

LET'S GO GREEN WITH HYDROGEN! THE GENERAL PUBLIC'S PERSPECTIVE

Zimmer, Rene¹ and Welke, Joerg²

¹ Resource Protection & Landscape Ecology, Independent Institute for Environmental Issues, Greifswalder Strasse 4, Berlin, 10405, Germany, rene.zimmer@ufu.de

² Resource Protection & Landscape Ecology, Independent Institute for Environmental Issues, Greifswalder Strasse 4, Berlin, 10405, Germany, joerg.welke@ufu.de

ABSTRACT

It is well known in socio-economics that the success of an innovation process depends to a great extent on public acceptance. The German HyTrust project analyzes the current state of public acceptance in hydrogen technology in the mobility sector. This paper focuses on cutting-edge results of interviews, focus groups and a representative survey. Based on these results, almost 80% of the Germans are in favor of introducing hydrogen vehicles. But from the perspective of the general public, it is important that hydrogen is produced in an environmentally friendly way. HyTrust is the socio-scientific research project that accompanies the German Federal Government's National Innovation Programme.

1. INTRODUCTION

In 2007 the National Development Plan for the "Hydrogen and Fuel Cell Technology Innovation Programme" was launched in Germany. It is intended to prepare HFC (hydrogen fuel cell) vehicles for commercial application by 2015, and HFCT (hydrogen fuel cell technology) is to become competitive for the transport sector by 2020. According to the German government, Germany will have 1 million electric cars on the road by 2020 including hybrid, battery as well as hydrogen and fuel cell electric cars. This demonstrates that many politicians and automobile manufacturers consider hydrogen fuel cell technology to be an option for the future for carbon-free mobility. We can assume that there is an interest in a smooth introduction of hydrogen cars to the market.

There have been only a few scientific studies of the public perception of hydrogen technology in the mobility sector in Germany to date. The first German acceptance study on this topic was carried out in 1997 by Ludwig-Bölkow-Systemtechnik GmbH in collaboration with the University of Munich [1] [2] [3]. Additional studies were conducted in the following years [4] [5] [6] [7] [8]. For the most part, they used quantitative methods and often employed standardized questions to survey passengers of hydrogen-powered buses. None of the studies was representative of the German population. Further studies on the acceptance of hydrogen technology in the mobility sector have been carried out in Great Britain [9], the Netherlands [10], Sweden [11], Iceland [12], Canada [13] and the US [14]. The few representative surveys on hydrogen technology are all from the US [15] [16] [17].

Even though they use varying study designs, the acceptance studies conducted to date conclude that the public seems to have a positive attitude towards hydrogen technologies at the moment. Associations with risk play only an insignificant role in the public's perception. The studies on hydrogen acceptance reveal that the public is still largely unaware of hydrogen and fuel cell technologies in the automotive sector and that the room for individual experiences with hydrogen powered vehicles is still very small. Personal experiences in using hydrogen-powered vehicles have a positive effect on the acceptance of hydrogen technology in the mobility sector.

At the same time, experts are worried about possible risks of hydrogen and fuel cell technologies and their consequences for public acceptance. A recurrent assumption on the part of experts is that the public has a largely negative opinion about hydrogen and that the word "hydrogen" tends to conjure up images of danger and explosions. Funded by the Federal Ministry of Transport in Germany, the 4-

year HyTrust project was launched in 2009 in order to analyze the current state of public acceptance of hydrogen technology in Germany. The HyTrust project is the socio-scientific research project that accompanies the National Innovation Programme for Hydrogen and Fuel Cell Technologies.

METHODOLOGY

Inquiry

In the HyTrust project, several tools were developed to analyze public acceptance: interviews, focus groups, representative surveys, a citizens' conference and case studies, e.g. with people passing by a hydrogen fuel station in Berlin. The aim was to understand how people perceive hydrogen technologies and which opinions, mental images and attitudes towards hydrogen technologies they have.

Interviews and focus groups

30 individual interviews were conducted and three focus groups of 12 participants were held with members of the general public to gain qualitative information about perceptions and attitudes of people in Germany towards hydrogen technologies. The interviews and focus groups were carried out in April and May, 2010, in Berlin and Hamburg, as hydrogen technology enjoys at least a certain presence in people's everyday experience of mobility in these cities. Altogether 60 people were interviewed. The interviews lasted approximately one hour, the focus groups took two hours. Audio or video recordings were prepared of the interviews and focus groups, and the recordings were transcribed and evaluated.

Representative survey

The results from the interviews and focus groups provided the basis for developing a questionnaire for a representative survey of the population. The survey was carried out using Computer-Assisted Telephone Interviews (CATI) in early December, 2010. The representative sample included a total of 1,011 individuals who were at least 18 years of age and residents of the Federal Republic of Germany. The data from the telephone survey were analyzed employing the statistical package *PASW Statistics 18*. This is the first time that representative results concerning the acceptance of hydrogen technology in Germany have been gained on the basis of a public survey. The survey will be repeated after two years to examine the level of acceptance over time.

RESULTS

Public awareness

How people assess a particular new technology depends to a large extent on how it can be experienced as well as on the actual experiences that people have already had with it. Therefore, one question in the representative survey was whether respondents had ever heard of hydrogen-powered cars. 71 % of respondents said that they had already heard or read about hydrogen-powered cars, and another 15 % of respondents had even used a hydrogen-powered car or bus. The following Table 1 provides an overview of the responses.

Table 1. Respondents' knowledge of and experience with hydrogen-powered cars

Have you ever heard of hydrogen-powered cars?	Frequency	Percent
No, never	141	13.9
I have heard or read about them.	714	70.6
I have heard about them and have used a hydrogen-powered car/bus.	156	15.4
Total	1011	100.0

While approximately the same percentages of men (73 %) and women (69 %) have already heard or read about hydrogen-powered cars, the majority of people who have used a hydrogen-powered car or bus are men (20 %). In contrast, only 11 % of women have used a hydrogen-powered car or bus. Due to the testing of hydrogen buses in normal operations there, Hamburg has the highest percentage of people who have already taken a hydrogen bus of all the German *Bundesländer* (federal states).

However, we can read only little about general knowledge of hydrogen and fuel cell technology into the fact that the German population's level of awareness of hydrogen-powered cars is relatively high. In the interviews and focus groups, it became apparent that the respondents' level of knowledge about hydrogen and fuel cell technology for mobility tends to be low. They do know something about processes for production and use, but as a rule cannot describe them in more detail. For the most part, they learned about hydrogen in general in school and therefore cannot access that knowledge readily, as it was acquired long ago. Respondents usually know that hydrogen gas involves energy supply or discharges of energy.

Awareness that hydrogen can be used as a vehicle fuel is fairly common among the respondents. They are even a step ahead of the actual development of the technology and assume that hydrogen-powered cars are in use today. In contrast, only a very small fraction of respondents are familiar with how the technology works, especially the use of fuel cells in combination with an electric motor. People who have already heard of fuel cells know that they produce energy and steam. However, nobody is able to explain the technology's structure and functioning. Some respondents confuse fuel cells with fuel rods as used in nuclear power plants, because of the similarity of the German words *Brennstoffzelle* and *Brennstäbe*.

Perceptions and associations

What people associate with hydrogen and hydrogen cars is a good indicator of how the public will frame the issues involved with the technology. For this reason, participants in interviews and focus groups were asked about their top-of-mind thoughts associated with the terms "hydrogen" and "hydrogen vehicles." Figure 1 summarizes 60 people's associations with the word "hydrogen." They were mostly neutral and revolved around topics such as chemistry, fuel cell cars and buses, peroxide blonde hair (*wasserstoffblond* in German) as well as hydrogen as the source of all energy. One main positive association was that hydrogen enables mobility without the use of fossil fuels. There were only very few associations with the hydrogen bomb or the zeppelin disaster (Table 2).

Table 2. Associations with “hydrogen” (n=60)

When I hear hydrogen, I think of ...		
positive associations	neutral associations	negative associations
<ul style="list-style-type: none"> • energy source of the future (12 answers) • environmentally friendly fuel (11 answers) • something nice (5 answers) 	<ul style="list-style-type: none"> • chemical element (29 answers) • H₂ vehicles / H₂ infrastructure (20 answers) • energy source (13 answers) • peroxide blonde hair (14 answers) • other (8 answers) 	<ul style="list-style-type: none"> • bomb / danger (10 answers)

When asked about hydrogen, roughly half of respondents think of a chemical element. Some are familiar with the chemical symbol for hydrogen: H. Some respondents mention the pop test for hydrogen from chemistry class at school, but few remember how it works and what it tells us. Some respondents confuse hydrogen (*Wasserstoff* in German) with steam (*Wasserdampf*). The fact that hydrogen occurs mostly in the compound H₂O is usually derived from the element’s name (the literal translation of the German word *Wasserstoff* is “the stuff of water”), but some respondents believe hydrogen is a component of air. People are aware of the fact that the production of hydrogen requires a lot of energy. The fact that hydrogen is energy-rich and therefore explosive was mentioned by a few respondents.

People mostly derive their assessment that the technology is environmentally friendly from the fact that its only product is water, and they believe that water is not harmful, be it because it “*protects the ozone layer*” or because it avoids “*carbon monoxide emissions.*” Many respondents believe that the supply of hydrogen is infinite. It is also considered a “*natural*” element.

As only a few people associate hydrogen with danger or risk, the interview partners were asked specifically whether they thought it was dangerous to live next to a hydrogen fueling station. The following quotes show, however, that hydrogen is considered just as dangerous or as safe as gasoline.

“I have no concerns about the safety and environmental effects of these fueling stations.”

“I do not feel more endangered by a hydrogen fueling station than by a conventional gas station.”

While associations with “hydrogen” tended to be neutral, associations with “hydrogen cars” were almost completely positive: In the interviewees’ opinion, hydrogen cars are a desirable technology for the future, because they are environmentally friendly, quiet and clean. The few negative associations were not linked to possible risks of hydrogen but to specific features of the car. From the general public’s perspective, hydrogen cars appeared slower, less powerful and more expensive than conventional cars (Table 3).

Table 3. Associations with “hydrogen vehicles” (n=60)

Hydrogen vehicles ...		
positive associations	neutral associations	negative associations
<ul style="list-style-type: none"> • are environmentally friendly, clean, quiet (52 answers) • are the future of mobility (20 answers) • are a desirable future technology (10 answers) • are efficient (4 answers) 	<ul style="list-style-type: none"> • other (7 answers) 	<ul style="list-style-type: none"> • face technical/economic barriers (27 answers)

According to the respondents, the hydrogen-powered car is practically the car of the future, and it represents a clear alternative to conventional cars powered by combustion engines. After all, hydrogen-powered cars provide:

“a potential possibility to be mobile without destroying the foundations of future generations’ existence.”

Accordingly, hydrogen-powered cars are perceived as being new, innovative, environmentally friendly and noiseless. This “desirable technology of the future” is still a dream today. The respondents see that hydrogen-powered cars are currently still at the stage of development and have not yet reached the market. However, they would like to see this task for the future be taken up and hopefully made a reality in the foreseeable future. But many respondents assume that hydrogen-powered cars will be significantly more expensive than conventional cars.

Attitudes towards hydrogen vehicles

The representative survey included several questions intended to analyze the attitude of the German population regarding hydrogen-powered cars. The interviewees were asked to consider why it was important to support hydrogen-powered cars or the establishment of hydrogen. In the respondents’ view, the most important reason to support hydrogen-powered cars is their contribution to global climate protection, and 85 % of respondents agreed with this statement. The contribution of hydrogen-powered cars to avoiding local emissions and therefore protecting health was almost as important to them, with 82 % of respondents agreeing with this statement. Hydrogen could also be an important way of dealing with the looming oil shortage and securing mobility long-term. 69 % of respondents consider this an important reason to support the technology, and 55 % of respondents consider hydrogen technology to be an important economic location factor (figure 1).

Hydrogen-powered cars/Hydrogen should be supported ...

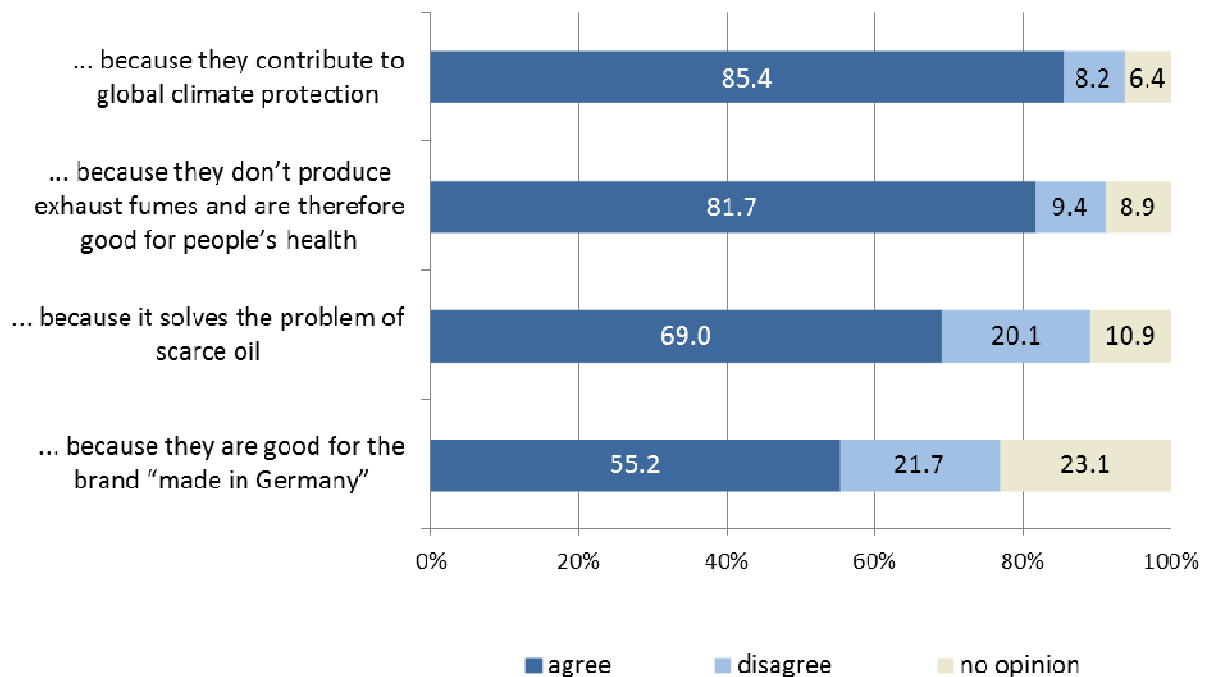


Figure 1. Reasons why hydrogen-powered cars or the establishment of hydrogen should be supported (n=1,011)

Even though climate protection is already the strongest argument for supporting hydrogen-powered cars, it is more important for women than for men. 89 % of women agreed with this argument – compared with 82 % of men. Somewhat more women (72 %) than men (65 %) agree with the argument that hydrogen can solve the problem of oil scarcity. The “made in Germany” argument, in contrast, is somewhat more important to men (58 %) than to women (52 %).

Respondents were also asked whether they would purchase a hydrogen-powered automobile or a conventional one if they had the choice the next time they bought a car. The question was worded: “Imagine you wanted to purchase a new car in the near future. If you had the choice: If the price, features, design, brand, etc. were the same, would you purchase a hydrogen-powered car, or would you still buy a conventional car?” In this situation, 63 % of respondents would purchase a hydrogen-powered car. Still, 24 % of respondents would stick with a conventional car, even if the price, features etc. were the same. And 13 % of respondents did not have an opinion on this matter (figure 2).

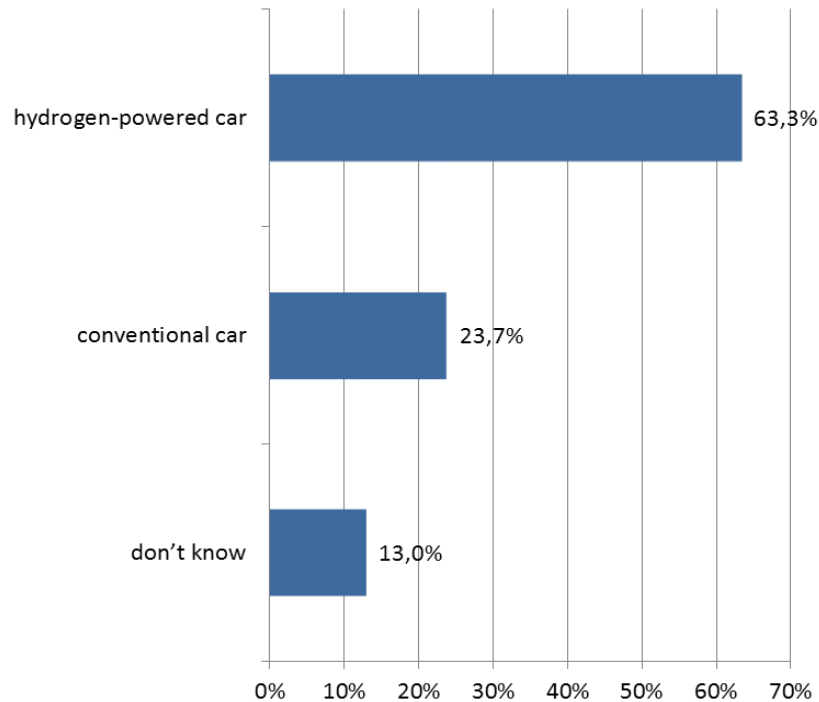


Figure 2. Purchasing preference if price, features, design, brand etc. are identical for hydrogen-powered and conventional cars (n=1,011)

While approximately the same numbers of men and women would purchase a hydrogen-powered car in these circumstances (62 % of men vs. 65 % of women), 30 % of the men said that they would still buy a conventional car. In contrast, only 17 % of women would decide to purchase a conventional car.

The following question was asked at the end of the representative survey: “Considering everything you know about hydrogen-powered cars or have just heard about them: Are you for or against the introduction of hydrogen-powered cars?” 79 % of respondents gave a clear vote for the introduction of hydrogen-powered cars. Only 4 % of respondents opposed the introduction of hydrogen-powered cars. 5 % of respondents did not care whether or not hydrogen-powered cars were introduced, and 12 % did not consider themselves competent to assess this matter (figure 3).

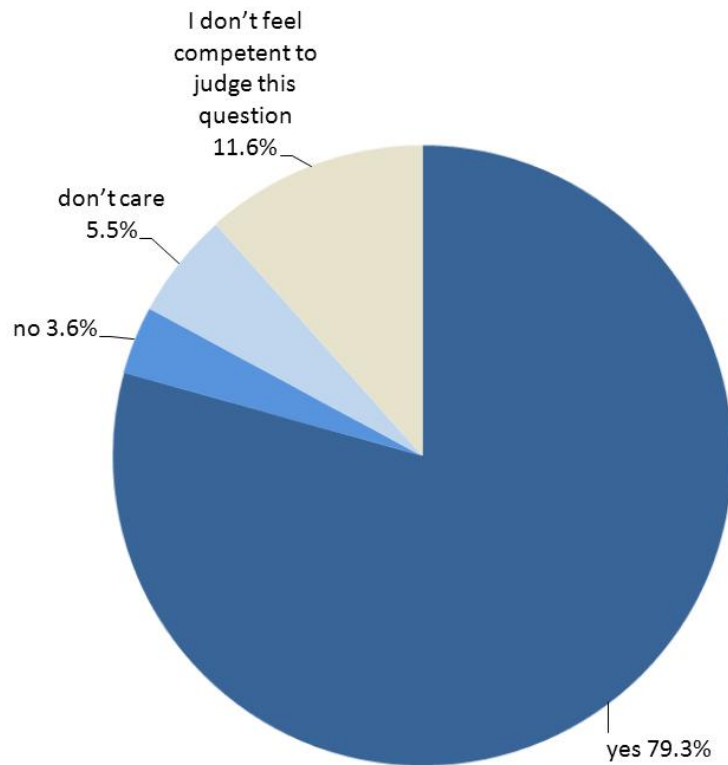


Figure 3. Attitudes concerning the question whether or not to introduce hydrogen-powered cars (n=1,011)

Conditions for hydrogen introduction

The generally positive attitude expressed toward hydrogen-powered cars is, however, by no means uncritical. For respondents feel that hydrogen-powered cars are environmentally friendly only if the hydrogen used was produced in a climate-neutral manner. There is great mistrust especially of the automobile industry in this regard. It ranges from diffuse unease about conspiracy theories to strategies on the part of the “*automobile and oil lobby*” to prevent alternative engines. Respondents were critical especially of hydrogen production via electrolysis using electricity generated from fossil fuels or nuclear energy, i.e. shifting CO₂ emissions from the tailpipe to the power plant.

In the representative study, respondents were asked to assess various development paths for establishing hydrogen technology in the field of mobility. The interviewees were presented with the following question: “Hydrogen can be produced in an environmentally friendly way using renewable energy. That is still very expensive today. Until the price of this process comes down, one could also produce hydrogen from natural gas. Do you think that natural gas should be used as a bridge technology for a transition period, or should hydrogen be produced in a more costly, environmentally friendly way? Or don’t you care?” A clear majority of 66 % would prefer hydrogen produced in an environmentally friendly way, even if its consumer price were higher. 27 % of the respondents were of the opinion that hydrogen should be produced from natural gas for a transition period. And 7 % had no preference one way or the other (figure 4).

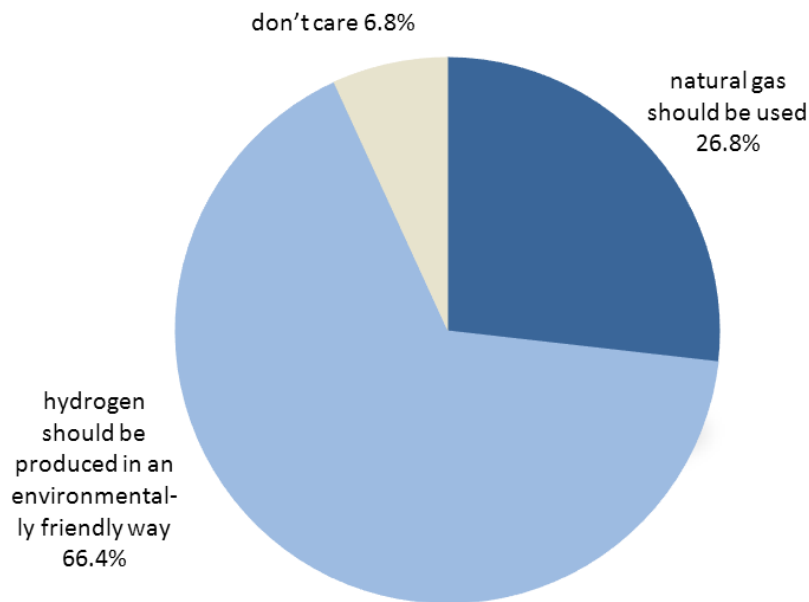


Figure 4. Relevance of the method of producing hydrogen (n=1,011)

Again it is the women to whom environmentally friendly production of hydrogen is particularly important. 71 % of women say that hydrogen should be produced in an environmentally friendly manner, but only 62 % of men. 33 % of men could also live with hydrogen being produced from natural gas for a transition period. Only 21 % of women would prefer this option.

Hydrogen and a clean conscience

Provided renewable energy is used to produce hydrogen, it would seem like the solution to all problems as it makes individual mobility possible without harming the environment. According to the people surveyed, this is the most important advantage of hydrogen cars over conventional cars: they give users a clean conscience because their only emission is steam.

“If hydrogen technology is really more environmentally friendly, I would be happy that our generation has found something like it.”

“ It would be a great feeling to be able to use cars and stay individually mobile without damaging the environment, without damaging the planet.”

So hydrogen cars are perceived as the solution to all problems. They maintain all the advantages of conventional cars, and they make it possible to drive in an environmentally friendly way. They do not require drivers to change their behavior, and people can drive them with a clean conscience.

The results from the representative study show that this point is in fact relevant. Interviewees were presented with the statement: “Driving a car is not all that bad for the environment.” A total of 68 % of respondents replied “disagree somewhat” or “strongly disagree.” Only a minority of 11 % agrees strongly with the statement (see Table 4).

Table 4. Automobiles and environmental pollution

“Driving a car is not all that bad for the environment.”	Frequency	Percent
agree strongly	110	10.9
agree somewhat	214	21.2
disagree somewhat	396	39.2
disagree strongly	291	28.8
Total	1011	100.0

Environmental awareness is generally more important for women than for men. Only 26 % of women agree somewhat or strongly with the statement that driving is not all that bad for the environment. In contrast, 38 % of men hold the opinion that driving is not all that bad for the environment.

In another question, interviewees were asked to state to what extent they agree with the statement “I feel guilty because automobile exhaust pollutes the environment.” A total of 51 % of interviewees agreed with this statement somewhat or strongly. But 47 % of interviewees said that they disagreed with this statement somewhat or strongly (Table 5).

Table 5. Driving and a guilty conscience

I feel guilty because automobile exhaust pollutes the environment.	Frequency	Percent
agree strongly	166	16.4
agree somewhat	351	34.7
disagree somewhat	263	26.0
disagree strongly	216	21.4
I have no opinion about this.	15	1.5
Total	1,011	100.0

The responses to this question display only minor differences between the sexes: 50 % of men and 52 % of women agreed somewhat or strongly with this statement.

Confronted with the statement: “Using a hydrogen-powered car would feel good. Then you could maintain your individuality, but not at the expense of the environment,” a total of 88 % of interviewees agreed with this statement somewhat or strongly. Only a minority of 12 % disagrees somewhat or strongly (Table 6).

Table 6. Hydrogen-powered cars permit individual mobility without polluting the environment

Using a hydrogen-powered car would feel good. Then you could maintain your individuality, but not at the expense of the environment.	Frequency	Percent
agree strongly	522	51.6
agree somewhat	364	36.0
disagree somewhat	100	9.9
disagree strongly	25	2.5
Total	1,011	100.0

Women in particular welcome the possibility to be mobile without damaging the environment by driving a hydrogen-powered car. 55 % of women state that they agree strongly with this statement. Among men, 48 % agree with this statement strongly.

SUMMARY AND CONCLUSIONS

The interviewees' lack of knowledge is directly linked to their experience. In their everyday lives, hydrogen and fuel cell technology do not feature at all, or only marginally. At best, they encounter the issue by chance when they see hydrogen-powered buses in Hamburg or the hydrogen fueling station in Berlin. Nonetheless, the population has a very positive attitude toward hydrogen-powered cars. In particular the possibility of being individually mobile without harming the environment is appealing, as people would not have to feel guilty then. However, the interviewees linked this to the condition that the hydrogen had to be "green," i.e. that it had to be produced using renewable energy. Hydrogen produced with energy generated from coal, natural gas or nuclear power would not lead people to feel less guilty and would thereby also not be an incentive to purchase hydrogen-powered cars, as environmental problems would only be shifted elsewhere.

The concern frequently expressed by experts that using hydrogen for transportation would lead to greater misgivings about safety among the general public could not be substantiated. The word hydrogen is linked to terms such as danger or risk only very seldom, if at all. And even when asked directly, the interviewees did not believe that hydrogen fueling stations were more dangerous than conventional ones.

Regarding the general public's acceptance of hydrogen technology, political and business decision-makers should worry less about whether people will consider the technology unsafe and instead focus more on the issue that people expect the hydrogen on the market to actually have been produced with renewable energy.

ACKNOWLEDGMENTS

The authors would like to thank the German Federal Ministry of Transport, Building and Urban Development represented by National Organisation Hydrogen and Fuel Cell Technology for financially supporting this research. However, all interpretations and other views are naturally those of the article's authors and do not represent any kind of official position. The authors would like to acknowledge the co-operation of the people who participated in the interviews, group discussions and the telephone survey on which this article is based. Thanks also to Sandra Lustig for translating this article.

REFERENCES

1. LBST - Ludwig-Bölkow-Systemtechnik GmbH, The Acceptance of Hydrogen Technologies. URL: <http://www.hyweb.de/accepth2/execsumm.html>, 1998.
2. Altmann, M., Wurster, R. and Graesel, C., HyWeb – The Hydrogen and Fuel Cell Information System. Publication of a Hydrogen Acceptance Study as an Example of the Dissemination of Hydrogen Information via the Internet, Proceedings of the 12th World Hydrogen Energy Conference, Buenos Aires, Argentina, 1998.
3. Altmann, M. and Graesel, C., The Acceptance of Hydrogen Technologies – Die Akzeptanz von Wasserstofftechnologien, www.HyWeb.de/accepth2 (English version), www.HyWeb.de/akzepth2 (German version), 1998.
4. Dinse, G., Wasserstofffahrzeuge und ihr Funktionsraum – Eine Analyse der technischen, politisch-rechtlichen und sozialen Dimensionen. Institut für Mobilitätsforschung, 1999.
5. Dinse, G., Akzeptanz von wasserstoffbetriebenen Fahrzeugen – Eine Studie über die Verwendung eines neuen und ungewohnten Kraftstoffs. Institut für Mobilitätsforschung, 2000.
6. Lossen, U., Armbruster, M., Horn, S., Kraus, P. and Schich, K., Einflussfaktoren auf den Markterfolg von wasserstoffbetriebenen Fahrzeugen, expert verlag, 2003.
7. Altmann, M.; Schmidt, P.; Wurster, R.; O’Garra, T.; Mourato, S.; Garrity, L.; Graesel, C.; Beerenwinkel, A.; Whitehouse, S., AcceptH2: Public Acceptance and Economic Preferences Related to Hydrogen Transport Technologies in Five Countries. 15th World Hydrogen Energy Conference, Yokohama, Japan, June 27 – July 2, 2004.
8. O’Garra, T., AcceptH2 Full Analysis Report: Comparative Analysis of the Impact of the Hydrogen Bus Trials on Public Awareness, Attitudes and Preferences: a Comparative Study of Four Cities, Study in the framework of the AcceptH2 project www.accepth2.com Public Acceptance of Hydrogen Transport Technologies, 2005.
9. Mourato, S.; Saynor, B.; Hart, D., Greening London's black cabs: A study of driver preferences for fuel cell taxis, Energy Policy, 2003.
10. Zachariah-Wolff, J. Leslie and Hemmes, K. “Public Acceptance of Hydrogen in the Netherlands: Two Surveys that Demystify Public Views on a Hydrogen Economy.” Bulletin of Science, Technology & Society. 32(4): 339-345, 2006.
11. Haraldsson, K., On Direct Hydrogen Fuel Cell Vehicles Modelling and Demonstration. [thesis] <http://www.diva-portal.org/kth/theses/abstract.xsql?dbid=147>, 2005.
12. Maack, M. H. and Skulason, J. B., Implementing the hydrogen economy, Journal of Cleaner Production, 14, pp. 52-64, 2006.
13. Hickson, A., Phillips, A. and Morales, G., Public perception related to a hydrogen hybrid internal combustion engine transit bus demonstration and hydrogen fuel, Energy Policy, 35, No. 4, pp. 2249-2255, 2007.
14. Eudy, L.; Parish, R.; Leonard, J., Hydrogen fuel cell evaluation. Proceedings of the 2001 DOE Hydrogen Program Review, 2001.
15. Schmoyer, R. L., Truett, T. and Cooper, C. Results of the 2004 Knowledge and Opinions Surveys for the Baseline Knowledge Assessment of the U.S. Department of Energy Hydrogen Program. ORNL/TM-2006/417, 2006.
16. Patterson, P., Choosing the Best Fuel to Replace Gasoline: Opinion Research Corporation Survey Conducted February 8, 2007. U.S. Department of Energy, 2007.
17. Schmoyer, R. L., Truett, T., Cooper, C. and Chew, A., Results of the 2008/2009 Knowledge and Opinions Surveys conducted for the U.S. Department of Energy Hydrogen Program. ORNL/TM-2009/242, 2009.