HYLIGHTS

Hydrogen for Transport in Europe

Monitoring & Assessment Framework (MAF) Handbook II at Demonstration Program Level for Large-Scale Road Transportation Demonstration Projects on "Hydrogen for Transport" under FP7/JTI

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

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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.

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1 Introduction

The Monitoring and Assessment Framework (MAF) handbooks will be used as a guideline for data monitoring and assessment of future European large-scale hydrogen demonstration projects and program in the transport sector. This report is the second MAF Handbook (II) addressing topics related to the demonstration program level. The MAF Handbook (II) is complementary at program level to the MAF Handbook (I) at project level.

Motivation

The European Commission and the European automotive and energy industries are preparing the introduction and commercialisation of hydrogen as fuel for road transport in Europe. Large-scale demonstration projects will accelerate and support the introduction and successful commercialisation of hydrogen vehicles and infrastructure. To monitor and assess the success and progress of the demonstration projects and program HyLights has developed two handbooks which will serve as a guideline for negotiation of future Lighthouse projects on hydrogen for road transport in Europe.

Objective

The objective of the Monitoring and Assessment Framework (MAF) on program level is

- to support and assess the performance of the project and program targets in terms of the general policy targets of the European Commission, i.e. energy supply security and diversification, reduction of emissions, improvement of energy efficiency and to foster the international competitiveness of European industry,
- to monitor and assess the success and progress of demonstration projects and program regarding specific targets,
- to summarise and disseminate demonstration project and program results and
- to support the verification of current and definition of future program targets of the European Commission.

Methodology

The HyLights consortium has developed two handbooks for the monitoring and assessment of large-scale demonstration projects in the road transport sector for hydrogen vehicles with focus on cars and buses. This activity has been funded by the European Commission under the 6th Framework Program.

All partners and participants in the Lighthouse demonstration projects and program commit to collect, provide and assess data and information on real

world demonstration of hydrogen technologies, including lessons learned and experiences made during public road testing, the public acceptance of hydrogen vehicles, transport fuel and infrastructure as well as safety issues and regulations, codes and standards.

The two handbooks are

- HyLights MAF Handbook (I) at demonstration project level and
- HyLights MAF Handbook (II) at demonstration program level.

As illustrated in Figure 1, the MAF Handbook (I) at demonstration project level addresses issues that are relevant to the demonstration project. Each Neutral Body (NB) at project level will monitor, collect and assess specific project performance,, lessons learned and will make recommendations to the Liaison Body (LB) at demonstration program level. The activities of the LB will be part of the MAF Handbook (II) at demonstration program level including the assessment of political targets, project and program performances, experiences made during the demonstration phase and recommendations to the JTI Program Office. The LB is in close relation with the JTI Program Office which represents industry, the EC as well as the Research community and the European regions interests.

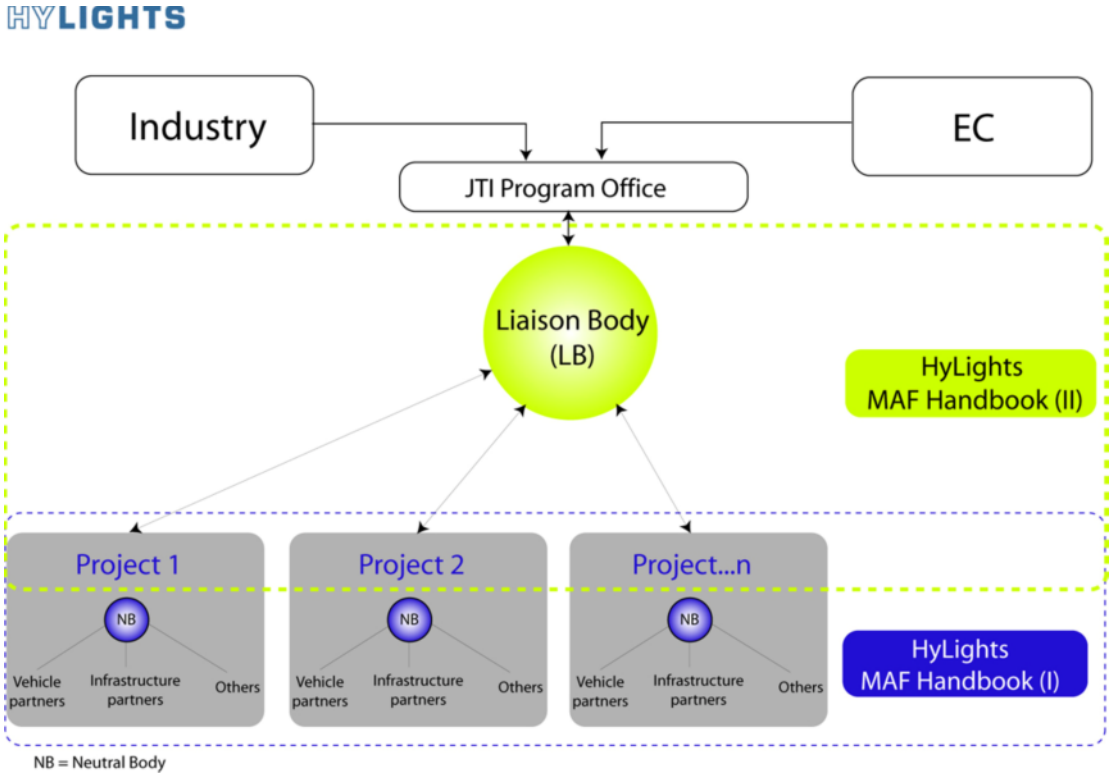

Figure 1: Scope of MAF Handbook (I) at demonstration project level and MAF Handbook (II) at demonstration program level

Confidentiality and IPR issues

Data handling

All reports, data or information, which are assessed within the demonstration projects and program have to be handled according to the following classification:

P	Public	Data, information and reports that are provided by any project/program partner or project can be reported to other project partners, projects and the public.
I	Project / program Internal	Data, information and reports that are provided by any project/program partner or project can be reported to other project partners but not to the public. This way, these data and information need to be aggregated before they are shared with non-project partners or presented to the public.
C	Confidential	Data, information and reports that are reported by any project / program partner or project that can neither be shared with other project partners or projects nor reported to the public. Thus, these data and information need to be aggregated before they are reported to others.

Table 1: Confidentiality levels of data reporting

Data storage

At demonstration project level all confidential data and information is stored by the original data/information provider for the duration of five years after demonstration project / program completion. All project and program internal data as well as public available data is stored by the responsible Neutral Body and the Liaison Body. HyLights recommends the storage of all relevant data and information for the duration of five years after demonstration program completion.[1]

[1] Compare consortium agreements of HyWays, 15 July 2004, Ref No: 502596, Article 9; HyApproval, 15 November 2005, Proposal / Contract No 019813, Article 10; and HyLights, June 2006, Proposal / Contract N°S07.53917/019990, Article 10

2 Involved parties

The Monitoring and Assessment Framework (MAF) involves and addresses different parties, i.e. the public, operators and technology demonstrators (potential customers), the European Commission, the industry and business sectors and non-governmental organisations.

For the successful implementation of the MAF it is recommended that a Neutral Body as part of each demonstration project and a Liaison Body as part of the demonstration program should be introduced.

Public

The Lighthouse projects will increase the public awareness of hydrogen and fuel cell technology for road transport. The public should get used to hydrogen and fuel cell technology and hence is invited to provide feedback and comments.

European Commission

The European Commission supports and co-finances industry activities for the demonstration of hydrogen fuel for road transport in Europe. The European Commission provides the overall policy targets for the demonstration program. The MAF will support the monitoring and assessment of large-scale demonstration activities. The MAF will serve as a tool for the provision and distribution of information on hydrogen technologies and future transport within Europe.

Industry and business partners

European automotive and energy partners will provide hydrogen-based technologies for large-scale demonstration projects. Business partners will participate in demonstration projects as operators or service providers.

Industry and business partners will closely cooperate with the Neutral Body at demonstration project level and the Liaison Body at demonstration program level and provide all relevant data and information on hydrogen technology performances and experiences. The MAF Handbooks (I) and (II) will serve as a guideline for data monitoring and assessment. Mutual trust needs to be established between all partners, the Neutral Bodies and the Liaison Body.

Industry will become an important stakeholder of the JTI Program Office.

Institute partners

Institute partners will provide support to industry and EC. Institutes as well as other partners could typically serve as “neutral” partner within the demonstration projects and the program.

Neutral Body

The Neutral Body (NB) will be appointed by the partners of each demonstration project. It will serve as neutral partner within each project[2] and collect and assess all relevant data and information at demonstration project level (see further details in the "MAF Handbook (I) at demonstration project level"). The NB is a facilitator of data handling and assessment, following predefined procedures and routines but does not conduct its own research activities.

All the project information to be collected by the NB should serve as an input to the demonstration program level. The Neutral Body provides reports and specific data and information of each demonstration project to the Liaison Body at demonstration program level.

The Liaison Body

The Liaison Body (LB) will be assigned by the JTI Program Office as a subcontractor and should serve as a neutral partner.

The LB will assess the demonstration project performance in view of the fulfilment of the demonstration program targets. Each demonstration project will provide progress reports including specific data and information to the LB through the corresponding NB of the project.

The LB is a facilitator of data handling and assessment, following predefined procedures and routines but does not conduct its own research activities.

The assessment of the individual demonstration projects by the Liaison Body will be supported by the relevant project partners at demonstration project level and the JTI Program Office.

The LB will prepare the necessary input for assessments, summaries, conclusions and recommendations for the JTI Program Office to be approved and commented. The LB is accountable for the JTI Program Office which approves all reports prepared by the LB. After approval by the JTI Program Office, the LB will provide reports to the public.

JTI Program Office

Regarding the monitoring and assessment of demonstration activities, the JTI Program Office supervises the Liaison Body and approves all reports prepared by the Liaison Body. The JTI Program Office will decide on the further use of the data and on the dissemination of the results. The LB is under the responsibility of the JTI Program Office.

[2] Projects, i.e. regional project clusters, may share the services of one neutral body.

3 Data collection and assessment

All relevant data and information are provided by the project and program partners to the Neutral Body at demonstration project level and to the Liaison Body at demonstration program level. The MAF (I) Handbook at demonstration project level and the MAF (II) Handbook at demonstration program level provide the guidelines for demonstration data and information collection and assessment.

3.1 Project level

All relevant project data and information is provided by each demonstration project to the Liaison Body at demonstration program level. Every Neutral Body and its project partners will prepare reports for the Liaison Body. The **HyLights MAF Handbook (I)** will serve as a guideline for data and information collection and assessment as well as for the report preparation.

The provided project reports include specific, aggregated and cumulated data as well as information on experiences, safety relevant events and recommendations made and are collected during the demonstration project. Table 2 summarises the reported data and information by each demonstration project according to the MAF Handbook (I).

Project Governance Indicators	Hydrogen Vehicle Performance Indicators	Hydrogen Infrastructure Performance Indicators
Project management scheduled development collaborations financing & budgeting quality assurance **Legal** contract negotiations liability Intellectual Property Rights **Socio-economics** dissemination and visibility education and training business opportunities	**Technical specifications** maximum speed acceleration and elasticity driving range drivetrain power density ambient temperature limits for vehicle operation maximum hydrogen storage capacity of the vehicle energy density of the hydrogen storage LH2 storage autonomy time of the vehicle **Cumulative performance data** total travelled distance hydrogen refuelled and consumed vehicle availability safety incidents reporting vehicle efficiency / fuel consumption vehicle emissions – regulated emissions customer satisfaction approval and operational hurdles of the vehicle buses – number of passengers	**Technical specifications** fuel dispensing capacity refuelling station siting boil-off rate of the stationary LH_2 storage (at HRS) **Cumulative performance data** refuelling quantity refuelling time utilisation rate of the refuelling station availability of the refuelling station safety incidents reporting fuel quality and composition hydrogen losses at the refuelling station quantity of delivered H_2 (central H_2 production) produced H_2 (onsite H_2 production) utilisation rate of fuel production unit (onsite H_2 production) specific energy demand customer satisfaction of the refuelling station handling and opening hours of the station approval and operational hurdles of the HRS

Table 2: Reported data and information by the MAF Handbook (I) at project level

3.2 Program level

HyLights has identified the following topics to be addressed at demonstration program level,

- environmental impacts and benefits, especially emissions,
- hydrogen fuel and vehicle costs,
- public acceptance and perception
- safety.

The Liaison Body will carry out the evaluations in accordance with the agreed methodology and in collaboration with the relevant industry partner(s) and the EC (i.e. JTI Program Office) and provide reports reflecting data in an aggregated form.

3.2.1 Environmental assessment

Well-to-Wheel analysis

The environmental assessment of the demonstration projects and program should consider GHG emissions of the Well-to-Tank (WTT), Tank-to-Wheel (TTW) and the total Well-to-Wheel (WTW) analysis. HyLights recommends using the results of the Well-to-Wheel (WTW) analysis of the Concawe/EUCAR/JRC consortium as a baseline.

See more details in ANNEX 1.

Life Cycle Analysis

To extend the depth of the analysis, HyLights recommends conducting a Life Cycle Analysis (LCA) in separate projects at European level. This will involve basic definitions of the effects and the LCA analysis.

The activity is beyond the scope of the MAF and hence should be embedded into a wider environmental assessment, involving other energy sectors and supply alternatives.

HyLights recommends that JTI should consider representing the hydrogen specific LCA issues within a wider group of energy stakeholders in order to put hydrogen into the perspective of other energy alternatives leveraging tools and data which have already been developed for other projects (e.g. Concawe/EUCAR/JRC).

Potential issues could be

- resources, consumption of water, platinum and rare raw materials
- vehicle and infrastructure costs.

Further information is given in Annex 1.

Demonstration program performance

For the overall environmental assessment, the cumulated performances of the demonstration program and projects should be presented. The presentation and discussion of the final results should assess the achieved performances of the demonstration program including,

- the amount of saved CO_2 emissions in [kg per year], [kg per km] or [kg]; this should include the analysis of the MAF Handbook (I) concerning the effect of "underutilisation" of hydrogen refuelling stations and hydrogen vehicles

and

- the comparison and discussions of the demonstration program results with the results of the *Concawe/EUCAR/JRC study.*

See further details in ANNEX 2.

3.2.2 Costs

The cost monitoring and assessment should address the costs of the hydrogen vehicle and hydrogen as transport fuel.

HyLights recommends assessing the costs as part of the WtW analysis conducted as part of the environmental assessment.

The cost assessment could be carried out as a two step approach:

Step one, results of EC funded projects such as HyWays [HyWays 2008] or Concawe/EUCAR/JRC [Concawe WtW] should serve as a guideline for cost assessment.

Step two, for further data assessment HyLights recommends the initiation of a separated project at JTI level. This activity could also take into consideration additional cost parameters such as land-use costs, taxation or other issues such as safety measures (e.g. safety distances). [3]

See further details in ANNEX 3.

[3] See also the "Handbook on estimation of external costs for the transport sector", released by the EC in February 2008 [ExternalCosts 2008].

3.2.3 Public acceptance and perception

The assessment of the public acceptance and perception of hydrogen and fuel cell technology is one of the most comprehensive issues to be assessed by the JTI on program level.

This topic is closely related to

- public perception,
- public education,
- public relations,
- project success and targets and
- commercialisation strategies.

The survey on hydrogen and fuel cell acceptance and perception should be addressed by the JTI Program Office in accordance to the overall commercialisation targets of the JTI.

All surveys on hydrogen related acceptance and perception issues should be representative.

The assessment of hydrogen and fuel cell acceptance and perception should

address:

- the public,
- authorities,
- operators (vehicle drivers and fuelling station operators),
- OEMs (equipment supplier, involved and not involved),
- refuelling infrastructure industry,
- energy provider & hydrogen supplier and
- others (Media, NGOs,…).

See further details in ANNEX 4.

Demonstration program performance

The assessment of the criteria above should provide information on the state-of-the-art of the,

- knowledge and perception regarding hydrogen and fuel cells (environmental issues, technology) – public and operator,
- knowledge and perception regarding the demonstration project and program and
- inputs and recommendations for future development and projects,

Results should be provided for individual social groups (e.g. by region, age, income…).

Recommendations for survey activities

It is recommended that,

- acceptance and public perception should be carried out by a specific project with focus on public survey as part of the demonstration program,
- the methodology for the survey should be defined at the beginning of the project,
- the type of the data to be collected by the demonstration projects should be defined by JTI prior to the start-up of the individual projects and
- harmonised with other projects or programs addressing the acceptance and perception of hydrogen as transport fuel in Europe, e.g. the ESTEEM tool (Engage stakeholders through a systematic toolbox to manage new energy projects) developed within the European Research Project *Create Acceptance* under FP 7 [ESTEEM 2008].

3.2.4 Safety

Safety incidents have to be reported at demonstration program level by each individual project according to the definitions in the MAF Handbook (I) at demonstration project level, including

- (V-12) Safety incidents of a vehicle or vehicle components
- (I-8) Safety incidents at the hydrogen refuelling station

See further details in the MAF Handbook (I) and the templates for incident reporting by the HyFleet:CUTE project (see Annex 5).

In addition, all relevant information and warnings regarding safety that may be identified during the demonstration program phase must be immediately reported by each project and program partner to the Liaison Body. As a central program institution the LB is responsible for distribution and coordination of all safety related information and recommendations.

The LB in cooperation with the JTI Program Office should inform and update all projects and program partners about the actual safety information on the basis of actual project and industry information and experiences.

The LB will prepare safety specific reports including safety statistics and recommendations to the JTI Program Office and the public. These safety reports should also include experiences made in other EC funded projects.

See further details in ANNEX 5.

4 Assessment of overall targets

The Liaison Body (LB) at demonstration program level should carry out assessments and provide draft reports to the JTI Program Office. These should include specific data and information as well as achieved performances provided by the demonstration projects and the program.

4.1 Project and program data

The assessment will be conducted by the LB in close cooperation with the JTI Program Office and the projects, if applicable.

Following information should be addressed,

- project specific information, i.e. MAF reports provided by the individual projects and
- program specific information, i.e. environmental assessment, costs, acceptance and perception and safety issues.

4.2 Key performance criteria, success and progress

HyLights recommends that the JTI Program Office should devise an activity / separate road map project to review / update the performance progress against the European Hydrogen Road Map (HyWays).

4.3 Recommendations for final reporting

The reports provided by the LB to the JTI Program Office should include conclusions and recommendations regarding,

- demonstration projects,
- demonstration program,
- technology development,
- R&D support,
- regulations, codes and standards,
- safety and
- other issues.

JTI is the owner of the assessment results.

5 Acronyms and abbreviations

CGH_2	Compressed gaseous 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

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Annex 1 – Vehicle segments

Definition of vehicle segments according to definitions described in the MAF Handbook (I) at project level:

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 requested that:

- 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 3 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 3: 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.

Annex 2 – Well-to-Wheel analysis and LCA

Analogue to the Well-to-Wheel (WTW) study conducted by Concawe/EUCAR/JRC, the environmental assessment should focus on the WTW assessment.

"Grey energy" emissions that are related to the building of the hydrogen infrastructure facilities and the hydrogen vehicles should not be considered. The WTW assessment will concentrate on hydrogen fuel production and hydrogen use in vehicles.

If the WTW data that are taken from the Concawe/EUCAR/JRC study are not detailed or comprehensive enough (e.g. other vehicle classes are required), it is recommended that a separate project for further data analysis is initiated.

The WTW analysis is split into a Well-to-Tank (WTT) and a Tank-to-Wheel (TTW) part.

Well-to-Tank (WTT)

The Well-to-Tank part assesses the supply chain of hydrogen as transport fuel from the resource recovery to the delivery to the vehicle. This includes the calculation of emissions on the basis of required and expended energy for the process of hydrogen fuel production, transport, manufacturing and distribution.

Extended calculations

For further, more detailed calculations, the required energy and the related GHG emissions are assessed on the basis of the provided data described in the MAF Handbook (I) for demonstration projects *(according to (I-14) Specific energy demand at the hydrogen refuelling station [in* kWh_{energy}/kWh_{H2} *)*. Synthesis of relevant outcomes from individual projects could be based on a common set of premises.

Data presentation

The required energy input (energy use) and the calculated GHG emissions are presented for selected reference and hydrogen fuel pathways. Analogue to the results of Concawe/EUCAR/JRC, the required energy is presented in [MJ per MJ] and the GHG emissions in [g of CO_2 equivalent per MJ]. If applicable, the WTT results should include identified ranges / bandwidths (e.g. minimal – maximal ranges, data variations and uncertainties).

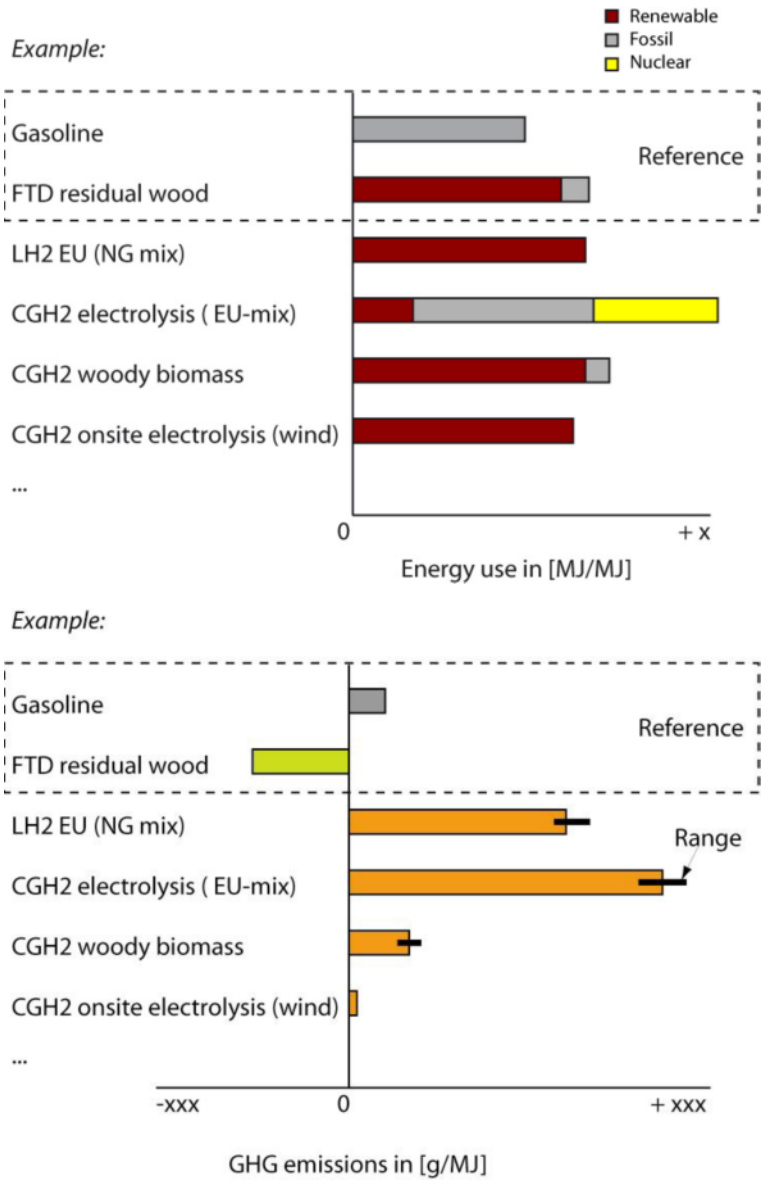


Figure 2: Example for presentation of the WTT results

Tank-to-Wheel (TTW)

The TTW part assesses different vehicle architectures, powertrains and fuel effects, specifically those reflected in the individual projects. The TTW assessment calculates emissions on the basis of required and expended energy.

Extended calculations

For further, more detailed calculations, the required energy and the related GHG emissions are evaluated on the basis of the provided data described in the MAF Handbook (I) for demonstration projects *(according to (V-13) vehicle efficiency / fuel consumption)*.

Data presentation

The required energy input (energy use) and the calculated GHG emissions are presented for selected reference and hydrogen vehicles. The fuel consumption (required energy) is presented in [liter of gasoline equivalent per 100 km] and the GHG emissions in [g of CO_2 equivalent per 100 km]. If applicable, the presented results should include identified ranges / bandwidths (e.g. minimal – maximal ranges, data variations and uncertainties).

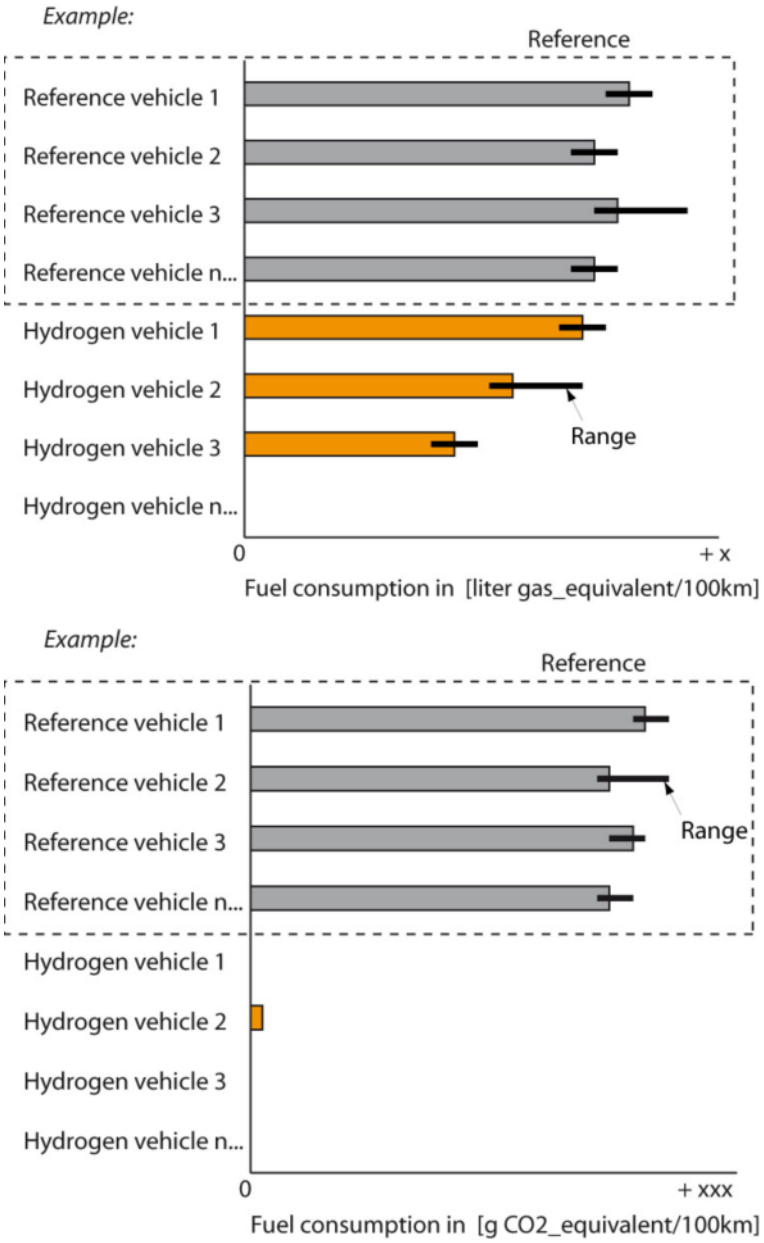


Figure 3: Example for presentation of the TTW results

Well-to-Wheel (WTW)

The WTW analysis combines the specific energy requirements and GHG emissions of the WTT and the TTW parts.

Data presentation

The required energy input and the calculated GHG emissions are presented for selected transport fuel pathways and vehicle powertrains. The required energy is presented in [MJ per 100 km] or [MJ per 100 person km] and the GHG emissions in [g of CO_2 equivalent per 100 km]. If applicable, the results should include identified ranges / bandwidths (e.g. minimal – maximal ranges, data variations and uncertainties).

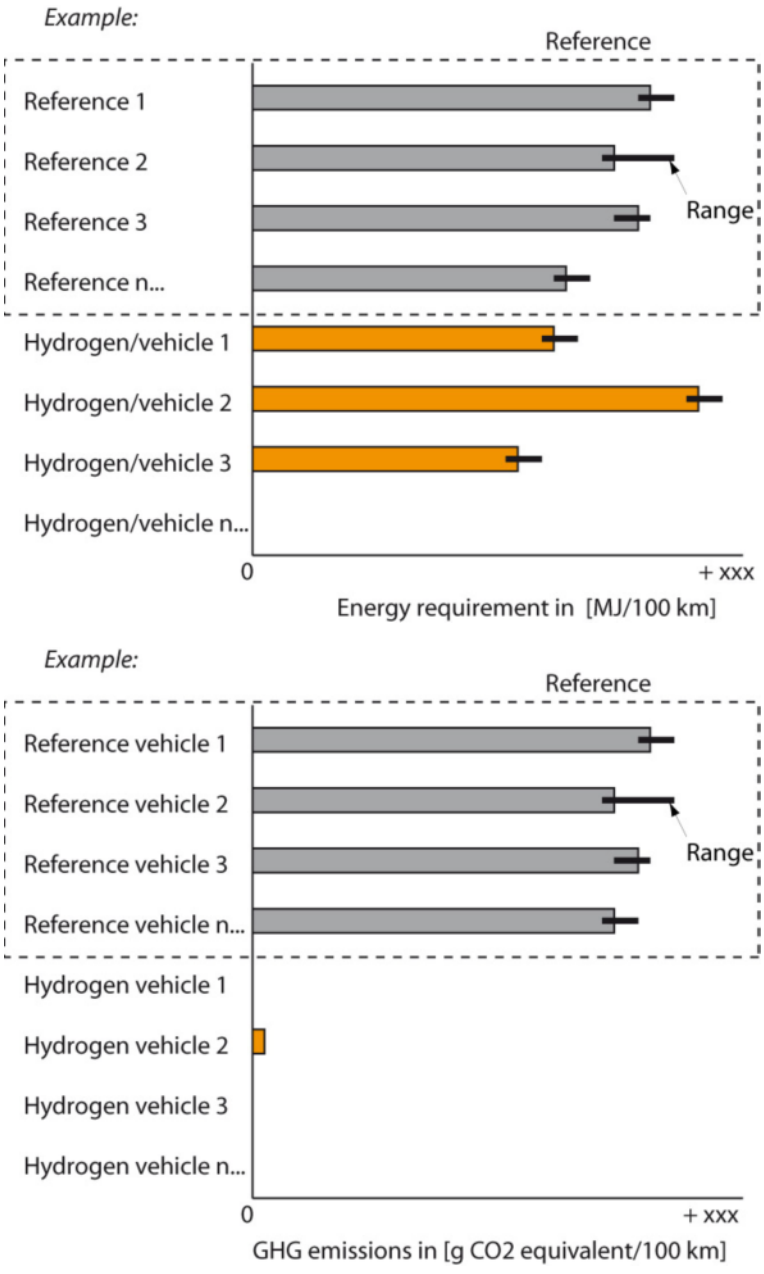


Figure 4: Example for presentation of the WTW results

Reference for Life-Cycle Analysis

For Life-Cycle Analysis (LCA), the following approaches and info sources related to Life Cycle Analysis are recommended:

- Concawe/EUCAR/JRC activities [Concawe/WtW]
- The European Reference Life Cycle Data System [ELCD 2008]
- California Environmental Protection Agency: Low Carbon Fuel Standard Programme [LCFS 2008]
- UC Davis Institute of Transportation Studies: Sustainable Transportation Energy Pathways (STEP) programme [STEP 2008]

Annex 3 – Hydrogen vehicle and fuel costs

Hydrogen supply and fuel cell vehicle costs of the equipment and prototypes that are presented in publicly funded demonstration projects typically do not reflect real (= competitive) market costs and hence are no measure to direct future R&D and demonstration project spending. For that reason, cost analysis needs to be carried out at demonstration program level, specifically to generate information about cost levels translating the current technology to real market conditions. In doing so, instruments to guarantee individual companies the necessary intellectual property rights will be applied.

All reported costs data by the industry partners will be handled as "sensitive information" by the Liaison body. Thus, all collected data that are reported to other project partners and the EC as well as those disseminated to the public will be presented in aggregated form, i.e. by presenting average, not individual values. This is needed in order to project the intellectual property rights (IPR) of the industry partners and to impede the rise of IPR concerns, as "sensitive" information will be presented in a way that precise sources cannot be extrapolated and the possibility of further use is excluded.

It is recommended that the hydrogen vehicle and fuel costs are assessed on the basis of the results of EC funded projects such as Concawe/EUCAR/JRC (Step ONE).

For further cost assessment HyLights recommends the initiation of a separated project at JTI level (Step TWO). This activity could include external land-use, taxation and other issue such as safety measures (e.g. safety distances).

Step ONE: Example – Concawe/EUCAR/JRC as reference

The cost analysis developed within the Well-to-Wheel (WTW) study by the Concawe/EUCAR/JRC consortium should be used as baseline for the "direct costs" assessment, i.e. costs to purchase feedstock, building plants, infrastructure and vehicles. The cost assessment should include CO_2 costs as described in Concawe/EUCAR/JRC [Concawe/WtW].

Analogue to the Concawe/EUCAR/JRC approach, it is recommended that costs and not customer prices without subsidies and taxes are assessed.

In addition a more comprehensive cost assessment could be initiated and conducted at demonstration program level (see Step TWO, below).

Well-to-Tank (WTT)

The WTT study conducted by the Concawe/EUCAR/JRC has estimated the "macro-economic" costs to the EU as an entity of producing a certain fuel in a certain way at a certain scale.

The main costs for hydrogen production pathways are based on feedstock costs and investment in manufacturing plants, distribution and refuelling systems. The

cost calculation includes thermal processes, electricity generation and electrolysers.

Extended WTT- calculations

Further, more detailed cost calculations and assessments could be carried out if the results of the WTT study of Concawe/EUCAR/JRC are not sufficient. It is recommended that cost assessment is harmonised with the Concawe/EUCAR/JRC approach.

Tank-to-Wheel (TTW)

The TTW costs are assessed on the basis of retail prices.

Maintenance costs are not included.

Extended TTW-calculations

Further, more detailed cost calculations and assessments could be carried out if the results of the TTW study of Concawe/EUCAR/JRC are not sufficient. It is recommended that cost assessment is harmonised with the Concawe/EUCAR/JRC approach.

Data presentation

Vehicle costs are presented on the basis of estimated incremental vehicle retail prices in percentage relative to a 2010 gasoline ICE vehicle. The graph shows the cost increase of the selected hydrogen vehicles for cars with ICE or FC and buses with ICE or FC. Relevant vehicle details should be stated in the report such as vehicle segment, type of fuel storage, hybridisation, plug-in options, and others.

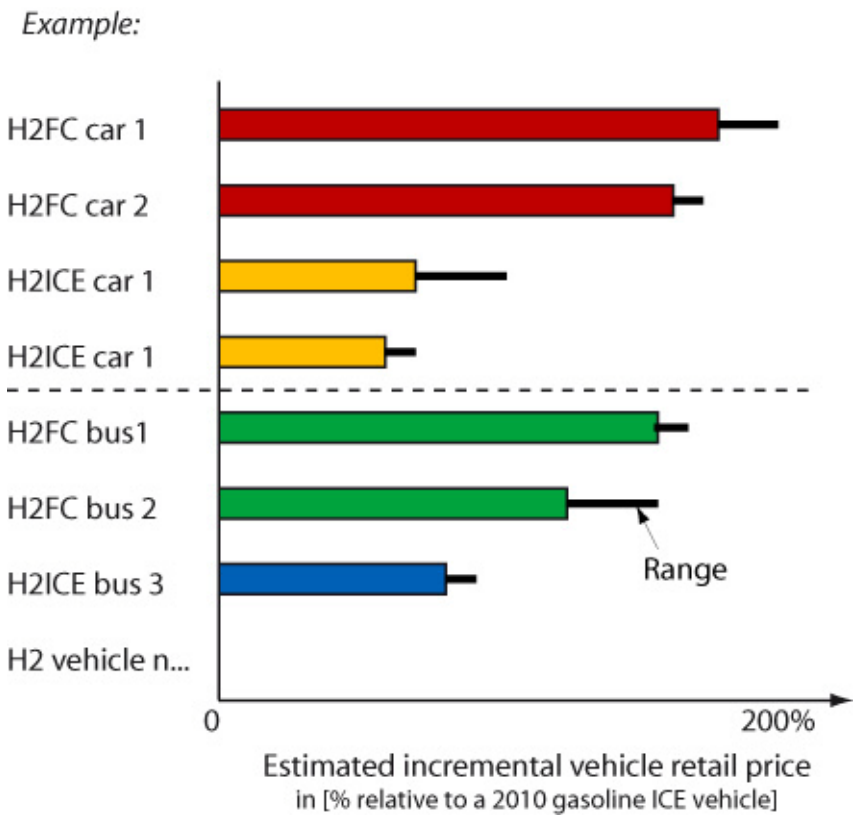


Figure 5: Example for presentation of the estimated vehicle retail price of hydrogen vehicles relative to a conventional vehicle in 2010

Step TWO – Extended cost calculations

For further cost assessment HyLights recommends initiating a separated project at JTI level.

This activity could also take into consideration additional cost parameters such as land-use costs, taxation or other issues such as safety measures (e.g. safety distances).

■ ***Example – calculation of hydrogen fuel costs***

Unit	Confidentiality level:	Data presentation
€ per kg	**Confidential**	**Aggregated Composite data**

HyLights recommends that the hydrogen fuel cost should be derived at each fuelling station from the investment and operation and maintenance (O&M) costs under specific assumptions for the hydrogen refuelling station (HRS) operation and the mass manufacturing of components. All required data for the cost calculation should be defined in agreement with the JTI Program Office.

Calculation of the hydrogen (H_2) fuel costs:

I) $Cost\_H_2 = \Sigma\ capital\ costs + \Sigma\ O\&M\ costs$

II) $\Sigma\ capital\ costs = cap\_costs\_HRS + cap\_costs\_onsite\text{-}production + cap\_costs\_H_2\text{-}transport$

III) $\Sigma\ O\&M\ costs = O\&M\_costs\_HRS + O\&M\_costs\_onsite\text{-}production + O\&M\_costs\_H_2\text{-}transport$

Cap – capital; O&M – operation and maintenances; HRS – hydrogen refuelling station

Capital cost:

- **capital cost of the hydrogen refuelling station, onsite production unit and the H_2 transportation hardware (e.g. pipeline) in [€] (excluding taxes):** the capital cost is based on the assumption of component mass production; the data are provided by the industry partners for the hydrogen refuelling station; major components of the hydrogen refuelling station include fuelling station, hydrogen compressor, onsite hydrogen storage, reformer or electrolyser, pipeline and other components.
- **technical lifetime of the refuelling station, onsite production unit and H_2 transportation hardware (major components) [years]:** the data need to be defined in agreement with the JTI Program Office. Table 4 presents suggested assumptions for the lifetime of major components.

Component	Years
Fuelling station	15 a
Reformer	15 a
Electrolyser	15 a
Compressor	15 a
Storage	20 a
Pipeline	25 a
Others	…

Table 4: Suggested assumptions for the technical lifetime of major hydrogen refuelling station (HRS) components

- **utilisation rate of the refuelling station [%]:** the definition of standardised utilisation rates is recommended, e.g. at full load (100%) and part load (50% and 25%)
- **transportation distance [km]:** definition of an average transport distance for the hydrogen delivery (e.g. by pipeline or trucked) for all refuelling stations (central hydrogen production). Suggested average transportation distance: **300** km (truck delivery of LH_2) , **50** km (pipeline)
- **Hydrogen quality [%]:** this data needs to be defined in order to be able to compare the calculated cost results.
  Suggested quality: **5.0** (i.e. the H_2 purity is **≥ 99,999%**)

Operational and maintenance costs – O&M costs:

The O&M costs include material and labour costs.

For **central hydrogen** production the hydrogen fuel costs are defined.[4] Operational and maintenance costs are only reported and calculated for the refuelling station and the fuel delivery but not for the centralised hydrogen production.

For **onsite production** the hydrogen fuel costs are calculated from the primary energy inputs.

Operational costs

- for onsite production the **primary feedstock costs [€ per unit]** (excluding tax) have to be defined in agreement with the JTI Program Office,
- the specific **fuel consumption [kWh_primary feedstock per kWh_H2]** (only applicable for onsite H_2 production) is defined in agreement with the JTI Program Office,
- the **annual electricity costs [€ per year]** are calculated on the basis of the specific electricity cost [€ per kWh_e] which needs to be defined in agreement

[4] *For innovative processes (e.g. electrolysis, biomass gasification, onsite or central) hydrogen costs should be presented in detail for the relevant sub-processes.*

with the JTI Program Office. The annual electricity costs are calculated by the amount of electricity consumption for the onsite production unit [kWh_e per kWh_H2], the H_2 transportation [€ per km of transport], H_2 transport distance [km of transport], the refuelling station [kWh_e per year] and the electricity costs [€ per kWh_e].

Maintenance costs

The maintenance costs are estimated and defined by the LB in agreement with the JTI Program Office.

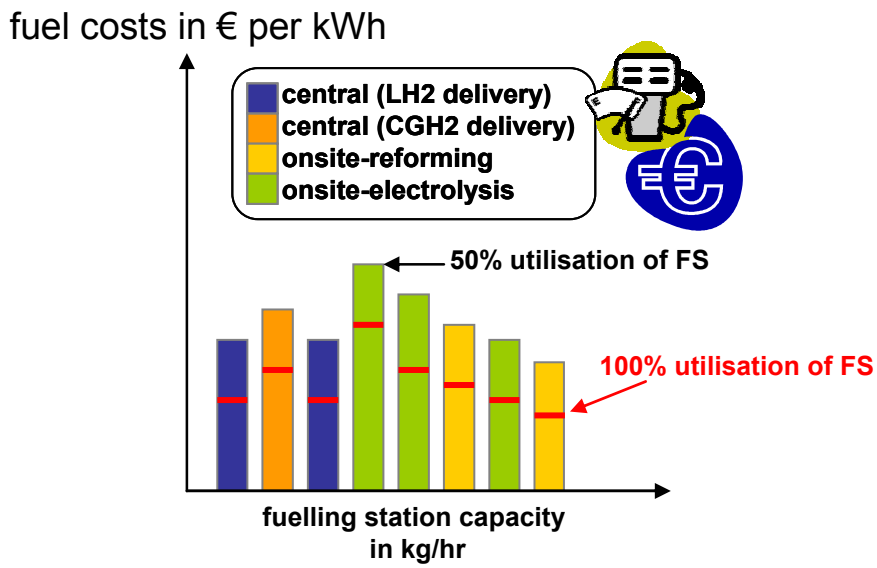
The **maintenance costs** include

- scheduled maintenance and
- repairs caused by unscheduled incidents.

Result presentation

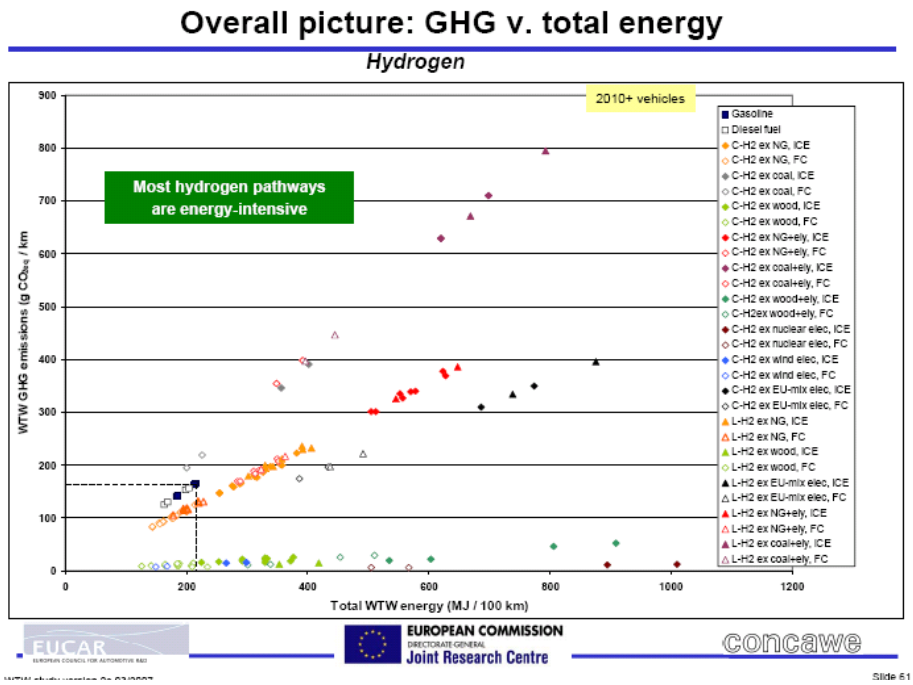
All cost results are presented by size and type of refuelling stations and defined utilisation rates.

Example results presentation: *fuel costs by size and type of refuelling station for 100% and 50% of utilisation rate of the hydrogen refuelling station*



Example for data presentation:

Source: Concawe/EUCAR/JRC



Performance of demonstration project

At demonstration program level, the overall amount of saved GHG emissions should be presented. Each project should be compared to a reference fleet with conventional gasoline or diesel vehicles based on the Concawe/EUCAR/JRC reference vehicles [in g_{CO2} per km]. The saved GHG emissions will be calculated in [tons of CO_2 $_{equivalent}$] on the basis of the same driving performances in [km].

Saved GHG emissions = GHG emissions reference fleet – GHG emissions demo project

with:

GHG emissions reference fleet
= GHG emission reference vehicle in [gCO2/km] x driving performance of the demo project in [km]*

** conventional gasoline or diesel reference vehicle – data provided by OEM where applicable (type approval)*

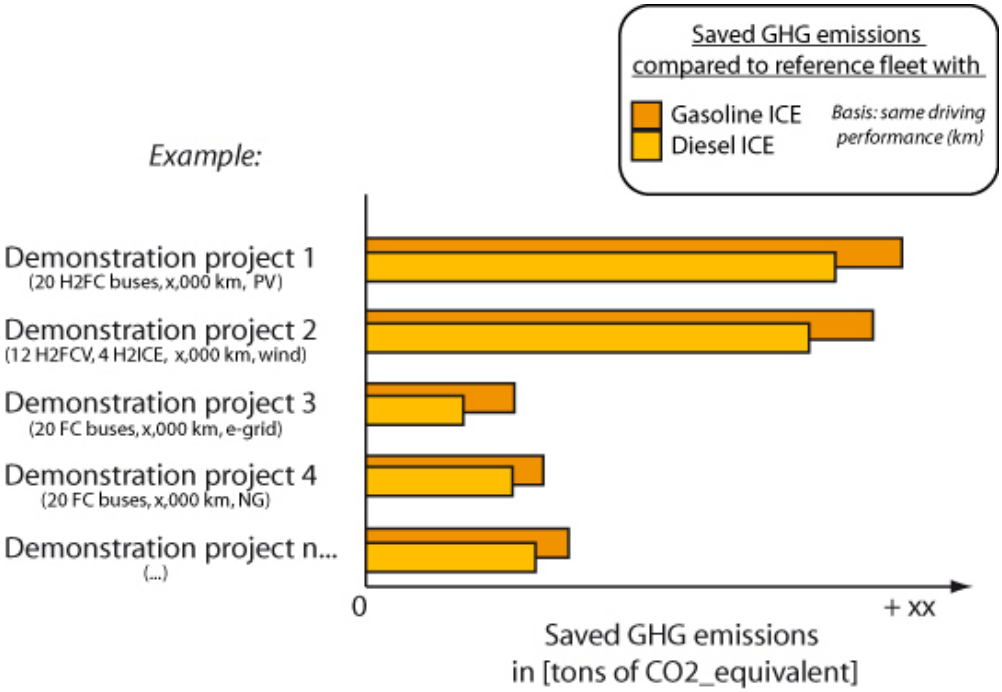


Figure 6: Overall saved GHG emissions by the hydrogen demonstration projects compared to conventional vehicles (gasoline/diesel) with the same driving performance

■ ***Vehicle costs***

Unit	Confidentiality level:	Data presentation:
€ per vehicle € per km € per kW	**Confidential**	**Aggregated Composite data**

The **vehicle cost** is defined as the cost that has to be paid by the vehicle owner (= operator) to buy, operate and maintain the hydrogen vehicle over the (technical) lifetime of the vehicle.

HyLights recommends calculating the capital costs of the vehicle on the assumption of **mass production** (100.000 units per year and manufacturer) and not on today's production or leasing/rental costs (today's leasing or rental costs of the vehicle are not considered for cost calculation). The total vehicle cost calculation does not include and consider taxes, subsidies or other benefits for hydrogen or fuel cell technologies.

The capital costs and the operation and maintenance (O&M) costs are provided for each vehicle by the automotive industry partners to the Liaison Body (LB).

In addition, the automotive industry reports the **specific drivetrain costs** to the LB: the drivetrain includes FC or ICE, electrical/mechanical energy storage, electric motor and inverter/controller; not included are: fuel storage and automotive cooler/fan.

All provided data are confidential. The LB calculates the vehicle costs and presents the costs in €/vehicle and the specific drivetrain costs in €/kW on an aggregated level.

Vehicle costs [€ per vehicle]

The total vehicle cost is calculated for the operational (technical) lifetime of the vehicle:

$$Cost_{vehicle} = \Sigma\, capital\ costs_{vehicle} + \Sigma\, O\&M\ costs_{vehicle}$$

Vehicle costs [€ per km]

$$Specific\ vehicle\ cost = cost_{vehicle} / \Sigma\, travelled\ km\ over\ the\ lifetime$$

with:

*travelled km = technical lifetime vehicle [years] * vehicle mileage per year [km per year]*

Capital cost $_{veh}$:

- **capital cost of the vehicle in [€]** (excluding taxes): the capital cost is based on the assumption of vehicle and component mass production (100.000 units per year); the data is provided by automotive industry partner

- **technical lifetime of the vehicle [years]:** this data needs to be defined in agreement with JTI Program Office at the beginning of the project; *suggested lifetime for cars = 10 years, for buses = 6 years, for scooters = 4 years*
- **vehicle mileage [km per year]:** this data needs to be defined in agreement with the JTI Program Office at the beginning of the project; *suggested mileage for cars = 12.000 km per year; for buses = xx.000 km per year, for scooters = xx. 000 km per year*

Operational & maintenance costs – O&M costs $_{vehicle}$:

The O&M costs include material and labour costs.

The **operational costs** are calculated from the fuel cost and electricity cost at the beginning of the project.

- **fuel costs [€ per kg]** (excluding tax): this data needs to be defined in agreement with the JTI Program Office at the beginning of the project, this fuel cost data is only relevant for vehicle cost calculation and independent from the calculation of the real fuel costs at the different filling stations. *Suggested hydrogen fuel cost: xx € per kg*
- **fuel consumption [kg per km]:** this data is provided by the automotive industry partner on the basis of the actual demonstration vehicles
- **electricity costs [€ per year]:** the electricity cost [€ per kWh_e] needs to be defined in agreement with the JTI Program Office at the beginning of the project; the annual electricity costs are calculated by the amount of electricity consumption [kWh_e per year] (provided by the vehicle operator) and the electricity costs [€ per kWh_e]. *Suggested electricity cost: xx € per kWh_e*

The **maintenance costs** include scheduled maintenance and repairs caused by unscheduled incidents. The maintenance costs are estimated and defined in agreement with the JTI Program Office. The cost assumption for scheduled maintenance and unscheduled repairs will be defined for all vehicles:

- scheduled maintenance costs per year [€ per year]: e.g. x % of the vehicle capital costs
- expected repair costs (caused by unscheduled incidents) per year [€ per year]: e.g. x % of the vehicle capital costs

Specific drivetrain costs [€ per kW]

The specific drivetrain cost (FC or ICE) in [€ per kW] is reported by the automotive industry. The costs are calculated on the assumption of mass production (100.000 units per year).

The drivetrain comprises the fuel cell or ICE, electrical/mechanical energy storage, electric motor, gear box, inverter and controller.

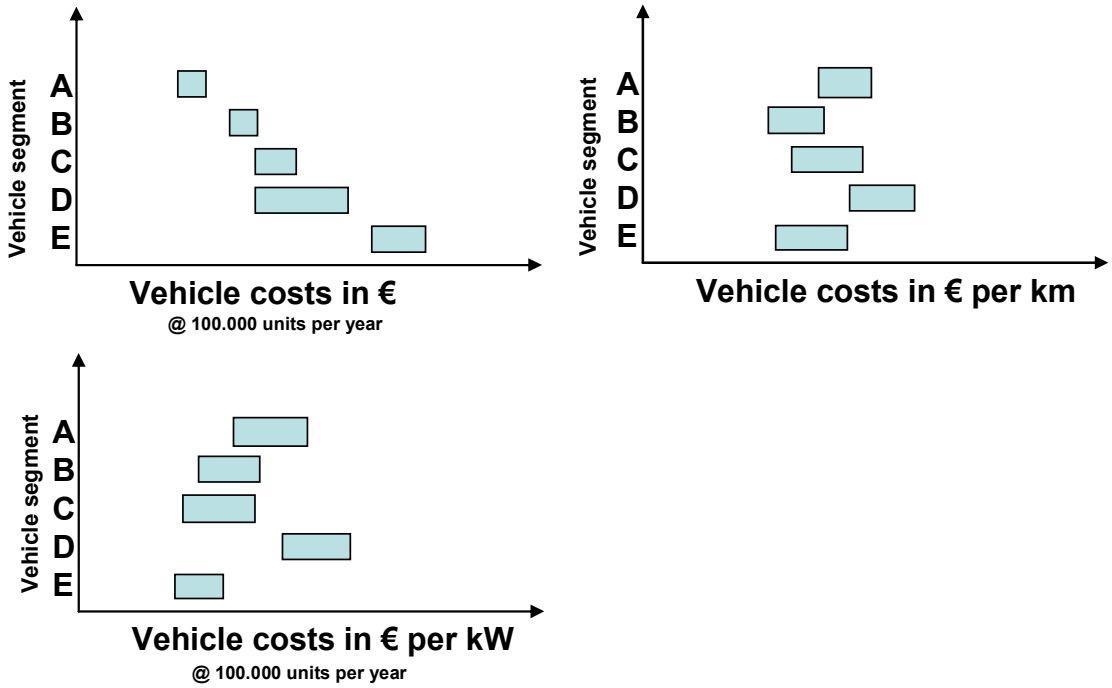
Specific hydrogen storage costs [€ per kg]

The specific hydrogen storage cost in [€ per kg of total stored hydrogen] is provided by the automotive industry partner. The costs are calculated on the assumption of mass production (x units per year).

Result presentation

All cost results are presented for different vehicle segments as defined in MAF handbook I at project level, see Annex.

Example for result presentation: *lower and upper cost limits for each vehicle segments*



Program performance

Example data presentation Concawe/EUCAR/JRC:

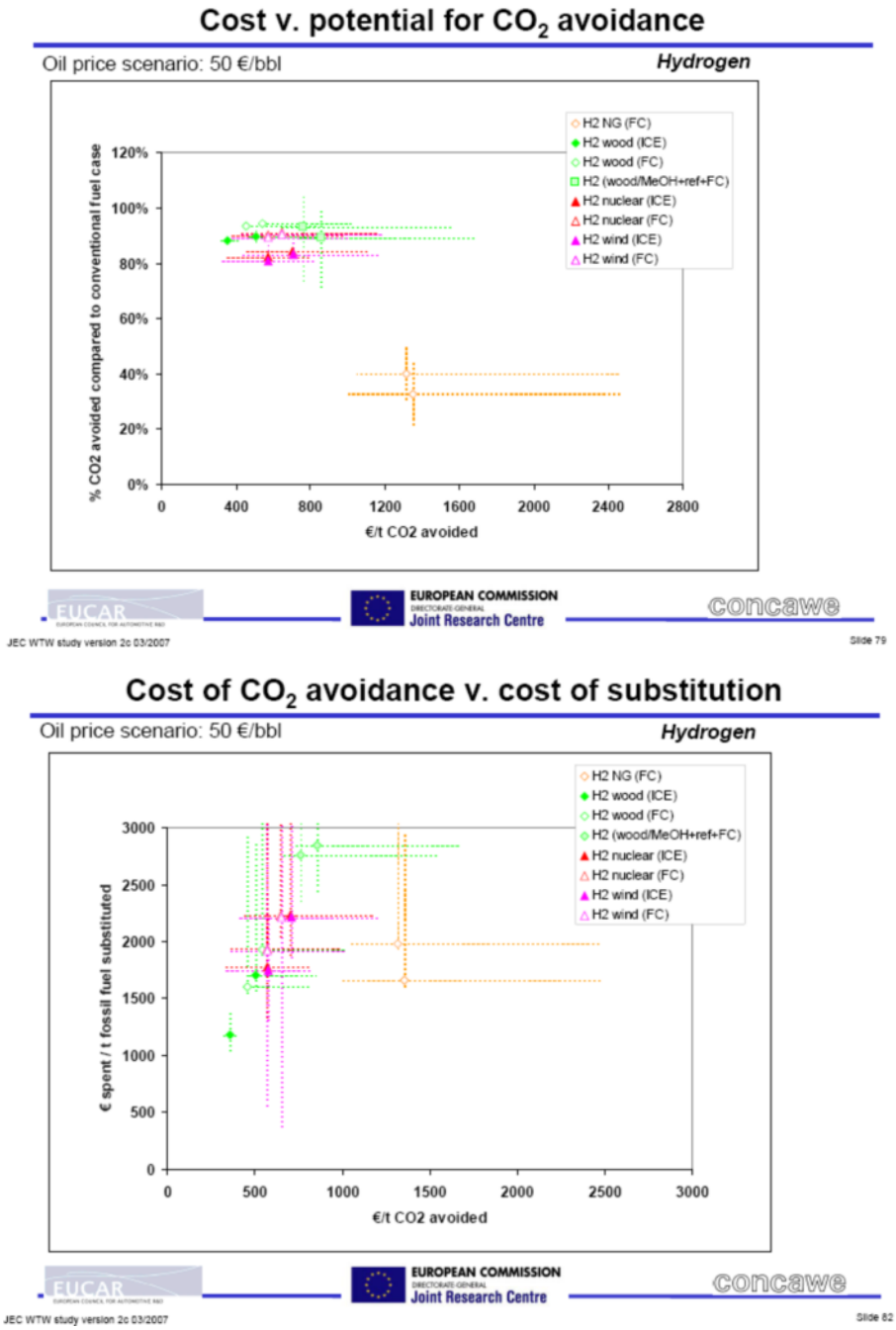


Figure 7: Example WTW cost results – Concawe/EUCAR/JRC

Handbook on external costs

In February 2008, the EC has released a “Handbook on estimation of external costs for the transport sector” [ExternalCosts 2008]. This activity is part of the study of “Internalisation Measures and Policies for All external Cost of Transport (IMPACT)” [Impact 2008].

Annex 4 – Public acceptance and perception

Following issues could be assessed,

related to hydrogen fuel,

- hydrogen as fuel for vehicles,
- the hydrogen fuel price,
- willingness to pay more for the fuel,
- availability of fuelling stations,
- the refuelling procedure / interface at the fuelling station and
- the build-up of hydrogen fuelling station in the neighbourhood,
- safety concerns,

related to hydrogen vehicle,

- the driving range of hydrogen vehicles,
- willingness to pay more for the vehicle,
- vehicle acceleration,
- comfort and noise,
- reliability,

related to general issues,

- major problems identified during the project,
- operator's opinion, experiences regarding hydrogen technology compared to conventional technology (e.g. hydrogen vehicle compared to gasoline vehicle) (definition of characteristics for comparison),
- demand for more information (to be specified),
- other criteria and
- suggestions and recommendations provided by the interviewee.

Annex 5 – Safety and RCS

Template for incidents reporting prepared by HyFleet:CUTE [HyFleet:CUTE]:

HyFLEET:CUTE – INCIDENT REPORT FORM

Near miss ☐ Incident ☐ Accident ☐ LTI		
Reported by:	**Job title and Company**	**Station identification:**
Date:	**Time**:	**Signature** (for hardcopy safety file)
Component category: (mark with x or shadow in the box)		
Affected unit: Production: ☐ Storage: ☐ Compressor: ☐ Dispenser: ☐ FC-bus	**Device:** Connection: ☐ Regulation: ☐ Measurement: ☐	**Others:**
Event category:		
Non-conformance: Off-spec hydrogen gas quality: ☐ FC-bus stop: ☐ Safety system out of order: ☐ Operation interrupted: ☐	**Incident/abnormal situation:** Affecting people: ☐ Affecting the environment: ☐ Affecting on-site equipment: ☐ Affecting off-site material: ☐ Emergency shut down: ☐ Leakage:	**Accident:** Minor injury: ☐ First aid injury: ☐ Injury, medical treatment: ☐ Material damage: ☐ Environmental damage:
Event description:		
Description:		**Discovered** Man. Aut. During operation: ☐ ☐ During inspection: ☐ ☐ During maintenance: ☐ ☐
Cause:		
Accident details:		
Injury to people: Separate report prepared: Yes: ☐ No: ☐ Personal protection equipment: Used: ☐ Not used: ☐	**Environmental damage:**	**Damaged object:**
Immediate Corrective actions if any:		
Description: Will this incident require further investigation and a final report further corrective action: YES ☐ NO ☐ Proposed: ☐ Planned: ☐ Implemented: ☐		