First come, first served: Profiling the potential early users of H_2 cars

Analysis of current car purchasing, driving and refuelling behaviour in the Netherlands

J. Backhaus

I.G. Bunzeck

R. Mourik

ECN-E--10-081 December 2010

Acknowledgement/Preface

This report is part of the THRIVE project, a study on the possible build-up of a hydrogen infrastructure in the Netherlands. The project is jointly carried out by ECN, Shell, Linde and TNO. Within ECN, the units Clean Fossil Fuels and Policy Studies contribute to the project. THRIVE is financed by Agentschap NL within the EOS-LT program under contract number EOSLT06025. The authors would like to thank Marcel Weeda and Ynke Feenstra for reviewing an earlier version of this report. This project is registered at ECN under the numbers 7.0325 (Clean Fossil Fuels) and 7.7897 (Policy Studies). Contact person for this publication is Ingo Bunzeck, email: bunzeck@ecn.nl.

Abstract

This report discusses people's car purchasing, driving and refuelling behaviour in order to get insight into requirements people have with respect to personal mobility. Insights gained deliver important implications for the introduction of hydrogen cars. Neither the vehicle technology nor the refuelling network is currently commercially available for a mass-market, however, both need to eventually meet current performance of and fuel availability for conventional cars in order to increase the likelihood of market success. Extensive literature review and a survey among 3000 Dutch drivers aimed to provide insight into issues determining vehicle purchase, driving and refuelling practices.

Outcomes show that most newly built cars are currently bought by the older segment of the Dutch population, with a higher income. It is particularly the male part of the population which makes use of the car most frequently. Generally, Dutch people buy cars in the C size segment (comparable to VW Golf), while currently most hydrogen models are available in the D segment with larger sized cars (e.g. VW Passat). However, the particular group who is likely to represent the largest group of initial buyers (older, male, high income), which may be most interested in the new technology and most likely to be able to afford it may also purchase cars of the larger vehicle segment. Previous studies have shown that people require a car price, driving range, and performance similar to what they are used to now in order to consider switching to an alternative fuel vehicle. Additionally, people are very brand loyal. The most frequently sold brand in the Netherlands is VW, which has no proven technology in demonstration projects so far.

Concerning requirements for refuelling station coverage Dutch drivers indicated in a survey conducted during the THRIVE project, that they most often refuel in the built environment, on the way to work, shortly after leaving home in the first five minutes of the trip. However, drivers also demand hydrogen to be available at 30 to 50 percent of all stations throughout the Netherlands, along highways and abroad in order to consider buying a car driving on an alternative fuel. Earlier research indicated that a well-planned refuelling infrastructure may provide current refuelling convenience at a lover coverage level of 10 to 20 percent. Recommendations following the outcomes of this report propose refuelling infrastructure development in the built environment at stations with high-turnover, along highways in the whole country and abroad, based on international cooperation at European level.

Contents

List of tables

List of figures

Executive summary

This report discusses current car purchasing and driving behaviour in the light of a strategic introduction of hydrogen fuel cell vehicles to the Dutch car market. Hydrogen fuel cell cars are a relatively novel technology but currently the technology is shifting from research and development (R&D) to an early market commercialisation phase, suggesting that vehicles will be available on the market within a few years. It is expected that in the first years of market introduction, manufacturers will not offer the full range of their models as a hydrogen fuel cell vehicle. Also, the initial price level for a hydrogen vehicle will be above that of a comparable vehicle that runs on conventional fuel. These issues influence the segment of people considered to be the first user group for hydrogen vehicles.

Within the framework of the THRIVE project it is of interest to gather more information on the profiles of Dutch car drivers. Parameters analysed are age, income, price and performance requirements, brand loyalty and current car purchasing decision-making behaviour. This can provide a picture of who might be the prototypical first users for hydrogen fuel cell vehicles in the Netherlands. Additionally, it is checked whether there are locations in the country that have higher concentrations of potential first users. This can have important implication for the development of a hydrogen refuelling infrastructure.

Age, income and location of potential first buyers
Generally, it can be concluded that it proves difficult to provide a sharp profile of potential first users of hydrogen vehicles. One reason for this is that decisive factors in car purchasing behaviour can change over time. Male citizens who are above 50 years of age and earn significantly more than the Dutch average (~ € 19,000 per year) can be expected to be potential first buyers of hydrogen cars. The build-up of hydrogen fuel stations should initially focus on the larger cities and high-income areas, as these locations represent the highest volume of potential first buyers. The highest income areas in the Netherlands are concentrated around larger cities, such as the area called ‘Randstad’ (Amsterdam, Rotterdam, Utrecht, Den Haag) or the other big cities of Arnhem and Eindhoven.

Knowledge and potential first buyers
Literature points at a positive correlation of education and knowledge concerning climate change and acceptance of low- or zero-emission technologies. Although literature suggests the segment of people that is strongly environmentally concerned is more willing to buy an environmental friendly vehicle, further research is necessary to link this knowledge and awareness issue to actual purchasing power and age parameters. At the time of writing people’s general knowledge of hydrogen as fuel is low and the number of popular media focusing on hydrogen cars is limited. Efforts could be directed towards more (positive) story telling about hydrogen vehicles in the media.

Vehicle and environmental performance and potential first buyers
Literature agrees that the most decisive factors in car purchasing-behaviour are (irrespective of order mentioned) brand, price, performance and other technical characteristics (e.g. up-to-dateness). If price and performance diverge greatly from what people are used to today, the uptake of hydrogen vehicles is expected to be considerably slower. The operating distance seems to be of particular importance and should enable the user to drive 400-500km without refuelling. It is the stated aim of the car manufacturers to offer hydrogen vehicles that have equal (or very close) performance characteristics compared to conventional cars, with comparable driving range, top speed and torque.

Environmental friendliness as such might not be a motivational factor for a specific car purchase. This characteristic is however indirectly taken into account through a preference for performance improvements such as decreased fuel consumption or refuelling cost which increasingly have the added benefit of increased environmental friendliness. It can, however, be assumed that environmental performance of vehicles can have a stronger influence on future purchasing decisions, especially if governmental incentives would continue favouring low- or zero-emission vehicles over conventional cars, e.g. by providing financial incentives.

Vehicle purchasing costs and potential first buyers

Above all, the most decisive purchasing factors are brand, price and performance of the vehicle. Consumers often choose from within the portfolio of a certain manufacturer they know and trust. If the first hydrogen vehicles are going to be considerably more expensive than regular fuelled cars, the likely group of early adopters of emission free vehicles would be the above average income class which is less price-sensitive. The market introduction of hydrogen vehicles in the Netherlands can be significantly influenced by governmental incentives that favour environmental cars over their conventional counterparts (e.g. by lowering the purchasing price by fiscal measures, incentives schemes, tax breaks for new technologies and agreements with manufacturers), all other issues such as performance being equal. Generally, for successful large-scale introduction of hydrogen vehicles, these vehicles need to be closely geared to conventional vehicles in terms of purchasing costs. The focus of hydrogen car manufacturers seems to be to a large extent on the lease segment, but this segment is most probably not going to be the first buyer of hydrogen cars because of cost efficiency issues.

Fuel costs and potential first buyers

Fuel price is one of the factors influencing the motivation to purchase an alternative car. In general it can be stated that the if the price of the alternative fuel is lower than the price of regular fuels over an extended period of time, drivers are more willing to consider switching to the alternative. A high petrol and diesel price over an extended period of time, coupled with purchasing incentives for alternative fuel vehicles can also be important market stimulants for hydrogen fuel cell vehicles. Consumer research can give important insights how fuel cost and pay-back times can be communicated most effectively.

Car brand, availability of models, customer loyalty and potential first buyers

Although the portfolio of available models may be limited in the beginning, car manufacturers should initially aim at the currently best-selling models among the male part of the population, which is older than 50 years of age and receives an above average income. The analysis of the current car fleet in the Netherlands shows that the brands and models sold most in the Netherlands do not match well with those currently available as hydrogen models. The six most frequently bought brands are Volkswagen, Toyota, Ford, Peugeot, Opel and Renault. Of this list, only Toyota, Ford and Opel are known for hydrogen fuel cell activities, while VW, Peugeot and Renault have not indicated much interest in this technology so far. Other major hydrogen players, namely Daimler, Honda, Hyundai and Kia, only hold smaller shares of the Dutch market. Of those three, only the last two have employed hydrogen cars in demonstration projects. However, the preferred size segment of Dutch car owners, namely the C segment (e.g. VW Golf) is currently only served by Daimler and Ford with hydrogen models. With the latter there is at least one top-selling car and size segment represented in the hydrogen models under development. The analysis did not go into sufficient detail to determine which size segment is most frequently bought by the earlier profiled first potential users of hydrogen cars, namely the male, above 50, higher income population segment.

Fuel availability, driving and refuelling patterns and potential first buyers

In addition to purchasing behaviour this report also analysed current driving and refuelling behaviour in order to gain insight into the kind of vehicle performance and fuel availability/refuelling station density required by users at market introduction of hydrogen cars. The annual mobility survey by the Dutch Ministry of Transport and Water works shows the car as

main means of transportation in the Netherlands, especially among the male, older and higher earning part of the population.

Drivers are currently used to a rather dense network of refuelling stations, especially in densely populated areas, and are generally not very willing to drive detours in order to refuel their car. Initial low fuel availability could therefore become a main obstacle to the successful introduction of an alternative fuel ('chicken-and-egg' problem of refuelling station availability and vehicle use). Due to the fact that most people currently refuel in the built environment but also require coverage along highways and abroad, early refuelling infrastructure roll-out could focus on highly frequented stations along daily commuting routes, and large stations at traffic hubs along highways. An initial hydrogen roll-out calls for a rudimentary coverage of the whole country and not just of key-cities or regions. In addition, European coverage will increasingly support the acceptance and uptake of hydrogen vehicles.

A survey among 3,000 Dutch car drivers revealed that most people refuel their car most frequently in the beginning of a trip, but still close to their home, about 5 minutes after leaving. They choose a refuelling station largely because of fuel price and location. Based on these determinants, most people currently refuel in the built environment, where stations are close to their home and comparatively cheaper than those along highways. Few people drive detours in order to refuel their car and those who do, only drive an extra 5 to 10 minutes. To consider switching to an alternative fuel, the majority of respondents requires sufficient fuel availability throughout the Netherlands, preferably at their most frequented refuelling station. Most people view 30-50 percent as 'sufficient' coverage. Earlier research has shown that a way to circumvent this high coverage in the beginning of hydrogen refuelling station build-up is to strategically plan the refuelling network focusing on a high predictability of stations offering the alternative fuel. This means that the necessary coverage of hydrogen stations to meet user requirements could be about 10-20% of regular fuelling stations. Besides national availability, also the fuel availability abroad is of concern to a rather large segment of Dutch drivers.

1. Introduction

This report has been written within the THRIVE project that analyses the build-up of a possible hydrogen infrastructure in the Netherlands. The THRIVE consortium consists of ECN and TNO as research institutes as well as Shell and Linde Benelux representing the industry. It aims to provide plausible routes and technological options for a hydrogen refuelling infrastructure for hydrogen-powered fuel-cell vehicles in the Netherlands. '*Plausible'* in this context does not only refer to cost and technical feasibility, but also explores other aspects, such as socio-economics, e.g. consumer behaviour with respect to the introduction of innovative technologies and other, non-technical reasons that need to be considered during the introduction process.

The project is based on the for this research taken for granted the premise that commercial roll-out of hydrogen vehicles and the development of the necessary infrastructure commence in the current decade (2010-2020). The 'plausible development' is projected up to 2050 with a focus on hydrogen as a transport fuel for passenger cars.

Part of the socio-economic research by ECN (unit Policy Studies) is a study on the current car purchasing and driving behaviour of people in the Netherlands and its implications for the introduction of hydrogen cars. Likely the first hydrogen vehicles available on the market will be more expensive than comparable conventional cars and it is therefore assumed that initially only a fraction of the total market comes into consideration for buying such a vehicle. In addition to the car purchase, the density of hydrogen refuelling stations require from a consumer perspective is of importance and needs to be understood in order to facilitate the introduction of hydrogen as alternative fuel.

The first part of this report (Chapters 2 and 3) deals with the factors influencing consumers' decision-making process when purchasing a car and aims to shed light on the question who might be the first buyers of hydrogen vehicles. The second part (Chapter 4 and 5) represents the results of two studies, one on the general travel behaviour of Dutch society and one that focuses on current refuelling behaviour of Dutch drivers and their willingness to switch to an alternative fuel. The sixth and final chapter presents conclusions drawn from the two major parts and their implications for the potential first user group of hydrogen vehicles and what their requirements are.

1.1 Rationale for studying purchase and refuelling behaviour

Cars that are propelled by a fuel cell, converting hydrogen into electricity represent a radical innovation in the transport sector and have a fundamentally different principle than the internal combustion engine. The introduction of hydrogen as a fuel will start with a (still small) variety of models being offered for purchase. Therefore, it is imperative to understand what factors influence consumers' choice for a specific car. In this report there will first be a focus on main parameters driving consumers' decision-making when buying a new car (e.g. costs, performance, environmental consciousness, knowledge). The discussion aims to evaluate which of these parameters may work in favour of the purchasing of a hydrogen-powered car. At the same time, it will become clear how consumer preferences can hamper the transition to an increased use of hydrogen cars. Following the focus on purchasing factors, sales figures help to get insight into the current models preferred by those who buy new cars.

Secondly, also the refuelling infrastructure for an alternative fuel needs to be in place early in order to make the switch to hydrogen-powered vehicles attractive to consumers. Generally, research states that an alternative fuel needs to be available conveniently and sufficiently in order to accommodate a smooth transition for consumers. What 'convenient' and 'sufficient' actually

mean, in terms of number and location of refuelling options, needs to be investigated as neither the dispersion of hydrogen refuelling points, nor the actual refuelling process should pose significant barriers to the introduction of the new fuel. It is therefore important to understand how, when and where people refuel their car nowadays in order to understand the most optimal situation for planning of a hydrogen refuelling infrastructure.

1.2 Research questions

This report aims to shed some light on current purchasing and driving/refuelling behaviour of people in the Netherlands in order to deliver important insights for the introduction of hydrogen cars and the development of a hydrogen-refuelling infrastructure. The research questions guiding the report were as follows:

1. What are the main factors influencing people's decision-making process when buying a new car?
2. What are current driving patterns of people in the Netherlands?
3. What does current refuelling behaviour look like?
4. Under what prerequisites would people be willing to switch to an alternative fuel?
5. What insights can be formulated as 'lessons learned' for the development of a hydrogen infrastructure and the introduction of hydrogen powered vehicles?
6. What are implications of these 'lessons learned' for the modelling of hydrogen vehicle uptake in the Netherlands?

1.3 Methodology

This report is based on desk research (relevant (international) publications and statistics) and a large-scale online survey among 3000 Dutch respondents.

2. Buying a new car - decisive factors, decisions made and implications thereof for the introduction of H2 vehicles in the Netherlands

2.1 Age, Income, Location and Car Ownership

One of the main factors contributing to the choice of vehicle is the budget available. Generally, age and income are positively related and older people have higher purchasing power (for various reasons, e.g. higher income, less children to support). Research conducted at the Swiss Federal Institute of Technology Zurich (ETHZ) argues that at present in Switzerland, buyers of new cars are generally older people with higher purchasing power, who have fewer kids under the age of 18, and who make on average more vehicle miles per year than the rest of the population. Younger users who usually still have more kids younger than 18 and travel less kilometres per year are more price sensitive and more frequently buy second hand cars (De Haan et al., 2007).

In 2008, the Dutch Ministry of Transport published a statistical report on Dutch mobility of the previous year. Results of this report focusing on mobility patterns will be discussed in more detail in Chapter 4. The figures relating to the general Dutch population show the following: firstly, the more people earn, the more likely they are to possess a car. While for example, about 50% of those who earn between € 7,500 and € 15,000 per year own a car, this holds for almost 80% of those who earn between € 22,500-€ 30,000 yearly. Secondly, people who earn more also drive younger/newer cars. While of those people with an annual income between € 7,500-€ 15,000 55% drive a car that is older than 10 years, this only holds for 25% of those in the higher income class with € 22,500 - € 30,000 per year. Furthermore, while only 15% of the former group drive a car that is between 3-5 years old and only 4% own a 2 year old car, these numbers increase to almost 26% and 12% for the higher income group. Thirdly, the older people are, the more likely they are to possess a car. While about half of the Dutch population in the age of 25 to 30 years owns a car, there is a peak for men at the age of 50-65 years with ~83% car ownership and for women in the age of 30-50 years with ~63% (MON, 2008). These numbers clearly suggest that the first people who are able to afford a new hydrogen powered car are older and earn more relative to the Dutch average. If one assumes that cars with newer propulsion systems will be more expensive, it follows that the first buyers of hydrogen vehicles can be assumed to be the older, less price sensitive population segment..

To arrive at conclusions as to where the potential first buyers and users of hydrogen cars might be located it is worthwhile considering where groups of above described citizens are concentrated in the Netherlands. The following table shows the average available income for the five top earning Dutch municipalities and the four cities Amsterdam, Rotterdam, Eindhoven and Arnhem[1].

[1] Amsterdam, Rotterdam and Eindhoven were included as the biggest urban agglomerations in the Netherlands. Arnhem was included due to its geographical position on the 'Eastern edge' of the Dutch areas with highest population density and because of already ongoing hydrogen activities in this region.

Table 2.1 *Municipalities and income*

Municipality/City/Region	# of earners * 1000	Net inc. p. earner[2] * € 1000
Wassenaar	15.7	31.1
Bloemendaal	11.0	31.4
Blaricum	5.9	29.0
Naarden	11.1	26.3
Abcoude	5.6	26.5
Amsterdam	486.8	19.0
Utrecht	188.7	18.2
Eindhoven	144.4	17.6
Rotterdam	381.1	17.3
Arnhem	96.2	17.1
Netherlands	10894.4	18.2

In line with the earlier mentioned relation between age and income, the average age of people living in the top-three above mentioned municipalities, Wassenaar, Bloemendaal and Blaricum is 3-4 years higher than the Dutch average of 39.9.

Concluding, literature and Dutch statistics agree that male citizens who are older and earn more than the Dutch average own the youngest cars and drive most kilometres per year. Their purchasing power profile fits best with probable hydrogen car buyers. Younger people often buy second-hand and hence drive older cars. In order to drive a hydrogen vehicle most will have to wait for these vehicles to be available on the second-hand market.

People matching the profile frequently live in the smaller municipalities close to the larger cities Utrecht and Amsterdam. Several municipalities west and north of Amsterdam host more than the average amount of older and financially better off people. While the age and income figures for the four cities Amsterdam, Arnhem, Eindhoven and Rotterdam do not reflect a higher than average presence of the segment with high purchasing power, because of the high population density and volume of these areas it can be assumed that the larger cities of the Netherlands would provide a sufficient high concentration of potential first buyers of hydrogen vehicles.

Conclusions with respect to age, income and location of potential first buyers

- Male citizens who are above 50 years of age and earn more than the Dutch average (~ € 19,000 per year) can be expected to be potential first buyers of hydrogen cars.
- The build-up of hydrogen fuel stations should initially focus on the larger cities and high-income areas (see table above for example municipalities), as these locations represent the highest volume of potential first buyers.

2.2 Green voting behaviour and green action

One possible indication how much people value sustainability and environmental performance is their voting behaviour. People who vote ‘green’ have such issues on their agenda, most likely also on their personal one. Green voting in this context should be understood as showing sympathies for parties that emphasize issues such as environmental protection and nature conservation in their political agendas. Therefore, they might be likely to let these aspects play a role in their behaviour, e.g. in their car purchasing choices. This chapter is assigned to finding out more about those people who vote for green parties.

In the US, where voters can be registered for a certain party research has shown that those who have signed up for the green party indeed also vote for pro-environmental legislation. One

[2] The income figures display the net average available income per earning individual working 52 weeks per year (including full-time and part-time workers). Figures are from 2005 and are taken from CBS.

would expect communities with a higher share of registered 'green' voters would for example also 'act green' and support environmental friendly shopping and transport. In fact, the distribution of green voters across ZIP codes is positively correlated with the amount of 'green' businesses in each area. A disproportional high amount of people even buy hybrid vehicles within green voting communities, especially the Toyota Prius. The popular choice of the Prius above other similarly efficient hybrids might be explainable by means of the neighbour effect (Mau et al., 2008)[3]. It could also be expected that in these areas the willingness to buy a hydrogen vehicle would be higher than in non-green voting behaviour areas (Kahn, 2007).

Such detailed figures could not be found for the Netherlands. Information on the registration of Dutch voters with parties was unavailable for this research, and municipalities contacted for our research are in possession of general election outcomes but do not have more detailed information on particular groups of voters, e.g. age, or zip code area they live in. Nevertheless, of the Dutch election outcomes in 2003 and 2006 those municipalities that yield a high percentage of green voters in the Netherlands can of course be identified. Paired with the average age of the voters in each district the following positive relation can be established: the younger the population of a certain area is on average, the higher is the percentage of people voting for the Dutch green party GroenLinks (GL). In other words, younger people are more likely to think and vote green. The scatter plot and the corresponding data look as follows[4]:

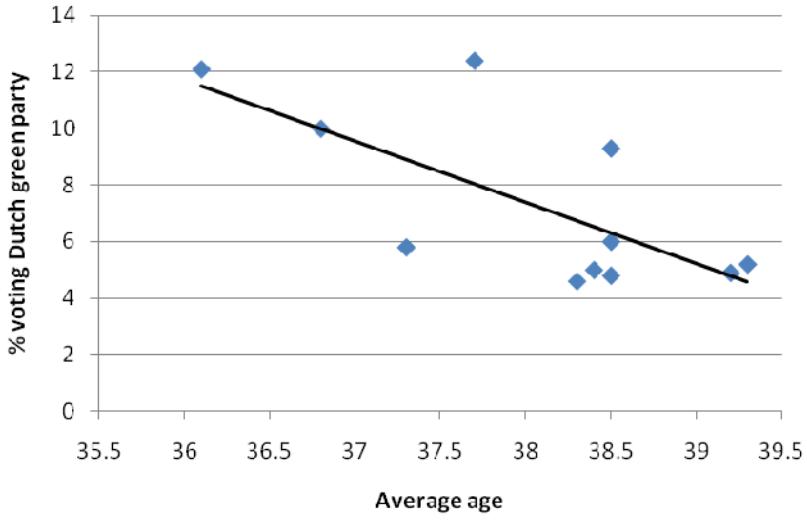


Figure 2.1 *Average age plotted against percentage of people voting for the Dutch green party (GroenLinks) for 11 Dutch municipalities (see table below for details)*

[3] People's value for a certain technology might increase of the number of people owning this vehicles increases.
[4] All data obtained from the Dutch Central Bureau of Statistics at www.CBS.nl

Table 2.2 *Dutch municipalities, their number of inhabitants, average age, and percentage voting GroenLinks*

Municipality	Number of inhabitants	Average age	% of GL 2006
Amsterdam	739,104	37.7	12.4
Utrecht	270,244	36.1	12.1
Groningen	179,185	36.8	10
Arnhem	142,101	38.5	9.3
Leeuwarden	91,354	38.5	6
Zwolle	110,880	37.3	5.8
Eindhoven	207,870	39.3	5.2
Rotterdam	598,923	38.4	5
Breda	166,035	39.2	4.9
Assen	61,925	38.5	4.8
Enschede	152,989	38.3	4.6

Although the graph and the table above show a clear relation between age and voting behaviour, the relation between 'voting green' and 'acting green' is less clear. Despite Kahn's findings that areas in the US with a high density of green voters also have a higher density of hybrid vehicles, such correspondence has so far not been duplicated for the Netherlands.

One popular explanation of voting behaviour is socio-economic class and citizens belonging to a lower economic class are often held to vote for left parties, which in the Netherlands would also include GroenLinks. Achterberg and Houtman (2006) show in a remarkable study of Dutch election results in 1997 that socio-economic class still plays a role in people's voting choice by drawing on values such as 'economic progressiveness' and 'cultural conservatism'. Following their findings, Dutch voters of the green party GroenLinks can be characterized as culturally active and progressive, middle class voters (Achterberg & Houtman, 2006). In other words, green voters are part of higher socio-economic classes, enjoy higher income and a higher level of education. Their engagement with culture and their progressiveness in that respect cause, or are strongly related with their choice for the green party.

2.3 Knowledge and awareness

Several reviews and research projects came to the conclusion that at this stage the general knowledge and awareness of people regarding hydrogen as a fuel and hydrogen cars is low. Molin (2005), for example, reviewed many available studies on acceptance of hydrogen and concluded that in general the public has little knowledge of hydrogen but in general has a positive attitude towards hydrogen and a high willingness to use hydrogen applications. Some general correlation that could be established was that higher education contributes to higher knowledge, while higher knowledge in turn relates positively to higher acceptance. However, conclusions cannot be drawn safely yet according to Molin because the level of knowledge is generally still low and mass media still have to start story telling about hydrogen. If this story telling will be negative, this can have irreparable negative implications for the level of acceptance. In addition Molin's research shows that the older the respondent is, the less he/she considered hydrogen as environmentally friendly and the less he/she was willing to use hydrogen applications. After controlling for perception and attitude in the model the age effect remained and was hence found to be much stronger than the effect of education and gender[5].

Another review of available literature on acceptance of hydrogen fuel and issues affecting this acceptance arrived at similar findings. Schulte et al. (2004) also concluded that knowledge of hydrogen typically is limited but the attitude is positive (Schulte, Hart & Van der Vorst, 2004). Furthermore, they found level of knowledge to be directly linked to attitude: the more in-depth

[5] Molin (2005) concludes that if this age effect exists, this will disappear in time, following a natural logic.

knowledge one has, the more positive is one's attitude towards hydrogen as a fuel. O'Garra et al. (2005) also found a direct relationship between knowledge and willingness to pay or acceptance. In addition these researchers found no relationship between awareness, gender, age, education and environmental knowledge.

Similar results were generated by a study in the UK. The University of Salford conducted research in focus groups in three UK regions and found that general awareness of hydrogen was low, but especially in regions with a former chemical/petroleum industry background the awareness of hydrogen higher than in those regions without. Hydrogen was found to carry a neutral connotation (Ricci et al., 2006).

The EU funded ECTOS project (Ecological City Transport System) financed three hydrogen fuel-cell busses driving around the Icelandic capital Reykjavík for two years (2000-2002) as part of the public transport system. The focus was on reliability, costs and benefits and learning from an economic, social and environmental point of view. While in the beginning of the study 93% of the population interviewed stated they had too little knowledge of hydrogen as an alternative fuel, after two years this number dropped to 45%. One of the lessons learned was that knowledge channels people are used to (e.g. radio, newsagents, schools) are the best way to disseminate information on technological innovation, since e.g. extra information leaflets are largely ignored. Generally, there was high interest in this project on a national level with teachers, interest groups or newsagents requesting information material and independently adding to its dissemination. Also internationally this project drew attention and hence greatly added to raised awareness with respect to hydrogen powered vehicles (Maack, 2006). Almost 50% of the Icelandic population interviewed in the framework of the ECTOS project regards hydrogen as a clean energy carrier and only 3% had very negative connotations with respect to hydrogen, such as explosiveness.

The Hyfleet Cute project report Milestone M5.1 which reviews many reports on attitudes towards hydrogen vehicles is in line with all the of the above mentioned. Its conclusions hold that in general reports are in agreement that quality information, higher education levels and positive personal experience make individuals more acceptable to novelties in general and that this also holds for hydrogen.

Conclusions with respect to knowledge and potential first buyers

- Literature points at a positive correlation of education, knowledge and acceptance, however, at the time of writing people's general knowledge of hydrogen as fuel is low and the number of popular media focusing on hydrogen cars is limited. Efforts could be directed towards more (positive) story telling about hydrogen vehicles in the media.
- Although literature suggests the segment of people that is strongly environmentally concerned is more willing to buy an environmental friendly vehicle, further research is necessary to link this knowledge and awareness issue to actual purchasing power and age parameters.

2.4 Vehicle and environmental performance

By and large there is general consensus on the importance of vehicle performance in the purchasing decision for a new car. Byrne et al. for example conclude quite generally that issues such as cost, maintenance (costs and availability), performance, size, access to roads and infrastructure (if design is different) range of the vehicle, power and acceleration, fuel availability, refuelling, safety, aesthetics and other issues are influencing the purchasing behaviour of consumers.

O' Garra et al. (2004) found that performance is one key determinant in the choice for a vehicle and the HyFleet:CUTE project report Milestone M5.1 concludes that the performance of the Hydrogen car has a medium to strong influence on the willingness to pay. The latter adds that

there is in general a strong confidence amongst manufacturers in hydrogen vehicle technology to be able to cope with a strict comparison to regular cars with respect to performance. It also states that car performance is in general considered important for the willingness to pay for a hydrogen vehicle, but in many cases the limited range and loss of booth space is acceptable when trade-off with the environmental performance is considered. However, most respondents would prefer good driving sensations, responsiveness and acceleration.

Research by Molin et al. (2007) on purchasing choices focused on the influence of the driving range and performance of the engine (top speed and acceleration) of hydrogen cars in comparison to the petrol-fuelled car. While the engine performance was not an influential determinant in this experiment the number of kilometres one could drive on one tank-fill with a hydrogen car influenced the choice to purchase such a vehicle heavily.

Overall, the requirements on the performance of hydrogen vehicles, the comfort and service offered are strongly oriented on what people are currently used to and the confidence of market and manufacturers seems to be large that these requirements can be met sufficiently. Research within the frame of the HYLIGHTS project demonstrates that technical performance requirements do not pose a barrier for hydrogen vehicle deployment in fleet environments because the requirements in terms of speed and driving distances are expected to be matched by next generation hydrogen vehicles (HyLights, 2008).

The reviewed literature does not offer consensus on the influence of the environmental performance on the purchasing decision of a new car. There may be a general trend towards a higher importance of low emissions and higher fuel economy in cars, especially in middle- or older-aged car buyers. Hence, although the HyFleet:CUTE project (Milestone M5.1) reports that several studies found that environmental consciousness influences the acceptance of hydrogen as transport fuel positively and the willingness to pay more than for conventional fuels increases, at present, environmental friendliness in terms of lower fuel consumption is mainly seen as an economic asset while consideration of sustainability remain secondary.

De Haan et al. (2007) state that cars have a high symbolic value (i.e. status symbol). Their research shows that fuel-efficiency already has generally a high symbolic value. Some people value climate neutrality or environmental friendliness and for them these attributes would also add to a higher symbolic value of a car.

This finding is replicated by Amelsfoort (2007) who found in a survey with 300 Dutch car drivers that consumers aged above 45 are more sensitive to the environmental performance aspect of a car. Generally across different age groups the environmental performance of a car is of decisive importance in purchasing a new car: 73% of the respondents consider the environmental performance of the car in a purchasing decision. 91% of those consumers that stated the intention of choosing for an E85 fuelled car when buying a new car labelled the environmental aspect as main incentive. All respondents who considered buying a CNG car cited environmental friendliness as their main motivation to do so. However, research conducted by the Dutch Ministry of Transport[6] highlights that the motivation of car drivers to buy a more environmentally friendly car is not the need to buy a 'green car', but a car that, because it is more environmentally friendly, is state of the art and a new technological gadget. The new generations are rather aware about the environment and more conscious about sustainability issues than their predecessors, but value their being technological up-to-date above their environmental performance.

Research by Molin et al. (2007) strengthens the finding that other issues weigh heavier than the environmental performance, although the car being environmentally more friendly can be the result of these other issues. In their stated choice experiment the reduction of emissions was

[6] Personal email correspondence with Andre Schoorlemmer of Rijkswaterstaat, member of the project Group 'Routes to the Future' [Wegen naar de Toekomst].

considered influential in car drivers' motivation to choose an alternative fuel but did not play a decisive role, and even seems to be one of the less important factors. Similarly, O' Garra et al. (2004) conclude that environmental concerns are not key determinants in the choice for a vehicle. A study conducted in the UK also found many other aspects leading the list of factors influencing a purchase decision. People predominantly focused on financial and performance considerations which hence included price, fuel consumption, comfort, size, practicality and reliability (Lane & Potter, 2007).

Conclusions with respect to vehicle and environmental performance and potential first buyers

- Literature agrees that the most decisive factors in car purchasing-behaviour are (irrespective of order mentioned) brand, price, performance and other technical characteristics (e.g. up-to-dateness). If price and performance diverge greatly from what people are used to today, the uptake of hydrogen vehicles is expected to be considerably slower.
- Additionally, hydrogen cars should be closely matched with the performance of currently available cars.
- Environmental friendliness as such might not be a motivational factor for a specific car purchase. This characteristic is however indirectly taken into account through a preference for performance improvements such as decreased fuel consumption or refuelling cost which increasingly have the added benefit of increased environmental friendliness.

2.5 Vehicle purchasing cost

This section will shed light on the question to what extent vehicle costs play a role in the purchasing decision and which incentives might contribute to a wider uptake of hydrogen vehicles. A literature review shows that price is one of the most important decisive factors.

Adamson (2003) models the market adoption of fuel cell vehicles (FCVs) and identifies three crucial stages that need to be dealt with for successful adoption: entrance into primary niche market, transition into secondary niche market and finally into mass market. In the first (small segment) niche the vehicles may be more expensive if the new function that fuel cell have over internal combustion vehicles (ICVs) justifies the early high economic value of FCVs. The larger but still size-restricted secondary niche market group increasingly adopts FCVs on the premise that their utility is higher in direct competition with ICVs. However, the industry should market these utility characteristics to allow successful market introduction. Adamson concludes that the final cross over into mass market is determined by the development of a market pull and constrained by budget which means that by this time purchasing costs of the new vehicles need to have decreased sufficiently.

Due to the fact that hydrogen vehicles are going to be considerably more expensive than regular fuelled cars (HyWays, 2008)[7], the likely group of early adopters of emission free vehicles is less price-sensitive and hence to be found in an above average income class. People with higher income who are less price-sensitive attribute to the price of a vehicle less influential power on their purchasing decision than people with lower income (Potoglou, 2007). However, those people who have less money available to spend on a car can be motivated to buy an environmentally friendly car by means of a higher purchase tax on conventional cars, incentives schemes, tax breaks for new technologies and agreements with manufacturers. Bonus schemes, however, hardly have the desired effect, due to the fact that they rather encourage people to buy a more expensive model - so happened with a 3000 CHF bonus in a Swiss study (De Haan et al., 2007). Generally, all else being equal, people prefer lower cost vehicles. Price of a vehicle is seen as a key determinant in the choice for a vehicle (O' Garra et al., 2004). However, inter-

[7] Toyota forecasts a price of 50,000 USD for the market introduction of a hydrogen fuel cell car. (FuelCellToday, 2010).

views with 75 Dutch car drivers showed that higher or lower purchasing costs, as long as they were in the range of - € 500 to + € 1500 in comparison to regular cars were - although not without influence - one of the least influential factors for people to choose a hydrogen car (Molin, Aouden & van Wee, 2007).

Two of the reviewed publications came to the conclusion that the choice for fuel efficient vehicles largely depends on purchasing cost and performance. Both need to be closely geared to conventional vehicles. The same goes for driving range (Dagsvik et al., 2002). Hence, performance, driving range and cost at purchase are crucial factors for a successful commercialisation of hydrogen vehicles (Ewing, 1998; Melaina & Bremson, 2008).

Research within the frame of the HYLIGHTS project demonstrates that fleet operators that have introduced corporate policies on low-emission fleet vehicles, fossil free energy plans or technological leadership can be considered potential first users of hydrogen vehicles if available at level-playing field prices. Otherwise they would always go for a cheaper alternative (HyLights 2008). Research within the frame of the HYLIGHTS project (2008) demonstrates that commercial fleet operators that focus purely on cost effectiveness are not likely to become potential first users of hydrogen vehicles because they consider second-best alternatives and thus cheaper alternatives such as biofuels before hydrogen.

Conclusions with respect to vehicle purchasing costs and potential first buyers

- If the first hydrogen vehicles are going to be considerably more expensive than regular fuelled cars, the likely group of early adopters of emission free vehicles would be the above average income class which is less price-sensitive.
- Literature suggests that purchasing cost, performance and driving range, in their combination, are crucial factors for a successful commercialisation of hydrogen vehicles.
- The market introduction of hydrogen vehicles in the Netherlands can be significantly influenced by governmental incentives that favour environmental cars over their conventional counterparts (e.g. by lowering the purchasing price by fiscal measures, incentives schemes, tax breaks for new technologies and agreements with manufacturers), all other issues such as performance being equal.
- A high petrol and diesel price over an extended period of time, coupled with purchasing incentives for alternative fuel vehicles can be an important market stimulant for hydrogen fuel cell vehicles.
- In general however, it can be concluded that to increase the successful introduction of hydrogen vehicles these vehicles need to be closely geared to conventional vehicles in terms of purchasing costs, and vehicle performance.

2.6 Fuel cost & fuel availability

Another factor contributing to the purchasing decision of a car is the fuel it is powered by. Generally, there are three main options to choose from in the Netherlands: diesel, regular unleaded fuel and liquefied petroleum gas (LPG). Vehicles entering the Dutch market and driving on a new type of fuel will have to compete with respect to the availability and cost of that fuel already at the time of purchase: most buyers take the expected (absolute and compared to reference fuel) price of the alternative fuel into account at the time of purchasing a vehicle.

Molin et al. (2007) found during a U.S. small-scale study that if the price of a new, alternative and supposedly more environmental friendly fuel exceeds the price of conventional fuel, only 15% of the respondents would consider switching to the new fuel, while 50% would not and the remaining 35% did not form an opinion. Consequently, the same percentages would not choose to buy the new car that drives on the new fuel (with the exception of cars that use alternative fuels as add-ons). If the price is comparable or lower, 80% of the respondents would consider switching. Interestingly, the research demonstrated that lower prices in comparison to conven-

tional fuel would not motivate more than those 80% to consider switching to the new type of fuel.

Another, larger scale American study has researched the effects of rising gasoline prices in the US. Generally, US motorists are not very responsive to changes in the price of gasoline, at least in the short run. According to the study, 10 percent increase in the retail price of gasoline would result in reduced consumption by about 0.6 percent in the short run. If the higher gasoline price would persist, more drivers would actually consider buying another automobile with better fuel economy. However, if the price remains high long enough, consumers would also find other ways to respond by moving or changing jobs to reduce commuting. Next to the overall responses to higher gasoline prices, there is also some adjustment in the driving patterns.[8]

Another small-scale survey amongst 75 U.S. car drivers by Molin et al.(2007) also highlights the importance of fuel price as one of the factors influencing the motivation to purchase a hydrogen car. From the stated choice experiment it was derived that the higher the fuel price compared to petrol fuels, the less the car drivers were willing to buy a car driving on the alternative fuel.

The Hyfleet:CUTE project report Milestone M5.1 discusses the influence of costs of hydrogen on willingness to pay for a hydrogen appliance such as a vehicle. Many studies conclude that there is a general willingness to use hydrogen as a fuel but that costs (vehicle and fuel) are the second or third most important obstacle in the willingness to purchase a hydrogen technology. In other words, again people's price sensitivity concerning fuel is high. All aforementioned studies assign considerable importance to the price of the alternative fuel in purchasing decisions, at the petrol pump as well as at the car dealer.

In the transition phase from leaded to unleaded fuel Greene (1989) conducted research on consumers' willingness to pay more for a newly introduced alternative fuel. The results can also serve as an indication for a transition to hydrogen: generally, people's willingness to pay is flexible, as long as the price falls in a similar range as the fuel used formerly. Additionally, there is a clear preference for the fuel preferred by law, which in the case studied was unleaded petrol. Finally, people are indeed willing to pay more for fuel in case the engine of their vehicle would have better performance with the more expensive fuel type. In other words, once the decision for a certain kind of engine is final, the fuel costs become secondary and are accepted even if they are a few cents higher.

The Icelandic ECTOS project showed that opinion about hydrogen and the acceptance of fuel costs correlate. People with a neutral or even reserved outlook on hydrogen reported to only accept fuel costs at a lower or roughly equal level compared to current fuel prices, while people who were greatly in favour of hydrogen as an alternative fuel were more likely to accept fuel prices up to 20% higher than those of conventional gasoline. Overall 36% of those in favour claimed that a price higher than current fuel would be acceptable during the introductory stages of hydrogen (Maack, 2006).

Turrentine and Kurani focused on the relation of fuel cost and higher fuel economy. Their survey among consumers showed that almost no respondents could indicate an acceptable price for fuel because payback periods or price development of fuel is hardly ever tracked in private homes. It was therefore deemed by the respondents impossible to make an estimate on payback time of a purchase premium for a car low in fuel consumption but driving on more expensive fuel. Such considerations could weigh significantly in purchase decisions for cars using innovative technology, using alternative fuel. Cited as reasons why people hardly include fuel economy as a rationale in their decision making was uncertainty relating to the development of future fuel prices (Turrentine & Kurani, 2006).

[8] Effects of gasoline prices on driving behaviour and vehicle markets, CBO, January 2008.

However, not only fuel cost is a decisive factor, but as mentioned in an earlier paragraph, the fuel availability plays a considerable role, and both have been shown to be mutually dependent (Stobart, 1999). Cheaper fuel can compensate for additional travel time and distance. Sperling and Kitamura (1986) conclude that in the US a station density of those offering an alternative fuel (in their case diesel) about $1/10^{th}$ of the size of the currently - possibly overbuilt - regular station network would be sufficient to convince drivers to switch to the alternative fuel (when buying a new car). In that case the predictability of station location could compensate for reduced availability. The question of fuel availability is also subject of research in a dedicated survey amongst Dutch car drivers, see Chapter 6.

An issue outside the scope of this report is the communication of fuel cost to car drivers. Liquid fuels are now sold with a price per litre while hydrogen will (most likely) be sold with a price per kilogram. How to make these units comparable for consumers and how to communicate which fuel is more or less expensive per kilometre driven are important questions to be answered.

Conclusions with respect to fuel costs and potential first buyers

- Fuel price is one of the factors influencing the motivation to purchase an alternative car. In general it can be stated that the if the price of the alternative fuel is lower than the price of regular fuels over an extended period of time, drivers are more willing to consider switching to the alternative. Consumer research can give important insights how fuel cost and pay-back times can be communicated most effectively.

3. The Dutch vehicle fleet: brand and model availability and customer loyalty

This chapter focuses on the current demand and supply situation of cars and issues of brand loyalty, e.g. what is currently the situation in the Netherlands with regard to private and business cars, which models are most popular and what does this say about the future? The results are matched with prospects of car manufacturers regarding the expected first hydrogen cars to be introduced on the market.

3.1 Vehicle and fuel Brand loyalty

The choice for a specific car cannot be understood as a rational logical and economical decision based on technical vehicle characteristics alone. Research by ETH Zurich (De Haan & Peters, 2008), based on a survey of 5,000 persons and focus panels in Switzerland shows that the main decisive aspect in purchasing choice is image (pertaining to brand loyalty). An earlier publication (De Haan et al., 2007) discusses that past experiences with brand and size influence choices concerning a new car strongly. Generally, consumers have a high level of loyalty to brand, gear type (automatic vs. manual) and specific size (and accompanying price segment). These aspects serve people as heuristics to effectively decrease the complexity of the purchasing decision ('constricted rationality' - eingeschränkte Rationalitaet) since there is only limited time, knowledge and processing capacity. Hence, De Haan and his co-authors understand decision making when buying a car as a two-step process: First, all possible alternatives are effectively limited to about 5 options based on (often unconscious) habits, 'killer criteria' and rules of thumb. Their detailed analysis provides insight how frequently loyalty to brand, vehicle size, type of fuel and gearing can be observed in this selection process of Swiss car buyers. 40-70% of the representative sample remained loyal to their previous brand. The following table shows how these figures vary across brands.

Table 3.1 *Amount of newly bought vehicles (n[IV]) and brand loyalty (MT in %) for the 15 most sold brands in Switzerland (taken from De Haan et al., 2007)*

Brand	Total # sold	Brand loyal [%]
Citroen	468	71.8
Honda	325	69.0
Toyota	598	63.8
Subaru	324	62.4
BMW	362	60.9
Peugeot	504	60.9
Ford	408	55.8
Opel	620	55.1
Mercedes-Benz	238	53.6
Mazda	219	53.2
Hyundai	255	52.3
Audi	374	49.2
Renault	356	45.9
Mitsubishi	229	44.8
Volkswagen	631	43.1

Furthermore, people tend to stick to their previous size or model segment. For the commonly driven models loyalty to vehicle size varied between 35-55%. The most loyal segment drives a compact car (52.1%), a compact van (49.6%), a small (56.2) or big (45%) SUV. Concerning

gear type, almost 66% remained loyal to automatic gear shifting, while almost 87% stuck to their preferred manual version. Finally, nearly 80% chose again a car driving on unleaded fuel, while 68% again decided for a diesel when buying a new car. These figures show, how significantly people are driven by habits and previous choices made when choosing for a new car and alongside with it for a specific fuel type.

Kasper (1988) helps to add another aspect to the discussion, namely consumer satisfaction and its link to brand loyalty. However, the correlation of the two is not perfect and straightforward relationships can hardly be established. Instead a number of factors influence the decision to buy a new product by the same brand or to switch to another. These include e.g. having experienced problems or not, the amount of information concerning the product made available and being collected before purchase, service and support by salesmen and/or the manufacturing company. If consumers collected a lot of information before the purchasing decision and did not experience any problems they are most likely to be very satisfied and make a similar purchasing decision with respect to product and brand the following time(s). This in turn does not mean that those who did experience problems are bound to switch. While Kasper bases his findings on a large range of products, he makes clear that these considerations largely hold for cars, since brand loyalty, while rather strong in general, is particularly at work in case of durable products even more so than in non-durables (Day & Landon in Kasper, 1988). As an addition, Kasper mentions that although socio-economic variables fail to explain purchasing behaviour significantly, there is, however, a tendency to increased brand loyalty in people with lower education and medium income.

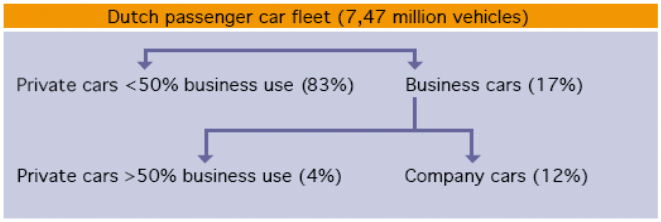
A focus on the U.S. shows similar issues at work: research amongst American car buyers demonstrated that all interviewees noted the importance of brand image (Johnson & Chang, 2000). Furthermore, an independent U.S. Consumer Report of April 2010 on satisfaction of car owners with their current model sheds light on which aspects of a car result in higher brand or model loyalty. Those cars that most people considered worth buying again were the ‘sporty’, ‘hybrid’ and ‘out of the mainstream’. The car receiving the second highest score in owner satisfaction with 91% of its owners indicating they would buy this car again was the Toyota Prius Hybrid. Top-scorer with 93% of the respondents indicating they would ‘definitely buy again’ was the Dodge Challenger roadster. Bottom of the list form two SUV/FWD vehicles with only about a third of their owners ready to buy the same model again (Consumer Reports, 2010). These figures are of course to be read in the context of the American car market which is (in comparison to the European) saturated with larger, and SUV-type vehicles, while offering little to no variety in the lower, smaller size and model segments. Additionally, there may be no other culture where car use and image communicated by means of car driving is as engrained as in the U.S.

Finally, loyalty issues to some extent also apply to the choice of the fuel supplier. Consumers that are strongly loyal to a specific brand may only buy fuel at their preferred brand, regardless of the price somewhere else. Oil companies are interested to build more brand loyalty and create stronger bonds with their customers to avoid large customer losses to non-branded refuelling stations. A strong bond can be created via Fuel reward programs. If a customer refills at the branded station and is in possession of a membership loyalty card, points are awarded for his refuelling. After a certain amount of points has been collected, they can be exchanged in return for soft or hard benefits (e.g. cash back, goods). Research has so far provided mixed results over the success of loyalty schemes as the most effective instrument to bind customers and increase sales. Largely it depends if the loyalty scheme can provide any additional value than what is inherited in the product or service (Wright & Baumann, 2007).

3.2 The Dutch car fleet

Of the total amount of passenger cars in the Netherlands, 83% (6.01m) are private cars and 17% (1.23m) are business vehicles. Those vehicles can be further classified by lease agreements that

have the biggest share (8%), but also vehicles that are directly assigned to a company (4%) and private cars that are used mainly for work purposes (5%), see Figure 4.1. The distribution of business vehicles across the different categories has remained virtually unchanged since years.



Source: Goudappel Coffeng (2007); RDC Data Centre (2009).

Figure 3.1 *Breakdown of Dutch passenger car fleet in 2009*

Business vehicles travel more kilometres per day than the average private car per year. The amount of km driven by business vehicles is about 19% or 21.4bn km of all kilometres travelled in 2009 within the Netherlands (VNA, 2009).

3.3 Types of cars driven - popular brands and models

The ten most popular car brands driven in the Netherlands are shown in the table below in cumulative numbers for the years 2007 and 2008. Of the brands included there are three French-, three German-, one Korean, one Italian, one Japanese and one American based. In addition to the amount of cars sold in 2007 and 2008, the change rate from the one year to the other is indicated. Over the two years shown the overall ranking did not experience any changes. By the end of 2008 Volkswagen still held the largest market share with 9.33%. Table 4.2 shows market shares of the top-ten brands in 2009 and sets them in relation to overall Dutch car sales in 2008[9].

Table 3.2 *The top-10 brands of all registered new cars in 2009 in the Netherlands*

Rank 2009 (rank 2008)	Brand	Market share 2009
1	Volkswagen	9.9
2 (5)	Toyota	9.8
3 (2)	Ford	9.6
4	Peugeot	7.7
5 (3)	Opel	6.8
6	Renault	6.1
7	Citroën	5.2
8	Fiat	4.4
9 (10)	Audi	4.0
10 (11)	Volvo	3.6

Details on the best selling models are shown for the top-five selling car brands in the table below. The figures given are the sum of all cars sold of each model since 1983 until December 2008. The most frequently sold cars are small to medium seized vehicles. Following the segment scheme for leasing cars, which is introduced in the next section, cars sold between 1983 and 2008 most often belong to the segments B, C and D. The larger vehicles included are so called multiple purpose vehicles (MPVs), as for example the Opel Zafira.

[9] Figures are taken from http://www.rankingthebrands.com/The-Brand-Rankings.aspx?rankingID=96&year=122, based on BOVAG/RAI (accessed 30 June 2010)

Table 3.3 *The top-5 of the top-5: accumulative sales figures for 5 models of each brand from 1983-2008*[10]

VW	cum. #	Ford	cum. #	Opel	cum. #	Peugeot	cum. #	Toyota	cum. #
Golf	531,906	Escort	315,580	Astra	397,874	206	145,219	Corolla	200,960
Polo	226,000	Fiesta	183,595	Kadett	367,053	205	142,349	Starlet	111,004
Passat	215,161	Focus	160,563	Corsa	342,523	307	111,329	Yaris	78,129
Jetta	56,683	Mondeo	151,001	Vectra	214,099	306	89,742	Carina	69,972
Touran	30,195	Sierra	148,868	Zafira	91,460	405	83,242	Avensis	60,859

3.3.1 Leasing Cars

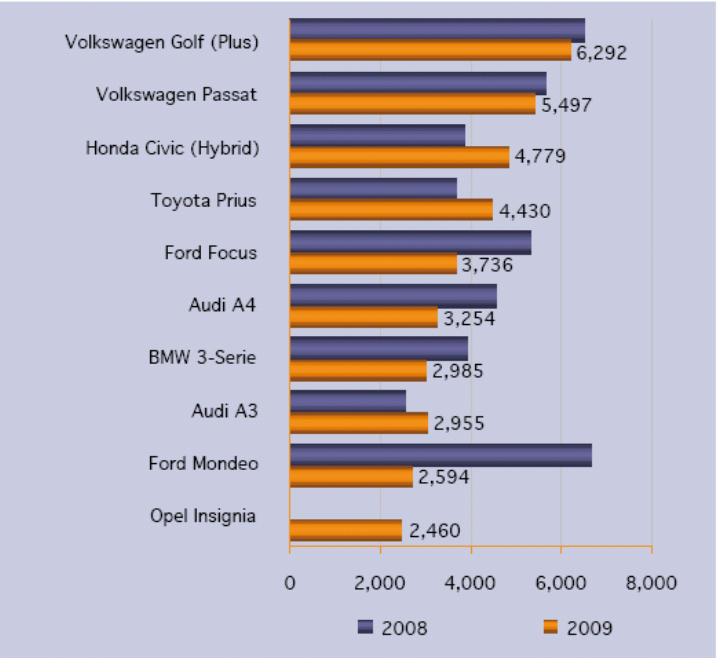
The amount of lease contracts for passenger cars is steadily rising in the Netherlands. The growth from 2006 to 2007 was + 5.3%. Of the whole group of business vehicles, the amount of lease vehicles is growing strongest by 13.4% in 2007, an amount almost double of that from the government and businesses. Lease-cars, as all others cars, are divided into different segments, see Figure 4.2.

Vehicle segments		Examples
Passenger Cars	Segment A	e.g. PANDA, TWINGO, SMART FORTWO, KA, AGILA, LUPO
	Segment B	e.g. 206, POLO, FIESTA, CORSA, PUNTO, MINI
	Segment C	e.g. GOLF, ASTRA, FOCUS, MEGANE, 307, A CLASS
	Segment D	e.g. SERIES 3, C CLASS, A4, PASSAT, MONDEO
	Segment E	e.g. SERIES 5, E CLASS, A6, V70, S-TYPE, A8
	Segment SUV	e.g. X3, RAV4, X5, TOUAREG, M CLASS, LAND CRUISER
	Segment MPV	e.g. TOURAN, ZAFIRA, XSARA PICASSO, FOCUS C-MAX, GALAXY, ESPACE
	Vans	e.g. Volkswagen Transporter, DaimlerChrysler Vito, DaimlerChrysler Sprinter, Ford Transit
	Buses	

Figure 3.2 *Car segments*

In 2009, the most popular size segment on the lease market was the C segment with 6 of the top-10 selling models belonging to this segment. These figures are mirrored by the general market sales figures where 7 of the top-10 selling models belonged to the C segment or smaller. Long-term tendencies show that there is growth in two directions; either in smaller cars in A or B segment or more luxurious, SUV category.

[10] Note that these figures cannot be compared straightforwardly, as . VW had its Golf model on the market for decades, while the Ford Focus is the Escort's successor, and the Peugeot 206 the 205´s successor.



Source: RDC Data Centre (2008-2009).

Figure 3.3 *Top 10 of the lease cars registered in the Netherlands in 2008-2009*

3.4 Comparison: What hydrogen models and brands are likely to be available in the beginning?

Commitments to introduce hydrogen fuel cell vehicles on a large-scale vary between original equipment manufacturers (OEMs). Some (Daimler, Toyota) have published concrete roadmaps for their planned technology trajectory to arrive at (mass-)series production for end-consumers. Virtually all manufacturers have taken on the challenge to develop more environmentally friendly vehicles. In a survey of automotive executives, hybrid-vehicles in different versions (micro, mild, full-hybrid) are seen as the most important (short term) solution, while electric vehicles and hydrogen fuel cells follow in the medium to long-term (Momentum, 2009). However, the worldwide economic downturn since 2007/08 has also hit automotive industry. Now, OEMs are taking customer demand for more economic and environmentally benign vehicles more seriously and accelerate the introduction of short term technologies.

Market entry strategies show some similarities among OEMs. For cost reasons, mostly existing vehicles (platforms) have been retrofitted with fuel cells, hydrogen storage and an electric drive train. After technological improvements some OEMs have made experiences with deploying the new technology on different vehicle platforms of their portfolio. In the next step, purpose built hydrogen vehicles are appearing (e.g. FCX Clarity). Daimler has revealed plans to share a common platform for its next generation of environmentally benign vehicle ‘Blue Zero’. A battery-electric vehicle for short distances (E-Cell, 200km range), a fuel cell vehicle (F-cell, 400km range) and an electric vehicle with range extender (E-Cell plus, 600km range) all planned to be built upon the next generation B-class platform (ECN, 2009).

What should be subject of some concern is the fact that the bestselling car brand in the Netherlands, Volkswagen has not yet made any announcements regarding their hydrogen car strategy publicly, while the brands ranked second and third, Toyota and Ford respectively are working already since some time towards market introduction of hydrogen fuel-cell vehicles. Until now most models developed focus on the D-size segment and no smaller model has been announced yet.

Segment	Europe	Currently testing US	Asia (Japan, Korea)	Planned market introduction
A-Micro				
B-Sub compact				
C-Compact	Daimler F-cell			2009, small series 2014/15, 100,000 units
	Ford Focus	Ford Focus		Unknown
D-Mid-size		Honda FCX Clarity	Honda FCX Clarity	Unknown
			Hyundai i-blue	2012
E-Full size				
F-Luxury	Mazda Premacy RE		Mazda Premacy RE	Unknown
MPV	GM HydroGen 4	GM Equinox		Unknown
SUV			Toyota FCVH	2015
SUV				

Figure 3.4 *Overview of current and expected hydrogen car models per segment*

Conclusions with respect to brand, availability of models, customer loyalty and potential first buyers

- Although the portfolio of available models may be limited in the beginning, car manufacturers should initially aim at the currently best-selling models among the male part of the population, which is older than 50 years of age and receives an above average income. An initial focus on the D-class segment or larger may be appropriate.
- The focus of hydrogen car manufacturers seems to be to a large extent on the lease segment, but this segment is most probably not going to be the first buyer of hydrogen cars because of cost efficiency issues.
- In addition, in the Netherlands, the brand sold most (Volkswagen) does not yet have a hydrogen model available. This might hamper the uptake rate of first models of hydrogen cars. Car manufacturers, especially those with highest sales and highest brand loyalty might consider investing in the development of more C-class models to accommodate their customers.
- Literature emphasises the great importance of service, support and information, before and after a purchase. Manufacturers should take care to inform customers thoroughly at an early stage to allow well-informed purchasing decisions. Furthermore, good service adds to product satisfaction and may lead to enhanced loyalty and repeated purchasing behaviour.

4. Current Dutch mobility patterns in relation to fuel availability

This chapter considers the current travel and particularly the car driving behaviour of Dutch citizens. Data made available by the Dutch Ministry of Transport help to get insight into mobility patterns across different age, income and geographical groups. Furthermore, a literature review aims to get insight into people's refuelling habits and behaviour. Wherever possible, attempts are made to identify the pattern of those who are most likely to belong to the early adopters of a hydrogen vehicle. The chapter at hand shall serve as a forerunner and supporting framework for the questionnaire survey carried out by ECN which is discussed hereafter. In the following, first, distances covered by Dutch car owners, also with respect to income and age are presented; second, availability trends in fuel stations and third, people's willingness to accept a detour for refuelling are discussed.

4.1 Travelling distances

The latest Mobiliteitsonderzoek Nederland (MON [mobility research Netherlands]) published by the Dutch Ministry of Transport, Public Works and Water Management (2009) provides in depth insights into travel habits and mobility patterns of people in the Netherlands for the year 2008. Variables such as age, gender, income class, preferred means of transportation, usual travel times of the day, average distance covered or final destination are statistically evaluated to allow conclusions that are highly relevant for the planning of new transport infrastructures. The subsequent paragraphs highlight outcomes providing insights relevant to an identification of mobility patterns of potential hydrogen car users:

The car is the most frequently and extensively used means of transportation by the Dutch population. Most often people report to be driving personally instead of walking, going by bike or joining a car as a passenger. Reasons for travel are going to work, business or private visits, shopping or engaging in other leisure and recreational activities. On an average people in the Netherlands travel about three times per day for one or a combination of these reasons. Most of these travels are done by car, followed by cycling and walking.

In the Netherlands, the average distance covered by car drivers (hence excluding other means of transportation and kilometres driven as passenger) amounts to 16 kilometres per day per person.[11] The average distance people drive to work is slightly above 6 km, while the distance to go shopping is on average only 1.4 km. More than half of the Dutch population drives the car for about 5 - 20 minutes every day and covers on average a distance of 1 - 10 kilometres every day. Traffic density is highest in the Netherlands between 9 a.m. and 12 p.m. and between 3 p.m. and 6 p.m.

Of all individuals owning a driver's license, 72% uses the highway at least once a month (Ministerie van Verkeer en Waterstaat , 2002). In this group of highway users, 27% uses the highway 1 to 3 times a month, 33% 1 to 3 times a week, and 40% more than 3 times a week (see Figure below). In total, per year, 39% of these highway users make less than 10,000 kilometres per year, 40% between 10 and 20,000 km, and 14% makes between 20 and 40,000 km per year. There is a geographical concentration visible: the area around the IJsselmeer in the North-West of the Netherlands has the highest percentage of people driving more than 40,000 km/p.a.

[11] This figure is calculated by counting all citizens aged above 12, including those not working. Freight transport and mobility abroad are not included.

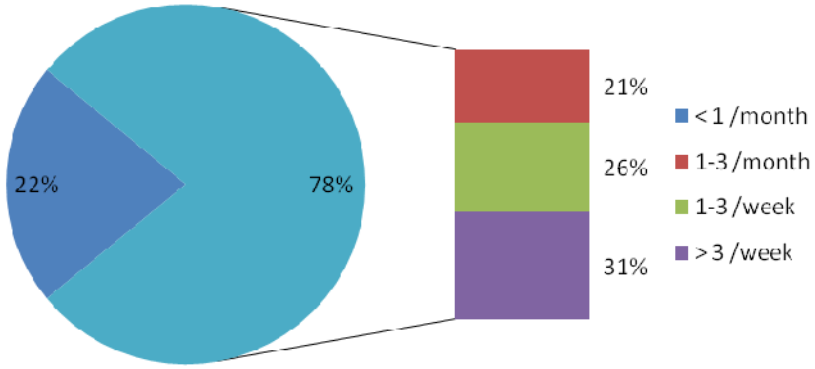


Figure 4.1 *Highway use in the Netherlands*

There are remarkable gender differences in mobility patterns of Dutch car drivers. In brief, the male half of the population covers much larger distances when travelling. Also the transport means used by men and women vary slightly. Across different age groups men drive more kilometres per day than women with the difference increasing the older people get. With the exception of the youngest age group (18-20), men drive twice as many or more kilometres as women. The following charts depict the difference in distances travelled per transportation means for men and women:

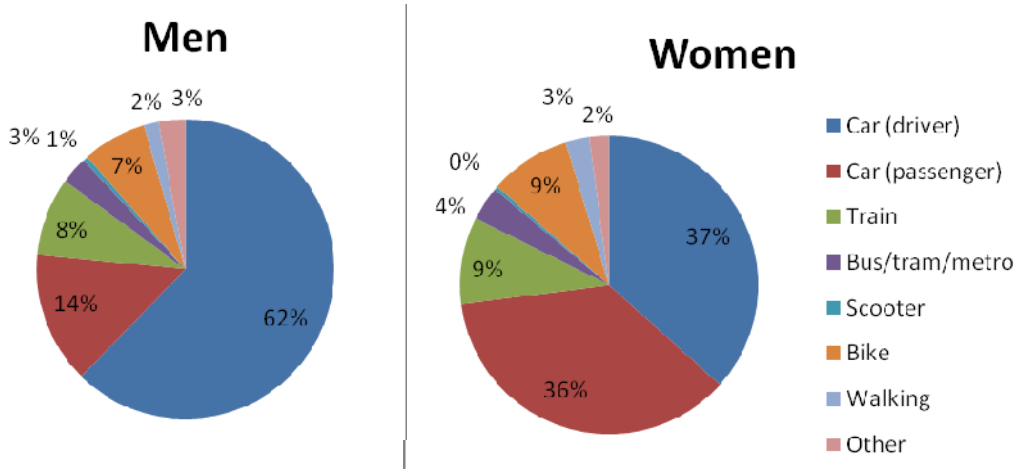


Figure 4.2 *Gender differences in the main use of different transportation means*

Another relation highlighted by the MON 2008 is that of income and mobility patterns. Generally, the patterns are similar across all income classes in terms of the amount of travels conducted every day, since all people most frequently travel between home and work, to go shopping or for recreational purposes. Those with a higher income cover more kilometres on average per day, however. While the lowest income classes, i.e. between € 0 and € 7,500 per year, cover about 25 - 30 km on average per day, those that earn € 30,000 and more travel twice as much. Additionally, most of this distance is covered by car. As figures mentioned in the first chapter of this report already showed, most new cars are possessed in the higher income classes. The figure below shows that people of the higher income classes also drive a car much more frequently than people of lower income classes:

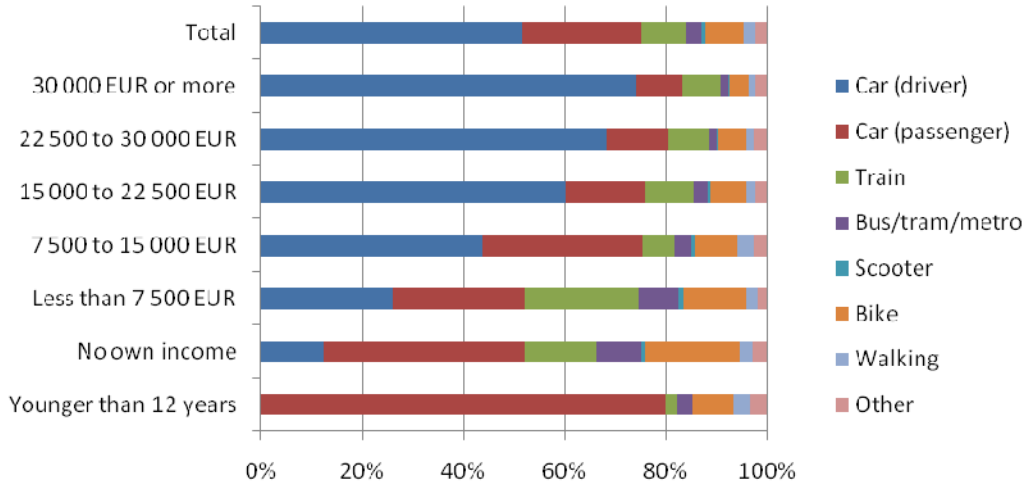


Figure 4.3 *Relation between income and means of transportation in the Netherlands in 2007*

Furthermore, the Dutch Ministry of Transport published details about the travel habits and mobility patterns of the population in the different Dutch provinces. The two provinces that are least densely populated, namely Drenthe and Flevoland, are those where people travel the most kilometres per day and also drive the larger distance by car themselves. In these areas people of course have to bridge larger distances to commute to work, or go shopping for example. In both these regions people drive above 40 km on average per person per day by car. In Utrecht that average is above 35 km and in Noord-Holland, Noord-Brabant, Overijssel, Groningen, Friesland and Gelderland is ranges between 33 and 35 km. Citizens of Zeeland, Limburg and Zuid-Holland remain below the average with between 27-30 km driven. These statistics are in line with the MON figures showing that almost 40% of those people who live in rural areas (with less than 500 addresses per km^2) drive a car personally, while this only holds for 25-30% in highly rural areas (above 1500 addresses per km^2).

4.2 Willingness to take a detour to a hydrogen refuelling station

Refuelling availability is of key importance for the introduction of alternative fuel vehicles (AFVs). Adoption of hydrogen vehicles will not take place if customers cannot easily refill their vehicles - regardless of vehicle cost or performance. Fuel availability, especially in the case of hydrogen, is also a cost factor in terms of investment for refuelling infrastructure. This chapter deals with people's willingness to make an extra detour to refill a hydrogen car or an alternative fuel vehicle (AFV) in general. Furthermore, research results concerning the initial percentage of hydrogen stations in the overall refuelling infrastructure required to convince people to switch to an alternative fuel are discussed.

The HyLights report (2008) concludes that first users of hydrogen vehicles are likely to be located in urban agglomerations and that fuel availability in larger cities and alongside main roads/highways is likely to be sufficient in the early phases of market introduction. Melaina and Bremson (2008) also state that alternative fuel vehicles will most likely be introduced in larger volumes in urban markets because this will reduce the needed infrastructure capital to ascertain refuelling station availability. Additionally, the limited range of some AFVs will make them less popular in rural areas. In line with results of the HyLights project they also conclude that increased refuelling availability can be achieved by means of stations along main roads and highways.

Melaina and Bremson (2008) analysed historical trends in gasoline outlets and stations, registered vehicles and gasoline consumption and concluded that station growth trends have neither

followed the trends of vehicles numbers nor fuel consumption. There even seems to be an inverse relationship starting in the 1970s. In the early years of station build-up when only few vehicles were driving around, many small-scale outlets existed. These were essential to vehicle mass penetration according to Melaina and Bremson, as they provided a sufficient level of refuelling availability for early adopters. In time, these outlets were replaced by high(er) volume large(er)-scale stations. Increasing vehicles numbers and fuel consumption and decreasing number of stations led to a spatially efficient network.

Melaina and Bremson (2008) discuss how many refuelling stations would be necessary to satisfy the refuelling needs of consumers in urban areas. In an attempt to analyse the minimal number of stations needed in urban agglomerations with a population density of more than 250 persons per square mile,[12] they found that in the US a driver currently needs to drive approximately 3.3 minutes to a local refuelling station. The authors propose that this is a level of convenience that is not necessary for convenient refuelling of an alternative fuel (comparable to current US standards). They propose that a hydrogen station network covering 67% of their current estimate of stations would provide a sufficient level of coverage.

Kitamura and Sperling (1986) identify more detailed patterns of refuelling behaviour. Drivers tend to refuel in areas that are known to them, e.g. in vicinity to their work/home, and the refuelling is usually done either at the start or at the end of the journey. Their research suggests that strategic locations for first outlets are along high-volume commuter routes in order to increase the predictability of station locations and to compensate for low initial refuelling station availability.

Molin et al. (2007) found that the willingness to detour in order to reach a refuelling station is an important barrier to market introduction of AFVs. However, their stated-choice experiment was conducted with rather large detours of 20 and 40 kilometres. Based on their results, a detour of 40 kilometres in the early phase of hydrogen vehicle market introduction a market penetration of 3.3 to 6.1% is achieved (depending on the availability of a purchase cost reduction of € 1500). In a scenario with improved emission reduction and vehicle range and a detour of 20 kilometres, a penetration between 18,4 and 30% (depending on the availability of a purchase cost reduction of € 1500) seems achievable.

Early studies on adoption of diesel and natural gas vehicle owners suggest that concerns over fuel availability becomes a minor issue when 10-20 percent of all stations offer the alternative fuel. Those results have been confirmed by a stated preference survey in California to find out the value consumers place on fuel availability. Generally, there is a low willingness to pay a higher fuel price for greater availability (Greene, 1998).

Another study carried out in the US aimed at quantifying the 'chicken-and-egg' barrier of hydrogen stations and hydrogen vehicle demand also analysed the influence of detours to refuel a hydrogen vehicle. This research modelled the market share of hydrogen vehicles under different circumstances. Results show that the market share of hydrogen vehicles is dependent on the interaction between e.g. the travelling distance to a station, the fuel cost of hydrogen and other fuels. The market share of vehicles diminished with almost 10% in case of a required detour for refuelling purposes of 10 minutes. In case of reduced detour time of only 3 minutes, the market share diminished with approximately 1% (Welch, 2007).

The amount and siting of hydrogen refuelling stations was analysed by means of geographical information systems (GIS) in Sacramento County (US). Based on the available gasoline network, drivers are currently used to travel not more than 1min 50sec to the next refuelling sta-

[12] Please note that this definition of urban (vs. rural) differs significantly from the definitions given for the Netherlands above. While Melaina and Bremson consider 250 persons per square mile as urban agglomeration, the figures for the Netherlands considered 500 addresses per square kilometre (~2600 people per square mile) as rural area.

tion. Compared to 319 conventional stations, this travel time could be achieved with the strategic placing of 96 hydrogen stations, equal to 30% coverage. Even assuming 5% hydrogen station coverage, average driving time would be 4min in worst case. Most effective in the initial stages are stations located near or along the highway (Nicholas, Handy & Sperling, 2004).

In a survey that was conducted at the ECN[13] Open day in 2007 completed by 89 visitors showed that 60% of the respondents found a hydrogen availability along all highways plus 20% of all other stations acceptable. Availability of hydrogen along all highways and at 50% of other stations made a consideration to switch to hydrogen more realistic for 93% of the respondents.[14]

Another study among 300 Dutch car drivers highlights the importance of distance in general in the choice for a refuelling station. 50% of the respondents stated that the distance from either home or work to the refuelling station was the second most important reason to choose a specific station over others. In more detail, the survey revealed that 18% are not willing to drive additional kilometres to refuel their car, 37% of the respondents were willing to travel up to 2 additional kilometres to refuel and 36% was willing to travel up to 5 additional kilometres, 8% was willing to travel 10 extra kilometres and a small percentage of 2% was willing to travel more than 15 kilometres (Amelsfoort 2007).

Conclusions with respect to driving patterns, fuel availability and potential first buyers

- Drivers are currently used to a rather dense network of refuelling stations, especially in densely populated areas, and are generally not very willing to drive detours in order to refuel their car. Initial low fuel availability could therefore become a main obstacle to the successful introduction of an alternative fuel ('chicken-and-egg' problem of refuelling station availability and vehicle use).
- Due to the fact that most people currently refuel in the built environment but also require coverage along highways and abroad, early refuelling infrastructure roll-out could focus on highly frequented stations along daily commuting routes, and large stations at traffic hubs along highways
- Based on literature it is recommended to aim for a percentage of 20% of refuelling stations offering the alternative fuel as a first milestone of infrastructure development. Such coverage seems to be acceptable to the majority of people. In addition it is recommended to plan a concentration of refuelling station strategically planned along highways and near high commuter volume hubs. A high predictability of the location of hydrogen stations can further increase the perception of an acceptable level even below the 20% coverage.
- An initial hydrogen roll-out calls for a rudimentary coverage of the whole country and not just of key-cities or regions.
- In addition, European coverage will increasingly support the acceptance and uptake of hydrogen vehicles.

[13] Energy research Centre of the Netherlands.

[14] As visitors of the ECN Open Day who have an interest in a more sustainable energy system these respondents may of course have a higher intrinsic motivation to switch to an alternative fuel than other Dutch citizens. Furthermore, the size of the group of respondents does not allow to draw generalisable conclusions, but merely gives an indication.

5. Field survey on consumer behaviour among Dutch car drivers

The social science research conducted within THRIVE is largely based on literature review, scientific articles that deal with car use, travel and refuelling behaviour but also on national statistics and annually conducted surveys. This provides a sound basis but not very detailed information. Therefore, a cross-check with more detailed and more recent data from the Netherlands adds valuable insights.

In order to verify existing data an external survey was commissioned to TNS Nipo (TNS), a Dutch market research company. The survey was aimed to find out in particular about the current refuelling behaviour and willingness to make the shift to an alternative fuel. The survey was divided in two parts. The first one aimed to gather more data on refuelling behaviour, i.e. how, when, and where people refuel their car. The second part targeted the willingness of people to step over to an alternative fuel and which preconditions need to prevail in this case. In the following, the most important results are summarized and briefly interpreted.

5.1 General information

To conduct the survey, TNS made use of their pre-existing database that allows for the selection of a representative sample of Dutch households. In total, the sample consisted of 2,970 households in the Netherland which are in the possession of at least one car. Those people were presented with an online questionnaire. The questionnaire was not specifically addressing hydrogen as a fuel but addressed more generally alternative fuels.

The age distribution of the sample consisted of roughly one-third of 30 to 49 years old people, roughly another third was above 65 years of age, while the largest group (43 percent) was in between 50 and 64 years of age, see Figure 6.1. The age group of the 18 to 29 year-olds was with 1 percent hardly represented. According to TNS, this unrepresentative age distribution can be attributed to the selection method of the sample. The TNS database selected households that were in possession of at least one car and the main earner of each household was contacted. The questionnaire was accompanied by the request for it to be filled in by the person that uses the car the most within this household. Arguably, TNS respondents therefore mirror the vehicle owners which are of most concern when introducing hydrogen vehicles quite well: earlier sections show that early adopters will most likely be above the age of 50 and earn an above-average income.

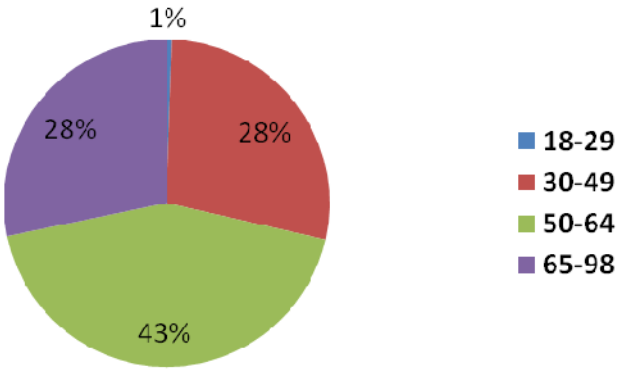


Figure 5.1 *Age structure of survey respondents in years of age*

5.2 Refuelling behaviour

As a start-up of the questionnaire, people were asked about their general motives for car use. The main reason for car use are shopping and groceries, followed by commuting to work. About one-fifth of the respondents indicated that they have other reasons than the ones suggested for car use, e.g. visiting other family members.

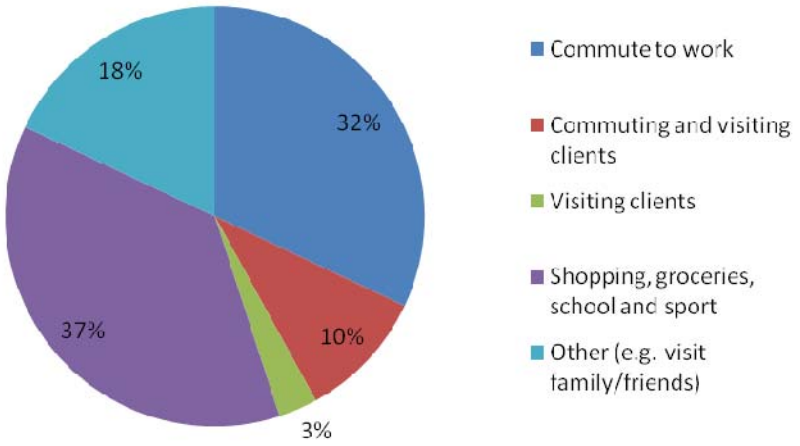


Figure 5.2 *Reasons for car use*

Moment of refuelling

More than half of the car drivers refuel their car just after they leave from home on the way to their destination. This is the preferred option across all age groups. Another almost 20 percent refuel their car close to home, on their way back home.

So, almost two-thirds refuel either shortly after departure from home or shortly on the way back. Similarly, almost 20 percent do an extra trip solely for the purpose of the refuelling. This is done in the majority by older people as they do not have to commute regularly and refuel along the way. It is rather unusual to refuel midway, but it may occur during long-distance trips, see Figure 6.3.

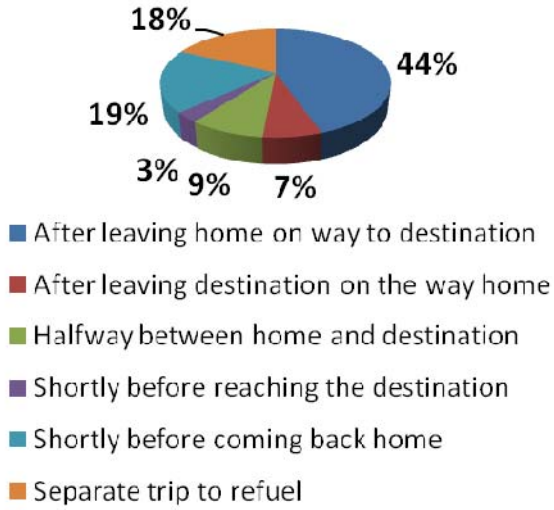


Figure 5.3 *Moment of refuelling*

Travel time between home and refuelling station

The moment of refuelling is closely connected to the average drive time between leaving from home and the refuelling station. Not surprisingly, more than half of all car drivers refuel their car within the first 5 minutes after leaving from home which corresponds with the results of the previous question. Another 25 percent refuels their car in up to 10 minutes after leaving from home. 8 percent is driving up to 15 minutes to refuel and only 9 percent take more than 15 minutes. That means that the vast majority of the people refuels in the first 5-10 minutes after leaving from home.

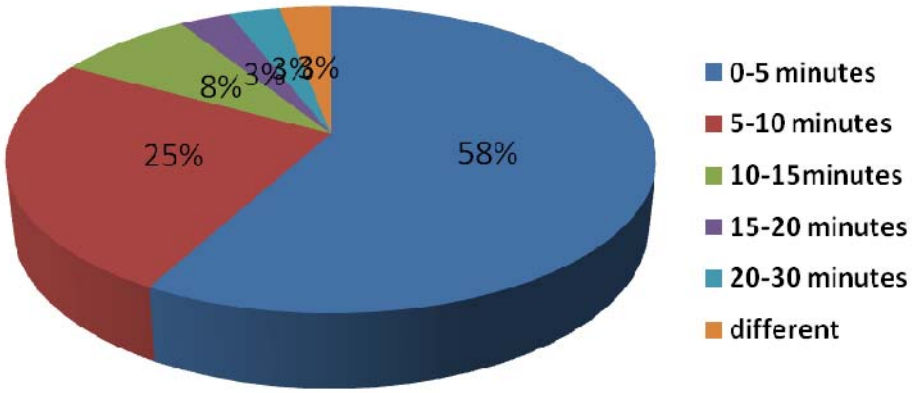


Figure 5.4 *Travel time between home and refuelling station*

Choice of refuelling station

Car drivers tend to make the choice for a refuelling station for a number of reasons. In the survey the respondents were asked about their preferences with a maximum of two answers. As a result, the large majority of car drivers chooses their station on the basis of fuel price. This reason is also confirmed across all age groups. The second most frequently stated reason is the convenience of the station location, i.e. along the normal way of the driver without requiring an extra detour. Other factors that are of influence are the availability of a bonus card system were the card holder can collect points that can later be exchanged against goods. People are also loyal to a certain fuel brand. Nevertheless, price and convenient location already make up the biggest decisions.

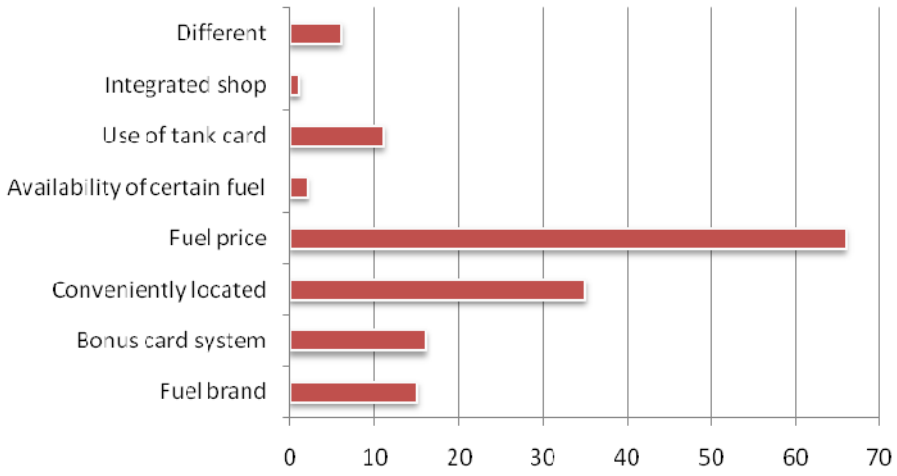


Figure 5.5 *Reason for choosing a refuelling station*

Location of refuelling station

Respondents were asked to provide information where their preferred location for a refuelling station is. The majority of the respondents is refuelling in the built environment, which is not surprising as most of the people refuel within a very short amount of time after leaving from home. 23 percent of the respondents refuel on their way to the highway and 13 percent in an industrial area.

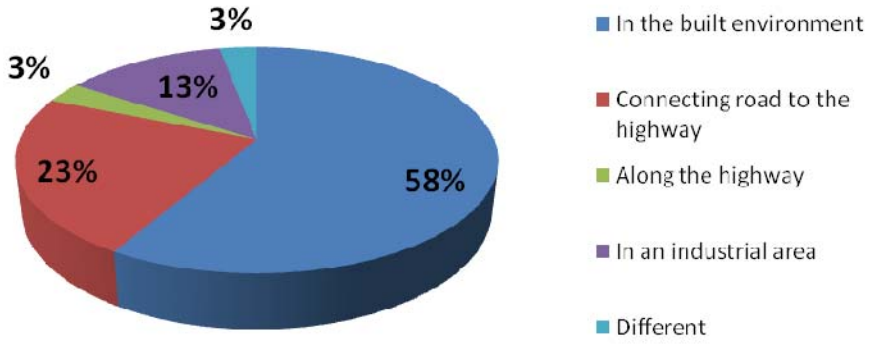


Figure 5.6 *Location of refuelling station*

Necessity to make a detour

It is also of interest if people take a detour to reach their preferred refuelling station. The initial hydrogen network will not be very densely spread and could therefore require a detour in order to refuel. The majority of respondents (69 percent) does not have to take a detour to reach their preferred refuelling station as it is located along their normal route. Slightly more than one quarter (26 percent) of respondents accepts a detour voluntarily while 5 percent always have to make a detour. Those respondents that have answered to make a detour have been presented with a follow-up question.

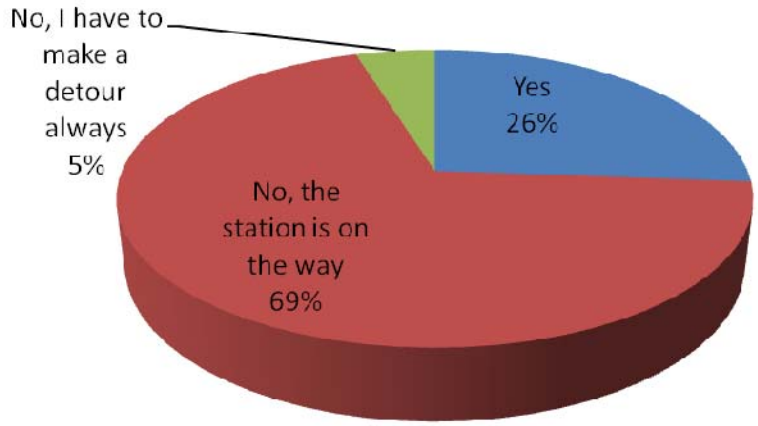


Figure 5.7 *Do you take a detour to reach your refuelling station?*

Length of detour

The group of respondents that previously indicated that they take a detour to reach their preferred refuelling station was presented with a follow-up question regarding the length of the detour. 78 percent of respondents only takes a relatively short detour of 5 minutes maximum, 18 percent drive up to 10 extra minutes. A very small group of people (4 percent) takes a larger detour of 10 minutes. In total this indicates that people are not willing to make long lasting detours. There may be several reasons why people do not make larger detours for refuelling. Many of them do not have to detour but only do it voluntarily, maybe for a price benefit. However, if

the detour becomes too large, this financial benefit is reduced and not attractive anymore. Other people may have to detour in order to get to a refuelling station, but because stations are also frequently available in more rural areas, detours do not have to be very long.

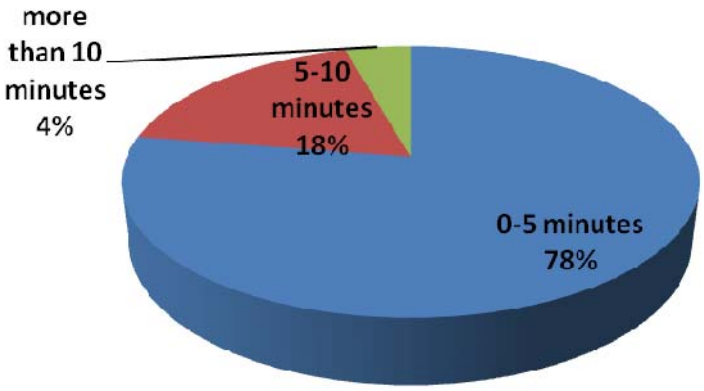


Figure 5.8 *How long do you take a detour?*

5.3 Willingness to switch to an alternative fuel

Availability of alternative fuel

The next question posed to the respondents was aimed to find out what availability of an alternative fuel needs to be present in order to trigger people to switch to the alternative fuel. In other words, the pre-conditions for switching should be evaluated. More than one answer could be given.

Before presenting the question, different information was given to three different (randomly chosen) groups of respondents. One group could view an alarming text about climate change and its consequences, the second group received a text about climate change stating that effects will only be limited without causing urgent problems and the third group received no introductory information. Answers to the following questions suggest that the information people receive affects attitude and opinion. 33%, 37% and 41%, respectively, answered they would like the alternative fuel to be available at the station where they predominantly refuel. Furthermore, the willingness to make a detour seems to increase, at least slightly: 23%, 22% and 21%, respectively answered they would like the alternative fuel to be available at a station nearby or within the distance of a 5 minute detour. The figures changed to 13%, 10% and 8% with a detour of 10 minutes.

Table 5.1 *Respondents' answers after being presented with (no) information about climate change*

Question: In the beginning alternative fuels are not available at every station. When would you consider switching to a car driving on an alternative fuel?			
Group	Alarming information	Calming information	No information
If it was available at the station where I usually refuel.	33%	37%	41%
If it was available at a station in my neighbourhood and I am willing to drive an extra 5 minutes.	23%	22%	21%
If it was available at a station in my neighbourhood and I am willing to drive an extra 10 minutes.	13%	10%	8%

More than 50% answered that the fuel has to be available throughout the country so they can drive through the Netherlands without having to worry about fuel availability. Almost 40% of respondents indicated that they require fuel availability abroad before considering to switch.

Based on the data TNS made available for this question it is not possible to identify what set of options respondents chose as answers. However, detailed information for the three groups who received different or no prior information about climate change is available. This revealed that 35% of respondents did not include countrywide availability and availability abroad in their answers, suggesting that local availability of an alternative fuel is sufficient for them, e.g. because the car is used only for 'local' trips. Due to the fact that this question did not specifically ask about hydrogen as a fuel but rather about alternative fuels in general, e.g. ethanol, CNG and hydrogen, it may not have been clear to respondents that they could actually run out of fuel if insufficient stations were available. The group of people that indicated they require 'sufficient coverage' were presented with a follow-up question to gather more details.

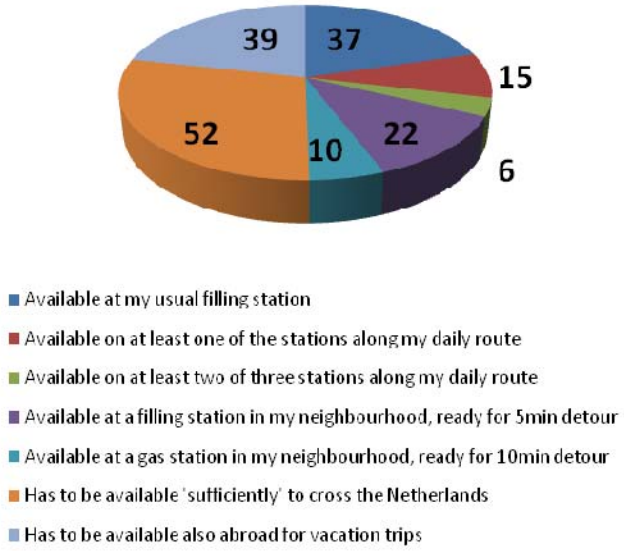


Figure 5.9 *Availability of alternative fuel*

Station coverage

In the previous question, respondents were asked where an alternative fuel would need to be offered in order for them to consider to buy a car driving on that fuel. Those that indicated 'sufficient' in their answer (the largest response group) were confronted with a follow-up question aiming to find out what station coverage they consider as 'sufficient to cross the Netherlands'. This formulation, unfortunately, leaves room for interpretation. Some people may only have considered stations along highways and main roads when choosing a 'cross country availability', while other may have considered all stations. For the first group of respondents this implies when opting for a 50% availability (meaning along highways and main roads) this corresponds to about a 20% availability at all stations.

When adding up the groups that accept an availability of one out of ten up to one out of three stations (30 percent availability), a group of 44 percent would be reached. Nevertheless, in order to satisfy a comfortable majority also the share of people that require a alternative fuel station coverage of one out of two (50 percent availability) has to be taken into account. Still, about one quarter of the respondents only accepts an alternative fuel if it is available at virtually every refuelling station.

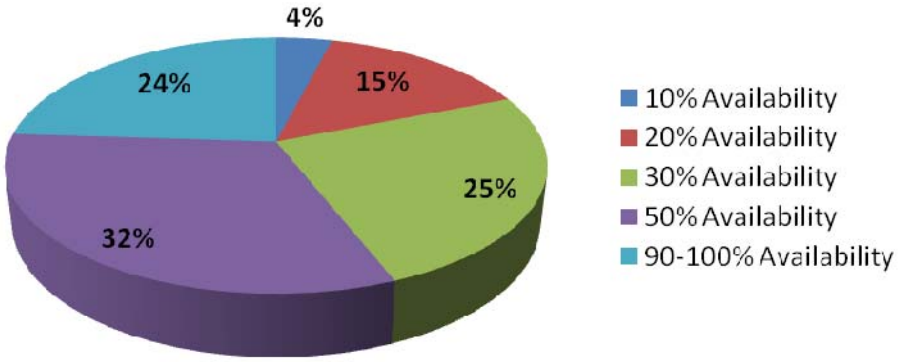


Figure 5.10 *Percentages considered 'sufficient' station coverage*

5.4 Comparison of research results

A comparison of results from the TNS survey among 3,000 Dutch car owners and results of previous research summarised earlier can provide additional insights, e.g. with respect to country specific differences. A comparison between the MON and the TNS study allows to cross-check survey results, as all data focus on the Dutch population. The main reasons for car use, namely commuting to work and shopping as reported in both surveys coincide.

The refuelling behaviour reported in different studies may vary slightly because of differences in refuelling station availability. In a US study conducted by Melaina and Bremson (2008) reported that people only need to drive about 3 minutes to reach a local refuelling station and in the Netherlands 60 percent indicated to drive 5 or less minutes. However, another quarter of Dutch drivers reported that they usually drive 5 to 10 minutes before they refuel their car. Differences between these figures may be due to the fact that the US authors reported how long people in the US (in theory) need to drive to a refuelling stations, while Dutch drivers indicated how long they need to their specific station of choice which they most often use shortly after leaving home. At the same time, these differences may also be due to a different density of the refuelling networks in the two countries.

There is also agreement between literature reviewed for this report and the TNS study conducted among Dutch drivers with respect to the preferred areas where people refuel. Most drivers, across countries and age groups, opt for a station in an area known to them, close to their home or along their daily route. Among the Dutch TNS respondents was a rather high percentage of people who makes an extra trip to refuel (18 percent). This may again be attributed to the rather disproportionate representation of people in retirement age and underrepresentation of people in the age group of 18 to 29.

Concerning the willingness to drive a detour results found in the literature cannot easily be compared to those reported in the TNS survey. A study by Molin et al. (2007) predicts an 18% penetration rate if people have to detour about 20km in order to refuel their car. A detour of 20km takes about 15 to 25 minutes to drive, depending on traffic and speed limits. Of Dutch respondents 5 percent indicated that they have to take a detour for refuelling and another 25 percent indicated that they are voluntarily doing so. However, only 4 percent of those who take detours drive more than an extra 10 minutes, the vast majority (78 percent) only drives a detour of about 5 minutes. These data roughly coincide with data for the Netherlands reported by Amelsfoort (2007). This may indicate that the willingness to accept a detour for refuelling is comparatively low in the Netherlands, which may hamper the initial up-take of hydrogen vehicles. The result for Dutch drivers may also indicate that Molin and co-authors were generally too optimistic in their estimates.

An analysis of people's requirement concerning the percentage of stations offering an alternative fuel when considering to buy a car driving on this fuel may help to shed light on the question whether people may be as flexible as estimated by Molin et al. (2007) or whether there may be country-specific differences. Greene (1997) came to a required 10 to 20 percent for US drivers, while Dutch drivers answering the TNS survey required a 30 to 50 percent refuelling station coverage. In a very small-scale survey among Dutch drivers at the ECN Open Day, the majority indicated a required coverage of 20 percent. In this context outcomes of the TNS survey seem exceptionally high and may again be accredited to the high percentage of people above retirement age who may be more reluctant to change than younger people who were underrepresented among respondents.

6. Summary and conclusions

This report discusses current car purchasing and driving behaviour in the light of a strategic introduction of hydrogen fuel cell vehicles on the Dutch car market. Hydrogen fuel cell cars are a relatively novel technology but currently the technology is shifting from an R&D to an early market commercialisation phase, suggesting that vehicles will be available on the market within a few years. It is expected that in the first years of market introduction, manufacturers will not offer the full range of their models as a hydrogen fuel cell vehicle. This practice can be also observed with other technologies, e.g. hybrid technology that is usually first introduced with one model and then further rolled-out into the vehicle portfolio. Also, the initial price for a hydrogen vehicle will be above that of a comparable conventional vehicle. These issues influence the segment of people considered to be the first user group for hydrogen vehicles.

Purchasing behaviour
For the THRIVE project it was of interest to gather more information on the profiles of Dutch car drivers with respect to age, income, price and performance requirements, brand loyalty and decision-making behaviour when purchasing a car. This analysis was expected to provide a profile of 'prototypical' first users for hydrogen fuel cell vehicles in the Netherlands. Additionally, it was checked whether there are locations in the Netherlands that have higher concentrations of potential first users. This can have important implications for the development of a hydrogen refuelling infrastructure.

Generally, it can be concluded that it proves difficult to provide a sharp profile of potential first users of hydrogen vehicles. Hydrogen vehicles are expected to be (at least initially) more expensive than currently available cars. Due to the fact that age, income and car ownership are all positively related, first users who are able to afford hydrogen-powered vehicles are likely to be above the age of 50. Due to large gender differences in car ownership, first users may be predominantly male. The highest income areas in the Netherlands are concentrated around larger cities, such as the area called 'Randstad' (Amsterdam, Rotterdam, Utrecht, Den Haag) or the cities of Arnhem and Eindhoven.

Research into different parameters that influence the purchase decision for a new car has shown that there are some strong, decisive ones and some of less influence, second-order parameters. A reason complicating the creation of a sharp profile of potential first users of hydrogen vehicles is that decisive factors in car purchasing behaviour can change over time. Above all, the decisive purchasing factors are still brand, price and performance of the vehicle. Consumers often choose from within the portfolio of a certain manufacturer they know and trust. The vehicle price is one of the main decision criteria. People also have certain expectations in terms of vehicle performance that are based on currently available technology. Therefore, market introduction of hydrogen fuel cell cars will be facilitated by performance characteristics that match today's conventional cars. The operating distance seems to be of particular importance and should enable the user to drive 400-500 km without refuelling. It is the stated aim of car manufacturers to offer hydrogen vehicles that have equal (or closely matching) performance characteristics as conventional cars, with comparable driving range, top speed and torque.

Fuel price has been found to play a less significant role compared to vehicle purchasing price. People's price sensitivity is rather high at the point of purchasing a car but fuel costs are often not considered in detail. Generally, people hardly follow their fuel expenses and hardly engage in detailed pay-back time calculations if choosing between two vehicles driving on slightly differently priced fuels. Nevertheless, a low pump price works in favour of a fuel, while a high pump price over an extended period of time can cause people consider switching to another less expensive one.

Following an increasing environmental consciousness, also the environmental performance of a car, i.e. its CO_2 emissions, is becoming a concern for users. However, environmental performance of a car has not been found to be one of the most influential factors in purchasing behaviour in this research. It can, however, be assumed that environmental performance of vehicles can have an influence on future purchasing decisions, especially if governmental incentives would continue favouring low- or zero-emission vehicles over conventional cars, e.g. by providing financial incentives. Some parts of the population that have sufficient funds available might choose more environmentally friendly cars over others, despite higher cost. This phenomenon was for example observed in the US where most hybrid owners were people in retirement age. In the Netherlands the uptake of hybrid electric vehicles was significantly influenced by governmental financial incentives.[15]

The analysis of the current car park in the Netherlands shows that the brands and models sold most in the Netherlands only somewhat match with those currently available as hydrogen models. The six most frequently bought brands are Volkswagen, Toyota, Ford, Peugeot, Opel and Renault. Of this list, only Toyota, Ford and Opel are known for hydrogen fuel cell activities, while VW, Peugeot and Renault have not indicated much interest in this technology, so far. Other major hydrogen players, namely Daimler, Honda, Hyundai and Kia, only hold smaller shares of the Dutch market. Of those three, only the last two have employed hydrogen cars in demonstration projects. However, the preferred size segment of Dutch car owners, namely the C segment (e.g. VW Golf) is currently only served by Daimler and Ford with hydrogen models. With the latter there is at least one top-selling car and size segment represented in the hydrogen models under development. The scope of this report does not allow to draw conclusions concerning which size segment is most frequently bought by the earlier profiled first potential users of hydrogen cars, namely the male, above 50, higher income population segment. It may well be, that this group more often purchases cars in the larger size segments which are currently targeted by OEMs.

Driving and refuelling behaviour

The annual mobility survey by the Dutch Ministry of Transport and Water Works shows the car as main means of transportation in the Netherlands, especially - as already mentioned above - among the male, older and higher earning part of the population.

A survey among 3,000 Dutch car drivers revealed that most people refuel their car most frequently in the beginning of a trip, but still close to their home, about 5 minutes after leaving. They choose a refuelling station largely because of fuel price and location. Based on these determinants, most people currently refuel in the built environment, where stations are close to their home and comparatively cheaper than those along highways. Few people drive detours in order to refuel their car and those who do, only drive an extra 5 to 10 minutes. To consider switching to an alternative fuel, the majority of respondents requires sufficient fuel availability throughout the Netherlands, preferably at their most frequented refuelling station. Most people view a coverage of 30-50 percent of stations offering the alternative fuel as ‘sufficient’. Earlier research has shown that a well planned refuelling network with a high predictability of stations offering an alternative fuel may be able to offer current convenience at lower coverage percentages, such as 10 to 20 percent. Besides national availability, fuel availability abroad is of major concern for Dutch drivers. The Netherlands have limited influence on the development of a hydrogen refuelling network abroad, but there are initiatives in Germany, France, Scandinavia and Spain, and also Italy. The importance of fuel availability abroad may cause countries to collaborate more closely on a European level in the future.

[15] In the Netherlands, people who purchase a hybrid electric vehicle whose emissions are below or equal to 110 g of CO_2 per km for a petrol hybrid and below or equal to 95 g $_C$O2 per km for a diesel hybrid do not pay an extra purchase tax which is usually paid in addition to VAT, and do not pay the annual vehicle tax.

References

Achterberg, P., D. Houtman (2006): *Why do so many people vote 'unnaturally'? A cultural explanation for voting behaviour*. European Journal of Political Research, 45, 75-92.

Adamson, K.-A. (2003): *An examination of consumer demand in the secondary niche market for fuel cell vehicles in Europe*. International Journal of Hydrogen Energy, 28, 771-780.

Amelsfoort, A. (2007): *Weg Vrij voor duurzame brandstoffen? Onderzoek naar bereidheid consument om over te schakelen op duurzame brandstoffen.* Rijksuniversiteit Groningen.

Centraal Bureau voor de Statistiek (CBS): Data retrieved from http://statline.cbs.nl/statweb/.

Consumerreports.org (2010): *Owner satisfaction - Which car would you buy again?* Retrieved on 8 July 2010 from http://www.consumerreports.org/cro/cars/new-cars/cr-recommended/would-you-buy-that-car-again/overview/index.htm.

Dagsvik, J.K., T. Wennemo, D.G. Wetterwald, R. Aaberge (2002): *Potential demand for alternative fuel vehicles*. Transportation Research Part B, 36, 361-384.

De Haan P., A. Peters (2008): *How do people decide on buying fuel efficient cars?* http://www.uns.ethz.ch/res/crp/emdm/carchoice.

De Haan, P., M. Müller, A. Peters, A. Hauser (2007): *Lenkungsabgaben zur Senkung des CO_2-Ausstosses beim Neuwagenkauf: Hintergrund, Mechanismen, Prognosen*. Zürich: ETHZ.

ECN (2009): *Market perspectives for H_2 vehicles - Analysis of current status and requirements*. ECN-E—09-028, Petten.

Ewing, G.O., E. Sarigöllü (1998): *Car fuel-type choice under travel demand management and economic incentives*. Transportation Research D, 3(6), 429-444.

FuelCellToday (2010): http://www.fuelcelltoday.com/online/news/articles/2010-05/Toyota-Outlines-Cost-Down.

Greene, D. (1998): *Survey evidence on the importance of fuel availability to the choice of alternative fuels and vehicles*. Energy studies review, 8(3), 215-231.

HyFleet:CUTE *Milestone M 5.1 Social Studies and Hydrogen- what has been done, what have we learned, what is missing? Review of CUTE deliverable socio-economic aspects*. TREN/05/FP6EN/S07.52298/019991.

HyLIGHTS (2008): *The GAPS analysis - minimal user requirements for hydrogen vehicles.*

Where in Europe and who is willing to bridge the gap between lighthouse projects and early-commercialization phase?, retrieved 15 June 2010 from http://www.hylights.org/.

Johnson, W.C., L. Chang (2000): *A comparison of car buying behaviour between American and Chinese people living in North America: an exploratory study*. Paper presented at the Southwestern Marketing association conference in San Antonio, Texas, 15-18 April, retrieved on 14 June 2010 from http://www.sbaer.uca.edu/research/swma/2000/17.pdf .

Kahn, M.E. (2007): *Do greens drive Hummers or hybrids? Environmental ideology as a determinant of consumer choice*. Journal of Environmental Economics and Management, 54, 129-145.

Kasper, H. (1988): *On problem perception, dissatisfaction and brand loyalty*. Journal of Economic Psychology, 9 (3), 387-397.

Kitamura R., D. Sperling (1986): *Refuelling behaviour for automobile drivers*. Transportation Research Part A, 21(3), 235-245.

KPMG International. Momentum: KPMG's Global Auto Executive Survey 2009 - Industry concerned and expectations 2009-2013. Retrieved on 14 June 2010 from http://www.kpmg.com/Global/en/IssuesAndInsights/ArticlesPublications/Momentum/Documents/Momentum-AutoExec-2009.pdf.

Lane, B., S. Potter (2007): *The adoption of cleaner vehicles in the UK: exploring the consumer attitude-action gap*. Journal of Cleaner Production, 15, 1085-1092.

Maack, M. (2006): *ECTOS. Deliverable no 17. Total Impact Assessment*. Icelandic New Energy

Mau, P. et.al. (2008): *The neighbor effect: Stimulating dynamics in consumer preferences for new vehicle Technologies*. Ecological Economics, 68, 504-516.

Melaina, M., J. Bremson (2008): *Refuelling availability for alternative fuel vehicle markets: sufficient urban station coverage*. Energy Policy, 36, 3223-3231.

Ministerie van Verkeer en Waterstaat (2002): *Gebruikersonderzoek Nederlandse Snelwegen.* Rijkswaterstaat.

Molin, E., F. Aouden, B. Van Wee (2007): *Car drivers' stated choices for hydrogen cars: evidence from a small-scale experiment*. Paper for the Transportation Research Board, 86th Annual meeting, Washington D.C.

Molin, E. (2005): *Causal Analysis of Hydrogen Acceptance*. Transportation Research Record: Journal of the Transportation Research Board, No. 1941. Transportation Research Board of the National Academies, Washington D.C., 115-121.

Nicholas, M.A., S.L. Handy, D. Sperling (2004): *Using geographic information systems to evaluate siting and networks of hydrogen stations*. Transportation Research Record: Journal of the Transportation Research Board, 1880, 126-134.

O'Garra, T., S. Mourato, P. Pearson (2004): *Analysing awareness and acceptability of hydrogen vehicles: A London case study*. International Journal of Hydrogen Energy, 30, 649-659.

Potoglou, D., P.S. Kanaroglou (2007): *Household demand and willingness to pay for clean vehicles*. Transportation Research Part D, 12, 264-274

Ricci, M., R. Flynn, P. Bellaby (2006): *Public Attitudes towards hydrogen energy, Preliminary Analysis of findings from focus groups in London, Teesside and Wales.* University of Salford

Schulte, I., D. Hart, R. van der Vorst (2004): *Issues Affecting the Acceptance of Hydrogen Fuel*. International Journal of Hydrogen Energy, 29(7), 677-685.

Stobart, R.K. (1999): *Fuel cell power for passenger cars- what barriers remain?* SAE Technical Paper Series, No. 1999-01-0321.

Sperling, D., R. Kitamura (1986): *Refuelling and new fuels: an exploratory analysis.* Transport Res—Int. Part A, 20A (1), 15-23

Turrentine, T.S., K.S. Kurani (2007): *Car buyers and fuel economy?* Energy Policy 35(2), 1213-1223

VNA(2009): *Autoleasemarkt Jaarcijfers 2009*, facts and figures Dutch Market, retrieved on 14 June 2010 from http://www.vna-lease.nl/docs/VNA%20Annual%20Figures%202009.PDF

Welch, C. (2007): *Using HyDIVE™ to Analyze Hydrogen Scenarios*, NREL/TP-560-41363, Golden, CO: National Renewable Energy Laboratory

Wright, K. and C. Baumann (2007): *The effectiveness of customer loyalty programs in comparison to supermarket fuel discount schemes: An empirical study*. Proceedings of the Australian and New Zealand Marketing Academy ANZMAC, Dunedin, New Zealand, 3-5 December 2007.