Does Size Matter? Investigating Laypeoples' Preferences for Roll-out Scenarios of Alternative Fuel Production Plants

Katrin Arning[1], Barbara Sophie Zaunbrecher[1], Maximilian Borning[2], Niklas van Bracht[2], Martina Ziefle[1] and Albert Moser[2]

[1]*Human-Computer Interaction Center, Chair of Communication Science, RWTH Aachen University, Campus Boulevard 57, 52074 Aachen, Germany*

[2]*Chair and Institute of Power Systems and Power Economics, RWTH Aachen University, Schinkelstraße 6, 52062 Aachen*

Keywords: Alternative Fuel, Production Infrastructure, Power System Design, Public Acceptance, Conjoint Analysis.

Abstract: The substitution of fossil fuels by alternative fuels (AF) is a promising approach to achieve climate protection goals. Since the production of AF places considerable demands on the existing power system, planning processes also have to consider the energy demand and supply of AF production plants. Apart from these technical requirements, the acceptability of new AF production plants and their power supply infrastructure also needs to be considered. An empirical study (n = 313, carried out 2018 in Germany) based on the conjoint measurement approach was conducted, which investigated the impact of acceptance-relevant criteria on preferences for infrastructure scenarios for AF production plants. Emissions of an AF production plant had the highest impact on preferences, followed by the electricity mix, where surplus and renewables were preferred as energy sources. Compensatory measures, especially price reductions for AF, and the application field of AF were of minor relevance for preference decisions. The size of AF production plants was also not relevant for scenario preferences, at least on an abstract meta-level of planning scenarios. Based on the results, the integration of acceptance as soft factor into power system planning processes is discussed and recommendations for future planning processes and -deployment activities for acceptable AF production infrastructure are derived.

1 INTRODUCTION

Compared to conventional fuels such as petrol and diesel, alternative fuels (AF) can significantly reduce the emission of greenhouse gases (Chu et al., 2012). Since the production of AF is very energy-intensive (Stephanopoulos, 2007), significant additional amounts of electricity are required, which places considerable demands on the existing power system, especially in combination with the integration of fluctuating sources of renewable energies (wind and photovoltaics) (dena, 2017). Therefore, infrastructure planning for the power grid also has to consider the energy demand and supply of AF production plants.

From other energy technology infrastructure contexts, it is known that public attitudes towards new technical infrastructures are not always supportive yet being decisive for a successful rollout (e.g., Batel et al., 2013). In order to avoid possible pitfalls with regard to the acceptability of new AF production plants, public perception, acceptance and social requirements need be identified a priori. The present study therefore aimed at an analysis of acceptance of AF production plant infrastructure scenarios in order to integrate public requirements and preferences into planning processes.

1.1 Power System Design for AF Production Infrastructure

The utilization of electrical energy for AF production has a significant impact on the power system, where it affects both, the generation stack and the underlying grid infrastructure (dena, 2017).

In general, power generation and consumption have to be balanced at any time. When dealing with an increased load due to additional consumers, particularly new installations of renewable energy sources are needed to provide the respective amount of emission-free energy. However, renewable

Arning, K., Zaunbrecher, B., Borning, M., van Bracht, N., Ziefle, M. and Moser, A.
Does Size Matter? Investigating Laypeoples' Preferences for Roll-out Scenarios of Alternative Fuel Production Plants.
DOI: 10.5220/0007697100910099
In *Proceedings of the 8th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2019)*, pages 91-99
ISBN: 978-989-758-373-5

energies that are politically favored (such as wind turbines and photovoltaics) are characterized by intermittent feed-in, which increases the need for flexibility in the system (Borning et al., 2018). Thus, both temporal flexibility options (e.g., storage systems, load flexibilization) as well as the spatial flexibility option of the grid are required for an efficient integration of additional consumers and producers into the power system. Therefore, suitable technical and operational restrictions of deployed technologies are of highest importance. Depending on the precise location and capacity of the fuel production plant, the impacts on the power system significantly vary, which imposes high challenges on future power system design.

Due to high capital expenditures and long lifetimes (40+ years) of the electrical assets, long-term expansion planning presents a method to anticipate future challenges and determine the most reasonable investments (Skar et al., 2014). One approach to consider public acceptance in power system planning is to add hard restrictions (e.g., minimal distances of wind power plants from residential areas) to the solution space (Cetinay et al., 2017, van Bracht et al., 2018). Hence, in order to provide robust investment recommendations, public acceptance should be taken into account as a soft factor in power system planning. Based on the interdependencies between the fuel production system and the electricity system, a first step is to include social acceptance in the infrastructure planning of fuel production plants. Thereupon, resulting social requirements regarding specific location types could be integrated within the long-term expansion planning of the power system.

1.2 Relevance of Acceptance in AF Production Infrastructure Design

AF have been researched from a social science perspective mainly with regard to the *acceptance of fuel as final consumer product* (e.g., Chin et al., 2014). AF are mostly positively perceived, as long as they are not significantly more expensive than conventional fuels (Hackbarth and Madlener, 2016). Further, ecologic aspects of reducing CO_2-emissions contribute to a positive perception, whereas the “fuel vs. food”-debate in growing feedstock for biofuels (Moula et al., 2017) or health or environmental risk perceptions (Roche et al., 2010) led to negative evaluations of AF.

The understanding of factors which influence *AF production facility acceptance, however,* is still limited. While economic and environmental impacts of biorefineries were intensively studied (e.g., Santibañez-Aguilar et al., 2014), only a few studies investigated AF production infrastructure acceptance. Most studies focused on site selection and ways of achieving community acceptance (e.g., Tigges and Noble, 2012; Fortenbery et al., 2013). However, some questions remain open: First, there is scarce knowledge on the accepted size of AF production plants. Second, since the energy system is currently in transition and is not yet able to provide the required electricity (dena, 2017), it would be valuable to know if an energy mix of renewable and conventional energy sources for AF production will be accepted by the public. Third, little is known about other factors which influence the acceptance of AF production plants, such as positive (local jobs, income, fuel price reduction incentives) or negative local effects (e.g. pollution and noise) (Lee et al., 2017). Especially smell emissions (Soland et al., 2013) and noise during the operation of the plant or increased transport negatively impact acceptance (Lee, 2017). Compensatory measures on the local level might also affect the acceptance of AF production plant siting. Beyond financial incentives, we want to find out which type of measure is preferred in this regard. Furthermore, the area of application of AF might also affect the acceptance of AF production plants (e.g., public transport or logistics).

Therefore, the present study examined the following research questions:

1.) Which aspects of AF production plant infrastructure design are most important for public acceptance?
2.) Which specific AF production plant scenario features are preferred by the public?
3.) How are future AF production plant scenarios evaluated by the public?

2 METHODOLOGY

In order to answer the research questions, an empirical, quantitative study was conducted using conjoint analysis (CA).

2.1 Conjoint Analysis

CA allows for an ecologically valid investigation of complex decision scenarios (Rao, 2014). Respondents are asked to evaluate specific product profiles or scenarios, which are composed of multiple attributes and differ from each other in the attribute levels. CA delivers information about which attribute influences respondents’ choice the most and which level of an attribute is preferred. Preference shares can be interpreted as indicators of acceptance (Arning, 2017).

2.2 Selection of Attributes

The selection of attributes for the conjoint study was based on interviews with laypeople and experts in order to ensure that they reflect valid and relevant aspects of power system planning for both groups:

Attribute 1: Size/distribution of AF production plants with four levels "small plants", "rather small plants", "rather large plants" and "large plants" (Figure 1).

Figure 1: Icons for the attribute levels "size/distribution".

Attribute 2: Electricity mix with the levels "conventional", "renewables", "mix (renewables and conventional", and "surplus renewables" (Figure 2).

Figure 2: Icons for the attribute "electricity mix".

Attribute 3: Field of application for AF with the levels "public gas stations (private cars)", "logistics" (heavy-duty traffic and ships), and "air traffic" (Figure 3).

Figure 3: Icons for the attribute "field of application".

Attribute 4: Emissions of an AF production plant with the levels "none", "smell", "noise", "smell and noise" (Figure 4).

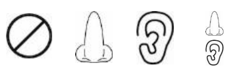

Figure 4: Icons for the attribute "emission".

Attribute 5: Compensation for AF production plant deployment with the levels "local jobs", "reduced price for alternative fuel", "local bus powered by alternative fuel", and "financial compensation" (Figure 5).

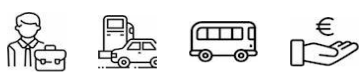

Figure 5: Icons for the attribute "compensation".

2.3 The Questionnaire

For the design of the questionnaire, SSI Web Software was used. The sample acquisition was done by an independent market research company to obtain a census-representative sample of people holding a driving license.

The questionnaire items were developed based on findings of qualitative pre-studies (interviews) and checked for comprehensibility, length of interview and wording. The questionnaire was structured as follows: First, quota-relevant information (driving license, gender, education, age, region) was assessed, followed by an assessment of driving-related characteristics. In the second part, the perception of and attitude regarding AF was measured by using 6-point Likert-scales (1 = "do not agree at all" to 6 = "fully agree"). The third part started with an introduction into AF production plants, followed by the description of attributes and levels of the conjoint study. Then, the conjoint part (choice-based conjoint) with 9 choice tasks was presented, where participants indicated their preferred AF production plant scenario (Figure 6).

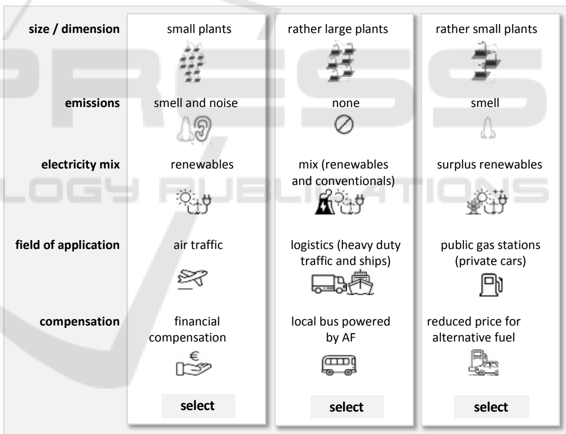

Figure 6: Screenshot of a choice task in the CBC-study.

2.4 The Sample

The sample (n = 313) was census-representative with regard to age, gender, and education in Germany. The mean age was M = 45.9 years (SD = 13.7, 18-80 years), with 50.8% male and 49.2% female respondents. 47.6% held a primary educational degree, 25.6% a secondary degree, and 26.2% a tertiary degree.

Car ownership and driving experience. The majority (88.3%) reported to use their own car, 5% drive a company car, 0.7% use car-sharing, and 6% drive a privately lent car. Most of these cars were gasoline-powered (74.3%), followed by diesel-powered cars (24.7%), only a small proportion were cars with gas- (0.7%) or hybrid (0.3%) drive. Asked for driving experience, the majority (46.3%) drove their car daily, 35.1% several times a week, 10.5% several times a month, 3.8% several times a year, and 4.2% reported to never use a car. Regarding annual mileage, 17.7% drive less than 5,000km/year, 25.3% drive 5,000-10,000km/year, 24.3% drive 10,000-15,000km/year, 19% drive 15,000-20,000km/year and 11% drive more than 20,000km/year. Based on these data, the sample was considered sufficiently familiar with the subject of driving and able to provide valid data when evaluating alternative fuels.

Interest in AF was moderate (M = 3.7, SD = 1.2). Self-reported AF *knowledge levels* were a rather low (M = 2.9, SD = 1.2). The majority reported to have very low (14.4%) or low (54.6%) knowledge about alternative fuels, whereas only 29.1% reported to have good and 1.9% to have very good knowledge about AF and production processes.

2.5 Data Analysis

The conjoint data were analyzed utilizing Sawtooth Software (Sawtooth Software, 2017). Partial value utilities were computed on the basis of Hierarchical Bayes (HB) estimates and part-worth utilities importance scores were calculated. They indicate how important the attribute is for the preference choice compared to all other attributes. By using zero-centred differential part-worth utilities, which are scaled to sum to zero within each attribute, it is possible to compare differences between attribute levels. Sensitivity simulations were carried out by using the Sawtooth Market Simulator (Sawtooth Software, 2009).

3 RESULTS

3.1 Alternative Fuel Production Plant Acceptance

General acceptance of AF production plants was positive (M = 4.0, SD = 1.1). Almost one quarter (23.9%) reported a high acceptance of AF production plants and 54.3% were positive about their deployment, whereas 13.7% were negative or even rejected (8%) the concept of AF production plants. The *local acceptance* of AF production plants, referring to a plant that is supposed to be built in the immediate neighbourhood, was lower (M = 3.1, SD = 1.3). Most respondents (61.0%) rejected the deployment of an AF production plant close to their home, with 16.3% strongly rejecting the idea. A total of 39% approved the deployment of an AF production plant near their homes, with 2.9% being very much in favour.

Regarding the perception of specific *risks or barriers*, land use of AF production sites was the greatest concern (M = 4.3, SD = 1.1). Other potential barriers, such as smell emissions (M = 3.3, SD = 1.1), a negative cost-benefit ratio of deploying AF production plants (M = 3.3, SD = 1.2), perceived health risks (M = 3.2, SD = 1.1), or noise emissions (M = 3.2, SD = 1.0), were not perceived as critical (ratings close to the midpoint of the scale (3.5)).

3.2 Impact of Attributes on AF Production Plant Scenario Preference Decisions

Relative importance scores were calculated to assess the relative impact of the included acceptance-relevant attributes on the preference decision for AF production plant scenarios (Figure 7).

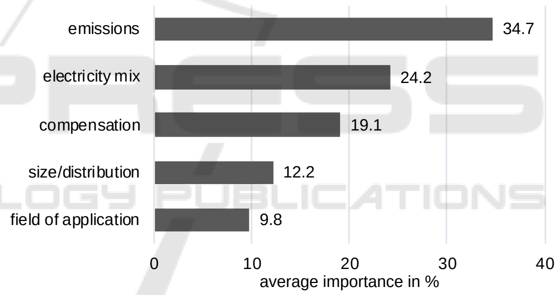

Figure 7: Relative importance scores for AF production plant attributes in the CBC study.

The attribute “emissions” had the highest importance score, i.e., the strongest relative impact on the scenario choice (34.7%, SD = 15.9), followed by the attributes “electricity mix” (24.2%, SD = 12.7) and “compensation” (19.1%, SD = 9.4). The size of an AF production plant was the second-least important criterion in preference decisions (12.2%, SD = 7.8), the attribute with the lowest impact on scenario preferences was the “field of application” (9.8%, SD = 6.4) of alternative fuels.

The findings indicate that potential emissions from an AF production plant were the most dominant attribute for AF production plant scenario acceptance. The electricity mix used to supply energy to the AF production facilities was also relevant, but with a lower impact on the preference decision. Interestingly, the size or distribution of AF production plants, one of the most relevant attributes for power system planning, was of minor importance for preference decisions relative to other acceptance-relevant criteria.

3.3 Preferences for AF Production Plant Scenario Features

Calculating the average zero-centred differential part-worth utilities for all attribute levels revealed how specific features within an attribute affected respondents' scenario choice. Levels with higher scores were strongly preferred, whereas levels with lower scores (in comparison to the other levels of the same attribute) were rejected (Figure 8).

The utility values of the attribute "*emissions*" showed the largest difference between part-worth utilities due to the high importance score of the attribute (see 3.2). "No emissions" was highly preferred, as indicated by the highest utility value (utility = 93.2, SD = 50.9). Compared to this, all other emission-attribute levels were rejected. The weakest rejection occurred for "noise" (utility = -4.1, SD = 19.3), followed by the rejection of the "smell" emission (utility = -17.1, SD = 25.9). The combination of "noise and smell" emissions from an AF production plant was most strongly rejected by respondents (utility = -72.7, SD = 41.7).

Referring to the levels of the attribute "*electricity mix*", the second-most important attribute, the most preferred energy sources were "surplus renewables" (utility = 29.8, SD = 29.2) and "renewables" (utility = 29.1, SD = 35.8). Compared to that, the "mix (renewables and conventional)" received lower preferences (utility = 6.8, SD = 21.2). Using "conventional" power supply for AF production (utility = -65.7, SD = 51.3) was the only level which was strongly rejected.

Focusing on the third most important criterion, "*compensation*", most features received slightly positive evaluations, such as the creation of "local jobs" (utility = 7.7, SD = 46.3), "reduced price for alternative fuel" (utility = 7.6, SD = 27.3) or "financial compensation" (utility = 2.7, SD = 45.5). The only "compensation"-feature, which was rejected was "local bus powered by alternative fuel" (utility = 18.1, SD = 37.3).

For the second-least important attribute "*size/distribution*" of AF production plants no systematic preference pattern showed, which might be due to the low importance score. "Large" (utility = 3.9, SD = 30.7) and "rather small plants" (utility = 3.8, SD = 21.9) were favoured in comparison to "rather large" (utility = -1.4, SD = 27.2) and "small" AF production plants (utility = -6.3, SD = 33.9).

Regarding the least important attribute "field of application", the usage of AF for "private cars, AF available at public gas stations" (utility = 13.2, SD = 21.9) was preferred in relation to "logistics - heavy duty traffic and ships" (utility = 6.0, SD = 19.6) and "aviation" (utility = 19.3, SD = 21.0), which was most strongly rejected.

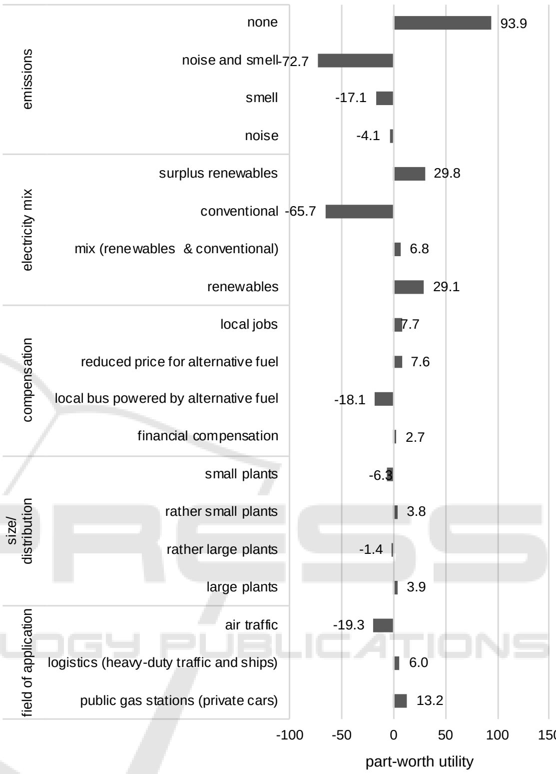

Figure 8: Part-worth utilities (zero-centred diffs) for AF production plant scenario levels in the CBC study.

However, the high standard deviations in level judgements for the attributes "compensation" and "size/distribution" indicate that respondents differed in their perception and evaluation of different compensation measures.

3.4 Preference Simulations of Future AF Production Plant Infrastructure Scenarios

Sensitivity simulations were carried out in a next step. The market simulator allows to estimate shares of preference for different scenarios and can be used as decision support tool in the roll-out planning stage of AF production plant scenarios. For this purpose, the most probable scenarios from power systems design perspective for the anticipated temporal development of AF production plants over the years 2025, 2035 and 2050 were analysed with regard to their social preference. In the scenario definition it was assumed that the entire energy system will be strongly decentralised, and renewables will play an important role. By 2050, the dominant electricity source for AF production will be "surplus renewables". Moreover, new innovative and cross sectorial technologies will lead to AF usage in all fields of application.

The "2025 scenario" with the scenario features "large plants", "electricity mix", "no emissions" and "private mobility" led to a preference share of 38.7% (SE = 1.4%). In the "2035 scenario" it was assumed that the AF production system was more decentralized with "rather small" plants, "no emissions", using an "electricity mix" for "logistics" purposes. The preference share for the "2050 scenario" was 31.2% (SE = 1.0%) for the logistics application context. The "2050 scenario" with the features "small plants", powered by "surplus" electricity, "no emissions", where fuel for the aviation context was produced, received a preference share of 30.1% (SE = 1.2).

Since the application context of AF for private mobility purposes was the most preferred, we also ran the simulation for the years 2025, 2035 and 2050 for the private mobility purpose (all other scenarios settings remained the same). Here, the scenario "2050" was the most preferred with a preference share of 39.5% (SE = 1.1%), followed by the scenario for the year "2025" (31.1%, SE = 1.3) and for the year "2035" (29.4%, SE = 0.9).

4 DISCUSSION

We investigated the acceptance of AF production plant infrastructure scenarios to integrate public requirements into future planning processes to design "acceptable" AF production infrastructure scenarios.

4.1 Perception and Acceptance of Alternative Fuel Production Plants

AF production plants and their required infrastructure were generally positively perceived. In line with other studies, local acceptance, i.e., being personally affected by an AF production plant, reduced acceptance ratings (e.g., Lee et al., 2017). Looking more specifically at risks associated with AF production plant roll-out, respondents were not too concerned by potential health risks or emissions from an AF production plant. The highest risk perception referred to large land requirements by AF production facilities. Interestingly, the *size or distribution of AF production plants* only played a minor role in determining preferences, as shown in the CBC-study. We assume that the meta-level of planning scenarios and missing local affectedness of respondents by AF production plant planning processes is the reason for the low relevance of this factor in our study. However, it would be wrong to assume that the size of AF production facilities is not acceptance-relevant at all. As soon as location decisions are made and local communities are chosen for AF production plant roll-out, the physical dimensions and land requirements of production facilities become relevant and might lead to protests (e.g., Fortenbery et al., 2013). This leads to one important conclusion: The planning of AF production infrastructure must always start at the local level, otherwise no valid predictions can be made for public acceptance.

The factor "*emissions*" of an AF production plant exerted a considerably higher impact on scenario preferences, supporting the thesis that local effects are important for acceptance. Noise and especially smell emissions were the strongest determinants of acceptance. From a technical point of view, emissions play a minor role in technical infrastructure planning processes at this stage. However, planners should therefore work on preventing emissions, especially of unpleasant smell emissions (Soland et al., 2013).

Beyond that, the strong acceptance-determining influence of "emissions" has another important significance for AF infrastructure planning processes. It shows that acceptance decisions can be shaped by dimensions that are not taken into account by the technical side because they are (not yet) part of the technical planning process. The "acceptance-relevance" of "technically irrelevant" factors was also found in other acceptance contexts, such as the perception of the CCU technology, where the disposal of CO2-derived products in particular influenced their acceptance (van Heek et al., 2017). Technical infrastructure planners should therefore be aware that apparently unimportant factors can strongly affect acceptance and can act as "NoGos". Investigating public acceptance in early stages of technology infrastructure planning can provide added value by identifying these factors and by taking them into account at an early stage in the roll-out process.

The preferences for the "*electricity mix*" used to supply energy for AF production plants showed that renewable energy resources are strongly preferred compared to conventional energy sources. Surplus energy was the most preferred, which explains the highest preferences for the AF production scenario in the year 2050, which was assumed to be based on surplus energy. Until the power system will be able to provide surplus energy to supply AF production plants with energy in the year 2050, the production of alternative fuels should not be operated using electricity from conventional sources. Otherwise, there is a risk that the population might perceive this as "greenwashing", i.e. the use of "dirty" energy sources for the production of "green" products (e.g., Plec and Pettenger, 2012).

Further factors mentioned as acceptance-relevant in the prestudy-phase but exerting less influence in the scenario judgments were "field of application" and measures of "compensation", which could be offered to the local population near AF production plants. With regard to the perception of *compensation measures* for the deployment of an AF site (e.g. financial compensation), serving either as compensation or as incentives for AF site deployment (e.g. free public transport), there are also mixed findings in the literature. While in some infrastructure projects compensatory measures had a positive effect on acceptance during roll-out (Upham and Shackley, 2006), there were also cases where compensation did not impact acceptance (Soland et al., 2013). We suggest therefore that a positive effect of compensations cannot be assumed per se but that such measures must be developed in a participatory way with the affected community in order to act as an incentive and positively influence acceptance. In the context of AF production plant rollout, more research is needed in this regard.

Regarding the "*field of application"* for AF we can conclude from the acceptance evaluations, that the public is more likely to accept the roll-out of AF production plants if they can benefit directly from it, i.e. if the fuel produced can also be used for their own mobility. Compared to that, the other application purposes did not exert positive effects on scenario preferences (logistics or aviation). With regard to further research on AF and the roll-out of AF production sites, it is therefore advisable to primarily develop fuels and infrastructure systems for private mobility and to supply the logistics and aviation industries with alternative fuels in a second step. This prioritization can help to increase the acceptance of alternative fuels in the population.

In order to predict public preferences and acceptance for concrete technical rollout planning scenarios, sensitivity analyses were simulated for three future AF production plant infrastructure scenarios for the years 2025, 2035 and 2050. The *preference simulations* showed that the area of application for alternative fuels, i.e. for private mobility, is a strong acceptance driver. The highest preference for the scenario in the year 2050 can be attributed to the intended use of surplus energies for the production of alternative fuels. This shows that the German "Energiewende" towards renewable energies in AF production system infrastructure design is not only a technical challenge for power system design, but also a concrete demand or social requirement by the public.

Even if the simulations do not consider all technically relevant factors and do not cover the level of local roll-out planning, they demonstrate how future roll-out scenarios can be complemented by an *a priori* acceptance assessment. So far, public acceptance of sustainable energy rollout scenarios has only been captured a posteriori, i.e. after the planning stage was completed and the deployment stage was initiated. The procedure presented here can contribute to promoting sustainable technology development that is also accepted by the population.

4.2 Implications for the Power System

Long-term planning tools for the power system generally use optimization models and mathematical programming to capture complex developments in the future. The objective function of those optimization problems is based on numerical values for the parameter (usually costs) being minimized or maximized (Luenberger et al., 2016). In the current study, a first attempt was made to include acceptance evaluations as further parameters into planning models. In a next step the acceptance evaluations need to be transformed to integrate them into power system planning models. Effects of the assessed acceptance-relevant attributes for AF production plants have to be either monetized or alternatively taken into account, e.g., within a multi-criteria objective function. By doing so, acceptance-relevant attributes can be considered as soft factors, which can serve as decision-support in making trade-off decisions for power system scenarios of AF production infrastructure.

4.3 Methodological Considerations and Future Research

Future studies should differentiate between a general acceptance level and local acceptance, since directly affected residents living close to AF production plants assess the preferred size of production facilities or the type/intensity of emissions differently. As indicated by high standard deviations in respondents' judgements, future research should integrate individual factors to develop more target-group oriented recommendations and communication strategies (e.g., Arning et al., 2018). Further, the study should be replicated with a larger representative sample in Germany, but also with international samples to allow cross-cultural comparisons of AF production plant infrastructure acceptance.

5 CONCLUSIONS

The present study successfully identified and assessed acceptance-relevant factors with regard to AF production plant infrastructure design. Although the integration of acceptance evaluations as soft factor into power design planning tools needs further methodological refinement, insights on drivers of AF production plant infrastructure acceptance were gained, which allowed to simulate preferences for future AF production plant roll-out scenarios.

ACKNOWLEDGEMENTS

This work was supported by the Cluster of Excellence “Tailor-Made Fuels from Biomass”, which is funded under Contract EXC 236 by the Excellence Initiative by the German federal and state governments to promote science and research at German universities.

REFERENCES

Arning, K. (2017). Conjoint Measurement. *The International Encyclopedia of Communication Research Methods, 1-10. Wiley*.

Arning, K., van Heek, J., & Ziefle, M. (2018). Acceptance profiles for a carbon-derived foam mattress. Exploring and segmenting consumer perceptions of a carbon capture and utilization product. *Journal of Cleaner Production, 188, 171-184*.

Batel, S., Devine-Wright, P., & Tangeland, T. (2013). Social acceptance of low carbon energy and associated infra-structures: A critical discussion. *Energy Policy, 58, 1-5*.

Borning, M., van Bracht, N., Moser, A., Doré, L., Wolff, M., & Walther, G. (2018). Electricity-Based Fuel Production: An Assessment of its Impact on the European Power System Considering Flexibility. In *2018 15th International Conference on the European Energy Market, IEEE*.

Cetinay, H., Kuipers, F. A., Guven, A. N. (2017). Optimal siting and sizing of wind farms. *Renewable Energy, 101, 51-58*.

Chin, H. C., Choong, W. W., Alwi, S. R. W., & Mohammed, A. H. (2014). Issues of social acceptance on biofuel development. *Journal of cleaner production, 71, 30-39*.

Chu, S., Majumdar, A. (2012). Opportunities and challenges for a sustainable energy future. *Nature, 488, 294–303*.

dena (2017). E-Fuels – The potential of electricity-based fuels for low emission transport in the EU. *Deutsche Energie-Agentur GmbH (dena). Berlin*.

Fortenbery, T. R., Deller, S. C., & Amiel, L. (2013). The location decisions of biodiesel refineries. *Land Economics, 89(1), 118-136*.

Hackbarth, A., & Madlener, R. (2016). Willingness-to-pay for alternative fuel vehicle characteristics: A stated choice study for Germany. *Transportation Research Part A: Policy and Practice, 85, 89-111*.

Lee, G. E., Loveridge, S., & Joshi, S. (2017). Local acceptance and heterogeneous externalities of biorefineries. *Energy Economics, 67, 328-336*.

Luenberger, D. G., Ye, Yinyu (2016). Linear and Nonlinear Programming. *Springer International Publishing*.

Moula, M. M. E., Nyári, J., & Bartel, A. (2017). Public acceptance of biofuels in the transport sector in Finland. International *Journal of Sustainable Built Environment, 6(2), 434-441*.

Plec, E., & Pettenger, M. (2012). Greenwashing consumption: The didactic framing of ExxonMobil's energy solutions. *Environmental Communication: A Journal of Nature and Culture, 6(4), 459-476*.

Rao, V. R. (2014). Applied conjoint analysis. *New York, NY: Springer*.

Roche, M. Y., Mourato, S., Fischedick, M., Pietzner, K., & Viebahn, P. (2010). Public attitudes towards and demand for hydrogen and fuel cell vehicles: A review of the evidence and methodological implications. *Energy Policy, 38(10), 5301-5310*.

Santibañez-Aguilar, J. E., González-Campos, J. B., Ponce-Ortega, J. M., Serna-González, M., & El-Halwagi, M. M. (2014). Optimal planning and site selection for distributed multiproduct biorefineries involving economic, environmental and social objectives. *Journal of cleaner production, 65, 270-294*.

Sawtooth, 2009. Introduction to Market Simulators for Conjoint Analysis. [WWW Document]. URL https://www.sawtoothsoftware.com/download/techpap/introsim.pdf (accessed 2.22.19).

Sawtooth, 2017. The CBC System for Choice-Based Conjoint Analysis. Technical Paper Version 9 [WWW Document]. URL https://sawtoothsoftware.com/download/techpap/cbctech.pdf (accessed 2.22.19).

Skar, C., Doorman, G. L., Tomasgard, A. (2014). The future European power system under a climate policy regime. *ENERGYCON 2014: IEEE International Energy Conference*.

Soland, M., Steimer, N., & Walter, G. (2013). Local acceptance of existing biogas plants in Switzerland. *Energy Policy, 61, 802-810*.

Stephanopoulos, G. (2007). Challenges in engineering microbes for biofuels production. *Science, 315(5813), 801-804*.

Tigges, L. M., & Noble, M. (2012). Getting to yes or bailing on no: the site selection process of ethanol plants in Wisconsin. *Rural Sociology, 77(4), 547-568*.

Upham, P. & Shackley, S. (2006). The case of a proposed 21.5 MWe biomass gasifier in Winkleigh, Devon: implications for governance of renewable energy planning. *Energy Policy 34, 2161–2172*.

van Bracht, N., vom Stein, D., Moser, A. (2018). Extinguish the Coal Flame? The Impact of a Lignite and Hard Coal Phase-Out on the European Power System. *53rd International Universities Power Engineering Conference*.

van Heek, J., Arning, K., & Ziefle, M. (2017). Reduce, reuse, recycle: Acceptance of CO2-utilization for plastic products. *Energy Policy, 105, 53-66*.