DELIVERABLE 2.1 AND 2.1a

"European Hydrogen Infrastructure Atlas" *and* "Industrial Excess Hydrogen Analysis"

PART I: Mapping of existing European Hydrogen Demonstration Sites

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The European Commission is supporting the Coordination Action "HyLights" and the Integrated Project "Roads2HyCom" in the field of Hydrogen and Fuel Cells. The two projects support the Commission in the monitoring and coordination of ongoing activities of the HFP, and provide input to the HFP for the planning and preparation of future research and demonstration activities within an integrated EU strategy.

The two projects are complementary and are working in close coordination. HyLights focuses on the preparation of the large scale demonstration for transport applications, while Roads2HyCom focuses on identifying opportunities for research activities relative to the needs of industrial stakeholders and Hydrogen Communities that could contribute to the early adoption of hydrogen as a universal energy vector.

Further information on the projects and their partners is available on the project web-sites www.roads2hy.com and www.hylights.org

ABSTRACT

Demonstration projects can be seen as showcases for future commercial products, bridging the gap between near-market products and commercially viable systems. They facilitate the necessary learning process for both technical as well as socio-economic aspects of a technology. In additon, these demonstration projects can act as seeds for other future hydrogen projects or the anticipated large-scale demonstrations also known as Lighthouse-Projects (LHP). In this study data on hydrogen demonstration projects were collected from various sources and synchronised with the currently largest database for demonstration projects held by the Hydrogen and Fuel Cell Platform (HFP) Europe. More than 70 data sets could be added to both databases. Also, all data sets in both databases were supplied with a geographical reference by Roads2HyCom. The geographic mapping of all identified projects revealed early clustering of demonstration projects with centres of aggregation in the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden. These were also the countries in which most of the demonstration projects are based or will be initiated so that it could be assumed that these are first signs and the success of local or regional dissimination efforts, but also regional expertise, co-operations or favourable rules and regulations. Stationary and transport applications dominated the different project types, highlighting a growing market maturity of applications in these areas as well as proving trust and confidence of industry in the prospects of these technologies. Also, industry clearly had a strong engangement in the project consortia. Although half of all collected demonstration projects were finished these could still serve as a track-record for future hydrogen communities, showing effort, political will as well as a learning process in the community. For further analysis, a representative subset of the data was taken. These nine selected projects, half stationary, half transport projects, were contacted and in-depths information were collected by means of a questionnaire, covering questions like investment costs, downtime, safety issues, CO2 emmissions etc. Data collection showed unsatisfying communication with projects, underlining the need for a common and mandatory framework of data provision from projects. The results were aligned to a fixed set of metrics that was developed for the common analysis of infrastructure, technologies, and communities in Roads2HyCom. All data were projected into a spiderweb diagramm after being adjusted to a metric scale, which can be altered at any given time. This approach was chosen as it is numerically open and gives decision makers the chance to implement a "weighing factor", reflecting the objectives of their analysis. In regard to the in depth data acquisition it was concluded that due the diverse data sets from a wide range of different project types no single performance figure can be calculated at this stage as it would only skew the overall scoring of each project. Instead, the proposed open approach with applicable "weighing factors" seemed to be the most suitable solution. Still, from comparing the spider diagrams from all nine demonstration projects it could deduced, that half of the projects identified lack of codes and standards as an obstacle, most projects received sufficient local political support, national political commitment was mostly restricted to financial subsidies, and almost all projects had little or no GHG emissions from running the site.

EUROPEAN HYDROGEN INFRASTRUCTURE ATLAS

PART I: MAPPING OF EXISTING EUROPEAN HYDROGEN DEMONSTRATION SITES

TABLE OF CONTENTS

1. Introduction

The Strategic Research Agenda is the main guidance for any future hydrogen and fuel cell activities in Europe. The Agenda states that „demonstration and lighthouse projects are necessary to obtain results under practical conditions to (i) improve systems design, (ii) identify further basic research needs and (iii) illustrate the benefits of the new technology to the public“ (EUROPEAN HYDROGEN & FUEL CELL TECHNOLOGY PLATFORM 2005). This clearly shows the importance of demonstrations as showcases for future commercial products, bridging the gap between near-market products and commercially viable systems. Therefore one of the initial activities of the EU project Roads2HyCom has been to map the existing European Hydrogen Demonstration Sites.

A more detailed description of a demonstration would be:

“A demonstration is a project which brings together systems and products related to Hydrogen and Fuel Cell technology, together with their stakeholders, in a realistic operating environment for the purpose of demonstrating the technology and evaluating its usage. Demonstration projects serve to provide useful information to all their stakeholders:

- Industry - techno-economic learning associated with the system or product being demonstrated, and further development of its reliability in service

- Regions, municipalities and local operators including any private or public user - gaining first experience with the new technology, building confidence in its safety and user-acceptance

- Political stakeholders at regional, federal or EU level - gaining better understanding of real life challenges and opportunities imposed by technological and economic issues, public acceptance, safety related issues, education and training; and furthermore to learn about the possible contribution of a new technology to fulfil the relevant policy goals“

In practice such demonstrations could be, for example, a fuel-cell bus fleet using hydrogen created by renewable energy, or a power generation device using fossil hydrogen from which the Carbon has been sequestered. Demonstrations usually exist within a broader environment where the majority of energy needs are supplied conventionally.

Learning from a single site, however, is not the only purpose of a demonstration. Bearing in mind the EU´s move towards the establishment of interconnected, large-scale demonstrations, i.e. lighthouse projects, these single demonstration sites could well serve as seed to such a large-scale project, providing the basic grid of sites, which then could be linked to each other.

In order to give the European Commission a comprehensive atlas of such an existing European hydrogen demonstration infrastructure (as opposed to „real“ distribution infrastructure, such as pipelines), a geographical overview of all demonstration sites in Europe was prepared. This does not only include their location, but also information on the nature and extent of the demonstrations, their energy supply etc. All this additional information should help to form an objective and reliable basis for future decisions on whether existing sites can be extended to or incorporated in lighthouse projects by knowing of any commonalities or possible incompatibilities. Furthermore, the analysis of the experience gathered in past demonstrations proves invaluable in setting up the next generation of large-scale projects (see Roads2HyCom WP 3 for community profiles; reports from this workpackage are already available to download from www.roads2hy.com.)

This report summarises the results from this mapping exercise and supports the wider task of producing an atlas of the European Hydrogen Infrastructure (see also part II and III of this Roads2HyCom report).

Roads2HyCom is a project that consists of eight workpackages. Each workpackage has a number of deliverables, which act as a proof for contractual obligations and form the basis of the published work of the project. This report is part of the deliverable D2.1 and D2.1a.

2. Mapping exercise

The mapping process can be divided into the following two parts:

- mapping demonstration sites geographically
- analysing demonstration sites with regard to their project content

Mapping demonstration sites geographically

To identify European hydrogen demonstration projects a literature search was carried out including sources like the internet, various EU sources including synopsis brochures of FP5 (EUROPEAN COMMISSION 2003) and FP6 (EUROPEAN COMMISSION 2004) and the Community Research & Development Information Service (CORDIS 2006).

The following definitions were chosen for classification, thereby excluding projects not applicable for this work:

- prototype: a single functional device developed as end-result of a research project
- proof of concept: a device or system used in proving the validity of the technical development, but not necessarily a prototype
- field test: a small series employed “in the field” under realistic conditions with the emphasis on collecting data and optimising operation. Equipment will mostly be maintained by the developers
- demonstration: a publicly visible and accessible proof of feasibility run in the hands of end-users under everyday conditions and with the main target of demonstrating the maturity of a technology or a concept to the public.

The identified projects were matched with the dataset held by the European Hydrogen and Fuel Cell Technology Platform´s HFP-Pro-Database (EUROPEAN HYDROGEN & FUEL CELL TECHNOLOGY PLATFORM 2006), the currently largest hydrogen projects database in Europe with about 1100 records of which about 100 involve hydrogen. Projects identified as missing in the database were added to it by Roads2HyCom. In addition, the entire HFP-dataset was updated and partly researched anew. Likewise projects only available in the HFP-database were incorporated into this new R2H-database. Apart from extending databases with new entries the main contribution to the existing knowledge was seen as the illustration of these entries in a geographical context.

In order to do so, all projects added were provided with a geographical reference, featuring the “Nomenclature of territorial units for statistics (NUTS)” (EUROPEAN PARLIAMENT 2003) which is the standard geo-reference for all statistical surveys and mappings in the EU. There are three levels of details, going from countries (e.g. Spain, Germany, UK) and large regions (e.g. Este, Nordrhein-Westfalen, East

Midlands) down to administrative districts (e.g. Cataluña, Düsseldorf, Derbyshire and Nottingham) and small localities (e.g. Girona, Kleve, Nottingham). With this reference it will then be possible to link the project database to a map. An interactive map and the new Roads2HyCom database of demonstration sites will be made available on www.roads2hy.com shortly. For an overview of the geographic distribution of sites please refer to figure 2.

Analysing demonstration sites with regard to their project content

The main activity of this mapping exercise was to collate data on hydrogen demonstration sites according to the metrics defined in the project methodology. Some analysis has been done on the data collected, the results of which are presented here. Further analysis, evaluation and benchmarking of these demonstration sites will be undertaken later in the Roads2HyCom project in Work Package 4.

The metrics defined in the project methodology include certain aspects against which current technologies, demonstration sites as well as communities can be rated, such as environmental impact, costs or safety, and are jointly valid for work packages 1, 2 and 3.

In order to individualise these main metrics to each work package with its individual specifications, a set of sub-metrics was developed for, in this case, hydrogen demonstration sites (table 1), reflecting the specialities and needs of these sites. For instance, main metric number 1 (technology accessibility) did not prove to be applicable to demonstration sites.

To obtain data from demonstration sites this format clearly needed to be optimised in terms of handling, workability and ease of understanding, especially against the background that sites all over Europe with different levels of language proficiency and availability of technical data would be addressed. The most favourable format seemed to be a questionnaire with detailed explanations and example answers. This would considerably reduce misunderstandings and questions. Annex 2 shows the final questionnaire with the following columns: main metric, submetric number, submetric, units to be used, keywords which give a general idea of what this question is about, a comprehensive explanation of the data needed, an example answer as a guidance of how extensive the answers are expected to be or what general style can be used, and then finally the entry field for the specific site that answers the questionnaire.

Table 1: Set of sub-metrics to the eleven main metrics of the Methodology Manual (metric no.1 not applicable to WP2)

Metric	N°.	Sub Metric
Technology Accessibility		Not applicable to WP2
Global Environmental Impact	2a	Source-to-user greenhouse gas emissions in setting up the site
	2b	Greenhouse gas emissions from running the site
	2c	Efforts of mitigation and minimisation of environmental impact
Local Environmental Impact	3a	Air quality impact
	3b	Noise impact
	3c	Land sealing impact
Efficiency	4a	Transport energy to/from/on site
	4b	Transport and storage losses to/from/on site
	4c	Energy investment in running site
	4d	Fossil energy investment
Capacity & Availability	5a	Unscheduled down times
	5b	Scheduled downtimes
	5c	Unattended operation
	5d	Purity of H_2 used
	5e	Physical state
	5f	Logistical capacity
	5g	Lifetime of the demonstration
Costs	6a	Capital investment costs
	6b	Operational costs
	6c	Decommissioning costs
Safety	7a	Incident likelihood
	7b	Incident severity
	7c	Vulnerability
Public Acceptance	8a	Public perception and opinion
Political Will	9a	Direct financial subsidies
	9b	Political commitments
	9c	Obstructions and barriers
Security & Sustainability	10a	Depletion of critical resources
	10b	Dependency on imports to the EU
Potential for Growth	11a	Potential for general access
	11b	Potential for expansion
	11c	Potential for EU job creation
	11d	Time to commercialisation

It was not the intention to approach all identified demos with this questionnaire, but to limit this task to a selection of representative hydrogen demonstration projects, bearing in mind that even with a “simple” questionnaire it would still take a considerable amount of time to get the demanded data due to the complexity of the data set and the additional difficulties of locating the proper contact person, acquiring permission for obtaining the data, and solving questions and problems.

The selection aimed at including typical projects with regard to the **type** of the demonstration (stationary or transport) or the **ownership** of the device or plant (serving as an indicator on how the community would benefit from a demonstration site in their neighbourhood). The question if a site was still **in operation** was also important for the selection. Although there is still a large learning potential from recently finished sites, a working demonstration is yet a greater asset in regard to being integrated into future Lighthouse Projects (LHP). Another aspect to be addressed was the balanced selection of single as well as integrated systems (**system complexity**), covering both near-market single products which might be very advanced for their specific industry branch, but also more complex, integrated setups that face different challenges than single applications, but might become very important in establishing future hydrogen projects.

To obtain the data from the sites a multi-approach strategy was utilised. First the questionnaires were pre-filled with all information available from published project descriptions or from what would be a common sense answer to the questions. The reason for this was to reduce the amount of time site operators or owners would have to spend on filling in forms, but also to give these people an incentive to complete the form. From experience it followed that a partly filled form more immediately calls for completion and correction than a blank form.

These pre-filled in questionnaires were sent to all contact persons as email. Parallel to this, phone calls were carried out in which a questionnaire would be filled in by the site contact person with the help of the Roads2HyCom contact. This proved to be time-consuming, but very successful in terms of obtaining sensible and complete answers in an adequate period of time.

A number of interviews were carried out in the context of the CA HyLights. The two projects are complementary and are working in close coordination. HyLights focuses on the preparation of the large scale demonstration for transport applications, while Roads2HyCom focuses on identifying opportunities for research activities relative to the needs of industrial stakeholders and Hydrogen Communities that could contribute to the early adoption of hydrogen as a universal energy vector. The unavoidable overlap was turned into synergies and work share between the two projects in respect to contacting demonstration sites. This also reduces the work load and the number of questionnaires projects have to fill in.

3. Data Analysis and Results

Over 130 projects were identified and matched with the dataset held by the European Hydrogen and Fuel Cell Technology Platform´s HFP-Pro-Database, the currently largest hydrogen and fuel cell projects database in Europe with about 1100 records of which about 100 involve hydrogen. More than 70 projects proved to be in both databases, meaning in return that about 30 new projects could be added to each database – a growth of 30%. These projects can be explored online at www.roads2hy.com.

Figure 1 shows the European distribution of those projects country by country. Most projects are based in Germany, Denmark, France, Italy, Spain, the UK, and Sweden. Projects have also been initiated in Norway, The Netherlands, Iceland, Portugal, Austria, Belgium, Greece, and Finland (grouped under "Others").

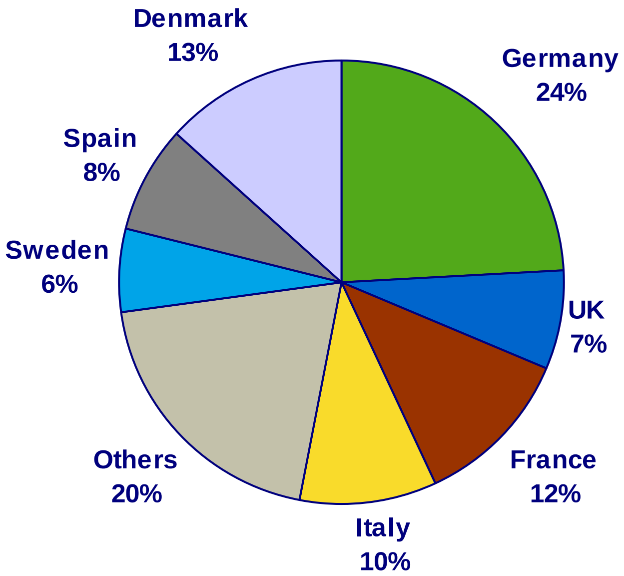

Figure 1: European distribution of over 130 identified hydrogen demonstration projects in a country by country split. Projects have also been initiated in Norway, The Netherlands, Iceland, Portugal, Austria, Belgium, Greece, and Finland, and have been grouped under "Others".

Figure 2 shows the geographic distribution of the identified projects. Clustering of hydrogen and fuel cell activity is already evident in this graph. Centres of aggregation are the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden. Apart from this one can see a general trend of activities in and around big cities. Not only population density, but also financial ability and dissemination impact might be a reason for this.

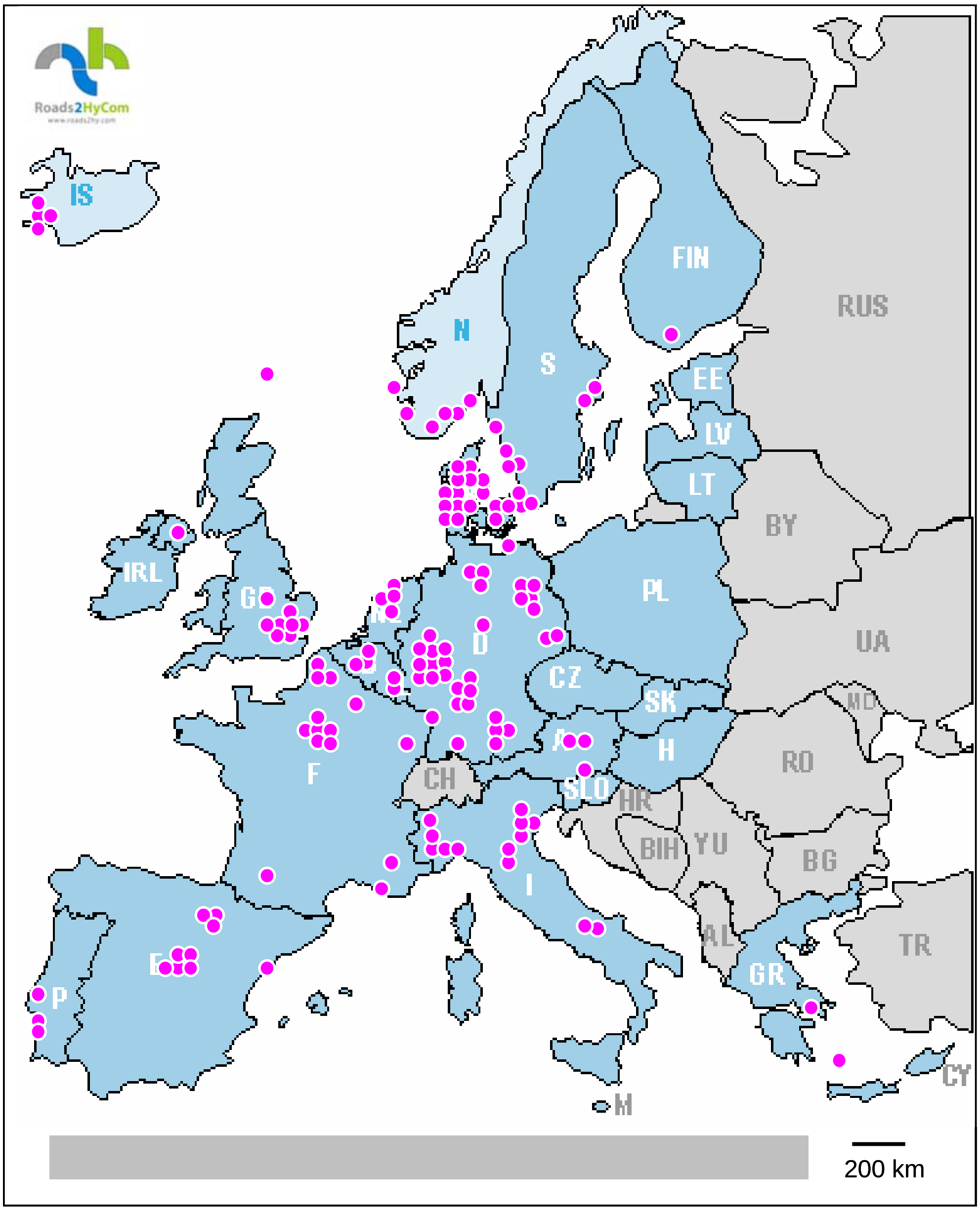

Figure 2: Geographic distribution of identified hydrogen demonstration projects. Centres of aggregated activity are the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden Clusters.

In figure 3 the different types of projects are analysed. The categories available are "Transport", referring to all projects with transport, i.e. moving applications, "Stationary", referring to all projects with stationary, i.e. not moving applications, Portable, referring to applications such as portable backup units, APU for leisure purposes, or mobile phone power devices, and "Multiple" which applies to projects where more than one of the aforementioned application types are demonstrated, for example a system that produces hydrogen from renewables and uses that hydrogen in a CHP system as well as providing it through a fuelling station to hydrogen vehicles. The numbers on the bars indicate the absolute number of projects in the respective category. Clearly, stationary and transport applications dominate the field, indicating that a market demand is mostly expected for these application types, hence resulting in stronger research activities. As pointed out earlier the purpose of a demonstration is also to act as a publicly visible and accessible proof of feasibility. Therefore, a stronger emphasis on stationary and transport projects as shown in figure 3 serves as a reliable indicator for the growing market maturity of applications in these areas and the trust and confidence of industry in the prospects of these technologies.

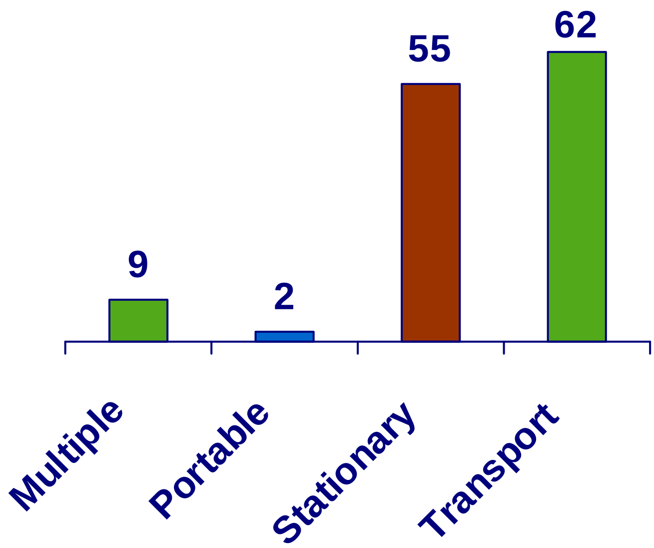

Figure 3: The bar chart shows the analysis of the identified hydrogen demonstration projects in Europe in respect to their application type. The numbers on the bars indicate the absolute number of projects in the respective category.

Another interesting aspect of the analysis was the status of the identified projects. Is Europe really active in the field of hydrogen and fuel cells or is it just resting on its laurels? Figure 4 answers this question by showing the current status of the identified hydrogen demonstration projects. Half of the projects are indeed finished. However, keeping those in the database is still of importance as they can still serve as a source of information for comparable, new initiatives. Also, some infrastructures might be reactivated for new projects in a large-scale deployment context (LHP). In this case, finished projects will form a vital part of each applying community´s track-record, proving organisational learning and experience.

The other half of the projects is either still in operation or in planning. Only 6% of the database entries were interrupted due to various problems. This is a pleasing low number, again displaying the maturity of the industry and the products being demonstrated.

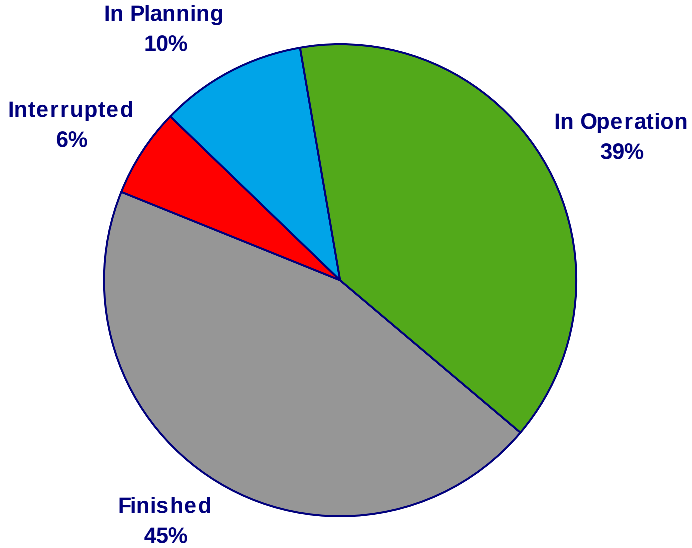

Figure 4: Project status of the analysed projects. Half of the projects have finished, while nearly 40% are still in operation. The low number of interrupted projects shows the maturity of the products being demonstrated.

Of the 130 identified projects a selection was made for further analysis (see annex 1). As outlined in the methodology the selection of the demonstration sites aimed at including significant projects with results and experiences that will be useful in the establishment of new projects. Figure 5 shows in which member states the analysed projects are based. It becomes clearly obvious that the “big players” in H2&FC research are well represented, but also minor players like Greece have their share.

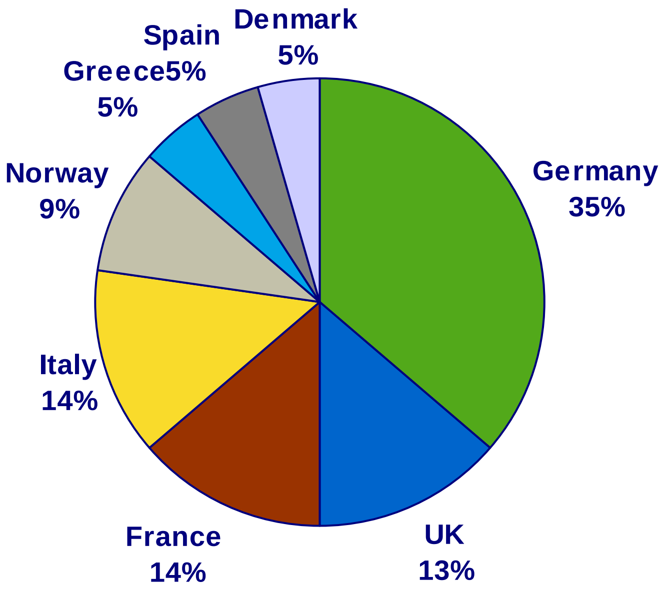

Figure 5: National distribution of the sub-set of analysed projects, showing that member states with intensive H2&FC engagement and research as well as with minor engagement are duly represented in the analysis.

The selected hydrogen demonstrations for the analysis can further be divided into two types: **stationary applications** and **transport applications**. Both types are equally represented in this evaluation as shown in figure 6. Other important aspects are the ratio of **projects in operation** to projects which either have not started yet or have already terminated. In the light of the upcoming LHPs an operational site is a valuable opportunity to build on existing infrastructure possibilities. In this context it should be defined that operational means state-of-the-art, and terminated often means outdated technology. Projects which have not started yet were generally excluded since they cannot provide any current data nor any previous experience. As can be seen in figure 6, eight out of nine projects were still ongoing, thus providing “fresh” data.

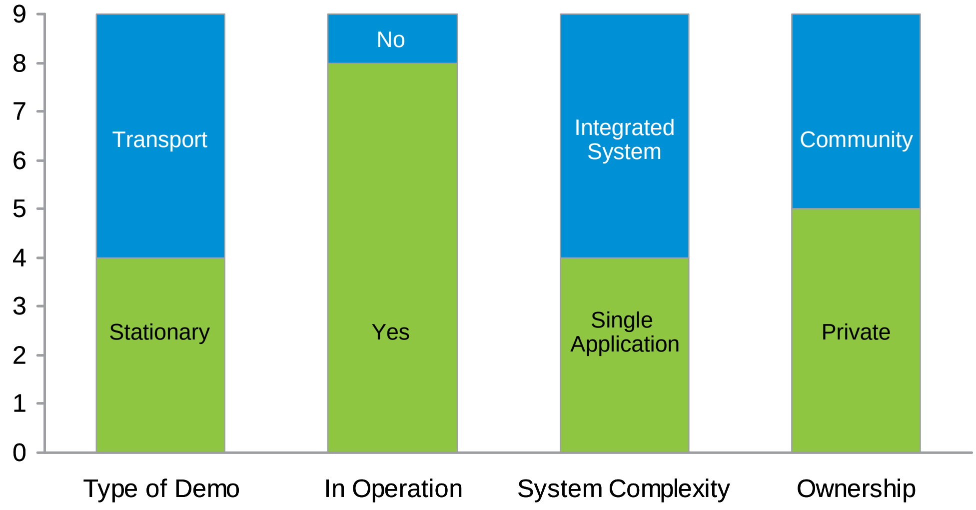

Figure 6: Key statistics of the selected 9 demonstration sites

The system complexity provides information on whether the project features an integrated system or just a single application. An integrated approach is anything where a system or supply chain of several, independent components is represented. This might be a solar-PV installation that produces electricity which is converted to hydrogen using an electrolyser, for example. A single application is a single technology which works independently of any other component. That would, for instance, include single grid coupled fuels cells, but also cars running on hydrogen where the hydrogen is supplied via a fuelling station with hydrogen trailers. Due to the goal of extracting useful information for future LHPs a preference was laid on integrated projects. In practice, though, single applications dominate the more recent projects.

Ownership can be an indicator as to how much the local community is involved in the H2&FC project. Is it just an industry showcase or a technology that has much support from the citizens? Especially with hydrogen technologies a wide public acceptance and education is still necessary when it comes to safety issues and the public perceptance of it. Visible projects supported by local politics are therefore a step towards more acceptance and support amongst taxpayers. On the other hand, some of the systems still need heavy financial support and in the face of restricted finances of public bodies the benefit of having a corporate investor should not be underestimated. It is for this reason that the selection of the demonstration projects aimed at an equilibrium between private and community ownership.

Similar to the question of how much the community is involved in the project one can apply this question as well to the industrial consortia or investors. Is it just one investor gaining the complete knowledge of the demonstration, thereby resulting in a poor dissemination of generated results?

Luckily and not surprisingly, though, most of the projects were set up by a number of different players due to the variety of technologies involved and the required financial capital. Figure 7 illustrates the different set-ups of consortia in the selected projects, with participation of industry, research, and government or similar bodies. This reflects the overall character of a demonstration project where the industry supplies its near-market products, flanked by research to evaluate data and learn for the current development, and public bodies as transmitters of new technologies to the public and providers of a public "test bench" with which industry can operate.

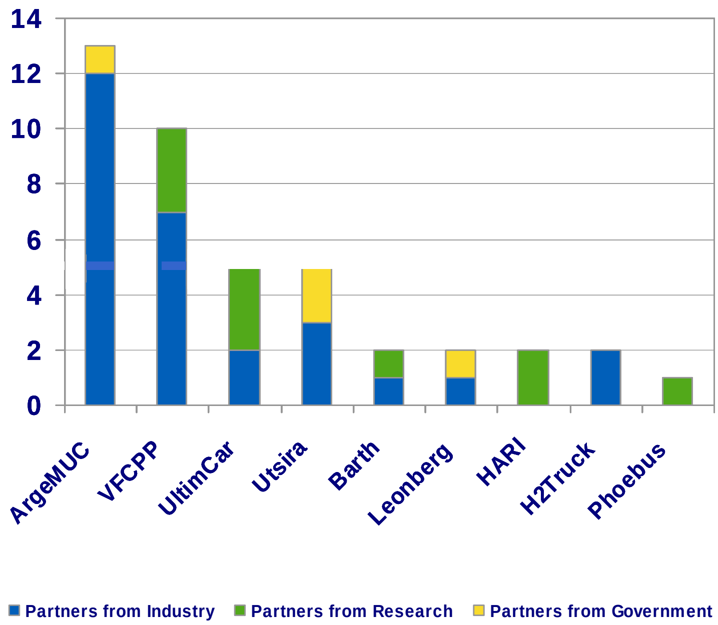

Figure 7: The different setups of consortia in the selected projects.

From these selected demonstration projects in depth technical and economic data were collected with the help of a questionnaire (see section 1.2.2 and annex 2). The collected data sets show a considerable diversity. This applies to the different submetrics, like land sealing impact or capital investment costs, where there are large differences between the analysed projects due to their specific nature; but also "soft" questions like public perception or political commitment produced a variety of answers. Another problem is that many data sets are incomplete. This was expected, because the questionnaires were to cover a wide range of projects, hence not all questions could be answered by each project. Unexpectedly, though, many site owners were not able to provide information due to the fact that they often deal with only certain aspects of the project, e.g. co-ordination, and find themselves unable to provide comprehensive figures.

Due to this diversity it proved difficult to project these data into one comparable scale. However, it was possible to reproduce the data for each project in a metrical system ("spider web" diagram) which allows for individual weighing and rating according to one's needs. Figure 8 shows an example of the analysis for the project Utsira in Norway (Wind-Hydrogen system) in the top section. On a scale of 0 to 10 the outer circle represents a "good" value (10), the hub of the web a "bad" value (0). The outer circle also shows the categories to which the values refer. The numbers represent the submetrics of the questionnaire, the brackets sum up the metric category. Gaps in the circle indicate missing answers to questions on the questionnaire.

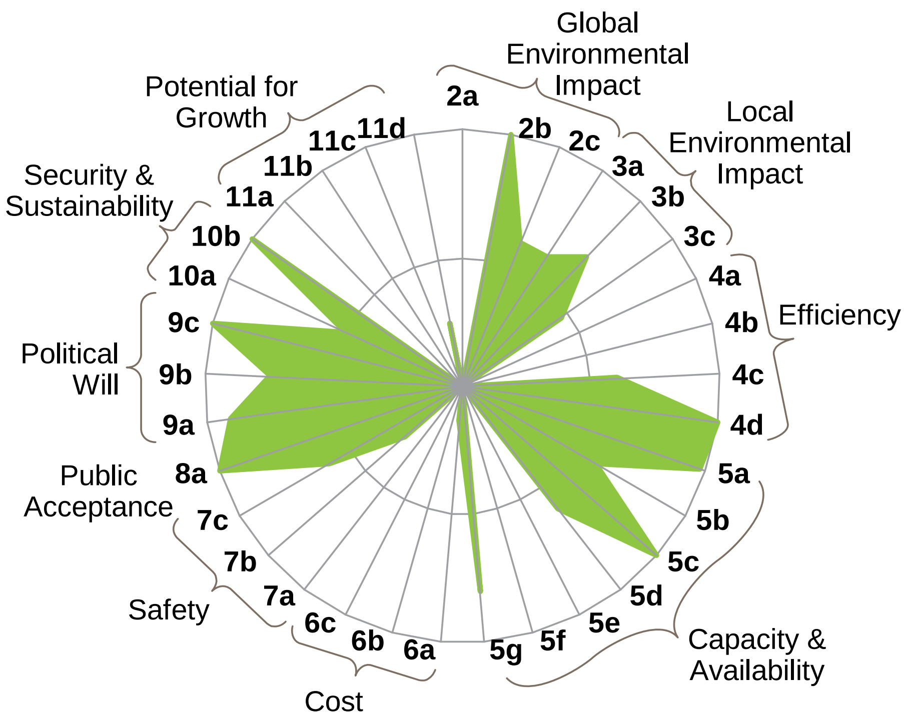

Figure 8: Sub-metric spider diagram for the demonstration project Utsira, Norway. The numbers represent the sub-metrics (see table 1 for the metrics or annex 2 for the accompanying questionnaire). Values near the outer edge are "good", while values near the hub are "bad". Gaps in the circle indicate missing answers.

This method was used for all selected projects. In figure 9 a direct comparison of the spider diagrams for all selected projects can be seen.

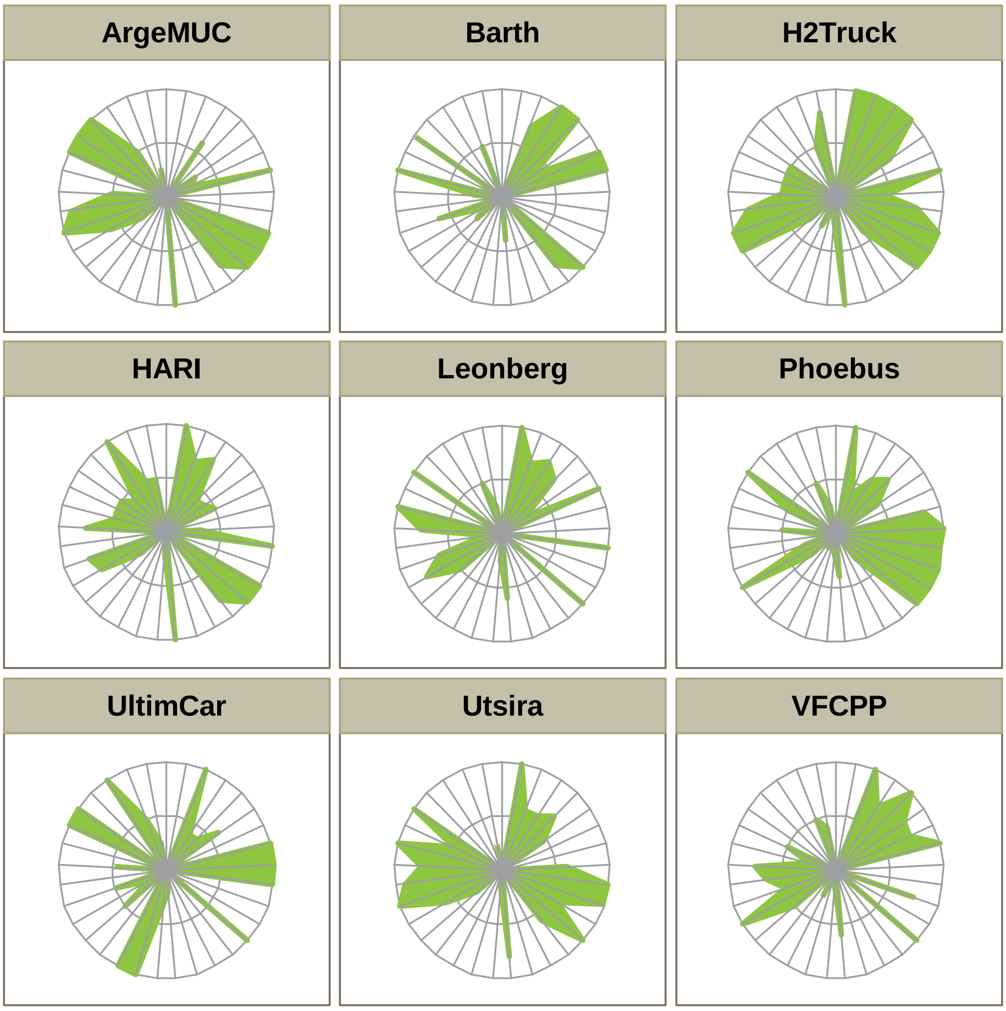

Figure 9: Sub-metric spider diagrams for the nine selected demonstration sites. This indicates trends in the analysis and also questions which could not be answered by several projects.

As with all comparative analyses of project data sets, though, it has to be considered that the 'analyst' will have a 'subjective' need for analysis, reflecting the motivation for performing the evaluation. In other words, various metrics could mean 'nothing' or 'all' depending on the status, background and motivation of the person performing the task (e.g. politician, administrative person, industry partner, end user etc.). Metrics 3b and c would for instance be meaningless for installations at industrial sites, whereas 8a and 9 could be of vital importance for projects driven by local authorities or industry. Therefore an analysis tool would have to reflect the low and high importance of metrics, respectively. 'Weighing' factors to reflect the analysis background will need to be introduced at a later stage.

4. Conclusions

The geographic mapping of all identified projects reveals early clustering of demonstration projects with centres of aggregation in the German Rhein-Ruhr/Rhein-Main area and Denmark in connection with southern Sweden. These are also the countries in which most of the demonstration projects are based or will be initiated so that it can be assumed that these are first signs and the success of local or regional dissemination efforts, but also regional expertise, co-operations or favourable rules and regulations.

When looking at the technologies that are being used, stationary and transport applications dominate the projects. This highlights a growing market maturity of applications in these areas. It also proves the trust and confidence of industry in the prospects of these technologies as in almost all projects of a representative sample the industry formed the majority of partners, thereby taking over a large part of the financing. This, however, must be distinguished from ownership of a project, which was equally distributed in the sample between private finance and the community, supporting public acceptance of hydrogen technologies.

Although half of all collected demonstration projects is finished these can still serve as a track-record for future hydrogen communities, showing effort, political will as well as a learning process in the community.

For further analysis data were collected from a representative sample of projects with the help of a questionnaire. The data collected, however, showed a great variety in quality and availability and caused difficulties for the comparison of projects. This lack of high quality information is a little alarming against the background of the amount of public spending that has entered into these projects. Confidentiality issues are a common problem, but also a lack of common data formats. It is strongly suggested that a project questionnaire is developed that helps collecting data from European and national demonstration projects (or any funded project) in order to establish adequate dissemination access through a database, for instance via Cordis. Alternatively, data from projects could be collected in a common data pool through a transparent reporting scheme to which solely other EU-funded projects would have access. It also posed a challenge to contact some of the projects and get any information at all. This seems unacceptable for the above mentioned reasons and does not promote interlinking of projects, which could ideally help to make put the funding to maximum use

On the other hand, these data highlight that projects cover a very wide range of applications and pathways. To still manage the diverse data sets that came out of the questionnaires a spider diagram projection was chosen. This is seen as one possible way of projecting the gathered data on a metrical scale. It also allows for a flexible interpretation at a later stage when a weighing factor is applied.

Neither now, nor even with a weighing factor, however, it is not possible to directly compare the sub-metric numerical scores from one project with the scores from another project, but the spider diagram serves as a reliable indicator for comparing the overall quality of a demonstration project with another. From comparing the spider diagrams from all nine demonstration projects (see figure 9) the following general trends can be deduced:

- half of the projects identified lack of codes and standards as an obstacle
- most projects received sufficient local political support
- national political commitment was mostly restricted to financial subsidies
- almost all projects had little or no GHG emissions from running the site
- the majority of projects did not supply financial data

Apart from these results, the main activity of this mapping exercise was to collate data on hydrogen demonstration sites according to the metrics defined in the project methodology. Some analysis has been done on the data collected, the results of which are presented here, but further analysis, evaluation and benchmarking of these demonstration sites will be undertaken later in the Roads2HyCom project in Work Package 4.

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Annex A: Selected demonstration sites

Country	Project Acronym	Project Name	Project Partners	covered by:	Data source:
Norway	**Utsira**	Wind-Hydrogen System Utsira	Hydro	Roads2HyCOM	information from project desk research
Iceland	**ECTOS**	H2-busses	INE	HyLights	information from project desk research
UK	**PURE**	Promoting Unst Renewable Energy	Unst Community	Roads2HyCOM	information from project desk research
	HARI	The Hydrogen and Renewables Integration (HARI) Project	West Beacon Farm (Uni of Loughborough)	Roads2HyCOM	information from project desk research
Germany	**VIRTUAL FC POWER PLANT**	Field installation of residential micro-CHPs	Vaillant	Roads2HyCOM	information from project desk research
	Barth	The H2-O2-Project in the sewage treatment plant at Barth	FH Stralsund	Roads2HyCOM	information from project desk research
	Biogas MCFC	Demonstration of a biogas operated MCFC in Leonberg		Roads2HyCOM	information from project desk research
	Phoebus	PHOEBUS Juelich	FZJ	Roads2HyCOM	information from project desk research
	ArgeMUC	Airport Munich	ET	Roads2HyCOM	information from project desk research
	CUTE	Busses	DC	Roads2HyCOM	information from project desk research

Country	Project Acronym	Project Name	Project Partners	covered by:	Data source:
France	**UltimCar**		H2Developpment	Roads2HyCOM	information from project desk research
	ALT-HY-TUDE - Dunkerque	Public Transportation using Hythane		Roads2HyCOM	information from project desk research
	ALT-HY-TUDE - Toulouse	Public Transportation using Hythane		Roads2HyCOM	information from project desk research
	HyChain-Minitrans	Minitransportation	Air Liquide	Roads2HyCOM	information from project desk research
Italy	**Arezzo Project**			Roads2HyCOM	desk research
	HighValley Project			Roads2HyCOM	desk research
	Hydrogen Park Project		Marghera Venice	Roads2HyCOM	desk research
Spain	**ITHER**	Technical Hydrogen Infrastructure and Renewables	Aragon Region	Roads2HyCOM	desk research
Denmark	**H2Truck Ringkjøbing**		h2 Logic	Roads2HyCOM	information from project desk research

Annex B: Final questionnaire for demonstration sites with enhanced user friendliness

Questionnaire 'Infrastructure' DRAFT

HYDROGEN DEMONSTRATION SITES (PLANET/T2.1-1)

Metric	No.	Sub Metric	Units	Keywords	Explanation	Example	Your entry
1 Technology Accessibility							
2 Global Environmental Impact	2a	source-to-user greenhouse gas emissions in setting up the site	g CO_2 equiv	CO_2 production from setting up of installation	How much GHG have been emitted while the site was set up? This could include road transport or steel production for the installation, concrete, other building materials etc. LCA values according to ISO 14000 and following, GEMIS or equivalent.	"According to the supplier the manufacturing of our wind turbine used up 500 kWh which equals 1.5 tons CO_2 equiv"	
	2b	greenhouse gas emissions from running the site	g CO_2 equiv/day	CO_2 production from operating installation	How much GHG are emitted while operating the site?	"Our current production emitts about 300 kg of CO_2 equiv per day"	
	2c	Efforts of mitigation and minimisation of environmental impact	list	difficult materials in use, special treatment after dismantling	What measurements do you take to minimise or mitigate the environmental impact when running the site or diposing of after the life-time? Are there any materials or substances used which need special treatment?	"We need the solvent XY for our production process" or "In the insulation of the reformer housing there is still asbestos which needed to be disposed of carefully when dismantling the site"	
3 Local Environmental Impact	3a	air quality impact	m3 / yr. m3 / hr. etc.	emissions of gases or leakages (NOx, HC, CO, Pm)	What is the emission of gases from the site - during normal operation and leakages? Please include controlled vented gases.	"There is only steam coming from the fuel cell" or "We vent about 1 m3 of excess H_2 per hour into the air"	
	3b	noise impact	dB	noise impact in 100 m distance	What is the rough noise impact in 100m distance from the site? As a guide, a diesel generator 10m distance emits 60 dB, a car in 10m 70 dB, a busy road in 10m 85 dB, a sledge hammer in 1m 100 dB.	"We keep two electrolysers in a single container housing: <30 dB in 100m distance"	
	3c	land sealing impact	m2	area of land sealed	areas covered by buildings, concrete base plates, paving, tarmac, etc.	"Our property is 5000m2 of which 250 m2 are covered by buildings and roads"	
4 Efficiency	4a	transport energy to/from/on site	kWh*km	from source to site	At some sites, hydrogen needs to be trucked in or some other resource has to be moved around on site. How much energy is involved to have this necessary supply? NB: You may also fill in the distance only when indicating the type of transport	"The hydrogen for our fuelling station is trucked in from a production site 50km away. This requires 200 kWh (=20l diesel) per 100 km of transport"	
	4b	transport and storage losses to/from/on site	kWh/km	losses of energy and gases	Are there any thermal losses during transport or leakages? Also, for instance, hydrogen can boil off during transport or on site during storage. If kWh cannot be specified, please give a percentage of loss (and the original capacity).	"During storage of hydrogen on our site we loose 5% of the 10k litre tank in one month before we use it in the fuel cell"	
	4c	energy investment in running site	kWh/year	energy expense for operation	How much energy needs to be invested to run the site, e.g. need pipelines be heated or buildings?	"We use 12k kWh each year to heat the buildings and run the compressors"	
	4d	fossil energy investment	%	fossil energy expense for operation	out of 4c, how much of the energy usage comes from fossil sources? (treat grid electricity as 100% fossil)	"All energy used is natural gas or grid electricity: 100%" or "We have an on-site wind turbine that produces 56% of the energy for operating the site: i.e. 44% fossil"	

Questionnaire 'Infrastructure' DRAFT							
HYDROGEN DEMONSTRATION SITES (PLANET/T2.1-1)							
Metric	**No.**	**Sub Metric**	**Units**	**Keywords**	**Explanation**	**Example**	**Your entry**
5 Capacity & Availability	5a	unscheduled down times	hours/year	reliability of use	How many hours per year can the site not be operated due to unplanned, unpredictable or non-recurring events, such as damages or severe wheather conditions?	"We have 100 hours a year too strong winds to produce power with our wind turbine" or "This year our fuelling nozzle was broken twice, resulting in 60 hrs. Downtime a year"	
	5b	scheduled downtimes	hours/year	reliability of use	How many hours per year can the site not be operated due to planned, predictable or recurring events, such as regular maintenance cycles?	"We have three maintenance cycles every month, resulting in 75 hrs planned downtime a year"	
	5c	unattended operation	yes/no		Is unattended operation possible? If not, how much investment would be needed to alter the site to be capable of unattended operation?	"Our remote plant is operated unmanned"	
	5d	purity of H2 used	3.0-6.0	industrial purity grades	Which purity grade (according to industrial standards) do you use/supply?	"We supply 3.5 quality of hydrogen"	
	5e	physical state	type	CGH / LH2	What physical state has the hydrogen you produce?	"We produce LH2"	
	5f	logistical capacity	number	volume flow of pipes/no. of lorries etc.	Depending on your branch, please state in a unit common to your field your logistical capacity. For instance, a refuelling station could give the numbers of vehicles they are capable of refuelling per day; a wind park could estimate the number of normal households it can supply per year.	"With our wind turbine we currently supply 60 homes all year long and could supply 15 more at xxx kWh/home.yr"	
	5g	lifetime of the demonstration	years	estimate of lifetime	What is the predicted lifetime of the demonstration installation in years?	"We foresee a lifetime of 2 years for our electrolyser"	
6 Costs	6a	capital investment costs	€	costs until operaton	How much money needed to be invested to have the site in an operating state?	"It cost us 2m Euros to set up the site and produce our first kWh"	
	6b	operational costs	€/year	costs to run the site	How much does it cost to run the site in an operating state every year?	"Every year we spent 500k Euros to operate the site"	
	6c	decommissioning costs	€	costs to decommission the site	How much would it cost to properly decommission the site?	"Once we stop operations it will cost us probably 1.5m Euros to remove all the installations and plant trees on the site"	
7 Safety	7a	incident likelihood	number	likelihood of a safety-critical failure (fatalities or disruption)	Probability of a severe incident causing harm or death to humans (users, personell, uninvolved residents). Use FEM analysis figures if available. Else, use a simple rough estimate.	"The risk of a fracture of the storage vessel is 10^10 per year"	
	7b	incident severity	list	severity of failure or leaks	What are the consequences of major incident(s)?	"A leakage of the electrolyser would lead to burns from the lye"	
	7c	vulnerability	list	forced disruption or failure	Risk of disrupture of service caused by external influences. Indicate for example by degree of service attention required, e.g. time span of unmanned operation.	"The plant runs unmanned but for a fortnightly maintenance cycle. Only a fence hinders someone to break in and disrupt service"	

Questionnaire 'Infrastructure' DRAFT							
HYDROGEN DEMONSTRATION SITES (PLANET/T2.1-1)							
Metric	**No.**	**Sub Metric**	**Units**	**Keywords**	**Explanation**	**Example**	**Your entry**
8 Public Acceptance	8a	public perception and opinion	list	technology perception	Can you provide any media coverage (news articles etc.) which shows the public perception of your site. Do you have visiter groups on your site? If yes, how many people per year?	"We show around 40 students per month"	
9 Political Will	9a	direct financial subsidies	€	initially or regularly	Did you get a lump sum as direct financial subsidy or do you receive regular subsidy payments from any authority?	"We got 150k Euro subsidies from the EU Regional Development Fund and a free site from the local authority worth 20k Euro"	
	9b	political commitments	list	commitment to the project	Did political bodies (local authorities, ministers, stakeholders, associations etc.) offer committments? (preferably in the form of written documents)	"The regional parliament committed itself to supporting the project in any possible way"	
	9c	obstructions and barriers	list	list of obstructions / hurdles / barriers	Were there any obstructions like missing or unfullfillable codes and standards prior to setting up the site? List any and give brief information on how you coped with them.	"We had problems getting our fuelling station certified with the local authority..."	
10 Security & Sustainability	10a	depletion of critical resources	data	use of critical resources for operation	Do you use any critical resources for your operation?	"The fuel cells we use have a Platinum loading of xx mg/cm2 of MEA, totalling to xx g of Pt"	
	10b	dependency on imports to the EU	list	dependency on imports of critical components	Will the EU be dependant on important parts, maintenance staff, knowledge or patents to operate this site or use the demonstrated technology?	"We use a certain power generator type where spare parts can only be obtained from Japan due to patents"	
11 Potential for Growth	11a	potential for general access	years	time for public access to the site	When will the site or the demonstrated technology/output be accessible to the general public. If you produce H2 at a bus depot, for instance, and your H2 is solely for the buses, in how many years could there possibly be a public fuelling station for everybody´s private car. If you don´t think this will ever happen, please choose the value "100 years", if it is immediately accessible, chose "0 years".	"All the hydrogen we produce at the moment is solely for the buses of the depot, but as we have some surplus and the potential to enlarge the electrolyser, we will probably open a small refuelling station for the public in 4 years"	
	11b	potential for expansion	%	enlargement of current installation	About how much percent could your site and its production or logistical potential be enlarged within the next 2/5/10 years?	"We produce about 3000 Nm3 hydrogen per year and could, with a new electrolyser, ramp up or production about 10% in 5 years and 30% in 10 years"	
	11c	potential for EU job creation	list	potential to promote EU economy	potential for job creation within the EU, i.e. on-site labour, EU produced equipment etc.	"The installation and operation of our site required xx man month of labour on-site. Equipment was bought from EU / non-EU sources."	
	11d	time to commercialisation	years	end-user availability	How many years will it roughly take until the technology you use on your site is available to the market at competitive costs ?	"In probably 10 years time this technology will be a market product for early markets"	