T1 Title: Acceptance of power to x technologies – perceptions of new energy technologies in a representative German sample

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T3 Date of Preregistration
26/02/2021 15:59:46

T4 Versioning information

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T5 Identifier

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T6 Estimated duration of project

6 months

T7 IRB Status

data collection via a standardised questionnaire (online-poll)

T8 Conflict of Interest Statement

Funding by the Federal Ministry of Education and Research under grant no. 03SFK2S1-2

T9 Keywords

acceptance of power to x technologies, influencing factors, representative sample, structural equation modeling

T10 Data accessibility statement and planned repository
No, we don't plan to make the data available.

T11 Optional: Code availability
No, we don't plan to make the code available

T12 Optional: Standard lab practices
We don't plan to use a predefined standard lab practice

Abstract

A1 Background

Power to x technologies are seen to be a solution for sustainable transition of the energy system in Germany because these technologies offer a solution how sustainable energy is transformed into hydrogen or synthetic gas which respectively can be transformed into the different sectors of application mobility, energy or chemical products. To date, no studies on public acceptance of power to x in Germany are available.

A2 Objectives and Research questions

Comparing the acceptance of power to x technologies and their influencing factors between different generations

A3 Participants

N=2300, age: 16-87, n1 = 1150 (16-25-years old) n2 = 1150 (>25-years-old)

A4 Study method

panel survey

quantitative study

structural equation modeling

Introduction

I1 Theoretical background

Climate change is one of the most important global challenges. The challenge is even bigger because several studies suggest that several climate tipping points are perilously close, making immediate action necessary (e.g., Lenton et al., 2019). In Germany, studies show that the Paris climate goals may be failed and great efforts are needed to achieve the goals at least to some extent (e.g., Agora Verkehrswende, 2019). Thus, a quick expansion of sustainable energy technologies is necessary to quickly reduce the emission of carbon dioxide. Besides a quick technical realization the public acceptance is one key success factor (e.g., Rau, Schweizer-Ries & Hildebrand, 2012; Perlavicuite & Steg, 2014). Studies show a high public acceptance for several new and renewable energy technologies in Germany (e.g., Kortsch et al., 2015; Arning et al., 2018). However, energy (infrastructure) projects are also the subject of protest (e.g., Devine-Wright, 2009). More recently, protests for more sustainability have increasingly been led by young people(e. g., the Fridays for Future movement).
Expanding renewable energies is part of the solution to reduce the emission of carbon dioxide. However, for a sustainable energy transition in Germany (“Energiewende”) not only the energy production must become “green” but also the whole energy system from the production to the consumption, including storage. Power to x technologies are seen to be a solution for this sustainable transition because these technologies offer a solution how sustainable energy is transformed into hydrogen or synthetic gas which respectively can be transformed into the different sectors of application mobility, energy or chemical products. Power to x technologies include the full range of the energy transition process to make the energy system more sustainable.
Building on research of (renewable) energy acceptance (e.g., Huijts et al., 2012; Perlavicuite & Steg, 2014), on the technology acceptance model (Venkatesh & Bala, 2008), and on models of sustainable consumption (e.g., Joshi & Rahman, 2015; Kim & Chung, 2011; Liobikienė & Bernatonienė, 2017) this research aims to focus on the acceptance of power to x as a new and complex technology. Acceptance of power to x is defined as a positive evaluation of power to x technologies (cf. Kortsch et al., 2015). Furthermore, according to Wüstenhagen et al. (2007) acceptance of power to x can be differentiated by the target group which is in focus into public acceptance (e.g., residents of a electrolysis plant), market acceptance (e. g., consumers of a consumer care product), and socio-political acceptance (e.g., people as citizens).

I2 Objectives and Research question(s)

Objective: Gain insight into the current acceptance of power to x technologies in Germany and which influencing factors are important for the occurence of acceptance

RQ1: How accepted are power to x technologies? To what extent are there differences between the acceptances of the various application areas?

RQ2: Which factors (i.e., technical, psychological, sociodemographic) influence the acceptance of p2x in general? Which differences can be seen in different sectors (i.e., mobility, energy, chemical sector)?

RQ3: How does the acceptance of young people differ from those of adults?

RQ4: Which factors (i.e., technical, psychological, sociodemographic) influence the acceptance of products which used power to x technologies in the production process? Under which conditions will the technology be accepted (i.e., conditional acceptance)?

I3 Hypothesis (H1, H2, …)

H1: Social norm (a), perceived behavioral control (b), environmental attitude (c), personal norm (d), perception of distributive justice (e), openness to innovation (f) at a general level predict acceptance of p2x technologies in general.

H2: The general acceptance of power to x technologies and the specific acceptance of power to x in the mobility sector influence the willingness to pay and the willingness to use power to x technologies in the mobility sector.

H3: The general acceptance of power to x technologies and the specific acceptance of power to x in the chemical sector influence the willingness to use power to x technologies in the chemical sector.

H4: Openness to innovation and environmental attitudes are important predictors of acceptance of p2x, age moderates these relations - the relations are stronger for younger people.

H5: Environmental awareness predicts attitude or personal norm.

H6: General acceptance of p2x interacts with the (specific) intention to accept and predicts (specific) acceptance

H7: Knowledge about the power to x technology has a moderating effect on H1a-d.

I4 Exploratory research questions (if applicable; E1, E2, ...)

E1: How differs the acceptance of power to x from different roles people can take (i.e., acceptance from a residents perspective, from a consumer perspective, from a citizen perspective; cf. Wüstenhagen et al., 2007)?

Method

M1 Time point of registration
Registration prior to analysis of the data

M2 Proposal: Use of pre-existing data (re-analysis or secondary data analysis)
No

Sampling Procedure and Data Collection.

M3 Sample size, power and precision
N=2300, consisting of two subsamples: N1 = 1150 (16 to 25 years old) and N2 = 1150 (>25 years old)

M4 Participant recruitment, selection, and compensation
a) recruitment and data collection by a professional data provider (UZBonn)
b) sample characteristics: representative sample - gender balanced, distribution all over Germany and age taken into account
c) none
d) location: Germany
e) Compensation: Participants were financially compensated for their participation by the provider of the data (1,50 EURO)

M5 How will participant drop-out be handled?
The provider of the data provides a sample of 2000 cases plus 15 % (N = 2300) to ensure that at least 2000 cases are valid and can be used. Data will then be screened and cases are deleted based on their response time and answer patterns if implausible.

M6 Masking of participants and researchers
The data was assessed by a professional data provider who was not aware of our research model and questions.

M7 Data cleaning and screening
In a first step, data will be screened to get an impression of the data quality (e.g., looking at answer patterns, comments of the participants, answer speed). After an initial screening based on criteria such as answer patterns (e.g., variance is zero for a

group of independent items), cases were selected for more detailed evaluation by at least two researchers. These cases are then inspected in terms of answer speed (below 5 minutes) and comments of the participants (i.e., nonsense comments). Cases are excluded only by consensus of both researchers. If there is no consensus between both researchers, a senior researcher is consulted to make a decision in the researcher team.

M8 How will missing data be handled?
Some cases are deleted by the described procedure. FIML procedure will be used in analyses.

M9 Other information (optional)
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Conditions and design.

M10 Type of study and study design
crosssectional study, two samples (age: <= 25 years vs. > 25 years

M11 Randomization of participants and/or experimental materials

not applicable

M12 Measured variables, manipulated variables, covariates
list of all measured variables:
Previous knowledge (self constructed)
General acceptance of Power-to-X technologies. (four items based on Kortsch, Hildebrand,& Schweizer-Ries (2015), five-step answer format: 1 = "do not agree at all" to 5 = "agree completely")
Sector-specific acceptance.
One item each; based on the items from Kortsch, Hildebrand,& Schweizer-Ries (2015). five-point scale from 1 = "do not agree at all" to 5 = "agree completely"
Corners of the triangle
(according to Wüstenhagen et al.)
Partial aspect of general acceptance, following the acceptance triangle of Wüstenhagen et al. (2007). Two self-constructed items, five-level answer scale from 1 = "do not agree at all" to 5 = "agree completely
perceived benefits (as a partial aspect of general acceptance) (Arning, van Heek,& Ziefle, 2018)
5 Items, Scale from 1 = "do not agree at all" to 5 = "agree completely

Conditional Acceptance-factors (self constructed)regarding
a) the type of hydrogen used
b) the extraction of the required water
c) carbon capture
Scale from 1 = "do not agree at all" to 5 = "agree completely”
Semantic differential with 12 pairs of opposites (self-constructed) regarding the question which attributes participants associate with Power-to-X technologies
Fields of application for
transport sector (6 items)
Energy sector (5 items)
chemical sector (3 items)
6 items; bipolar five-point Likert scale (from 1 = "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge"
Willingness to pay (self constructed)
transport sector (4 items)
chemical sector (1 Item)
bipolar five-point Likert scale (from 1 = "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge"
Readiness to use various sustainable means of transport (self constructed)
bipolar five-point Likert scale (from 1 = "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge"
Willingness to buy (--> chemical sector)
4 items, bipolar five-point Likert scale (from 1 = "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge"
Levels of participation
(based on Rau et al. 2012 and Kortsch et al. 2015) 4 items, bipolar five-point Likert scale (from 1 = "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge"
concrete ideas regarding the integration into the Power-to-X development
open question
distributive justice (based on Kortsch, Hildebrand,& Schweizer-Ries, 2015)
6 Items, bipolar five-point Likert scale (from 1 = "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge"
Advantages of Power-to-X Technologies
open question
disadvantages of Power-to-X Technologies
open question

Environmentally consciousness/ sustainable behaviour (three items by Arning et al. 2018, bipolar five-point Likert scale (from 1= "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge")
environmental awareness (four items by Arning et al. 2018),bipolar five-point Likert scale (from 1= "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge")
personal innovativeness (four items by Herrenkind et al. 2019, bipolar five-point Likert scale (from 1= "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge")
collective effectiveness (one item based on Vainio et al. 2020, bipolar five-point Likert scale (from 1 = "do not agree at all" to 5 = "agree completely" with the evasion option "I cannot judge")
social/subjective norm (four items by Wang et al. 2016, five-step answer format: 1 = "do not agree at all" to 5 = "agree completely
persons remembert in the last question (one self developed open question)
personal moral norm (three items by Wang et al. 2016, five-step answer format: 1 = "do not agree at all" to 5 = "agree completely)
perceived behavior control. (two items based on Fieldings et al. 2018, five-step answer format: 1 = "do not agree at all" to 5 = "agree completely")

M13 Study Materials
Some graphics that visualize the power to x technology and the fields of application to enable participants to answer the questionnaire.

M14 Study Procedures

M15 Other information (optional)
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Analysis plan

AP1 Criteria for post-data collection exclusion of participants, if any
In a first step, data will be screened to get an impression of the data quality (e.g., looking at answer patterns, comments of the participants, answer speed). After an initial screening based on criteria such as answer patterns (e.g., variance is zero for a group of independent items), cases were selected for more detailed evaluation by at

least two researchers. These cases are then inspected in terms of answer speed (below 5 minutes) and comments of the participants (i.e., nonsense comments). Cases are excluded only by consensus of both researchers. If there is no consensus between both researchers, a senior researcher is consulted to make a decision in the researcher team.

AP2 Criteria for post-data collection exclusions on trial level (if applicable).

AP3 Data preprocessing
Scale values in terms of mean values of the respective items are calculated
Recoding:
Attitude toward P2X/general acceptance:
In principle, I am against power-to-X technologies in Germany.
In principle, I reject power-to-X technologies.

AP4 Reliability analysis (if applicable).

AP5 Descriptive statistics
Mean, standard deviation, cronbachs alpha

AP6 Statistical models (provide for each hypothesis if varies).

AP7 Inference criteria

AP8 Exploratory analysis (optional)

AP9 Other information (optional)

Other information, optional

O1 Other information (optional)

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