Moving towards more efficient car use – what can be learnt about consumer acceptance from analysing the cases of LPG and CNG?

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Abstract
Electric mobility is currently being discussed as a more energy-efficient and climate-friendly means of individual mobility. So far, there are relatively few electric vehicles on the roads. This means that insights into consumer perceptions and acceptance of electric vehicles are still limited. In contrast, vehicles running on liquefied petroleum gas (LPG) or compressed natural gas (CNG) have been on the market for years and have some comparable characteristics with electric vehicles (EVs). Consequently, consumer perceptions of LPG and CNG vehicles may be similar to those of electric mobility and could be a valid analogy.

This paper summarises the insights into consumer acceptance of LPG and CNG vehicles obtained from a literature review. These findings are supplemented by twelve in-depth interviews and questionnaire data from a survey of 142 individuals. Both the interviews and the questionnaires were conducted with vehicle users in Germany. The studies showed that users came into contact with the technology in various ways and then started to collect more information, mainly through the internet and – preferably – by talking to other users, before deciding to switch to alternative fuels. The interviewees reported that they had concerns regarding infrastructure and the reliability of the technology, even the possible explosiveness of the vehicle. However (and fortunately), none of these concerns turned out to be realistic and all interviewees reported high levels of satisfaction with their LPG and CNG vehicle. The economic advantage played a crucial role in the decision-making process; however, environmental issues were also important.

Applied to electric vehicles, these insights suggest that the experiences communicated by other users seem to be important in improving the perceived reliability and safety of a technology. This confirms strategies like field trials. The high relevance of economic motives might, however, pose a challenge when marketing electric vehicles.

Introduction
Electric vehicles (EVs), their future development and integration into the transport and energy sector are currently the subject of intensive discussions. It is often hoped that an increasing market share of electric vehicles could lead to significant environmental advantages: increase energy efficiency, reduce CO_2 and other local emissions, and offer the possibility to better integrate fluctuating renewable energy sources. Moreover, in the light of the finiteness and instability of fossil fuel supply, governments and industry have significantly enhanced their efforts with regard to electric mobility. The term 'electric mobility' is normally applied to individual motorized passenger transport by vehicles which use electric energy for propulsion in the form of one or more electric motors (cp. Wietschel & Dallinger 2008). In the 1990s, electric cars already received significant interest with some commercially available models and field trials. However, very low prices for oil of around US$20 per barrel and little progress in battery technology led to an end of this trend. The last companies to stop producing battery-powered cars were the French car manufacturers in 2005. Since then, almost the only type of electric vehicle available on the market was a manual conversion of standard petrol cars. Recently, several Original Equipment Manufacturers (OEMs) have presented new electric models,

e.g. Mitsubishi I-MIEV, or have announced their intention to launch them soon.

Even though a technological breakthrough has not taken place, some progress has been achieved with regard to battery technology: The energy densities of batteries are higher now, and charging times and costs are lower than in the 1990s (de Haan 2009). The energy demand of solely battery-powered cars lies between 40 and 48 kWh with power requirements between 80 and 100 kW, allowing driving ranges between 150 and 200 km (Hacker et al. 2009): Mean charging periods amount to around eight to ten hours in the standard charging mode. The costs per kWh amounted to over 400 Euro in 2010 and are expected to decline to perhaps 250 to 200 Euro until 2020. Today, a 40 kW battery costs roughly 16,000 Euro which may drop to 8,000 Euro. In general, it is difficult to find or make precise estimates about how much batteries will cost in the future, but it is obvious that the battery will always be the most costly part of an EV.

There are still many critical issues to be solved with regard to EVs before they become comparable to conventional cars, e.g. their maximum range and reliability have to be improved, their purchase price and charging duration reduced, and there have to be feasible concepts for providing infrastructure. From a consumer's point of view, the use of electric vehicles also implies significant changes: Consumers will be confronted with new vehicle models that need to be charged instead of being filled up, that will produce a different sound to conventional vehicles, are likely to accelerate faster (especially in low speed ranges) and include new instruments to be monitored by the driver (e.g. on battery status).

Currently, several industrialised countries and automobile manufacturers have launched huge research projects and are starting field trials to test technology as well as new mobility concepts and business models. EVs have just started to enter the market – the number of vehicles being driven by consumers outside field trials is still low and only a few models are available on the market. Thus, relatively little is known about consumer acceptance of EVs. Especially the willingness to buy an EV is difficult to study under these conditions (Peters et al. 2010): Research using potential consumers as participants faces the problem that it is difficult for consumers to express valid attitudes, preferences and intentions regarding new, unfamiliar vehicle types. Usually, such statements are strongly influenced by comparisons with conventional vehicles and are based on the corresponding use patterns which form the basis for judgement.

Another way to arrive at conclusions about consumer interest and acceptance of EVs is to draw on related and comparable fields in order to make valid predictions about the market diffusion of electric vehicles and to give recommendations for policy making and industry. As a helpful analogy, we identified vehicles powered by liquefied petroleum gas (LPG) or compressed natural gas (CNG) which have already been available on the market for several years. From a consumer's point of view, these technologies are – at least to some extent – similar to electric vehicles: LPG/CNG cars as well as electric vehicles are seen as alternatives to conventionally-powered cars and are considered to be more environmentally-friendly. Moreover, the public infrastructure for fuelling or charging these vehicles is obviously less developed than that for conventional cars and the acquisition costs are higher than for a comparable conventional model. Consequently, we expect that analysing the development of consumer perceptions and adoption in the case of LPG/CNG vehicles might allow conclusions to be drawn with regard to the future of electric mobility.

Vehicles running on LPG and CNG have gained noteworthy market shares if absolute numbers are analysed: In 2011, the number of LPG powered vehicles was estimated at over 10 million globally, approximately 5 million of them in Europe. Additionally, there are approximately 1,400 LPG buses on the roads in Europe (ARAL 2011). India, Italy and South Korea are the leading markets for LPG vehicles worldwide; Turkey and Poland are expected to have the highest growth rates in the years to come (Frost and Sullivan 2010).

Worldwide, there are approx. 11.3 million CNG vehicles. The majority is registered in Pakistan (2.3 million at the end of 2009), followed by Argentina, Iran, Brazil, India and Italy. The average growth rate for CNG vehicles over the past nine years is given as 28 % (IANGV 2010); the highest growth rates are assumed for Asian-Pacific countries (51 %), the lowest for Northern America (0 %), with 16 % in Europe and 1.3 million vehicles in 2009.

If the environmental impact of LPG/CNG powered vehicles is analysed, several aspects have to be taken into account and a final conclusion is difficult to draw: CNG has a higher, and LPG a lower energy content than petrol or diesel. Vehicles using CNG are heavier than LPG vehicles and vehicles using conventional fuels due to the need for pressured and reinforced tanks. Both CNG and LPG emit fewer well-to-tank and tank-to-wheel CO_2 emissions per kilometre driven (120 grams for CNG, 145 grams for LPG) than petrol and diesel vehicles (190 and 155 grams, respectively, Engerer & Horn 2008). LPG is a by-product of natural gas and oil production and mineral oil processing and is usually burned off without further use if it is not captured and stored as a fuel for vehicles. However, LPG and CNG are of course – like petrol and diesel – non-renewable resources. From a consumer point-of-view, LPG and CNG are nevertheless usually perceived as an alternative to conventional fuels (cp. Continental 2010 and further analyses in this paper).

In this paper, our main focus is on the individual decision-making process of private consumers to purchase an LPG or CNG vehicle, their relevant motives as well as how they evaluate this decision after everyday-experience with the vehicle has been gained. Our empirical work was conducted in Germany and therefore mirrors the specific conditions and contextual factors in this country. This paper is structured as follows: The theoretical section on consumer acceptance begins with a brief outline of the German CNG and LPG vehicle market and a summary of the research characterising consumer perceptions of LPG and CNG in Germany. Next, we present a conceptual framework based on theories of technology acceptance, the diffusion of innovations as well as consumer behaviour literature. This framework will be used as a means to structure the results from a literature review as well as our own empirical work throughout the remainder of this paper. In the literature review, we identified a lack of studies analysing the decision-making process of consumers for LPG and CNG as a fuel. Therefore, we conducted two explorative studies ourselves: Interviews

with twelve current German owners of an LPG or CNG vehicle which are presented in detail and complemented by descriptive results from a recent survey of 142 current users of an LPG or CNG vehicle. Finally, conclusions are derived with regard to electric vehicles.

Consumer acceptance of LPG/CNG vehicles

LPG AND CNG VEHICLES IN GERMANY

In Germany, the share of CNG /LPG vehicles is relatively low compared to vehicles fuelled by petrol or diesel: only 0.9 % of the total German vehicle stock is powered by LPG and 0.2 % by CNG. However, LPG and CNG have by far the highest share within the sector of alternative fuels and drives, with hybrids at 0.07 % and EVs at 0.004 % (data for 2010 from KBA, 2011). In the case of CNG vehicles, their purchase and use are promoted by the German government (reduced tax on fuel and reduced motor vehicle tax) as well as by gas suppliers who offer rebates on fuel and some also on acquisition costs. There is also a reduced tax on LPG as a fuel but no reduction for the annual vehicle tax (Bundesministerium der Justiz 2006). With regard to the infrastructure, the situation for CNG vehicle drivers is more difficult than for owners of an LPG vehicle: In 2010, approx. 850 of the 14,500 filling stations in Germany offered CNG (especially on motorways there is still a lack of filling stations offering CNG) compared to more than 5,800 gas stations for LPG vehicles (ADAC 2010a, Deutscher Verband Flüssiggas e.V. 2010).

CNG vehicles are offered by several Original Equipment Manufacturers (OEMs) and are more expensive to buy than conventional petrol or diesel cars: A CNG car costs approximately 1,500 Euro more than a diesel one, and approximately 4,000 Euro more than a petrol one. LPG vehicles in Germany are usually conversions of conventional petrol-fuelled vehicles, at an average extra cost of 2,000 to 2,500 Euro (ADAC 2008, Deutsche Energie-Agentur GmbH 2010).

The break-even distance for CNG powered vehicles in Germany is approx. 50,000 kilometres if the vehicle is replacing a petrol-driven one, i.e. after 50,000 km the driver starts to save money due to lower fuel and tax costs. Subsidies from gas suppliers which are available in some regions can further reduce this distance. An LPG powered vehicle has a break-even distance of approx. 71,000 kilometres if it replaces a petrol one (these calculations are based on additional costs of 3,500 Euro for CNG powered vehicles and LPG conversion costs of 2,350 Euro, ADAC 2011, www.amortisationsrechner.de).

People are much more aware of LPG/CNG as alternative fuels for cars than might be assumed from their market shares: As part of their annual survey of 1,000 German car drivers, KÜS & kfz-betrieb (2008) asked whether they knew about LPG and CNG as a fuel for cars. 75 % indicated they knew about CNG; 70 % had heard of LPG. Up to 60 % stated they might be willing to drive an LPG/CNG vehicle in the future; however, 70 % also admitted they did not know the difference between the two fuels which shows that even though many drivers are aware of these types of alternative fuels their knowledge is superficial. This is supported by the findings of another survey of 1,000 German car drivers in 2008 by tns infratest for Continental (2010), where participants were asked to spontaneously name energy-efficient powertrains and fuels: 28 % of the respondents mentioned CNG and 20 % LPG. This reveals that, without clues, the awareness of LPG and CNG is probably lower.

The intention to purchase a vehicle able to use LPG or CNG as a fuel was analysed by Frost and Sullivan (2008). 25 % of the participants indicated that they intended to consider LPG the next time they were purchasing a car; 19 % mentioned CNG in the same context. However, participants were reluctant to pay more for an LPG/CNG vehicle than for a conventional one: 14 % indicated they would not consider buying such a vehicle at all, 41 % were not willing to pay more and 16 % were willing to pay a premium up to a maximum of 499 Euro. The remaining 29 % indicated they would be willing to pay a premium between 500 Euro and even over 2,000 Euro – amounts that are close to the premium that has to be paid in reality. In sum, this study shows there is a vague interest among German car drivers in LPG and CNG as alternative fuels; however, declaring interest or willingness in a survey is not the same as actually making the investment. That declaring an intention does not necessarily lead to realisation of the stated behaviour is a finding that has been confirmed for several domains in the literature (cp. Armitage & Conner, 2001; Bamberg & Möser, 2007).

Correspondingly, the survey results of the ADAC (2009), which found that the intention rates to buy an LPG/CNG vehicle were between 3 and 6 % for 2008 and 2009, respectively, probably provide a more realistic estimate of the intentions of German consumers. Two other studies assess the barriers and concerns that play an important role among German non-users of LPG and CNG: Pascaud et al. (2009) found a negative net score of 2 % for spontaneous associations in a survey of 1,000 German car drivers, that is to say, there were 2 % more negative than positive evaluations of CNG powered vehicles. The main concerns of the participants in relation to CNG were that infrastructure is scarce and that it is unsafe and difficult to fill. Similarly, participants in the KÜS & kfz-betrieb-study (2008) mentioned above stated that a low number of filling stations, a restricted car range, the initial investment and the low reliability of the technology were the main barriers to purchasing a LPG/CNG vehicle. Moreover, the participants of this study were also asked whether their car dealer or repair shop had ever actively offered CNG or LPG as alternatives to them. 90 % of respondents said they had not, thus indicating that these alternative fuels do not seem to be promoted very actively.

THEORETICAL FRAMEWORK

Theories about the acceptance of new technology and the diffusion of innovation aim to explain how and when individuals adopt innovations (i.e. ideas, applications or objects that are perceived as new), and thus, why some innovations successfully enter the market, while others do not. Empirical research indicates that, even if the innovation provides significant improvements from a technological or economic point of view, new products are often associated with a high failure rate, up to 90 % in some industries (Kuester et al. 1999). Thus, there are obviously more variables involved than just a simple comparison of the usefulness of a conventional and an innovative technology.

The model which is most often applied to the diffusion of innovation and which is empirically well proven is the Diffu-

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sion of Innovation model (DoI) by Rogers (2003). According to Rogers (2003), besides socio-economic characteristics, the general or specific innovativeness and the communication behaviour of an individual, the decision process, and thus, the intention to adopt or reject an innovation is also influenced by the individually perceived attributes of the innovation: (i) its relative advantage, (ii) its compatibility with the adopter's values, experiences and needs, (iii) its complexity, i.e. difficulties with understanding and using the innovation, (iv) its trialability and (v) its observability. Applied to alternative powertrains like EVs or fuels like LPG/CNG this means that potential users evaluate these options using the factors listed in order to decide whether they are preferable to their currently used option, in this case most likely a conventional car.

Other theories that have been applied to explain user acceptance of new technologies are based on the theory of reasoned action by Fishbein and Aijzen (1975). This theory describes the intention to use or apply a technology as predicted (i) by the attitude towards the relevant behaviour, i.e. the expectation and evaluation of consequences of this behaviour, as well as (ii) by the perceived social norm, i.e. an individual's expectation that this kind of behaviour is expected by others. Applied to the context of LPG/CNG vehicles, this implies that the probability to adopt a vehicle powered by LPG/CNG would be influenced by the personal attitude, i.e. the expectation and evaluation of consequences of adopting an LPG/CNG vehicle, as well as by the more general societal perception of electric mobility, e.g. LPG/CNG vehicles as 'green' vehicles that should be used in order to combat climate change.

The Technology Acceptance Model (TAM) by Davies (1989) explains technology acceptance as being influenced by two variables: the perceived ease of use and the perceived usefulness of a technology. The TAM-model has been extended to include social norm, thereby adding an inter-individual factor.

Comparing the three approaches to technology acceptance reveals that they feature similar variables that are supposed to explain acceptance on an individual level: the usefulness of the product and its relative advantage compared to alternatives, the compatibility with personal as well as social norms, values and attitudes, the complexity or ease of use. Exclusive to Rogers' (2003) model are the variables trialability and observability. These two, however, refer to a more basic and inter-individual level and to characteristics of a technology which can be used actively in the marketing process.

Marketing literature on consumer behaviour also shows that it is not sufficient to offer innovations with a relative advantage, but that several adoption barriers within the decision and adoption process have to be overcome (Heß 2009). Therefore an in-depth understanding of a consumer's attitude formation and decision-making process with respect to new products is required, as the individual adoption influences the innovation diffusion on the market. Three main barriers have been identified: (1) cognitive barriers, (2) functional barriers and (3) innovation bias.

1. Consumers can have difficulties categorising innovations into existing cognitive schemes if there are no cognitive links to the new product (Binsack 2003). These links can be prior knowledge or prior experiences with similar products that can also be based on the knowledge or experiences of others, such as experts, friends or relatives. Given a basic knowledge of motor vehicles, it is possible that consumers demand standard performance parameters (e.g. charging time) for electric vehicles without ever having seen one and therefore judge them on the basis of typical characteristics of conventional cars. Therefore, consumers are more likely to purchase an innovation if they are able to easily create a cognitive link between the innovation and a similar well-known product (Binsack 2003).
2. At the same time this implies that consumers are likely to compare the innovation to existing products as a reference point (Gourville 2005). Functional barriers, such as usage barriers, can occur if innovations require a change in behaviour compared to existing products, e.g. in the case of EVS, planning daily mobility in more detail due to their more restricted driving range. Offering consumers a suitable reference point when marketing new innovations can be a good strategy to overcome functional barriers.
3. The decision-making process of consumers regarding innovations is not fully rational, as they suffer from an innovation bias, meaning that they tend to under-evaluate the benefits offered by new products and prefer to stick to familiar, existing solutions (Gourville 2005).

These three barriers provide further insights why innovations or new products are not evaluated based solely on their usefulness and which factors may play a role in their assessment. Cognitive barriers are likely to play a role when potential users evaluate the usefulness of a new product as well as its ease of use. Functional barriers, especially if suitable reference points are missing, probably influence the ease-of-use-perception. And the innovation bias is prone to impact the perceived usefulness.

The concepts outlined in this section will be used in the remainder of this paper in order to structure findings from the literature as well as from the empirical studies presented below.

EMPIRICAL STUDIES ON LPG/CNG USAGE

The focus of this paper is on studies which analyse private consumers' opinions with regard to actual or intended usage of LPG/CNG vehicles. Scientific databases and the internet were searched for appropriate literature. The majority of papers adopt an economic approach (e.g. Flynn 2002; Frick et al. 2007; Janssen et al. 2006) and do not involve empirical data of users/non-users and are thus not relevant to the focus of this paper. The number of empirical studies analysing the decision-making process for purchasing a LPG/CNG vehicle is relatively low. Additionally, it is difficult to make direct comparisons of the studies identified because they analyse consumer attitudes and behaviour under a wide variety of conditions which have to be taken into account. For example, the countries where user studies were conducted differ in terms of the range of models available on the market, the price of LPG and CNG, infrastructure and the ratio of gas-vehicles to refuelling sites offering gas, conversion costs or the additional costs for purchasing a gas-powered vehicle, past experience with LPG/CNG vehicles and related technologies (e.g. natural gas resources), population density and topography. Thus it is to be expected that the studies will lead to heterogeneous results even if similar approaches are used.

For Germany, only two studies could be identified: Kannwischer et al. (2010) conducted focus-groups with German drivers of LPG vehicles and discussed their motives for purchasing such a vehicle. It turned out that economic advantages due to lower fuel costs were the main driver for nearly all the participants (with one exception); however, the majority also mentioned environmental advantages as the second most relevant motive or viewed it as an important side-effect. Similarly, in a survey by German energy companies among actual users of CNG, 91 % mentioned economic advantages and 77 % environmental reasons as important motives (RheinEnergie et al. 2006).

The findings presented by Jonkers (2009) paint a slightly different picture: Jonkers interviewed stakeholders as well as actual users of CNG vehicles in the Netherlands and Switzerland. In both countries, saving the environment played a central role for adopting the technology; respondents from Switzerland also emphasised economic aspects. The countries differ with regard to infrastructure and subsidies with higher tax reduction and a higher density of filling stations in Switzerland. In the Netherlands, it is thus far more difficult for users of CNG to realise economic advantages at all, so that an economic motivation for switching to CNG from conventional fuels is unlikely. In Switzerland, several campaigns have promoted the image of CNG as a green fuel (cp. Gasverbund Mittelland AG 2011) and these probably reinforced the individual perception of CNG as environmentally-friendly to a greater extent than is the case, e.g. in Germany.

Saldarriaga-Isazu and Vergara (2009) analysed the reasons for purchasing a CNG vehicle in Colombia in a period during which CNG vehicles were subject to high subsidies. In their study, economic advantages were the main, almost the only driver for purchasing such a vehicle. CNG usage was positively related to bigger cars, commercial car usage, higher mileage, lower distance to CNG filling-station, a lower initial investment, and awareness of the available subsidies. Of those who decided against a CNG vehicle, 26 % did not give reasons, 18 % were afraid of a lower vehicle performance and 17 % had doubts about the economic potential.

Di Pascoli et al (2001) systematically explored the perception of CNG in Italy, surveying a sample of 178 individuals, of which 91 lived near a CNG filling-station. 6 % of the participants owned a natural gas vehicle. 85 % of those surveyed knew that CNG is cheaper than petrol; however, many of them still overestimated the price of CNG. 22 % of the survey participants indicated their intention to buy a CNG vehicle when next purchasing a car; 6 % would choose a LPG vehicle. Poor infrastructure was perceived as the most important barrier. Moreover, concerns which were voiced repeatedly included doubts about the safety of CNG cars and the fear of poor performance. In contrast, performance was most often cited as the reason for opting for a petrol car. Interestingly, individuals who had had direct experience of CNG vehicles were much more likely to opt for a CNG vehicle (48 % compared to 12 % in the no experience group). Furthermore, those with direct experience of CNG were also more likely to choose LPG (10 % compared to 5 %). Indirect experience – i.e. via friends or family – also led to a higher probability of choosing CNG (22 %). This ties in with another result of this study: A vast majority of respondents indicated that family and friends were their main sources of information on these issues.

A similar effect was found by Johns et al. (2009), who analysed drivers with access to vehicles with bivalent engines as part of their organisation's fleet. These drivers could choose whether or not to use alternative fuels. Besides external factors like comfort and ease of filling, the frequency of use depended on informal communication processes between the drivers. As the vehicles were acquired by the company and the fuel was also paid for by the employer, it is not surprising that factors like comfort play a role because the drivers themselves did not benefit economically from either alternative. Still, the study confirms the relevance of social interaction when making decisions about the uptake of an innovation.

DISCUSSION AND RESEARCH QUESTIONS

In summary, the publicly available empirical studies on consumer acceptance of LPG/CNG vehicles are relatively rare and the results are not homogeneous, probably due to the varying conditions under which these studies were conducted. Economic and environmental advantages appear to be the main motives for purchasing a LPG/CNG vehicle across the studies (Kannwischer et al. 2010; RheinEnergie et al. 2006; Jonkers 2009; Saldarriaga-Isazu & Vergara 2009). The specific impact of each of these factors is not clear. While some studies, for example, point out that economic motives are the most important, others indicate that environmental motives are nearly as important and Jonkers (2009) even finds the reverse effect. However, the extent of the possible economic advantage depends heavily on country-specific conditions, e.g. tax reductions and rebates. Correspondingly, the perceived environmental advantage may depend on public campaigns and similar communication processes that have taken place and influenced the image of these fuels.

Referring back to the conceptual framework, economic advantages may contribute to a positive evaluation of LPG or CNG as a fuel in different ways: They may enhance the perceived usefulness as well as the relative advantage and may also be in line with personal or social norms and values. Environmental advantages mostly correspond to compatibility with personal and social norms; however, they do not contribute to the other factors which may also explain why they are sometimes rated second behind economic advantages.

The studies by Di Pascoli et al. (2001) and Johns et al. (2009) point to the importance of colleagues, friends and family: Individuals who know others who drive a CNG /LPG vehicle are more likely to be willing to use one as well. When trying to interpret these results, it is not clear whether people make these experiences by chance and then become more interested in buying such a vehicle, or whether those who are interested in purchasing such a vehicle actively try and gather direct experience. Thus, the direction of influence is not clear – it is probable that both types play a role. In any case, it seems likely that this informal information can help to lower cognitive barriers as well as overcome the innovation bias and thereby contribute to enhancing the perceived usefulness and the perceived ease of use of LPG and CNG as fuels.

Infrastructural deficiencies, safety and reliability concerns, loss of performance, as well as a low willingness to make the higher initial investment are identified as the main barriers to

LPG and CNG (KÜS & kfz-betrieb 2008; Frost & Sullivan 2008; Saldarriaga-Isazu & Vergara 2009; Di Pascoli et al. 2001). All of these factors decrease the perceived usefulness especially with regard to the relative advantage compared to conventional vehicles; thus it is very plausible that these perceptions prevent consumers from becoming interested in acquiring a LPG/CNG vehicle. The high relevance of these contextual factors for the acceptance of CNG and LPG vehicles has been verified by different findings from studies in different countries. In countries without a fully developed infrastructure and no or limited subsidies for gas-powered vehicles, e.g. the Netherlands, environmental advantages become more important as motives for purchasing them (Jonkers 2009). Enthusiasm for the technology or technological innovation in itself might be an additional motive.

Jonkers (2009) notes that, in analysing the evaluations of users, commercial and private use have to be differentiated as an additional contextual factor when interpreting results: In the case of commercial use, the actual user and the individual making the decision to purchase the vehicle are not necessarily the same; moreover, even if economic benefits are likely it may not be the user benefitting from them. This is mirrored in the study by Johns et al. (2009), where comfort factors played an important role.

To sum up, several factors that are likely to play a role with regard to choosing alternative fuels like CNG and LPG have been identified from the literature. However, it turned out that contextual factors - which are often contingent on the conditions within a specific country - also play an important role. Moreover, the decision-making process has hardly been analysed at all. In order to contribute to enhancing the knowledge on this issue, we therefore conducted our own empirical work, focusing on the following topics:

1. How did actual users learn about the technology and what were the most important sources of information accessed prior to the purchasing decision?
2. What are the relevant motives for purchasing a LPG/CNG vehicle? Economic and environmental advantages have already been clearly identified; however, other motives may also play a role. Additionally, the relationship between these two main motives should be analysed in more detail.
3. What were the main concerns of individuals before purchasing a LPG/CNG vehicle and what happened to them during usage? Most studies include the perceived advantages from the perspective of actual users and the perceived disadvantages from the perspective of non-users.

Interviews and questionnaire

METHODOLOGY INTERVIEWS

Semi-structured interviews were conducted. The main advantage of this approach is that the interview resembles a normal conversation; however, a guideline structures the conversation ensuring that all topics of interest are covered. This format was chosen to allow a certain degree of comparability between the individual interviews and to be able to explore new aspects that interviewees might raise due to the openness of the conversation. An interview guideline was prepared covering the topics mentioned in the research questions as well as background questions (e.g. demographics, data on the LPG/CNG vehicle).

Various ways were used to recruit interviewees in order to obtain a heterogeneous sample. Individuals were asked to participate via specialised internet platforms on LPG/CNG and using mailing lists of LPG/CNG drivers. Other individuals were recruited while they refilled their vehicle at fuelling stations. Additionally – and mainly to recruit female interviewees who are underrepresented in the sample – personal contacts were used as well. Twelve individuals aged between 20 and 62 from various professions finally took part (ten men, two women), six of them regular users of a CNG vehicle, the other half users of an LPG vehicle. Most of the interviewees had had their vehicle converted to LPG, or had purchased a CNG vehicle one to three years ago, two of them several years ago.

The interviews were conducted by phone, recorded and later transcribed. The average duration was 30 to 40 minutes. The transcripts were then coded; the topics from the interview guideline were used to produce a preliminary list of codes, which was extended if necessary.

METHODOLOGY QUESTIONNAIRE

As a follow-up to the interview study, a questionnaire was developed as an online survey and distributed to users of LPG or CNG vehicles via specialised online forums. The survey was accessible for three weeks around Christmas in 2010 and usable data sets of 142 individuals were able to be collected. The survey included items on the CNG /LPG vehicle and its current use, mobility behaviour in general (e.g. number of vehicles / household), attitudes towards the environment, technological progress and general price sensitivity, relevant motives in the decision-making process for the vehicle, experiences with the vehicle, socio-demographic data and familiarity with other alternative technologies like EVs.

60 % of the study participants said they own a CNG vehicle, 40 % a LPG one; one respondent owned both. The age of the respondents ranged between 21 and 73 with a mean of 44 years (standard deviation SD=11 years). Male respondents clearly dominated with 94 % of the sample. 42 % stated they had some kind of university degree, 35 % had completed a vocational training.

Descriptive results from the questionnaire are presented in the following together with the interview results in order to complement interpretations of the interview data with more quantitative data. More detailed information on the wording and the answer format of the items is provided in the results section.

RESULTS

Learning about LPG/CNG and information sources

Because time had passed since the decision was made in favour of purchasing the vehicle, some of the interviewees did not remember when and where they had first heard about LPG/CNG as a vehicle fuel. Most of those who did remember stated that it happened accidentally, e.g. via friends or colleagues. Two CNG vehicle users learned about it through local campaigns conducted by energy utilities, a third received an invitation to a specialized automobile fair. Others reported that the idea of using an alternative fuel resurfaced when they started thinking

about purchasing a new car. The promotion of CNG vehicles directed the attention of several interviewees towards this fuel type and sparked their interest. Three users of compressed natural gas vehicles reported that they were very enthusiastic about this type of fuel when they heard about it the first time, because they very much appreciated the combination of economic and ecological advantages.

Before taking the final purchasing decision, all the interviewees searched the internet for further information. Internet platforms of actual users were perceived to be the most helpful source of information as it is assumed that this information is not filtered or driven by a vested interest in selling a certain technology.

> Those offering the conversion of the vehicle will never talk negatively about the technology. […] Thus, it does not make sense to talk to them. I do the same, when I go on a holiday: I look at the ratings on the internet, the ratings of those who have been there. […] It's a similar case for LPG. (P4, LPG vehicle)

Interestingly, some of the interviewees also mentioned the problem that these kinds of internet platforms might give the impression of being negatively biased since people primarily use them to discuss problems with the technology. They concluded that it is important to keep this in mind when forming an opinion by referring to this source. Talking to actual users was also a valued way of gaining further information; however, not all the interviewees had that possibility.

> Because we had someone around who knew a lot about it, we had all the information needed, we knew about the advantages of the technology. And that made it easy for us. That's great if you have such an expert around. (P10, CNG vehicle)

Car dealers/mechanics were also consulted; however, the information provided by them was repeatedly characterised as being of low quality and negatively-biased towards LPG/CNG.

> I had to persuade my car dealer to sell me a CNG vehicle. […] He would have preferred to give me a diesel vehicle. (P6, CNG vehicle)

Consequently, these users had to be even more convinced of this technology if they had to persuade their car dealer first.

The survey included five questions about how the participants collected information before making the decision about the LPG or CNG vehicle. The questions consisted of statements that were rated on a seven-point Likert-scale (1=applies not at all, 7=perfectly applies). The answer patterns reveal that users were most likely to either talk to other users and / or collect information from specialised media (including the internet): These two items received the highest mean ratings, each with a mean of 4.9. The knowledge or expertise of repair shops (mean rating of 2.9) and car dealers (3.0) was referred to less frequently; similarly, friends and family in general were also less frequently consulted (3.3).

Motives for purchasing a LPG/CNG vehicle

Economic advantages were mentioned most often as a motive and this was also the most important motive for several of the interviewees. Economic advantages were expected because many of the interviewees have relatively long commuting distances to their workplace.

However, two CNG users explicitly noted that the vehicle is not economically advantageous for them, one of them stating:

> … on the other hand, I enjoy it, simply, I enjoy driving the most recent technology up to now. (P6, CNG vehicle)

Environmental advantages were also an important motive. However, their relevance differed among the interviewees: While some of them saw them as positive side-effects, others, especially the CNG users, rated them as being very important.

> Conventional fuels are always bad for the environment. And gas is environmentally-friendly, I always liked it, we also use it for heating our home; insofar, we or I always thought that this would be the best alternative if it was possible. (P10, CNG vehicle)

One CNG user noted that CNG vehicles are also able to run on biogas, which is carbon neutral. For this reason, he rates biogas as better than natural gas in terms of sustainability and future potential. Enthusiasm about the technology was also mentioned – explicitly, as in the quote cited above, or implicitly, as a motive for purchasing a LPG/CNG vehicle.

In the questionnaire, participants were asked to rank the motives of economy, environment and technology according to their preferences at the time of purchasing the vehicle. Preliminary analyses of the survey data confirm the conclusions from the interviews: For two thirds of respondents, the economic motive was the most important one, and one third puts the main emphasis on the environment. Very few ranked technology in first place, but it is the second most important motivation for 20 % of the participants. An additional open question allowed participants to complement this list; although several participants entered statements here, they all referred to the three motives already included.

Prior concerns and actual experiences with the vehicle

Several interviewees remembered that during the decision-making process they were afraid that it might be dangerous to use CNG/LPG and of a possible explosion of the vehicle. Only two of the interviewees mentioned that they had concerns about the infrastructure.

> I heard that the infrastructure is bad. Thus, I was concerned about this. However, then I looked for further information, where do I usually drive, where do I go for holidays. (P5, CNG vehicle)

Others expected problems because the technology is relatively new and, thus, maybe less reliable. They searched the internet to find further information on this issue. Another interviewee worried whether the LPG powertrain would negatively influence the performance of the car. Further concerns were connected to the high pressure in the CNG tank and the process of refilling.

> I was a bit afraid about the refilling – I mean, there's a lot to screw and to consider, that was a bit, hmmm, well, I was a bit reluctant at the beginning. (P12, LPG vehicle)

However, at the time of the interviews, all interviewees stated that they were happy with their choice. Some of them had tech-

nical problems at the beginning, which, however, were able to be resolved. The technology is perceived to be safe:

> Well, you always think, gas, uuh, that's explosive etc. but that's nonsense. (P11, LPG vehicle)

Infrastructural gaps required some flexibility, e.g. regarding the choice of holiday destination, especially from those who have been using the technology for several years.

> No, I wouldn't go anywhere, where I can't refill. (P6, CNG vehicle)

Another interviewee found another strategy to deal with bad infrastructure during holidays:

> When I'm on holidays, I have the time to go detour or to make an additional break or whatever, you know. During holidays, I don't mind it. (P9, CNG vehicle)

The topic of infrastructure did not turn out to be relevant for LPG users, who stated that it is not necessary to prepare for journeys and that they have always been able to find a refilling station without major problems.

Refilling itself became a moment of pleasure for several of the interviewees:

> Then, it's this smile at the refilling station: When the others pay 1.55, and we pay 0.60. […] That's more than happiness, that's … Well, I'm always pleased. (P4, LPG vehicle)

Thus, during actual usage, the concerns held prior to the purchase were usually solved and disappeared.

Perceived attitudes by others towards driving a LPG/CNG vehicle

The interviewees reported different reactions by others to their gas-powered cars. Some noticed that only those friends or acquaintances with a prior special interest in technology, knowledge of gas vehicles and/or direct or indirect experiences were interested in the gas-powered vehicle and often reacted in a positive way concerning the adoption. The others were not interested at all. About half of the interviewees remembered sceptical reactions (e.g. concerning loss of vehicle power, reliability, infrastructure, risk of explosion).

Other interviewees experienced their peers expressing strong interest in the technology with the intention to buy, but when these people learned about the necessary initial investment, a lot of them lost interest. However, four gas-users were able to persuade colleagues, family members or friends of the advantages of gas-powered vehicles; as a result, these people also converted their cars to LPG, or purchased a CNG vehicle.

One owner of a natural gas-powered vehicle had the feeling that others admired him for his courage in using a relatively unfamiliar technology. It is important to note that this user bought his first CNG vehicle in 2001, when natural gas vehicles and refuelling stations were very rare in Germany.

Two CNG users reported negative reactions to their gas-powered cars. In one case, colleagues made fun of him and his car (e.g. they joked he was no longer able to afford to buy petrol). Another owner had the impression that acquaintances regarded him as a freak due to his decision to change fuels. Concerning the reactions of strangers to the gas-powered cars, e.g. at filling stations, several interviewees noticed that the interest of non-users in the technology varied according to the price of conventional fuels. Seven interviewees reported that they had been addressed by petrol- or diesel-users while refuelling (two of them have stickers on their cars which indicate they use gas – consequently this arouses the interest of non-users more frequently and in more places).

The questionnaire also included five items referring to the perceptions and attitudes of others towards driving a LPG/CNG vehicle as well as self-perception. Items presented the following statements that were rated on a seven-point Likert-scale (1=applies not at all, 7=perfectly applies):

- People react positively if they see a LPG or CNG vehicle on the street.
- LPG/CNG vehicles have a good image in society.
- People that are important to me like LPG/CNG vehicles.
- This vehicle is congruent with my personality.
- My acquaintances will notice it, if I am driving a LPG/CNG vehicle.

Figure 1 illustrates the answer patterns.

It turns out that the ratings of the perceived positive reactions by others, as well as the notice taken by acquaintances range around the neutral point of the Likert-scale. The fact that LPG and CNG vehicles are not recognisable as such at first sight might have negatively influenced these ratings. However, more participants have the impression that the persons who are important to them positively evaluate them driving the LPG/CNG vehicle. The item referring to the congruence with personality received the most positive rating. Participants used the full Likert-scale to express their opinions and all standard deviations exceeded 1.3, implying that the experiences made and the participants' perceptions of these issues are not unequivocal. On a more general note, the answer patterns are congruent with the interview results where interviewees reported mixed reactions in general. The higher rating for personality fit can be seen as matching the general high level of satisfaction of the interviewees with the decision which was mentioned in an earlier section.

Discussion

SUMMARY AND DISCUSSION OF RESULTS

It was the aim of the empirical studies to complement the findings from the literature with regard to three aspects:

1. Strategies for acquiring information prior to the purchasing decision
2. Motives for purchasing a LPG/CNG vehicle, and
3. Main concerns prior to the decision and the experiences made in relation to these concerns.

The interviews revealed that those questioned had learned about the possibility of using LPG or CNG as a fuel for their cars on various occasions and from diverse sources. However, when individuals went systematically looking for further information, their experiences converged: The internet is the most important source of information, especially social online

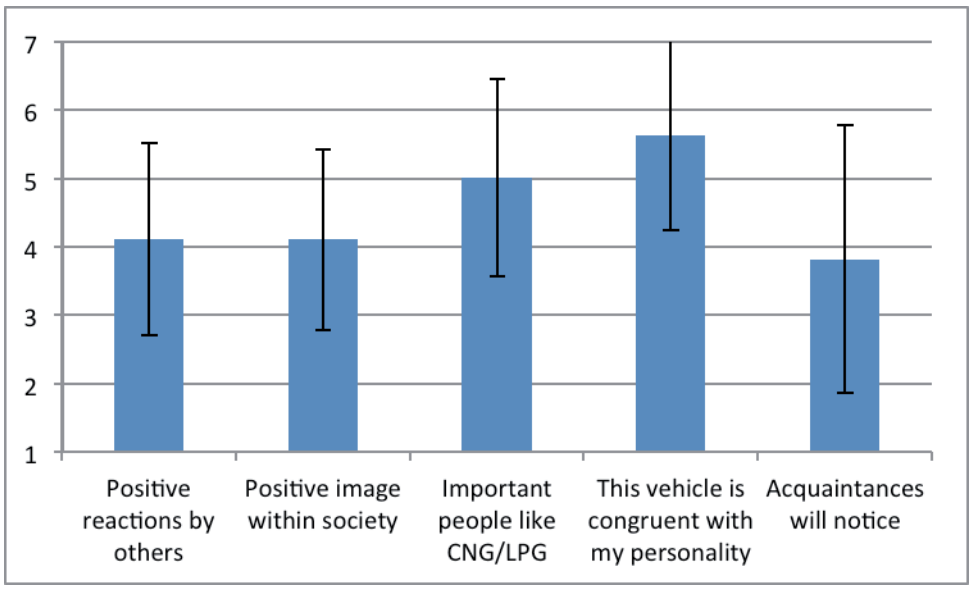

Figure 1. Ratings of questionnaire participants on items concerning social and individual attitudes towards LPG/CNG vehicles; n=142; 1=applies not at all, 7=perfectly applies; Mean ratings and standard deviations.

networks like specialised platforms. Although the interviewees regard some of the information provided there as being biased, it is still seen as a valid data source during the decision-making process. Talking directly to other users was also regarded as helpful; however, not everybody had this opportunity. These two findings are congruent with the answers provided by the greater number of questionnaire participants. Generally, this is also in line with findings from the literature (Di Pascoli et al. 2001; Johns et al. 2009). Furthermore, the interview results confirm the assumption that knowing other users supports the decision in favour of an LPG/CNG vehicle and that these contacts are also actively sought out by those who are already interested in the technology. Other sources of information, e.g. car dealers, were seen as less helpful for forming an opinion. In sum, these reports seem to indicate that the information provided by persons who are trusted and regarded as reliable contributes to increasing the perceived ease of use as well as the usefulness (e.g. in realising economic advantages), and helps to reduce all three biases identified from the literature, i.e. cognitive barriers as well as a possible functional or innovation bias.

The main motives from the literature for buying an LPG/CNG vehicle were confirmed by both studies. Economic motives ranked first; however, the environmental impact was also important for most interviewees, some regarding it as a positive side-effect, others rating it as important as economic reasons. A third motive, although less dominant, was simple enthusiasm for the technology and for using a modern and innovative fuel. There were no indications from the studies that other motives might play a central role.

The interviewees recounted having had various concerns about safety, reliability, availability of filling stations, performance losses, and the process of refilling, all of which affect the usefulness and the ease of use of LPG/CNG vehicles. Overall, these concerns resemble those found in the literature. However, the lack of infrastructure, which is often mentioned by non-users in surveys (KÜS & kfz-betrieb 2008; Di Pascoli et al. 2001), was not referred to very often by the interviewees – at least they did not recollect having had major concerns about this. Generally, all interviewees were satisfied with their decision; most of the concerns did not turn out to be relevant in everyday-life or they were easily able to develop strategies to deal with them, e.g. strategies to deal with infrastructural gaps. Concerning the reactions of strangers to the gas-powered cars, e.g. at filling stations, several interviewees noticed that the interest of non-users in the technology varied according to the price of conventional fuels, an insight which is also found in the literature (de Haan et al. 2007). The questionnaire data also mirror the mixed experiences in this regard.

These results reveal that the advantages of LPG/CNG are not immediately obvious to the general public in Germany – a finding that has to be expected taking into account the market characterisation and the state of knowledge among non-users cited above. Neither LPG nor CNG vehicles seem to have a clear "green" image in Germany, perhaps due to the fact that they are non-renewable resources and that a precise assessment of their environmental impact is a complex business, especially for LPG. Di Pascoli et al. (2001) found similar results: respondents regarded CNG as simply "gas" – the technology is not perceived as anything new or very innovative. Apart from this, surveys of non-users also indicate that the majority is not aware of the difference between LPG and CNG (KÜS & kfz-betrieb 2008), thus negative information about either of the two fuels may also impact the perception of the other one (e.g. doubts about the environmental advantages of LPG or the limited infrastructure for CNG). However, the fact that several users in the interview study reported having been able to persuade non-users of the benefits of LPG/CNG illustrates the importance of indirect experience for the adoption of alternative fuels, which corresponds to the results of Di Pascoli et al. (2001) and Struben & Sterman (2008). When questionnaire participants indicate they see (some) fit between the use of LPG/CNG and their personality, this is congruent with the fulfilment of personal norms. The relevance and impact of social norms is difficult to evaluate in this study. The visibility of LPG/CNG seems to be relatively

low among the public – which is not surprising because CNG vehicles are usually special editions of conventional models, which share the same design, and LPG vehicles are usually conversions of conventional vehicles (ADAC 2010b). Thus, it is almost impossible to tell from the outside if a vehicle uses these alternative fuels – the users themselves have to provide others with this information (e.g. in personal discussions or via signs/stickers attached to the vehicle). The only situation where the use of these kinds of fuels becomes obvious is during refilling.

Before the transferability of the results of this paper to EVs can be discussed, it is necessary to point out the limitations of our empirical data. The generalizability is limited due to the fact that both the qualitative and the quantitative study have relatively small sample sizes and are neither representative for the German population in general, nor German car-users in general (e.g. men being strongly overrepresented in the sample). Precise statistical data could not be found on the population of German CNG /LPG users or users of alternative fuels, so it is not possible to assess the extent to which our sample is representative for this population. Moreover, self-selection effects are likely here, e.g. that individuals who had positive feelings about their decision are much more willing to provide information about them. Thus, positive evaluations might be overrepresented in our sample. Since the infrastructure and subsidies from the state or gas suppliers play a crucial role in consumer acceptance of LPG and CNG, the results of this study cannot be applied to other countries. Further limitations result from the fact that the interview was conducted after the decision-making process and the memory gaps of interviewees might affect the results. However, as the number of studies researching these issues on a detailed level is very low and as we asked actual users of LPG/CNG vehicles about their experiences and are thus building on reports of real practices and behaviours, we assume some validity for our results. This is underlined by the finding that the overall results are congruent with the findings from the literature; however, they also add further details to several of these findings.

With regard to future research, further analyses of information search strategies may be important in order to inform politics and industry about effective strategies for supporting the market entrance of new technologies. Additionally, in this context, it might be useful to survey individuals who started to gather information about LPG/CNG vehicles and then decided against a purchase. This would also contribute to overcoming the possible self-selection effects of our study.

CONCLUSIONS FOR ELECTRIC MOBILITY

This study was motivated by the intention to acquire knowledge that could be useful for assessing the potential of electric vehicles from a consumer's point of view and to develop recommendations on how to support the market penetration of electric vehicles. LPG and CNG vehicles were identified as a valuable analogy as they have been available on the market for some time and have attracted a relevant number of users. Furthermore, it was assumed that they share some characteristics with EVs from a consumer's point of view: They are all relatively new fuel alternatives on a vehicle market that is dominated by petrol and diesel, they require a new kind of infrastructure as well as a higher initial investment by the user and share the image of offering environmental benefits.

Our analyses indicate that economic and environmental motives are the central ones for those willing to invest in an alternative technology. In Germany, (potential) users of LPG/CNG vehicles can estimate on a relatively clear basis whether they are likely to realise economic benefits as the premium for the technology and the price for the vehicle are known as are the expected tax reductions. If the user has basic knowledge of their typical yearly mileage, he/she can make a fairly reliable estimation. This appears to be very important because participants emphasised the relevance of this motive. However, these estimates are less clear for EVs and the premium which has to be paid in relation to a comparable or even a smaller conventional car is much higher (Gastes & Paetz 2011). This underlines the fact that it will probably be very important to offer additional financial incentives for buying an EV, e.g. in the form of subsidies. If economic advantages cannot be realised by EV users, measures will have to be taken to direct the public's attention to other motives.

Environmental concerns also had some relevance in our studies, but usually ranked second behind economic motives. This indicates that there may be some potential to motivate people to invest in a technology on these grounds. However, at least from the point of view of the sample of our LPG/CNG users, this does not appear to be a very promising option. Studies which analysed the use of LPG/CNG under less favourable economic conditions (especially Jonkers for the Netherlands indicated that reinforcing environmental motives may be worthwhile – but the potential market share to be gained from building solely on environmental efforts is probably quite small. Enthusiasm for technological progress was not a very dominant motive in our study; it could, however, have supporting effects. This is especially important when transferring our results to EVs: LPG/CNG vehicles use fossil fuels like conventional cars and they are usually not recognisable from the outside and thus have low visibility. This is different for EVs. Thus, it is likely that EVs harbour a greater potential for fulfilling motives like showing personal innovativeness. That this motive is rated low in our study may simply be the effect of the limited potential to fulfil this motive using an LPG/CNG vehicle.

Furthermore, our analyses suggest that experience as communicated by other users seems to be one of the most important factors to boost the perceived reliability and safety of a technology, enhancing its perceived usefulness and ease of use. On this basis, we recommend creating possibilities for informal social interaction around electric vehicles as an important element for successful marketing. Users seem to place strong trust in first-hand information from other users – in this respect, projects like the field trials which are a popular instrument at the moment seem to be very promising. Additionally, setting up and promoting internet forums on electric vehicles is another way to induce contacts between users and potential users. Our analyses indicate that infrastructural concerns are lower among those willing to use an LPG/CNG vehicle than among car drivers not interested in the technology. On the one hand, this insight seems banal as users who are seriously afraid of not being able to get fuel will certainly not acquire the respective vehicle. On the other hand, the experiences reported by the interviewees showed that, in reality, infrastructural drawbacks were seen as relatively low. It can be concluded that, although

public infrastructure for EVs might be relevant, e.g. for the visibility of the technology, the necessary electricity supply is actually provided for a large share of potential users via home-charging (Biere et al. 2009) so that issues around investments in public infrastructure should not be overestimated when promoting the market entry of EVs. It might be more important to direct potential users towards the already available options for charging the EV, e.g. at home or at the workplace, in order to reduce innovation and functional bias.

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