User perceptions of the emerging hydrogen infrastructure for fuel cell electric vehicles

picture: dpa

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- Discussion and conclusions

picture: https://werk-1.schilderhersteller.de

Introduction

Fuel cell electric vehicles (FCEVs): more energy efficient than conventional cars with internal combustion engines (Jacobson et al. 2015; U.S. DOE 2008).

Need specific and novel **infrastructure** of hydrogen refuelling stations (HRS).

Different **funding measures** in place to promote the market diffusion of FCEVs and hydrogen infrastructure:

- EU Directive 2014/94/EU on deployment of alternative fuels infrastructure (AFID).
- National Innovation Programme Hydrogen and Fuel Cells Technology (NIP) in Germany.

Use of hydrogen vehicles and infrastructure implies major **changes from a consumer's point of view**.

Aim of the paper: Analysis of (first-time) user attitudes towards the hydrogen infrastructure, hydrogen refuelling stations and the refuelling procedure.

Hydrogen infrastructure and FCEVs in Germany

- 22 publicly accessible **HRS** in operation in Germany (274 worldwide, 106 in Europe) (h2stations.org).
- A few **FCEV models** available on the market, e.g. Toyota Mirai

HRS worldwide

HRS in Europe

pictures: TUEV Sued, h2stations.org

Methodology

1 **Qualitative study (QUAL)**: refueling tests and focus groups with experienced and first-time users

2 **Quantitative study (QUANT)**: German-wide survey with experienced users of HRS

Objective: Deeper analysis of customer perceptions of refuelling procedure, identify topics for survey.

Sample: 6 experienced, 8 first-time users from Berlin. Half of the participants women, ages 23 to 72, high level of education.

Procedure: First briefed on fueling procedures, afterwards individually refueled vehicles at HRS in Berlin. Asked to “think aloud” while refueling. Pre- and post questionnaires. Afterwards asked about their experiences in 4 focus groups.

Objective: Follow-up to refuelling tests and focus group study.

Sample: 100 experienced HRS users in Germany. Two thirds men, mean age 42 years, high level of education, majority professionally involved in hydrogen and fuel cell technologies.
Usage patterns of FCEV: 84% for business purposes, the rest also for private purposes.

Method: Online questionnaire.

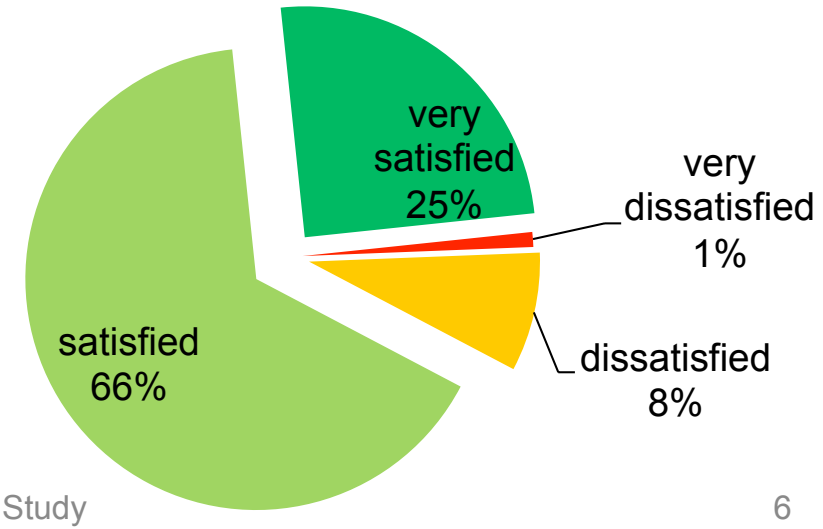
Results: Refueling experience I

- **QUAL**: Everyone successfully refueled FCEV. Generally perceived as simple and pleasant.
  - **No safety concerns**: after the tests technology perceived as even safer.
  - **Technical malfunctions** during the tests: led to some irritation among participants, in particular inexperienced ones.

"Yes, I also think that you will get used to it relatively quickly, maybe after three times" (first-time user)

- **QUANT**: Positive evaluation, especially short duration of refueling process.
  - **Technical malfunctions:** More than 80% experienced problems at least once (premature stops of the refuelling process most often).

QUANT: Satisfaction with refueling process

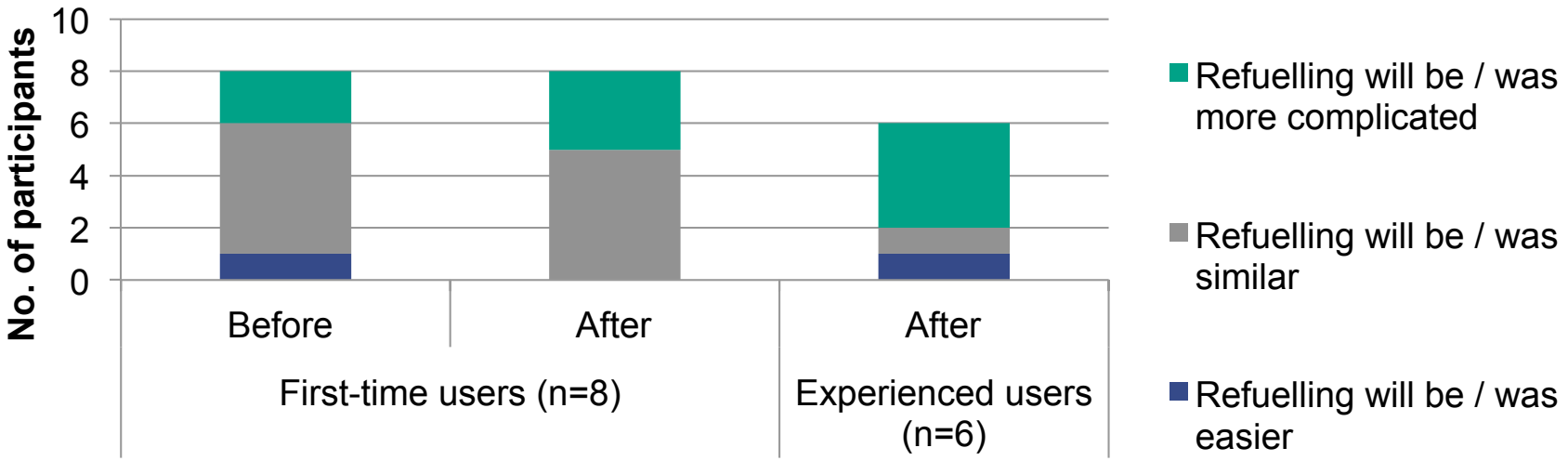


Results: Refueling experience II

"It would be nice if it would be indicated "it starts in 10 seconds" or so. Because you were standing there, and at some point there was a loud noise and then you knew "o.k. now something is happening." (experienced user)

- **QUAL and QUANT**:
  - **Handling the pump nozzle sometimes problematic**: caused difficulties due to its weight and inflexible hose
  - **Wish for more customer information** while refuelling

QUAL: Comparison of conventional and hydrogen refuelling processes

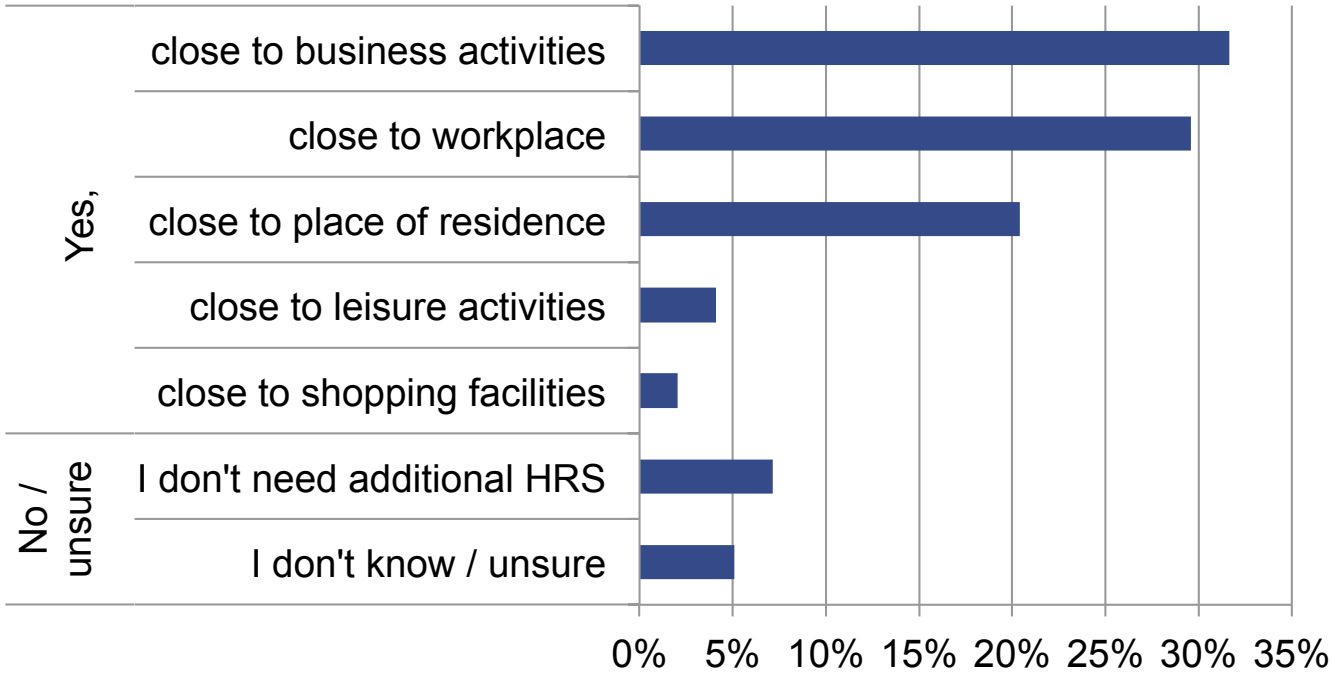


Results: Perceptions and demands with regard to hydrogen infrastructure

- **QUAL**: Both user groups favour expansion of HRS network. **Current users** demanded construction of HRS especially in central Germany to make travelling from the north to the south possible.

- **QUANT**: Users express high willingness to take detours for refueling: 48% would drive up to 15 minutes extra per trip to be able to refuel a FCEV.

QUANT: Do you wish for further HRS and if yes, where?



Results: Evaluation of the hydrogen technology

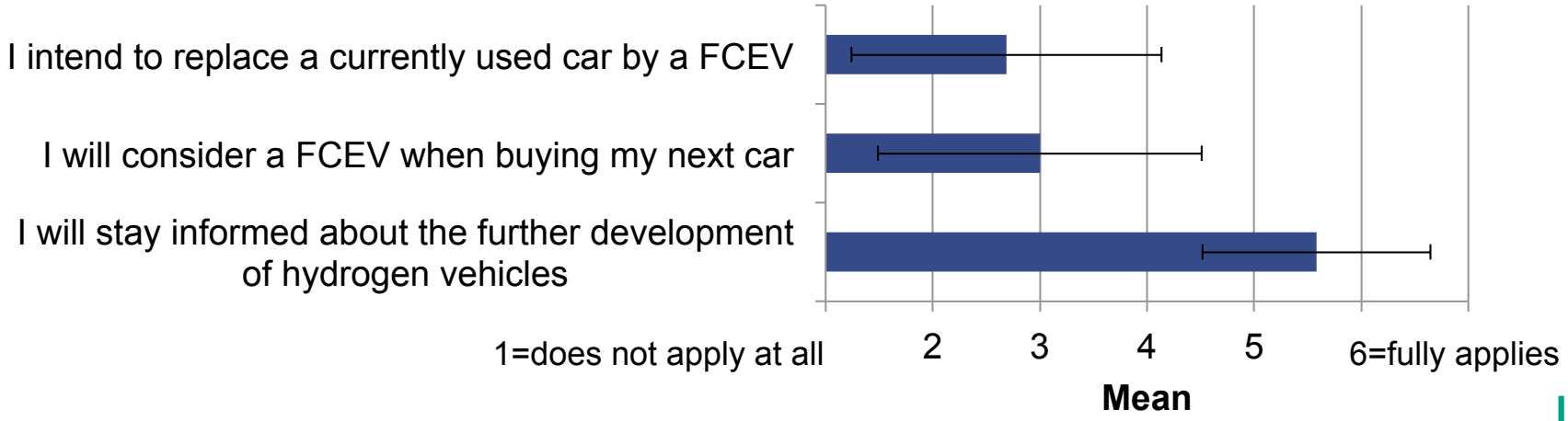
- **QUAL:**
  - Hydrogen technology perceived positively by all respondents; appreciated FCEV's quietness. Hydrogen mobility seen as an eco-friendly technology.

"Well I think this is definitely a promising technology" (experienced user)

Readiness for daily use and future intentions

- **QUAL:** at present not yet taken for granted. Important reason: HRS network density.
- **QUANT:** Vehicles considered as easy to use, useful for daily life and environmentally friendly. However: Low purchase intentions for FCEV

Intentions to purchase and use a FCEV



Discussion and conclusions

- One important reason for **lack of interest in FCEVs** is their **high purchase price and the lack of HRS**.
  - Offer additional financial incentives to buy a FCEV, e.g. in the form of higher subsidies.
  - Further expand hydrogen network, especially fill existing gaps

- **Direct experiences** with the technology can lead to **more positive evaluation** of hydrogen mobility (cf. Martin et al. 2009). Important precondition: required high reliability of the technology.
  - Improve functionality for the further diffusion of the technology and provide opportunities for testing vehicles and HRS.

- General **lack of knowledge** not only with regard to **technology itself** but in terms of its **environmental effects**: Hydrogen has **eco-friendly image** in general, but some participants in QUAL study became more sceptical when learning about resources currently used for producing it.
  - Inform public about potential hydrogen has to contribute to a low-carbon transport sector and the storage of renewable energy.

Thank you for listening

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Back up

Empirical studies on the perceptions of hydrogen refuelling and infrastructure

Relatively few publicly available empirical studies on the user acceptance of hydrogen infrastructure and the refuelling procedure. Studies have been conducted under varying conditions.

- **Perceptions of hydrogen refuelling**
  - No safety concerns while refuelling; evaluations did not change over time, refuelling procedure was not perceived as very difficult (Shaheen et al. 2008)
  - Safety perceived more positively after **testing FCEV** (Martin et al. 2009)

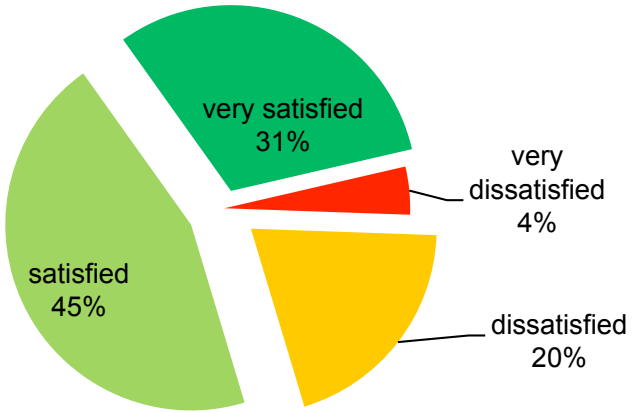
- **Expectations with regard to hydrogen infrastructure**
  - Nearly a third of the respondents would accept detour of 5 minutes for refuelling, 29% state they would even drive 10 minutes to be able to refuel (Martin et al. 2009)
  - **Experienced individuals** voiced fewer concerns with regard to limited infrastructure than **inexperienced individuals**. Concerns of first-time users decreased over time. Users have concerns in terms of range anxiety due to the lack of HRSs (Shaheen et al. 2008).
  - Limited hydrogen infrastructure likewise important issue for **non-users**: most important reason stated against purchase is lack of refuelling stations (Zimmer and Welke 2013). Some non-users aware of high costs of developing hydrogen infrastructure but still assume that this will be further expanded in the future (Welke et al. 2013)

Results: Availability / technical reliability of HRS

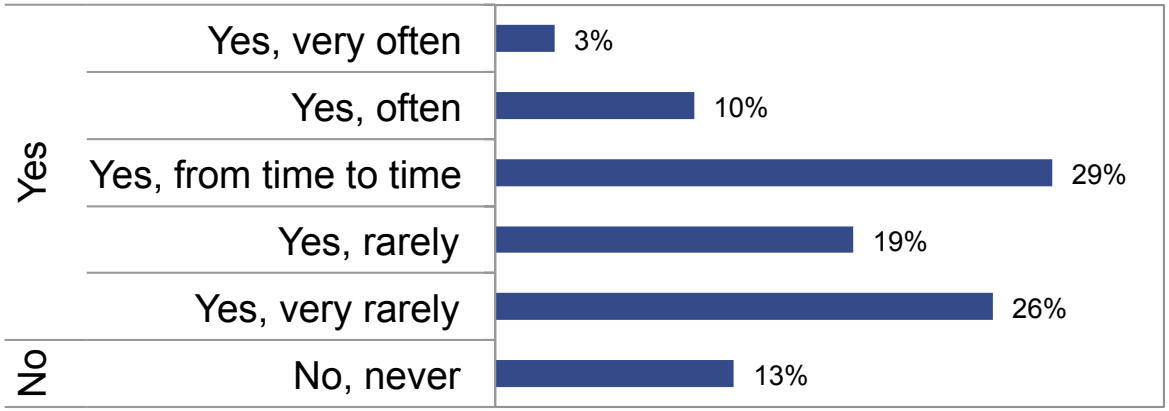
QUANT study:

- majority is satisfied with technical reliability of HRS.
- However, > 80% were confronted with technical problems at least once (earlier stops of refueling process occurred most often)

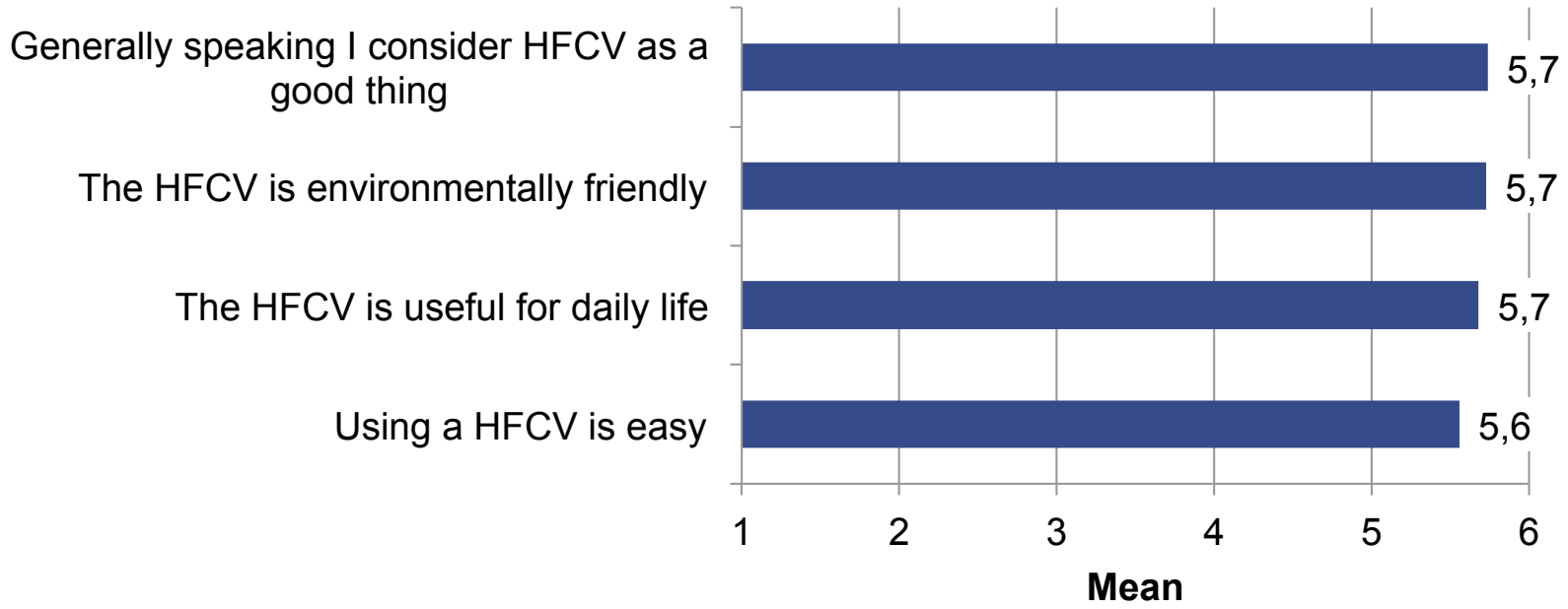
Satisfaction with regard to technical reliability of HRS



Have you ever been confronted with technical problems while refueling?



Evaluation of the hydrogen technology



Results: Hydrogen refuelling and functionality

Hydrogen refuelling:

- **QUAL**: Everyone was able to successfully refuel the vehicle. Generally perceived as simple and pleasant. Regular users have higher expectations with respect to simplicity of H2 refueling than first-time users, possibly as they use technology frequently.

- **QUANT:** positive evaluation, especially short duration of refueling process (>90% satisfaction). Points of criticism: handling with the pump nozzle, wish for more customer information while refueling

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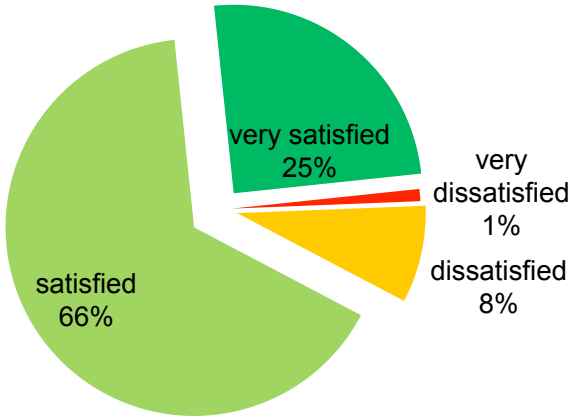
Satisfaction with refueling process



Functionality:

- **QUAL:** During the test a few technical problems occurred. Expectations of some first-time users with respect to maturity of the technology were disappointed during the trials.

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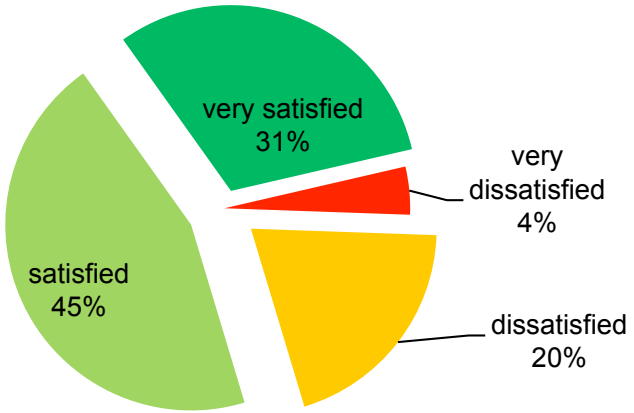
Satisfaction with regard to technical reliability of HRS



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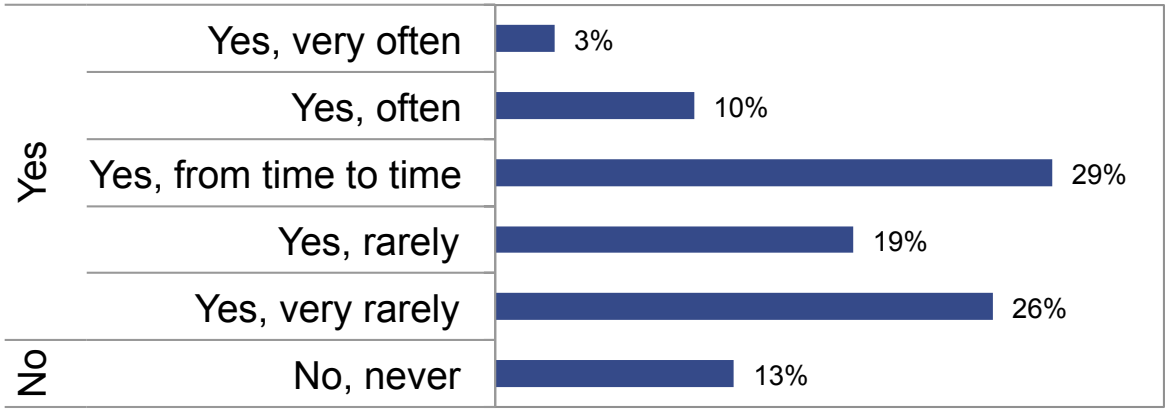
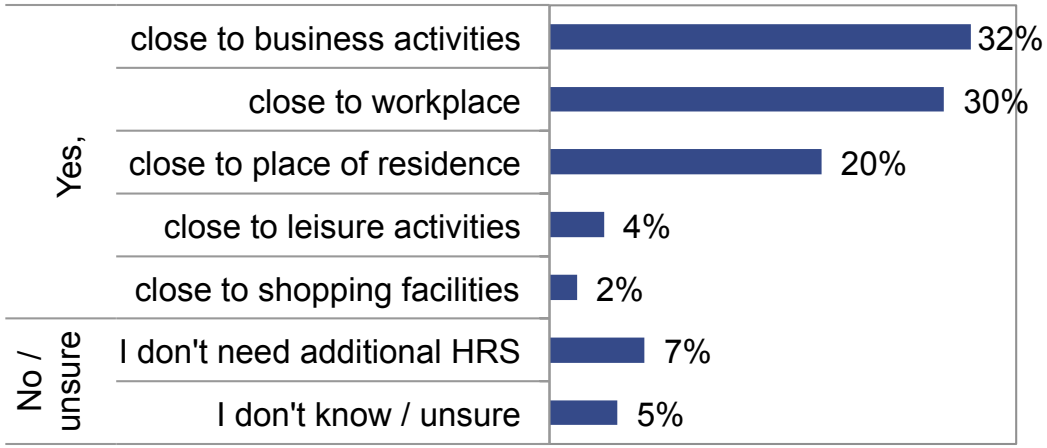


Results: Evaluation of hydrogen infrastructure

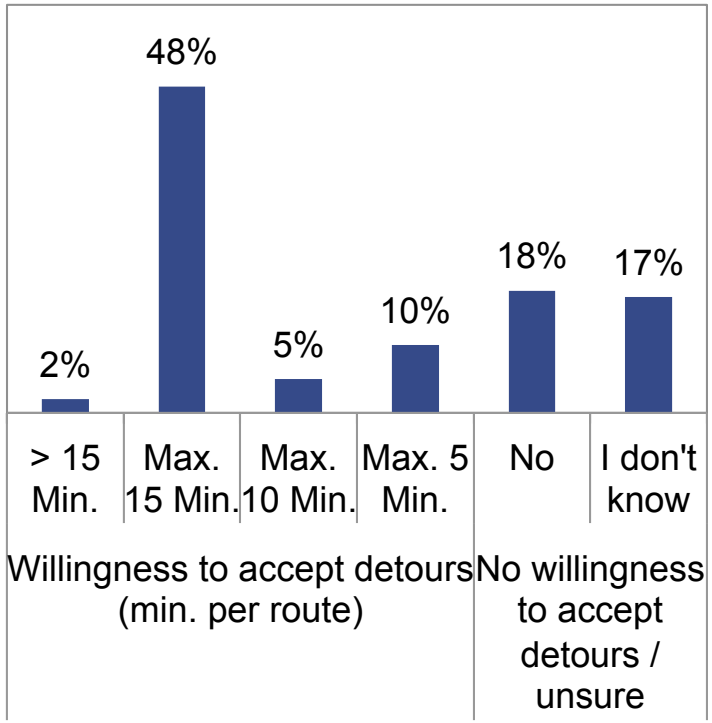
QUANT study:

- Users express a high willingness to take detours for refueling. Nearly 60% would wait up to 10 minutes before refueling.
- For the future they wish for further expansion of hydrogen infrastructure, especially in central Germany. Majority wishes for further HRS close to their business activities or workplaces.

Do you wish for further HRS and if yes, where?



Willingness to accept detours for refueling a HFCV



Results: Readiness for daily use and future intentions

- **QUAL:** at present not yet taken for granted. One important reason: low HRS network density. However, expectations that network extension will take place.
- Positive valuation of future potential of technology.
- **QUANT**: Low purchase intentions for HFCV, but very interested in the future development of the technology. Vehicles are considered as easy to use, useful for daily life and environmentally friendly.