Impact of industry strategies and consumer attitude on growth of the hydrogen vehicle fleet and corresponding refuelling infrastructure

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Summary

Hydrogen is seen as a major energy carrier for future transport. For this to be actualized, the parallel roll-out and growth of the hydrogen passenger car fleet and corresponding refuelling infrastructure must be guaranteed. Within the THRIVE project[1] ('Towards a Hydrogen Refuelling Infrastructure for Vehicles') a tool called THRIVE ALLOCATE has been developed to simulate the interdependent rollout of hydrogen cars and refuelling infrastructure in both temporal and spatial domains. The behaviour and strategies of three major actors involved – consumers, fuel suppliers and car manufacturers – are modelled and their impacts analysed. The model has proven to generate plausible results by combining assumptions in consistent ways, which in this study are considered to reflect low to high industry ambition levels. Simulations of base case scenarios show H_2 car penetrations ranging from about 5% to 35% of the total passenger car fleet by 2050. However, extension of the initial H_2 refuelling network, the introduction of H_2 cars via the lease car market or a change in consumers' refuelling behaviour might lead to hydrogen car penetrations of 60% or even more.

1 Introduction

THRIVE ALLOCATE is the core of the project THRIVE. This study tackles the chicken-and-egg dilemma from a demand-pull rather than technology-push perspective, simulating interdependent rollout of cars and infrastructure taking real-world conditions into account. Further projects can use this study's results and tools to help identifying potential regions, relevant stakeholders as well as economic and environmental impact of different technologies and strategies involved. Consequently it can help evaluating actions to be taken for a successful introduction of hydrogen as alternative transport fuel for passenger cars.

In this paper we present the working principles of THRIVE ALLOCATE, the storylines behind the scenarios and give an insight into sensitivities towards industry strategies and consumer attitude. More detailed information on the model, input parameters and other analyses carried out in the course of the THRIVE project can be found in [1, 2].

[1] THRIVE is a 3-year research project led by ECN and joined by TNO (representing research institutes), Shell and Linde Benelux (representing industry).

2 THRIVE ALLOCATE

2.1 General Working Principles

In the real world consumers purchase cars mainly based on the car's price and characteristics (brand, model, safety, range, etc) as well as the local and countrywide availability of the fuel and its price [3]. These criteria are influenced by car manufacturers, fuel suppliers and policy makers (regulations, taxes, subsidies, …). THRIVE ALLOCATE, a MATLAB® based dynamic model, simulates the consumer's purchase behaviour on zip code level and annual basis for any defined timeframe. It starts, amongst other parameters, from an initial hydrogen refuelling network and the total number of cars being sold in a particular year and zip code (Figure 1, step 0.). Coefficients, varying from 0 to 1 depending on the availability of fuel cell electric vehicle (FCEV) models and fuel, reflect the fraction of car buyers addressed. These coefficients are multiplied with the total number of cars sold in a year and zip code resulting in the total number of FCEV sold in each zip code in that particular year (Figure 1, step 1.). Subsequently it evaluates the number of new hydrogen refuelling units necessary to meet the countrywide demand (Figure 1, step 2). These units are optimally allocated to meet the local demand and to attract new consumers as much as possible (Figure 1, step 3.). Hence, the model creates its own new starting situation (Figure 1, step 0) and proceeds with the next iteration, i.e. the next year. Costs are not considered in the simulation as we assume that rollout of H_2 and FCEV on large-scale will only take place if the option is fully cost-competitive from an end-user perspective. But, as H_2 and FCEV will initially be relatively expensive, the financial consequences of assuming this "level playing field" are evaluated by post-processing simulation results in separate cost models [1, 2, 4, 5].

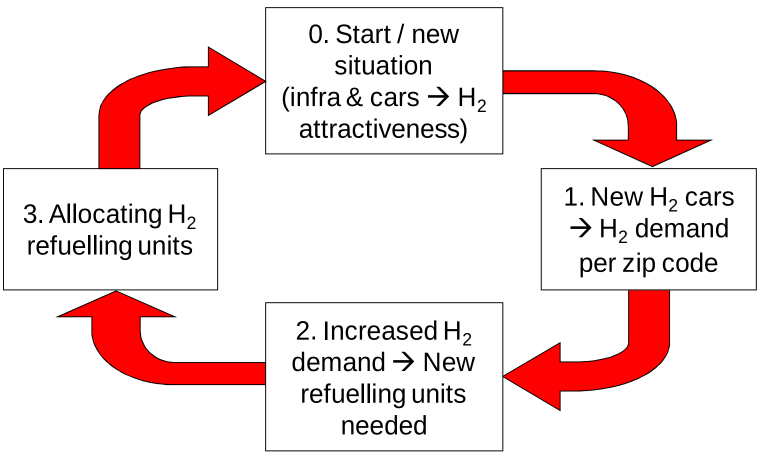


Figure 1: THRIVE ALLOCATE: Model schematics

2.2 Description of Input

General parameters and starting points [1, 2]

- Spatial resolution: Zip codes (NL: ~4000) & drives time between zip codes
- Number of non-hydrogen passenger cars per zip code & potential fleet increase
- Annual car replacement rate resulting in annual car sales for each zip code

- Current conventional refuelling station network (location, characteristics, …)

Fuel Supplier Strategies

- Initial refuelling station network

  To start a simulation the model requires an initial hydrogen station network (initial “seeds”), for example resulting from large-scale demonstration projects. Based on population density, visibility and size of current refuelling stations and considerations such as availability of space and safety, we differentiate three “seeding scenarios”: “Careful” (17 seeds in 2015), “Reactive” (17 seeds in 2015, 44 additional seeds by 2019) and “Proactive” (17 seeds in 2015, 88 additional seeds by 2019).

- Required refuelling unit utilisation:

  Each fuel supplier strives towards optimising the utilisation of his assets in order to stretch costs over a larger amount of fuel sold. As it takes time for hydrogen demand to develop, refuelling units are initially underutilised. As stricter the fuel industry is with regard to required increase of utilisation, the more time it will take before new refuelling units are installed and the slower the fuel availability will increase. Hence, the market for FCEV cannot develop quickly either. However, if fuel suppliers were convinced to receive a positive return on their investments, they might relax their utilisation requirements, expand their refuelling networks faster and consequently create a higher market potential for FCEV. Three strategies are differentiated: “Careful”, “Reactive” and “Proactive” (see Figure 2). They are based on the development of successful natural gas vehicle markets in Brazil and Argentina.

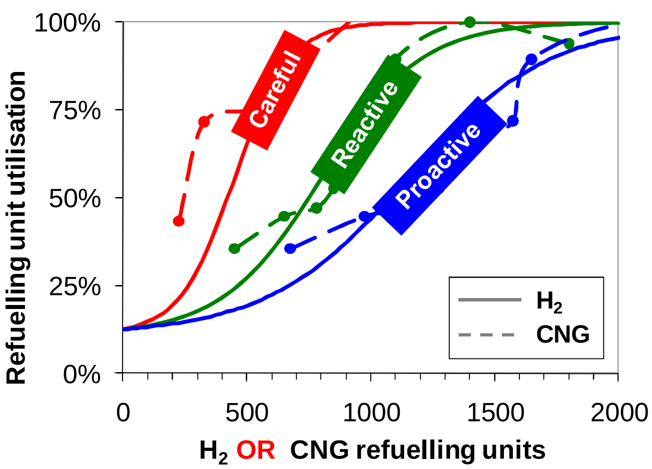


Figure 2: Fuel Supplier Strategy: Required utilisation

Car Industry Strategies

Dutch car market statistics show that around 100 car models deployed by 20 brands cover around 90% of the annual car sales in the Netherlands. Consequently we assume that each introduced FCEV model addresses on average 1% of all car buyers. By following statements of car manufacturers in press and discussions we assume that six brands will enter the market by 2015 with one FCEV model each. By 2030, we estimate that 20 brands have introduced at least one model. The three different strategies (again distinguished into “Careful”, “Reactive” and “Proactive”) are modelled based on varying FCEV deployment schemes.

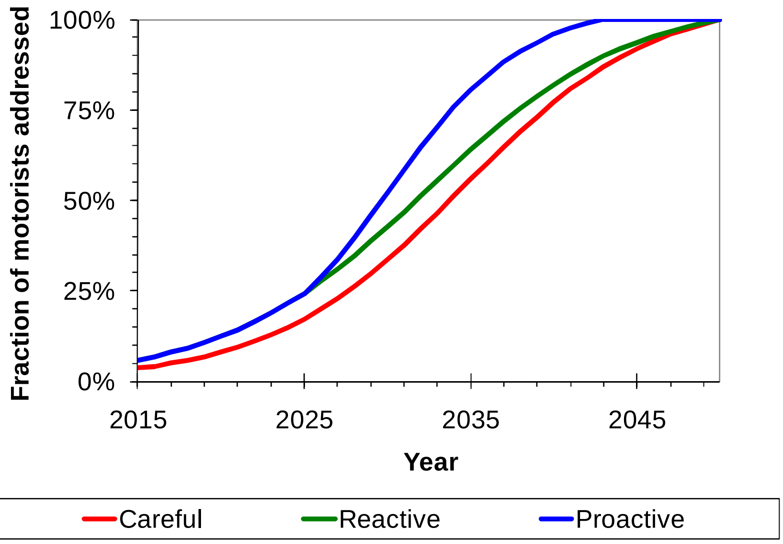


Figure 3: Car industry strategies: FCEV model deployment schemes

Consumer attitude and refuelling behaviour

3000 Dutch motorists were questioned on their attitude towards alternative fuels and their current refuelling behaviour by TNS-NIPO [1, 6]. This survey is part of the THRIVE project and used to model the consumers’ refuelling behaviour. Figure 4 illustrates the resulting “Drive-time-function” (solid line). Assuming that people stick to their current (usual) refuelling behaviour, the solid line reflects how far they are willing to drive (in minutes) from their home to refuel their car. The dashed line reflects a more eager attitude of people who are willing to drive further. It is derived from combining the TNS-NIPO results with another survey [2, 7]. The Drive-time-function is used to determine the local fuel availability for each zip code. Refuelling stations located closer to the consumer are more attractive for refuelling and therefore contribute more to the consumer’s perception of local fuel availability. Compared to usual consumers, eager consumers perceive a better local fuel availability due to their willingness to drive further. To their awareness, more refuelling stations are locally available.

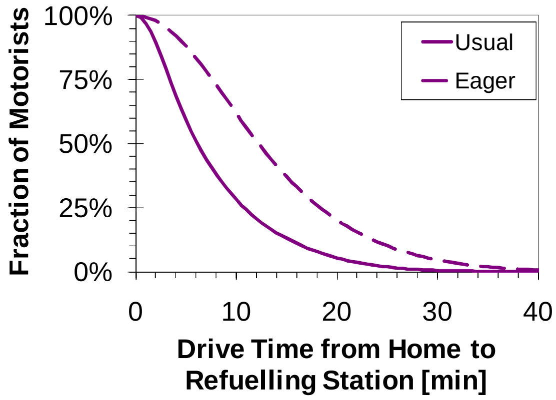
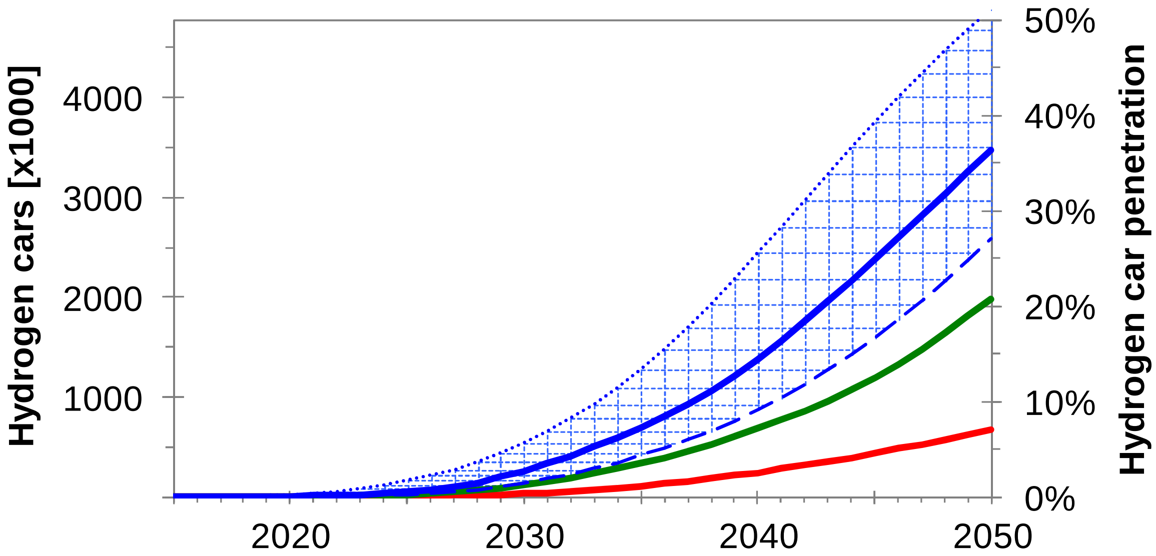


Figure 4: Refuelling behaviour and “Drive-time-function”

2.3 THRIVE Storylines

The input parameters presented in the previous sections reflect plausible consumer behaviour and industry strategies for the Netherlands as analysed within the THRIVE study. However, THRIVE ALLOCATE is capable to run any combination of assumptions and variation of input. But not every combination of assumptions makes sense. For example: If car manufacturers do not pursuit highly ambitious strategies and deploy FCEV models only on small scale, the fuel supplier industry probably won't install a large initial network of refuelling stations and vice versa. Three scenarios are developed based on coherent model assumptions on actor behaviour reflecting low, medium and high ambition levels that represent a certain trust of industries in the success of hydrogen as transportation fuel. But, even with equally careful, reactive or proactive actors on all fronts, there are still uncertainties left, which are not included in the scenarios but rather treated as sensitivities (see Figure 5).

3 Results



Scenario	Low	Medium	High		
Variation	Standard	Standard	Standard	Eager	Delayed

Figure 5: Simulation results for car fleet penetrations of FCEV. Solid lines show the results for the base case scenarios based on coherent industry ambition levels. The upper, dotted line is based on the high scenario and illustrates the effect if consumers are willing to change their refuelling behaviour. The lower, dashed line is also based on the high scenario and indicates the effect of a delayed FCEV model deployment by car manufacturers.

4 Discussion and Conclusions

THRIVE presents an integrated perspective for the deployment of hydrogen cars and corresponding refuelling infrastructure. THRIVE ALLOCATE simulates consumer-driven rollout influenced by industry market strategies reflecting different ambition levels. As its working principles can be translated to other technologies as well, the concept of THRIVE ALLOCATE could be adjusted to research chicken-and-egg dilemmas in other fields too. However, in case of hydrogen as transportation fuel for the Netherlands, THRIVE ALLOCATE shows that meaningful penetration requires a widespread upfront availability and visibility of H_2 stations, fast expansion of hydrogen refuelling station network and rapid deployment of different FCEV models. Simulations of base case scenarios show H_2 car penetrations ranging from about 5% to 35% of the total passenger car fleet by 2050. Studying sensitivities on extending the initial H_2 refuelling network, the introduction of H_2 cars via the lease car market or a change in consumers' refuelling behaviour indicate that up to 60% of all cars could run on hydrogen by 2050. Nevertheless, transition takes time and requires an approach on large scale to be successful: even with coherent, specific and long term policy stimulation it may well take over a decade before penetration becomes significant. Therefore, large scale demonstration projects and policy instruments have to be prepared now and have to be in place before market introduction to stimulate a smooth transition from demonstration to commercialisation.

References

[1] Official website of the THRIVE project: www.thrive.nu

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