2011, 31st March

Social studies in context with hydrogen deployment: Analysis, quality, gaps and recommendations

Prepar-H2 No: 245332

Deliverables 1 & 3

PM: Icelandic New Energy

2011, 31st March

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FCH-JU-2008-1
Coordination and Support Action (FCH)

Preparing Socio and Economic Evaluations of Future H2 Lighthouse Prepar-H2s

Acronym: Prepar-H2

Grant Agreement ref. No: 245332

Editor: María Maack[2]

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Date of this document:

March.2011

0 Executive Summary

Europe needs to change its transportation systems to clean technology solutions in order to reach the goals formulated by the European Commission to protect the environment. A possible contribution to this can be hydrogen mobility. Social studies play an important role in order to facilitate the market integration of this clean technology and support understanding between manufacturers and the public.

In this deliverable, social studies accompanying hydrogen demonstrations up to 2011 have been compiled and classified according to background factors. These are then examined in respect to possible bias, methods, geographic boundaries and topics. The analysis is concluded with suggestions from stakeholders in former demonstration projects on future research and supportive ideas concerning quality management procedures as to maintain the value of the studies.

In the first sections a short overview of methods is given and six possible issues that affect data or assessment quality in social studies are presented that can prove to be helpful when dealing with these. Then a few quantitative insights are presented with suggestions for amendments.

The PreparH2 partners have found gaps in addressed socio-economic issues, populations or target groups for interviews as well as methodological approach.

Stakeholders are in general happy for the themes that social studies have brought forth but point to a few main themes for further research: Consumer expectations, the role of media and PR in the integration of clean technology in society, effectiveness of policy measures, and comparison of transport and fuel options in the different European countries.

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1 Introduction

The project PreparH2 was established under the Joint Technology Initiative for Fuel Cells and Hydrogen and is financially supported by the European Commission's 7th Framework Research Programme. In times of vivid public discourse about climate change, efforts to reduce emissions, and rising oil prices, the transportation sector has to look for new, clean, and affordable fuels. The European Union has committed itself to take a leading role in this process. Hydrogen plays a key role in the European strategy to achieve the goals. However, for the diffusion of a new transportation technology like hydrogen mobility, the new transportation technology needs to be thoroughly tested and widely accepted by society.

The goal of the Prepar-H2 project is to report stakeholders' experiences and insights from national and international hydrogen demonstrations in order to collect a comprehensive background for further hydrogen deployment and assist future lighthouse hydrogen projects to avoid repeating eventual mistakes and conduct relevant social studies of high quality that can support industry in their market – introduction. The goal of this deliverable is twofold:

Goal 1) Give an overview and analysis of the social research that has been undertaken so far, shed light on important aspects of these studies and suggest procedures for quality management in the context

Goal 2) Deliver first insights from stakeholders along the hydrogen fuel chain concerning social research topics that may be interesting or helpful to pursue.

In order to get hydrogen mobility closer to a mass-implementation research in social acceptance is undoubtedly necessary. There have been a couple of studies in the past assessing social acceptance of hydrogen mobility solutions (see Figure 2). An overview of existing studies in this field is given here to enable a holistic view and eventually pinpoint possible gaps where further research is needed.

The Department of Energy Systems at the Technische Universität Berlin, together with other project participant of PreparH2, have collected reports and articles on social studies regarding hydrogen mobility. The results were set up in an organized matrix. Subject of research, applied methods and main findings, as well as conclusions are condensed in the matrix. The goal of this deliverable is to serve as a reference for further studies in future hydrogen

lighthouse demonstration projects. Also, procedures for the quality management of the data and associated evaluations will be given in order to maintain good quality of eventual social research in this context.

The matrix was first compiled for the project Hy-Approval (2006) and updated in 2008 within HyFLEET:CUTE. Here, recent studies are added and then the compiled list is analyzed as to give it added value. This matrix gives a good overview of already existing social studies for hydrogen projects.

A summary of methods used in these social studies are presented as to give an overview. Then issues in the studies and findings are listed and lastly suggestions for quality management procedures are given using the social study matrix as basis for the work.

2 Methods used in Social Studies

It is outside the scope of this report to go into depth in describing methodology in social research. Instead the methods that have been used so far in the studies relating to hydrogen mobility will be outlined shortly. The methods can be divided into two types, quantitative and qualitative methods.

The characteristic trait for quantitative methods is the measurability of the findings in numbers. Quantitative methods in social research try to develop and apply mathematic models or theories that describe human behaviour and interactions in numbers, graphs and functions. These methods therefore allow statistical analyses of the data and adaption of the findings for forecast and prognosis on other topics, situations or groups.

Qualitative methods in social studies are used to assess and explore specific situations and analyze them in depth (refer to Figure 1). These methods focus on human behaviour, perceptions and opinions in a group according to an individualistic stand. In order to receive good qualitative data, the subject is approached on several levels and the outcome is more flexible and prone to interpretation.

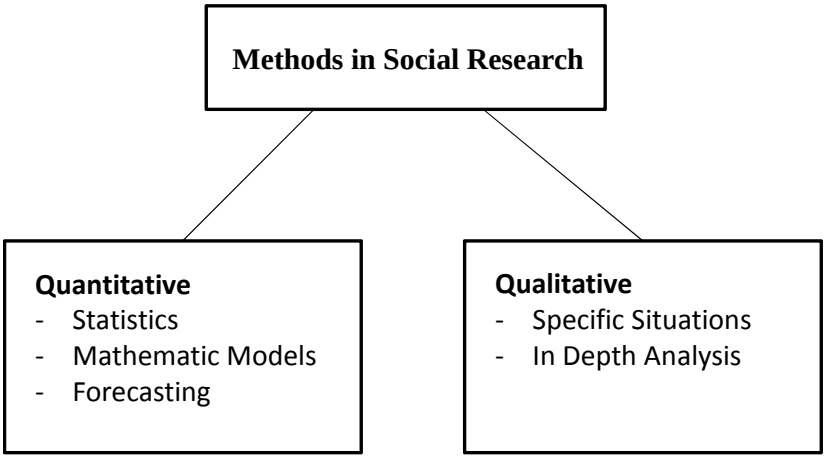

Figure 1: Methods in Social Research

The focus of this chapter will however be on the qualitative research methods as they are those main approaches used in the identified social studies concerning mobility and accepted technology studies. For a further reading, refer to Denzin and Lincoln (2005) and Trochim (2006).

2.1 Surveys, questionnaires, interviews

Surveying is an established and approved method to gather data. There are several kinds of surveys that are explained in this part of the present work. Depending on the purpose, a fitting survey medium and survey type is selected. The survey can be done over different media, e.g. face-to-face, phone-based, web-based or paper-based. The different types of surveys (structured, semi-structured and unstructured) are described in the following.

2.1.1 Structured Survey

In a structured survey every participant is asked the same questions in a fixed order. The questionnaire is designed before the first survey. The process of surveying is static; meaning that the questionnaire stays unmodified during the entire interview phase. Mostly, a fixed range of possible answers is given to the respondents (closed-ended) but open questions are also possible. Evaluation of the outcome allows a good comparability of the answers. A structured survey can also be used for further quantitative research and allows statistical analyses of the data. The main problem of structured questionnaires is inflexibility; changes and modifications cannot be made even if ideas of improvement come up. Also, questions and selected topics may or may not fit in various cultures.

2.1.2 Semi-structured interviews or survey

In a semi-structured survey, again the goals of the interview are clear but the interviewer allows the respondent to lead the interview if the imitative arrives. Thus if topics emerge that were not foreseen by the interviewer questions are added during the interview as to gather information on topics that are brought up within the process.

The formulated questions are mostly open-ended so that this method fits only for qualitative research. In a semi-structured interview, the interviewer has pre-established questions just like in structured interviews but further discussions and additional topics are allowed. The researcher has a framework of goals and topics he wants to cover with the interview. The evaluation of these interviews might be more difficult than the evaluation of structured interviews but the subject has a better chance of taking the lead and more topics may be covered. This method offers the chance to gather more and different information and data than

expected, and the assessment must be flexible and appropriate to allow for dimensions not foreseen when planning the interviews.

2.1.3 Unstructured interviews

The interviewer asks the interviewee about his opinion on a certain topic. The interviewee then talks freely about his opinion. This method is only applicable to qualitative research but offers the opportunity to gather as much information and data from the responder as possible. However, the evaluation of the outcome and data to this type of interview might be a lot more difficult than in the previously mentioned types because every single interview can be different.

2.2 Focus group discussions

In focus groups, topics are presented for a group discussion. It is custom to offer participants information generated by a neutral partner before the discussion begins. The discussion in a focus group has an interactive character, which is considered a frequent way to establish views, whereas points from other participants can influence former believes. The topics are presented before the discussion and a moderator assists in keeping the preset issues. Discussions can also be conducted without a moderator but usually observers take notes during the meetings. The goal of a focus group discussion is to bring out views and choices in a relaxed atmosphere. Focus groups are often combined with the method "participant observation" presented below. For a further reading, refer to Marshall and Rossman (2006).

2.3 Observation

2.3.1 Participatory observation

Participant observation is a qualitative research method where the researcher gets fully or partially involved in the action he wants to explore and participates in selected events over an extended time. The researcher is in interaction with the observed phenomenon. With that, the

researcher can better understand relationships between actions, opinions, culture, gender, etc. compared to the non-participant observation.

> Example: An individual washes his clothes by hand rather than using a washing machine. If the researcher is in interaction with the observant she can find out that the observant fears that his clothes can get damaged if washed in a machine. If she does not interact she can only observe his behaviour but not find the reason behind his acts.

The researcher also interacts with the selected subjects. This can be done in many ways for example in interviews, conversations, narrations, etc.

This method can reveal differences and inconsistencies in what people say and how they act. With this method, the researcher can receive more detailed and realistic findings when compared to one-time interviews or short-term surveys but the evaluation of these research findings might prove quite difficult.

2.3.2 Non-participant observation

Non-participant observation is a qualitative research method akin to the participant observation. The researcher watches the subject, and researches the behaviour and acting. The people are in general informed about the observation. In contrast to the participant observation no interaction between the researcher and observed people is allowed. Also, the researcher simply explores and observes from the background. The advantage of this method is that the researcher does not influence the behaviour of the subjects by interacting or talking with them. The difficulty in evaluation is that the researcher has to interpret the observations and findings on his own, without the feedback of people. Therefore, the personal perception, opinion and experiences of the observer can influence the outcome of the findings.

2.4 Document Analysis

Document analysis is a social research method used in qualitative and quantitative research. The researcher relies on documented data or findings. Several sources can be used, such as public records, media, private papers, visual documents or biographies.

In the qualitative research the following methods count as document analysis: Semiotics, Discourse analysis, Interpretative analysis, Conversation analysis and Grounded theory.

These methods are mentioned here to give a holistic overview but will not be discussed or explained any further if they have not been used in studies related to hydrogen mobility.

3 Factors affecting research and quality of data

After having presented methods used in social studies in the previous chapter, this section focuses on what can influence the quality of the collected data and the evaluation. Criteria to ensure and improve quality of the data will be presented as to facilitate quality management procedures, which should be of paramount concern for social studies within future hydrogen lighthouse demonstration projects.

The approach to collect data and assessment methods applied to evaluate these are of utmost importance as to establish quality and validity within the scientific field. It is therefore necessary to implement mechanisms that help to gather accurate and useful data in well defined manner.

Issues that may affect the quality of data that has been collected and is presented in the study matrix are discussed below and procedures to avoid them are suggested.

A. Bias: Can data collection methods bias the data?

The formulation, selection of words or tone of questions that are used in interviews or the framework setting during observations, can heavily influence the outcome of the data.

> Example 1: Interviewer A wants to know what person B thinks about security in hydrogen mobility solutions. A starts his interview with telling B all accidents that happened in the past and were related with hydrogen before asking B's opinion.

This short example shows that questions and other framework settings need to be free from bias in order to receive unbiased data. In order to get the best possible data, different independent researchers should check formulated questions for interviews in advance and adjust the questions before the collection of data if needed. This is simply done by conducting interviews with colleagues and using remarks that arise to reformulate questions.

B. Authenticity: Is the authenticity of the data ensured?

The undoubted authenticity (e.g. is it legitimate, and valid?) of the data is indispensable in order to make acknowledged conclusions.

> Example 2: The case of the researcher Marc Hauser, who was found guilty by Harvard University for scientific misconduct because data that was non-existent and invented, show that mechanisms to ensure the authenticity of data are necessary for qualitative social research.

We suggest the implementation of the four-eye-principle in the process of data collection to ensure authenticity. The collected data must be stored and made available for later use by other researchers. In cases where a similar survey has been conducted in several geographic areas simultaneously it is hereby recommended that the project manager sees to the collection and storage of all the raw-data, clearly market with title of project, date and name of a contact person who was involved in the research. The project manager should ensure that all documents can be approached by others.

C. Actuality: Is the assessed data from a contemporary sampling?

Social research connected to innovative fields where the research environment quickly changes with technological development such as within hydrogen mobility depends on contemporary data.

> Example 3: Discussion peoples' view of the range of hydrogen cars in the year 2010 cannot be combined with data on the same issue from 2003 while the range has perhaps been extended by 50-100%.

Important technological changes and improvements can alter perceptions significantly and turn people's opinions from negative to positive. The quality of a social study in this specific context therefore improves with the actuality of the data. The gathered data in these studies should not be significantly older than 2 years except if the state of the art is described at each point in time.

D. Time-Lag: Keep the time lag between the interview and the recording short

Interviewers and observers are met with a flow of information and new comments during the interviews or observation. In order to preserve the highest accuracy of what the interviewee actually said during an interview it is of utmost importance to record (for example with a tape recorder) and transcribe the interview directly and edit notes on observations as soon as possible. If this is impossible due to any circumstances, the data should at least be recorded

immediately after the interview or observation to ensure that it the data stays unaltered and every important piece of information gets recorded. It is also better to assess the information shortly after it has been collected.

E. Filtering: Influence of the background of the interpreter

Every individual carries a certain personal background (e.g. experience, education, culture, personal views, political adherence, religion, etc.). This background can on one hand prove helpful but on the other hand also be an unwanted filter when interpreting the data. With this, important data can possibly remain unnoticed and not perceived, or misinterpreted according to the interviewers' rather than the interviewees' views. To gather the data in the highest possible quality in this context, we recommend that experienced persons work in a team with persons that have not been heavily involved with hydrogen activities when collecting and interpreting the data. Interviewers should respect the interviewees' time and avoid misinterpretation due to lack of understanding but rather ask for further interpretation when replies are not clear.

F. Source: What is the origin of the interviewee's information?

First-hand experience and knowledge is better than only education or recounted second-hand experience.

> Example 4: As in the game "Chinese Whispers", where participants whisper one after another into the ear of the next player in the game what they believed to have heard whispered in their own ear, information can get diluted and altered when passed from people to people.

It is relevant to identify the source of information the respondent used established insights and views. If the person has not personal experience, then views depend highly on the interpretation of the facts that lie behind the views. This can significantly affect the quality of statements made.

4 Social Hydrogen research prior to 2011

As mentioned earlier a table that brings together and classifies social research in connection with hydrogen deployment will be used to analyse main feature of this research. 27 studies were found with a combined effort within the Prepar-H2 consortium. Some of these were provided as the partners´ own work while others have been published as journal articles. The social study matrix was first compiled for the project Hy-Approval (2006) and updated in 2008. But in this round, recent studies are added and then the compiled list is analyzed as to give it added value.

While only very few studies on social acceptance of hydrogen mobility solutions before 2000, a significant number of studies have accumulated during the first decade of this millennium, see Figure 2

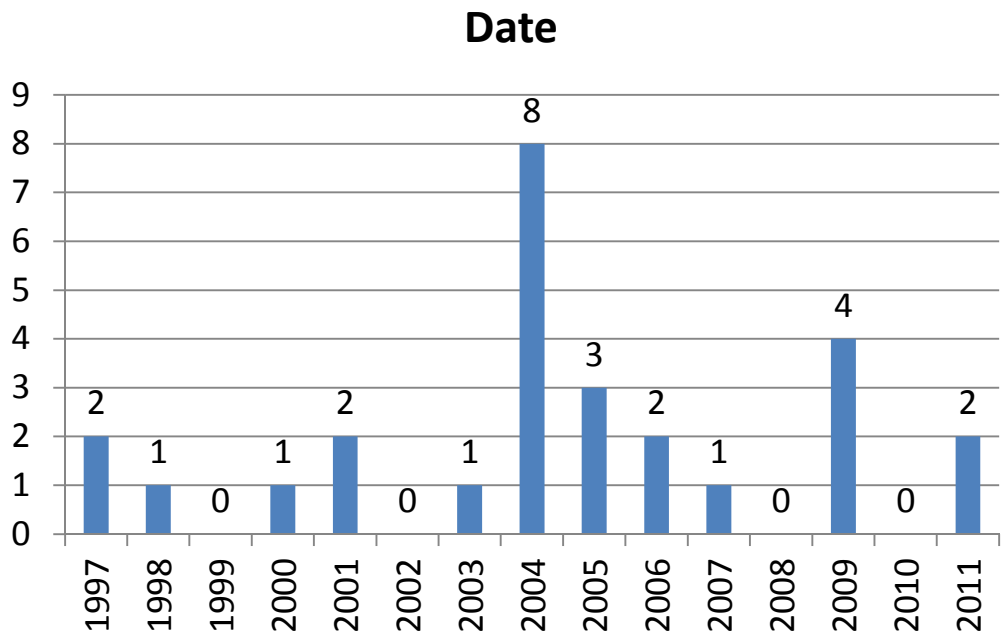

Figure 2: Number of social studies in relation to Hydrogen by year

The overview is given here as a beginning of a search for areas that may have been left out but could influence the social aspects of integrating hydrogen transportation Main findings,

conclusions and other basic data from the past studies are condensed in the matrix and discussed in the following table of the deliverable to give this overview.

4.1 Guide to the social study matrices

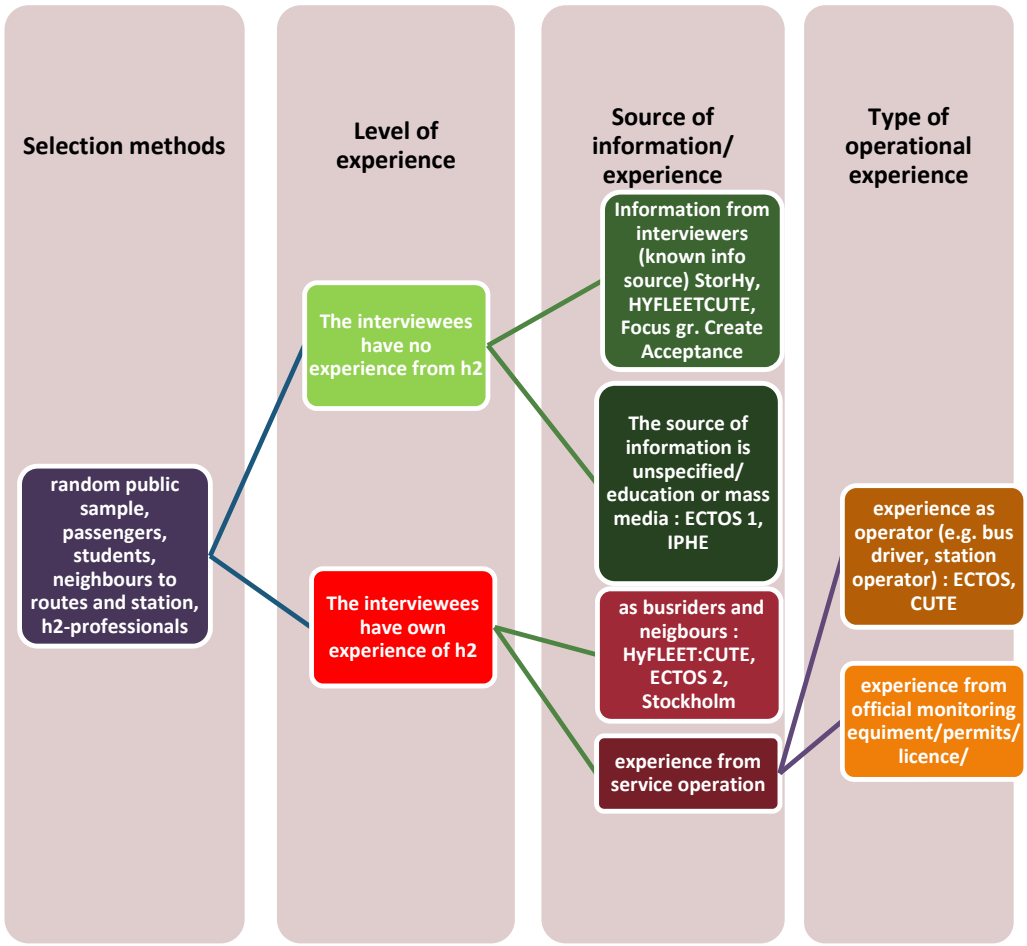

Figure 3: Colour coding of the matrices

The matrices showing all social research have been organized according to the following criteria and coloured in the matrices as indicated in figure 3. :

1) level of experience with hydrogen technology,
    a. own experience
        i. Experience as an operator within the system
            a. Experience from monitoring or permit issuing

b. Experience from hands on operation of station or vehicles

ii. Experience a passive user such as a passenger

b. b) no personal experience

i. The information received before interview is known

ii. The information available to the subjects of the research is unknown

The first table shows studies where interviewees have no experience with H2 and where they have got information from the interviewers. The second table shows studies where interviewees have no experience with H2 and where their source of information is unspecified (e.g. from education or mass media). The third table shows studies where interviewees have own experience with H2 and where their source of experience is for example from being a passenger on a hydrogen bus or a neighbour to a filling station (passive).The forth table shows studies where interviewees have own experience with H2 and where their source of experience is from service operation (active) as an operator, for example a hydrogen bus driver. The fifth table shows studies where interviewees have own experience with H2 and where their source of experience is from service operation but from the monitoring perspective (as officials).

The tables 1 – 5 are to be found in the following 11 pages and the references to the studies are given in the deliverable reference list. These tables are available also as excel sheets.

It is recommended that these tables and the documents behind the studies (see reference list) are consulted before social studies in context with hydrogen demonstrations are suggested. After each study has been finalized it would be an advantage for the JTI to have the description added to the tables according to the classification outlined above (see code in Figure 3). In this way a short overview of social –hydrogen studies can be accessed by all relevant partners.

Table 1: Social studies matrix A: Interviewees have no Experience with H2 (Information from Interviewer)

Author, Date and Geography	Size and description of sample	Goals	Integrated criteria		Vehicle criteria		HRS criteria		
			Environment		Safety	Performance	Practicality		Conclusions/ Comments
Truett, T., Schmoyer, R. et al - 2006 - DOE (USA)	General public, 1 000 people	Knowledge test & opinion	Second / third most important		Most important		Fourth most important		Strong linkage between technical knowledge and positive acceptance. Survey focused on the general knowledge and need for education
Altmann, M., Graesel, C. - 1998 - LBST - (Munich, Oldenburg)	410 secondary school students	Knowledge test & opinion			Risk of explosion (14 %) is an obstacle to broad introduction of hydrogen technologies.				Lacking acceptance by the public (10 %) and too little information among the public (8 %) are obstacle to the broad introduction of hydrogen technologies
Dinse, G. - 2000 - Institut für Mobilitäts-forschung, Berlin - (mainly Munich)	150 persons randomly selected in the street (open questions)	Explorative survey to generate hypotheses on the acceptance of hydrogen technologies	Interest in Fuel efficiency and Environmental performance			1st interest in Technology 4th interest in Performance : driving autonomy and engine power	Last interest in Infrastructure issue		The knowledge on hydrogen technologies is low but German acceptance level is rather high.

Table 1 continued

Lossen, U., Armbruster, M, et al. - 2003 - Bayerische Eliteakademie - (GER / Web)	37 high level executives 417 internet questionnaires (non representative)	Knowledge test & opinion	High environment. consciousness has a positive influence on acceptance of H2 technologies	Safety concerns : low / medium Noticeable but limited reservations concerning safety	Performance of H2 Car : medium/ high Strong confidence in technology, positive attitude	Flexibility : medium / high concerns on distance between hydrogen filling stations	Assessment of personal / societal advantages : low / medium
Truett, T., Schmoyer, R. et al - 2006 - DOE (USA)	Students 12-17y, 10.000 p.	Knowledge test & opinion	Negative comments			Safety concerns	28% response rate.
Thorolfsson, A. - 2002 - ECTOS, Institut of applied social sciences, University of Iceland (IS)	1 200 people, general public	Explorative to generate hypotheses on local acceptance of h2 technologies	positive towards testing H2, positive towards using H2 as main fuel, want to move faster				Benchmarking survey before tests, 93% of respondents made positive comments about using hydrogen as fuel
Heinz, B, Erdmann, G. - 2008 - HyFleet:CUTE, Technical University of Berlin (Berlin)	519 energy engineering students and energy specialists online interviews in Germany (TUB)	Find out awareness of h2 as an alternative fuels, Information level and assodation with h2.	Majority associate h2 with eco-friendly, water and energy			10% associate h2 with danger	High awareness of h2 as alt.fuel.

Table 2: Social study matrix B: Interviewees have no experience with H2

(Information source unspecified)

Author, Date and Geography	Size and description of sample	Goals	Integrated criteria		Vehicle criteria		HRS criteria	Conclusions/ Comments
			Environment	Safety	Performance	Practicality		
Dr. Strubel, V. - 2008 - STORHY, CEA - (France, small and big towns)	30 indept interviews with general public, 15 qualitative interviews with selected professionals (taxi drivers, company fleet managers, urban transport fleet managers) 200 quantitative interviews general public	Checking which criteria influence opinion before demonstrations start, only slides and photos of prototypes which explain what is hydrogen and what are the different H2 storage modes	Important criteria: H2 produced without pollution No polluting emissions in driving No problem from recycling of waste materials Silent, No bad smell	Important criteria: No tank leakage Car reliability, No breakdown No burns by cold	Good driving sensations : responsiveness, acceleration, smoothness Power, speed - Psychological well-being: physical comfort - Capacity and available booth space	Keep usual habits same method of tank filling Fast filling easy to understand , safe filling Safety of transport to supply filling stations	As this study focused on hydrogen storage modes, there is no detailed information on acceptance of H2 refuelling station by the public (neighbourhood) or by authorities. (the natural Hy is collaboration between car manufacturers in EU)
Mourato, S., Saynor, B. et al. - 2003 - Imperial College (London)	London black cab drivers 12 p. focus-groups + 99 pers interviewed Presented features : 140 mile range, same price per mile for hydrogen as for diesel and 2 H2 refuelling stations.	Group asked if interested in participating in a pilot FC taxi project (6 taxi drivers for 18 mo) A future scenario; increased range to 200 miles, H2 cost half as much as diesel and 10 H2 refuelling stations	Silent taxis considered to be a big advantage over current diesel models	- No concern over the safety of the FC taxis, even fuelled by compressed hydrogen	140 miles range disavantage but acceptable for most drivers Loss of booth space for H2 tank accepted, regarding the environmental advantages (silent, zero emissions)	Availability of Refueling stations	The lack of safety concern expressed about H2 fuelled vehiclesis probably due to taxi drivers'confidence in Public Carriage Office regulatory body
O'Garra, T. - 2005 - Imperial College London (Berlin, London, Luxembourg, Perth)	bus users 345 in Berlin 414 in London mainly 300 in Luxembourg 300 in Perth	Knowledge test & opinion about hydrogen and hydrogen buses deployment	Fumes and noise from existing buses are quoted (ex-ante)			60% would support local hydrogen storage while opposition (2 %) noted risk and fear of explosions. Others need more information or are indifferent.	Initial awareness higher in Berlin than London (previous demonstrations) Perceptions of H2 neutral and knowledge of H2 technologies limited.

Table 2 continued

O'Garra, T. - 2005 - Imperial College London (Berlin, London, Luxembourg, Perth)	bus users 345 in Berlin 414 in London mainly 300 in Luxembourg 300 in Perth	Knowledge test & opinion about hydrogen and hydrogen buses deployment	Fumes and noise from existing buses are quoted (ex-ante)			60% would support local hydrogen storage while opposition (2 %) noted risk and fear of explosions. Others need more information or are indifferent.	Initial awareness higher in Berlin than London (previous demonstrations) Perceptions of H2 neutral and knowledge of H2 technologies limited.
Maack, M., Kristindottir, G. et al. - 2008 - HyFLEET:CUTE, University of Iceland (IS)	27 young scholars and politiciansfrom various disciplines	Find out awareness of alternative fuels and energy preferences in Iceland	Environmental damages should be accounted for in price			Participants did not connect new fuel with available local natural resources, lack background information	Participants revealed no fear for lack of oil, alternative fuels not urgent, cost is more prominent than environm.
Saviko Consultants - 2007-2009 - Zero Regio (Frankfurt am Main and Mantova)	700 Italian high school students, questioned 1-2 months after a hydrogen lessons in school, combined with brief demonstrations of H2 vehicles.	Reactions to vehicle demonstrations and opinion on safety, costs and environmental advantages.	Image of hydrogen as a clean technology. Quite neutrality about H2 from fossil sources or nuclear.	High pressure storage is seen as dangerous by 77% of students. Hydrogen cars are considered dangerous as well as ordinary cars.	Majority of students noticed H2 car was less noisy than ordinary car, lack of noise is considered not fundamental issue.	--	

Table 3: Social study matrix C: Interviewees have own experience with H2

(as passive experience – e.g. bus-passengers, neighbours, etc.)

Author, Date and Geography	Size and description of sample	Goals	Integrated criteria		Vehicle criteria	HRS criteria		Conclusions/ Comments
			Environment	Safety	Performance	Practicality		
Altmann, M., Graesel, C. - 1998 - LBST - (Munich)	- 145 bus passengers of the worldwide first hydrogen bus in Munich	Knowledge test & opinion (maximum value : 5)	"Hydrogen does not produce harmful emissions" (4.08)	"Hydrogen is dangerous as explosions are possible"				A high level of acceptance was found among the passengers of the bus (4.28)
Haraldson, K., Folkesson, M. et. Al. - 2004 - KTH/CUTE (Stockholm)	518 answers	From media and bus company	less noise	Feel safe and comfortable, rated 2nd as important factors	Punctuality highest rate of criteria			
Heinz, B., Erdmann, G. - 2008 - HyFLEET:CUTE, Technical University of Berlin (Amsterdam, Barcelona, Berlin, Hamburg, London, Luxembourg, Madrid, Reykjavik)	2833 p in 8 cities (>2700) FC bus riders in Europe were led through same translated questionnaire	To estimate/ acceptance, fear of H2 accidents, awareness of technological maturity. Compare acceptance and vulnerability of acceptance	Associations with hydrogen neutral	Free assiciations with hydrogen are generally neutral or positive		Minoritiy (8%) associate h2 with danger, bombs and explosive		Acceptance of h2 as fuel is high, but level of knowledge is low. High awareness of H2 as alt.fuel, most are "not very well" informed. Awareness of bus-test in the city high (61%) and most like it (60%) and would support a substitution. High dynamic of acceptance (31%). 50% see lack of oil coming.
Chandler, K., Eudy, B. et. al. - 2009 - EERE-NREL, CTTRANSIT (Connecticut)	Bus passengers, 79 people	Evaluate passenger's awareness on fuel cell bus performances respect to diesel buses	Although the survey showed a lack of knoledge about the most important environmental features of FC bus, the respondents prefer this bus to conventional ones	Not addressed	In general considered better respect to conventional buses (noise, acceleration, braking, vibration and comfort)			Need to improve passenger awareness on hydrogen buses, although the passenger showed positive attitude towards the new technology

Table 3 continued

Maack, M., Nielsen, K. et al. - 2004 - ECTOS (Reykjavik)	100 passengers, qualitative on board diesel and hydrogen buses	Check on acceptance of bus riders	Connect H2 to water and clean environt, positive for low noise, clean emission, acceleration, trust technology, small majority willing to pay higher prices	Feel safe and comfortable inside the bus	Passengers like riding the bus, its power, speed and punctuality	High level of acceptance, positive in all aspects, want to see faster development. Ask for cost and when proliferation is expected. Need for more info drops from 90% to 45% between 2001 and 2004
	50 neighbours to bus routes and station qualitative/	Check on acceptance of neighbours	less noise from bus traffic appreciated	Find diesel also safe, no remarks on station	Not mind the noise in diesel buses	
	50 pedestrians, qualitative	Check on public acceptance, collect questions	Find city pollution problematic but mostly want to reduce noise			

Table 4: Social study matrix D: Interviewees have own experience with H2 (as Operators)

Author, Date and Geography	Size and description of sample	Goals	Integrated criteria	Vehicle criteria		HRS criteria	Conclusions/ Comments
			Environment	Safety	Performance	Practicality	
Dinse, G. - 2000 - Institut für Mobilitäts-forschung, Berlin - (Munich)	593 employees of the BMW (developing H2 cars) asked through a written questionnaire	opinion test in a H2 vehicle production plant		public opportunity to test h2 vehicles would be effecive to decrease the perception of risk.		Sufficient refuelling infrastructure is a precondition for positive attitude	The acceptance of the hydrogen technologies is high among the employees of the BMW group who has been developing H2 vehicles from 80s
Maack, M., Nielsen, K. et al. - 2004 - ECTOS (Reykjavik) bus drivers 2004 Is (Reykjavik)	20 H2 bus drivers 2 years of driving experience Only 15 drivers responded to the survey	Opinion on their experience of driving FC vehicles	Very positive comments on cleanliness of hydrogen	Very reliable, fast filling, no detected leaks, no fears of explosions, no problems from cold start,	good stability, driving sensation, AND acceleration, compatible power, excellent comfort for drivers, happy passengers	Easy to fill, operation as usual, too short range	Drivers were happy with h2 buses, when compared to similar diesil buses. Drivers associate H2 future deployment with renewable energy and energy indipendence.
Chandler, K., Eudy, B. et. al. - 2009 - EERE-NREL, CTTRANSIT (Connecticut)	21 Bus drivers	Evaluate drivers' awareness on fuel cell bus performances respective to diesel buses	Some drivers showed a positive indication on the environmental features of FC bus.	Not addressed	Most considered better noise, vibration and acceleration respect to conventional buses while braking is considered similar	driving conditions similar to conventional buses, but some declared they would need adaptation time	The passenger showed a neutral attitude towards the new technology.
Saviko Consultants -2007-2009 - Zero Regio (Frankfurt am Main and Mantova)	Daily H2 vehicle drivers: 41 German and Italian ordinary citizens, 6 drivers working for the car makers (5 for Daimler, 1 for FIAT). Interviewed (face-to-face and written questionnaires) not less than 3 months after their first driving experience.	Opinion on technological maturity (safety, comfort, ease of handling,costs) and on environmental advantages.	Image of hydrogen as a clean technology. Significantly negative about H2 from coal or nuclear, neutral about gas.	89% of drivers have no problem with the high pressure storage. Vehicle safety is an important reason why hydrogen might succeed as a future fuel.	Short driving range.	Majority of drivers prefer H2 cars to remain quiet; minority are worried of traffic safety due to the low external noise level of the vehicles.	Hydrogen refuelling procedures score very well for safety. Easy for an experienced person and learning is quick. Refuelling must be more reliable (more associated with the hydrogen supply than with the dispensing mechanism).

Table 4 continued

Saviko Consultants -2007-2009 - Zero Regio (Frankfurt am Main and Mantova)	Daily H2 vehicle drivers: 41 German and Italian ordinary citizens, 6 drivers working for the car makers (5 for Daimler, 1 for FIAT). Interviewed (face-to-face and written questionnaires) not less than 3 months after their first driving experience.	Opinion on technological maturity (safety, comfort, ease of handling,costs) and on environmental advantages.	Image of hydrogen as a clean technology. Significantly negative about H2 from coal or nuclear, neutral about gas.	89% of drivers have no problem with the high pressure storage. Vehicle safety is an important reason why hydrogen might succeed as a future fuel.	Short driving range.	Majority of drivers prefer H2 cars to remain quiet; minority are worried of traffic safety due to the low external noise level of the vehicles.	Hydrogen refuelling procedures score very well for safety, Easy for an experienced person and learning is quick. Refuelling must be more reliable (more associated with the hydrogen supply than with the dispensing mechanism).
PreparH2 - 2010-2011 (Iceland, Germany, Norway, Italy, Denmark)	58 stakeholders from 7 EU and national hydrogen lighthouse demonstration projects	Stakeholders' opinions on strengths and weaknesses in H2 demo projects and gaps in social studies		Suprised that the vehicles are a lot better than expected	Suprised that the vehicles are a lot better than expected	The handling with the infrastructure was often more complicated than expected	There are gaps in social studies on hydrogen

Table 5: Social Matrix E: Interviewees have own experience with H2 (from Official Monitoring)

Author, Date and Geography	Size and description of sample	Goals	Integrated criteria: Environment	Vehicle criteria: Safety	Vehicle criteria: Performance	HRS criteria: Practicality	Conclusions/ Comments
Truett, T., Schmoyer, R. et al - 2005 - DOE (USA)	250 local government officials, qualitative	Knowledge test & opinion	Positive comments				Acceptance is highly correlated with education on H2 and own experience

4.2 Quantitative Analysis of the Matrix

4.2.1 Analysis of social studies related to the respondents experience

With the colour coding of the matrix, the following analysis of the studies according to experience with H2 was made. The shares are related to the number of studies.

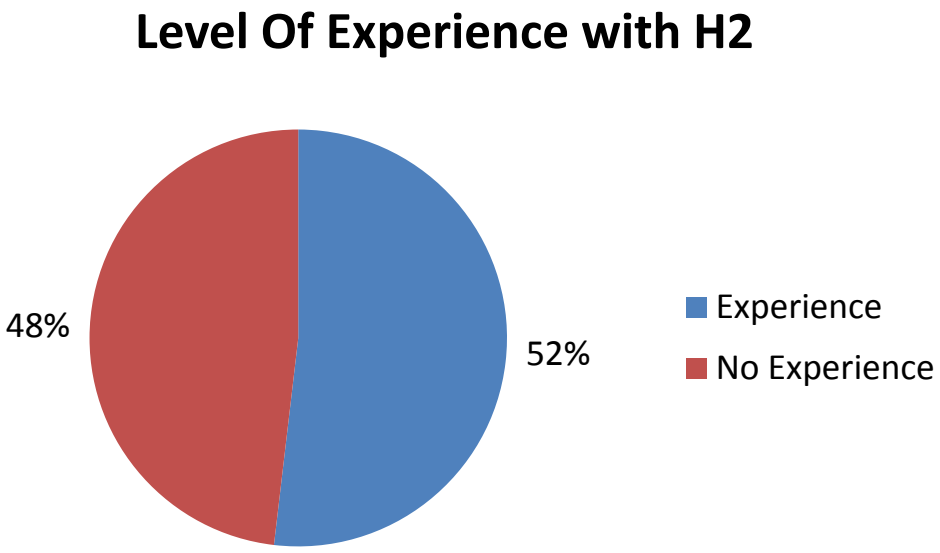

Figure 4: Analysis experience of interviewees

We can see that the number of social studies involving individuals with and without experience from hydrogen mobility is almost equal. In order to diffuse a new technology in a population, persons with experience need to share their findings with inexperienced persons. Therefore, individuals that have experience can give feedback for further technological development and need to be convinced about the technology but inexperienced individuals also need to be open for it. For a further reading refer to Rogers (2003).

4.2.2 Analysis of the Geographic Distribution of Social Studies

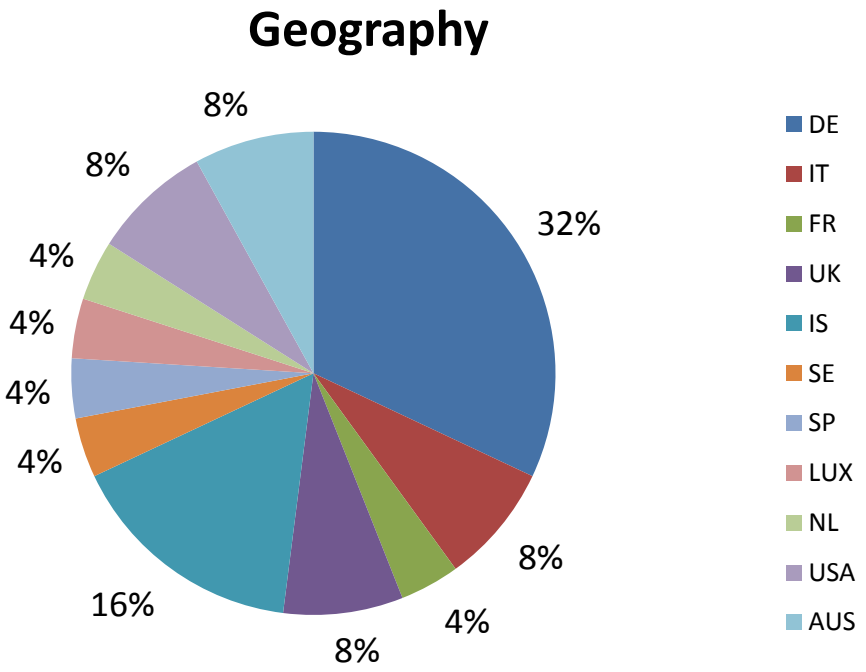

Figure 5: Analysis – Geography

Cultures and habits can differ from country to country even within the European Union. The studies listed in the matrices have been carried out in 11 countries so far (refer to Figure 5) with a bias towards Germany and Iceland. When relating clean transportation with how much is driven in each country the German bias may be justified. Yet the country where the second most kilometres are covered, France, only a small portion was found; at least ones that were published in English. (see Figure 6: Daily Passenger Traffic (Car and Bus) in Million Kilometers) Such findings can indicate geographical caps in the research. Further studies on acceptance therefore may take note of this pattern.

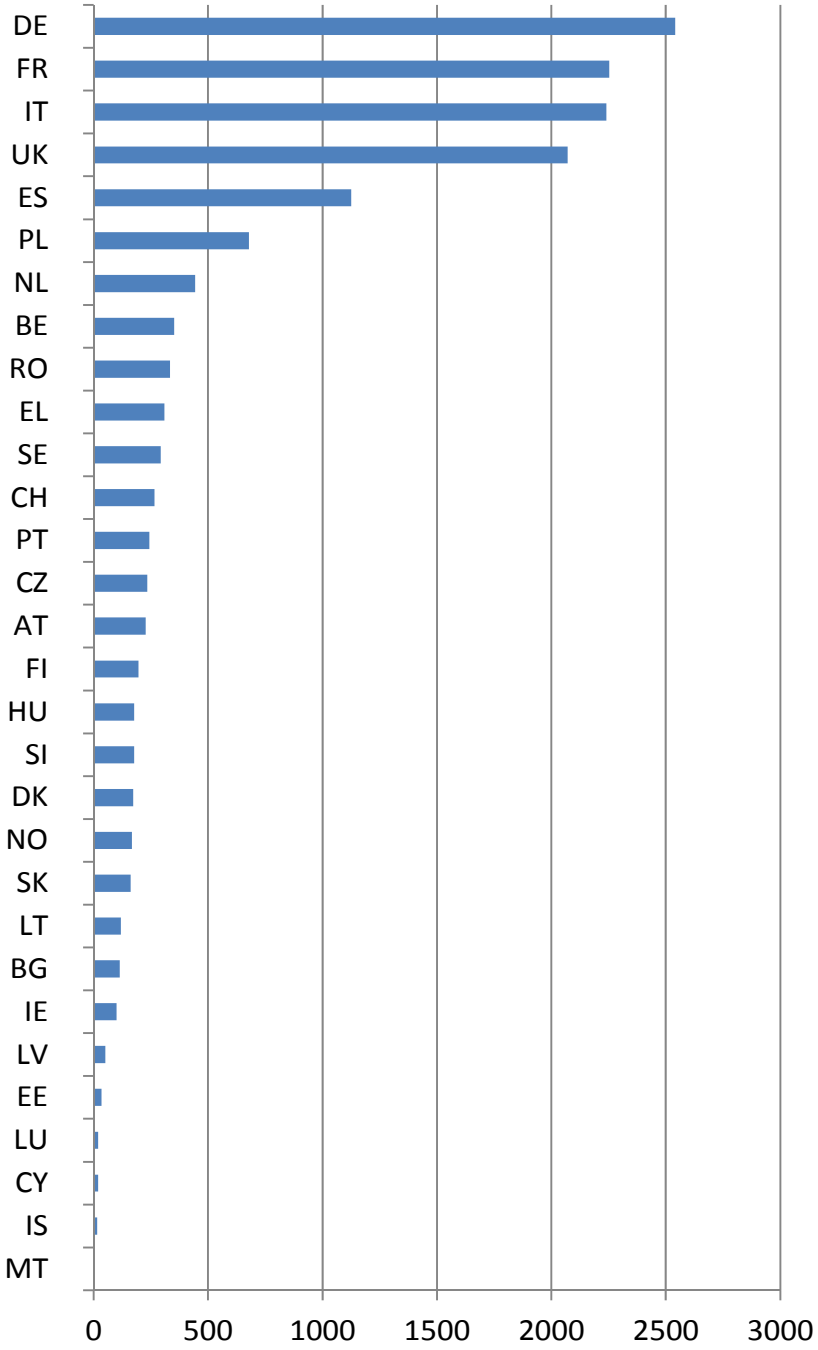

Figure 6: Daily Passenger Traffic (Car and Bus) in Million Kilometers

Source compiled by the authors, data from Eurostat (2009)

4.2.3 Analysis of assessments according to stakeholder group

Different interest groups are joined in a system of transportation. These interest groups or stakeholder groups can be generally divided into the following categories:

- Public, society as a whole: Passengers, neighbours, bus drivers, pedestrians, etc.

- Administration & Politics: Local government, national government, supra-national government, agencies and regulation monitors.
- Technology providers: Car and bus manufacturers, infrastructure manufacturers, etc.
- Market: Investors in new technology, entrepreneurs etc.
- Science: Researchers, interaction between technology and theoretical principles etc.

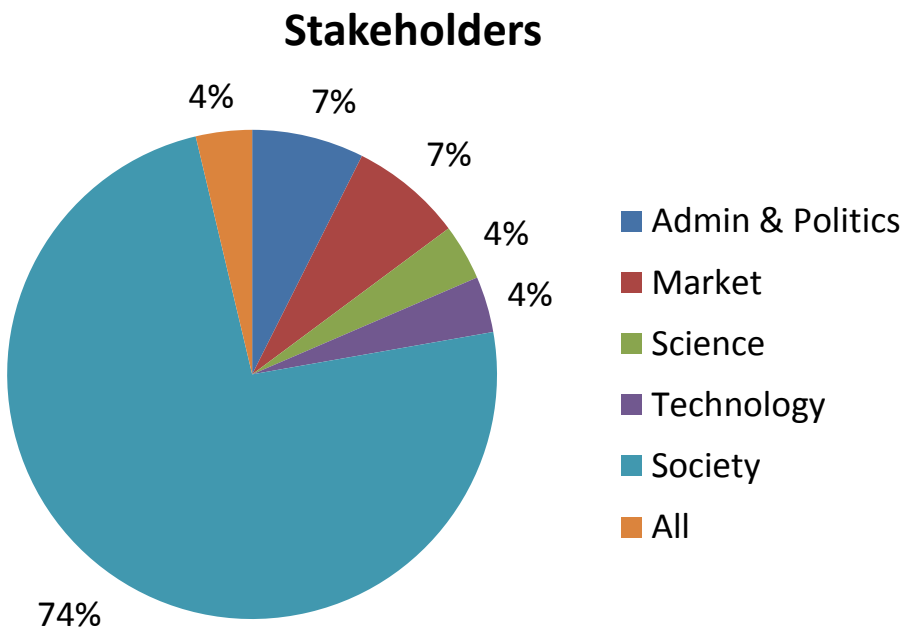

Figure 7: Analysis – Stakeholders

As can be seen to Figure 7 the overwhelming majority of participants that have been involved in social research are the society or the public citizens. Later, the report will present what stakeholders within former demonstration projects think of this bias (see section 4.3). Most of these individuals also fall under the category of having no experience or having passive experience. To pursue a holistic picture of a possible future transport system all stakeholder groups need to be taken into account and future studies should focus on stakeholders that have experience and insight from operating such systems. .

4.2.4 Analysis of social studies according to research methods

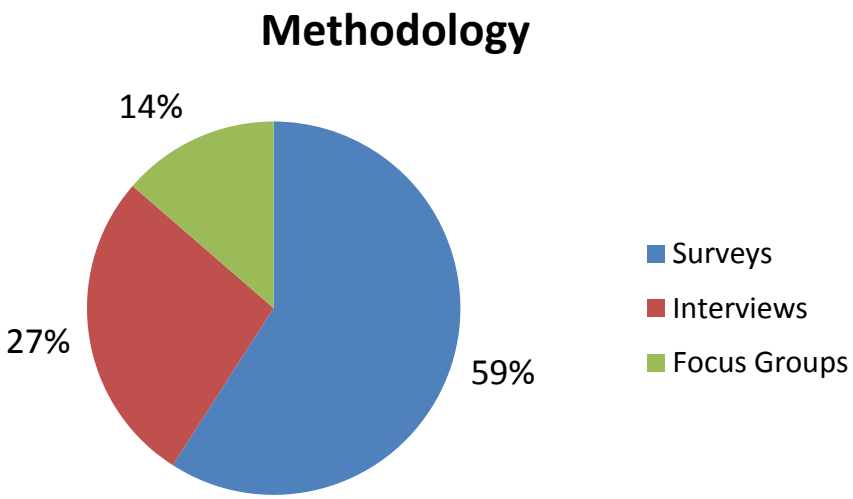

Figure 8: Analysis – Methods

Out of the previously presented methods presently used in social research studies, the following three have been used so far in the identified studies: surveys with rigid questionnaires, interviews and focus groups (refer to Figure 8). The observation approach have not been reported as of yet or even not carried out. New findings may emerge by using this method and observation as a method could be considered in further lighthouse demonstration.

4.3 Qualitative analysis– gaps identified by stakeholders

During demonstration activates social studies are frequently conducted alongside the implementation. At times the studies are conducted by partners, which are not directly participating in the demo activities and have a more theoretical approach to the subject, i.e. universities, research institutes etc. The stakeholders within the project may have different views about what are relevant social aspects, whereas they have rooted experience from interacting with the public.

Therefore within the Prepar-H2 project, contact was made with several stakeholders from former hydrogen demonstration projects and they were asked to list up topics that they find interesting for social research or topics in socio-economics. They were asked directly in

meetings, via email and phone. They were asked to identify gaps in the social research connected to hydrogen demonstrations, whether these were supported or not by EU framework programs.

- What issues concerning society and economy do you think are influential to understand dynamics if hydrogen integration and would be worth finding out?
- Can you identify gaps or subjects which had not been addressed in studies so far?.

4.3.1 Replies containing suggestions for research

The Prepar-H2 team got replies from about ½ of the contacted stakeholders. The reason for this is not known. But complaints from stakeholders about the irrelevance of research topics should be noted, even though it may be difficult for them to pinpoint topics themselves.

The key issues which stakeholders mentioned as important are listed here below:

1. A comparison between several alternative fuels and investigation of options that suit best for each country or region according to the available energy resources

2. I experience a lot of confusion in the field of alternative fuels because these are presented one by one and the drawbacks kept from the public Therefore the following topics:
   - Find out in broad terms which level of technological understanding is relevant or necessary for the average consumer before he can make is choice of mobility options
   - Find out what consumers will expect from each category of drive train and fuel type, not the least concerning convenience.
   - Total life cycle cost – not many people do a full auto cost-of-ownership calculation – so people often delink purchase and operating cost.

3. . Questions that are relevant for the public is rather try to find out concern and willingness to pay for the environment, for convenience of various transport methods and views on the role of transportation. There is no point in asking them about hydrogen acceptance. There is no point in asking the public about the technology, due to lack of their experience and no knowledge in the field

4. Ask workers in a hydrogen car facility about their ideas related to successful marketing for the public. These workers interact with consumers every day.

5. Consumer expectancies concerning vehicle convenience and necessary technological understanding.

6. The role of PR-work in the process of acceptance and diffusion of hydrogen mobility

7. Effectiveness of various policy measures for the integration of clean transport technology

8. Comparison of transport options in the different European countries

9. Suggested stakeholder group for interviews: middle managers, whereas these have contacts both to top management and to the people on the floor. These individuals have often better insight than top managers.

4.3.2 Discussion on gaps in the social research

Many of these replies indicate similar topics which are classified here into 3 main areas:

i) The necessity of cross sector fuel studies. Almost all the stakeholders identified the lack of useful comparative studies between the different fuel types. Most frequently, studies are specific on single fuels – hydrogen or batteries or ethanol, etc. Most stakeholders agree that the future will probably not be one solution and therefore it is necessary to conduct studies which compare advantages and disadvantages for different fuels/vehicles in local conditions.

ii) Expectations. The public should be asked more about their expectations for emerging technologies, but at the same time at it is mentioned that public insight is lacking (see below).

iii) Education versus media messages and PR by manufacturers. There is a lot of mismatching information offered in the mass media regarding benefits of future vehicle technologies without describing eventual drawbacks.

More than often the public has neither tried nor seen new technology vehicles and therefore fully relies on information from the media. Interviews with people that issue unsupported statements from companies promoting their own products are broadcasted and these statements quoted as the latest facts. The reasons and repercussions of such waves of media coverage could affect market introduction.

The stakeholders indicate that they themselves should be asked more about the technology and performance. Yet when a project like PreparH2 comes around and starts asking questions it is difficult to get replies. – Is it possible that middle managers cannot or are not allowed to give information, and which implications may that have for educating the public?

It should also be addressed that some stakeholders also mentioned comparison of transport options in Europe and policy steps. Almost all European countries have taken some policy measures to support introduction of new environmentally friendly transport. Some policy measures have had a very strong impact and have functioned well when others have had little impact. It could be beneficial to the industry and policy/decision makers to have a better overview of what has been tried and what has worked and what has not along with the set targets and involvement of stakeholders as well as the local conditions as mentioned in section 4.3.2.

Lastly, only a few of the topics mentioned here are in the social study-matrices and therefore the suggestions qualify as identified possible gaps. These are therefore topics that should be considered s topics for future studies in connection to hydrogen RD&D projects and eventually be applied to all further studies on alternative fuels in general.

In general stakeholders are satisfied with social work conducted alongside RD&D projects because it brings in angles that otherwise be hidden from view. The topics they miss are therefore not many. This of course is viewed very positively by the PreparH2 project; cross-cutting issues in general seem to have been well covered and are feeding the information into the industry as a whole.

However the industry needs to keep in mind that some social indicators might not be fully correct due to the lack of knowledge of the majority of interviewees. Education might therefore be a key issue to the correct information out.

5 Conclusions and recommendations

In order to sharpen the most important findings, this chapter is simply set up as a list of recommendations, for which the prerequisites are given in the document.

I. There exist several helpful research approaches to acquire valuable data in social research. Select appropriate methods according to the objectives of that research

1) Manage research as to avoid bias, in the research design, execution and evaluation of results. The six issues are bias, authenticity, actuality, time-lag, filtering, and source level.
2) Train the interviewers and test the research methods. The researcher should always be aware of his own social stand. This will always influence the outcome in some way as well as the methods applied. It is important for the researcher to be aware of this and develop accordingly a reflexive and conscious handling.
3) Organise the work as a collaboration between those who are directly involved with hydrogen equipment and those who have a more theoretical stand. Thus the research may be directed at issues that have proved to be relevant in practical execution, but the theoretical outline makes the research less vulnerable to influence

II. **New project proposals should familiarize themselves with the available overview of the studies that have already been conducted as both to maintain and further improve the quality of social studies on hydrogen mobility but also to avoid unnecessary repetitions.**

4) Gaps are found when looking into the group of interviewees. In 2011 almost 50% of studies have involved people that are supposed to reply to questions about hydrogen mobility, without having tried it. Stakeholders that work within the hydrogen fuel chain suggest that a more enlightened discussion can be conducted if experienced persons are also involved.
5) The geographic distribution of studies could be better balanced.
6) It is custom to keep raw data available for investigation for further or other research. Therefore it is recommended that the organisation behind each project manager keeps the raw data stored / archived for later consultancy.

III. **Stakeholders in hydrogen demonstrations have suggested new unexplored areas of research:**

7) The public seems to be confused about alternative fuels and drive trains; comparative assessments are recommended.
8) The difference between selling elements and expectations has not been clear in media message. There is a need to link customer expectations concerning new drive technology and actual performance. The concept of willingness to pay cannot be connected to emerging technology until it is clear which services these offers.
9) Whether or not there will be a single winning future technology for transport solutions or several competing technologies, it is recommended that each country or region looks at local energy sources and how these may be used both to function in efficient transport and to lower carbon footprint. These may be methane from biomass, biofuels from waste, recycled carbon, electric charge etc.

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