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Building a Hydrogen Refuelling Infrastructure in the Netherlands: Influencing Factors from the Car Drivers' Perspective

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1 Introduction

The introduction of hydrogen as a new, alternative fuel bears numerous challenges, one of which is the development of a refuelling infrastructure. The THRIVE ('Towards a Hydrogen Infrastructure for Vehicles') project aims to provide possible developmental routes and technological options for a hydrogen refuelling infrastructure in the Netherlands[1]. The model builds on the assumption that the commercial roll-out of hydrogen vehicles and the necessary infrastructure will take off within the coming decade. By making this assumption, research can focus on identification of relevant stakeholders, cost analyses, testing of technological options and actions to be taken for a successful introduction of hydrogen as alternative transport fuel for passenger cars.

The modelling approach at the core of the project allows testing different roll-out scenarios for the 15-20 years after commercial introduction. The modelling efforts have been underpinned by socio-economic research, such as supporting policy measures and consumer behaviour with respect to the introduction of innovative technologies.

This paper focuses on relevant behavioural aspects, in particular on car drivers' current refuelling behaviour and its implications for the development and layout of a hydrogen refuelling infrastructure. 'Refuelling behaviour' is in this context concerned with the temporal and spatial dimensions of decisions and actions car drivers take when wanting and/or needing to fill up the fuel tank of their car.

Previous research concerning refuelling behaviour provides important insights which are reviewed in more detail in the following chapter. The importance of matching the usability of a new alternative fuel to the current use of incumbent fuels called for an analysis of current refuelling behaviour of Dutch car drivers for the THRIVE project. The need for country-specific and up-to-date results is particularly relevant as existing research on refuelling behaviour mostly focuses on the US and dates from the 1980s. Drivers' refuelling behaviour varies between countries as it depends on a country's size, road infrastructure, dispersion of cities, refuelling infrastructure (i.e. station network), and cultural norms and values related to driving. US cities sprawl and often lie far apart. In the Netherlands, the population density is much higher and cities are located close to one another.

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[1] The THRIVE consortium consists of ECN and TNO as research institutes as well as Shell and Linde Benelux representing industry.

The present analysis therefore aims to provide new insights on Dutch car drivers' refuelling behaviour. Another objective of this analysis is gaining an understanding of the relation of fuel availability and people's willingness to use a particular fuel. Fuel availability in this context refers to the number of stations per zipcode-area offering a particular fuel. This 'station coverage' is set in relation to people's 'willingness to switch', namely their readiness to start using a different fuel than the one they are currently driving on. In particular, it aims to answer the questions: When and where during a trip do Dutch car drivers decide to refuel their car? And what station coverage of an alternative fuel do people consider acceptable when deciding to buy an alternative fuel car. By means of an online survey, Dutch car drivers were presented with a number of questions. The quantitative analysis of their answers is discussed in this paper.

The paper is structured in four sections. Following this introduction, section 2 reviews previous research outcomes on refuelling behaviour and strategic infrastructure development for an alternative fuel. The same section describes in more detail the survey on refuelling behaviour of Dutch car drivers carried out in the framework of the THRIVE project the results of which will be presented in section 3. Conclusions can be found in section 4.

2 Background

2.1 Previous research

The build-up of refuelling infrastructure for an alternative fuel has already received attention by the research community for a couple of decades. Of particular interest are the station coverage required to make a successful introduction of a new fuel [1], and drivers' willingness to make a detour in order to reach a station offering the fuel they need. Both these issues are firmly rooted in drivers' current refuelling habits. Although not all studies were concerned with the same alternative fuel, general consensus is that the successful introduction of alternative fuel vehicles (AFVs) strongly depends on (perceived) fuel availability. Sperling and Kitamura [2] enquired into decisive factors for people considering the purchase of an AFV and conducted a large survey among Californian drivers. They conclude that perceived fuel availability plays an important role in the purchasing decision for a car. Interestingly, a spatially well-planned refuelling infrastructure with high predictability of the location of stations offering a certain fuel can well compensate for overall lower availability. Furthermore, Sperling and Kitamura analysed the relation of fuel price and the necessity to make a detour in case of lower fuel availability. Generally, drivers are ready to make a detour if the additional fuel used to detour is offset by means of a lower fuel price.

Research by the same authors [3] reveals behavioural patterns or habits important for the strategic planning of an alternative refuelling infrastructure. Their data show that most people refuel in areas they are rather familiar with, e.g. close to their home or close to their work. Furthermore, people frequently refuel on their daily travel, e.g. the commute between home and work, rather than on trips they do less often, e.g. for shopping. However, there are also drivers who make special tours only to refuel their car. The results of these two studies point to the importance of strategic planning of an alternative refuelling infrastructure with a focus on main commuting routes (along highways or larger roads) in order to meet drivers' most common demands and to compensate for the (initially) lower availability of a new fuel.

More recent research – also based on American data – comes to similar conclusions as the two publications reviewed above. Melaina and Bremson argue that an alternative refuelling infrastructure is best initiated in urban agglomerations, as it requires less capital investment and meets the possibly more frequent need to refuel caused by the lower range of some AFVs [4]. However, the current station coverage of one in every 3.3 minutes drive time that the authors found in urban areas with a population density above 250 people per square mile^2 is deemed unnecessary. They conclude that a density of station offering an alternative fuel could be 33% lower than current coverage and still supply sufficient availability[3].

Apart from research mostly focusing on the US, also some data are available for the Netherlands. A research carried out by Van Amelsfoort [5] among 300 Dutch car drivers indicates that the distance of a refuelling station to the location of their work or home is for half of the respondents the second most important decision-making factor when choosing a station. Furthermore, 18% of the respondents are not ready to make a detour for an alternative fuel, while 37% is willing to drive an extra 2 km, 36% willing to drive an extra 5 km, and 10% an extra 10 km. The lack of detailed data from the Netherlands and the US-bias of available literature on refuelling behaviour called for a larger survey among Dutch drivers.

2.2 THRIVE survey

In order to gain better insight into Dutch drivers' current refuelling behaviour and willingness to switch a survey was commissioned to TNS NIPO, a market research company based in Amsterdam. For the selection of a suitable sample, the TNS NIPO database of registered participants was searched and Dutch households owning at least one car were contacted. These households received a weblink that allowed respondents to enter their answers to the questions posed online. It was explicitly asked that the person using the car most frequently filled in the questionnaire.

The survey consisted of twelve questions. It was answered by 2,970 respondents. Most likely due to the fact that the most frequent driver of (one of) the household's car(s) was asked to reply to the questionnaire, most of the respondents were older than 40 (90%) and male (84%). Results of the statistical analysis of responses are presented in more detail and discussed in the following section.

3 Results

3.1 Introduction

The focus of the survey was to study the influence of the layout of a refuelling station grid on the willingness to switch to another fuel, assuming that there is a motivation to switch to more sustainable alternative vehicles. The scope of this study was not to answer the question why people would want to switch to a more sustainable energy source for their mobility. Typical

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[2] Although they also found great variations in station coverage amongst different urban agglomerations with similar population densities.

[3] For more research available on sufficient station coverage, i.e. fuel availability, see e.g. Melania, M., McQueen, S., & Brinch, J. (2008) Refueling infrastructure for alternative fuel vehicles: Lessons learned for hydrogen, NREL/BK-560-43669

causes that may make consumers consider choosing for different, more sustainable and maybe more costly fuels can be, among others, climate change, oil depletion.

3.2 Refuelling behaviour

The first set of questions addressed habitual behaviour of drivers regarding the refuelling process, the location of the station they most frequently use and how much time it takes to get there. The most important results are elaborated in the following.

Nearly three quarters (74%) of all car drivers in the survey indicated that they refuel their car just after leaving home on the way to their destination or vice versa. This behaviour is not correlated with the driver's age. Almost 20% perform an extra trip solely for refuelling the car. This behaviour is correlated with age: the majority of people who makes an extra trip for refuelling is 55 years old or older. A plausible explanation for the large representation of this age-group could be the large representation of pensioners in this group that don't commute regularly and thus don't have the opportunity to refuel during habitual commutes. The survey indicates that it is rather unusual to refuel halfway for the majority of people. For long haul car-use however, it is reasonable to assume that refuelling far away from the point of departure and point of arrival is a logical choice.

The results of the survey show that the moment of refuelling is closely connected to the average drive time between home and the refuelling station. More than half (58%) of all drivers refuel their car within the first 5 minutes after departure. Another 25% refuels in between a time window of 5-10 minutes after departure. Summarised, this means that more than two-thirds of all drivers refuel their car within a maximum of 10 minutes after departure from a destination. Increased attention for the fuel gauge during the initial phase of a trip could be an explanation for the tendency to refuel shortly after departure but this has not been investigated further. The majority of the car drivers (59%) most frequently visits filling stations which are located in the built environment. Second most frequently visited are petrol stations which are located in between the place of departure and an access road to a highway (23%).

Drivers tend to choose their filling station for a number of reasons. In the survey, more than one answer was allowed. The large majority of the drivers (66%) throughout all age groups choose their stations on the basis of fuel price. The second most specified argument (35%) is the station's location along a driver's habitual route. Price and convenience are thus by far the two most important factors mentioned. Other factors that influence the choice of the refuelling station are the driver's participation in a bonus card system and brand-loyalty, each mentioned by 15% of the respondents.

3.3 Willingness to switch

The second set of questions in the survey specifically aimed at clarifying which preconditions are required to trigger a consumer to switch to sustainable automobility in terms of fuel availability. A consumer may be able to buy a hydrogen a biofuel powered vehicle but if the fuel-availability is below a certain threshold, the consumer may feels he runs the risk of regularly running empty on fuel. This of course may strongly reduce a consumer's will to switch to an alternative fuel vehicle.

More than one third of the survey participants (37%) indicated that it would be sufficient if the fuel is available at their most frequented filling station. However, the majority requested the alternative fuel to be available across the whole country, see Figure 1.

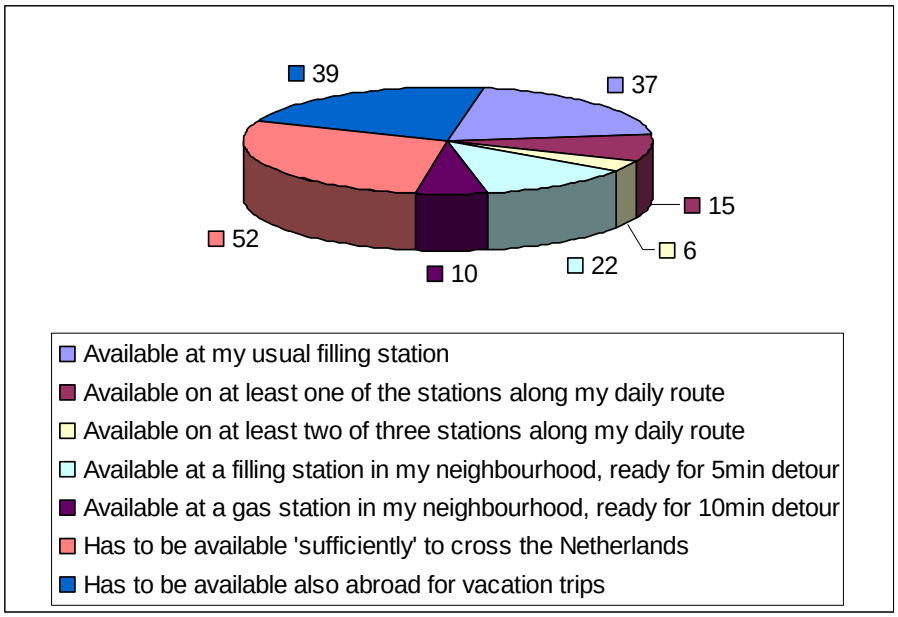

Figure 1: Preconditions for fuel switching.

Strikingly, the second most often chosen response was confirmative to a desired fuel availability abroad indicating that people like the possibility of being able to go on holidays abroad by car. Because of the structure of the questions used in the survey, it is however not possible to identify what set of correlations exists between multiple answers given by participants.

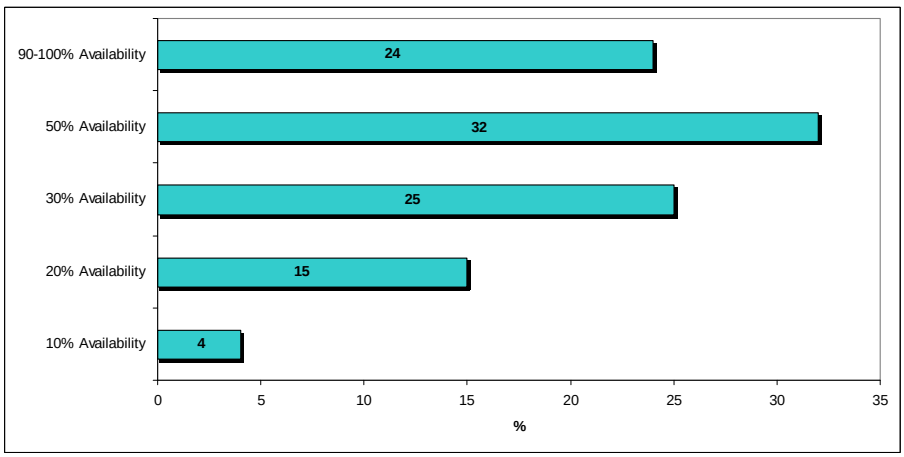

Figure 2: Required alternative fuel station coverage.

In the previously mentioned question, respondents could indicate that the alternative fuel has to be available sufficiently (i.e. at a number of random filling stations) to drive through the whole country of the Netherlands without fearing to run out of fuel. The participants who confirmed received a follow-up question to find out what exactly they define as sufficient

station coverage. One quarter would require every third filling station of the existing fuel station grid to be equipped with the alternative fuel, while about one-third of the respondents (32%) requires the alternative fuel to be available at every second station. Taking into account the responses that would require low station coverage (1 out of 10 and 1 out of 5), almost 74% percent of the respondents would be satisfied if every second station offered the alternative fuel. Still, one quarter to the respondents' demands availability of fuel throughout the country with a higher response rate in the group of older people (>55 yrs.).

4 Conclusions

This study is based on a survey that was performed to chart the refuelling preferences of the Dutch population. The survey was performed to obtain insight in the initial requirements to realise a hydrogen refuelling infrastructure in the Netherlands. Very few results from studies to refuelling behaviour have been published before. An important comparable study was performed at the University of California by Kitamura and Sperling on refuelling behaviour among US citizens.

Comparison shows, that despite cultural differences between the USA and the Netherlands, a preference among drivers to refuel their car shortly after leaving a point of departure is a shared result of both our study and the work of Kitamura and Sperling. Furthermore, our study also confirmed the earlier findings of Kitamura and Sperling on the low willingness to make a detour to reach a refuelling station.

Further results of our study indicate that an initial infrastructure should be based on sufficient availability of hydrogen refuelling stations in the built environment and not just along highways. Drivers prefer to visit a refuelling station along their habitual route. Therefore, the highest acceptance of hydrogen-fuelled mobility among drivers could be achieved, as far as the influence of the refuelling infrastructure reaches, by upgrading existing, high turnover stations in the built environment. But local availability is not sufficient. Drivers require refuelling stations across the whole country and not only in key cities or regions. An initial hydrogen roll-out would therefore calls at least for a rudimentary coverage of the whole country and not just of key-cities or regions. It is a plausible assumption that drivers' demand for national refuelling grid coverage is based on people's fear to run out of fuel. However, it can also be argued that the widespread of availability of hydrogen refuelling points may be interpreted by consumers as a measure of success of an alternative fuel technology, as it may indicate that many more people throughout the whole country are choosing for the same alternative technology.

Furthermore, it was found in this study that Dutch car drivers appreciate the availability of an alternative fuel abroad. Again one could assume functional reasoning of the driver here: the international availability will facilitate international car-based travelling. Yet, the international availability of an alternative fuel refilling infrastructure may also be interpreted by a driver as an indication that that particular alternative fuel is internationally successfully adopted and thus a proven technology. This may be an additional factor facilitating people's switch to hydrogen-fuelled vehicles.

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