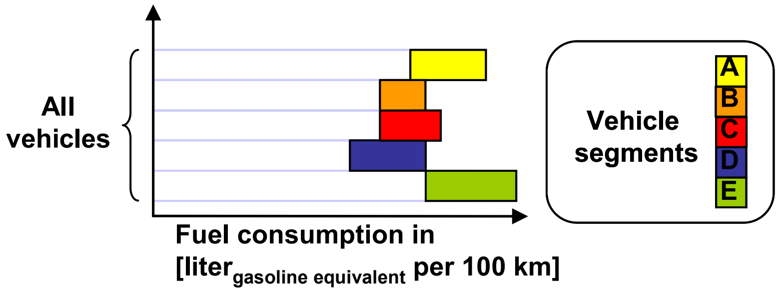
(V-13) Vehicle efficiency / fuel consumption

Unit	Confidentiality level:	Data presentation:	Data reporting:
% **kg_{H2} per 100 km** **$litre_{gasoline\ equivalent}$ per 100 km**	**Confidential**	**Aggregated Composite data**	**Every six months**

The fuel efficiency and specific fuel consumption of each hydrogen vehicle segment is reported to the Neutral Body (NB) by the vehicle manufacturers / operators. The reported data are based on the NEDC.

<u>Example for data presentation:</u> *Lowest and highest performance data for each vehicle segment based on the figures reported by the vehicle manufacturers.*





(V-14) Regulated vehicle emissions

Unit	Confidentiality level:	Data presentation:	Data reporting:
g per km	**Confidential**	**Aggregated Composite data**	**Every six months** **At project end**

Regulated emissions of hydrogen fuelled vehicles with internal combustion engines will be reported to the NB by the vehicle manufacturer. The data should be assessed on the basis of regular procedures, i.e. NEDC type approval or during repeated inspections.

(V-15) Customer satisfaction

Unit	Confidentiality level:	Data presentation:	Data reporting:
Report	**Public**	**Aggregated**	**Every six months At project end**

Customer satisfaction (performance / usability of the hydrogen vehicle) will be reported at demonstration program level by each individual demonstration project. The vehicle manufacturer reports information on customer satisfaction to the NB who reports to the Liaison Body at program level.

The reporting will be focused on the customer satisfaction relative to the performance of the vehicle and the related infrastructure, e.g. refuelling time, handling of the refuelling device and user-interface (see also (I-16)).

(V-16) Approval and operational hurdles of the vehicles

Unit	Confidentiality level:	Data presentation:	Data reporting:
Report	**Public**	**Aggregated**	**Every six months At project end**

Each vehicle manufacturer will report lessons learned related to the approval and the operation of the hydrogen vehicle and possibly proposed actions to the Neutral Body of each project. The NB reports this information to the LB.

Each demonstration project should collect information on certification and safety specific issues in a dedicated report, which will serve as input at demonstration program level.

(V-17) Buses – number of passengers

Unit	Confidentiality level:	Data presentation:	Data reporting:
Number of passengers per day of operation	**Public**	**Aggregated**	**Every month At project end**

Each vehicle manufacturer in cooperation with the bus operator(s) will report the number of passengers per bus to the Neutral Body of each project. The NB reports this information to the LB.

C. Hydrogen Infrastructure Performance Indicators

The hydrogen **I**nfrastructure **P**erformance **I**ndicators (IPI) to be addressed by each individual demonstration project comprise two types of data:

1. **Technical Specifications**: The technical specification comprise design specific data which are reported by the hydrogen refuelling station (HRS) operator **once** at the beginning of each demonstration project. Should the HRS specifications change during the project the technical specifications must be updated.
2. **Cumulative Performance Data**: In contrast to the technical specifications, the cumulative performance data are measured and collected **continuously** during the project. The intervals of data acquisition are event or time specific, e.g. every refuelling, every incident or every six months.

Technical specifications

a) Refuelling station

(I-1) Fuel dispensing capacity

Unit	Confidentiality level:	Data presentation:	Data reporting:
kg per h **kg per day** **# of dispensers** **# of nozzles**	**Public**	**Aggregated**	**At project beginning**

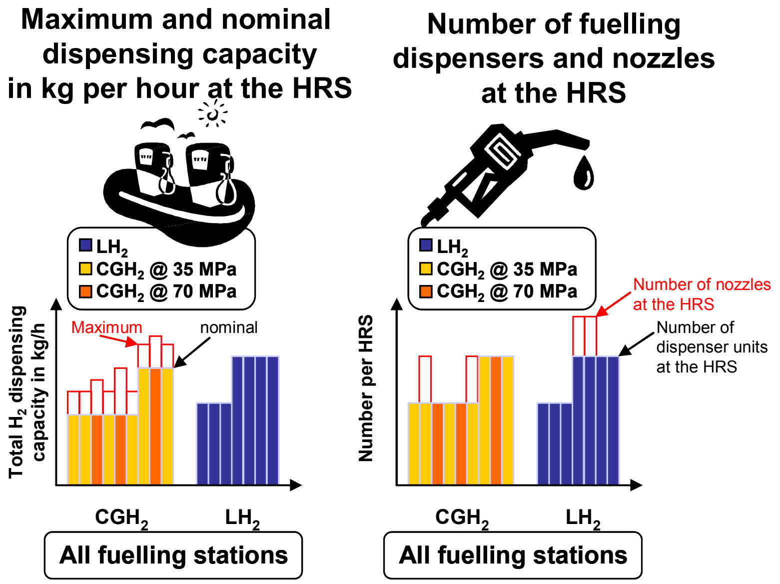
The **maximum hydrogen fuel dispensing capacity** [kg/h] and [kg/day] is reported to the Neutral Body (NB) by the hydrogen refuelling station (HRS) operator. The HRS operator reports the nominal and maximum dispensing capacity. The information includes also the number of H_2 dispenser units and the number of filling nozzles. The HRS operator reports whether the data provided is calculated or measured.

Definition

Nominal dispensing capacity = design capacity for consecutive vehicle refuelling.

The dispensing capacity can temporary exceed the nominal capacity up to a maximum dispensing capacity value of the HRS. As a consequence, the refuelling station could not be available for consecutive vehicle refuelling (e.g. the hydrogen buffer storage at the HRS must be refilled by the on-site production facility during the next hours before another refuelling sequence is possible).

Example for data presentation: *Lowest and highest performance data for each hydrogen refuelling station based on the figures reported by the HRS operators.*



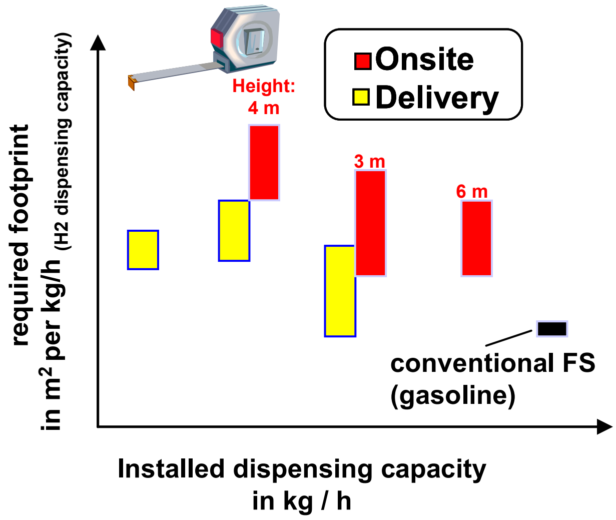
(I-2) Refuelling station footprint and siting

Unit	Confidentiality level:	Data presentation:	Data reporting:
m*m (*m), descriptive	**Public**	**Aggregated**	**At project beginning**

The (additional) **refuelling station footprint** (length and width) in [m*m] including the dimensions of the **onsite fuel production unit** (length, width and height) in [m*m*m] and a description of the location of the refuelling station (e.g. inner city, perimeter) is reported to the Neutral Body (NB) by the hydrogen refuelling station operator. If the scalability of the fuel supply capacity of the refuelling station is restricted, the operator will report the major reason (e.g. due to available footprint, regulation, codes & standards (RCS) issues or design limits of the concept).

The NB presents the specific space (footprint) requirements for the refuelling station and its specific fuel dispensing capacity in [kg/h].

Example for data presentation: *Lowest and highest performance data for each hydrogen refuelling station based on the figures reported by the HRS operators.*



*Required footprint in [m*m] per installed H_2 dispensing capacity – for onsite production and hydrogen fuel delivery (central production).*

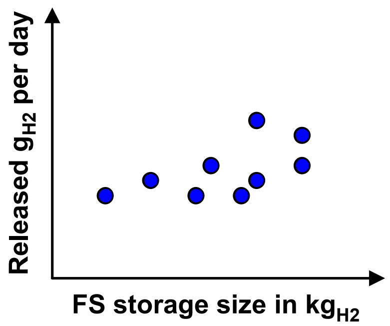
b) Hydrogen storage

(I-3) Boil-off rate of LH_2 storage

Unit	Confidentiality level:	Data presentation:	Data reporting:
g (H_2) per day	**Confidential**	**Aggregated**	**At project beginning**

The design specific boil-off rate of the onsite hydrogen storage is reported by the equipment manufacturer to the Neutral Body (NB).

Example for data presentation: *The boil-off rate is presented in relation to the storage size.*

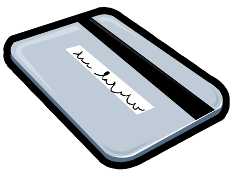


Cumulative operating performance

Methodology

Fuelling card

Specifically for large fleets, it is recommended that the data assessment for each vehicle **hydrogen refuelling** is recorded by appropriate electronic methods like **refuelling cards** (e.g. tested within *CEP Berlin, see [CEP]*), (see also page 31). The function of a refuelling card is described as an example:



Each vehicle should be equipped with its own **fuelling card**. The vehicle driver inserts the fuelling card of the vehicle into the card terminal at the dispenser unit of the hydrogen refuelling station (HRS) before starting the vehicle refuelling process. To start the H_2 refuelling process each driver has to enter a personal code for identification at the terminal.

The following data should be collected for each vehicle refuelling at the fuelling station (see also Table 9, page 31)*:*

- Date and time*
- vehicle specific identification number*
- vehicle segment – e.g. bus or car
- refuelling station (identification number)*
- refuelling time (coupling/de-coupling) and ambient temperature*
- amount of refuelled hydrogen*
- type of refuelled hydrogen (CGH_2 @ 35 MPa, CGH_2 @ 70 MPa, LH_2)*

* data required by the hydrogen refuelling station operator

Date, time	Vehicle ID	Refuelling station ID	Refuelling duration [min]	Amount of refuelled H_2 [kg]		
				CGH_2 35 MPa	CGH_2 70 MPa	LH_2
1.1.2006; 14:00	xxx	yyy	3		2	

Table 13: Example: Type of data collected for each vehicle refuelling

All data that are recorded by the electronic logbook of the refuelling station are electronically transmitted to the NB.

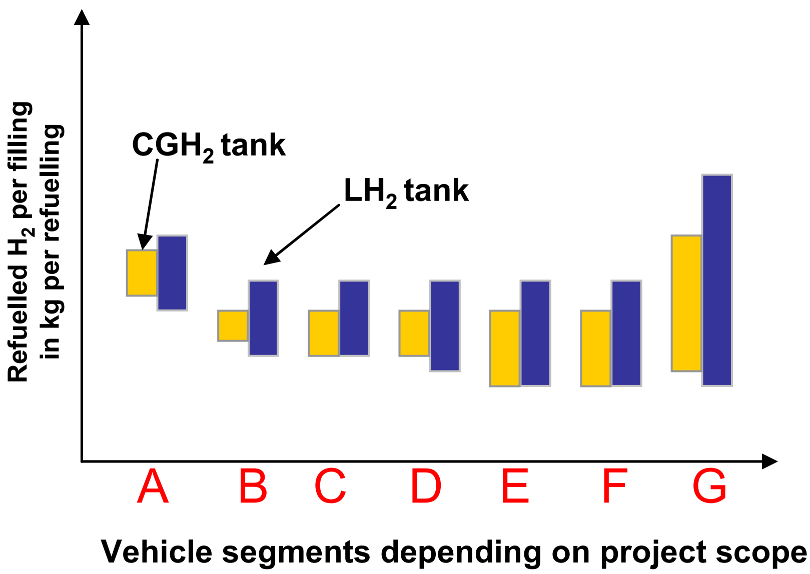
Cumulative performance data to be reported

(I-4) Refuelling quantity

Unit	Confidentiality level:	Data presentation:	Data reporting:
kg per day **kg (total)**	**Public**	**Aggregated**	**Each refuelling**

The **refuelling quantity** in [kg] for project internal and external vehicles is reported to the NB by the hydrogen refuelling station operator. Before passing the collected data to the NB, the validity of the collected data must be verified by the other industry partner, i.e. automotive manufacturer.

Example for data presentation: *Lowest and highest performance data for each hydrogen refuelling station based on the figures reported by the HRS operators: Refuelled hydrogen by vehicle segment and type of hydrogen (LH_2 / CGH_2)*



Optional: Differentiation between different CGH_2 pressure levels (e.g. 35 and 70 MPa)

(I-5) Refuelling time

Unit	Confidentiality level:	Data presentation:	Data reporting:
min per kg	**Public**	**Aggregated**	**Each refuelling**

The **refuelling time** in [minutes] and the **amount of refuelled hydrogen** in [kg] (see (I-4) Refuelling quantity) is reported to the Neutral Body (NB) by the hydrogen refuelling station (HRS) operator. Before passing the collected data to the NB, the validity of the collected data must be verified by the other industry partners, i.e. automotive manufacturers.

The NB calculates and presents the **average refuelling time** in [min/kg] and in [min] by vehicle segment, split by type of hydrogen fuel (35 MPa / 70 MPa / LH_2 or CCH_2).

It is recommended that the refuelling data for project vehicles are assessed on basis of refuelling cards. The HRS operator should also report data on hydrogen refuellings for vehicles that are not part of the project.

The **fuel dispensing time** is defined as the time between the coupling and de-coupling of the filling nozzle at the vehicle. The total **vehicle refuelling time** is derived from the measured **fuel dispensing time** by the dispenser unit and a **standardised handling time** for the coupling/de-coupling process that needs to be defined by all project partners:

Vehicle refuelling time = fuel dispensing time + standardised handling time

with:

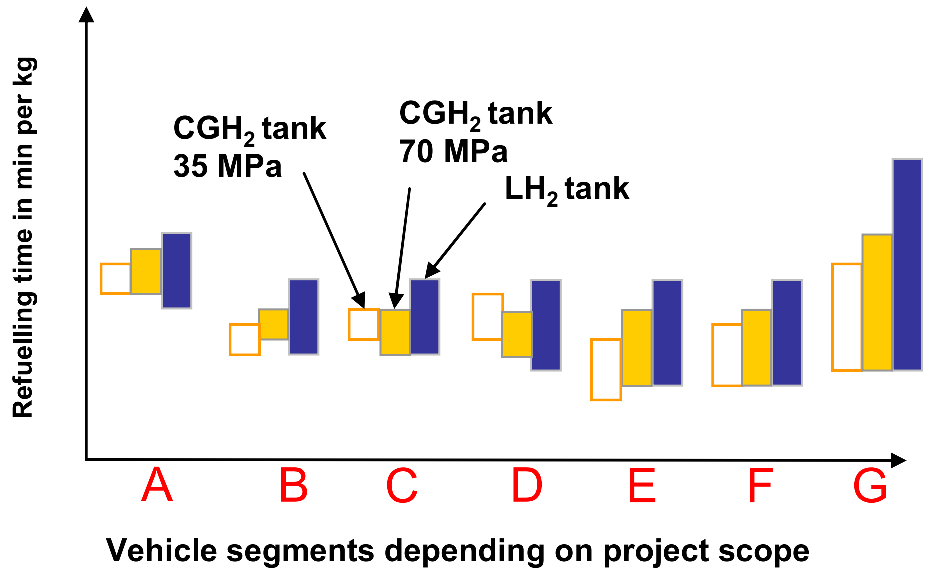
fuel dispensing time = measured refuelling time **between** the coupling/de-coupling of the filling nozzle at the vehicle and

standardised handling time = measured time for the **coupling/de-coupling process** of the filling nozzle.

Refuelling of CGH_2

The refuelling time of CGH_2 vehicles depends strongly on the vehicle tank pressure at the beginning of the refuelling process (= remaining fuel level in the vehicle storage tank). When comparing results from different CGH_2 refuellings, it must be considered that no constant linearity exists between the amount of refuelled gaseous hydrogen and the required refuelling time.

<u>Example for data presentation:</u> *Lowest and highest performance data for each hydrogen refuelling station based on the figures reported by the HRS operators.*



(I-6) Utilisation rate of the refuelling station

Unit	Confidentiality level:	Data presentation:	Data reporting:
%	**Public**	**Aggregated**	**Every six months** **At project end**

The **utilisation rate of the refuelling station** in [%] indicates the real workload of the hydrogen refuelling station. Basis for the calculation is the real measured amount of dispensed fuel (see (I-4)) and the design capacity for nominal fuel dispensing[2]:

Utilisation rate = real dispensed fuel in [kg/h] / designed fuel dispensing capacity (nominal) in [kg/h]

The utilisation rate of 100% equals the nominal fuel dispensing capacity. Depending on the refuelling station concept a temporary excess of the nominal dispensing capacity is possible.

The results are presented according to typical design patterns respecting typical expected and actual utilisation patterns.

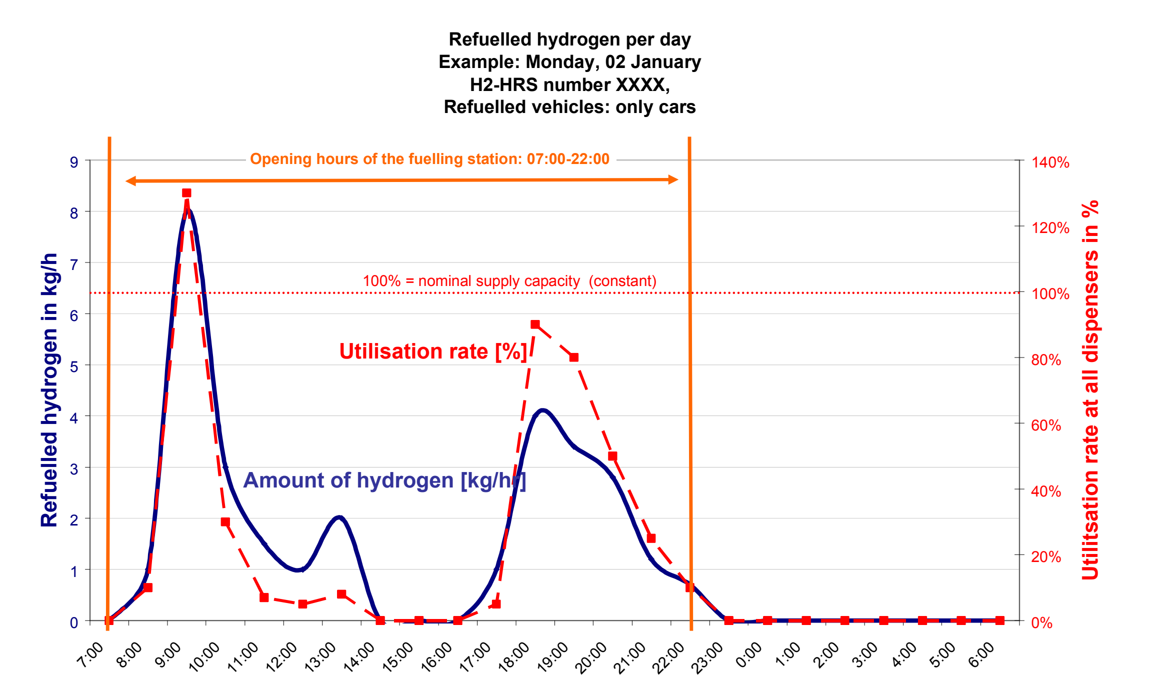
The NB presents results for **a typical working day** for **selected** hydrogen refuelling stations;

- for different HRS fuel dispensing capacities
- different types of dispensed hydrogen fuel (CGH_2 or LH_2)
- different vehicle segments (e.g. for cars, buses or scooters)

and for **an exceptional working day** for selected refuelling stations, such as the excess of the nominal fuel dispensing capacity (utilisation > 100%).

Example for data presentation: *Hydrogen refuelling profile for a selected hydrogen refuelling station and a selected day.*

[2] fuel dispensing capacity = capability of constant fuel dispensing (depends on HRS concept)



(I-7) Refuelling station availability

Unit	Confidentiality level:	Data presentation:	Data reporting:
%	**Project internal**	**Aggregated**	**Intervals (e.g. every six months)**

The **availability** of the refuelling station in [%] is reported to the NB by the refuelling station operator (e.g. every six months).

The availability is defined as :

<u>Availability in [%]</u> = actual operating time in [h] / potential operating time in [h]

with

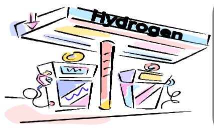
<u>actual operating time in [h]</u> = potential operating time in [h] - Σ down-times in [h]

and

<u>potential operating time in [h]</u> = opening hours of the refuelling station during the reported project time period (e.g. 10 hours per day, during 300 days = 3 000 h)

<u>Σ down-times, ** in [h]</u> = total time, no hydrogen refuelling is possible at the refuelling station (= unavailability of HRS, see below)*

* Excluded are problems / incidents caused by the vehicle (e.g. problem with the vehicle storage)
** Excluded are problems / incidents caused by the failure of the primary energy supply (e.g. electricity supply for hydrogen generation, NG, LPG or other fuels)



Green **H_2 available at HRS**

Red **H_2 unavailable at HRS**

<u>Reporting of availability and unavailability to refuel hydrogen:</u>

The **unavailability** to refuel hydrogen vehicles at the HRS (e.g. due to incidents or scheduled repairs (= maintenance) of the HRS) has to be reported[3] to the manufacturers and the operators of the vehicles and other fuelling stations by the refuelling station operator:

- Beginning of the unavailability to refuel H_2 at the HRS (start / recognition of the problem) and
- end of the unavailability (end of repair).

The **duration** of an incident or repair that affects the capability of the HRS to refuel hydrogen (**down-time**) is derived from the above described unavailability reporting (start and end of the problem to refuel hydrogen vehicles). The down-time is calculated on basis of the **HRS operation hours**, see examples:

<u>Example 1:</u> *A hydrogen refuelling station that opens daily at 07:00 and closes at 22:00 reports the start of a major problem (no H_2 refuelling is possible) on Monday at 13:00 and the successful repair on Tuesday at 13:00. Considering the opening hours of the HRS, the duration of the H_2 unavailability is 15 h.*

<u>Example 2:</u> *Due to a problem with the hydrogen compressor the HRS is not able to refuel hydrogen vehicles. The operator reports the start of the problem at 08:00 on Monday, June 01. Because the repair of the compressor is impossible, a new one must be ordered by the equipment manufacturer. Due to a delivery delay of a new compressor of almost four weeks, the repair of the HRS takes more time as expected and the HRS is fully operational on July, 05 at 16:00. The down-time of the HRS is calculated on basis of the HRS operation hours (daily open from 07:00 to 22:00 on 330 days per year):*

Calculation of the down-time:

June 01	*14 hours out of operation*
June 02 – July 04	*33 days, each 15 hours out of operation = 495 hours out of operation*
July 05	*9 hours out of operation*
Total down- time	***518 hours out of operation***

Considering, that no other incidents occur during the year, the availability of the HRS will be 90 %:

3 e.g. status report of the individual HRS (red, green light) on a webpage

Availability in [%] = 4.432 hours / 4.950 hours = 0,90

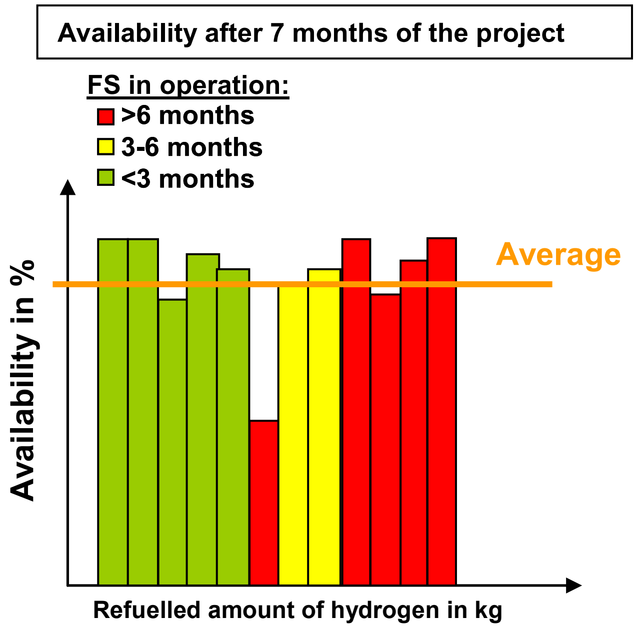
with

actual operating time in [h] = 4.950 hours – 518 hours = 4.432 hours]

and

*potential operating time in [h] = 330 days * 15 hours/day = 4.950 hours)*

Example for data presentation: *Availability in [%] for each hydrogen refuelling station based on the data reported by the HRS operators.*



Incidents and maintenance reporting

As described above, the availability of the HRS is derived from the potential operating time and down-times. Down-times are caused by certain incidents / maintenances and reported for the hydrogen refuelling station and major components such as the production unit (if applicable) (see further details in Table 15).

Details on incidents / maintenances will be reported by the HRS operator in regular project reporting meetings (e.g. every six months). Information has to be provided for incidents/repairs when:

- the **hydrogen dispensing** of a vehicle was **not possible***, ** and
- an **alert or failure of the onsite production unit** was **detected** (independent from the actual capability of the refuelling station to refuel a vehicle)**

* Excluded are problems / incidents caused by the vehicle (e.g. problem with the vehicle storage)
** Excluded are problems / incidents caused by the failure of the primary energy supply (e.g. electricity supply for hydrogen generation, NG, LPG or other fuels)

Any safety related occurrence must be handled according to (I-8) (Safety incidents).

The incidents / maintenances reporting by the HRS operator comprises the following information:

- Incident number
- HRS identification
- date/time of out of operation
- date/time back to operation
- scheduled repair (yes/no)
- if unscheduled, classification: Category A-F
- safety relevant (yes/no)
- if safety relevant, classification: Category 1-5
- comments

Incident / maintenance #	HRS identification	day/time out of operation	date/time back to operation	unscheduled event					Comments	safety relevant				Comments
				yes, category A	yes, category B	yes, category C	yes, category ...	no		yes, category 1	yes, category 2	yes, category ...	no	
1	xxx	01/01/ 2007; 14:30	02/01/ 2007; 17:30			X			component xyz exchanged				X	-
2														
3														

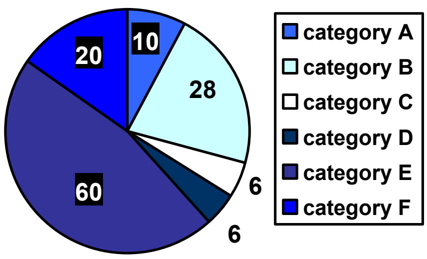
Table 14: Example for a template: Incident reporting by the HRS operator

The following failure categories for incidents reporting are recommended:

Level	Description
A	Fuelling dispenser (including filling nozzle)
B	Compressor / pump
C	Hydrogen storage
D	Onsite core fuel production unit (electrolyser or reformer)
E	Electrical components
F	Other onsite fuel processing equipment

Table 15: Classification of failure categories related to HRS

Example for aggregated data presentation: *Unscheduled incidents by category, to be presented for each hydrogen refuelling station*



(I-8) Safety incidents reporting

Unit	Confidentiality level:	Data presentation:	Data reporting:
Report of each HRS	**Project internal**	**Detailed**	**Each incident**

Safety incidents must be reported at program level by each individual project.

Each safety related incident at the HRS has to be reported to the NB by the HRS operator. Basis for the reporting is the incidents template, as presented in Table 14.

The following safety incident categories are recommended:

Level	Description	Definition	
		People	Environment
1	CATASTROPHIC	Several fatalities	Time for restitution of ecological resource such as recreation areas, ground water > 5 years
2	SEVERE LOSS	One fatality	Time for restitution of ecological resource 2 – 5 years
3	MAJOR DAMAGE	Permanent disability. Prolonged hospital treatment	Time for restitution of ecological resource < 2 years
4	DAMAGE	Medical treatment. Lost time injury	Local environmental damage of short duration < 1 month
5	MINOR DAMAGE	Minor injury. Annoyance. Disturbance	Minor environmental damage

Table 16: Classification of safety incident categories related to HRS

(I-9) Fuel quality and composition

Unit	Confidentiality level:	Data presentation:	Data reporting:
Quality in %, Composition in ppm	**Project internal**	**Aggregated**	**At project beginning Every six months At project end**

The **quality** and **composition** of the hydrogen refuelled at the refuelling station is measured at the filling nozzle of the fuel dispenser units and reported to the Neutral Body by the HRS operator.

Specifications of the hydrogen fuel should be defined by the automotive partners of the demonstration projects for vehicles with fuel cells and internal combustion engines for all test sites and demonstration projects and agreed upon by the H_2 supplier. The definition should reflect the state-of-the-art discussions of ISO / SAE.

Fuel quality: The fuel quality indicates the purity of the hydrogen in [%].

Composition: The composition of the hydrogen fuel shows the impurities that are measured in [ppm] in the hydrogen fuel. The type of impurities that are measured and reported by the HRS operator needs to be agreed by the project partners (on basis of ISO / SAE discussions) or ISO standard if applicable.

Both, the fuel quality and composition, have to be **measured at an agreed sampling point** at the refuelling station. The measuring process needs to be repeated periodically, e.g. every six months.

Results of the measurement need to be analysed and compared with the defined project limits. If the measured results are not acceptable and fail to fulfil the defined limits or an unacceptable quality degradation since the last measuring is detected, the origin of the quality decrease and/or source for the impurities have to be identified and reported.

The quality/impurity tests should be conducted by qualified test personnel. The test personnel has to be supported by the refuelling station operator/owner, the hydrogen supplier and developer of the onsite production unit.

The data and results have to be reported to the NB.

It is recommended that the regular measurement of fuel quality and composition is **subcontracted to a qualified third party by the HRS operator** on a confidential basis.

(I-10) Hydrogen losses

Unit	Confidentiality level:	Data presentation:	Data reporting:
%	**Confidential**	**Aggregated**	**Intervals (e.g. every six months)**

The **amount of hydrogen losses** at the HRS is reported to the Neutral Body by the HRS operator.

For (liquid) hydrogen fuelling stations mass flows (LH_2 and cold gaseous hydrogen, H_2 losses) can be metered, e.g. by coriolis mass flow meters, or calculated from monitoring data. Depending on the scale and utilisation patterns of the stations the individual H_2 mass flows could be deduced.

Each individual demonstration project needs to report process efficiencies, hydrogen losses and hydrogen mass flows, also including cross flows between the LH_2 and CGH_2 side in combined fuelling stations, to be aggregated by the NB (e.g. every six months). Process efficiency (for on-site hydrogen production) and hydrogen loss data (at the HRS) also always need to be reported relative to the utilisation patterns.

(I-11) Quantity of delivered H_2 (central H_2 production)

Unit	Confidentiality level:	Data presentation:	Data reporting:
kg per interval	**Public**	**Aggregated**	**Every six months At project end**

For centralised hydrogen production and hydrogen delivery via truck or pipeline the quantity of transported fuel to the refuelling station is reported to the NB by the refuelling station operator (e.g. every six months):

- Supplied amount of H_2: Pipeline in [kg] per interval or
- supplied amount of H_2: Trailer, bundles in [kg] per interval.

(I-12) Hydrogen produced (onsite H_2 production)

Unit	Confidentiality level:	Data presentation:	Data reporting:
kg per interval	**Public**	**Aggregated**	**Every six months** **At project end**

The **amount of onsite produced hydrogen** in [kg] is reported to the NB by the refuelling station operator (e.g. every six months).

(I-13) Utilisation rate of the fuel production unit (onsite H_2 production)

Unit	Confidentiality level:	Data presentation:	Data reporting:
%	**Public**	**Aggregated**	**At project beginning** **Each day**

The utilisation rate of the onsite fuel production unit indicates the real workload and is reported to the NB by the HRS operator. This data is derived from the average amount of fuel production per day and the installed production capacity:

Utilisation rate = average amount of produced fuel in [kg/day] / nominal. fuel production capacity in [kg/day]

H_2 losses

The operator should report (if applicable) on major H_2 losses (e.g. amount of venting) during the operation of the fuel production unit – as these affect the calculation of the real utilisation rate.

(I-14) Specific energy demand at the hydrogen refuelling station

Unit	Confidentiality level:	Data presentation:	Data reporting:
kWh_{energy} / kWh_{H2}	**Confidential**	**Aggregated** **Composite data**	**Each reporting**

The fuel supply efficiency should be evaluated at demonstration program level. Therefore data on the specific energy demand at the HRS will be reported to the NB by the HRS operator, preferably split by hydrogen fuel type (35 MPa / 70 MPa / LH_2 or CCH_2). The NB reports all collected data to the Liaison Body (LB) at program level.

At the beginning of each project details on data (e.g. frequency of reporting) must be defined among the project partners.

At the demonstration program level the specific energy demand of the hydrogen refuelling station will be evaluated using the methodology of the Well-to-Tank

(WtT) analysis conducted by the Concawe/Eucar/JRC consortium (see [Concawe/WtT]).

In addition, the specific electricity demand should be metered individually for all major electric consumers; in particular separately for the production unit (if applicable), the station unit and major consumers such as compressors and pumps.

The reported information to the NB and LB should also include data on energy related by-products that needs to be included as a credit into the calculations (e.g. heat useable for other processes or applications, i.e. combined heat and power).

(I-15) Customer satisfaction

Unit	Confidentiality level:	Data presentation:	Data reporting:
Report	**Public**	**Aggregated**	**Every six months** **At project end**

Customer satisfaction will be reported to the demonstration program level by each individual demonstration project. The HRS operator reports to the NB who reports to the Liaison Body at program level.

The reporting will be focused on customer satisfaction relative to the performance, handling and the opening hours of the hydrogen refuelling station.

It is recommended that the HRS operator subcontracts this task to a third qualified party.

(I-16) Approval and operational hurdles of the HRS

Unit	Confidentiality level:	Data presentation:	Data reporting:
Report	**Public**	**Aggregated**	**Each reporting**

Each HRS operator will report lessons learned related to the approval and the operation of the hydrogen refuelling stations to the NB of each project. The NB will report this information to the LB.

Each demonstration project should collect information on certification and safety specific issues in a dedicated report, which needs to serve as input to the demonstration program level.

D. Literature

[ACEA] European Automobile Manufacturers Association, (Association des Constructeurs Européens d'Automobiles), http://www.acea.be/ASB20/axidownloads20s.nsf/Category2ACEA/381E834521EFC79FC125702F004A7D14/$File/Segment-Bodies-90-05.pdf, 18 August 2006

[CEP] Clean Energy Partnership, Berlin, http://www.cep-berlin.de/

[Concawe/TtW] Edwards, Larivé, Mahieu, Rouveirolles, etal., Concawe/ EUCAR/ European Commission – JRC, Tank-to-Wheels Report, Version 2b, May 2006, page 7, table 2.3, http://ies.jrc.ec.europa.eu/WTW, August 2006

[Concawe/WtT] Edwards, Larivé, Mahieu, Rouveirolles, etal., Concawe/ EUCAR/ European Commission – JRC, Well-to-Tank Report, Version 2b, May 2006, http://ies.jrc.ec.europa.eu/WTW, August 2006

Annex: Data tables

Template for General Vehicle Data Status: 23 October 2008, v1.1

Date:

Name

HYLIGHTS

ISSUE	UNIT	DATA / DESCRIPTION
General		
Vehicle operator	-	
Vehicle identification number	-	
Vehicle type (vehicle segment)	-	
Vehicle manufacturer	-	
Model & variant name	-	
Model year	-	
First time on the road (with road certification)	-	
Travelled km @ project beginning	-	
Operating hours @ project beginning (if applicable)	-	
Propulsion system (ICE, FC, with or without hybrid)	-	
Propulsion system manufacturer/integrator	-	
Home base (depot/garage)	-	
Fuel		
Fuel type (CGH2 @ … MPa, LH2,…)	-	
Fuel standard	-	
Other fuel specifications	-	
Vehicle dimensions		
Length	m	
Width	m	
Height	m	
Wheel base	m	
Number of seats	-	
Empty weight	kg	
Gross vehicle weight	kg	

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Template for General Hydrogen Refuelling Station Data (1) Status: 23 October 2008, v1.1

Date:
Name:

HYLIGHTS

ISSUE	UNIT		DATA / DESCRIPTION
General			
Fuelling station owner / operator	-		
Fuelling station location	-		
Date of final construction / first operation	month/year		
Total hydrogen onsite production capacity	$kg_{(H2)}$ per day		
User interface / terminal	Description		
Type of filling station (multiple choice)			
Stand alone, only hydrogen	MC		
Integrated hydrogen station (e.g. into conventional HRS)	MC		
Accessibility (multiple choice)			
public	MC		
limited / restricted	MC/description	X	*Example: only to project partners*
Opening hours (per week)	-		
Refuelling procedure (multiple choice)			
Self-service refuelling			
Assisted refuelling service, why?			
Automatic - robotic refuelling			
Dispensed fuels (multiple choice)			
CGH2 @ …. bar	MC/description	X	*Example: 700 bar*
LH2	MC		
Other fuels	MC/description		
Concept of the filling station (multiple choice)			
Booster concept	MC		
Cascade concept	MC		
Vapourisation of LH2	MC		
Other	MC/description		
Key components			
Dispenser supplier	-		
Hydrogen storage supplier	-		
Hydrogen storage type (LH2, CGH2,…)	Description		
Hydrogen storage capacity	kg (H2)		
Hydrogen storage volume	m^3		
Hydrogen compressor / pump supplier	-		
Hydrogen compressor / pump type	-		
Hydrogen compressor capacity	Nm^3/h		
Pipeline pressure	bar		
Distance	km		

MC = multiple choice

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Template for General Hydrogen Refuelling Station Data (2) Status: 23 October 2008, v1.1

Date:
Name:

HYLIGHTS

Hydrogen supply (multiple choice)

On-site fuel production - if yes….	Y/N		
….natural gas & reformer	MC		
...LPG & reformer	MC		
...other primary fuel & reformer	MC/description		
...electricity & electrolyser	MC		
other	MC/description		
Central production - if yes...	Y/N		
description	-		
Hydrogen transportation - if yes…	Y/N		
… via pipeline	MC		
…via delivery truck	MC		
… other	MC/description		
Primary feedstock mix for H2 generation			
NG	%		
Liquid hydrocarbons	%		
coal	%		
nuclear	%		
national electricity grid mix	%		
biomass	%		
hydro	%		
wind	%		
solar	%		
geothermal	%		
others	%		
	Total:	100%	

MC = multiple choice

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Template for Technical Vehicle Specifications Status: 23 October 2008, v1.1

Vehicle identification:
Date:
Name:

HYLIGHTS

(PI-#)	ISSUE	UNIT	DATA
Vehicle			
(V-1)	Maximum constant speed	km/h	
(V-2)	Acceleration 0-50 km/hr (car)	s	
	Acceleration 0-60 km/hr (bus)	s	
	Acceleration 0-100 km/hr (car)	s	
	Elasticity 80-120 km/hr (car)	s	
(V-3)	Driving range	km	
Drivetrain			
(V-4)	Volumentric power density	l per kW	
	Gravimentric power density	kg per kW	
(V-5)	Ambient temperature limits for vehicle operation	min°C	
		max °C	
Hydrogen storage			
(V-6)	Maximum hydrogen storage capacity of the vehicle	kg of H_2	
(V-7)	Energy density of the hydrogen storage system	w%	
		kg per liter	
(V-8)	LH_2 storage autonomy time of the vehicle	days from 50% state of filling to remaining range of 20 km	

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Template for Technical Hydrogen Refuelling Station Specifications Status: 23 October 2008, v1.1

HYLIGHTS

Date:
Name:

(PI-#)	ISSUE	UNIT	DATA
Filling station			
(I-1)	Total number of hydrogen dispensers	#	
	Total number of H2 fuelling nozzels at the HRS	#	
	Total installed dispensing capacity at the HRS	kg per h	
	Total hydrogen onsite production capacity	$kg_{(H2)}$ per day	
(I-2)	Footprint of the total fuelling station (LxW)	m x m Description	
	Footprint of the onsite fuel production unit (LxWxH)	m x m x m Description	
On-site fuel storage			
(I-3)	Boil-off rate of LH2 storage	$g_{(H2)}$ per day	

HRS = Hydrogen Refuelling Station

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Status: 23 October 2008, v1.1

Template for Vehicle Incidents Reporting

Number of incident	Vehicle identification	Day, time out of operation	Day, time back to operation	km reading of the vehicle	Operating hours of the vehicle	unscheduled event							safety relevant						
						yes, category A	yes, category B	yes, category C	yes, category D	yes, category E	no	comments	yes, category 1	yes, category 2	yes category 3	yes, category 4	yes, category 5	no	comments
1	xxx	01/01/2007, 14:30	02/01/2007; 17:30	8,000 km	160 h			X				Stack changed						X	
2																			
3																			

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HYLIGHTS
Status: 23 October 2008, v1.1

Template for Hydrogen Refuelling Station Incidents Reporting

Number of incident	Hydrogen refuelling station identification	Day, time out of operation	Day, time back to operation	unscheduled event								safety relevant						
				yes, category A	yes, category B	yes, category C	yes, category D	yes, category E	yes, category F	no	comments	yes, category 1	yes, category 2	yes category 3	yes, category 4	yes, category 5	no	comments
1	xxx	01/01/2007, 14:30	02/01/2007; 17:30			X					Component xyz changed						X	
2																		
3																		

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HYLIGHTS

Status: 23 October 2008, v1.1

Template for Vehicle Refuellings

Number of refuelling #	Date; time	Vehicle identication id-#	Driver identification id-#	Refuelling time coupling/de-coupling in [min]	Amount of refuelled H2 CGH2 at 35 MPa	CGH2 at 70MPa	LH2
1	*01.08.2006; 14:00*	*123456*	*78910*	*3 min*	-	-	3 kg
2							

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HYLIGHTS

Template for H2 delivery (central production)

Status: 23 October 2008, v1.1

Fuelling station identification:

Number of H2 delivery	date, time	LH2	CGH2	Amount of delivered H2 in kg
1	*01/08/2008, 14:35*	**X**		**50 kg**
2				
3				

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