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Original research article

Does the public want green hydrogen in industry? Local and national acceptance of methanol and steel transitions in Germany

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ABSTRACT

Public perceptions might determine the ease of the transition from a fossil-based to a green hydrogen-based production pathway in the industrial sector. The primary objective of this paper is to empirically identify the antecedents of the acceptance of two relevant industrial applications of green hydrogen: green methanol and green steel. The analysis, relying on linear regression models, utilises survey data from samples of residents near a chemical park and a steel plant (509 and 502 participants, respectively), contrasting them with a representative sample of 1502 individuals in Germany. The findings suggest that acceptance of the transitions to green methanol and green steel is high both locally and nationally. In all surveys, >59 % of the participants are in favour, while the share of those who are opposed to the respective transitions is below 9 %. Key antecedents of acceptance, which are conducive in all models, relate to individuals' attitudes towards green hydrogen and perceptions of the legitimacy of the industry actors involved, with varying results across legitimacy types. In general, the findings were similar across industrial applications and across levels of observation, but varied across regions. This study highlights the importance of civil society perceptions and suggests that relationship management efforts aimed at maintaining positive perceptions of industrial hydrogen applications should consider their broader physical and social contexts.

1. Introduction

Achieving climate change mitigation targets is dependent on the successful transition towards green energy alternatives across all sectors. The industrial sector is particularly vital here, as it accounts for a significant share of CO_2 emissions globally and in Germany [1,2]. Moreover, it consists of energy-intensive and so-called difficult-to-decarbonise industries, specifically the chemical and steel industries. Both, direct emissions from the production of chemicals and their derivatives and from steelmaking are causing significant amounts of CO_2 emissions [1,3,4]. The provision and use of energy created from renewable sources – including wind and solar energy – and the electrification of energy services, such as electricity, or transport can directly result in energy and CO_2 emission savings. For energy-intensive industries, however, direct electrification is insufficient to fully decarbonise due to the need for high-temperature heat, which cannot be generated fully or cost-effectively through electrification alone [5,6]. An important alternative pathway for the chemical and steel industries – unlike others, such as cement, where emissions are process-based – is the use of green hydrogen.[1] While fossil-based hydrogen is already widely used in these industries, the use of green hydrogen – produced with electricity from renewable sources – is a newly emerging solution. Its use allows for the provision of high-temperature heat and can contribute to the direct avoidance of CO_2 emissions. This distinguishes it from solutions based on carbon capture technologies [9–11].

The transition from a currently fossil-based to a green hydrogen-based production pathway in difficult-to-decarbonise industries will be subject to technological, economic, and environmental constraints, as well as social challenges related to public support [12]. Previous literature concerned with transitioning to green energy technologies highlights the importance of the acceptance by key stakeholders and the public as a necessary prerequisite for successful market uptake and

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[1] Green hydrogen is generally understood as hydrogen that meets certain sustainability criteria, but there is no universally agreed definition. In this study, green hydrogen is defined as hydrogen produced by electrolysis powered by renewable energies. While this process results in low CO_2 emissions, it does not completely eliminate them due to upstream activities such as the construction of hydrogen production plants and the transport of hydrogen [7,8].

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deployment [e.g. 13–15]. With regard to the transition to the application of green hydrogen in industrial processes, the acceptance by civil society is particularly relevant, since public perceptions might determine the ease of implementing policy interventions related to their employment [16]. Given the localised nature of the chemical and steel industries, which often operate in large industrial sites or clusters [17], public support at the local level is particularly important [18]. Acceptance, in the form of favourable attitudes and behaviours in support of these transitions, can facilitate timely deployment, for example by mitigating potential legal objections to the development of new infrastructure [16]. Although public awareness of hydrogen technologies is currently low, civil society support is already needed for current funding or investment decisions. This support will also be essential when these technologies are to be deployed at full industrial scale and require extensive infrastructure development [13,19]. Thus, public support is not static, but can change over time, shaped by changes in its antecedents [20]. Past experiences with hydrogen for residential heating showed how the absence or loss of public support can ultimately lead to the cancellation of projects [21].

The primary objective of this paper is to empirically identify antecedents of the acceptance of the transitions to green methanol and green steel, i.e. methanol and steel produced using green hydrogen. Both represent key applications for the early adoption of hydrogen, given their significant hydrogen consumption in production and their broad applicability across market sectors [22]. Acceptance is assessed in terms of favourable attitudes towards the industrial transitions under study. A further objective of this paper is to contrast acceptance by the local community with overall trends in the general public. To this end, I draw on two online surveys of residents in the vicinity of a chemical park and a steel plant in Germany, with samples of 509 and 502 participants respectively which are compared to an online representative sample of 1502 individuals in Germany. The econometric analysis employs linear regression models. The findings of this research allow for insights into public perceptions towards transitions in the industrial sector and provide guidance on how policies should be designed to foster acceptance by local communities and the general public.

This study contributes to knowledge in several ways. Although the acceptance by civil society is described as relevant in industrial settings (e.g. in the context of chemical [23] or steel transitions [24]) and in terms of hydrogen technologies [e.g. 10,18,25], the antecedents of acceptance of the transitions to hydrogen-based production pathways in the chemical and the steel sector are thus far not well understood. These are empirical objects that are physically extensive and encompass multiple processes and multiple companies, making them inherently different from those commonly researched [17]. Only few studies look at industrial green transitions [e.g. 15,24], or specifically at the acceptance of industrial applications of hydrogen [e.g. 24,26]. Consequently, to my knowledge, this study is the first to offer a comprehensive assessment of the antecedents of acceptance of transitions to green methanol and green steel by civil society actors. By contrasting local and national levels, this research further generates insights into the so-called social gap identified in previous studies in related contexts, which refers to differing levels of acceptance by local communities and the general public [13,16,27–29].

The remainder of this paper is structured as follows. Section 2 conceptualises acceptance within the scope of this paper. Section 3 reviews the state of research on antecedents of acceptance of industrial transitions towards the implementation of green hydrogen-based processes. Based on this, I derive hypotheses for antecedents of acceptance at local and national levels, while focussing specifically on transitions to green methanol and green steel. Section 4 introduces the case studies and describes the data and methods used in this study. Section 5 presents the results. Section 6 discusses the findings and the limitations of the study's approach. Additionally, recommendations for future research are given. Finally, Section 7 concludes and provides implications for policymakers.

2. Conceptualising acceptance of green hydrogen-based industrial transitions

Acceptance is commonly defined as 'a favourable or positive response (including attitude, intention, behaviour and – where appropriate – use) relating to a proposed or in situ technology or socio-technical system, by members of a given social unit (country or region, community or town and household, organization)' [30: 103]. In this paper, acceptance evaluations are examined in terms of the prevalent attitudes of individuals towards green methanol and green steel. These attitudes are understood as evaluative judgments towards the industrial transitions under study [31,32]. By focusing on individuals' attitudes rather than their behaviours, this paper aims to analyse whether individuals are in favour of the respective transitions.[2] This is assessed on both the meso-scale (community acceptance) and the macro-scale (socio-political acceptance) [13,25,34]. By adopting a perspective that considers the systems level and takes into account that 'preferences, attitudes, expectations and behaviours are embedded in and shaped by broader physical and social systems' [35: 79], this paper responds to a call by Bögel and Upham [36] to bridge the divide between individual and societal levels.

To this end, and in line with Azarova et al. [27] and Ricci et al. [37], this study utilises an understanding of the acceptance of industrial transitions to green hydrogen-based processes that simultaneously involves public perceptions regarding green hydrogen, the corresponding infrastructures, the actors involved, and towards policies and funding directed at promoting these transitions [10,13,19,23,28].[3] At the meso-scale, this further includes the local impacts of the industrial transitions and the upscaling of related infrastructure [18]. The latter is particularly relevant for acceptance evaluations in regions where the chemical or steel industries are core industries, providing employment opportunities and secondary economic activities, while potentially being closely linked to local identity and culture [24,39]. This makes these transitions and public perceptions of them also relevant from a justice perspective (see, for example, Swennenhuis et al. [39] and Upham et al. [17]).

Finally, the empirical analysis of this study juxtaposes the interrelated but distinct concepts of acceptance and legitimacy. Following a widely used definition by Suchman [40: 574], legitimacy is 'a generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definitions'. Legitimacy therefore refers to the alignment of a particular object with this social system, i.e. the so-called institutions. This distinguishes it from the more micro-level concept of acceptance, which focuses on the attitudes and behaviours of individuals (see Alsheimer et al. [41] for a detailed comparison of the two concepts). Building on Genus and Iskandarova's [42] findings on the interdependencies between technology and organisational legitimacy, this paper examines the interactions between public perceptions of technologies, i.e. the acceptance of the transition to green methanol and green steel, and organisations, including the perceived legitimacy of the chemical and steel industries (see Section 3.3).

3. Antecedents of acceptance of green hydrogen-based industrial transitions

Previous empirical studies generally show that green hydrogen and the respective technologies are perceived rather favourably by various

[2] In this sense, my understanding of acceptance aligns with that of Dreyer and Walker [33: 355], who characterise acceptance as "an attitude structure, which is passive, [while] support includes not only this same attitude structure, but also a more active behavioural dimension".

[3] In this context, public perceptions refer to the collective views of a group of individuals towards a particular object [38]. These perceptions are analysed using concepts such as acceptance and legitimacy.

actors across industries, as well as – despite its low public awareness – the public [13,18,25,28,43,44]. However, only few of the studies analysing the acceptance of hydrogen technologies focus on acceptance outside the transport sector [13,18,25]. With regard to green hydrogen-based industrial transitions, and in particular green methanol and green steel, the evidence provided by the empirical literature to date is even more limited (see Section 1). Thus, the following review of the literature on the antecedents of acceptance at local and national levels is further informed by insights obtained from studies on hydrogen (technologies) in general and from related fields.[4] Based on this, I derive hypotheses for the subsequent empirical analysis.

Previous literature has used a variety of theoretical models to examine the antecedents of hydrogen technology acceptance. Prominent models include the Technology Acceptance Model (TAM) [45,46], the Technology Acceptance Framework (TAF) [10,47], or the Domestic Hydrogen Acceptance Model (DHAM), which was specifically developed to analyse the acceptance of specific hydrogen applications, i.e. domestic hydrogen [46]. However, these models tend to focus on the adoption and use of technologies (e.g. TAM [45] or DHAM [46]), or do not sufficiently address individual traits and, importantly, situational factors (e.g. TAF [10,47]). As this study examines individuals' acceptance in the form of favourable attitudes towards industrial hydrogen applications, it goes beyond the scope of these models, by analysing not only perceptions and attitudes towards the specific applications, but also by considering the broader context in which they are embedded (see Section 2). Accordingly, the reviewed literature suggests that relevant antecedents of the acceptance of green methanol and green steel relate to individuals' environmental perceptions and attitudes, their attitudes towards upstream processes, and their perceptions of the respective industries (see Fig. 1). Subsequently, I formulate the corresponding hypotheses.

3.1. *Environmental perceptions and attitudes*

As hydrogen technologies are typically discussed as green energy technologies, environmental and climate change-related values and beliefs are identified as relevant determinants of acceptance [10,13,25].[5] Although there is some variation with regard to national contexts [49] and spatial levels [50], previous literature typically identifies positive associations between acceptance of hydrogen applications and individuals' environmental self-identify [10,50,51], their belief that environmental problems – such as the ones caused by climate change – exist [10,13,50] and their assessment of the effectiveness of climate action [47]. Evidence by Scovell and Walton [26] further suggests that environmental political orientation is positively associated with the acceptance of green hydrogen-based industrial transitions.

To conclude, I formulate the following hypotheses:

H1a. Pro-environmental perceptions and attitudes are positively associated with individuals' acceptance of green methanol and green steel.

H1b. An environmental political orientation is positively associated with individuals' acceptance of green methanol and green steel.

3.2. *Attitudes towards upstream processes*

Public perspectives are contingent upon the specific context of the evaluated object, including the technology alternatives competing with the technology under study, and spill over effects from related or similar technologies [14]. As hydrogen technologies rely on hydrogen as an energy carrier, relevant spill over effects for the downstream acceptance of hydrogen technologies relate to attitudes towards the respective upstream method of hydrogen production [10,28,52]. Accordingly, attitudes towards green hydrogen might be antecedents of the acceptance of green hydrogen-based industrial transitions. However, as public knowledge of hydrogen is low and individuals might not distinguish between different forms of hydrogen, this might also apply to blue hydrogen. This form of hydrogen is produced from fossil fuels and is additionally equipped with carbon capture technologies. Although discussed controversially, it is often presented as a bridging technology that is essential for building the market for the future widespread use of green hydrogen [11,53,54]. Finally, given that acceptance evaluations regarding decarbonisation pathways based on the use of green hydrogen are argued to follow the energy transition discourse [28], individuals' attitudes towards renewable energies as an energy source for green hydrogen might also be influential in this context.

Hence, I hypothesise the following:

H2a. Favourable attitudes towards green hydrogen are positively associated with the acceptance of green methanol and green steel.

H2b. Favourable attitudes towards blue hydrogen are positively associated with the acceptance of green methanol and green steel.

H2c. Favourable attitudes towards renewable energies are positively associated with the acceptance of green methanol and green steel.

3.3. *Perceptions of industry*

Studies on hydrogen (technologies) commonly identify factors related to the individuals' personal familiarity, including their knowledge and previous experiences, as being associated with their acceptance ratings [10,18,43,55]. While knowledge about hydrogen is low, it has been found to be positively related with acceptance [10,18,43] – although not consistently across all studies [55]. Controlling for other factors, some studies found knowledge to be only weakly correlated with hydrogen acceptance [10,56]. Besides knowledge, experiences with hydrogen technologies gained through the exposure to the technologies can influence their acceptance [10,55]. In this context, previous research suggests that the overall familiarity with (heavy) industry and the respective infrastructures is correlated with the acceptance of hydrogen and the respective infrastructures [13].

Thus, as part of the particular context of the evaluated object, individuals' acceptance evaluations also include perceptions of the various stakeholders involved in implementing hydrogen technologies in the industrial sector, particularly the industry actors themselves [23,25]. Previous research provides indications for the acceptance of green hydrogen-based industrial transitions to be related to the (local) public trusting these stakeholders [10,13,15,43,57]. This trust might become particularly important in explaining individuals' attitudes when knowledge about the technology under evaluation is low [57,58].

Associated with trust, findings by previous studies suggest that the (perceived) legitimacy of industry actors can be expected to be conducive to the acceptance of green hydrogen-based industrial processes [25,59,60] (see also Section 2). This contribution relies on individuals' legitimacy assessments, which collectively form the micro-foundations of the socially constructed shared beliefs of society. Thus, my understanding of legitimacy corresponds to Suddaby et al.'s [61] perspective of legitimacy as a perception. In line with this, I understand organisational legitimacy as a socio-cognitive evaluation of the appropriateness of industries [61,62]. Suchman [40] distinguishes between the taken-for-grantedness of the organisations or industries under evaluation (cognitive legitimacy), the assessment of their outputs, procedures, and standards as the right thing to do (moral legitimacy), and self-interested cost-benefit analyses (pragmatic legitimacy). Since these cost-benefit

[4] Here, also studies focusing on related concepts, such as *social license to operate* (e.g. [15]), are considered.

[5] In this study, values are understood as the guiding principles of individuals, while beliefs refer to the underlying perceptions they hold. Both are considered influential in shaping an individual's attitudes towards a particular object [26,48].

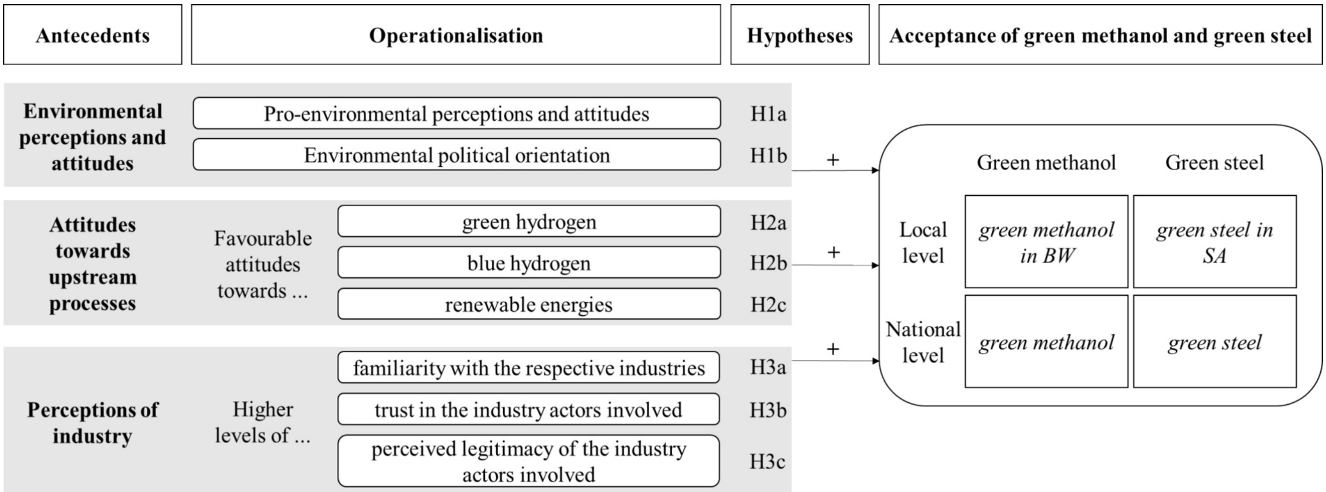

Fig. 1. Antecedents of the acceptance of green methanol and green steel. BW refers to the region of Bitterfeld-Wolfen and SA to the region of Salzgitter (see Section 4.1).

analyses also involve broader economic interdependencies between the respective organisations or industries and the evaluator's well-being [40], pragmatic legitimacy might be strongly related to the perceived economic importance of the industries involved in the transitions under evaluation.

In conclusion, I hypothesise the following:

H3a. Higher levels of familiarity with the respective industries are positively associated with the acceptance of green methanol and green steel.

H3b. Higher levels of trust in the industry actors involved are positively associated with the acceptance of green methanol and green steel.

H3c. Higher levels of perceived legitimacy of the industry actors involved are positively associated with the acceptance of green methanol and green steel.

4. Data and methods

4.1. Case study selection

The case studies for this research, which are further contrasted with findings at the national level, are two areas in Germany – Bitterfeld-Wolfen[6] (BW) and Salzgitter[7] (SA). Both are highly industrialised regions with long-standing ties to heavy industry.

BW has a strong tradition in the production of chemicals and their derivatives, with first activities dating back to the late 19th century. Following the reunification of Germany in 1990, the resident large conglomerates of companies in the chemical industry underwent restructuring and privatisation processes, with medium-sized companies taking their place [63]. In an effort to reduce CO_2 emissions, between March 2021 and February 2022, the CarbonCycleMeOH project investigated the feasibility of converting CO_2 from various sources into usable products, such as green methanol, using green hydrogen at the Bitterfeld-Wolfen Chemical Park. The methanol produced can be used locally for the synthesis of a variety of products such as building materials, paints, or renewable fuels [64].

SA's tradition in steelmaking is also long-standing, with activities dating back to the 19th century [65]. Until today, the area is still strongly characterised by manufacturing, which accounts for 55 % of all employment in the city of Salzgitter [66], and in particular by the steel industry [67]. With the Salzgitter Low CO_2 Steelmaking (SALCOS) project, which started in 2015, the steel company *Salzgitter AG* aims at transitioning from a coal-based to a natural gas and later green hydrogen-based production of steel. To this end, natural gas and later green hydrogen are planned to be used in direct reduction plants, replacing the coal-based blast furnace process. The first direct reduction plant is planned to go into operation in 2026, with the transition process planned to be concluded in 2033 [68,69].

4.2. Data collection

Three self-administered online surveys in Germany were used as the database for this analysis, including a survey of residents in the vicinity of the chemical park (BW) and a survey of residents in the vicinity to the steel plant (SA), with samples of 509 and 502 participants respectively. In addition, a representative sample of 1502 individuals in Germany was employed. The recruitment of participants was done by the market research company Dynata, which invited participants to take part in the online surveys. Dynata adheres to the guidelines of the European Society for Opinion and Market Research. More information on the panel demographics for the German national sample can be found on their website [70]. For the regional sample in BW, Dynata worked with two partners. The surveys were carried out between March and April 2022. In order to comply with data protection and ethical guidelines, participants were provided with details on data protection and informed consent was obtained. While the two regional surveys each focussed on the transition in one industrial sector, i.e. the chemical or the steel industry, the national survey comprised of questions on both sectors. The order of the questions on the two sectors was randomised, in order to prevent skewing the results.

In the surveys, the participants' acceptance of the green hydrogen-based industrial transitions under study was measured. Furthermore, the surveys contained items regarding their environmental perceptions

[6] Bitterfeld-Wolfen does not refer to any formal administrative boundaries. Instead, I define Bitterfeld-Wolfen as the area comprising the districts of Anhalt-Bitterfeld, Jerichower Land, Nordsachsen, Potsdam-Mittelmark, Saalekreis, Salzlandkreis, and Wittenberg, and the independent city of Dessau-Roßlau.

[7] Similarly to footnote 6, I define Salzgitter as the area comprising the independent cities of Salzgitter and Braunschweig, and the districts of Goslar, Hildesheim, Peine, and Wolfenbüttel. These are all part of the wider 'Hanover Braunschweig Goettingen Wolfsburg Metropolitan Region'.

and attitudes, attitudes towards upstream processes, perceptions of industry, and socio-economic characteristics.[8] The development of the questionnaire was informed by 7 semi-structured interviews with researchers and industry experts involved in the local transition to green methanol (conducted in September and October 2021) and 26 interviews with researchers and experts from intermediary organisations and industry involved in the transition to green steel both in SA and at supra-regional levels in Germany (conducted between December 2020 and October 2021). As with the surveys, interviewees were provided with details on data protection and informed consent was obtained.

4.3. Variables

This section presents the dependent variables and the covariates used in the multivariate analysis. Table 1 provides a brief description of these variables and the corresponding survey items. More details on the construction of the variables can be found in Appendix A, where Table A1 documents the survey items, and Table A2 provides descriptive statistics for all variables used in the multivariate analysis.

In the national survey, the acceptance of the transitions to the production of *green methanol* and *green steel* served as the dependent variables. In the regional surveys, the acceptance of the transitions to the production of *green methanol in BW* and *green steel in SA* was assessed. Measurement of the acceptance evaluations followed a basic description of the transitions to the respective green hydrogen-based industrial processes (see Appendix B for details). The regional surveys further provided basic information on the specific projects planned in the case study regions (see Appendix C for details), while also including a map, in which the locations of the industrial sites within the case study regions were depicted. All dependent variables were measured via a five-point likert scale ranging from 1 (fully opposed) to 5 (fully in favour), with an additional option allowing participants to indicate that they could not judge the item.

The multivariate analysis also included covariates that were used as proxies to test the hypotheses developed in Section 3. These covariates distinguish between antecedents of acceptance related to the individuals' environmental perceptions and attitudes, their attitudes towards upstream processes, and their perceptions of the respective industries. In addition, control variables related to socio-economic characteristics, place attachment (in terms of *local identification* and *long-term residency*), and place of residence, were included to account for potential confounding factors and to help isolate the effects of the covariates used to test my hypotheses. Table 1 lists the covariates and provides an overview of previous studies that have identified relationships between the covariates and the acceptance of hydrogen technologies.

4.4. Multivariate analysis

The multivariate analysis relies on the four ordinally scaled dependent variables to discern patterns related to the antecedents of acceptance of green methanol and green steel in Germany. I estimated linear regression models using ordinary least squares (OLS) estimations. The analysis was carried out using IBM SPSS Statistics software. Cases with missing values were excluded from the analysis.

[8] The surveys also included a randomised experiment. The aim of this experiment was to assess the effects of providing information on specific characteristics of the transitions to green methanol and green steel on acceptance evaluations. To test the sensitivity of the study's findings (see Table 3), I estimated an alternative model specification that included these treatments. Details of the randomised experiment and the results of this robustness check are documented in Appendix D.

5. Results

In this section, I focus on presenting the key descriptive results for the dependent variables and the findings of the multivariate analysis, which will then be discussed in Section 6.

5.1. Acceptance of green hydrogen-based industrial transitions

The descriptive statistics showed high levels of acceptance for the transitions to the investigated hydrogen-based industrial processes among the participants in all surveys, with participants featuring comparable response patterns across the dependent variables (see Table 2). In all surveys, >59 % of the participants are in favour, while the share of those who are opposed to the respective transitions is below 9 %. Nationally, acceptance levels for both *green methanol* and *green steel* are similar, with only those who are fully in favour being more strongly represented for *green steel*. At the regional level, the differences are more pronounced, with participants in SA more in favour of the respective transition than participants in BW.

5.2. Multivariate results

Table 3 presents the results of the four linear regression models.[9] Since the estimated models are all significant at the 0.01 level, I can reject the null hypothesis that all coefficients are jointly equal to 0. Robustness checks for my results are reported in Appendix D.

The findings in Table 3 show that *environmental self-identity* is positively and statistically significantly related at conventional levels (i.e. $p < 0.05$) with both dependent variables used in the national models. *Problem perception* and *environmental politics* are positively correlated with all dependent variables, with only the coefficients for *green methanol in BW* being insignificant. *Climate action effectiveness* features statistically significant and positive correlations for *green methanol* and *green steel in SA*. *Problem perception* demonstrates relatively strong relationships in the national models, with higher standardised coefficients β than most of the other covariates in the respective models. Similarly, *environmental politics* exhibits a relatively strong association with *green steel*.

In terms of attitudes towards upstream processes, *green hydrogen* is positively and statistically significantly correlated with all dependent variables. These relationships are comparatively strong, with standardised coefficients particularly high in the regional samples ($\beta = 0.282$ in BW and $\beta = 0.206$ in SA). The correlation coefficients for *blue hydrogen* are only statistically significant at conventional levels for *green methanol in BW*. *Renewable energies* features statistically significant and positive associations with *green methanol* and *green steel in SA*.

With regard to perceptions of the respective industries, the findings in Table 3 show that *familiarity* exhibits positive values across all dependent variables, with statistical significance observed for *green steel*. *Employment in industry* also features positive and statistically significant correlation coefficients with *green steel*. *Trust* has four positive correlation coefficients, with the only statistically significant coefficient for *green steel in SA*. The strength of this association is particularly high with a standardised coefficient β of 0.227. There are also strong relationships with the perceived legitimacy of the respective industries. Specifically, *cognitive legitimacy* is positively related with all dependent variables, with the strength of these relationships being particularly high for the two green methanol models (compare standardised coefficients β in Table 3). In contrast, *moral legitimacy* is strongly negatively and statistically significantly correlated with the acceptance of *green steel in SA*. *Pragmatic legitimacy* is positively and significantly related with both dependent variables used in the national models and with *green steel in*

[9] Individual variance inflation factors (VIFs) vary between 1.044 and 2.401. Thus, the covariates do not appear to be highly inter-correlated.

Table 1
Overview of the variables used in the multivariate analysis. For the covariates, this includes the corresponding hypotheses and supporting literature.

	Hypothesis	Variable	Variable description	Survey item example	Literature
Dependent variables					
1		*green methanol*[a]	5-point Likert scale	I1: Please indicate to what extent you are in favour of or opposed to a transition to the production of green methanol in Germany.	
2		*green steel*[a]	5-point Likert scale	I2: Please indicate to what extent you are in favour of or opposed to a transition to the production of green steel in Germany.	
3		*green methanol in BW*[b]	5-point Likert scale	I3: Please indicate to what extent you are in favour of or opposed to a transition to the production of green methanol in Bitterfeld-Wolfen.	
4		*green steel in SA*[c]	5-point Likert scale	I4: Please indicate to what extent you are in favour of or opposed to a transition to the production of green steel in Salzgitter.	
Covariates					
Environmental perceptions and attitudes	H1a	*environmental self-identity*[d]	summary index of the three-item scale I5 i–iii	I5 i: Behaving in an environmentally friendly way is an important part of my personality.	[10,50,51]
		problem perception	5-point Likert scale	I6: To what extent do you think climate change is a serious problem?	[10,13,50]
		climate action effectiveness	5-point Likert scale	I7: How effectively can people still limit climate change through climate action measures?	[47]
	H1b	*environmental politics*	5-point Likert scale	I8: I am in favour of environmentally oriented politics.	[26]
Attitudes towards upstream processes	H2a	*green hydrogen*	5-point Likert scale	I9/I10: Please indicate to what extent you are in favour of or opposed to the production of hydrogen from the following forms of energy.	[10,28,52]
	H2b	*blue hydrogen*	5-point Likert scale		
	H2c	*renewable energies*	summary index of the four-item scale I11 i–iv	I11: Please indicate to what extent you are in favour of or opposed to electricity production from the following forms of energy.	[28]
Perceptions of industry	H3a	*familiarity*	dummy variable based on I12/ I13	I12: Have you ever heard of green [methanol/steel]?	[10,18,43,55]
		employment in industry	dummy variable based on I14	I14: Are you or a family member currently or have you ever been employed in the [chemical/steel] industry?	[13]
	H3b	*trust*	5-point Likert scale	I15: In general, I trust companies from the [chemical/ steel] industry in Germany.	[10,13,15,43,57]
	H3c	*cognitive legitimacy*	summary index of the three-item scale I16 i–iii	I16 i: I believe that the [chemical/steel] industry is necessary.	[25,59,60]
		moral legitimacy	summary index of the six-item scale I16 iv–ix	I16 iv: The general public would approve of the practices of the [chemical/steel] industry.	[25,59,60]
		pragmatic legitimacy	summary index of the three-item scale I17 i–iii/the two-item scale I17 iv & v	I17: How important do you generally consider the economic contribution of the [chemical/steel] industry …	[25,59,60]
Control variables		*female*	dummy variable based on I18	I18: Please indicate your gender.	[49]
		age	participant age	I19: Please indicate your age.	[13]
		high education	dummy variable based on I20	I20: Please indicate your highest educational qualification.	[49]
		high income	dummy variable based on I21	I21: What is the monthly household income of all persons living permanently in your household?	[71]
		local identification[b,c]	summary index of the two-item scale I22 i & ii	I22 i: I identify with the municipality I live in.	[13,28]
		long-term residency[b,c]	dummy variable based on I23	I23: How long have you lived at your current place of residence or in its immediate vicinity?	[13,28]
		spatial proximity[a]	dummy variable based on I24	I24: To the best of your knowledge, do you live close (<50 km) to [chemical/steel] industry facilities?	[13,28]
		federal state[a]	dummy variable based on I25	I25: In which federal state do you live?	
		district[b,c]	dummy variable based on I26	I26: In which district do you live?	

Note: The survey asked participants to indicate the extent to which they perceived the chemical or steel industries to be (i) taken for granted (*cognitive legitimacy*), (ii) doing the right thing (*moral legitimacy*), and (iii) economically important (*pragmatic legitimacy*). These survey items were derived from legitimacy theory [40], with the assessment of cognitive and moral legitimacy based on scales developed by Alexiou and Wiggins [62], and the perceived economic importance of the industries used to assess pragmatic legitimacy [40].

[a] Only used in the national survey.

[b] Only used in the regional survey in BW.

[c] Only used in the regional survey in SA.

[d] To construct the indices, I first took an average of the item scores (excluding items with 'don't know' responses). I then created the z-score, i.e. I subtracted the average score from the raw score and then divided the result by the standard deviation. As is common in social sciences, I assumed that the scores on the scale are equidistant, and that the data can be treated as interval data. I used Cronbach's alpha to test whether the items are consistent with each other and whether the scale is reliable.

SA. The relationship with *pragmatic legitimacy* is particularly strong for *green methanol* ($\beta = 0.164$).

Among the control variables, there is a positive and statistically significant relationship between *age* and *green steel in SA*.

6. Discussion

The findings of the econometric analysis are summarised for each hypothesis in Table 4. The empirical results of this study provide support

Table 2
Item responses for the dependent variables.

	fully in favour	rather in favour	undecided	rather opposed	fully opposed	I don't know/ n.a.
green methanol (n = 1502)	23 %	37 %	26 %	4 %	3 %	7 %
green steel (n = 1502)	30 %	33 %	25 %	4 %	2 %	6 %
green methanol in BW (n = 509)	26 %	35 %	27 %	5 %	1 %	6 %
green steel in SA (n = 502)	41 %	29 %	18 %	5 %	3 %	3 %

for H1a and H1b, indicating that environmental perceptions and attitudes are antecedents of the acceptance of the green hydrogen-based industrial transitions to green methanol and green steel, especially at the national level. Specifically, pro-environmental perceptions and attitudes (H1a) and an environmental political orientation (H1b) are positively associated with acceptance, reaching statistical significance at the national level and in the regional sample in SA. While these results are generally consistent with previous studies [10,26], they contrast with the findings of Emmerich et al. [50], who observed a negative relationship between environmental self-identity and acceptance at the local level. As they focused on hydrogen fuel stations rather than industrial hydrogen applications, these differences may be due to the fact that these are inherently different empirical objects, with industrial hydrogen applications often located in heavily industrialised areas where their implementation is less likely to be seen as disruptive to the local environment.

Supporting the expectations articulated in previous research [e.g. 10], the results of the multivariate analysis provide strong support for H2a that favourable attitudes towards green hydrogen are conducive to the acceptance of its downstream application in industrial settings. This appears to be particularly true at the local level, where the strength of the effect is comparatively high. With regard to *blue hydrogen*, the significant positive relationship with *green methanol in BW* provides some support for H2b. In this context, findings by Scovell and Walton [26] suggest that more balanced correlations between both green and blue hydrogen and acceptance might be obtained when additional information on both production methods is provided. Finally, favourable attitudes towards renewable energies as an energy source for green hydrogen are indeed associated with acceptance (H2c). This is in line with Buchner et al. [72] and contradicts the notion that land use concerns about additional renewable energy installations for downstream green hydrogen production might be negatively associated with the acceptance of hydrogen applications (see, for example, [73]). However, the relationship with *renewable energies* is less pronounced than that with *green hydrogen*, possibly highlighting the more direct link between attitudes towards green hydrogen and acceptance of its application in industrial settings. Overall, my findings indicate that attitudes towards upstream processes are antecedents of acceptance.

Turning to perceptions of the respective industries, the findings provide some support that these perceptions might be influential for the acceptance of green methanol and green steel. Specifically, personal familiarity with the respective industries (H3a) is positively associated with acceptance in three of the four models, reaching statistical significance for green steel at the national level. This aligns well with findings of previous research [10,18,43,55]. In line with Schönauer and Glanz [13], higher levels of *trust* in the industry actors involved are positively associated with acceptance and statistically significant in the regional sample in SA, supporting H3b. Similarly, perceived legitimacy also appears to be correlated with the individuals' acceptance of industrial transitions to green hydrogen. While this is in line with previous research [25], the differing findings for the covariates used to test H3c suggest that the direction of the association with acceptance diverges, depending on the type of legitimacy. While acceptance of the transitions under study is positively related with *cognitive legitimacy*, i.e. the taken-for-grantedness of the respective industries, and with *pragmatic legitimacy*, which was measured in terms of their perceived economic importance at supra-regional or local levels, the unexpected negative associations with *moral legitimacy* might imply that individuals accepting the transitions do not necessarily also support the (current) practices of these industries.

In general, the findings were relatively, but not fully consistent across the four models. This is a first indication that similar antecedents of acceptance of hydrogen-based industrial transitions are relevant both across industrial applications of hydrogen and possibly across local and national levels. Some differences become evident when comparing acceptance across regional contexts. Compared to the other dependent variables, acceptance of the transition to green methanol in BW was statistically significantly correlated with the fewest variables considered. Antecedents that appear to be susceptible to regional differences relate in particular to environmental perceptions and attitudes, as these do not appear to be associated with acceptance of green methanol in BW. Instead, the most prominent antecedents of acceptance in this region are attitudes towards upstream hydrogen production methods and the cognitive legitimacy of the respective industries.

From a theoretical perspective, the findings underscore the importance of tailoring the conceptualisation of acceptance to the specific empirical context. Industrial hydrogen applications differ significantly from the empirical objects commonly studied [17]. As individuals do not interact directly with the technology, situational factors become more influential. Therefore, future research using prominent theoretical models such as the TAM, TAF, or DHAM to analyse the antecedents of acceptance in this or similar contexts should consider adapting these models to account for these characteristics. This might involve incorporating measures that reflect attitudes towards related technologies and perceptions of the actors involved in the respective implementation processes, as these antecedents were found to be significant in this study.

When interpreting the results of this investigation, several potential constraints should be considered, with implications for future studies. Some limitations arise from the study design. First, the survey approach might have typical limitations, such as social desirability bias in self-reported data, or sampling bias due to the way the market research institute's panels are constructed. Second, this study's findings are correlational and not causal. Third, this study relates current levels of acceptance with current levels of variables reflecting antecedents of acceptance. This cross-sectional design does not adequately reflect the dynamic nature of some of the concepts measured, particularly acceptance, trust, and legitimacy. Thus, it does not take into account the temporal dynamics in technology deployment, such as the influence of ongoing engagement of local communities on acceptance evaluations. Relatedly, this research relies on proposed or early stage projects. As projects progress and public awareness increases, future studies might gather more substantiated acceptance assessments [18].

Other aspects that limit the generalisability of my findings relate to my focus on green methanol and green steel in Germany – particularly during the energy crisis following Russia's invasion of Ukraine, which increased the importance the public attached to energy security [74]. Future research could conduct similar studies in other countries and include other industrial hydrogen applications or other difficult-to-decarbonise industries for external validity of the obtained findings. This could also counteract another limitation of this study, as certain specificities of the proposed green production methods vary between the cases studied, limiting their comparability. However, these variations should not have significantly affected the identification of patterns in

Table 3
Antecedents of the acceptance of green hydrogen-based industrial transitions (OLS estimations).

	green methanol		*green steel*		*green methanol in BW*		*green steel in SA*	
	B	*β* (95 % CI)	*B*	*β* (95 % CI)	*B*	*β* (95 % CI)	*B*	*β* (95 % CI)
Environmental perceptions and attitudes								
environmental self-identity	0.079**	0.078 (0.020;0.138)	0.119***	0.122 (0.061;0.178)	0.017	0.017 (−0.077;0.111)	−0.025	−0.024 (−0.131;0.080)
problem perception	0.128***	0.137 (0.068;0.188)	0.133***	0.146 (0.073;0.193)	0.062	0.074 (−0.030;0.154)	0.165***	0.163 (0.066;0.265)
climate action effectiveness	0.081**	0.089 (0.028;0.134)	0.028	0.032 (−0.025;0.081)	0.066	0.075 (−0.024;0.157)	0.104**	0.105 (0.019;0.188)
environmental politics	0.093**	0.098 (0.037;0.150)	0.147***	0.159 (0.090;0.204)	0.062	0.066 (−0.030;0.153)	0.182***	0.175 (0.090;0.275)
Attitudes towards upstream processes								
green hydrogen	0.115***	0.118 (0.055;0.176)	0.189***	0.198 (0.127;0.250)	0.277***	0.282 (0.167;0.387)	0.183***	0.206 (0.093;0.273)
blue hydrogen	0.035	0.039 (−0.009;0.078)	−0.023	−0.027 (−0.066;0.021)	0.116**	0.123 (0.034;0.199)	0.014	0.015 (−0.061;0.089)
renewable energies	0.063*	0.065 (0.004;0.122)	−0.001	−0.001 (−0.061;0.060)	0.054	0.056 (−0.048;0.156)	0.135**	0.125 (0.020;0.251)
Perceptions of industry								
familiarity	0.080	0.039 (−0.022;0.182)	0.176**	0.086 (0.073;0.279)	0.112	0.053 (−0.072;0.296)	0.050	0.023 (−0.120;0.221)
employment in industry	0.039	0.014 (−0.101;0.178)	0.164*	0.065 (0.023;0.304)	−0.109	−0.047 (−0.317;0.099)	0.002	0.001 (−0.194;0.197)
trust	0.058	0.060 (−0.005;0.121)	0.024	0.024 (−0.041;0.090)	0.097	0.099 (−0.013;0.207)	0.267***	0.227 (0.150;0.383)
cognitive legitimacy	0.146***	0.148 (0.079;0.213)	0.112**	0.116 (0.046;0.178)	0.232***	0.241 (0.133;0.330)	0.125**	0.114 (0.020;0.229)
moral legitimacy	0.009	0.009 (−0.061;0.079)	−0.029	−0.030 (−0.095;0.038)	−0.036	−0.038 (−0.149;0.076)	−0.277***	−0.259 (−0.392;-0.163)
pragmatic legitimacy	0.163***	0.164 (0.097;0.228)	0.096**	0.099 (0.030;0.162)	−0.058	−0.061 (−0.141;0.025)	0.105**	0.097 (0.014;0.196)
Control variables								
female	−0.049	−0.025 (−0.143;0.044)	−0.065	−0.034 (−0.159;0.030)	0.087	0.046 (−0.080;0.254)	−0.132	−0.061 (−0.292;0.027)
age	−0.001	−0.010 (−0.004;0.002)	0.001	0.011 (−0.003;0.004)	0.001	0.011 (−0.005;0.006)	0.008**	0.109 (0.002;0.013)
high education	0.042	0.021 (−0.057;0.141)	−0.033	−0.016 (−0.134;0.068)	0.112	0.059 (−0.052;0.277)	0.028	0.013 (−0.141;0.197)
high income	−0.030	−0.015 (−0.127;0.066)	0.053	0.027 (−0.044;0.151)	0.118	0.061 (−0.042;0.277)	−0.007	−0.003 (−0.172;0.157)
local identification					0.013	0.013 (−0.075;0.102)	0.084	0.076 (−0.015;0.183)
long-term residency					0.102	0.054 (−0.070;0.275)	0.024	0.011 (−0.156;0.203)
spatial proximity	0.054	0.026 (−0.049;0.158)	−0.059	−0.028 (−0.174;0.056)				
federal state	Yes		Yes					
district					Yes		Yes	
Constant	1.723***	(1.247;2.198)	1.779***	(1.288;2.270)	0.966*	(0.188;1.743)	0.243	(−0.544;1.031)
Number of observations	1199		1194		406		414	
F	F(33;1165) = 21.32***		F(33;1160) = 17.85***		F(26;379) = 9.71***		F(24;389) = 16.75***	
Adjusted R^2	0.359		0.318		0.359		0.478	

Note: *B* = regression coefficient, *β* = standardised regression coefficient, CI = Confidence Interval.
*** $p < 0.001$.
** $p < 0.01$.
* $p < 0.05$.

relevant antecedents of acceptance – the primary objective of this study.

Finally, while my analysis covered a wide range of potential antecedents of the acceptance of green hydrogen-based industrial transitions, additional factors like affects, perceived benefits or risks, perceived fairness, or social norms could be considered in future research [10,16,27,55]. Furthermore, future studies could employ qualitative methods to further disentangle the relationships this study identified. Interesting avenues for future research include a more in-depth understanding of the interactions between (competing) technology alternatives [14], between public perceptions of technologies and the organisations involved, and between the concepts of acceptance and legitimacy [42]. In doing so, future research should be aware of potential variations between different types or dimensions of acceptance and legitimacy, as suggested by my findings on cognitive, moral, and pragmatic legitimacy.

7. Conclusion

While the ease of transitioning to green hydrogen in industrial settings is – among other factors – dependent on its perception by the general public, no comprehensive assessment of the antecedents of acceptance has been undertaken to date. Based on a review of the literature, I identified multiple potential antecedents of the acceptance of green hydrogen-based industrial transitions, specifically green methanol and green steel. Conceptually, I utilised an understanding of acceptance that differs from the one found in the majority of studies

Table 4
Summary of results for each hypothesis.

Hypothesis (…of green methanol and green steel.)	*green methanol*	*green steel*	*green methanol in BW*	*green steel in SA*
Environmental perceptions and attitudes				
H1a: Pro-environmental perceptions and attitudes are positively associated with acceptance…	✓	✓/n.s.	n.s.	✓/n.s.
H1b: An environmental political orientation is positively associated with acceptance…	✓	✓	n.s.	✓
Attitudes towards upstream processes				
H2a: Favourable attitudes towards green hydrogen are positively associated with acceptance…	✓	✓	✓	✓
H2b: Favourable attitudes towards blue hydrogen are positively associated with acceptance…	n.s.	n.s.	✓	n.s.
H2c: Favourable attitudes towards renewable energies are positively associated with acceptance…	✓	n.s.	n.s.	✓
Perceptions of industry				
H3a: Higher levels of familiarity with the respective industries are positively associated with acceptance…	n.s.	✓	n.s.	n.s.
H3b: Higher levels of trust in the industry actors involved are positively associated with acceptance…	n.s.	n.s.	n.s.	✓
H3c: Higher levels of perceived legitimacy of the industry actors involved are positively associated with acceptance…	✓/n.s.	✓/n.s.	✓/n.s	✓/×

✓ Results are statistically significant and support the hypothesis.
n.s. Results are not statistically significant.
× Results are statistically significant and in contrast to the hypothesis.

conducted to date in related fields, and which recognises that acceptance evaluations of green hydrogen-based processes are embedded in the broader physical and social contexts of the respective transitions. By employing citizen surveys at local and national levels, I contrasted community and socio-political acceptance and thereby generated insights into the often identified gap between favourable attitudes by the general public and acceptance issues at the local level.

This study's findings provide empirical support that public perceptions towards transitioning to green hydrogen-based industrial processes in methanol and steel production are generally positive. Furthermore, the similar patterns identified in the local and national acceptance evaluations do not corroborate the notion that there is a clear contrast between the views of wider society and the acceptance of local communities. Instead, the findings on the antecedents of acceptance suggest that public perceptions of the transitions to green hydrogen-based processes studied are determined by similar factors, which are largely consistent across industries and across levels of observation. However, there are some differences between the two regions studied. These findings underscore the need of scholars analysing acceptance of hydrogen technology applications in industrial settings to consider the particular (local) contexts of the objects under study.

Policymakers and industry actors seeking to maintain the current high level of acceptance for industrial transitions to green methanol and green steel should be aware that attitudes formed with limited information are susceptible to change, especially with full industrial scale implementation [13,27,28,43,55]. Although public awareness is currently low, interest in the transitions might increase in the future, particularly at the local level, where the continuation of economic activity in the respective sectors is highly valued [39,75]. This study strongly suggests that maintaining positive perceptions of the upstream processes associated with green hydrogen, and fostering the legitimacy of industry actors, appears to be critical for the acceptance of the implementation of green hydrogen in industrial settings. To achieve this, clear and transparent communication about the transitions is expected to be beneficial [25]. As some of the antecedents of acceptance studied vary across regions and – to a lesser extent – across levels of observation, policies aimed at promoting or maintaining acceptance should take into account the local (historical) contexts and the administrative levels at which these policies operate.

In conclusion, the findings can guide policymakers and industry actors in advancing the transition to green hydrogen in industrial settings. They suggest that local communities and the general public are currently generally supportive of green hydrogen applications in this sector, which facilitates their successful uptake. To maintain this high level of acceptance, the study underlines the importance of promoting not only the green hydrogen application to be implemented, but also related technologies along the value chain, while ensuring the legitimacy and trustworthiness of the implementing actors. Further research will be essential to understand how these complex dynamics evolve once industrial applications of green hydrogen are scaled up.

CRediT authorship contribution statement

Sven Alsheimer: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author used "DeepL Write" in order to improve readability and language. After using this tool, the author reviewed and edited the content as needed and takes full responsibility for the content of the publication.

Declaration of competing interest

The author declares that he has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Survey items, descriptive statistics, and hypotheses

Table A1
Survey items and valid item response categories for variables used in the multivariate analysis.*

Variable	Survey item
Dependent variables	
green methanol[a]	I1: Please indicate to what extent you are in favour of or opposed to a transition to the production of green methanol in Germany. (fully in favour – rather in favour – undecided – rather opposed – fully opposed)
green steel[a]	I2: Please indicate to what extent you are in favour of or opposed to a transition to the production of green steel in Germany. (fully in favour – rather in favour – undecided – rather opposed – fully opposed)
green methanol in BW[b]	I3: Please indicate to what extent you are in favour of or opposed to a transition to the production of green methanol in Bitterfeld-Wolfen. (fully in favour – rather in favour – undecided – rather opposed – fully opposed)
green steel in SA[c]	I4: Please indicate to what extent you are in favour of or opposed to a transition to the production of green steel in Salzgitter. (fully in favour – rather in favour – undecided – rather opposed – fully opposed)
Covariates	
environmental self-identity	I5: To what extent do you agree or disagree with the following statements? (fully agree – rather agree – undecided – rather disagree – fully disagree) (i) Behaving in an environmentally friendly way is an important part of my personality. (ii) I am one of those people who behave in an environmentally friendly way. (iii) I see myself as an environmentally friendly person.
problem perception	I6: To what extent do you think climate change is a serious problem? (a very serious problem – a rather serious problem – undecided – not really a serious problem – not a serious problem at all)
climate action effectiveness	I7: How effectively can people still limit climate change through climate action measures? (very effectively – rather effectively – undecided – rather ineffectively – not effectively at all)
	Please indicate to what extent you agree with the following statements: (fully agree – rather agree – undecided – rather disagree – fully disagree)
environmental politics	I8: I am in favour of environmentally oriented politics.
	Please indicate to what extent you are in favour of or opposed to the production of hydrogen from the following forms of energy: (fully in favour – rather in favour – undecided – rather opposed – fully opposed)
green hydrogen	I9: Electricity from renewable energies such as wind energy or photovoltaics, making it climate-neutral (green hydrogen)
blue hydrogen	I10: Fossil fuels such as natural gas or coal, but whose CO_2 is captured and stored as it is emitted (blue hydrogen)
renewable energies	I11: Please indicate to what extent you are in favour of or opposed to electricity production from the following forms of energy: (fully in favour – rather in favour – undecided – rather opposed – fully opposed) (i) solar power; (ii) hydropower; (iii) wind energy; (iv) energy from biomass; (v) energy from hard coal and lignite; (vi) energy from natural gas; (vii) nuclear power
familiarity	I12[a]: Have you ever heard of green [methanol/steel]? (i) Yes, I have heard of it and I know what it is. (ii) Yes, but I don't know exactly what it is. (iii) No, I have never heard of it. I13[b,c]: Before today, had you ever heard that a project for the production of green [methanol/steel] exists in [Bitterfeld-Wolfen/Salzgitter]? (i) Yes, I have heard about it and I know what this project is about. (ii) Yes, but I don't know exactly what this project is about. (iii) No, I have never heard of it.
employment in industry	I14: Are you or a family member currently or have you ever been employed in the [chemical/steel] industry? (multiple selections possible) (i) Yes, I am currently or have previously been employed in this field. (ii) Yes, one or more people in my family are currently or have previously been employed in this field. (iii) No.
trust	I15: In general, I trust companies from the [chemical/steel] industry in Germany. (fully agree – rather agree – undecided – rather disagree – fully disagree)
cognitive legitimacy/moral legitimacy	I16: To what extent do you agree or disagree with the following statements? (fully agree – rather agree – undecided – rather disagree – fully disagree) (i) I believe that the [chemical/steel] industry is necessary. (ii) In general, the [chemical/steel] industry fulfils an essential function. (iii) It is difficult to imagine a world in which the [chemical/steel] industry does not exist. (iv) The general public would approve of the practices of the [chemical/steel] industry. (v) Most people would view the practices of the [chemical/steel] industry as moral. (vi) The way the [chemical/steel] industry operates, promotes the common good. (vii) The [chemical/steel] industry strives to maintain acceptable standards of ethical behaviour in its field. (viii) The practices of the [chemical/steel] industry appear to be appropriate. (ix) If more industries acted like the [chemical/steel] industry, the world would be a better place.
pragmatic legitimacy	I17: How important do you generally consider the economic contribution of the [chemical/steel] industry … (totally important – rather important – undecided – rather unimportant – totally unimportant) (i) in Europe? (ii) in Germany? (iii) in your federal state? (iv) in your region? (v) in your municipality?
female	I18: Please indicate your gender. (male – female – diverse)
age	I19: Please indicate your age. (open-ended)
high education	I20: Please indicate your highest educational qualification: (i) I left school without a diploma; (ii) Elementary/secondary school diploma (GDR: 8th grade); (iii) Secondary school diploma/Mittlere Reife (GDR: 10th grade); (iv): Advanced technical college entrance qualification (completion of a specialised secondary school); (v): Abitur/general or subject-specific university entrance qualification; (vi): University of applied sciences or vocational academy degree (GDR: engineering and technical college degree); (vii): University or college degree; (viii): Doctorate or habilitation; (ix): Other qualification with Abitur/general or subject-linked higher education entrance qualification, namely x (open-ended); (x): Other qualification without Abitur/general or subject-linked higher education entrance qualification, namely x (open-ended)
high income	I21: What is the monthly household income of all persons living permanently in your household? Please refer to the net monthly amount, i.e. after deduction of taxes and social security contributions, and please add regular payments such as pensions, housing allowance, child benefit, BAföG, alimony payments, etc. If you are not sure, please estimate the monthly amount. (11 response categories from under 1000 Euro (1) to 10,000 Euro and more (11))
local identification[b,c]	I22: To what extent do you agree or disagree with the following statements? (fully agree – rather agree – undecided – rather disagree – fully disagree) (i) I identify with the municipality I live in. (ii) I identify with the region I live in. (iii) I identify with the federal state I live in. (iv) I identify with Germany. (v) I identify with the European Union.
long-term residency[b,c]	I23: How long have you lived at your current place of residence or in its immediate vicinity? (i) $<$1 year; (ii) 1 to 4 years; (iii) 5 to 9 years; (iv) 10 to 14 years; (v) 15 to 19 years; (vi) $>$20 years
spatial proximity[a]	I24: To the best of your knowledge, do you live close ($<$50 km) to [chemical/steel] industry facilities? (yes – no)
federal state[a]	I25: In which federal state do you live? If you have more than one place of residence, please always refer to your current primary residence. (response categories refer to the federal states listed in Table A2)
district[b,c]	I26: In which district do you live? If you have more than one place of residence, please always refer to your current primary residence. (response categories refer to the districts listed in Table A2)

* Translated by the author from the original German.
a Only used in the national survey.
b Only used in the regional survey in BW.
c Only used in the regional survey in SA.

Table A2
Descriptive statistics for all variables used in the multivariate analysis, and overview of the hypotheses and the corresponding covariates. Note: Sample sizes are shown in parentheses.

Hypothesis	Variables	Description	Median/mean/share[a]			
			[1]	[2]	[3]	[4]
Dependent variables						
1	*green methanol*[b] (S)	5-point Likert scale ranging from 1 (fully opposed) to 5 (fully in favour)	4 (1400)			
2	*green steel*[b] (S)	5-point Likert scale ranging from 1 (fully opposed) to 5 (fully in favour)		4 (1417)		
3	*green methanol in BW*[c] (S)	5-point Likert scale ranging from 1 (fully opposed) to 5 (fully in favour)			4 (480)	
4	*green steel in SA*[d] (S)	5-point Likert scale ranging from 1 (fully opposed) to 5 (fully in favour)				4 (487)
Environmental perceptions and attitudes						
H1a	*environmental self-identity*[f] (I)	summary index of the three-item scale I5 i–iii	0.00 (1484)		0.00 (505)	0.00 (499)
	problem perception (S)	5-point Likert scale ranging from 1 (not a serious problem at all) to 5 (a very serious problem)	5 (1476)		4 (502)	5 (489)
	climate action effectiveness (S)	5-point Likert scale ranging from 1 (not effectively at all) to 5 (very effectively)	4 (1444)		4 (494)	4 (490)
H1b	*environmental politics* (S)	5-point Likert scale ranging from 1 (fully disagree) to 5 (fully agree)	4 (1422)		4 (481)	4 (481)
Attitudes towards upstream processes						
H2a	*green hydrogen* (S)	5-point Likert scale ranging from 1 (fully opposed) to 5 (fully in favour)	5 (1427)		4 (483)	4 (488)
H2b	*blue hydrogen* (S)	5-point Likert scale ranging from 1 (fully opposed) to 5 (fully in favour)	3 (1371)		3 (463)	3 (479)
H2c	*renewable energies*[f] (I)	summary index of the four-item scale I11 i–iv	0.00 (1476)		0.00 (498)	0.00 (500)
Perceptions of industry						
H3a	*familiarity* (D)	1 if participant has heard of the industrial process under study/the respective local project	0.31 (1502)	0.30 (1502)	0.23 (509)	0.48 (502)
H3b	*employment in industry* (D)	1 if participant or a member of the participant's family has at some point been employed in the respective industry	0.15 (1502)	0.16 (1502)	0.20 (509)	0.39 (502)
H3c	*trust* (S)	5-point Likert scale ranging from 1 (fully disagree) to 5 (fully agree)	4 (1426)	4 (1388)	3 (485)	4 (482)
H3d	*cognitive legitimacy*[f] (I)	summary index of the three-item scale I16 i–iii	0.00 (1416)	0.00 (1405)	0.00 (491)	0.00 (490)
	moral legitimacy[f] (I)	summary index of the six-item scale I16 iv–ix	0.00 (1397)	0.00 (1374)	0.00 (486)	0.00 (481)
	pragmatic legitimacy[f] (I)	summary index of the three-item scale I17 i–iii[b]/the two-item scale I17 iv & v[c,d]	0.00 (1416)	0.00 (1400)	0.00 (479)	0.00 (483)
Control variables						
	female (D)	1 if participant is female	0.50 (1502)		0.58 (509)	0.46 (502)
	age	participant age [in years]	50.06 (1502)		43.37 (509)	41.09 (502)
	high education (D)	1 if participant has at least Abitur	0.36 (1502)		0.41 (509)	0.50 (502)
	high income (D)	1 if participant's income is above the median	0.38 (1502)		0.41 (509)	0.49 (502)
	local identification[c,d,f] (I)	summary index of the two-item scale I22 i & ii			0.00 (509)	0.00 (502)
	long-term residency[c,d] (D)	1 if participant's duration of residence within the study region is above the median			0.49 (509)	0.46 (502)
	spatial proximity[b] (D)	1 if participant states to live within 50 km distance to the respective industry	0.34 (1502)	0.26 (1502)		
	Baden-Wuerttemberg[b] (D)	1 if participant's place of residence is in the respective federal state (n = 1.502)	0.14			
	Bavaria[b] (D)		0.16			
	Berlin[b] (D)		0.04			
	Brandenburg[b] (D)		0.03			
	Bremen[b] (D)		0.01			
	Hamburg[b] (D)		0.02			
	Hesse[b] (D)		0.08			
	Lower Saxony[b] (D)		0.09			
	Mecklenburg-Western Pomerania[b] (D)		0.02			
	North Rhine-Westphalia[b,e] (D)		0.23			
	Rhineland-Palatinate[b] (D)		0.05			

(*continued on next page*)

Table A2 (*continued*)

Hypothesis	Variables	Description	Median/mean/share[a]			
			[1]	[2]	[3]	[4]
	Saarland[b] (D)			0.01		
	Saxony[b] (D)			0.05		
	Saxony-Anhalt[b] (D)			0.02		
	Schleswig-Holstein[b] (D)			0.03		
	Thuringia[b] (D)			0.03		
	Anhalt-Bitterfeld[c] (D)	1 if participant's place of residence is in the respective district (n = 509)			0.14	
	Dessau-Roßlau[c] (D)				0.08	
	Jerichower Land[c] (D)				0.09	
	Nordsachsen[c] (D)				0.16	
	Potsdam-Mittelmark[c,e] (D)				0.15	
	Saalekreis[c] (D)				0.14	
	Salzlandkreis[c] (D)				0.16	
	Wittenberg[c] (D)				0.08	
	Braunschweig[d] (D)	1 if participant's place of residence is in the respective district (n = 502)				0.31
	Goslar[d] (D)					0.12
	Hildesheim[d,e] (D)					0.23
	Peine[d] (D)					0.12
	Salzgitter[d] (city) (D)					0.13
	Wolfenbüttel[d] (D)					0.09

[a] S: score, D: 0/1-dummy, I: index of average z-scores. I report the median for score variables, the shares for dummies, and the mean for other types of variables.
[b] Only used in the national survey.
[c] Only used in the regional survey in BW.
[d] Only used in the regional survey in SA.
[e] To prevent singularity of the regressor matrix, this variable was dropped from the analysis.
[f] The process of constructing the indices includes the creation of z-scores, which centres the indices and gives them a mean of 0.00.

Appendix B. Details on the basic information on the industrial transitions provided in all surveys[10]

Description of green hydrogen-based transitions:

The [chemical and steel industries require] a lot of energy. [They] therefore [cause] large amounts of CO_2 emissions. These emissions can be reduced by transitioning to green hydrogen in industrial processes. This is achieved if the hydrogen is produced using renewable energies. Renewable energies such as wind power or solar energy are characterised by the fact that they do not cause any CO_2 emissions during operation.

Specific description of the green hydrogen-based transition in the chemical industry:

In the chemical industry, not all CO_2 emissions can be avoided in the long term. However, CO_2 can be captured to prevent it from escaping into the atmosphere. It can then be reused as a raw material. In the chemical industry, CO_2 can be used to produce green methanol. In addition to CO_2, this also requires green hydrogen.

Methanol is one of the most widely produced chemicals. It is used to manufacture a variety of products such as building materials, paints and renewable fuels.

Specific description of the green hydrogen-based transition in the steel industry:

Coal has been the main source of energy for the steel industry. This results in high CO_2 emissions. To reduce these emissions, coal is to be replaced first by natural gas and then by green hydrogen. In the production of green steel, water vapour is emitted instead of CO_2.

Appendix C. Details on the additional information on the planned industrial transitions in the case study regions provided in the regional surveys[11]

Description of the planned green hydrogen-based transition in the chemical industry in BW:

A research project at the Bitterfeld-Wolfen Chemical Park is currently investigating how green methanol can be produced at the plant. The aim is to use the plant's CO_2 exhaust gases as well as green hydrogen. In the future, this is intended to reduce the chemical park's CO_2 emissions.

Description of the planned green hydrogen-based transition in the steel industry in SA:

A research project at the Salzgitter AG site in Salzgitter is currently investigating how green steel can be produced at the plant. The aim is to restructure the plant and use an increasing amount of green hydrogen. In the future, this is intended to reduce the steelwork's CO_2 emissions.

Appendix D. Robustness checks

To examine the validity and consistency of this study's findings, a series of robustness checks on selected covariates was conducted.

First, it was tested whether the inclusion of treatments used as part of the randomised survey experiment are consistent with the results presented in Table 3. Participants in each survey were randomly assigned to one control and two treatment groups using random 'triggers' within the online survey tool. Individuals in the control groups (T0) received only the basic information described in Appendices B and C. The information provided to the participants in the treatment groups are related to different characteristics of the transitions under study, with *T1* and *T2* pertaining to the effects of the transitions, *T3* pertaining to the costs of the respective processes, and *T4* pertaining to the decision-making in the respective implementation

[10] See * legend in Table A1.
[11] See * legend in Table A1.

processes. In the following, the provided information for each treatment is presented.[12]

T1 (national survey): A challenge for the implementation of green [methanol/steel] is the large amount of electricity needed to produce the required quantities of hydrogen. This will require the construction of a large number of additional renewable energy plants (e.g. wind power and photovoltaics) in Germany.

T2 (regional surveys): In [Bitterfeld-Wolfen/Salzgitter] and the surrounding region, the transition to green [methanol/steel] requires the construction of additional renewable energy plants (e.g. wind power and photovoltaics). Furthermore, the infrastructure for green hydrogen must also be expanded (e.g. through additional pipelines).

T3 (national survey): A challenge for the implementation of green [methanol/steel] is the higher cost compared to alternatives based on fossil fuels. Even if the technology continues to develop, this cost difference will remain for some time to come.

T4 (regional surveys): Municipalities and districts in the region are supporting the transition to green [methanol/steel]. To this end, they are working together in networks with [chemical/steel] companies. They are also involved in establishing the necessary hydrogen economy in the region as part of the [Hydrogen Region Central Germany/Hydrogen Model Region].

T1 and *T3* were employed in the national survey, *T2* and *T4* in the regional surveys. As the national survey covered both the chemical and the steel industry, assignment to the treatment groups was held consistent throughout the survey. The findings of this alternative specification of this study's main model, which are documented in Table D1 are broadly consistent with those shown in Table 3.

Table D1
Antecedents of the acceptance of green hydrogen-based industrial transitions – treatments included (OLS estimations).

	green methanol		*green steel*		*green methanol in BW*		*green steel in SA*	
	B	*β* (95 % CI)	*B*	*β* (95 % CI)	*B*	*β* (95 % CI)	*B*	*β* (95 % CI)
Environmental perceptions and attitudes								
environmental self-identity	0.083**	0.082 (0.024;0.142)	0.122***	0.125 (0.064;0.181)	0.017	0.017 (−0.077;0.111)	−0.025	−0.023 (−0.131;0.081)
problem perception	0.126***	0.135 (0.066;0.186)	0.133***	0.146 (0.073;0.193)	0.063	0.075 (−0.029;0.156)	0.165***	0.163 (0.066;0.265)
climate action effectiveness	0.082**	0.090 (0.029;0.135)	0.027	0.030 (−0.026;0.080)	0.067	0.076 (−0.024;0.157)	0.101*	0.103 (0.016;0.186)
environmental politics	0.092***	0.096 (0.035;0.148)	0.145***	0.156 (0.088;0.201)	0.061	0.065 (−0.031;0.152)	0.182***	0.175 (0.089;0.275)
Attitudes towards upstream processes								
green hydrogen	0.113***	0.115 (0.053;0.174)	0.186***	0.195 (0.125;0.247)	0.278***	0.283 (0.168;0.388)	0.182***	0.205 (0.091;0.272)
blue hydrogen	0.036	0.041 (−0.007;0.079)	−0.021	−0.025 (−0.065;0.022)	0.118**	0.125 (0.035;0.201)	0.012	0.013 (−0.063;0.087)
renewable energies	0.064**	0.066 (0.006;0.123)	0.000	0.000 (−0.061;0.060)	0.050	0.052 (−0.053;0.152)	0.135*	0.126 (0.020;0.251)
Perceptions of industry								
familiarity	0.079	0.038 (−0.023;0.181)	0.176**	0.087 (0.073;0.279)	0.121	0.057 (−0.064;0.306)	0.048	0.022 (−0.124;0.219)
employment in industry	0.053	0.020 (−0.087;0.193)	0.170*	0.067 (0.030;0.310)	−0.110	−0.048 (−0.318;0.098)	0.003	0.001 (−0.193;0.199)
trust	0.063*	0.065 (0.000;0.126)	0.027	0.026 (−0.038;0.092)	0.098	0.100 (−0.012;0.208)	0.270***	0.229 (0.152;0.387)
cognitive legitimacy	0.150***	0.151 (0.083;0.216)	0.112**	0.116 (0.046;0.177)	0.230***	0.239 (0.131;0.329)	0.125*	0.114 (0.020;0.229)
moral legitimacy	0.003	0.003 (−0.067;0.073)	−0.033	−0.035 (−0.100;0.033)	−0.034	−0.036 (−0.147;0.079)	−0.279***	−0.261 (−0.394;-0.164)
pragmatic legitimacy	0.157***	0.158 (0.091;0.222)	0.098*	0.101 (0.032;0.164)	−0.058	−0.061 (−0.141;0.026)	0.106*	0.098 (0.015;0.197)
Control variables								
female	−0.056	−0.028 (−0.150;0.037)	−0.070	−0.036 (−0.164;0.024)	0.097	0.051 (−0.071;0.265)	−0.133	−0.061 (−0.293;0.027)
age	−0.001	−0.009 (−0.004;0.003)	0.001	0.011 (−0.003;0.004)	0.001	0.014 (−0.005;0.007)	0.007*	0.107 (0.001;0.013)
high education	0.047	0.023 (−0.051;0.146)	−0.028	−0.014 (−0.129;0.073)	0.106	0.056 (−0.059;0.272)	0.025	0.012 (−0.145;0.194)
high income	−0.029	−0.014 (−0.125;0.067)	0.055	0.028 (−0.042;0.152)	0.125	0.065 (−0.035;0.286)	−0.008	−0.004 (−0.173;0.157)
local identification					0.014	0.014 (−0.075;0.103)	0.085	0.077 (−0.014;0.185)
long-term residency					0.100	0.053 (−0.073;0.272)	0.024	0.011 (−0.156;0.204)
spatial proximity	0.043	0.021 (−0.061;0.146)	−0.063	−0.029 (−0.178;0.052)				
federal state	Yes		Yes					
district					Yes		Yes	
T1	−0.048	−0.023 (−0.159;0.063)	−0.028	−0.014 (−0.140;0.084)				

(*continued on next page*)

[12] See * legend in Table A1.

Table D1 (*continued*)

	green methanol		*green steel*		*green methanol in BW*		*green steel in SA*	
	B	*β* (95 % CI)	*B*	*β* (95 % CI)	*B*	*β* (95 % CI)	*B*	*β* (95 % CI)
T2					0.097	0.051 (−0.071;0.265)	−0.020	−0.009 (−0.209;0.168)
T3	−0.159*	−0.076 (−0.268;-0.049)	−0.168**	−0.082 (−0.278;-0.058)				
T4					−0.091	−0.045 (−0.280;0.098)	0.047	0.020 (−0.143;0.236)
Constant	1.794***	(1.315;2.272)	1.856***	(1.364;2.349)	0.965***	(0.184;1.745)	0.257	(−0.541;1.055)
Number of observations	1199		1194		406		414	
F	F(35;1163) = 20.45***		F(35;1158) = 17.24***		F(28;377) = 9.04***		F(26;387) = 15.42***	
Adjusted R^2	0.362		0.323		0.357		0.476	

Note: *B* = regression coefficient, *β* = standardised regression coefficient, CI = Confidence Interval.

*** $p < 0.001$.

** $p < 0.01$.

* $p < 0.05$.

Second, I have included additional control variables related to the participants' attitudes towards *grey hydrogen* and their political orientation to examine the sensitivity of my findings. The latter includes whether they are in favour of conservative politics, liberal politics, politics oriented towards national interests, or socially oriented politics. The findings are documented in Tables S1 and S2 in the Supplementary Material and are broadly consistent with those shown in Table 3.

Finally, I estimated specifications that applied only to the regional samples. Instead of using *familiarity*, I estimated a specification for the regional samples in which – as in the national sample – I used familiarity with the more general industrial processes instead of familiarity with specific local projects. Similarly, I have estimated a specification in which *pragmatic legitimacy* was assessed in the same way as in the national survey, i.e. in terms of perceived economic importance at a supra-regional level. The results obtained are similar to those reported in Table 3 (see Tables S3 and S4 in the Supplementary material).

Appendix E. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.erss.2025.103973.

Data availability

The author does not have permission to share data.

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